The PAN-PACIFIC ENTOMOLOGIST

Volume 73 January 1997 Number 1

Published by the PACIFIC COAST ENTOMOLOGICAL SOCIETY
in cooperation with THE CALIFORNIA ACADEMY OF SCIENCES
(ISSN 0031-0603)

The Pan-Pacific Entomologist

Published quarterly in January, April, July, and October with Society Proceedings usually appearing in the October issue. All communications regarding nonreceipt of numbers should be addressed to: Vincent F. Lee, Managing Secretary; and financial communications should be addressed to: Julieta F. Parinas, Treasurer; at: Pacific Coast Entomological Society, Dept. of Entomology, California Academy of Sciences, Golden Gate Park, San Francisco, CA 94118-4599.

Application for membership in the Society and changes of address should be addressed to: William Hamersky, Membership Committee chair, Pacific Coast Entomological Society, Dept. of Entomology, California Academy of Sciences, Golden Gate Park, San Francisco, CA 94118-4599.

Manuscripts, proofs, and all correspondence concerning editorial matters (but not aspects of publication charges or costs) should be sent to: Dr. Robert V. Dowell, Editor, Pan-Pacific Entomologist, California Dept. of Food & Agriculture, 1220 N St., Sacramento, CA 95814. See the back cover for Information-to-Contributors, and volume 66(1): 1–8, January 1990, for more detailed information. Information on format for taxonomic manuscripts can be found in volume 69(2): 194–198. Refer inquiries for publication charges and costs to the Treasurer.

The annual dues, paid in advance, are $25.00 for regular members of the Society, $26.00 for family memberships, $12.50 for student members, or $40.00 for institutional subscriptions or sponsoring members. Members of the Society receive *The Pan-Pacific Entomologist.* Single copies of recent numbers or entire volumes are available; see 72(4): 247 for current prices. Make checks payable to the *Pacific Coast Entomological Society.*

Pacific Coast Entomological Society

THE PAN-PACIFIC ENTOMOLOGIST (ISSN 0031-0603) is published quarterly for $40.00 per year by the Pacific Coast Entomological Society, % California Academy of Sciences, Golden Gate Park, San Francisco, CA 94118-4599. Periodicals postage is paid at San Francisco, CA, and additional mailing offices. POSTMASTER: Send address changes to the Pacific Coast Entomological Society, % California Academy of Sciences, Golden Gate Park, San Francisco, CA 94118-4599.

This issue mailed 14 February 1997

The Pan-Pacific Entomologist (ISSN 0031-0603)
PRINTED BY THE ALLEN PRESS, INC., LAWRENCE, KANSAS 66044, U.S.A.

PAN-PACIFIC ENTOMOLOGIST
73(1): 1–3, (1997)

A NEW *POECILONOTA* FROM SOUTHERN CALIFORNIA (COLEOPTERA: BUPRESTIDAE)

G. H. NELSON
College of Osteopathic Medicine of the Pacific
Pomona, California 91766-1889

Abstract.—*Poecilonota viridicyanea* Nelson, NEW SPECIES, is described from southern California. It is compared to its closest relative, *P. bridwelli* Van Dyke.

Key Words.—Insecta, Coleoptera, Buprestidae, *Poecilonota,* southern California

---

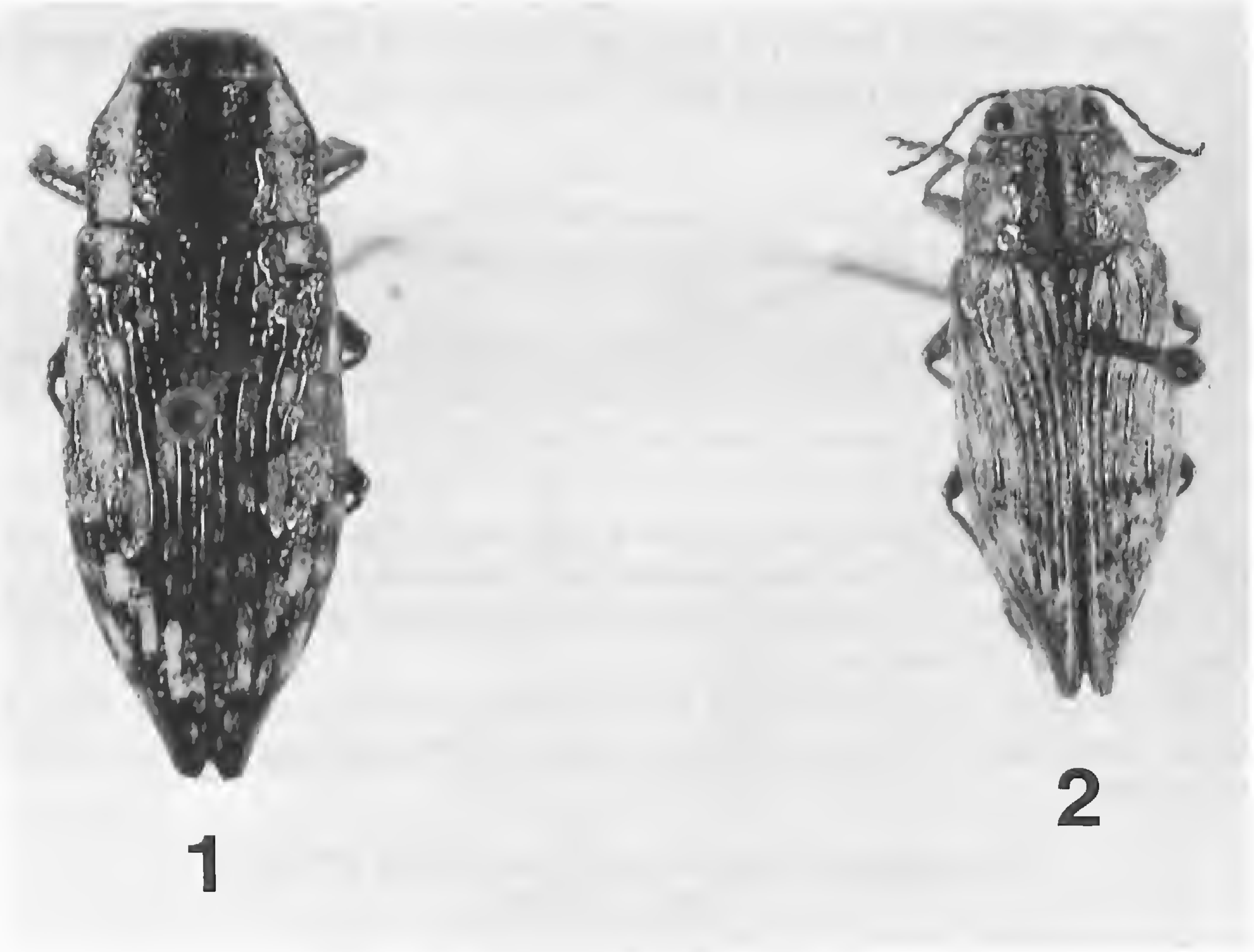
A new species of *Poecilonota,* that is most similar to *P. bridwelli* Van Dyke, and is allopatric with it, has been discovered in desert areas of southern California. It is described here to make it available for a general work on Buprestidae of America north of Mexico.

Abbreviations of collections are as indicated in Arnett et al. (1993). Measurements were made with the use of either a half millimeter scale ruler or an ocular net reticule.

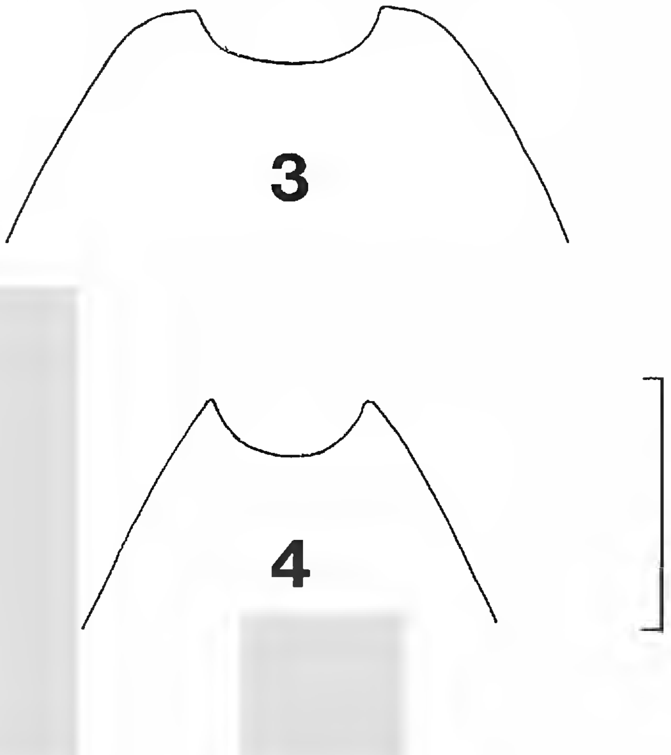
Poecilonota viridicyanea Nelson, NEW SPECIES
(Figs. 1, 3, 5)

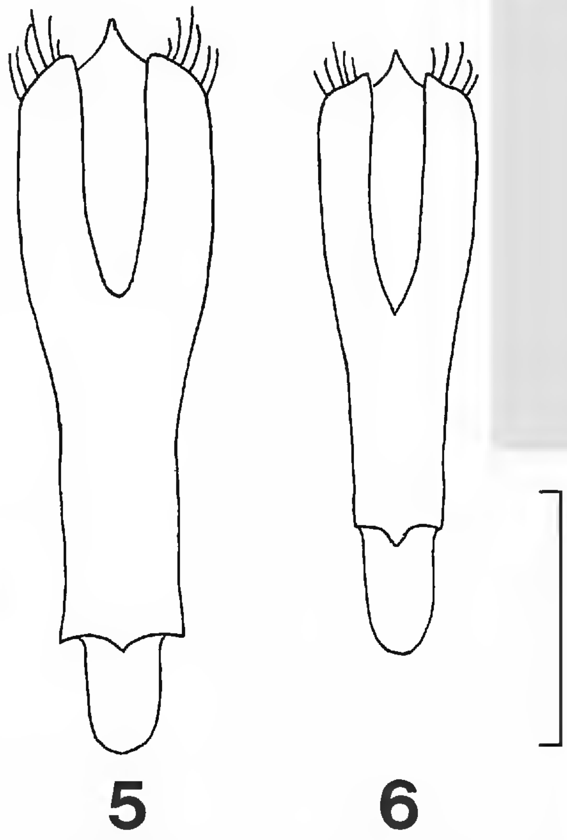
Types.—Holotype, male; data: CALIFORNIA. *SAN BERNARDINO Co.*: Yermo, 4 May 1939, J. Helfer, flying near cottonwood; deposited: California Academy of Sciences, San Francisco. Paratypes: data: *IMPERIAL Co.,* Palo Verde, R. A. Flock, reared from "desert willow", wood collected 2 May 1972, emerged 16 May 1972, 1 male; deposited: GHNC; Palo Verde, 6 Jun 1972, D. H. Harris, from willow, 1 male; deposited: GHNC.

Description.—*Holotype, male* (Fig. 1). Size, 15.0 × 5.6 mm. Green-blue above and below with brassy tints at elytral apices. Elongate-oval, moderately transversely convex. *Head.* Frontovertex flattened above, concave below; surface densely, rugosely punctate, punctate areas clothed by semirecumbent white setae; frontovertex with fine midline sulcus on elongate raised carina that bifurcates at midpoint of eyes, bifurcations joining supraantennal ridges to surround concavity; clypeus impunctate, margin shallowly arcuately emarginate; antennae reaching middle of pronotum when laid alongside, serrate from antennomere 4, antennomere 11 elongate-oval and truncate apically. *Pronotum.* Width 1.5 × length; lateral margins expanding from posterior angles in nearly straight line to widest point at middle, then converging in straight line to narrowest point at anterior angles; anterior margin arcuately emarginate with faint median lobe; posterior margin subtruncate with weak median lobe; surface with median $\frac{1}{5}$ smooth and impunctate, $\frac{1}{5}$ on either side smooth with some moderate sized punctures, lateral $\frac{1}{5}$ except for margin densely punctate and clothed with short, semirecumbent, white setae with white pulverulentus. Scutellum transversely cordate, surface glabrous, impunctate. *Elytra.* Length 3.6 × pronotal length, slightly wider at base than pronotum; lateral margins weakly sinuately expanding to widest point at middle then arcuately converging to slightly prolonged obliquely truncate apices; sutural margin diverging near tips; disk with intervals variously raised, intervals 3 and 5 distinctly raised and uninterrupted from basal $\frac{1}{7}$ to apical $\frac{1}{4}$, others interrupted by finely, densely punctate areas clothed by short, semirecumbent, white setae and pulverulentus. *Ventral side.* Prosternum with disk and process longitudinally concave, concavity finely, densely punctate and clothed with long, curved, slender, white setae, less densely punctate posteriorly, process with smooth, impunctate, raised lateral margins; thoracic sterna more densely punctate laterally, less densely medially, metasternum with midline sulcus, punctate areas clothed by semirecumbent white setae and with pulverulentus laterally; pro- and mesofemora slender fusiform, metafemora more parallel-sided; tibiae



Figures 1–2. Male holotypes, dorsal views. Fig. 1. *Poecilonota viridicyanea.* Fig. 2. *P. bridwelli.*





Figures 3–4. Last visible abdominal sterna. Fig. 3. *P. viridicyanea.* Fig. 4. *P. bridwelli* (line = 1.0 mm).

Figures 5–6. Male genitalia, dorsal views. Fig. 5. *P. viridicyanea.* Fig. 6. *P. bridwelli* (line = 1.0 mm).

straight; abdominal sternum 1 impunctate and longitudinally concave medially; other sterna sparsely punctate medially, all more densely punctate laterally, punctate areas clothed by recumbent white setae; last visible sternum with apex broadly arcuately emarginate, lateral angles rounded (Fig. 3). *Male genitalia* (Fig. 5).

Female.—Unknown.

Diagnosis.—*Poecilonota viridicyanea* is most similar to *P. bridwelli* Van Dyke and will key to that species in Evans (1957). It can, however, be distinguished as follows: it is vivid green-blue in color; the frontovertex of the head has a broad prominent carina; the pronotum has a median impunctate area that is $\frac{1}{5}$ the total width and without a punctate channel on either side (Fig. 1); the prosternum and its process are deeply longitudinally concave; the apex of the last abdominal sternum has the posterolateral angles broad and blunt (Fig. 3); and the juncture of the parameres is rounded (Fig. 5). In *P. bridwelli* the color is dull green to purple; the carina on the frontovertex is narrow and not prominent; the median impunctate area of the pronotum is much less than $\frac{1}{5}$ its total width with a punctate channel on either side of it (Fig. 2); the prosternum and its process are weakly convex; the posterolateral angles of the last abdominal sternum are acute (Fig. 4); and the juncture of the parameres is acutely angulate (Fig. 6).

Variation.—The three males are closely similar. One paratype is the same size as the holotype, the other is 13.8 × 5.3 mm. The bifurcation of the frontal carina does not join the supraantennal ridges on one paratype.

Distribution.—Known only from Imperial and San Bernardino Counties.

Hosts.—One specimen was reared from "desert willow", *Chilopsis linearis* (Cav.) Sweet (confirmed by the collector); one was collected on willow, *Salix* sp.; and one was found flying around cottonwood, *Populus* sp. The other species in this genus are associated either with *Salix* or *Populus,* so the rearing from *Chilopsis* is remarkable.

Etymology.—The specific name is derived from the green-blue color.

ACKNOWLEDGMENT

Sincere thanks is extended to the following for the loan of types and/or specimens in their care: California Academy of Sciences, R. Brett and D. Kavanaugh; University of Arizona, C. A. Olson, and to T. C. MacRae, Chesterfield, Missouri and R. L. Westcott, Salem, Oregon for helpful suggestions, R. A. Flock for specimens, Juliette Chitjian Wright for typing the manuscript, and Joe Marilo for the photographs.

LITERATURE CITED

Arnett, R. H., Jr., G. A. Samuelson, and G. M. Nishida. 1993. The insect and spider collections of the world (2nd ed.). Flora & Fauna Handbook No. 11, Sandhill Crane Press, Gainesville, Florida.

Evans, D. 1957. A revision of the genus *Poecilonota* in America north of Mexico (Coleoptera: Buprestidae). Ann. Entomol. Soc. Amer., 50: 21–37.

Received 26 Oct 1995; Accepted 22 Apr 1996.

PAN-PACIFIC ENTOMOLOGIST
73(1): 4–8, (1997)

EXPERIMENTAL ARENA FOR CONFINING THRIPS AND OTHER SMALL ARTHROPODS IN THE LABORATORY

Brook C. Murphy, Jane Adams and Michael P. Parrella
Department of Entomology, University of California,
Davis, California 95616

Abstract.—A new experimental arena to confine western flower thrips, *Frankliniella occidentalis* (Pergande) and other small arthropods in order to conduct laboratory bioassays and behavioral studies is described. Arenas are constructed from cardboard paper cartons using a clear plastic petri dish lid and weather stripping to form an insect tight seal. A water pic inserted into the side of the arena is used to maintain plant material within the arena. The configuration of the arenas allows for direct visual observation of arthropods on portions of whole plants using a dissection microscope while leaving the arena sealed. The arenas successfully confined western flower thrips adults for 14 d and survival rates in the arenas over 7 d were at levels acceptable for check treatments in laboratory bioassays.

Key Words.—Insecta, experimental arena, bioassay, *Frankliniella occidentalis*

Thrips are a major pest of ornamental and food crops and their pest status seems to be increasing on a wide range of crops (Mound & Teulon 1995). Plants are damaged by direct feeding on foliage, fruit and flowers and by thrips vectored disease. Management strategies have relied almost exclusively on repeated chemical applications. Intensive use of chemical controls has resulted in widespread development of resistance by economically important species such as the western flower thrips, *Frankliniella occidentalis* (Pergande) (Immaraju et al. 1992, Robb et al. 1995). As a result, there has been an increased interest in the development of alternative control agents such as predators, parasitoids and pathogens for thrips management in addition to evaluation of new biorational pesticides for thrips control.

The small size and intense activity of thrips, particularly adults, has made confinement and treatment in experimental arenas for laboratory bioassays challenging. Most researchers have relied on Munger cells (Munger 1942) or modifications thereof (Tashiro 1967, Morse et al. 1986) to conduct bioassays of chemical pesticides against thrips and other small arthropods. Typically, a known number of arthropods are confined on a leaf surface within the cells, exposed to a chemical pesticide and monitored for mortality over time. However, use of Munger cells has several disadvantages: their small size allows only a few insects to be assayed for extended periods of time; maintaining leaf vigor during the experiment can limit the length of bioassays; direct application of chemical treatments to thrips and other arthropods can be difficult; efficacy can only be determined in a simplified environment (a flat leaf surface); and realistic temperature and relative humidity conditions are difficult to manipulate within the cells. Nonetheless, use of Munger cells has proven to be a useful standard technique for evaluating pesticides against thrips and other small arthropods.

The limitations of Munger cells reduces their usefulness for evaluations of alternative control agents such as microbial insecticides, natural enemies and some biorational insecticides which act more slowly than conventional pesticides and therefore require longer observational times. Maintaining plant vigor through this interval is critical. Thus, bioassays of alternative agents conducted on simple leaf surfaces in small enclosed cells may not simulate actual mortality in a field setting occurring over a 2 week time period and within complex environments.

Here we describe an alternative experimental arena used to evaluate the performance of entomopathogenic fungi against western flower thrips, *Frankliniella occidentalis.* Bioassays using entomopathogenic fungi can take 7 d or more and the degree of effectiveness can be influenced by temperature and relative humidity conditions. Furthermore, the behavior of thrips on plants may determine the degree of exposure to the pathogen and influence the extent of fungal infection and mortality. Therefore, we designed arenas with greater volume that can enclose larger amounts of plant material (whole leaves, terminal shoots, buds and flowers). This allowed assays of larger numbers of thrips in a situation similar to that in which thrips are found in the field or greenhouse while minimizing influence of the experiment on thrips behavior. Through ventilation of the containers we also achieved greater control over internal environmental conditions. As a result, experiments using these arenas are able to assess the efficacy of fungi on a wide range of different plant parts and under temperature and relative humidity regimes that more closely simulate field conditions.

MATERIALS AND METHODS

Construction.—Components of an experimental arena are shown in Fig. 1. Units are constructed using a pint (473 ml) paper can (Fonda Paper can, Fonda Group, P.O. Box 500953, St Louis, MO) cut to a height of 5.1 cm (Fig. 1a). Two 2.5 cm holes are cut in the sides of the paper can and covered with organdy polyester netting to allow for airflow. The top of the arena uses a 90 mm diameter plastic petri dish lid (100 × 15 mm petri dish, Fisher Scientific, Pittsburgh PA) lined with foam weather stripping (Fig, 1b). Two rubber bands compress the lid to the top of the paper can to form a seal preventing thrips from escaping. A 5 ml plastic specimen tube (Rohre tube, Sarstedt, Germany) is used as a water pic to support plant material (Fig. 1c). The cap of the specimen tube is mounted into the side of the paper can by cutting a hole just large enough so the cap can be inserted through the can and sealed using silicon glue. The tube can then be inserted into the cap mounted into the side of the can which operates as a water reservoir (Fig. 1d). A stem, branch or petiole can be inserted through a hole drilled in the cap on the inside of the arena. Replenishing water from the outside is inserted through a water hole drilled in the tube.

Evaluation.—The experimental arenas were evaluated for their ability to 1) successfully confine thrips for 14 d without escape or significant increases in adult mortality, 2) demonstrate and quantify variation in survival rates of adult thrips on rose foliage in the arenas over a 7 d period, and 3) monitor the internal temperature and relative humidity to determine the influence of arenas on environmental conditions. Adult thrips of various ages were collected from a thrips colony maintained in a greenhouse on potted chrysanthemums. For the confinement test 43 to 54 adults were placed in each of seven arenas, 4 arenas contained rose foliage and 3 contained chrysanthemum foliage. The arenas were maintained at 26° C and 60% RH in an environmental chamber during the course of the tests. For the survival tests 23 to 53 adults were placed in arenas containing rose foliage and held at 26° C and 75% RH for 7 d. The tests compared thrips survival rates

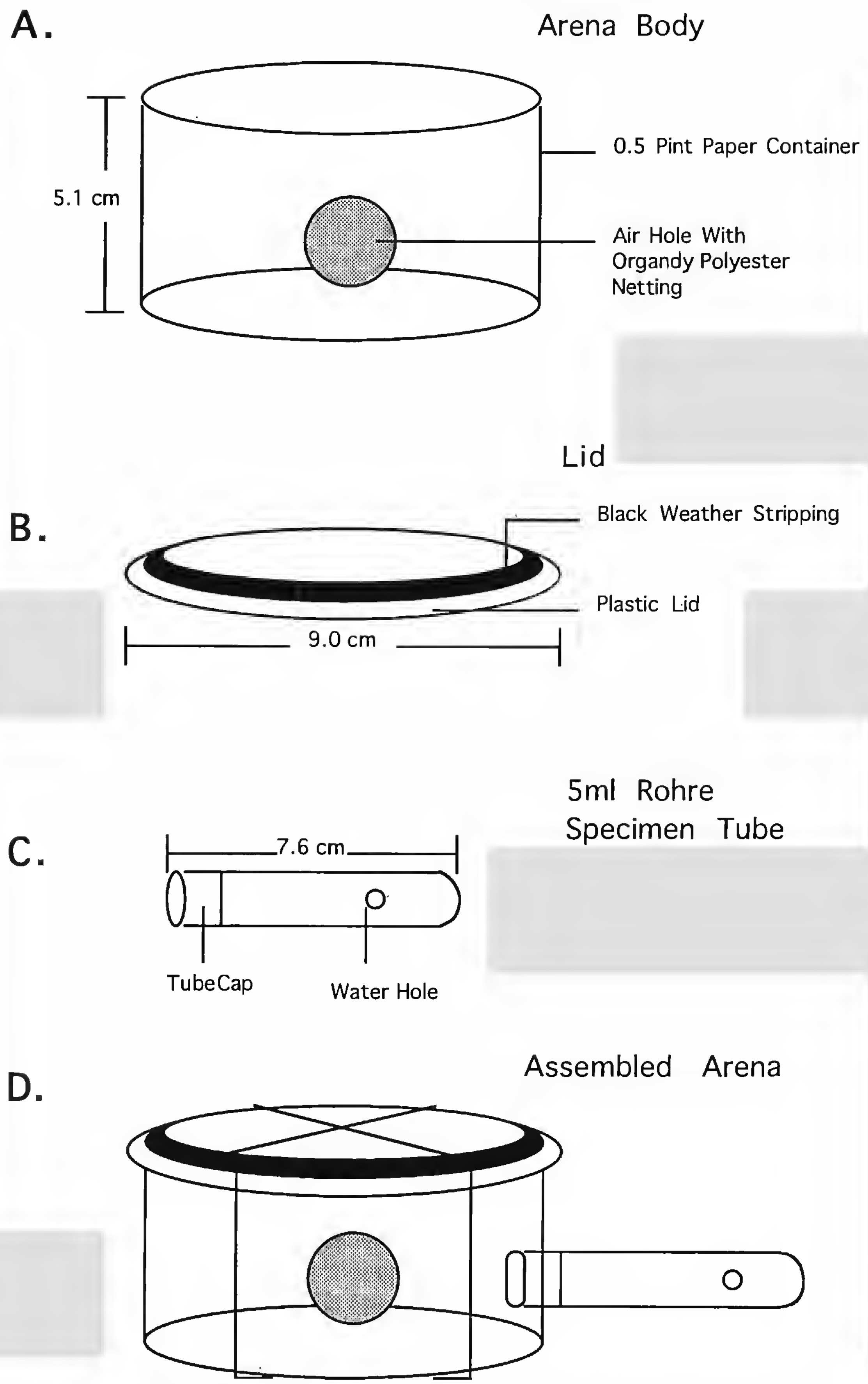


Figure 1. Schematic of experimental arena components, a) arena body, b) lid, c) specimen tube and d) assembled arena.

among five arenas within each experiment and 3 different experiments were performed on different dates. At the end of the experiments all thrips were removed from the arenas and the number of live and dead thrips recorded. Two other arenas containing plant material but no thrips were used to compare the influence of arenas on the temperature and relative humidity within the containers using a digital temperature and relative humidity meter (Fisher scientific, model 1055712). The expected background mortality of adult thrips over the 14d confinement trial and 7 d survival trial was estimated using longevity data for adult thrips reared

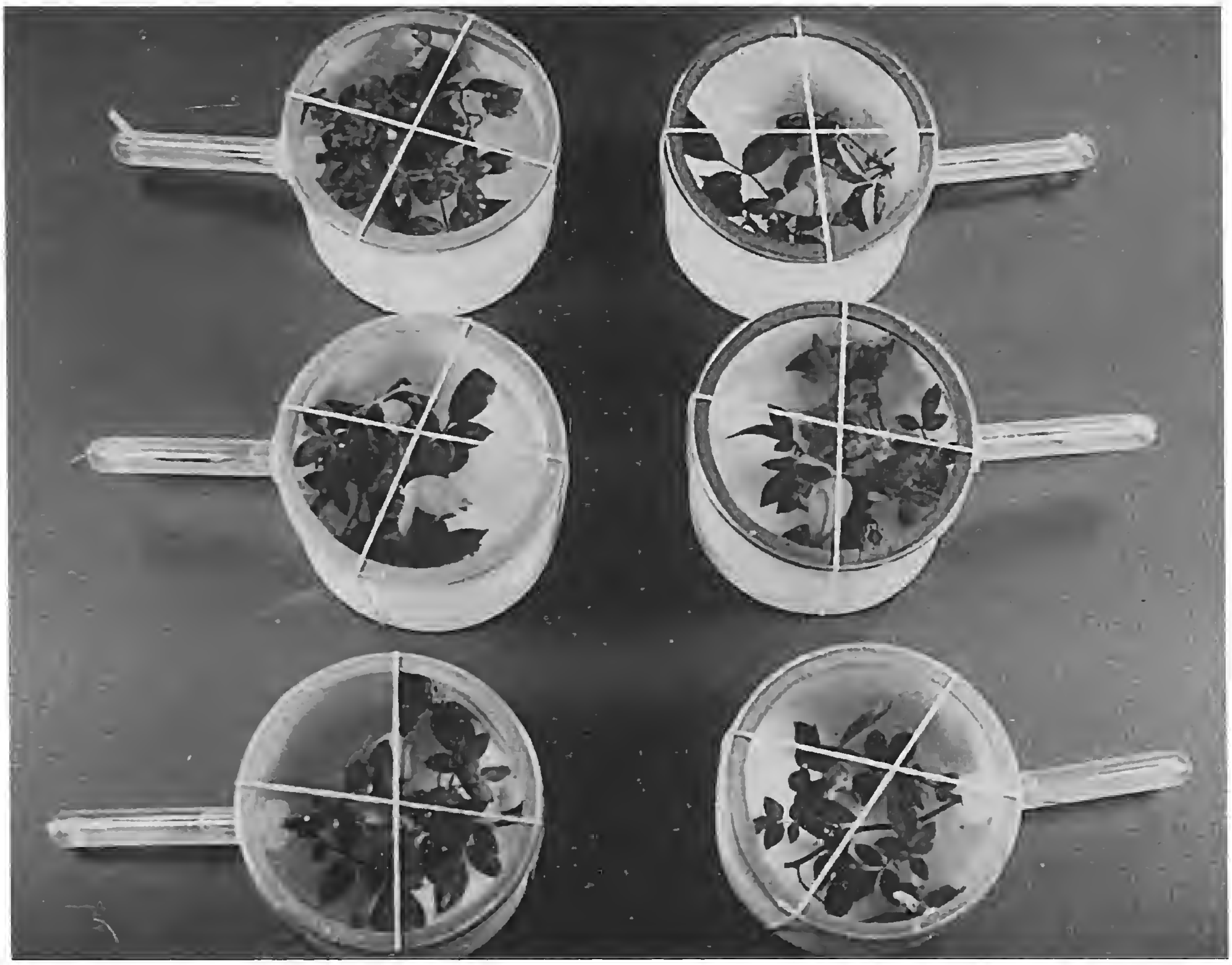


Figure 2. Photograph of experimental arena test units showing rose host material for assays using entomopathogenic fungi against thrips.

on chrysanthemum in environmental chambers from Robb (1989). At 26° C adult longevity is approximately 32 d. Assuming a normally distributed age distribution of adults was obtained from the colony, an expected mortality of approximately 44 percent at 14 d and 22 percent at 7 d was estimated and compared to actual mortality in the arenas. Statistical analyses were performed using *t* tests.

RESULTS AND DISCUSSION

The experimental arenas successfully contained and maintained adult thrips during the 14 d period. For the containment test an average (± SD) of 46.85 ± 1.42 thrips were placed in the arenas and after 14d an average of 45.85 ± 1.29 were recovered demonstrating a 97.9 ± 1.16 percent recovery rate. Adult mortality during this period averaged (± SD) 39.6 ± 4.8 percent which was not significantly different from the expected 44 percent mortality ($t = 0.92$, df = 6, $P < 0.05$). Thus the results demonstrated thrips could be successfully confined within experimental arenas for extended periods of time without adversely affecting survival rates. The average (± SD) percent adult thrips mortality for the 3 survival test experiments were 12.1 ± 2.9, 11.3 ± 0.75 and 19.2 ± 4.3 percent after 7 d. Thrips mortality was significantly lower than expected for the first two trials ($t = 3.41$, df = 4, $P < 0.05$; $t = 14.26$, df = 4, $P < 0.05$) and not significantly different from expected for the third trial ($t = 0.65$, df = 4, $P >$

0.05). Results demonstrated that efficacy trials could be conducted over a 7 d period without unexpected mortality and at survival rates that would be acceptable for check treatments in laboratory bioassays. Temperatures and relative humidity inside the arenas averaging 26.5° C, and 64 percent respectively, were found to be slightly higher than the environmental chamber of 26° C and 60 percent RH.

Based on these results we have concluded that the arenas may be applicable for conducting bioassays using fungi and other microbial or biorational pesticides against thrips for at least 7 d in length. The depth of the container allows for a full range of observation of insect subjects using dissecting microscopes or through visual observation. We have found that dead insects tend to drop from the plant material and can be easily counted against the white background of the bottom of the container. Mortality as a function of time can therefore be determined without opening the containers. Ventilation of the containers allows for similar internal environmental conditions to outside conditions and the containers are versatile enough to conduct bioassays on many different host plants and host plant parts. The arenas can be constructed rapidly and the materials are inexpensive and readily available. We believe the use of this design may provide a more realistic assessment of mortality under conditions that more closely resemble field conditions.

In addition to thrips, we have successfully used these arenas for conducting efficacy trials against aphids and mites and have begun to evaluate the effects of entomopathogenic fungi on thrips natural enemies. This technique may also have additional experimental applications such as in behavioral studies, survival and longevity studies and experiments examining plant-insect and predator-prey interactions.

ACKNOWLEDGMENT

We thank Tunyalee Morisawa (Department of Entomology, University of California, Davis) for assistance in construction of experimental arenas and conducting survival tests. This work was funded in part by the University of California Division of Agriculture and Natural Resources Special grant number 074, the Mycotech Corporation, Butte MT and the American Floral Endowment.

LITERATURE CITED

Immaraju, J. A., T. D. Paine, J. A. Bethke, K. L. Robb & J. P. Newman. 1992. Western flower thrips (Thysanoptera: Thripidae) resistance to insecticides in coastal California greenhouses. J. Econ. Entomol., 85: 9–14.

Morse, J. G., T. S. Bellows & Y. Iwata. 1986. Technique for evaluating toxicity of pesticides to motile insects. J. Econ. Entomol., 79: 281–283.

Mound L. A. & A. J. Teulon. 1995. Thysanoptera as phytophagous opportunists. pp. 3–19. *In* L. Parker, M. Skinner & T. Lewis (eds.). Thrips Biology and Management. Plenum Press, NY.

Munger, F. 1942. A method for rearing citrus thrips in the laboratory. J. Econ. Entomol., 35: 373–375.

Robb K. L., 1989. Analysis of *Frankliniella occidentalis* (Pergande) as a pest of floriculture crops in California greenhouses. Ph.D Dissertation, University of California, Riverside.

Robb, K. L., J. Newman, J. K. Virzi & M. P. Parrella. 1995. Insecticide resistance in western flower thrips. pp. 341-346. *In* L. Parker, M. Skinner & T. Lewis (eds.). Thrips Biology and Management. Plenum Press, NY.

Tashiro, H. 1967. Self-watering acrylic cages for confining insects and mites on detached leaves. J. Econ. Entomol., 60: 354–356.

Received 16 May 1996; Accepted 20 Aug 1996.

PAN-PACIFIC ENTOMOLOGIST
73(1): 9–15, (1997)

AN EXAMINATION OF SPATIAL INPUT PARAMETERS IN ORDER TO IMPROVE CORN EARWORM (LEPIDOPTERA: NOCTUIDAE) DAMAGE PREDICTIONS FOR A PHEROMONE TRAP CATCH REGRESSION MODEL

R. J. Drapek, B. A. Croft, and G. Fisher
Department of Entomology, Oregon State University,
Corvallis, OR 97331-2907

Abstract.—A regression model relating cumulative pheromone trap catch and date of corn silking to subsequent damage in sweet corn by *Helicoverpa zea* (Boddie) was improved in one year by including additional spatial input parameters. Spatial inputs included information from timings and locations of corn plantings around the trap as well as from locations of wind blocking features. Wind blocking features were: tree rows, wooded areas, large buildings close to the trap, and abrupt hillsides. Pheromone traps were monitored at 28 and 30 sites in 1990 and 1991. Corn development through the year and damage levels at harvest (percent infestation) were also recorded for these locations. Maps of all corn plantings and wind blocking features within 2.5 kilometers of the trap were created, digitized, and entered into a Geographical Information System for each site. A stepwise regression analysis considering 18 spatial and two non-spatial variables resulted in a highly significant ($P < 0.001$) regression model with four variables (trap catch, silking date, the number of hectares of corn within 2.0 kilometers of the trap, and the average distance to wind blocking features on the north side of the trap) explaining 82% of the variability for the 1990 data. In 1991, of the 20 input parameters considered only one was significant, date of first silk. An extremely low corn earworm population was considered to have caused this inability to find correlations for the other parameters in 1991.

Key Words.—Insecta, *Helicoverpa zea*, corn earworm, sweet corn, pheromone, trapping, monitoring

In the Willamette Valley of western Oregon, *Helicoverpa zea* (Boddie) populations are low but periodically cause extensive damage to corn which is valued at $45 million per annum, statewide (Miles 1992). Earworm damage is usually limited to tips of ears, with older larvae tending to feed farther down the ear (Coop et al. 1992). This damage is intolerable on fresh market sweet corn where pesticides routinely are applied. Corn processors remove the tips of the ears whether or not earworm damage is present. Therefore earworm is only a problem in processed corn when populations are much larger than normal. In 1985, following a year of severe earworm damage, a study was initiated to provide pest managers with the means to predict earworm damage on processed corn. Based on 5 years of pheromone trapping, a two variable regression model was developed that related cumulative pheromone trap catch from first tassel to first silk as well as the date of first silk to subsequent percent ears infested by *H. zea* (Coop et al. 1992).

In this study, additional input variables were considered for inclusion into the regression model. The inclusion of these variable is based on two hypotheses: 1) that wind blocking features potentially interfere with normal wind flow around the trap or act to block pheromone plumes downwind of the trap and 2) that the amount, age, and position of corn plantings around the pheromone trap will affect moth populations in the region around the trap as well as moth movement dynamics. Therefore, positions and timings of corn plantings around the trap as well as positions of wind blocking features were considered as additional input variables.

MATERIALS AND METHODS

Pheromone traps were placed in corn plantings prior to tasselling in 1990 and 1991. Traps were inspected every 3 d to record the number of moths trapped. Traps were a standard Texas wire cone trap (75–50 of Hartstack et al. 1979) with a Scentry pheromone cap containing Z-11-Hexadecenal, Z-9-Hexadecenal, Hexane, and Tenox 4. This trap/lure combination is one of the most cost effective monitoring tools available for *H. zea* (Drapek et al. 1990, Gauthier et al. 1991). In 1990 and 1991, 28 and 30 plantings were trapped respectively. Plantings covered an area about 80 km. north to south by 40 km. east to west and consisted primarily of the variety "Golden Jubilee".

Traps were placed, when possible, 75 m within corn fields in accessible locations. In some fields, irrigation equipment prevented placement of traps within the field. Instead, traps were placed as close to the edge of the field as possible. Witz et al. (1992) found that at low populations of *H. zea* (less than 50 moths per trap-night), traps placed within 5 m of the perimeter of cotton fields caught as many moths as interior traps. Willamette Valley trap catches seldom exceed 50 moths in a night. Traps were situated without regard to wind direction as previous tests had shown little effect of wind-side on trap catch (Drapek et al. 1990).

When traps were placed in plantings prior to tasselling, they were set so that the bases were about 1.5 m from the ground. As the corn grew to the height of the trap base, the trap was raised so that the pheromone cap at the base of the trap was within 20 cm of the corn plants. With each checking of a pheromone trap, the stage of corn development was recorded.

Corn plantings and wind blocking features within 2.5 km radius were mapped for every trap location. Wind blocking features included large buildings within 200 m of the trap, windrows, wooded areas, and large hills. For each mapped site, the mapping date and the stage of every corn planting were noted. Every feature was mapped using a compass to obtain directions and pacing to obtain distances (Figure 1). Maps were checked against 1:24,000 USGS topographic maps and were digitized to a geographical information system (GIS) for area calculations.

Mature ears within study fields were collected as close to harvest date as possible and inspected for earworms and damage. As plantings approached harvest, a 200 ear random sample was taken from every planting. If the corn field was not harvested within 6 d, a second sample was taken.

A stepwise regression was used which considered 20 independent variables and ear infestation level at harvest as the dependent variable. Independent variables included: 1) cumulative trap catch from first tassel to first silk; 2) date of first silk measured as the number of days since 31 December; 3–5) average distance to wind blocking features north of the trap, south of the trap, and all around the trap; 6–10) hectares of corn older than the trapped planting within 0.5, 1.0, 1.5, 2.0, and 2.5 km of the trap; 11–15) hectares of corn the same age as the trapped planting within 0.5, 1.0, 1.5, 2.0, and 2.5 km. of the trap; and 16–20) hectares of

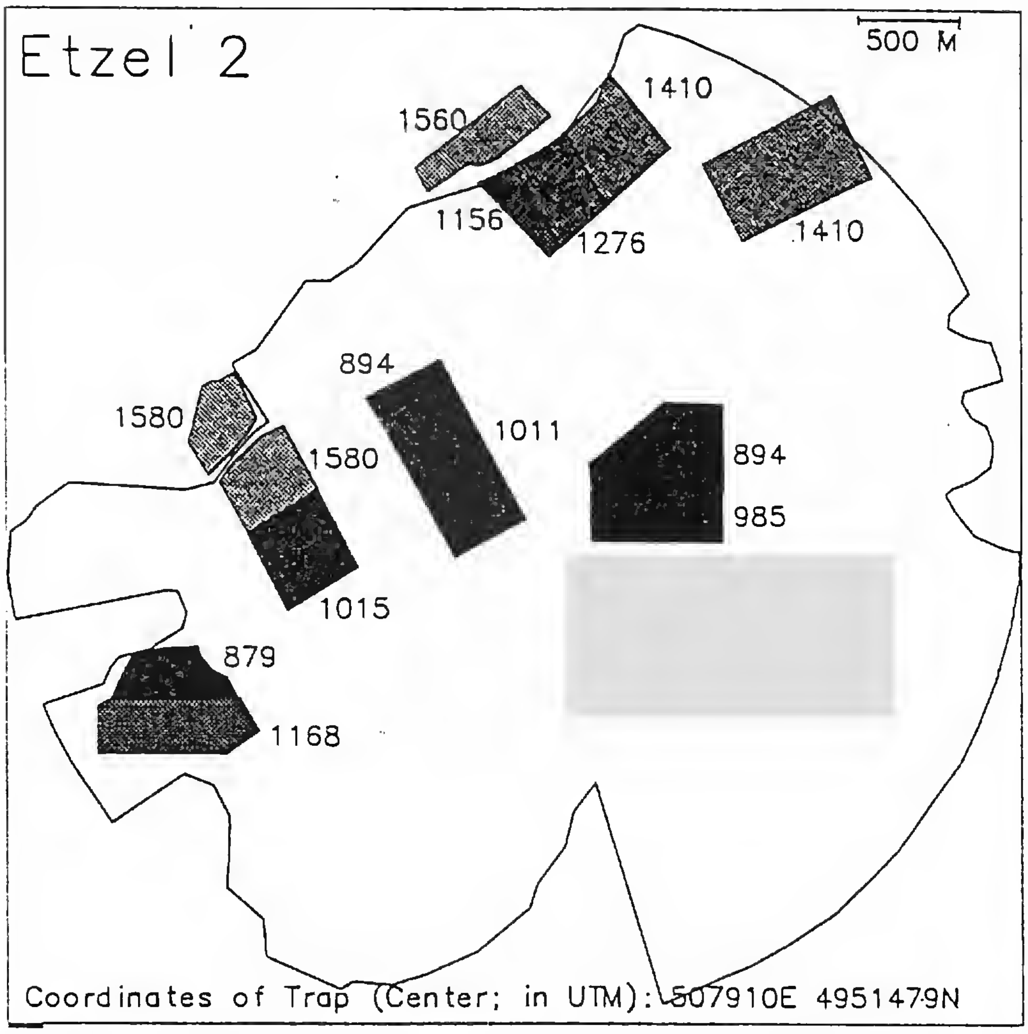


Figure 1. Example map of one of the monitored plantings. Shaded polygons indicate locations of corn plantings. Numbers adjacent to the polygons indicate cumulative degree-day development as of August 1. The large unshaded polygon shows all locations within 2.5 kilometers of the trap that have no wind-blocking feature between them and the trap.

all corn plantings within 0.5, 1.0, 1.5, 2.0, and 2.5 km. of the trap. The dependent variable was an arcsine-square-root transformation of the proportion of ears damaged. This transformation is suggested for variance stabilization by Weisberg (1985) for dependent variables that are binomial proportions and was used by Coop et al. (1992).

A 0.5 km/radius around the trap was used to calculate average distances to wind blocking features because it was assumed that wind blocking features beyond 0.5 km. would have minimal effect on the pheromone plume. The average was obtained by taking the mean distance to wind blocking features for radius lines drawn from the trap at 10° intervals. Average distances were calculated for each site for locations north, south, and all around the trap. A north-south distinction was made because early evening winds come predominantly from the north during summers in the Willamette Valley (Coop and Croft, 1995).

Hectares of corn within the various radii away from the trap were calculated using the GIS. All plantings that at some point in the season were silking at that same time as the trapped field were called "same age" for the purposes of the model. "Silking" is defined as that period of time starting when silks could be observed on a substantial minority of corn stalks (~ 5%) and ending when a substantial minority (~ 5%) of stalks had silks with distinct browning (~ 50% of silks on an ear being brown).

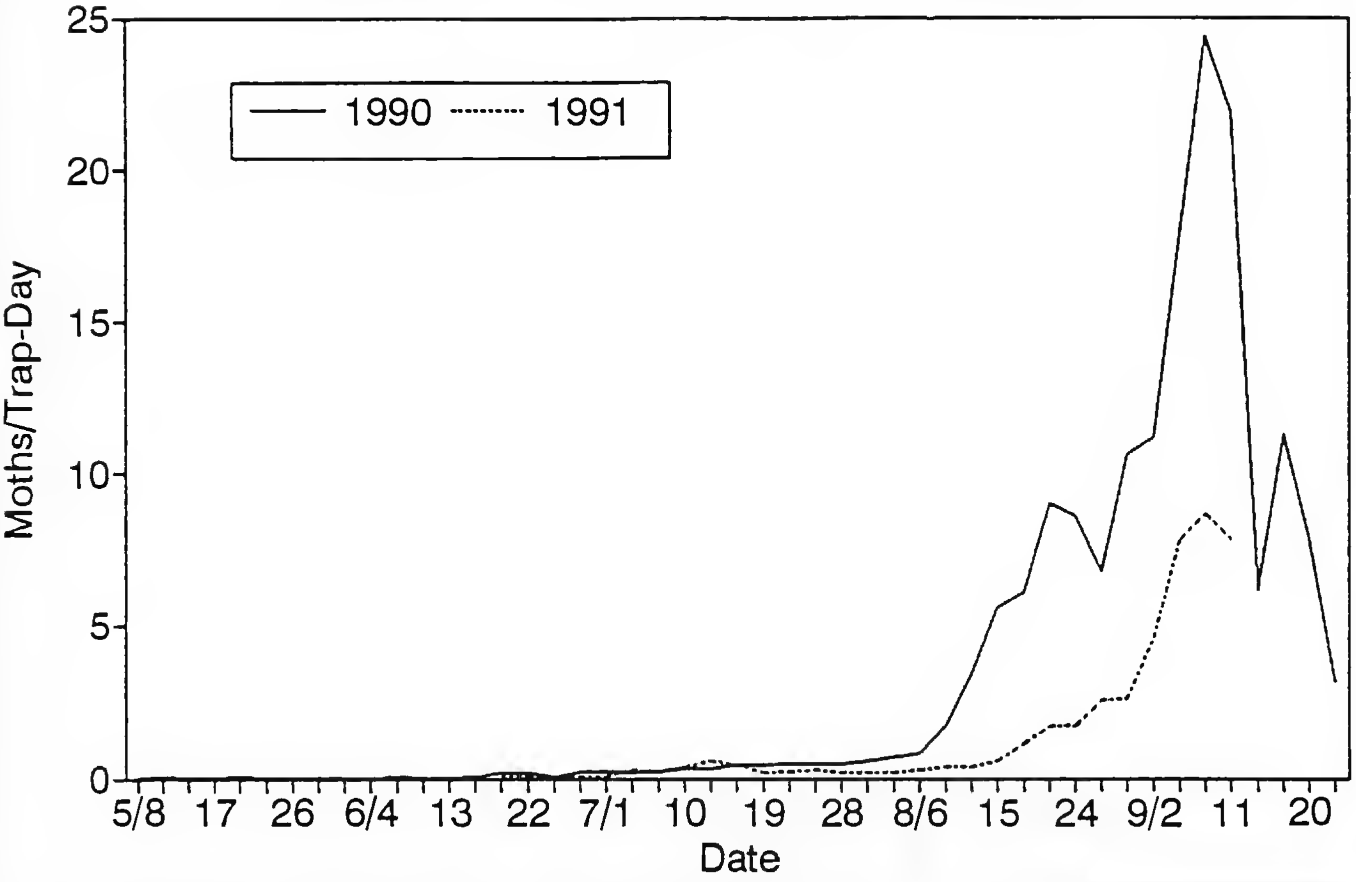


Figure 2. Average moth catch per trap-day observed in 1990 and 1991.

RESULTS

Moth flight patterns as measured by pheromone trap catches did not display any unusual patterns in 1990 or 1991 (Fig. 2), compared to 1986-1988 (Coop et al. 1992, Drapek 1993). For both years a peak in catch started in early August, peaked in late August or early September, and dropped again towards the end of September. The first moths were captured on 8 May 1990 and 10 June 1991. The June 10 date was unusually late, reflecting a wet and cool spring.

For both years the silking date proved to be a significant input variable (Table 1). Trap catch was a significant variable in 1990, but not in 1991. Significant

Table 1. Models resulting from a stepwise regression considering 2 nonspatial and 18 spatial input parameters as predictors of percent ear infestation by *Helicoverpa zea*[a].

Year	# Sites	Variable	Reg. coeff.	SE	F	Prob > F
1990[b]	30	Intercept	−0.6026	0.2527	5.68	0.025
		1st Silk[c]	0.0039	0.0012	11.17	0.003
		Corn Area[d]	0.0004	0.0002	6.41	0.018
		WBF[e]	−0.1083	0.0587	3.40	0.077
		Trap Catch[f]	0.0018	0.0003	39.96	<0.001
1991[g]	27	Intercept	−0.9062	0.3226	−2.81	0.010
		1st Silk[c]	0.0047	0.0015	3.21	0.004

[a] Dependent variable = Sin^{-1}(Sqrt (proportion infested ears)).
[b] $R^2 = 0.82$. Model $P = 0.000$.
[c] 1st Silk is the date on which silking is first noted (measured as the number of days since Jan. 1).
[d] Corn Area is the number of hectares of corn within 2.0 kilometers of the trap.
[e] WBF is the average distance on the north side of the trap to a wind blocking feature.
[f] Trap Catch is the cumulative trap catch from 1st tassel to 1st silk.
[g] $R^2 = 0.29$. Model $P = 0.004$.

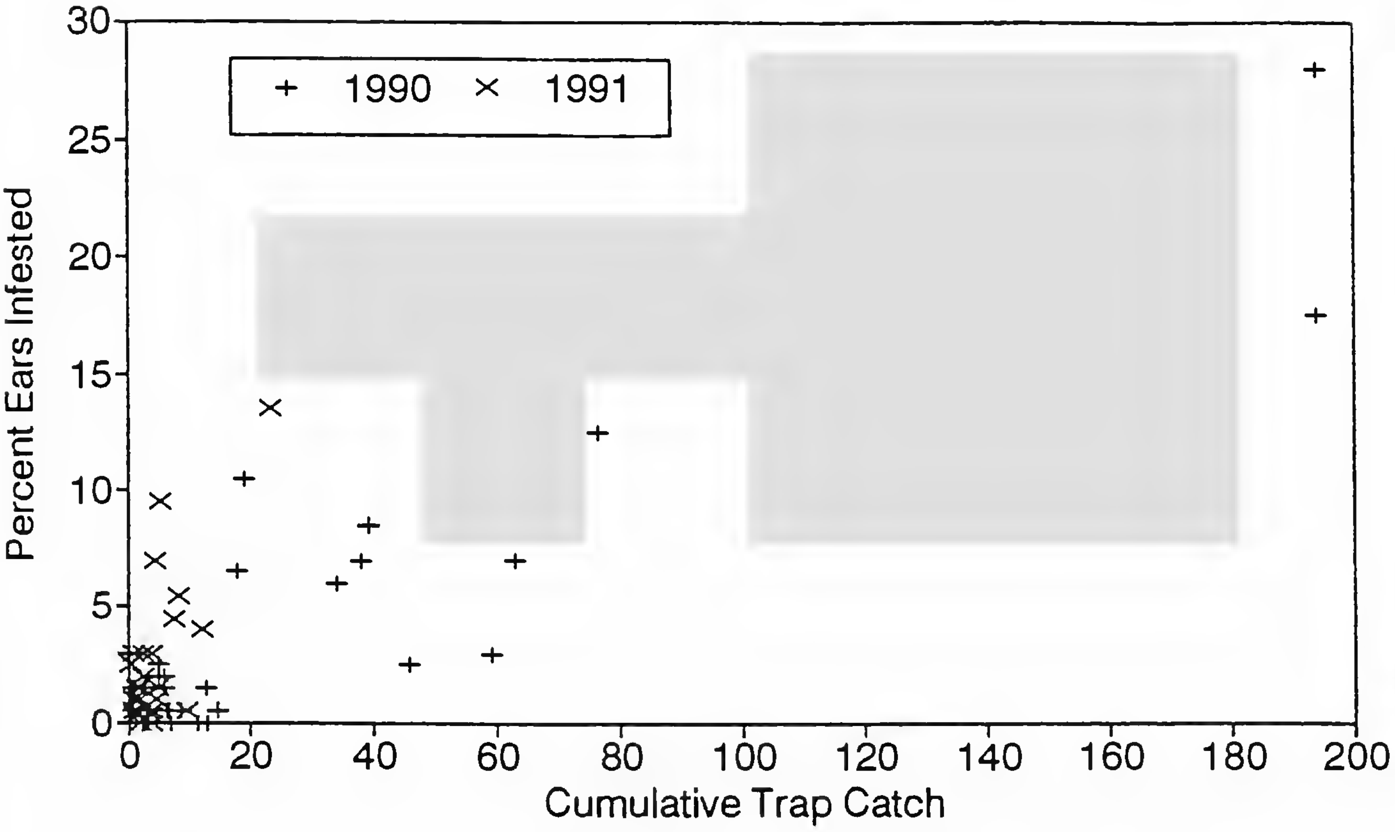


Figure 3. Trap catch and damage levels observed for individual sites in 1990 and 1991. Trap catch is the cumulative moth catch between 1st tassel and 1st silk. Damage in measured as percent of ears infested with earworm at the time of harvest.

input from spatial variables occurred in 1990, but not in 1991. The significant variables were corn area within 2.0 km of the trap and average distance on the north side of the trap to wind blocking features. Where trap catch and date of first silk were significant, the regression coefficients were positive.

Discussion

The optimal multiple regression model obtained from 1990 data included four input variables: date of 1st silk, the number of hectares of corn within 2 km of the trap, the average distance north of the trap to wind blocking features, and cumulative trap catch. Date of 1st silk had a positive regression coefficient. This means that later silking corn plantings can be expected to have higher damage levels. This may result from timings of moth flight relative to corn development. Peak moth flights tended to be somewhat later than peak corn silking dates (Drapek et al. 1993).

High trap catches imply large moth populations. Large moth populations imply that oviposition and subsequent damage should be high as well. Therefore, our expectation was that trap catch and damage would have a significant positive correlation. Moth flights and damage were so low both years, that the results did not meet our expectations (Figure 3). Coop et al. (1993) observed that corn earworm-caused damage did not equal control costs until infestation levels approached 30% or higher. Over the 2 years we monitored earworms, infestation rates only reached that level for one planting, and all but 2 plantings had infestation levels less than 15%. Both plantings occurred in 1990. These 2 plantings were very influential in producing the significant regression coefficients between trap catch and damage in 1990. Because no plantings had such damage levels in

1991, the relationship between trap catch and damage did not prove to be significant for that year.

The positive relationship between corn earworm trap catch, moth activity levels, and subsequent damage has been verified for other locations and years. Latheef et al. (1993) were able to demonstrate a significant correlation between daily pheromone trap catches and moth flights (both male and female) as measured by hand-net. Additionally, Latheef et al. (1991) observed a weak, but significant linear relationship between the number of eggs laid per day versus the daily pheromone trap catch. The positive trap catch versus subsequent damage relationship concurs with observations made by Chowdhury et al. (1987) and Coop et al. (1992).

In 1990, both spatial variables (corn area and average distance to north wind-blocking features) had negative regression coefficients. The negative coefficient for distance to wind-blocking features implies that the farther away from the trap north wind-blocking features occur, the lower should be the damage prediction. One explanation for this observation is that wind-blocking features interfere with the normal movement of the plume. In the Willamette Valley, evening winds come predominantly from the north during the summer (Coop & Croft, 1995). Therefore wind-blocking features on the north side of a field will probably have the most disruptive effect on the pheromone plume.

In 1991 only the date of 1st silk proved to be significant as an input variable for prediction of percent earworm infestation. The regression coefficient for date of 1st silk was positive. The fact that trap catch and none of the potential spatial input parameters proved significant in 1991 does not necessarily invalidate them as useful model parameters. Earworm population and damage levels were unusually low in 1991. Though the correlation between trap catch and damage levels for individual sites was low, the low trap catch levels observed for all sites did accurately reflect the low damage levels observed valley-wide. Anyone using pheromone traps in 1991 to monitor for earworms would have correctly determined that earworms would not be a problem that year. When damage levels are so low, normal variation nullifies all but the strongest trends. Future observations from years with moderate to high earworm populations are required before a final evaluation can be made on the reliability of adjacent corn acreage and distance to wind blocking features as damage prediction modifying inputs.

LITERATURE CITED

Chowdhury, M. A., R. B. Chalfant & J. R. Young. 1987. Ear damage in sweet corn in relation to adult corn earworm populations. J. Econ. Entomol., 80: 867–869.

Coop, L. B., R. J. Drapek, B. A. Croft & G. C. Fisher. 1992. Relationship of corn earworm pheromone catch and silking to infestation levels in Oregon sweet corn. J. Econ. Entomol., 85: 240–245.

Coop, L. B., B. A. Croft & R. J. Drapek. 1993. Model of corn earworm development, damage, and crop loss in sweet corn. J. Econ. Entomol., 86: 906–916.

Coop, L. B. & B. A. Croft. 1995. *Neoseilus fallacis*: dispersal and biological control of *Tetranychus urticae* following minimal inoculations into a strawberry field. Exper. & Appl. Acarol., 19: 31–43.

Drapek, R. J., L. B. Coop, B. A. Croft & G. C. Fisher. 1990. *Heliothis zea* Pheromone trapping: studies of trap and lure combinations and field placement in sweet corn. S. W. Entomol., 15: 63–70.

Drapek, R. J. 1993. Use of a geographical information system to modify pheromone trap-based predictions of *Helicoverpa zea* (Boddie) damage. PhD. Thesis. Oregon State University.

Gauthier, N. L., P. A. Logan, L. A. Tewksbury, C. F. Hollingsworth, D. C. Weber & R. G. Adams.

1991. Field bioassay of pheromone lures and trap designs for monitoring adult corn earworm in sweet corn in southern New England. J. Econ. Entomol., 84: 1833–1836.

Hartstack, A. W., J. A. Witz & D. R. Buck. 1979. Moth traps for the tobacco budworm. J. Econ. Entomol., 72: 519–522.

Latheef, M. A., J. A. Witz & J. D. Lopez Jr. 1991. Relationships among pheromone trap catches of male corn earworm moths, egg numbers, and phenology in corn. Can. Entomol., 123: 271–281.

Latheef, M. A., J. D. Lopez Jr. & J. A. Witz. 1993. Capture of corn earworm in pheromone traps and hand nets: relationship to egg and adult densities in field corn, Texas Brazos River Valley. J. Econ. Entomol., 86: 407–415.

Miles, S. D. 1992. 1991 Oregon County and State Agricultural Estimates. Oregon States University Extension Service. Special Report 790.

Weisburg, S. 1985. Applied Linear Regression. John Wiley & Sons. New York.

Witz, J. A., J. D. Lopez & J. L. Goodenough. 1992. Influence of sex pheromone trap placement relative to field edge on catch of bollworm males in cotton. S. W. Entomol., 17: 1–6.

Received 6 Jun 1996; Accepted 7 Sep 1996.

PAN-PACIFIC ENTOMOLOGIST
73(1): 16–20, (1997)

CHRYSOMYA MEGACEPHALA (FABR.) IS MORE RESISTANT TO ATTACK BY *CH. RUFIFACIES* (MACQUART) IN A LABORATORY ARENA THAN IS *COCHLIOMYIA MACELLARIA* (FABR.) (DIPTERA: CALLIPHORIDAE)

JEFFREY D. WELLS[1] AND HIROMU KURAHASHI
Department of Medical Entomology, The National Institute of Health,
Toyama 1-23-1, Shinjuku-ku, Tokyo 162, Japan

Abstract.—*Chrysomya* Robineau-Desvoidy blow flies recently introduced to the Americas include two species, *Ch. megacephala* (Fabr.) and *Ch. chloropyga* Wiedemann (= *Ch. putoria*) with purely saprophagous larvae, and two, *Ch. albiceps* (Wiedemann) and *Ch. rufifacies* (Macquart), that are facultative predators on other maggots. Patterns of adult abundance suggest that the invading species suppress the saprophagous native *Cochliomyia macellaria* (Fabr.), and do so more effectively in combination than individually. We hypothesized that *Ch. megacephala*, historically sympatric with *Ch. rufifacies*, is relatively resistant to predation by *Ch. rufifacies*, which could provide it with a competitive advantage over a more vulnerable *C. macellaria* when larvae of all three occur together. To test this hypothesis, larvae of both prey species were individually paired with larvae of *Ch. rufifacies* in the laboratory. *C. macellaria* were consistently killed at a higher rate than were *Ch. megacephala*.

Key Words.—Insecta, biological invasion, introduced species, competitive displacement, higher-order interaction, carrion, blow fly

Old World blow flies in the genus *Chrysomya* Robineau-Desvoidy have been spectacularly successful following their recent invasion of the Western Hemisphere. Introduced at two locations in the mid 1970's, *Ch. albiceps* (Wiedemann), *Ch. chloropyga* Wiedemann (= *Ch. putoria*) and *Ch. megacephala* (Fabr.) in Brazil (Guimarães et al. 1979) and *Ch. rufifacies* (Macquart) in Costa Rica (Jirón 1979), they quickly became widespread and abundant in Latin America (Baumgartner & Greenberg 1984, Baumgartner 1988, Mariluis & Schnack 1989, Olsen et al. 1992., J. Mendez L., pers. comm., Kurahashi et al. 1994). Within two decades, *Ch. rufifacies* and *Ch. megacephala* had spread far enough to be firmly established at locations in the southern USA (Wells 1991, Baumgartner 1993), and *Ch. chloropyga* occurs as far north as Panama (J. Mendez L., personal comm.).

Chrysomya chloropyga and *Ch. megacephala* are typical synanthopic pests, with saprophagous larvae usually found in carrion or feces (Greenberg 1971, Laurence 1986). *Chrysomya albiceps* and *Ch. rufifacies*, so similar to each other in form and natural history that their status as separate species has been debated (Tantawi & Greenberg 1993), have larvae that eat both carrion (and rarely live flesh) and other maggots (Fuller 1934, Ullyett 1950). The latter two species are also distinguished by the presence of prominent spiny tubercles (Fig. 1), which we believe serve to reduce cannibalism.

As *Chrysomya* densities in the New World have increased, sympatric popula-

---

[1] Current Address: Dept. ESPM, Div. Insect Biology, University of California, Berkeley, CA 94720.

Figure 1. Larva of *Chrysomya rufifacies* (with tubercles) attacking a larva of *Phormia regina* (Meigen). The head of *C. rufifacies*, inserted into the other larva, is down in this view.

tions of the native calliphorid *Cochliomyia macellaria* Fabr. have decreased, sometimes precipitously, and this has been interpreted as competitive displacement (Guimarães et al. 1979, Baumgartner & Greenberg 1984, Wells & Greenberg 1992, Paraluppi & Castellon 1994). A similar decline may be happening to *Lucilia exima* (Wiedemann) (Baumgartner 1993). Competition for food between carrion-fly larvae is often intense (Hanski 1987). Because the invaders don't seem to be filling any previously unexploited niche, i.e., they are eating the same carrion and feces that are already exploited by native flies, the ability to out-compete native species seems necessary for the success of *Chrysomya* in the Americas.

Some evidence indeed suggests that the *Chrysomya* spp. have a stronger negative effect on *Co. macellaria* in combination than individually. At a site in Peru where *Ch. chloropyga* became common but *Ch. albiceps* was rare, *Co. macellaria* dropped during a 4-year period from 46% to 11% of the adult population at baits, while at a site where both invaders were common, reduction of the native fly was from 89% to 0.2% (Baumgartner & Greenberg 1984). At Brazilian locations where all three *Chrysomya* are abundant, the previously common *Co. macellaria* has been described as rare or absent (Guimarães et al. 1979, Paraluppi & Castellon 1994). *Ch. rufifacies* is the only member of the genus known to be established in Texas, and although it was experimentally shown to reduce the number of *Co. macellaria* bred from carrion, the native fly is still abundant (Wells & Greenberg 1992, 1994).

The advance of these flies is in contrast to previous (and separate) introductions to Latin America of *Ch. megacephala*, *Ch. chloropyga* and *Ch. rufifacies* that failed (Baumgartner & Greenberg 1984, Baumgartner 1993). It is rather difficult to determine why an invasion did or did not succeed, but we hypothesize that the appearance of several *Chrysomya* spp. at the same time at least contributed to their successful establishment. Others have observed that coevolved sets of introduced species can be more able to invade because they have a greater impact on the invaded community than would be predicted from their individual interactions with native organisms (Simberloff 1991). In the case of *Chrysomya*, this would occur if the purely saprophagous larvae are adapted to resist or avoid the attack of their predaceous congeners with which they have long been sympatric. *Chrysomya megacephala* or *Ch. chloropyga* would then be more likely to successfully invade if *Ch. albiceps* or *Ch. rufifacies* were also present.

Chrysomya megacephala is commonly found with *Ch. rufifacies* in the Oriental, Autralsasian and Oceanic regions (James 1977, Kurahashi 1989). In addition, its successional position within carrion is similar to *Co. macellaria* (making them almost certainly competitors for the same food), and both are species attacked by *Ch. rufifacies* in the field (Bohart & Gressitt 1951, Wells & Greenberg 1994). In this study, we measured the rate of predation by *Ch. rufifacies* larvae on *Ch. megacephala* and on *Co. macellaria* in a laboratory arena.

METHODS AND MATERIALS

All larvae used were third instars approximately one cm in length. During a trial, 20 *Co. macellaria* and 20 *Ch. megacephala* were individually paired with a single *Ch. rufifacies* (40 total) within a 60 × 15 mm plastic petri dish. Dishes were arranged in a 5 by 8 pattern on a laboratory shelf, with alternating prey species in place. A trial began when a *Ch. rufifacies* larva was quickly dropped

Table 1. Number of *Cochliomyia macellaria* and *Chrysomya megacephala* larvae, out of a total of 20 each, successfully attacked by *Chrysomya rufifacies.*

Trial	*Co. macellaria*	*Ch. megacephala*
1	18	15
2	18	14
3	18	14
4	5	2
5	17	16
6	9	6

into each dish. After 20 min at 25 C, all larvae that, based on our experience, were damaged enough to be fatally wounded were counted. These included larvae that were shriveled, had body contents extruded through a hole in the cuticle, or were in the grip of a feeding *Ch. rufifacies*. Six trials were performed, each with a new generation of larvae.

Larvae were obtained from two sets of fly colonies. For trials 1–4 these were: *Co. macellaria* from Kerr County, TX, USA, colonized for an unknown number of generations; *Ch. megacephala* and *Ch. rufifacies* from Yona, Okinawa, Japan, colonized for 3–10 generations. Colonies for trials 5 and 6 were: *Co. macellaria* from W. Lafayette, IN, USA, colonized for 4–5 generations; *Ch. megacephala* from Kimbe, New Britain, Papua New Guinea, colonized for 10–11 generations; *Ch. rufifacies* from Matsuda, Okinawa, Japan, colonized for 3–4 generations.

RESULTS AND DISCUSSION

In every trial, *Ch. rufifacies* killed or wounded a greater number of *Co. macellaria* than *Ch. megacephala* (Table 1). Under these conditions, *Ch. megacephala* was more resistant to attack by its historically sympatric congener than was the previously allopatric *Co. macellaria* (sign test, $p = 0.03$). From casual observation, we believe that *Ch. megacephala* was more quick to struggle vigorously and flee following contact with the mouthparts of *Ch. rufifacies*, although no effort was made to quantify such behavior.

Although the total number killed per trial varied from in 7 to 33, the relative difference between the two prey species was similar for all trials. We suspect that each batch of *Ch. rufifacies* had a particular "hunger level" that influenced the overall probability and/or strength of attack, but that had no influence on the relative vulnerability of prey species.

These results, albeit produced in a highly artificial setting, support the hypothesis that *Ch. megacephala* is a stronger competitor against *Co. macellaria* when *Ch. rufifacies* is present. To the extent that our observations apply to wild populations, it follows that the establishment and spread of *Ch. megacephala* within the range of *Co. macellaria* was aided by the presence of *Ch. rufifacies* or the nearly identical *Ch. albiceps*. Further experimental manipulations and field observations are needed to confirm this complex interaction.

ACKNOWLEDGMENT

Ichiro Miyagi, University of the Ryukyus, Bernard Greenberg, University of Illinois at Chicago and S. Adam Shahid, Purdue University, kindly helped us to obtain our fly colonies. JDW was supported by a fellowship from the National Science Foundation (INT-9311789) and the Japanese Science and Technology Agency (193040).

Literature Cited

Baumgartner, D. L. 1988. Spread of introduced *Chrysomya* blowflies (Diptera, Calliphoridae) in the Neotropics with records new to Venezuela. Biotropica, 20: 167–168.

Baumgartner, D. L. 1993. Review of *Chrysomya rufifacies* (Diptera: Calliphoridae). J. Med. Entomol., 30: 338–352.

Baumgartner, D. L. & B. Greenberg. 1984. The genus *Chrysomya* (Diptera: Calliphoridae) in the New World. J. Med. Entomol., 21: 105–113.

Bohart, G. E. & J. L. Gressitt. 1951. Filth-inhabiting flies of Guam. Bull. Bernice P. Bishop Mus., 204: 1–169.

Fuller, M. E. 1934. The insect inhabitants of carrion: a study in animal ecology. Aust. Counc. Sci. Ind. Res. Bull., 82: 4–63.

Greenberg, B. (ed.). 1971. Flies And disease. Vol. I. Ecology, classification and biotic associations. Princeton University Press, Princeton.

Guimarães, J. H., A. P. do Prado & G. M. Buralli. 1979. Dispersal and distribution of three newly introduced species of *Chrysomya* Robineau-Desvoidy in Brazil (Diptera, Calliphoridae). Rev. Bras. Entomol., 23: 245–255.

Hanski, I. 1987. Nutritional ecology of dung- and carrion-feeding insects. pp. 837-884. *In* Slansky, F. & J. G. Rodriguez (eds.). Nutritional ecology of insects, mites, spiders and related invertebrates. John-Wiley, New York.

James, M. T. 1977. Family Calliphoridae. pp. 528-556. *In*. Delfinado, M. D. & D. E. Hardy (eds.). A catalog of the Diptera of the Oriental region. University Press of Hawaii, Honolulu.

Jirón, L. F. 1979. Sobre moscas califoridas de Costa Rica (Diptera: Cyclorrhapha). Brenesia, 16: 221–222.

Kurahashi, H. 1989. Family Calliphoridae. pp. 702–717. *In*. Evenhuis, N. L. (ed.). Catalog of the Diptera of the Australasian and Oceanian regions. Bishop Museum Press, Honolulu.

Kurahashi, H., J. D. Wells & K. Ogino. 1994. The Oriental latrine fly, *Chrysomya megacephala* (Fabricius) (Diptera), newly recorded from Honduras, Central America. Jpn. J. Entomol., 62: 860.

Laurence, B. R. 1986. Old World blowflies in the New World. Parasit. Today, 2: 77–79.

Mariluis, J. C. & J. A. Schnack. 1989. Ecology of the blow flies of an eusynanthropic habitat near Buenos Aires (Diptera, Calliphoridae). EOS, 65: 93–101.

Olsen, A. R., S. C. Angold, D. F. Gross & T. H. Sidebottom. 1992. New record of the blowfly, *Chrysomya megacephala* (Fabr.), from Ecuador. Pan-Pac. Entomol., 68:280–281.

Paraluppi, N. D. & E. G. Castellon. 1994. Calliphoridae (Diptera) em Manaus: I. Levantamento taxonomica e sazonalidade. Rev. Bras. Entomol., 38: 661–668.

Simberloff, D. 1991. Keystone species and community effects of biological introductions. pp. 1–19. *In* Ginzbeg, L. R. (ed.). Assessing ecological risks of biotechnology. Butterworths-Heinemann, Stoneham, MA.

Tantawi, T. I. & B. Greenberg. 1993. *Chrysomya albiceps* and *C. rufifacies* (Diptera: Calliphoridae): contribution to an ongoing taxonomic problem. J. Med. Entomol., 30: 646–648.

Ullyett, G. C. 1950. Competition for food and allied phenomena in sheep-blowfly populations. Phil. Trans. Roy. Soc. Ser. B., 234: 77–174.

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: 471–472.

Wells, J. D. & B. Greenberg. 1992. Interaction between *Chrysomya rufifacies* and *Cochliomyia macellaria* (Diptera: Calliphoridae): the possible consequences of an invasion. Bull. Entomol. Res., 82: 133–137.

Wells, J. D. & B. Greenberg. 1994. Resource use by an introduced and native carrion flies. Oecologia, 99: 181–187.

Received 26 Apr 1996; Accepted 6 Aug 1996.

PAN-PACIFIC ENTOMOLOGIST
73(1): 21–27, (1997)

ECOLOGICAL STUDIES ON *CARDIOCONDYLA ECTOPIA* SNELLING (HYMENOPTERA: FORMICIDAE) IN SOUTHERN CALIFORNIA.[1]

HANIF GULMAHAMAD
3547 Centurion Way, Ontario, California 91761

Abstract.—At this location, *Cardiocondyla ectopia* Snelling is a largely diurnal species which foraged throughout the year when ambient temperatures exceeded 18.9° C. Its major food source was nectar from sweet alyssum flowers, *Lobularia maritima* Desvaux. It preyed on insects, particularly small caterpillars, and it was also a scavenger. It nested in small cavities in mortar, cracks and expansion joints in concrete, and in soil. A colony was excavated from which 322 ants were retrieved. This represented the largest nest population ever recorded for a *Cardiocondyla* species. A number of behavioral strategies, in addition to a potent repellent chemical, probably allow *C. ectopia* to live in sympatry and synchrony with *Linepithema humile* (Mayr).

Key Words.—Insecta, Formicidae, *Cardiocondyla ectopia*, foraging, food sources, nest sites, nest population, coexistence, *Linepithema humile*, *Lobularia maritima*

Cardiocondyla ectopia Snelling was described in 1974 from specimens taken from Orange and Los Angeles counties, California (Snelling 1974). This species was also reported from Arizona (MacKay 1995). Although this species was recorded from southern California, it has been rarely collected from this area. A survey of urban ants of California yielded 30 species but *C. ectopia* was not recorded (Knight & Rust 1990.) However, I collected this species on several occasions around structures in the cities of Downey and Long Beach (Los Angeles County), and Montclair and Ontario (San Bernardino County). This ant has been overlooked by structural pest control operators in southern California probably because of its small size, small colonies, cryptic nests, absence of trailing behavior, and its apparent inability to invade structures.

All current biological information available on *C. ectopia* is contained in Creighton & Snelling (1974). Herein I provide additional information on *C. ectopia* foraging behavior, food resource utilization, nest sites, nest population, and its coexistence with the Argentine ant, *Linepithema humile* (Mayr).

MATERIALS AND METHODS

I observed six colonies of *C. ectopia* located on my property in Ontario, San Bernardino County, California. Periodic observations, encompassing an hour or more at a time, began in January 1995 and continued through May 1996 as time permitted. On weekends, intermittent observations began as early as 08:00 h and continued for several hours at a time until 23:00 h. Most of the observations recorded here were made with an OptiVisor optical glass binocular magnifier (Donegan Optical Company, Kansas City, Missouri). From these observations, information was gathered on foraging behavior, food resource utilization, nest location, coexistence with the Argentine ant, *Linepithema humile* (Mayr), and

---

[1] Author page charges partially offset by a grant from the C. P. Alexander Fund, Pacific Coast Entomological Society.

chemical defense strategy. On 25 Nov 1995, a colony of *C. ectopia* was excavated and the number of ants retrieved was recorded.

RESULTS AND DISCUSSIONS

Foraging Behavior.—Cardiocondyla ectopia is a largely diurnal species. Above ground activity of this ant is governed by temperature. Foraging activity in July 1972 was reported to begin when the ambient temperature ranges from 18.9 to 20 °C (Creighton & Snelling 1974). When asphalt temperature reached 26.1 °C foragers were no longer using the exposed surfaces (Creighton & Snelling 1974). I observed surface activity of this ant during the third and fourth weeks of December 1995 when the concrete temperature was 15.6 °C (recorded with a surface temperature thermometer - Sybron Taylor Products, Arden, North Carolina). This activity was observed as early as 08:40 h when several workers and four alates were found around the nest entrance area. These ants were lethargic and a few appeared to be moribund. As the temperature increased ant activity increased. They may have been induced to emerge from this nest in an expansion joint in the slab because bright sunlight was shining directly on this area. Creighton & Snelling (1974) recorded some surface activity of this ant as late as 19:25 h in July 1972. During the last week of December 1995, foraging activity on sweet alyssum flowers, *Lobularia maritima* Desvaux was observed as late as 16:30 h. On 19 May 1996, foraging on these flowers was observed at 20:10 h. Some ant activity around the nest area was observed at 20:26 h on 19 May 1996 when observations had to be made with a flashlight as it was too dark to see these ants. Ant activities were observed as late as 23:05 h in July and August 1996 at unusual food sources such as dog food and soda. At this location, *C. ectopia* foraged throughout the year whenever temperatures were conducive to above ground activity.

Cardiocondyla ectopia searched its foraging territory in a random manner. Individuals were found traversing areas as much as 6 m away from the nest. The colonies I observed foraged mostly on nectar from flowers of sweet alyssum. This landscape annual produces tiny white four-petaled flowers which are borne in clusters and the flowers emit a honeylike fragrance. Once a plant was located, *C. ectopia* foragers returned to this resource many times to exploit it. I observed numerous individuals from two colonies travelling directly to a clump of sweet alyssum located 3 m away from the nests. Tandem running and recruitment to a food source occurs in the genus *Cardiocondyla* (Wilson 1959a, Creighton & Snelling 1974). *Cardiocondyla ectopia* also exhibited this behavior, but it was not common. Associative learning appeared to be present in this species as these ants repeatedly returned to a productive floral food source by different routes over many days. I observed foragers returning to a location where I had removed a clump of flowers for up to two h after the plants were gone.

Foragers of *C. ectopia* readily ascended various herbaceous plants and explored their surfaces. Many of these plants did not have flowers and it appeared that the ants were searching for other food sources, probably, extrafloral nectaries, glandular plant exudates, honeydew, live and dead insects, etc.

On 26 Nov 1995, four foragers of *C. ectopia* were observed searching the surfaces of a small bean plant. The leaves of this plant exhibited typical caterpillar damage and it may have been the source of some of the first instar caterpillars retrieved from foragers returning to their nests.

On 26 Nov 1995, five dead *C. ectopia* workers were found at different locations on the stem of a small tomato plant, *Lycopersicon esculentum* Miller. Microscopic examination of these ants revealed no obvious bodily injury. It is possible that these ants were killed by toxic glandular exudates from this plant. Glandular exudates, particularly sucrose and glucose esters from solanaceous plants such as tomato and tobacco, have been reported to immobilize small herbivores, inhibit and/or deter feeding, or to be toxic (Kennedy & Yamamoto 1979, Gregory et al. 1986, King et al. 1990).

During the first three weeks of November 1995, several foragers of *C. ectopia* were observed ascending and descending a cardboard receptacle that was 0.6 m in height and was located about 0.6 m from their nest. This container held empty soda cans for recycling and *C. ectopia* workers were observed on the lids of several cans feeding on soda remnants. On 13 Aug 1996 as many as 75 ants were counted on this soda can. This is an example of an opportunistic ant species exploiting a man-made food resource.

Food Resource Utilization.—Information on food resource utilization by members of the genus *Cardiocondyla* is scarce. *Cardiocondyla venustula* Wheeler is reported to be a scavenger (Wilson 1959a); *C. emeryi* Forel is thought to be omnivorous (Creighton & Snelling 1974); *C. wroughtoni* Forel is reported to be a predator (Lupo & Gerling 1984); and *C. ectopia* has been observed taking nectar from *Chamaesyce serpens* Small (Creighton & Snelling 1974).

At this location, ants from all *C. ectopia* colonies fed primarily on nectar from flowers of sweet alyssum. Twelve foragers were recorded from one plant and as many as three workers were found on one tiny flower. Foragers often spent considerable time on flowers of this plant.

Cardiocondyla ectopia also exhibited predatory behavior. The following live insects were retrieved from individual foragers returning to their nests: two first instar caterpillars, one second instar caterpillar, one first instar geometrid larva, an unknown small legless larva, and a small aphid. When freed from the mandibles of the foragers, the caterpillars attempted to crawl away. On 25 Dec 1995, one forager was observed attempting to remove a second instar caterpillar from a sweet alyssum plant. It was experiencing great difficulty in doing so because the caterpillar was holding on to the plant. Finally, the ant and its quarry fell off the plant. Once on the ground, the ant was more successful in carrying the caterpillar especially when it grasped the caterpillar at about its midsection. Even when the prey was on the ground, the ant was not able to transport it more than a few centimeters at a time. Occasionally, it left the prey and ran about the area in a "frenzied" manner perhaps attempting to locate another nestmate which it could possibly recruit to this food resource.

At this site, *C. ectopia* also functioned as a scavenger. The following dried, dead arthropods were retrieved from foragers returning to their nests: a small caterpillar, a cast larval skin, three small flies, a thrips, a drain fly (family Psychodidae) two collembolans, one earwig nymph, a chironomid midge, and a spiderling.

In August 1994, while evaluating commercial ant baits for Argentine ant control, small amounts of Drax Ant Kill Gel—a sucrose/orthoboric acid ant gel bait, (Waterbury Companies, Waterbury, Connecticut) were dispensed in short pieces of plastic straws and placed at various locations on the study site. *Cardiocondyla ectopia* foragers discovered this bait at one location and fed on it.

The fact that this ant fed on soda and on a sugar-based ant bait indicates that, if accessible in nature, *C. ectopia* will probably feed at extrafloral nectaries. On 13 Jul 1996, *C. ectopia* were observed feeding on honeydew produced by aphids on cowpea plants at this location. Members of the genus *Cardiocondyla* have been reported to feed on honeydew (Smith 1944).

Nest Location.—Around human habitation *C. ectopia* utilized various sites to establish its nests. At least six nests existed on this property during these investigations. Two nests were located in cavities in mortar at the edge of bricks along the side of the concrete driveway. A third nest was located in soil on the south side of the house next to a concrete walkway. The fourth nest was found at the southeast corner of the building in an expansion joint where the concrete walkway met the foundation of the structure. The fifth nest was located in a crack in a concrete walkway at the southeast corner of the house. The sixth nest was located in soil at the edge of a concrete walkway leading to the front door of the structure. Only one of the nest entrances on this property was ever surrounded by a pile of debris as reported elsewhere (Creighton & Snelling 1974). However, nests of *C. ectopia* which were located in bare soil on a residential property in Montclair, California, were always surrounded by piles of miscellaneous materials. The presence of debris around a nest entrance is probably influenced by soil type, nest location, and type of food utilized.

On two occasions, when attempting to pinpoint nest entrances, the entry points were inadvertently enlarged by the author. The ants immediately closed off the entrances. They quickly gathered whatever materials were available from around the nest entrances and began piling them into the opening. Examples of materials used were small pieces of stucco, dirt, sand grains, small rocks, small pieces of mortar and concrete, flower petals of alyssum, and tiny pieces of grass clippings.

Nest Population.—Reported colony size of some members of the genus *Cardiocondyla* are as follows: *C. venustula*—probably no more than 100 or 200 workers (Wilson 1959a); *C. nuda*—two dealated queens and 38 workers (Creighton & Snelling 1974); *C. paradoxa*—50 adults (Wilson 1959b); *C. thoracica*—70 adults (Wilson 1959b); *C. ectopia*—eight dealate females, two alate females, 75 workers and 2 males. Immatures were not counted but they were estimated at 55 larvae and 15 pupae (Creighton & Snelling 1974).

A total of 322 ants were recovered from an excavated colony of *C. ectopia* representing the largest number ever recorded for a *Cardiocondyla* species. Castes retrieved included 72 alate females, 13 dealate females, two males and 233 workers. Immatures were not counted. These numbers are considerably higher than the numbers previously recorded for a colony of *C. ectopia* (Creighton & Snelling 1974).

Coexistence with the Argentine Ant.—The Argentine ant *Linepithema humile* (Mayr), is a notoriously aggressive species which can negatively impact the biodiversity of ecosystems (Smith 1936, Haskins 1939, Michener 1942, Haskins & Haskins 1965, Smith 1965, Wilson & Taylor 1967, Crowell 1968, Fluker & Beardsley 1970, Ebeling 1975, Erickson 1975, Lieberburg et al. 1975, Ward 1987, Gulmahamad 1995). However, *C. ectopia* was observed by the author coexisting with the Argentine ant at four different geographical locations in southern California. At one site, it was surviving in a nest with the entrance located only 8 cm from a nest of the Argentine ant and only 3 cm from an active trail of this species.

Cardiocondyla ectopia appears to employ a number of behavioral strategies to survive in association with the pugnacious Argentine ant. Some examples of these behavioral strategies might be (1) it forages individually and seldom recruits to food sources by tandem running, thus maintaining a low profile presence in sympatric and synchronous situations, (2) although it is omnivorous, its major food source is nectar from certain flowers, and its predaceous and scavenging activities do not appear to bring it in conflict with the Argentine ant as far as food resource utilization is concerned. No agonistic interactions were ever observed between the two species at any food source during these observations, (3) it maintains small colony populations and thus there are fewer opportunities for conflict among individuals of the two species, (4) it utilizes small, cryptic nest entrances, (5) only a small number of foragers of *C. ectopia* are usually above ground at a given time thus the potential for conflicts between the two species is much reduced, (6) foragers of *C. ectopia* enter and leave the nest singly, thus workers do not draw attention to the nest entrance (7) alates leave the nest singly and at intervals, thus there is no aggregation of swarmers at the nest entrance to draw unwanted attention to the nest, and (8) during favorable temperature and daylight conditions, workers emerging from a nest crawl away from the nest entrance immediately thus there is no congregation of ants at or around the nest area.

All of the above strategies probably enables *C. ectopia* to maintain a low profile existence in a hostile territory.

Chemical Defense Strategy of C. ectopia.—Ants are known to use chemicals as defense weapons when threatened by other species (Blum 1981, Hermann & Blum 1981, Buschinger & Maschwitz 1984, Hermann 1984). Members of the genus *Cardiocondyla* are known to use chemicals to protect themselves from aggressive and carnivorous species (Creighton & Snelling 1974). These authors reported that *C. emeryi* often nest in close proximity to colonies of *Solenopsis geminata* (F.) and *Pheidole dentata* Mayr in Texas. They observed minor workers of *P. dentata* responding in a near panic manner in the presence of workers of *C. emeryi*. They postulated that the use of repellent chemicals may explain the nesting of *C. emeryi* close to other aggressive ants species. Creighton & Snelling (1974) also noted that Argentine ant workers often behaved in a very erratic fashion when they encountered workers of *C. ectopia*.

I observed *C. ectopia* using a chemical to defend itself against the Argentine ant on many occasions. When this material was released, it elicited a dramatic frenzied and agitated running behavior in an affected Argentine ant. Shortly thereafter, the recipient was often vigorously engaged in cleaning its eyes, antennae, and mouthparts with its forelegs. This material is of abdominal origin as crushed abdomens of *C. ectopia* elicited frenzied and agitated running behavior when touched on the heads of conspecifics as well as workers of *L. humile*. The repellent material elicited the most dramatic reaction when applied to the head of the aggressor. Chance encounters between individual ants of these species often did not result in the use of this repellent chemical. At least twelve interspecific contacts between these ants were observed which did not result in the use of the repellent material. In these situations, the individuals involved briefly examined each other and then separated. This is a beneficial strategy because production of defensive chemicals represents a drain of resources which dictates prudent use. Possession of a potent repellent chemical does not always insure self preservation in a continuous hostile territory. On two occasions, individual *C. ectopia* workers inadvertently wandered into well established trails of the Argentine ant. In these situations, *L. humile* workers attacked and dispatched these individuals with mandibular cuts. Two encounters between individuals of *C. ectopia* and *L. humile* resulted in the loss of an antenna by *C. ectopia.*

A combination of the various behavioral strategies described earlier in this paper and the prudent use of a repellent chemical probably enables *C. ectopia* to survive in disturbed urban environments around structures in southern California which are dominated by the Argentine ant.

ACKNOWLEDGMENT

I thank the following people who kindly read the manuscript and offered suggestions for its improvement: Roy Snelling, Los Angeles County Natural History Museum; Stoy Hedges, Terminix Int.; Rusty Bracho, ServiceMaster; Ken Hobbs, Entodendrex; William MacKay, University of Texas at El Paso, and William MacKay for providing the identification of *C. ectopia.*

LITERATURE CITED

Blum, M. S. 1981. Chemical defenses of Arthropods. Academic Press, New York.

Bolton, B. 1982. Afrotropical species of the myrmicine ant genera *Cardiocondyla*, *Leptothorax*, *Melissotarsus*, *Messor*, and *Cataulacus* (Formicidae). Bull. Brit. Mus. Natur. History. (Entomol. Series), 45: 307–370.

Buschinger, A. & U. Maschwitz. 1984. Defensive behavior and defensive mechanisms in ants. pp. 95–150. *In* Hermann, H.R. (ed.). Defensive mechanisms in social insects. Praeger, New York.

Creighton, W. S. & R. R. Snelling. 1974. Notes on the behavior of three species of *Cardiocondyla* in the United States (Hymenoptera: Formicidae). J. N. Y. Entomol. Soc: 82: 82–92.

Crowell, K. L. 1968. Rates of competitive exclusion by the Argentine ant in Bermuda. Ecology, 49: 551–555.

Ebeling, W. 1975. Urban Entomology. Univ. Calif. Press, Berkeley, California.

Erickson, J. M. 1971. The displacement of native ant species by the introduced Argentine ant, *Iridomyrmex humilis* (Mayr). Psyche, 78: 257–266.

Fluker, S. S. & J. W. Beardsley. 1970. Sympatric associations of three ants: *Iridomyrmex humilis*, *Pheidole megacephala*, and *Anoplolepis longipes* in Hawaii. Ann. Entomol. Soc. Amer., 63: 1290–1296.

Gregory, P., D. A. Ave, P. Y. Bouthyette & W. M. Tingey. 1986. Insect defensive chemistry of potato glandular trichomes. *In* Juniper, B. E. & T. R. E. Southwood (eds.). Insects and the plant surface. Edward Arnolds, London.

Gulmahamad, H. 1995. Argentine ant: the Genghis Khan of the ant world. Pest Mgmt, 14: 9–15.

Haskins, C. P. 1939. Of ants and men. Prentice-Hall, New York.

Haskins, C. P. & E. F. Haskins. 1965. *Pheidole megacephala* and *Iridomyrmex humilis* in Bermuda-equilibrium or slow replacement? Ecology, 46: 736–740.

Hermann, H. R. & M. S. Blum. 1981. Defensive mechanisms in the social Hymenoptera. pp 77–197. *In* Hermann, H. R. (ed.). Social insects, Vol. 2. Academic Press, New York.

Kennedy, G. G. & R. T. Yamamoto. 1979. A toxic factor causing resistance in a wild tomato to the tomato hornworm and some other insects. Ent. Exp. Appli. 26: 121–126.

King, R. R., L. A. Calhoun, R. P. Singh & A. Boucher. 1990. Sucrose esters associated with glandular trichomes of wild *Lycopersicon* species. Phytochemistry, 29: 2115–2118.

Knight, R. L. & M. K. Rust. 1990. The urban ants of California with distribution of imported species. Southwestern Entomol., 15: 167–178.

Lieberburg, I., P. M. Kranz & A. Seip. 1975. Bermudian ants revisited: the status and interaction of *Pheidole megacephala* and *Iridomyrmex humilis.* Ecology, 56: 473–478.

Lupo, A. & D. Gerling. 1984. Bionomics of the tamarix spindle-gall moth, *Amblypalpis olivierella* Rag. (Lepidoptera: Gelechiidae) and its natural enemies. Boll. Lab. Entomol. agr. Filippo Silvestri, 41: 71–90.

MacKay, W. P. 1995. New distributional records for the ant genus *Cardiocondyla* in the New World. (Hymenoptera: Formicidae). Pan-Pacif. Entomol., 71: 169–172.

Michener, C. D. 1942. The history and behavior of a colony of harvester ants. Sci. Mon., 55: 248–258.

Smith, M. R. 1936. Distribution of the Argentine ant in the United States and suggestion for its control and eradication. U.S. Dept. Agric. Circ. No. 387.

Smith, M. R. 1944. Ants of the genus *Cardiocondyla* Emery in the United States. Proc. Entomol. Soc. Wash., 46: 30–41.

Smith, M. R. 1965. House-infesting ants of the eastern United States. Tech. Bull. Agr. Res. Svc., U.S. Dept. Agr. No. 1326.

Snelling, R. R. 1974. Studies on California ants. 8. A new species of *Cardiocondyla* (Hymenoptera: Formicidae). J. N. Y. Entomol. Soc., 82: 76–81.

Ward, P. S. 1987. Distribution of the introduced Argentine ant (*Iridomyrmex humilis*) in natural habitats of the lower Sacramento Valley and its effects on the indigenous ant fauna. Hilgardia, 55: 1–16.

Wilson, E. O. 1959a. Communication by tandem running in the ant genus *Cardiocondyla.* Psyche, 66: 29–34.

Wilson, E. O. 1959b. Some ecological characteristics of ants in New Guinea rain forests. Ecology, 40: 437–447.

Wilson, E. O. & R. W. Taylor. 1967. The ants of Polynesia (Hymenoptera: Formicidae). Pac. Ins. Monog. No. 14.

Received 19 Jan 1996; Accepted 1 Jun 1996.

PAN-PACIFIC ENTOMOLOGIST
73(1): 28–35, (1997)

REPRODUCTIVE BEHAVIOR OF THE FEMALE CAROB MOTH, (LEPIDOPTERA: PYRALIDAE)

RICHARD S. VETTER, STEVE TATEVOSSIAN,[1] AND THOMAS C. BAKER[2]
Department of Entomology, University of California,
Riverside, CA 92521

Abstract.—Periodicities of the female reproductive behavior of the carob moth, *Ectomyelois ceratoniae* (Zeller), were investigated in regard to calling, mating, and oviposition. Under varying photoperiods (16:8, 14:10, 12:12 L:D h), female carob moths initiated calling about the mid-point of the scotophase to which they were entrained resulting in a shift to later mean initiation times as the nocturnal period lengthened. Matings were initiated during the fifth and sixth h of scotophase in a 16:8 L:D h light regime; this corresponded with the calling periodicity. Carob moth females laid significantly more eggs in the first hour of scotophase (16:8 L:D h) than in any other hour, after which oviposition declined significantly. Oviposition was greatest from the third through sixth scotophase after which it decreased. Oviposition periodicity was developed by the third scotophase, and peaked during the fourth.

Key Words.—Insecta, Pheromone Behavior, Mating Periodicity, *Ectomyelois ceratoniae*

The carob moth, *Ectomyelois ceratoniae* (Zeller), has occasionally been found in the southern United States. This species was most likely introduced from the Middle East where it is a pest of dates, almonds and pomegranates and was first noticed in California in 1982 (Eichlin 1982). It has since become a serious pest of dates in the Coachella Valley in southern California (Warner 1988, Warner et al. 1990a, b) and is of concern to growers as fewer insecticides are available for controlling this pest. In addition, there is concern that the carob moth may spread northward and threaten the almond and walnut industries in California's Central Valley.

Little information is available regarding behavior of the carob moth. Research has been performed on the effects of abiotic factors on development and diapause (Cox 1976, 1979), however, most research has focused on applied aspects in relation to agricultural crop damage (see Gothilf 1984 and references therein). Due to the recent immigration of the carob moth in the U.S., studies have been initiated to develop semiochemical control of this insect: assessment of male responses to both female sex pheromone and a formate analog (Baker et al. 1991, Todd et al. 1992), and female responses to volatile date odors (Cossé et al. 1994). The goal of this study was to develop a knowledge of the reproductive behavior of the carob moth.

MATERIALS AND METHODS

Insects.—Moths were obtained from date (*Phoenix dactylifera* L.) gardens in the Coachella Valley, California (Lat. 30°30′N, Long. 116°W) in 1985 and maintained year-round in the laboratory for >6 yr with no infusion of wild insects. Larvae were reared on a wheat bran-honey diet (Finney & Brinkman 1967) sup-

---

Present Address: [1]School of Dentistry, Loma Linda University, Loma Linda, CA 92350; [2]Entomology Dept. Iowa State University Ames, IA 50011.

plemented with brewer's yeast and maintained in clear, 4-liter, screened-lid glass jars at 28 ± 2°C with a 16:8 L:D h photoperiod. Additional rearing methods were slightly modified from those of Strong et al. (1968). For the calling and mating studies, pupae were separated by sex and placed in moistened vermiculite-filled cups inside of screen cages (30 by 30 by 30 cm) at the light cycles under which the adult moths were eventually tested. Cups of pupae were removed daily to an empty cage, leaving behind moths of known age. When 3 differing light cycles were used in the calling experiment, pupae harvested each day were separated into three groups with one group set up in each light regime. In the mating experiment, male and female pupae were placed in separate environmental chambers and allowed to emerge. For the oviposition study, pupae were not separated by sex but were otherwise treated as above. All moths were maintained at 23 ± 2° C throughout the course of the study and supplied with 8% sugar water solution ad libitum.

Periodicity of Pheromone Calling.—Females were held under 16:8, 14:10 and 12:12 L:D h light cycles to investigate the periodicity of calling. Virgin females were individually placed into plastic, air-tight vials (70 mm by 33 mm) in the last hour of photophase; a 10 mm by 10 mm diam piece of moistened dental wick was added to each vial as a water source. Cohorts of females that had been adults for 1, 2, 3, 4 and 5 days were set up for each of the 16:8 and 14:10 L:D h cycles; a single cohort of Day 2 females was set up for the 12:12 L:D h cycle. In this experiment, the term "Day" is used to indicate a 24-h period starting with the first hr of scotophase; this is to avoid confusion between the ambiguous use of "day" for 24 h or for only its photoperiod. Insects labelled as "Day 2" were entering their 2nd complete scotophase as moths and therefore were 25–48 h old. Each cohort consisted of 30 females except for Day 1 for the 16:8 (n = 24) and 14:10 (n = 10) light cycles. Females were moved into a bioassay room that was illuminated by dimmed white and red incandescent lighting (combined lighting level = 0.3 lux). Females were checked for calling (i.e., visible extrusion of the ovipositor/sex pheromone gland and hence, presumed sex pheromone emission) every hr during the scotophase. Observations were made using a flashlight covered by several pieces of red cellophane. This light did not appear to alter the females' behavior. Observations in photophase were made at 2 h intervals until the next scotophase at which point the bioassay was terminated. Data were omitted for any moth which died in the course of the experiment.

Periodicity of Mating Behavior.—As a correlate of the calling periodicity, a mating study was performed. Virgin male-female pairs were placed together in screen mating cages (80 mm by 50 mm, 18 by 14 mesh), the ends of which were closed with plastic petri dishes. Moths were maintained on a 16:8 L:D h cycle and, in the last hour of photophase, a male-female pair (each of Day 3) was introduced into a mating cage; Day 3 moths were chosen because in many moth species, males typically require several days to become sexually mature (Shorey et al. 1968). Pairs were then placed in a bioassay room with dimmed, white incandescent lighting (0.3 lux). Fan-forced air was circulated around the room and another fan continually exhausted the room air outside the building. Moths were observed every 30 min of scotophase until the first pair mated, whereafter they were observed every 15 min until the end of scotophase when the bioassay was terminated. Observations were aided with a red cellophane-covered flashlight, although at 0.3 lux, there was sufficient light to see pairs coupled. Two replicates were run, 30 pairs per replicate. Data were excluded if either moth of a pairing was dead or moribund at the conclusion of the test.

Periodicity of Oviposition.—Female carob moths (16:8 L:D cycle) were removed from their emergence cage (which contained males of equal age as mating partners) and were set up in screen cages (80 mm by 50 mm) with an open end which was covered with a clear polyethylene sleeve. A cohort consisting of 10 females of known age (Day 2, 3, 4, 5, 6, 7 or 8) was placed in a cage; four cohorts were run for each age of female. The dates used as the oviposition substrate (variety Deglet Noor) have low water content and are preferred by the carob moth in the Coachella Valley over other, moister varieties (C. Kerby, pers. comm.). These dates were of commercial sale quality taken from a recent harvest, rinsed with water to remove elemental sulfur used for mite control, and air-dried. For the experiment, dates were impaled on a bent paper clip tied to a piece of string so they could be easily lowered into and pulled out of the cages. Decaying dates might prove more attractive as oviposition lures because female carob moths are attracted to odors of fermenting or fungus-infested host fruits (Gothilf et al. 1975, Warner 1988, Cossé et al. 1994). However, using them might introduce greater variation into the experiment; hence, non-decaying dates were used. One date was placed in each cage of 10 females and the plastic sleeve was folded over and clipped to minimize moth escape. Cages were transferred to a bioassay room described above. Dates were replaced hourly and deposited eggs were counted and totalled for each of the 8 h of scotophase. Because few eggs were laid on the cage that housed the moths, no attempt was made to count them. At initiation of photophase, females were given another date which was not removed until the end of the 16 h light period; we previously observed little oviposition occurs during photophase. The experiment was terminated at the start of the next scotophase. Females were transferred to vials containing 90% alcohol and later dissected to determine the number of spermatophores in the bursa copulatrix.

Statistics.—Calling periodicity was analyzed with one-way ANOVA with Tukey-Compromise test or two-way ANOVA with Tukey's studentized range tests separations. Mating periodicity was analyzed with a X^2 test for independence using Yate's correction. Oviposition periodicity data were square-root transformed because there was a high variance within the data sets, and then analyzed using two-way ANOVA with Tukey's studentized range test for separation (SAS Institute, 1982).

RESULTS

Calling Periodicity.—Female carob moths initiated calling in the fourth through sixth h of scotophase (16:8) and fourth through seventh h (14:10) for all five age cohorts of females; Day 2 females on the 12:12 light cycle initiated calling in the fifth h (Fig. 1). ANOVA of the 14:10 and 16:8 cohorts revealed a significant difference among the groups for initial onset of calling (two-way ANOVA, F = 9.80; df = 9, 220; $P < 0.0001$). The 16:8 moths called significantly earlier than the 14:10 females ($F = 61.97$; df = 1; $P < 0.0001$), however, there was also a significant difference between cohorts within a light cycle ($F = 3.51$; df = 4; $P < 0.01$). The interaction of age × light cycle was not significant ($F = 2.08$; df = 4; $P > 0.05$). In the 16:8 groups, as the age of the female cohort increased,

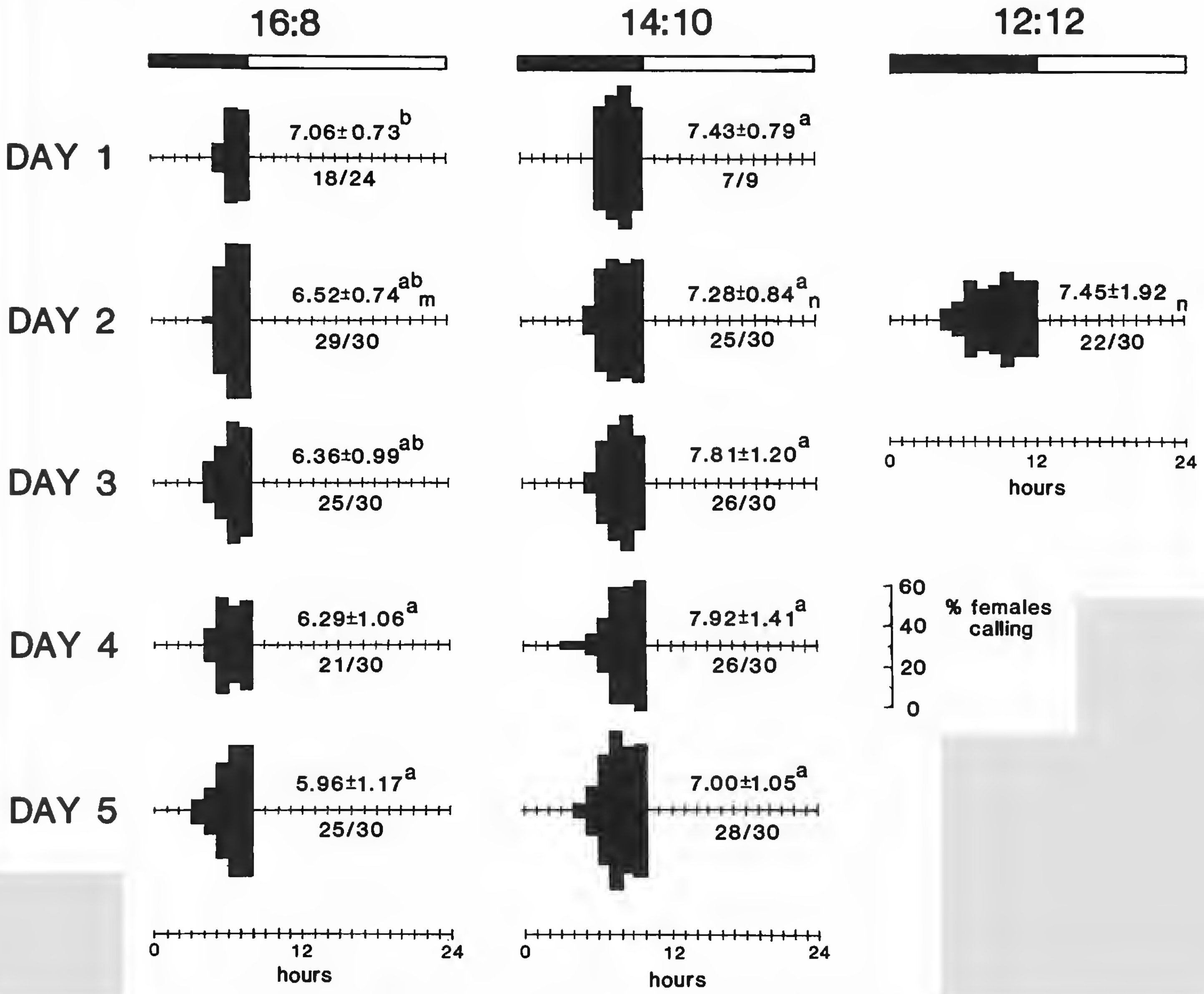


Figure 1. Percentage of calling female carob moths at 16:8, 14:10 and 12:12 L:D hr photoperiod regimes. Bar above symmetric histograms indicates dark:light cycle. Average initial onset of calling (x ± SD) is indicated above the tick-marked axis; # females observed calling at least once/# females alive at experiment termination is indicated below. 16:8 versus 14:10 data were analyzed by two-way ANOVA. Means having none of the superscript letters (^{a,b}) in common indicate significant differences within a column (Tukey's Studentized Range test). Day 2 females were compared with a one-way ANOVA. Means having none of the subscript letters ($_{m,n}$) in common indicate significant differences across the row (Tukey-Compromise test).

their time of initial onset of calling occurred significantly earlier in the scotophase (Fig. 1). This behavior was not exhibited, however, with the 14:10 cohorts. Additionally, all calling terminated during the first hr of photophase and no calling was observed during the remainder of the photophase.

When Day 2 females were analyzed across the three light cycles, the 16:8 females called significantly earlier than either of the other two groups (one-way ANOVA; $F = 4.37$; df = 2, 73; $P < 0.01$). The 14:10 and 12:12 groups were statistically indistinguishable (Fig. 1).

Mating Periodicity.—There was no difference between the 2 replicates for hour of mating initiation ($X^2 = 3.13$; df = 7; $P > 0.05$) or frequency of mating between pairs ($X^2 = 0.30$; df = 1; $P > 0.05$) so the data were pooled. Mating occurred in 43 of 55 (76.4%) of the pairings; five pairs were excluded due to death or moribund condition of one of the partners. Mating times were not randomly distributed throughout the scotophase ($X^2 = 72.04$; df = 7; $P < 0.001$) and carob moths started mating in the fourth h of scotophase (N = 3). There was a significant increase of initiated matings during the fifth and sixth h (N = 20 and 13 respectively; these values are statistically similar). After this, the number of matings initiated within the seventh (N = 5), and eighth h (N = 2) of scotophase decreased significantly. The number of pairs observed *in copula* during each h was 3, 21, 35, 34 and 23 for the fourth, fifth, sixth, seventh and eighth h respectively. Pairs remained in the coupled position for 2.35 ± 0.84 h.

Oviposition Periodicity—There was a very pronounced nocturnal periodicity and age effect for carob moth female oviposition behavior ($F = 11.03$; df = 83, 168; $P < 0.0001$, Table 1). Two-way ANOVA revealed highly significant effects for hour of scotophase ($F = 69.21$; df = 8; $P < 0.0001$), age of female ($F = 23.74$; df = 6; $P < 0.0001$) and the interaction of these variables ($F = 2.37$; df = 48; $P < 0.0001$). Carob moths laid the greatest number of eggs during the first hour of scotophase (Table 1). There is a statistically significant decrease for each of the following 2 h periods followed by a diminishing of the behavior to near zero by the sixth h. Virtually no eggs were laid during the 16 h photophase. Considering the effect of age, egg deposition rose significantly by Day 3, peaked with Day 4 females whereafter egg production decreased to significantly lower levels by Day 7 (Table 1).

Virtually all females were mated at the end of their second full scotophase (Day 3) as indicated by the presence of spermatophores, and the number of matings increased with age with a mode of one spermatophore for Day 3 thru Day 6 females, and two spermatophores beyond Day 6 (Table 1). This increase with age was significant across the group ($F = 34.56$; df = 6, 248; $P < 0.0001$) with Day 7 and 8 females having significantly more spermatophores than Day 3 through 6 females (which were all statistically similar). Day 2 had significantly fewer spermatophores compared to every other group (Table 1).

DISCUSSION

Female carob moths exhibit periodicities in their reproductive behavior which may be useful in developing field control methods for the insect. The only previous reference to female reproductive behavior of the carob moth was that of Cox (1976) in which he states that calling occurred "when it became darker" and that oviposition occurred "during twilight and dark periods." Carob moth calling was initiated near the mid-point of the scotophase over a range of ages and light regimes from short (16:8) to longer night (12:12) (Fig. 1). When observed as a group, carob moth females continued calling until the photophase, whereupon they abruptly ceased.

When virgin carob moth females were placed with males under a 16:8 L:D cycle, matings were initiated at the same period (fifth to sixth h scotophase) as the initiation and rise in calling of 16:8 females (Fig. 1).

Overall, most carob moth oviposition in this study occured during the first 3 h of scotophase with the highest number of eggs deposited during the first h (16:8 light regime) (Table 1). Oviposition decreased sharply by the mid-point of the scotophase and was virtually zero during the photophase. An ontogeny of oviposition may occur where a periodicity develops by Day 3, production peaks at Day 4 and then drops off afterward. The lower performance of the Day 2 and Day 3 females may be partly due to some females still being virgins. This pattern

Table 1. Hourly mean (SD) egg output and number of spermatophores detected for groups of 10 female carob moths (four replicates) at differing ages.

	Hour of scotophase								16 h photophase	Avr. for each day	Avr. no. spermatophores	*n*
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th–24th			
Day 2	6.3	7.0	7.5	7.5	5.5	2.5	3.8	1.3	1.0	42.3 bc	0.30 c	(40)
	(8.5)	(10.7)	(9.7)	(8.1)	(1.9)	(1.3)	(2.6)	(1.0)	(0.8)	(38.7)	(0.46)	
Day 3	31.5	18.3	18.3	11.3	14.3	5.3	2.5	4.5	1.3	105.0 ab	1.10 b	(38)
	(8.2)	(10.3)	(9.7)	(7.4)	(6.8)	(1.9)	(2.1)	(2.6)	(1.0)	(32.0)	(0.51)	
Day 4	43.5	41.0	31.3	16.0	8.5	7.3	6.3	8.3	2.5	164.8 a	1.26 b	(35)
	(16.7)	(40.2)	(28.7)	(11.7)	(6.8)	(3.9)	(1.3)	(4.7)	(1.3)	(88.7)	(0.70)	
Day 5	44.5	15.6	10.8	9.0	8.0	4.3	2.0	4.3	0.5	99.0 abc	1.53 b	(38)
	(21.0)	(7.4)	(9.2)	(4.8)	(1.2)	(2.2)	(1.4)	(2.8)	(1.0)	(30.3)	(0.60)	
Day 6	46.8	18.0	9.0	7.0	8.8	4.0	1.5	3.3	0.3	98.5 abc	1.54 b	(35)
	(25.4)	(11.2)	(6.4)	(5.6)	(9.0)	(3.6)	(1.0)	(1.7)	(0.5)	(56.4)	(0.70)	
Day 7	31.0	13.0	5.3	3.3	2.3	2.0	2.8	1.0	0.3	60.8 bc	2.32 a	(37)
	(12.9)	(7.8)	(3.4)	(1.0)	(2.5)	(1.8)	(4.9)	(1.4)	(0.5)	(24.8)	(0.94)	
Day 8	32.5	11.8	2.8	3.0	0.8	1.5	0.3	1.0	0	53.5 c	2.17 a	(35)
	(17.2)	(6.3)	(1.0)	(0.2)	(1.0)	(0.6)	(0.5)	(1.4)	(0)	(25.4)	(1.07)	
Mean for each h	33.7 a	17.8 b	12.1 c	8.1 c	6.9 cd	3.8 de	2.7 ef	3.4 e	0.9 f			
	(19.7)	(18.5)	(14.6)	(7.3)	(6.2)	(2.9)	(2.7)	(3.3)	(1.1)			

Overall means having no letters in common are significantly different for hourly oviposition (row), daily egg output (column) and spermatophores (column). Oviposition data were analyzed with two-way ANOVA with Tukey's studentized range test separation. Spermatophore data were analyzed with one-way ANOVA with Tukey's compromise test separation.

of oviposition is found in at least five other species of pyralid moths (Bell 1981, Andrews et al. 1980). As the females age and egg production decreases, the number of spermatophores per female continues to increase suggesting that lack of sperm is probably not an explanation for decreased oviposition (Table 1).

The information presented here may be of importance to date growers in their attempts to control the carob moth. Because females oviposit most heavily right after sunset, insecticide sprays during this time might increase the chances of killing egg-laden females. Similar studies with cotton pests documenting their nocturnal behavior patterns have resulted in changes in control strategies in that some crop-dusting is performed at night when the insects are more likely to contact pesticide (UC Press, 1984). In contrast, trying to control carob moths by targeting the mating behavior might be difficult because mating periodicity in moths is dependent on abiotic variables other than photoperiod (e.g., temperature, Baker & Cardé 1979, Kanno 1981). Also control methods may be ineffective for interrupting the mating behavior of the carob moth because the actual mating location in the date agrosystem is unknown. Therefore, targeting the ovipositing female may be the more effective control strategy because females are in the date canopy laying their eggs.

ACKNOWLEDGMENT

Thanks are extended to Neil Q. Vickers and P. K. Visscher for statistical help, Steve McElfresh for making copious improvements on an earlier draft of the manuscript, Judy Chari Kang and Dondi M. Flanagan for rearing the insects used in this study (all personnel from Univ. Calif., Riverside) and Cathy Kerby of Covalda Date Co., Coachella, CA for supplying the Deglet Noor dates. This research was funded in part by the Date Packer's Council.

LITERATURE CITED

Andrews, K. L., M. M. Barnes & S. A. Josserand. 1980. Dispersal and oviposition by navel orangeworm moths. Envir. Entomol., 9: 525–529.

Baker, T. C. & R. T. Cardé. 1979. Endogenous and exogenous factors affecting periodicities of female calling and male sex pheromone response in *Grapholitha molesta* (Busck). J. Insect Physiol. 25: 943–950.

Baker, T. C., W. Francke, J. G. Millar, C. Löfstedt, B. Hansson, J.-w. Du, P. L. Phelan, R. S. Vetter, R. Youngman & J. L. Todd. 1991. Identification and bioassay of sex pheromone components of carob moth, *Ectomyelois ceratoniae* (Zeller). J. Chem. Ecol., 17: 1973–1988.

Bell, C. H. 1981. The influence of light cycle and circadian rhythm on oviposition in five Pyralid moth pests of stored products. Physiol. Entomol., 6: 231–239.

Cossé, A., J. J. Endris, J. G. Millar & T. C. Baker. 1994. Identification of volatile components from fungus-infected date fruit that stimulate upwind flight in female *Ectomyelois ceratoniae*. Entomol. exp. et appl., 72: 233–238.

Cox, P. D. 1976. The influence of temperature and humidity on the life cycle of *Ectomyelois ceratoniae* (Zeller) (Lepidoptera: Phycitidae). J. stored Prod. Res., 12: 111–117.

Cox, P. D. 1979. The influence of photoperiod on the life-cycle of *Ectomyelois ceratoniae* (Zeller) (Lepidoptera: Pyralidae). J. stored Prod. Res., 15: 111–115.

Eichlin, T. D. 1982. Carob moth in California: New state record. Calif. Dept. Food Agric. Memo Nov. 26.

Finney, G. L. & D. Brinkman. 1967. Rearing the navel orangeworm in the laboratory. J. Econ. Ent., 60: 1109–1111.

Gothilf, S. 1984. Biology of *Spectrobates* on Almonds in Israel. Phytoparasitica, 12: 77–87.

Gothilf, S., E. C. Levy, R. Cooper & D. Lavie. 1975. Oviposition stimulants of the moth *Ectomyelois ceratoniae*: the effect of short-chain alcohols. J. Chem. Ecol., 1: 457–464.

Kanno, H. 1981. Mating behaviour of the rice stem borer moth, *Chilo suppressalis* Walker (Lepidoptera: Pyralidae). VI. Effects of photoperiod on the diel rhythms of mating behaviours. Appl. Entomol. Zool., 16: 406–411.

SAS Institute. 1982. SAS user's guide: statistics. SAS Institute, Cary, North Carolina, USA.

Shorey, H. H, K. L. Morin, & L. K. Gaston. 1968. Sex pheromones of noctuid moths. XV. Timing of development of pheromone-responsiveness and other indicators of reproductive age in males of eight species. Ann. Entomol. Soc., Amer. 61: 857–861

Strong, R., G. J. Partida, & D. N. Warner. 1968. Rearing stored-products insects for laboratory studies: six species of moths. J. Econ. Entomol., 6: 1237–1249.

Todd, J. L., J. G. Millar, R. S. Vetter, & T. C. Baker. 1992. Behavioral and electrophysiological activity of (Z,E)-7,9,11-dodecatrienyl formate, a mimic of the major sex pheromone component of carob moth, *Ectomyelois ceratoniae*. J. Chem. Ecol., 18: 2331–2351.

Univ. Calif. Press 1984. Integrated Pest Management for Cotton in the Western Region of the United States. Univ. Calif. Div. Agric. Nat. Resources Pub. #3305.

Warner, R. L. 1988. Contributions to the biology and the management of the carob moth, *Ectomyelois ceratoniae* (Zeller), in 'Deglet Noor' date gardens in the Coachella Valley of California. Ph.D dissert. University California, Riverside.

Warner, R. L., M. M. Barnes, & E. F. Laird. 1990a. Reduction of insect infestation and fungal infection by cultural practice in date gardens. Envir. Entomol., 19: 1618–1623.

Warner, R. L., M. M. Barnes, & E. F. Laird. 1990b. Chemical control of a carob moth, *Ectomyelois ceratoniae* (Lepidoptera: Pyralidae) and various nitidulid beetles (Coleoptera) on 'Deglet Noor' dates in California. J. Econ. Entomol., 83: 2357–2361.

Received 13 Jun 1996; Accepted 15 Aug 1996.

PAN-PACIFIC ENTOMOLOGIST
73(1): 36–39, (1997)

LILIOCERIS SP. (COLEOPTERA: CHRYSOMELIDAE) HERBIVORY ON *CYCAS SIAMENSIS* MIQUEL (TRACHEOPHYTA: CYCADALES)

William D. Shepard
Department of Biological Sciences, California State University, Sacramento,
Sacramento, California 95819

Abstract.—The chrysomelid *Lilioceris* sp. was found feeding on the leaflets of cycads in northeastern Thailand. Many cycads were significantly damaged. Larval and adult *Lilioceris* sp. coloration suggests aposematic coloration.

Key Words.—Insecta, Chrysomelidae, Cricocerinae, *Lilioceris*, cycad, herbivory, aposematic coloration

Beetles are increasingly being associated with cycads either by entomologists (Crowson 1991) or by cycadologists (Norstog 1990). Most species either bore through the frond rachis or the trunk, or they attack the cones. Several species have been demonstrated to be pollinators. One species of chrysomelid beetle, *Lilioceris clarki* (Baly), has been reported to feed on the fronds of *Cycas* sp. in New Guinea (Szent-Ivany et al. 1956). Here I report *Lilioceris* sp. larvae feeding on the frond leaflets of *Cycas siamensis* Miquel in Thailand.

The cycads were part of the understory vegetation of a "dry dipterocarpus" forest located along Highway 213, 2 km south of the headquarters of Phu Phan National Park, Sakhon Nakhon Province, in northeastern Thailand. The cycads were numerous and easily seen as a fire some months previously had reduced the understory cover. I estimated that about half of the cycads had either beetle larvae actively feeding or bore evidence of their feeding. Infested cycads usually supported only a few larvae (> 10) on a few fronds, although some had heavy infestations (20+ larvae) and abundant frond damage (Fig. 1). In both cases there always were nearby cycads that had no larvae. Infested cycads could be distinguished easily from a distance as the damaged leaflets were a pale brown color that contrasted sharply with the dark green of undamaged leaflets (Figs. 2–3, 5). Infested cycads were located both in and outside of the burn area. The fire may have made the cycads more visible to the beetles as the infestation was generally heavier in the burn area.

Lilioceris sp. was present mainly as larvae. One adult was swept from the cycads. All larvae were located on the lower surfaces of the leaflets (Fig. 4). Feeding involved rasping away the lower epidermis and part of the mesophyll. Generally larvae only ate part of the tissue of any one leaflet before leaving to find another. However, when larval numbers were high the larvae remained on single leaflets until they were substantially consumed. On one heavily infested frond, the end of the rachis was chewed through. The ground under the cycads with heavy infestations was carpeted with feces (Fig. 6) which had a characteristic coiled shape both when being eliminated by the larva and when on the ground. One larva was dissected to examine the structure of the digestive tract. It was typical for herbivores, being voluminous in capacity, long and coiled. Attempts to rear larvae to adults in the lab failed due to lack of a proper pupation site,

Figure 1. *Cycas siamensis* frond heavily damaged by *Lilioceris* sp. larval herbivory. This frond has 20 larvae showing.

Figure 2. *Cycas siamensis* with heavy damage caused by *Lilioceris* sp. larvae feeding on frond leaflets. Note end of rachis is chewed through.

Figure 3. *Cycas siamensis* leaflets discolored by herbivory on the lower sides.

Figure 4. *Lilioceris* sp. larva on underside of leaflet of *Cycas siamensis.*

Figure 5. *Cycas siamensis* fronds heavily damaged by insect herbivory.
Figure 6. Accumulation of beetle larva feces under a heavily infested *Cycas siamensis*.

which is thought to be the soil. Reared larvae that reached what appeared to be the last instar climbed down from the fronds and crawled around the laboratory.

Larvae were bright red-orange in color and visible against the darker foliage, suggesting aposematic coloration warning of chemical defenses. Chemicals may be sequestered from the cycad tissue as they are known to have chemical defenses. None of the larvae evidenced signs of predation attempts or parasitism. When disturbed they remained immobile on the leaflets. The single adult *Lilioceris* sp. was also a bright red-orange in color.

Voucher specimens deposited at the Entomology Collection at California Academy of Sciences (San Francisco) include one adult and five larval *Lilioceris* sp. plus several cycad leaflets fed upon by the larvae.

ACKNOWLEDGMENT

Special thanks go to Samang Homchuen who shared with me her wonderful country and its flora. Edward Riley provided the identification of the chrysomelid and a copy of Crowson's paper. Travel to Thailand was provided by United States Information Agency Grant # IA-ASCS-G1190232.

LITERATURE CITED

Crowson, R. A. 1991. The relations of Coleoptera to Cycadales. pp. 13–28. *In* M. Zunino, X. Bellés & M. Blas (eds.). Advances in Coleopterology. AEC, Barcelona.

Norstog, K. J. 1990. Studies of cycad reproduction at Fairchild Tropical Garden. pp. 63–81. *In* D. W. Stevenson (ed.). The biology, structure, and systematics of the Cycadales. Proceedings of the Symposium CYCAD 87, Beauliey-sur-Mer, France, April 17–22, 1987. Mem. N. Y. Bot. Garden, 57: 1–210.

Szent-Ivany, J. J. H., J. S. Womersley & J. H. Ardley. 1956. Some insects of *Cycas* in New Guinea. Papua and New Guinea Agric. J., 11: 1–4.

Received 21 Feb 1996; Accepted 16 Jun 1996.

PAN-PACIFIC ENTOMOLOGIST
73(1): 40–45, (1997)

ELECTROPHORETIC COMPARISON OF *DENDROCTONUS PUNCTATUS* LECONTE AND *D. MICANS* (KUGELANN) (COLEOPTERA: SCOLYTIDAE)

Sandra J. Kegley,[1] Malcolm M. Furniss,[2]
and Jean-Claude Grégoire[3]

Abstract.—The taxonomic status of the American boreal spruce beetle, *Dendroctonus punctatus* LeConte, and its Eurasian sibling species, the European spruce beetle, *D. micans* (Kugelann), has been in doubt. The genetic relationship of adult *D. punctatus* from Montana, USA, and of *D. micans* from Belgium was examined by isozyme electrophoresis. Average heterozygosity and polymorphism was 0.075 and 37.5% for *D. punctatus* and 0.026 and 6.25% for *D. micans*, much lower than reported in other *Dendroctonus* species and which may result from the high degree of inbreeding that is characteristic of both species. Five of the 16 loci examined were fixed, or nearly fixed, for different alleles in the two species. Genetic identity between *D. punctatus* and *D. micans* was 0.693, lower than that reported between two other, uncontested, host-isolated sibling species, *D. ponderosae* Hopkins and *D. jeffreyi* Hopkins. Furthermore, the genetic distance between *D. punctatus* and *D. micans* was 0.366, similar to another distinct pair of host-isolated sibling species, *D. pseudotsugae* Hopkins and *D. simplex* LeConte. These results support recent morphological evidence in favor of retaining *D. punctatus* and *D. micans* as separate species.

Key Words.—Insecta, Scolytidae, *Dendroctonus punctatus*, *Dendroctonus micans*, isozyme electrophoresis

The genus *Dendroctonus* Erichson is represented in North America by 17 species, including the boreal spruce beetle, *D. punctatus* LeConte, and in Eurasia by two species, including the European spruce beetle, *D. micans* (Kugelann) (Wood 1982, Wood & Bright 1992). Because the present center of diversity of *Dendroctonus* species is North America, the ancestor of *D. micans* is thought to have migrated from a spruce refugium in Alaska to Siberia via Beringia during the Wisconsinian glaciation and eventually reached Europe through intervening spruce forests. In recent times, *D. micans* has become of great economic importance where it has invaded new territory in Europe, particularly in exotic spruce plantations in France and England (Bevan & King 1983, Grégoire 1988). On the other hand, *D. punctatus* has so far caused little economic damage, being apparently at a competitive disadvantage in Nearctic boreal spruces to the economically important spruce beetle, *D. rufipennis* (Kirby) (Furniss 1995). Taxonomists have noted the anatomical similarity of *D. punctatus* and *D. micans* and have expressed uncertainty about their status as separate species (Wood 1963, 1982).

The biology of *D. micans* has been studied in Europe by Grégoire (1988); that of *D. punctatus* has been studied in western North America by Furniss (1995). Features that these two species share, differing from most others of the genus, are: a sex ratio strongly in favor of females; mating by siblings in the brood chamber prior to emergence (males never occur with females in egg galleries);

---

[1] USDA Forest Service, 3815 Schreiber Way, Coeur d'Alene, Idaho 83814-8363.

[2] Division of Entomology, University of Idaho, Moscow, Idaho 83844-2339.

[3] Laboratoire de Biologie Animale et Cellulaire, Université Libre de Bruxelles, 1050 Bruxelles, Belgique.

and aggregation in the larval stage rather than as attacking adults (Grégoire 1983, Furniss 1995). Their main biological difference appears to be that *D. punctatus* has four larval instars, whereas *D. micans* is reported to have five larval instars (Furniss 1995). Morphologically, *D. punctatus* and *D. micans* have been found to differ in 10 discrete characters (Furniss and Johnson 1989, Furniss 1996). This paper presents results of isozyme electrophoresis that further support the validity of these two species.

MATERIALS AND METHODS

Dendroctonus micans were collected as larvae at Wellin, Belgium, January 8, 1990 and sent to Moscow, Idaho, for rearing to the adult stage in 15 × 15 cm pieces of Norway spruce phloem (*Picea abies* (L.) Karst.) pressed between glass plates. *Dendroctonus punctatus* were F_1 progeny reared in Engelmann spruce logs (*P. engelmannii* Parry) (Furniss 1995). Their parents were collected from a white spruce hybrid (*P. glauca* (Moench.) Voss. × *engelmannii*) in Meagher Co., Montana in June 1989. Representative voucher specimens are deposited in the W. F. Barr Entomological Museum, University of Idaho.

Each adult was immersed in 1 cc of distilled water and macerated vigorously with pointed tweezers to develop a homogenate. Four filter paper wicks were soaked in each homogenate, wrapped individually in parafilm, and stored overnight at −18°C. Numbers of individuals tested were: *D. micans* = 58 female, 2 male; *D. punctatus* = 57 female, 2 male.

Electrophoretic techniques used were those of Stock et al. (1987). Gels were made from a 13% solution of hydrolyzed potato starch and the appropriate buffer. Wicks containing beetle homogenate were inserted into slots in each gel and subjected to electrophoresis. Gels were then cut horizontally and stained for different enzymes. Eleven enzyme systems were assayed (Table 1). Banding patterns were scored as homozygotes (appearing as a single band) or heterozygotes (appearing as multiple bands) for each gene locus resolved. Genotype frequencies for each population were recorded. Genetic data were analyzed using BIOSYS-1, a computer program for analysis of allelic variation (Swofford and Selander 1989).

Observed genotype frequencies were compared to values derived from random mating (Hardy-Weinberg expected proportions) using a chi-square test. Genetic diversity was estimated using Nei's (1978) unbiased estimate of average heterozygosity and polymorphism (%). A locus was considered polymorphic when the frequency of the most common allele was less than or equal to 0.99. The relationship between *D. punctatus* and *D. micans* was evaluated using Nei's (1978) genetic identity value, Nei's (1978) unbiased genetic distance value, and Rogers' (1972) similarity index.

RESULTS AND DISCUSSION

Allele frequencies were calculated at 16 gene loci (Table 1). Major differences occurred between the two species at several loci. Six loci (Aat, Idh-2, Mdh-2, Me-1, Me-2, Mpi) were polymorphic in *D. punctatus* while only one (Me-2) was polymorphic in *D. micans*. As a result, average heterozygosity and polymorphism were much higher for *D. punctatus* (0.075 and 37.5%; respectively) than for *D. micans* (0.026 and 6.25%, respectively).

Table 1. Allele frequencies at 16 enzyme loci, percent polymorphism, average heterozygosity, and chi square comparisons of observed to expected (Hardy-Weinberg) numbers of each genotype for *D. punctatus* and *D. micans*.

Enzyme	Locus abbrev.	Allele	*D. punctatus*	*D. micans*
Aspartate aminotransferase	Aat	A	0.064	1.0
		B	0.936	0
		χ^2	45.8**	
Catalase	Ck	A	1.0	1.0
Esterase	Est-1	A	1.0	1.0
	Est-2	A	0	1.0
		B	1.0	0
	Est-3	A	1.0	1.0
Isocitrate dehydrogenase	Idh-1	A	1.0	1.0
	Idh-2	A	0.034	0
		B	0.966	1.0
		χ^2	78.0**	
Malate dehydrogenase	Mdh-1	A	1.0	1.0
	Mdh-2	A	0.964	0
		B	0.036	1.0
		χ^2	74.0**	
Malic enzyme	Me-1	A	0.034	0
		B	0.966	1.0
		χ^2	76.7**	
	Me-2	A	0.512	0.292
		B	0.488	0.708
		χ^2	0.7	6.3*
Phosphomannose isomerase	Mpi	A	0	1.0
		B	0.750	0
		C	0.250	0
		χ^2	20.8**	
Peptidase glycyl-leucine	Pep-gl	A	1.0	1.0
Peptidase leucyl-alanine	Pep-la	A	1.0	1.0
Glucose phosphate isomerase	Pgi	A	1.0	0
		B	0	1.0
Superoxide dismutase	Sod	A	1.0	1.0
% Polymorphism (0.99 criterion)			37.50	6.25
Av. heterozygosity			0.075	0.026

* = significant at 0.05 level, ** = 0.01 level.

In an earlier study (Stock et al. 1987), average heterozygosity and polymorphism of *D. micans* were 0.053 and 27%, respectively. However, the gene loci that were resolved and analyzed differed somewhat between their study and ours, perhaps contributing to the difference in values for *D. micans*. For example, the latter authors reported that locus Est-2 had six alleles; we observed only two. An additional possible source of the difference is foreign protein such as from a parasitic nematode (Higby and Stock, 1982). With that in mind, we had examined prior to maceration each of our specimens for ecto- and endoparasitic nematodes; *D. micans* contained none. If, however, the *D. micans* that were analyzed by Stock et al. (1987) had nematodes, that might explain the difference in heterozygosity and polymorphism of *D. micans* in the two studies. In any case, we tested paired sets of *D. micans* and *D. punctatus* simultaneously in the same gels, and we are confident that the resultant values for heterozygosity and polymorphism truly reflect relative differences between the two species.

Dendroctonus punctatus and *D. micans* were much less genetically diverse than 10 other North American *Dendroctonus* species which have an average of 0.213 heterozygosity (range = 0.156–0.247) and 64% polymorphism (range = 50–72%) (Bentz and Stock 1986). Analysis of the deviations of alleles from Hardy-Weinberg equilibrium showed significantly less heterozygosity in *D. punctatus* than would be expected of random mating in a population (Table 1). This may be explained by the high degree of inbreeding in this species (Furniss 1995). The one locus that was polymorphic for *D. micans* showed more heterozygosity than expected. Selection may be favoring heterozygotes at this locus.

The fact that *D. micans* was less heterozygous and less polymorphic than *D. punctatus* may relate to the following. The immediate ancestor of *D. micans* must have migrated from an Alaskan glacial refugium. The particular genetic composition of individuals of this isolated population may have been subjected to intense selective pressure in its various, entirely new, host species and the differing climate as it extended thousands of miles eastward to Europe. On the other hand, during the time since *D. micans* migrated to Asia, its American ancestor has reunited with other population segments as its main host, *Picea glauca*, followed the retreating glaciers northward, eventually extending across the continent and throughout boreal North America.

Five loci (Aat, Est-2, Mdh-2, Mpi, Pgi) (Table 1) were fixed, or nearly fixed, for different alleles in the two species. Fixation of different alleles at one or more loci is characteristic of separate species or geographically separated non-interbreeding populations (Ayala and Powell 1972, Berlocher 1979, as cited by Higby and Stock 1982). Genetic similarity of *D. punctatus* and *D. micans* was 0.682. Conspecific populations of organisms commonly have similarity indices above 0.75 on a scale of 0-1 (Avise 1974, Ayala 1975).

The genetic identity index of *D. punctatus* and *D. micans* was 0.693. In comparison, the genetic identity index of two well-defined, host-isolated, sibling species, of Scolytidae, *D. ponderosae* Hopkins and *D. jeffreyi* Hopkins, was greater, being 0.83 (Higby and Stock 1982). That of conspecific populations of *D. ponderosae* from Utah in two different species of host trees (*Pinus contorta* Douglas and *P. ponderosa* Lawson) was 0.992–0.993 (Stock and Amman 1980) and the genetic identity index of *D. ponderosae* populations in Alberta in three pine hosts were above 0.978 (Langor and Spence 1991). In further comparison, the genetic identity of humans and chimpanzees is 0.680 and that of humans and Borneo orangutans is 0.707 (Bruce & Ayala 1979).

The genetic distance value for *D. punctatus* and *D. micans* was 0.366. This is somewhat similar to the genetic distance (0.305) of two uncontested sibling species, *D. pseudotsugae* Hopkins and *D. simplex* LeConte (Bentz and Stock 1986). No unique genetic difference was found between females and the few available males of *D. punctatus* and *D. micans*.

The genetic characters reported here supplement recent biological and morphological evidence (Furniss and Johnson 1989, Furniss 1995, Furniss 1996) in support of retaining *D. punctatus* and *D. micans* as separate species.

ACKNOWLEDGMENT

Steven J. Brunsfeld, Department of Forest Resources, University of Idaho, provided laboratory facilities and helped analyze data and interpret results. Molly W. Stock, Department of Forest Resources, University of Idaho, provided chemicals and laboratory materials and reviewed the manuscript. The manuscript was also reviewed by James B. Johnson, Division of Entomology, University of Idaho, and by David W. Langor, Northern Forestry Centre, Forestry Canada, Edmonton, Alberta. This is University of Idaho Agricultural Experiment Station Research Paper No. 95753.

LITERATURE CITED

Avise, J. C. 1974. Systematic value of electrophoretic data. Syst. Zool., 23: 465–481.

Ayala, F. J. 1975. Genetic differentiation during the speciation process. p. 1–78. *In* T. Dobzhansky, M. K. Hecht, and W. C. Steere, [eds.], Evolutionary biology. Vol. 8. Plenum Press, New York.

Ayala, F. J. & J. R. Powell. 1972. Allozymes as diagnostic characters of sibling species of *Drosophila.* Proc. Nat. Acad. Sci. USA, 69: 1094–1096.

Bentz, B. J. & M. W. Stock. 1986. Genetic relationships among ten species of *Dendroctonus* bark beetles (Coleoptera: Scolytidae). Ann. Entomol. Soc. Amer., 79: 527–534.

Berlocher, S. H. 1979. Biochemical approaches to strain, race, and species discriminations, pp. 137–144. *In* M. A. Hoy and J. J. McKelvey, Jr. [eds.], Genetics in relation to insect management. Rockefeller Foundation.

Bevan, D. & C. J. King. 1983. *Dendroctonus micans* Kug.—a new pest of spruce in U.K. Comm. For. Rev., 62: 41–51.

Bruce, D. J. & F. J. Ayala. 1979. Phylogenetic relationships between man and the apes: electrophoretic evidence. Evolution, 33(4): 1040–1056.

Furniss, M. M. & J. B. Johnson. 1989. Description of the gallery and larva of *Dendroctonus punctatus* LeConte (Coleoptera: Scolytidae). Can. Entomol., 121: 757–762.

Furniss, M. M. 1995. Biology of *Dendroctonus punctatus* LeConte (Coleoptera: Scolytidae). Ann. Entomol. Soc. Amer., 88: 173–182.

Furniss, M. M. 1996. Taxonomic status of *Dendroctonus punctatus* and *D. micans* (Coleoptera: Scolytidae). Ann. Entomol. Soc. Amer., 89: 328–333.

Grégoire, J.-C. 1983. Host colonization strategies in *Dendroctonus*: larval gregariousness or mass attack by adults? pp. 147–154. Proc. IUFRO Conf. Role of host in population dynamics of forest insects. Banff, Alta., Can. Sept. 4-7, 1983.

Grégoire, J.-C. 1988. The greater European spruce beetle, pp. 455–478. *In* Berryman, A. A. [ed.], Dynamics of forest insect populations: patterns, causes, implications. Plenum, New York.

Higby, P. K. & M. W. Stock. 1982. Genetic relationships between two sibling species of bark beetle (Coleoptera: Scolytidae), Jeffrey pine beetle and mountain pine beetle, in northern California. Ann. Entomol. Soc. Amer., 75: 668–674.

Langor, D. W. & J. R. Spence. 1991. Host effects on allozyme and morphological variation of the mountain pine beetle, *Dendroctonus ponderosae* Hopkins (Coleoptera: Scolytidae). Can. Entomol., 123: 395–410.

Nei, M. 1978. Estimation of average heterozygosity and genetic distance from a small number of individuals. Genetics, 89: 583–590.

Rogers, J. S. 1972. Measures of genetic similarity and genetic distance. Studies in Genetics, Univ. Texas Publ 7213: 145–153.

Stock, M. W. & G. D. Amman. 1980. Genetic differentiation among mountain pine beetle populations from lodgepole pine and ponderosa pine in northeast Utah. Ann. Entomol. Soc. Amer., 73: 472–478.

Stock, M. W., J-C. Grégoire & M. M. Furniss. 1987. Electrophoretic comparison of European *Dendroctonus micans* and ten North American *Dendroctonus* species (Coleoptera: Scolytidae). Pan-Pac. Entomol., 63: 353–357.

Swofford, D. L. & R. B. Selander. 1989. BIOSYS-1. A computer program for the analysis of allelic variation in population genetics and biochemical systematics. Illinois Natural History Survey. Univ. of Illinois, Urbana-Champaign.

Wood, S. L. 1963. A revision of the bark beetle genus *Dendroctonus* Erichson (Coleoptera: Scolytidae). Grt. Bas. Nat., 23: 1–117.

Wood, S. L. 1982. The bark and ambrosia beetles of North and Central America (Coleoptera: Scolytidae), a taxonomic monograph. Grt. Bas. Nat. Mem. 6.

Wood, S. L. & D. E. Bright, Jr. 1992. A catalog of Scolytidae and Platypodidae (Coleoptera). Part 2: Taxonomic index. Grt. Bas. Nat. Mem. 13.

Received 16 Jan 1996; Accepted 9 Oct 1996.

PAN-PACIFIC ENTOMOLOGIST
73(1): 46, (1997)

Scientific Note

THE FIRST RECORD OF THE ANT *PHEIDOLE MOERENS* WHEELER FROM THE WESTERN UNITED STATES (HYMENOPTERA FORMICIDAE)

Pheidole moerens (Wheeler) is native to the West Indies, originally described from Puerto Rico in 1908 by Wheeler in the U.S. It is known from Florida and Southern Alabama (Naves M.A. 1985. A monograph of the genus *Pheidole* in Florida (Hymenoptera Formicidae). Insecta Mundi, 1: 53–90). *Pheidole moerens* is easily confused with *P. floridana* (Emery) of the southeastern U.S. and which is not known from California.

The light brown minor worker is minute, between 1.5 and 1.75 mm in total body length. The larger major worker is also small: about 2.5 to 2.75 mm in total body length and darker in color than the minor worker with a disproportionately larger and broader head that is characteristic of the genus. This ant is highly variable in color. On 8 Nov 1995, in a section of Shoreline Aquatic Park in the city of Long Beach called Palm Island, and in an adjacent area, I discovered *P. moerens* nesting at the base of and in the bark of several California fan palms, *Washingtonia filifera* (Lindley) Wendland. The trees are from 6 to 11 m high and 46 to 61 cm in diameter at the base. Workers, and one alate male, were collected on the above date and more workers and female alates were collected on 18 Nov and 9 Dec 1995. I also observed brood as I dug around the base of the trees and pulled apart some bark.

The nests of *P. moerens* are small to moderate in size and were only found around the California fan palms. There were no nests along the edges or cracks in the sidewalk. In the immediate vicinity there are large aggressive nests of the southern fire ant, *Solenopsis xyloni* (McCook) which mostly nests on the edge of and cracks in the side walk; there are some nests around the Fan palms and at least one *P. moerens* nest was taken over by *S. xyloni. Pheidole moerens* appears to be a general scavenger ant with little or no economic importance.

Material Examined.—CALIFORNIA *LOS ANGELES Co.*: Long Beach Shoreline Aquatic Park 200 West Shoreline Dr. Entrance on Shoreline Drive and Pine Ave. on Palm Island just southeast of the entrance across the lagoon on 8 Nov 1995. M.J. Martinez.

Acknowledgments.—I thank my wife Charlean for her support; Dr. Rosser W. Garrison Los Angeles County entomologist and Robert J. Hamton, a fellow myrmecologist, for confirming my identification of this ant to the *Flavens* group and for reviewing the manuscript; Roy R. Snelling Los Angeles County Natural History Museum for determining this species as *Pheidole moerens*; and my nephew Eric Weis for typing the manuscript.

Michael J. Martinez *City of Long Beach, Dept. of Parks, Recreation and Marine, 2760 Studebaker Road, Long Beach California 90815.*

Received 31 Jan 1996; Accepted 1 May 1996.

PAN-PACIFIC ENTOMOLOGIST
73(1): 47–48, (1997)

Scientific Note

AGGREGATIONS OF *THAUMATOMYIA GLABRA* (MEIGEN) (DIPTERA: CHLOROPIDAE) ON *WISTERIA* FLOWERS (FABACEAE)

During April, 1995, aggregations of *Thaumatomyia glabra* (Meigen) were noticed on the flower clusters of *Wisteria sinensis* (Sims) Sweet, at El Dorado Hills, in the Sierra Nevada foothills of California. Over a two week period, individuals were observed to each occupy an individual blossom, and flies were spread over all available flower clusters. All sampled flies were males. On each sequentially opening inflorescence, many blossoms, often adjacent, were occupied. The flies sat motionless, usually on one side of the front portion of the white banner of the blossom, but occasionally, if disturbed, they moved to the lavender keel of the blossom. Movement of flies between blossoms was not observed, nor were encounters among flies on blossoms. In one instance, two flies occupied the same blossom, with one on the front of the banner, and the other on the venter of the keel, so that they apparently could not see each other. The aggregations, which formed by mid-morning and dispersed at twilight, continued until all flower clusters had finished blooming. Mid-instar lepidopteran larvae, which had fallen or dropped from the overhanging canopy of *Quercus douglasii* W.J. Hooker & G.A. Walker-Arnott, and which occasionally crawled across occupied blossoms, did not elicit a reaction from the flies.

Thaumatomyia glabra is considered an "almost cosmopolitan" chloropid species with a vast array of geographically variable phena (Sabrosky, C.W. 1943. Canad. Entomol., 75: 109–117). Therefore, we assume that *T. glabra* either represents an adaptively polytypic species, or a group of sibling species. Sabrosky's (1943: 114) description of a phena for "western and far western states," which has rather distinct mesonotal setae and yellow fore metatarsi, most closely matches the flies that we observed; his description of certain California populations that have reduced cheeks does not match.

Because *Wisteria sinensis* is of oriental origin, and these *T. glabra* have a western Nearctic phena, it seems implausible that this behavioral association could pre-date the introduction of *Wisteria* to the area. *Thaumatomyia* are predators of root aphids [*Pemphigus* sp.] (Alleyne, E. & F. Morrison. 1977. Ann. Soc. Entomol. Que., 22 : 181–187; Roman, E. & C. Chauve. 1979. Bull. Mens Soc. Linn. Lyon, 48: 263–267), but there is a record of *T. glabra* from a spider egg sac (Sabrosky 1943). Because we did not observe interaction among the sitting flies on *Wisteria*, it is difficult to speculate about the evolutionary benefit of this behavior, except to mention that it seemed to resemble an apparent form of leking in the absence of observed interaction. It may involve an anticipation of mates drawn to the fragrant blossoms as a resource. Vouchers are deposited at the PPDC, CDFA, Sacramento.

Acknowledgement.—We thank Eric M. Fisher (CDFA-PPDC) for the identifications, information and discussions.

Material Examined.—CALIFORNIA. *EL DORADO Co.:* El Dorado Hills, 4–18 Apr 1995, K.H. Sorensen, ex *Wisteria sinensis* blossoms.

John T. Sorensen[1] and Kathleen H. Sorensen[2]; [1]*Plant Pest Diagnostics Center, California Dept. of Food & Agriculture, Sacramento, California 95832-1448; and* [2]*El Dorado Hills, California.*

Received 2 May 1995; Accepted 1 Aug 1996.

PAN-PACIFIC ENTOMOLOGIST
73(1): 49–51, (1997)

Scientific Note

OCCURRENCE OF A NEOGREGARINE PROTOZOAN, *OPHRYOCYSTIS ELEKTROSCIRRHA* MCLAUGHLIN AND MYERS, IN POPULATIONS OF MONARCH AND QUEEN BUTTERFLIES

The monarch butterfly, *Danaus plexippus* (L.), along with another New World species, the queen butterfly (*Danaus gilippus berenice* Cramer) are both susceptible to a neogregarine parasite, *Ophryocystis elektroscirrha* McLaughlin & Myers, in Florida. The neogregarine parasite, described by McLaughin & Meyers (1970. J. Protozool., 17: 300–305), involves a life cycle strategy that incorporates the occurrence of spores on the scales and hairs of the infected butterflies. The neogregarine has been reported from monarch butterflies in California (Leong, K. et al. 1992. Ecol. Entomol., 17: 338–342), Hawaii and Mexico (Brower, L. et al. 1995. BioSci., 45: 540–544). However, except for California, the prevalence of infection and the occurrence of this neogregarine in other populations of the monarch butterfly and a closely related species, the queen butterfly, are unknown. Accordingly, we conducted a survey of monarch butterflies from various parts of the world and queen butterflies from Florida to gain a better insight into their distribution and prevalence of infection.

Our survey confirms the presence of *O. elektroscirrha* on monarch butterfly adults collected from Hawaii, Mexico, Florida, Australia and New Zealand (Table 1). The survey data show that the percentage of butterflies with spores (based on a wash method by Leong et al. 1992) ranged from 3.8% (Mexico) to 100% (Maui, Hawaii). Among butterflies with spores, those collected from Oahu, Hawaii had the highest average number of spores per individual (197,480) and those from New Zealand, the least (10,500). Six of the 32 queen butterflies (*D. gilippus berenice*) examined had neogregarine spores (18.8%) with an average of 1500 spores per individual.

The spore dimensions varied considerably depending upon the geographical regions and species (Table 2). The queen butterflies collected from Fort Lauderdale, Florida had the smallest spores whereas monarch butterflies from California, Hawaii and the queen from Gainesville, Florida, had the largest. Notably, spores from the queen butterflies had both the smallest (Fort Lauderdale) and largest (Gainesville) measurements. Spores recovered from butterflies collected in Fort Lauderdale were significantly smaller than those recovered from queen butterflies collected in Gainesville or from monarch butterflies ($P < 0.01$, $F = 12.8$, df = 7,313; Table 2). The different sizes within the queen butterflies suggest the occurrence of distinct strains or possibly another neogregarine species, perhaps one unique to the queen.

The larger neogregarine spores isolated from *D. gilippus berenice* from Gainesville, Florida, were infectious to the monarch butterfly. When leaves of the blood flower milkweed, *Asclepias curassavica* L., were sprayed with 50,000 spores/ml until runoff and fed to first instars, 3 of 9 (33.3%) monarch larvae became infected. We were unable to test the pathogenicity of the smaller neogregarine spores

Table 1. Isolation of neogregarine spores from monarch butterflies (*Danaus plexippus* [L.]) from various geographical areas and from the queen butterfly (*D. gilippus berenice* Cramer) from Florida.

Species/Location	*n*	#S/*n*[a]	(%)	Mean[b]	(Range)[c]	M/F[d]
Monarch butterfly						
United States of America						
Florida						
Broward County	7	6/7	(85.7%)	347,200	(200–232,000)	6/1
California						
San Luis Obispo County	160	92/160	(57.5%)	59,470	(200–565,000)	80/80
Santa Cruz County	130	86/130	(66.2%)	76,000	(400–497,000)	70/60
Hawaii						
Oahu County	17	14/17	(82.3%)	197,480	(200–974,000)	11/6
Maui County	2	2/2	(100%)	17,900	(2000–33,800)	1/1
Kauai County	3	2/3	(66.7%)	47,600	(2000–94,800)	2/1
Hawaii County	7	5/7	(71.4%)	42,600	(400–240,000)	6/1
Australia	20	12/20	(60%)	53,400	(200–436,000)	10/10
New Zealand	7	1/7	(14.3%)	300	(300)	3/4
Mexico	26	1/26	(3.8%)	1400	(1400)	10/16
Queen butterfly						
Florida (combined)	32	6/32	(18.8%)	1500	(200–8600)	23/9
Gainesville	14	2/14	(14.3%)	600	(200–1000)	10/4
Fort Lauderdale	18	4/18	(22.2%)	2400	(200–8600)	13/5

[a] = no. of individuals with spores/total number of individuals.
[b] = average spore level from abdomens of butterflies.
[c] = range of spore levels among individuals with spores.
[d] = male/female.

from Fort Lauderdale to monarchs because they were recovered earlier in our investigation (January 1993), and a colony of protozoan-free monarch butterflies was not available at that time.

Neogregarine spores recovered from the monarch butterflies were not infectious to the silkworm, *Bombyx mori* (L.). When 30 first instar silkworm larvae were

Table 2. The length, diameter and area of neogregarine spores recovered from monarch and queen butterflies from various geographical areas. Spore area with different superscript letters are significantly different ($P < 0.01$, F = 12.8; df = 7313).

Species/Location	*n*	Length (um)	Diameter (um)	Area (um^2)
Queen, Fort Lauderdale, Florida, USA	37	12.3 ± 0.2	8.1 ± 0.2	101.2 ± 2.6^{a}
Monarch, Australia	50	13.9 ± 0.1	7.8 ± 0.3	114.0 ± 1.7^{b}
Monarch, New Zealand	22	13.0 ± 0.2	8.9 ± 0.2	117.2 ± 3.2^{bc}
Monarch, Fort Lauderdale, Florida, USA	50	14.1 ± 0.1	8.4 ± 0.1	118.2 ± 1.2^{bc}
Monarch, Mexican	42	13.9 ± 0.1	8.6 ± 0.2	119.6 ± 2.9^{bc}
Monarch, California, USA	50	13.7 ± 0.1	8.8 ± 0.1	120.6 ± 2.2^{c}
Monarch, Hawaii, USA	50	14.3 ± 0.1	8.9 ± 0.1	127.3 ± 1.9^{c}
Queen, Gainesville, USA	30	13.2 ± 0.2	9.6 ± 0.1	127.4 ± 2.6^{c}

fed mulberry leaves sprayed with 100,000 spores/ml until run-off, none of the resulting adults had neogregarine spores.

Thirty-five striated queen butterflies, *D. g. strigosus* (Bates), a subspecies found in the desert regions of Colorado and southern California, were examined for neogregarine spores. None of the adults surveyed had neogregarine spores. Their absence in the striated queen population may reflect an inadequate sample size, infection levels too low to be detected with our method, or the resistance of this subspecies to the protozoan. A more likely explanation is that the striated queen is susceptible to the protozoan, but are not exposed to the parasite because they do not share a common milkweed host plant with the monarch butterfly. The striated queen larvae feed mainly on the rambling milkweed, *Sarcostemma hirtellum* R. Holm, a plant not used for oviposition by monarch butterflies. The populations of queen and monarch butterflies of south central Florida are ecological competitors during early spring (March-May). The adults of the two species are found in the same habitat where they will feed on similar nectar sources and oviposit on common *Asclepias* plants. The larvae of the two species have been reported on the same milkweed host (Brower, L. 1961. Ecol., 42: 76–83).

Our previous observations indicated that the neogregarine is passed vertically from one generation to another by infected adults contaminating eggs or milkweed leaf surfaces with spores directly or with scales containing spores during oviposition. The larvae become infected when they ingest the spores. Our survey data show that the infection level of butterflies overwintering in California ranges from 200 to > 900,000 spores per individual. Even at the higher levels of infection in the California monarch butterfly populations, the protozoan appeared to have little effect on the butterfly's winter survival and mating successes (unpublished data). The low pathogenicity of this parasite on its host in nature has allowed it to persist widely within populations of monarch butterflies. Studies on the genus *Danaus* suggest that the monarch butterfly evolved in the New World, probably South or Central America (Kitching, I. et al. 1993 pp. 11–16. *In* Biology and conservation of the monarch butterfly, Natural History Museum of Los Angeles County, Los Angeles, CA). We hypothesize that the neogregarine co-evolved with its host and because of the high rate of infection, the parasite moved with its host into other geographic regions. We cannot discount the possibility that the queen butterfly or other related Danaid species were the original host for this neogregarine which subsequently became adapted to the monarch butterfly. Regardless, both the queen and monarch butterfly are hosts of *O. elektroscirrha*. Examination for neogregarine spores on other closely related species to the queen and monarch butterflies may provide further insights into the distribution of *O. elektroscirrha* and its host spectrum.

Acknowledgment.—Authors thank J. Capinera, R. Giblin-Davis, T. A. Jackson, L. LeBeck, W. Sakai, L. Tsutsumi, and M. P. Zalucki for the monarch butterflies used in this survey. Authors page charges partially offset by a grant from the C. P. Alexander Fund, Pacific Coast Entomological Society.

Kingston L. H. Leong,[1] Michael A. Yoshimura,[1] & Harry K. Kaya, [2] [1]*Biological Sciences, California Polytechnic State University, San Luis Obispo, California, 93407;* [2]*Department of Nematology, University of California, Davis, California 95616.*

Received 15 May 1996; Accepted 15 Aug 1996.

PAN-PACIFIC ENTOMOLOGIST
73(1): 52–54, (1997)

Scientific Note

FLOWER-VISITORS OF *BACCHARIS PILULARIS* DE CANDOLLE SUBSP. *CONSANGUINEA* (DE CANDOLLE) C.B. WOLF (ASTERACEAE) IN BERKELEY, CALIFORNIA

Coyote brush (*Baccharis pilularis* De Candolle subspecies *consanguinea* (De Candolle) C.B. Wolf (Asteraceae)) is a dioecious evergreen perennial, native throughout cismontane California, Baja California, and as far north as Oregon (Wright, A.D. 1928. Ph.D. Thesis, University of California, Berkeley). It is a relatively common xerophyte ranging in altitude from sea-level to approximately 400 m, and although it does not compete well in areas where evaporation rates are particularly high, it can withstand seasonal drought stress (Wright 1928). Tilden's (Tilden, J.W. 1951. Microentomology, 1: 149–188) study of *B. pilularis* catalogued the arthropod associates of coyote brush; this initial work, however, did not include the suite of insects visiting the flowers of coyote brush. As a supplementary study, I have provided a list of the insect flower-visitors collected in Strawberry Canyon in 1992.

Large stands of coyote brush exist in the scrub oak communities of Strawberry Canyon (Berkeley, Alameda Co., CA). The two study sites of this project (both approximately 70 sq. meters) were within such plant communities. In addition to coyote brush, both sites had dense populations of *Avena barbata* Pott ex Link (Poaceae) (slender wild oat), *Brassica nigra* (L.) W.D.J. Koch (Brassicaceae) (black mustard), and *Silybum marianum* (L.) Gaertn. (Asteraceae) (milk thistle). The following plants occurred in much lower densities: *Foeniculum vulgare* P. Mill. (Apiaceae) (sweet fennel), *Carduus* sp. (L.) (Asteraceae), *Bromus hordeaceus* L. (Poaceae) (soft chess), *Cirsium arvense* (L.) Scop. (Asteraceae) (Canada thistle), *Genista monspessulana* (L.) L. Johnson (Fabaceae) (French broom), *Eriogonum latifolium* Sm. (Polygonaceae) (buckwheat), *Phalaris aquatica* L. (Poaceae), *Heteromeles arbutifolia* (Lindl.) M. Roemer (Rosaceae), *Quercus agrifolia* Nee (Fagaceae) (live oak), and *Nassella lepida* (A.S. Hitchc.) Barkworth (Poaceae) (needle grass). Soil moisture (% water of a 20cm soil-core) at both sites was approximately 7% during the sampling period. Daytime temperatures ranged from about 16° C to 37°.

During the peak coyote brush flowering period in 1992 (mid-September through mid-October), insects visiting the inflorescences of gynoecious (female) and androecious (male) coyote brush plants were collected. The pistillate flower of coyote brush is a brush-type flower; the staminate flower is a disk-type. Collections were made on 20 and 26 Sep and 4 and 10 Oct 1992. They commenced at about 08:45 h, paused from noon to 12:45 h, and continued until about 15:45 h. Any insect seen on a flower or hovering directly above an inflorescence was collected using a small net and aspirator. Identifications were done by various specialists, as well as by the author.

Representatives of at least 55 insect species were collected (five orders and 32

Table 1. List of insects visiting *Baccharis* flowers.

Order/Family/(Subfamily)	Genus/Species	No.
Hemiptera		
Cixiidae	undetermined adult	1
Lygaeidae	*Nysius* sp.	18
undet. nymph		1
undet. nymph		1
Coleoptera		
Coccinellidae	*Cryptolaemus montrouzieri* Mulsant	1
	Psyllobora vigintimaculata Say	1
	Rhyzobius forestieri Mulsant	1
Chrysomelidae	*Diabrotica undecimpunctata* Mannerheim	3
	Diachus sp.	3
Staphylinidae	undet. sp.	1
Lepidoptera		
Nymphalidae	*Junonia coenia* Hubner	1
Diptera		
Agromyzidae	undet. sp. 1	2
	sp. 2	1
Anthomyiidae	undet. spp.	2
Anthomyiidae/Muscidae	undet. spp.	3
Bombyliidae	*Mythicomyia* sp. 1	8
	Mythicomyia sp. 2	1
Chamaemyiidae	*Leucopsis* sp.	1
Muscidae	*Coenosia* sp.	4
Sarcophagidae	undet. spp.	2
Syrphidae		
(Syrphinae)	*Allograpta* sp.	2
	Paragus sp.	1
	Sphaerophoria sp.	1
(Microdontinae)	*Syritta pipiens* (L.)	1
Tachinidae	*Chetogena parvipalpus* Wulp	2
	Microchaetina sp.	1
Tephritidae	*Tephritus* sp.	1
	Trupanea sp.	2
Hymenoptera		
Apidae	*Apis mellifera* L.	11
	Bombus sp.	1
Braconidae		
(Agathidinae)	*Agathis gibbosa* (Say)	68
(Braconinae)	*Atanycolus* sp.	1
(Microgastrinae)	*Apanteles* sp. 1 (*metacarpalis* spp. group)	9
	Apanteles sp. 2 (*ater* spp. group)	1
	Apanteles sp. 3 (*metacarpalis* spp. group)	2
	Apanteles sp. (males) (*metacarpalis* spp. group)	3
	Dolichogenidea sp. (*laevigatus* spp. group)	15
Chalcididae	*Spilochalcis* sp.	1
Colletidae	*Hylaeus* sp.	4
Eulophidae		
(Tetrastichinae)	*Aprostocetus* sp.	6
Eumenidae	undet. sp.	1
Eurytomidae	*Eurytoma* sp.	1
Formicidae	*Linepithema humile* (Mayr)	80

Table 1. Continued.

Order/Family/(Subfamily)	Genus/Species	No.
Ichneumonidae		
(Cremastinae)	undet. sp.	1
Platygastridae	*Synopeas* sp.	66
Pompilidae	undet. sp. 1	1
	sp. 2	1
	sp. 3	1
Pteromalidae		
(Pteromalinae)	undet. sp. 1	1
	sp. 2	3
Sphecidae	*Sceliphron caementarium* Drury	1
	undet. sp.	1
Torymidae	*Megastigmus* sp.	1
Unidentified Chalcidoidea	undet. sp.	5
Vespidae	*Vespula pensvlvanica* Saussure	2

families) including an undescribed *Synopeas* species near *anomaliventre* (Ashmead) (Table 1.). Particularly well represented were *Linepithema humile* (Mayr) (Hymenoptera: Formicidae), *Agathis gibbosa* (Say) (Hymenoptera: Braconidae), *Synopeas* sp. (Hymenoptera: Platygastridae), Microgastrinae (Hymenoptera: Braconidae), and several chalcidoid species (Hymenoptera). Hymenoptera comprised approximately 81% of all insect specimens, Diptera accounted for 10%, and the remaining orders, 9%. It is worth noting that foraging *A. gibbosa* females frequently probed pistillate inflorescences with their ovipositors. The individual would repeatedly insert its ovipositor into the side of the flower and angle the thrusting motion downward. This behavior was restricted to *A. gibbosa* and usually occurred whenever the wasp was present at a pistillate flower.

Acknowledgment.—The author thanks Robert L. Bugg for support throughout the project (Information Group, SAREP, University of California, Davis). Leopoldo Caltagirone (Laboratory of Biological Control, University of California, Berkeley) provided laboratory space and guidance in the identification of parasitoids. Kenneth Hagen (Laboratory of Biological Control, University of California, Berkeley) identified all Coleoptera as well as providing much support. Paul Arnaud (Department of Entomology, California Academy of Sciences, San Francisco) identified the Diptera. Robert Zuparko (Laboratory of Biological Control, University of California, Berkeley) and Howell Daly (Department of Environmental Science, Policy, and Management, University of California, Berkeley) helped with the identification of some Hymenoptera. Robert Wharton (Department of Entomology, Texas A&M University, College Station) provided the species name of the many *Agathis* specimens. James Whitfield (Department of Entomology, University of Arkansas, Fayatteville) provided the group names of the microgastrines. Author page charges partially offset by a grant from the C.P. Alexander Fund, Pacific Coast Entomological Society.

Shawn A. Steffan, *Department of Entomology, University of Wisconsin, Madison, Wisconsin 53706.*

Received 13 Feb 1996; Accepted 27 Sep 1996.

PAN-PACIFIC ENTOMOLOGIST
73(1): 55–57, (1997)

SCIENTIFIC NOTE

THE IDENTITY OF *CHELANOPS SERRATUS* MOLES (PSEUDOSCORPIONIDA: CHERNETIDAE)

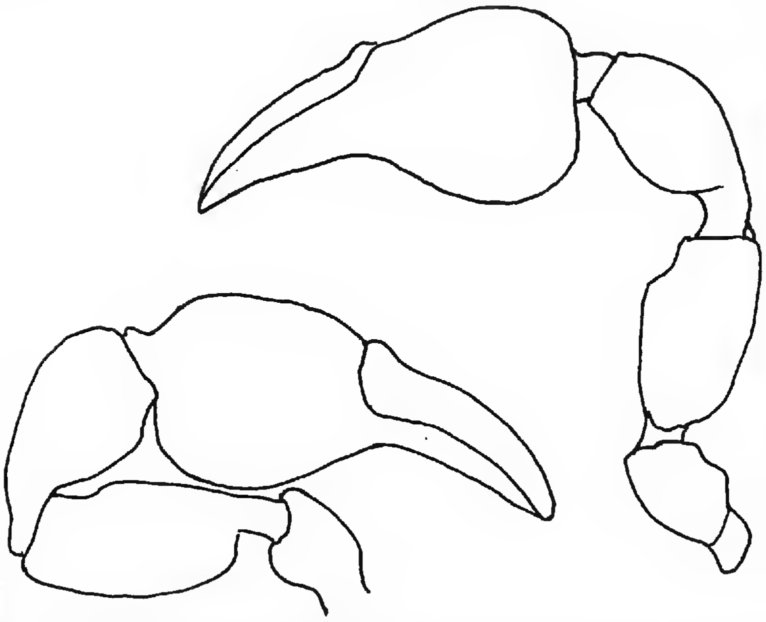
Chelanops serratus was described on the basis of a single individual found "on the window pane of the Pomona College greenhouse" [Pomona, Los Angeles County, California] (Moles, M. M.[sic] 1914. J. Entomol. Zool., 6: 187–197). The specimen was mounted on a slide, which was said to be "so poorly made" [probably by a student at Pomona College] that it was impossible to take measurements of any parts but the palps. The whereabouts of that holotype is now unknown, and it must be presumed lost. Nevertheless, the species was described in sufficient detail that many important characters are clear, especially of the palp, which was illustrated (1914: fig. 3). It is obvious that this is the same pseudoscorpion species as that later described by Chamberlin as *Dinocheirus sicarius* (1952. Bull. Amer. Mus. Nat. Hist., 99: 259–312), from the Frances Simes Hastings Natural History Reservation, Monterey County, California. This conclusion is supported by my own study of numerous representatives of the species from many locations in California, from San Diego County in the south to Modoc County in the north.

Dinocheirus serratus (Moles)

Chelanops serratus Moles, 1914: 193, fig. 3; Moles, M. & W. Moore. 1921. J. Entomol. Zool., 13: 7.
Dinocheirus? serratus (Moles): Hoff, C. C. 1958. Amer. Mus. Novitates, 1875: 28.
Dinocheirus serratus (Moles): Harvey, M. S. 1991. Catalogue of the Pseudoscorpionida. Manchester Univ. Press: 573.
Dinocheirus sicarius Chamberlin, 1952: 279–292, figs. 6-9; Hoff 1958: 28; Harvey 1991: 573 (complete synonymy to 1989). NEW SYNONYMY

Although Moles's specimen of *Chelanops serratus* was apparently badly damaged, she was able to provide enough detail to allow some comparison with other chernetids in California. A glance at her illustration of the palp immediately suggests a close relationship to *Dinocheirus sicarius* Chamberlin. Though Moles did not mention the sex of her specimen, it is evident that it was a male, as the palp is like that of the holotype of *D. sicarius* (see Figs. 1, 2). The shapes and proportions of the segments are very similar—distinctive are the robust palpal segments, especially the chela of the male, and the unusual configuration of the medial side of the femur. The latter was described by Moles (1914: 195), "femur - - - pedicellate, inner margin almost straight at base, then suddenly concave to tip," and by Chamberlin (1952: 280), "unique angular protuberance on the inner or subdorsal face of the palpal femur of the male." The form of the palpal femur is diagnostic for this species; I do not know of any other chernetid that looks like this. Actually, there is considerable variation in size and proportions of the palpal segments, especially in males, so that the chela may be more or less stout and the protuberance of the femur more or less pronounced (Chamberlin 1952: 282; personal observation).

Sizes are comparable: Moles gave only the length of the pedipalp, 3 mm (1914:



1

2

Figure 1. *Chelanops serratus*, outline of palp of holotype (redrawn from Moles 1914: fig. 3).
Figure 2. *Dinocheirus sicarius*, outline of palp of holotype male (redrawn from Chamberlin 1952: fig. 6B).

193); this compares well to 3.15 mm, the sum of the average lengths of the palpal segments reported by Chamberlin (1952: 284). Setae of the palps are similar: Chamberlin characterized them as "thickened and variously denticuloclavate" (p. 282); in profile, these appear "saw-like" (serrate), as described by Moles (p. 195). Moles described the cheliceral galea, or spinneret, as "small and transparent" (p. 195), while Chamberlin showed that of the male to be smaller and more slender than that of the female (1952: fig. 6E, F). Moles and Chamberlin agreed that the carapace is granulate, but Moles (p. 193) apparently erred in stating that there are "no eye spots" (2 distinct eyespots are present) and only "one distinct median suture" (2 transverse furrows are present); it is understandable that she might not have seen these details on the damaged specimen she was studying.

Altogether, it is clear that Moles and Chamberlin were dealing with the same species and that *Dinocheirus sicarius* Chamberlin (1952) is a junior synonym of *Chelanops serratus* Moles (1914). It is also quite clear, from the very detailed description by Chamberlin, that the species is a representative of the genus *Dinocheirus* Chamberlin (see also Muchmore, W. B. 1974. J. Arachnol., 2: 34).

The known range of *Dinocheirus serratus* now extends from San Diego County, California northward to Columbia County, Oregon (see below and Benedict, E. M. & D. R. Malcolm. 1982. J. Arachnol., 10: 100); there is also an unsubstantiated record from the Great Salt Lake Desert, Utah (Gering, R. L. 1956. p. 50 *in*: Woodbury, A. M., [ed.] Ecological Check Lists. The Great Salt Lake Desert Series, Univ. of Utah, Dugway). I have made detailed studies on the following specimens.

Material Examined.—CALIFORNIA. *ALAMEDA Co.*: Berkeley, nest of *Neotoma fuscipes* Baird, Nov 1926, 1 male, 3 females. *COLUSA Co.*: 4 km W of Stonyford, *Neotoma* nest at base of oak, 30 Apr 1980, F. G. Andrews, 6 males, 9 females, 6 nymphs. *MODOC Co.*: Big Sage Reservoir, *Neotoma* nest at base of *Juniperus occidentalis* Hooker, 31 May 1978, F. G. Andrews, 1 male. *RIVERSIDE Co.*: Mt. San Jacinto, 1250 m, litter from hollow of fallen oak, 28 Mar 1978, K. W. Cooper, 1 male, 2 females, 5 nymphs. *SAN BERNARDINO Co.*: E of Summit [only 40 km from Pomona], damp *Neotoma* nest, 5 Jun 1979, K. W. Cooper, 1 male, 3 females, 4 nymphs. *SAN DIEGO Co.*: 1.5 km E of Leucadia, *Neotoma* nest in chaparral, very dry, 8 Aug 1979, K. W. Cooper, 7 males, 5 females, 4 nymphs. (All deposited in Florida State Collection of Arthropods, Gainesville).

Acknowledgment.—I am greatly indebted to F. G. Andrews and K. W. Cooper for sending me many pseudoscorpions for study. Author page charges partially offset by a grant from the C. P. Alexander Fund, Pacific Coast Entomological Society.

William B. Muchmore, *Department of Biology, University of Rochester, Rochester, New York 14627.*

Received 13 Feb 1996; Accepted 16 Oct 1996.

PAN-PACIFIC ENTOMOLOGIST
73(1): 58–59, (1997)

Scientific Note

WEEVILS NEW TO THE STATE OF WASHINGTON (COLEOPTERA: CURCULIONIDAE)

During 1994–95, a qualitative study to evaluate insect biodiversity was conducted at the Hanford Site which is located in southcentral Washington State. Situated in the semi-arid Columbia Plateau Basin, this 560 square mile site was closed to the general public in the early 1940s. Originally acquired by the United States federal government as a site for the production of plutonium to be used in weapons production, the site is currently administered by the Department of Energy for nuclear waste management, environmental restoration, and research and development.

Our studies were confined primarily to the Fitzner-Eberhardt Arid Lands Ecology Reserve (ALE). An area of over 100 square miles, the ALE is located in the southwestern portion of the Hanford Site (latitude N 46°, longitude W 119°). Physiographically diverse, the site consists of a steeply rising, northeast facing slope (Rattlesnake Ridge — 1150 m) and extensive flats that slope gently from 500 to 150 m. Vegetation consists primarily of a sagebrush-bitterbrush/Sandberg's bluegrass-cheatgrass type, the general habitat is referred to as a shrub-steppe.

Thirty-three species of Curculionidae were collected during this study. Twenty-six are species more common to the central basin of Washington State and are associated with primary vegetation including rabbitbrush, sagebrush, lupine, and balsamroot (Hatch, M. H. 1971. The Beetles of the Pacific Northwest., Univ. Washington Press). Seven of the species collected have previously not been recorded for Washington. Distributional data primarily are from O'Brien and Wibmer (1982. Mem. Amer. Entomol. Institute, 34: 1–382). The majority of specimens are in the M. T. James Entomological Collection, Washington State University; voucher specimens are in the private collection of the senior author (CWOB). A list of species and exact locations for individual collections within the ALE are available from RSZ.

First documented records for species from Washington State:

Anthonomus cycliferus Fall: widespread but spotty distribution throughout the western states.

Anthonomus sphaeralciae Fall: widespread throughout the southwest and central states, the species has also been found in Idaho. It is known to feed on several species of *Sphaeralcea* (Malvaceae) one of which, *S. munroana* (Dougl.) Spach, is widespread on the Hanford site.

Ceutorhynchus erysimi (Fabr.): an introduced species, it is widespread throughout the eastern United States and Canada but previously recorded only from Oregon in the western United States. The species feeds on various Cruciferae.

Cleonidius erysimi (Fall): previously known only from scattered locations throughout the western United States and Canada. It has been predominantly taken in sand dune habitats, as were our specimens. Adults and immatures have been collected from a variety of plants, primarily Cruciferae and some Compositae (Anderson, R. S. 1988. Quaest. Entomol., 23: 431–709).

Gymnetron pascuorum (Gyllenhal): an introduced species that is widespread throughout much of the eastern and western United States. It has been reared from *Plantago lanceolata* (L.) (English plantain) (Hatch, M. H. 1971. The Beetles of the Pacific Northwest. Univ. Washington Press) which is widespread and common on the Hanford site.

Lepesoma remota (Van Dyke): previously known only from Oregon.

Mecinus pyraster (Herbst): an introduced species previously known only from Maryland, New Jersey, Florida, Virginia, and Oregon. The primary larval host is *Plantago* (Plantaginaceae) but *Mecinus* have also been found feeding in several genera of Scrophularaceae (Warner, R. E. 1955. Entomol. News, 66: 209–211).

Acknowledgement.—This project was funded by The Nature Conservancy with awards from the U. S. Department of Energy, The Nature Conservancy of Washington State, and The Bullitt Foundation.

Charles W. O'Brien, *Entomology-Biological Control, Florida A&M University, Tallahassee, Florida 32307-4100* and Richard S. Zack, *James Entomological Collection, Department of Entomology, Washington State University, Pullman, Washington 99164-6382.*

Received 27 Feb 1996; Accepted 16 Oct 1996.

PAN-PACIFIC ENTOMOLOGIST
73(1): 60, (1997)

Book Review

Bleuzen, P. 1994. Les Coleopteres du Monde (The Beetles of the World). Prioninae 1: Macrodontini: *Macrodontia, Chalcoprionus, Ancistrotus, Acanthinodera, Acalodegma*: Prionini: *Titanus, Braderochus*. Volume 21. Sciences Nat. 92 pp., 16 plates.

This is another volume in the marvelous series of beetle picture books. The text is done in French and English (Brian Morris). This volume contains keys for the determination of genera and species treated. There are distribution maps for the species although single locality records appear to be of little value in ascertaining distributions.

One new species of *Macrodontia, M. jolyi* is described from Venezuela. The genus *Titanus* Audinet-Serville is treated as monotypic and *Braderochus* Buquet is elevated to generic status with five species, three of these new (*B. jolyi* from Venezuela and Guyana; *B. salcedoï* from Venezuela, and *B. shuteae* from Honduras and Panama). One of these is unfortunately a synonym.

The illustrations are of the usual superb quality of this series and are a great aid in species determinations.

The bilingual text is very useful but the English version is often awkward and somewhat incomprehensible, probably due to a very literal translation from the French.

This, however, does not appreciably detract from the overall usefullness of the book and the modest price of $150.00 makes this a very desirable item for students and collectors of large beetles, particularly *Cerambycidae*. The book is now available from Sciences Nat, 2, rue Andre Mellene, 60200 Venette, France.

John A. Chemsak, *Division of Insect Biology, University of California, Berkeley, CA. 94720.*

PAN-PACIFIC ENTOMOLOGIST
Information for Contributors

See volume 66(1): 1–8, January 1990, for detailed general format information and the issues thereafter for examples; see below for discussion of this journal's specific formats for taxonomic manuscripts and locality data for specimens. Manuscripts must be in English, but foreign language summaries are permitted. Manuscripts not meeting the format guidelines may be returned. Please maintain a copy of the article on a word-processor because revisions are usually necessary before acceptance, pending review and copy-editing.

Format. — Type manuscripts in a legible serif font IN DOUBLE OR TRIPLE SPACE with 1.5 in margins on one side of 8.5 × 11 in, nonerasable, high quality paper. THREE (3) COPIES of each manuscript must be submitted, EACH INCLUDING REDUCTIONS OF ANY FIGURES TO THE 8.5 × 11 IN PAGE. Number pages as: title page (page 1), abstract and key words page (page 2), text pages (pages 3+), acknowledgment page, literature cited pages, footnote page, tables, figure caption page; place original figures last. List the corresponding author's name, address including ZIP code, and phone number on the title page in the upper right corner. The title must include the taxon's designation, where appropriate, as: (Order: Family). The ABSTRACT must not exceed 250 words; use five to seven words or concise phrases as KEY WORDS. Number FOOTNOTES sequentially and list on a separate page.

Text. — Demarcate MAJOR HEADINGS as centered headings and MINOR HEADINGS as left indented paragraphs with lead phrases underlined and followed by a period and two hypens. CITATION FORMATS are: Coswell (1986), (Asher 1987a, Franks & Ebbet 1988, Dorly et al. 1989), (Burton in press) and (R. F. Tray, personal communication). For multiple papers by the same author use: (Weber 1932, 1936, 1941; Sebb 1950, 1952). For more detailed reference use: (Smith 1983: 149–153, Price 1985: fig. 7a, Nothwith 1987: table 3).

Taxonomy. — Systematics manuscripts have special requirements outlined in volume 69(2): 194–198; if you do not have access to that volume, request a copy of the taxonomy/data format from the editor before submitting manuscripts for which these formats are applicable. These requirements include SEPARATE PARAGRAPHS FOR DIAGNOSES, TYPES AND MATERIAL EXAMINED (INCLUDING A SPECIFIC FORMAT), and a specific order for paragraphs in descriptions. List the unabbreviated taxonomic author of each species after its first mention.

Data Formats. — All specimen data must be cited in the journal's locality data format. See volume 69(2), pages 196–198 for these format requirements; if you do not have access to that volume, request a copy of the taxonomy/data format from the editor before submitting manuscripts for which these formats are applicable.

Literature Cited. — Format examples are:

Anderson, T. W. 1984. An introduction to multivariate statistical analysis (2nd ed). John Wiley & Sons, New York.

Blackman, R. L., P. A. Brown & V. F. Eastop. 1987. Problems in pest aphid taxonomy: can chromosomes plus morphometrics provide some answers? pp. 233–238. *In* Holman, J., J. Pelikan, A. G. F. Dixon & L. Weismann (eds.). Population structure, genetics and taxonomy of aphids and Thysanoptera. Proc. international symposium held at Smolenice Czechoslovakia, Sept. 9–14, 1985. SPB Academic Publishing, The Hague, The Netherlands.

Ferrari, J. A. & K. S. Rai. 1989. Phenotypic correlates of genome size variation in *Aedes albopictus*. Evolution, 42: 895–899.

Sorensen, J. T. (in press). Three new species of *Essigella* (Homoptera: Aphididae). Pan-Pacif. Entomol.

Illustrations. — Illustrations must be of high quality and large enough to ultimately reduce to 117 × 181 mm while maintaining label letter sizes of at least 1 mm; this reduction must also allow for space below the illustrations for the typeset figure captions. Authors are strongly encouraged to provide illustrations no larger than 8.5 × 11 in for easy handling. Number figures in the order presented. Mount all illustrations. Label illustrations on the back noting: (1) figure number, (2) direction of top, (3) author's name, (4) title of the manuscript, and (5) journal. FIGURE CAPTIONS must be on a separate, numbered page; do not attach captions to the figures.

Tables. — Keep tables to a minimum and do not reduce them. Table must be DOUBLE-SPACED THROUGHOUT and continued on additional sheets of paper as necessary. Designate footnotes within tables by alphabetic letter.

Scientific Notes. — Notes use an abbreviated format and lack: an abstract, key words, footnotes, section headings and a Literature Cited section. Minimal references are listed in the text in the format: (Bohart, R. M. 1989. Pan-Pacific. Entomol., 65: 156–161.). A short acknowledgment is permitted as a minor headed paragraph. Authors and affiliations are listed in the last, left indented paragraph of the note with the affiliation underscored.

Page Charges. — PCES members are charged $35.00 per page, for the first 20 (cumulative) pages per volume and full galley costs for pages thereafter. Nonmembers should contact the Treasurer for current nonmember page charge rates. Page charges do not include reprint costs, or charges for author changes to manuscripts after they are sent to the printer. Contributing authors will be sent a page charge fee notice with acknowledgment of initial receipt of manuscripts.

THE PAN-PACIFIC ENTOMOLOGIST

Volume 73 January 1997 Number 1

Contents

SCIENTIFIC NOTES

BOOK REVIEW

The
PAN-PACIFIC
ENTOMOLOGIST

Volume 73 April 1997 Number 2

Published by the PACIFIC COAST ENTOMOLOGICAL SOCIETY
in cooperation with THE CALIFORNIA ACADEMY OF SCIENCES
(ISSN 0031-0603)

The Pan-Pacific Entomologist

Published quarterly in January, April, July, and October with Society Proceedings usually appearing in the October issue. All communications regarding nonreceipt of numbers should be addressed to: Vincent F. Lee, Managing Secretary; and financial communications should be addressed to: Julieta F. Parinas, Treasurer; at: Pacific Coast Entomological Society, Dept. of Entomology, California Academy of Sciences, Golden Gate Park, San Francisco, CA 94118-4599.

Application for membership in the Society and changes of address should be addressed to: William Hamersky, Membership Committee chair, Pacific Coast Entomological Society, Dept. of Entomology, California Academy of Sciences, Golden Gate Park, San Francisco, CA 94118-4599.

Manuscripts, proofs, and all correspondence concerning editorial matters (but not aspects of publication charges or costs) should be sent to: Dr. Robert V. Dowell, Editor, Pan-Pacific Entomologist, California Dept. of Food & Agriculture, 1220 N St., Sacramento, CA 95814. See the back cover for Information-to-Contributors, and volume 66(1): 1–8, January 1990, for more detailed information. Information on format for taxonomic manuscripts can be found in volume 69(2): 194–198. Refer inquiries for publication charges and costs to the Treasurer.

The annual dues, paid in advance, are $25.00 for regular members of the Society, $26.00 for family memberships, $12.50 for student members, or $40.00 for institutional subscriptions or sponsoring members. Members of the Society receive *The Pan-Pacific Entomologist.* Single copies of recent numbers or entire volumes are available; see 72(4): 247 for current prices. Make checks payable to the *Pacific Coast Entomological Society.*

Pacific Coast Entomological Society

THE PAN-PACIFIC ENTOMOLOGIST (ISSN 0031-0603) is published quarterly for $40.00 per year by the Pacific Coast Entomological Society, % California Academy of Sciences, Golden Gate Park, San Francisco, CA 94118-4599. Periodicals postage is paid at San Francisco, CA, and additional mailing offices. POSTMASTER: Send address changes to the Pacific Coast Entomological Society, % California Academy of Sciences, Golden Gate Park, San Francisco, CA 94118-4599.

This issue mailed 22 April 1997

The Pan-Pacific Entomologist (ISSN 0031-0603)
PRINTED BY THE ALLEN PRESS, INC., LAWRENCE, KANSAS 66044, U.S.A.

PAN-PACIFIC ENTOMOLOGIST
73(2): 61–69, (1997)

FOUR NEW SPECIES OF COSTA RICAN *CERAEOCHRYSA* (NEUROPTERA: CHRYSOPIDAE)

Norman D. Penny
Department of Entomology, California Academy of Sciences, Golden Gate Park,
San Francisco, California 94118

Abstract.—Four new species of Costa Rican *Ceraeochrysa* are described, and compared to closely related congeneric species.

Resumo.—Cuatro nuevas especiés de *Ceraeochrysa* costaricense son descrito, y comparadas a unas especiés cerca relativas congenericas.

Key Words.—Insecta, Neuroptera, Chrysopidae, *Ceraeochrysa,* Costa Rica.

The genus *Ceraeochrysa* was erected by Adams (1982) for 24 species of green lacewings distributed from southern Canada to Argentina. More recently, Brooks and Barnard (1990) included 40 valid species in this genus. They are primarily tropical, and some species may be valuable as biological control agents in plantation ecosystems (Adams & Penny 1987). *Ceraeochrysa* species are medium-sized (forewing length 9 to 15 mm) pale green lacewings that usually bear red or black markings on the pronotum and, less commonly, on the labial palps. An elongate gonapsis, the presence of entoprocesses, a decurved mediuncal apex, and the absence of a tignum are diagnostic traits of the male genitalia.

In a recent study of the Neuroptera fauna of Costa Rica, 17 species of *Ceraeochrysa* were examined, five of which are undescribed. Four of the latter species are described here. The available material of the fifth species, a single female, is insufficient to warrant its description at the present time.

Materials and Methods

The apical part of the abdomen of each specimen was broken off with fine forceps and macerated in 10% KOH, stained in Chlorazol Black E, and preserved in a glycerin-filled microvial pinned beneath the rest of the specimen. Wing tracings were made with a Ken-a-vision microprojector from temporary wing mounts on microscope slides. Following illustration, wings were glued to cards pinned beneath the appropriate specimen. Body and genital drawings were made with the aid of a micrometer grid. Morphological terminology follows Adams & Penny (1987).

Ceraeochrysa nigripedis Penny, NEW SPECIES

Types.—Holotype, male: COSTA RICA. *PUNTARENAS:* Monteverde Biological Reserve, La Casona Station, UTM map coordinates L-N 253250, 449700, 1520 m, Nov 1991, N. Obando. Bar Code: INBIO, CR1000, 602561. Holotype deposited: Instituto de Biodiversidad (INBIO), Santo Domingo de Heredia, Costa Rica. Allotype female, same data as holotype, except Bar Code: INBIO, CR1000, 602560; deposited California Academy of Sciences, San Francisco, California.

Description.—*Head* (Fig. 3). Vertex, frons, clypeus, genae, labrum, and palpi pale yellow. Antennal scape, pedicel, and flagellum pale, without markings; flagellum slightly shorter than forewing length.

Thorax (Fig. 2). Pronotum wider than long, pale yellow, immaculate, with four small indentations. Meso- and metanota pale yellow, with a pair of round dark brown spots at the suture between prescutum and scutum on mesonotum and laterally on scutum of metanotum. Pleural and sternal areas pale yellow. Each leg pale yellow, except apical tarsomere contrastingly dark brown. *Wings* (Fig. 1). Forewing length—12.7 mm. Longitudinal veins pale green; crossveins and apical twiggings dark brown, except for apical costal crossveins. Gradate veins dark with strong infuscation of membrane along inner series. Seven inner and eight outer gradate veins. Very dark markings at apex of 1A, posterior cubitus, and cua-cup crossvein, forming a point of visual attraction on the wing. Hindwing length—11.5 mm. All veins pale green, except for most gradate veins dark. Six inner and seven outer gradate veins. *Abdomen*. Pale yellow. Female subgenitale (Fig. 4) broadly heart-shaped, with deep central cleft. Spermatheca strongly arched anterior to spermathecal ducts. Male ectoproct + tergite 9 (Fig. 5) short and broad, with scattered setae with thickened bases; dorsal apodeme simple, reaching callo cerci, without ventral lobe. Sternite 9 with broad, latero-dorsal subapical projection; numerous setae with thickened bases. Gonarcus (Figs. 7–8) medially narrow, with broad lateral plates. Ventral arms of gonarcus laterally embedded in simple, membranous gonosaccus. Entoprocesses of gonarcus-absent. Mediuncus very long, narrow, straight, with decurved apical point. Gonapsis (Fig. 6) elongate, with slightly upturned and expanded, smoothly rounded apex.

Diagnosis.—No other species of *Ceraeochrysa* has this spotting pattern on the thorax, nor the darkened apical tarsal segment. *Ceraeochrysa nigripedis* appears to be most closely related to *C. tauberae,* with which it shares an elongate, straight arcessus and dark area of visual attraction on the forewing at 1A. They differ by *C. nigripedis* having the aforementioned characteristics, in addition to a much longer ventral projection of the gonarcus and no strong gonosetae on the gonosaccus.

Etymology.—This species is named for the distinctively dark apical tarsal segments.

Material Examined.—In addition to holotype and allotype, one additional female from INBIO: same data as holotype, except collected Jul 1992.

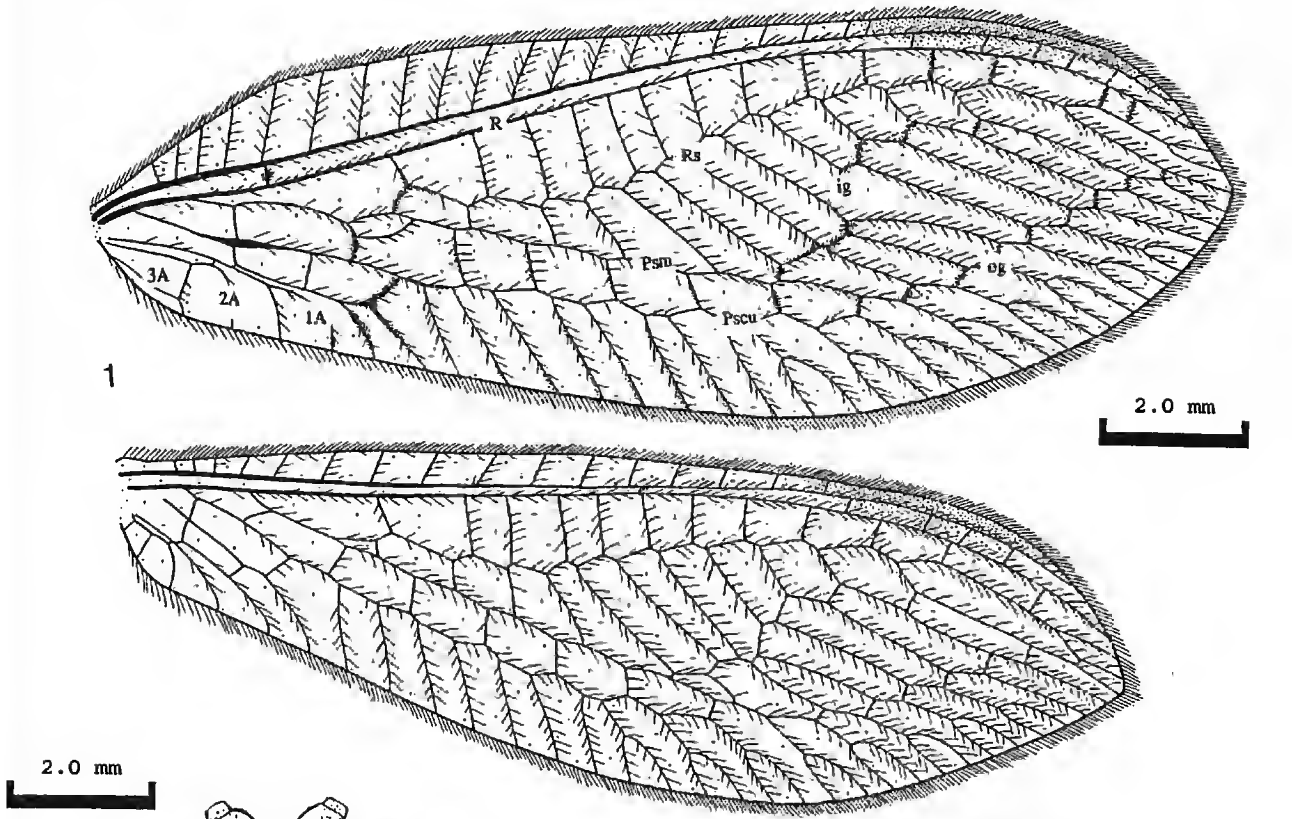
CERAEOCHRYSA INBIO PENNY, NEW SPECIES

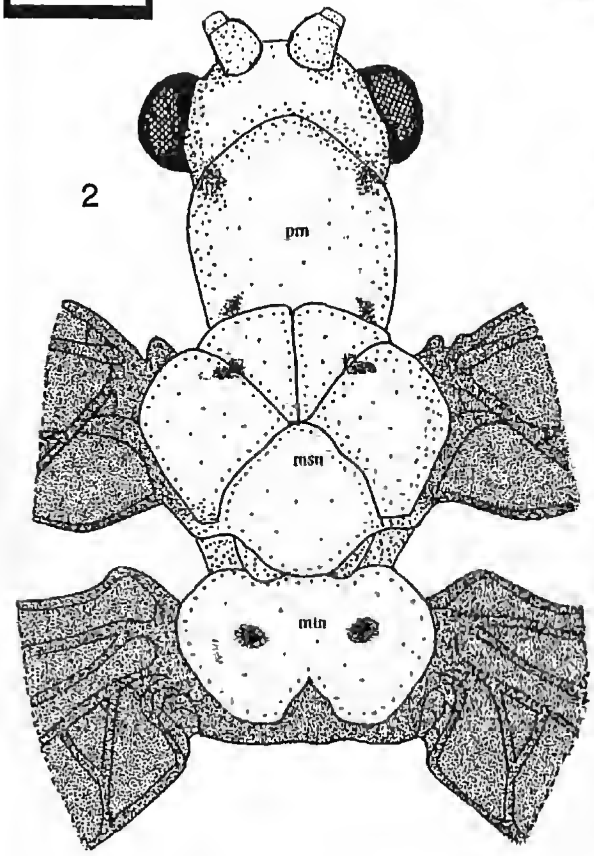
Types.—Holotype, male: from COSTA RICA. *CARTAGO:* La Amistad Biosphere Reserve, Guayabo National Monument, UTM grid coordinates L-N 217400, 570000, 1100 m, Jul 1994, G. Fonseca. Bar code: INBIO, CR1001, 887909. Holotype deposited: Instituto de Biodiversidad (INBIO), Santo Domingo de Heredia, Costa Rica.

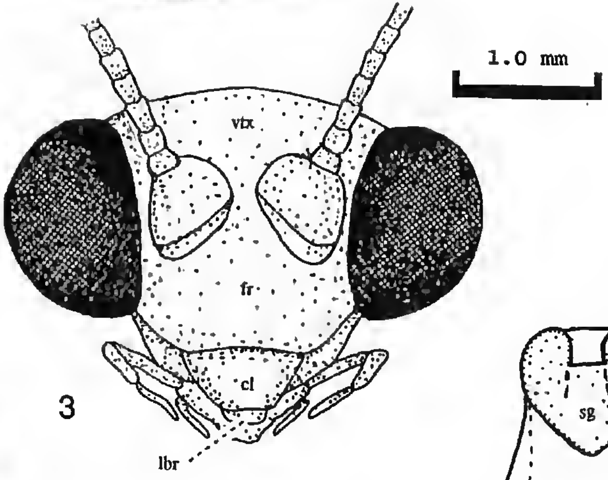
Description.—*Head* (Fig. 10). Vertex, frons, clypeus, genae, labrum, and palpi bright yellow. Antennal scape and pedicel bright yellow, with scape bearing longitudinal, mid-dorsal brown stripe. Antennal flagella missing. *Thorax* (Fig. 11). Pronotum wider than long; pale green with dark brown spots in anterio-lateral and posterio-lateral corners of sclerite. Meso- and metanota pale yellow, immaculate, except for a pair of small, elongate, brown spots on mesonotum along suture between prescutum and scutum. Pleural and sternal areas pale green, immaculate. Legs pale green, becoming gradu-

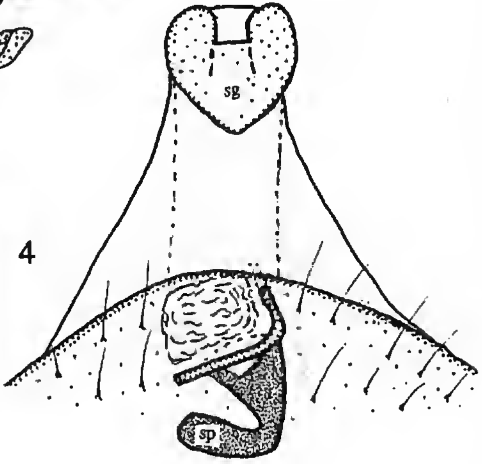
→

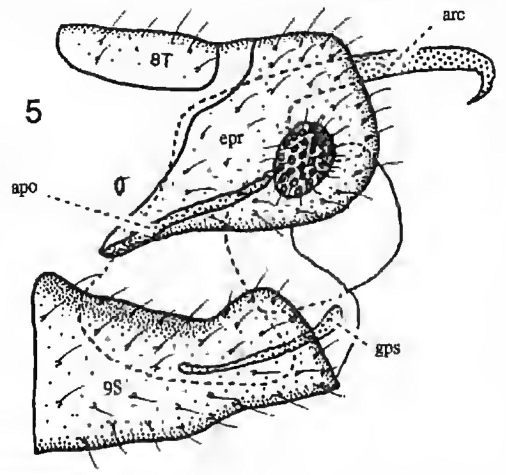
Figures 1–8. *Ceraeochrysa nigripedis,* NEW SPECIES. Figure 1. Right wings. Figure 2. Head and thorax, dorsal view. Figure 3. Head, frontal view. Figure 4. Female genitalia, ventral view. Figure 5. Apex of male abdomen, lateral view. Figure 6. Gonapsis, dorsal view. Figure 7. Male genitalia, lateral view. Figure 8. Male genitalia, dorsal view. Abbreviations: arc = arcessus, cl = clypeus, epr = tergite 9 + ectoproct, fr = frons, gps = gonapsis, gs = gonarcus, ig = inner gradate veins, lbr = labrum, msn = mesonotum, mtn = metanotum, og = outer gradate veins, prn = pronotum, Pscu = pseudocubitus, Psm = Pseudomedia, Rs = radial sector, sg = subgenitale, sp = spermatheca, vtx = vertex, 1A = third anal vein, 2A = second anal vein, 3A = third anal vein, 8T = tergite 8.


1
R
Rs
ig
Psm
og
Pscu
3A
2A
1A
2.0 mm
2.0 mm

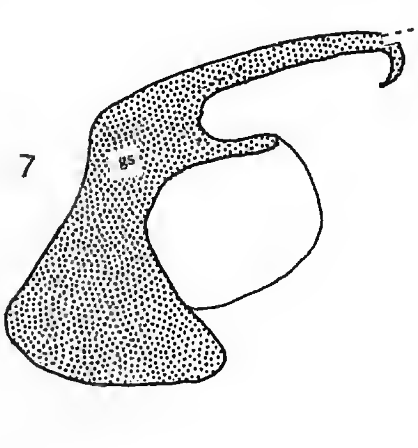

2
pm
msn
mtn

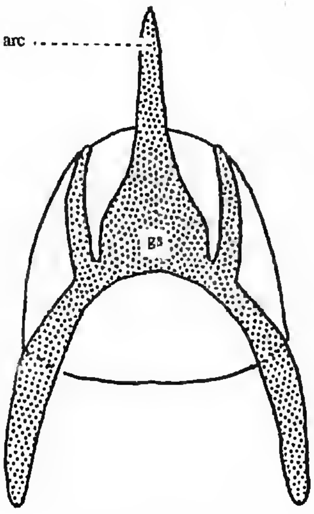

3
vtx
fr
cl
lbr
1.0 mm


4
sg
sp
0.4 mm


5
8T
arc
epr
♂
apo
9S
gps


6


7
arc
gs


8
gs

ally dark yellow on tarsi. *Wings* (Fig. 9). Forewing length—17.3 mm. Longitudinal veins pale green with dark brown crossveins, except apical costal and radial crossveins pale. Gradate crossveins dark, with some membrane infuscation along inner gradates; nine inner and ten outer gradate veins. Costa slightly swollen and darkened basad of apex of 3A. Hindwing length—15.0 mm. Longitudinal and crossveins completely pale green, immaculate. Eight inner gradate and nine outer gradate veins. *Abdomen.* Tergites dark green, with pair of small dark spots at posterior margin of tergites 2 and 3. Sternites pale yellow. Male terminalia: ectoproct + tergite 9 elongate, without a ventral lobe (Fig. 12); dorsal apodeme forked, with straight, posterodorsally branch apically forked around callo cerci; ventral fork posteroventrally directed, elongate, straight, heavily-sclerotized projection terminating in a small, acute, ventral point. Sternite 9 apically tapering sharply to ventral point; bearing numerous setae with expanded (stalked) bases. Gonarcus (Figs. 14–15) narrow medially, tapering to relatively elongate, narrow, lateral plates. Entoprocesses elongate, evenly tapering points extending about 0.67 length of arcessus. Arcessus a broad, flat plate, terminating in a short, decurved median hook, and a pair of smaller bilaterally symmetrical lateral points. Ventral arms of gonarcus embedded in and supporting lateral margins of gonosaccus. Gonosaccus lacking gonosetae and gonocristae; membrane between gonosaccus and sternite 9 bearing a broad field of small gonocristae, giving membrane a rugose appearance. Gonapsis elongate, upturned for posterior fifth, terminating in unexpanded, smoothly rounded apex (Fig. 13).

Diagnosis.—*Ceraeochrysa inbio* is a part of the *cincta* species group, all of which have a caudally recurved ventral fork of the dorsal apodeme and a field of gonocristae between the gonosaccus and ninth sternite in males. *Ceraeochrysa inbio* differs from *C. claveri* (Navás) in the latter's distinctive gonapsis, which terminates in a broad, U-shaped bifurcation, and in the lack of pronounced entoprocesses. *Ceraeochrysa cincta* (Schneider) also has much shorter entoprocesses and a shorter, more highly curved dorsal apodeme. *Ceraeochrysa arioles* (Banks) has a much larger, more recurved apex of the ninth sternite. *Ceraeochrysa inbio* is very similar to *C. caligata* (Banks), except for the former's uniquely spotted pronotum and small apical point on the male ninth sternite.

Etymology.—This species is named after the Instituto de Biodiversidad, commonly referred to as "INBIO", to recognize the hard work and pioneering methods that its staff has instigated to increase knowledge about the biodiversity of Costa Rica.

Material Examined.—See Type.

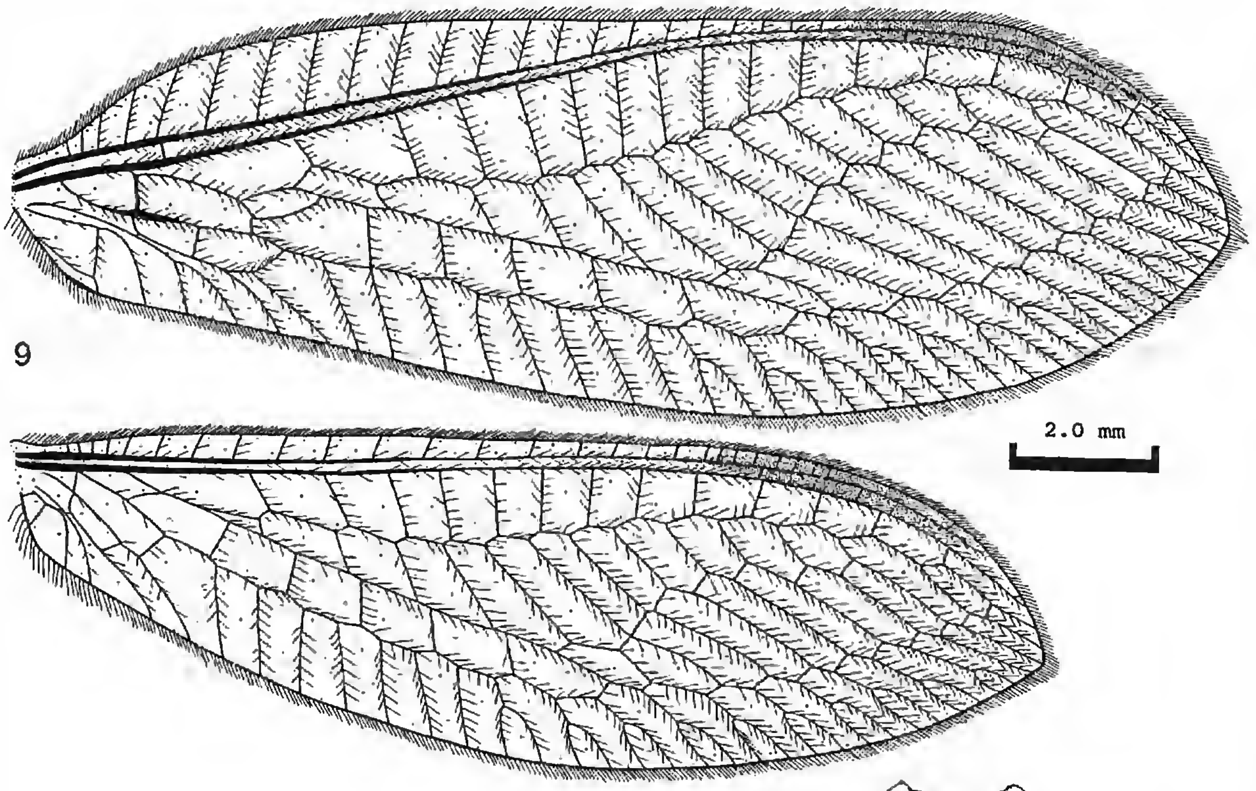
CERAEOCHRYSA COSTARICENSIS PENNY, NEW SPECIES

Type.—Holotype, male: COSTA RICA. *PUNTARENAS:* Los Alturas, 1360 m, 27 Feb 1991, Helen Sparrow. Holotype deposited: Instituto de Biodiversidad (INBIO), Santo Domingo de Heredia, Costa Rica.

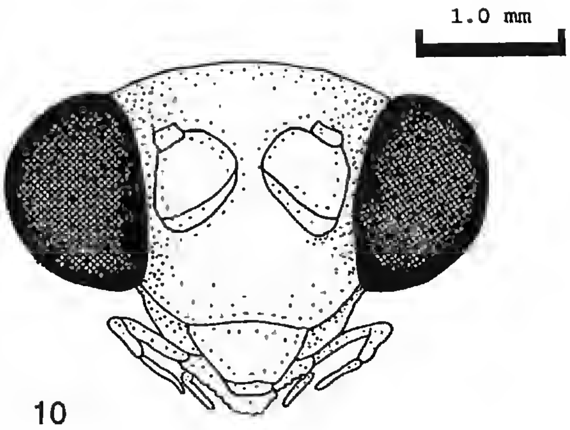
Description.—*Head* (Fig. 18). Vertex, frons, clypeus, genae, labrum, and palps bright yellow. Antenna slightly shorter than forewing length. Antennal scape suffuse orange dorsally, pale yellow ventrally; pedicel and flagellum pale yellow. *Thorax* (Fig. 17). Pronotum wider than long, pale green with pair of large reddish brown spots laterally. Smaller red brown spot on membrane under anteriolateral margins on either side of pronotum. Meso- and metanota pale green, immaculate. Pleural and sternal areas pale green to pale yellow. Legs entirely pale green. *Wings* (Fig. 16). Forewing length—13.5 mm. Longitudinal veins pale green; crossveins dark, except for apical costal crossveins. Four

→

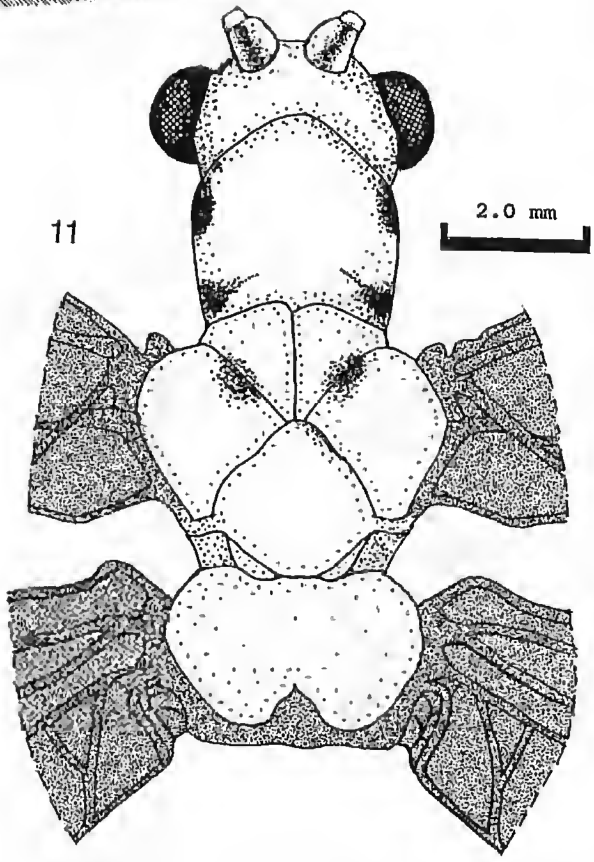
Figures 9–15. *Ceraeochrysa inbio,* NEW SPECIES. Figure 9. Right wings. Figure 10. Head, frontal view. Figure 11. Head and thorax, dorsal view. Figure 12. Apex of male abdomen, lateral view. Figure 13. Gonapsis, dorsal view. Figure 14. Male genitalia, lateral view. Figure 15. Male genitalia, dorsal view.



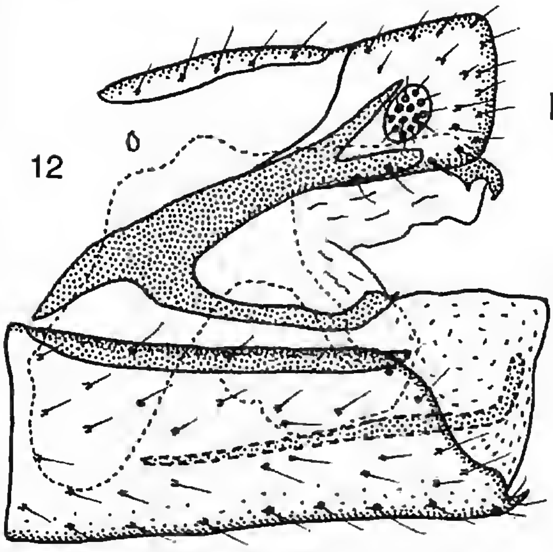
9



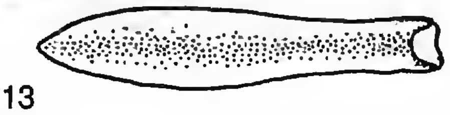
10



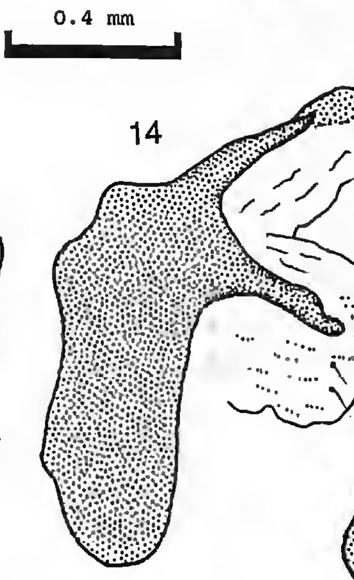
11



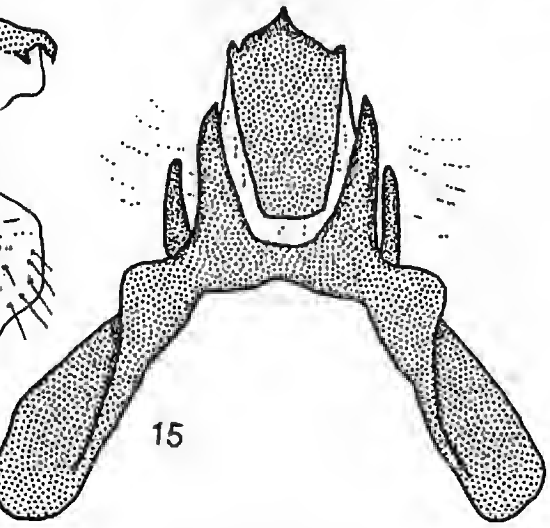
12



13



14



15

inner and seven outer gradate veins in parallel series forming cells approximately twice as long as wide. Hindwing length—12.0 mm. Longitudinal and crossveins uniformly pale green. Three inner and seven outer gradate veins. Apex angulate. *Abdomen.* Pale green. Male ectoproct + tergite 9 (Fig. 19) elongate, with scattered chalazate setae; an acute posteroventral lobe supported by ventral lobe of dorsal apodeme. Sternite 9 tapering to apex bearing chalazate setae. Gonarcus (Figs. 21–22) narrow medially, and narrow, caudally-projecting flat plates laterally. Broad dorsal plate at medial part of gonarcus. Mediuncus laterally forming pair of elongate, upturned plates, which end in dorso-caudal acute point. Mediuncus with pair of small projections basally and an evenly decurved medial point apico-ventrally. Convoluted field of small gonocristae on gonosaccus. Gonapsis (Fig. 20) relatively short, with subapical lateral arms and acute, upturned apical point.

Diagnosis.—This species is very closely related to *C. everes* (Banks), with which it shares a very distinctive dorsal hood medially on the gonarcus, upturned plate of the arcessus, and thickened setal bases at the apex of the ninth sternite. They differ in that *C. costaricensis* has two pairs of pronotal spots (not stripes), antennal bases pale (not infused with red), and apex of gonapsis simply upturned (not toothed dorsally with a ventral medial lobe).

Etymology.—This species is named after Costa Rica, in homage to all of the efforts that have been made to make known and conserve its fauna.

Material Examined.—See Type.

CERAEOCHRYSA TAUBERAE PENNY, NEW SPECIES

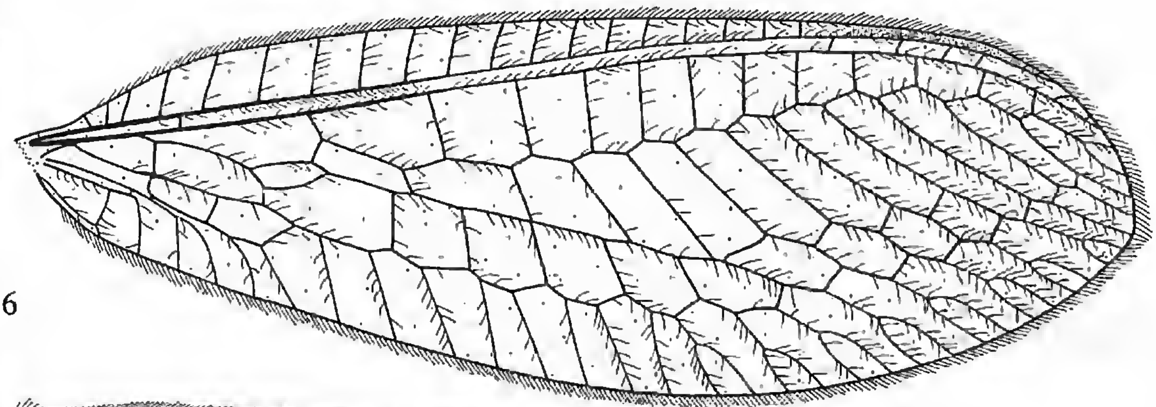
Type.—Holotype, male: COSTA RICA. *CARTAGO*: near Eslabón, 21 Dec 1994, C.A., M.J. and P.J. Tauber. Holotype deposited: Instituto de Biodiversidad (INBIO), Santo Domingo de Heredia, Costa Rica.

Description.—*Head* (Fig. 25). Vertex, frons, clypeus, genae, labrum, and palps bright yellow. Antennal scape and pedicel bright yellow. Antennal flagella missing. *Thorax* (Fig. 24). Pronotum as wide as long, pale yellow, with faint indications of darker markings at anterio-lateral and posterio-lateral margins. Meso- and metanota entirely pale green. Pleural and ventral surfaces of pterothorax pale yellow, immaculate. Legs pale yellow, changing to pale brown on tarsi. *Wings* (Fig. 23). Forewing length—10.0 mm. Longitudinal veins pale green, crossveins and apical twiggings brown. Three inner and four outer gradate veins present, dark brown with extensive infuscation of membrane adjacent to veins. Two additional areas of forewing heavily infuscated: apex of CuP and adjacent crossveins, and 2A-3A crossvein. Hindwing length—8.8 mm. Apex angulate. All longitudinal and crossveins entirely pale green. Two inner and four outer gradate veins. *Abdomen.* Entirely green. Male ectoproct + tergite 9 (Fig. 26) short, broadly ovate, only slightly extended ventrally, bearing scattered chalazate setae. Dorsal apodeme apically forked around callo cerci, but without ventral projecting lobe. Sternite 9 elongate, notably narrowed at mid-length, bearing scattered stalked setae. Gonarcus (Figs. 28, 29) formed by two very broad lateral plates which almost fuse along midline. Entoprocesses poorly developed as short, pointed lobes caudally and tiny points anteriorly. Ventral lobes of gonarcus absent. Mediuncus elongate, straight, tapering to apical decurved point. Gonosaccus bearing numerous gonosetae. Gonapsis (Fig. 27) elongate, apically forked, with both forks apically rounded.

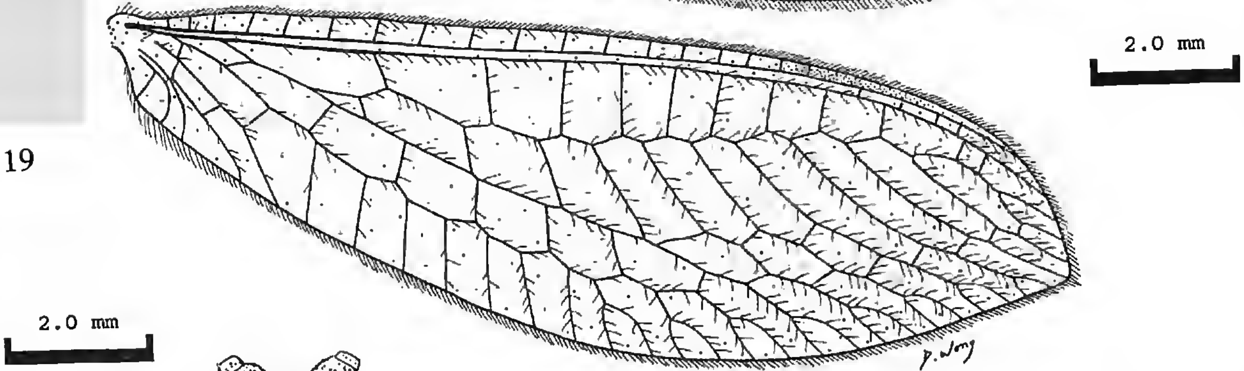
Diagnosis.—This species appears most closely related to *C. nigripedis,* in part due to the long, straight arcessus and shape of the male ectoproct and ninth sternite. There is also a similar area visual attraction on the forewing at the apex of

→

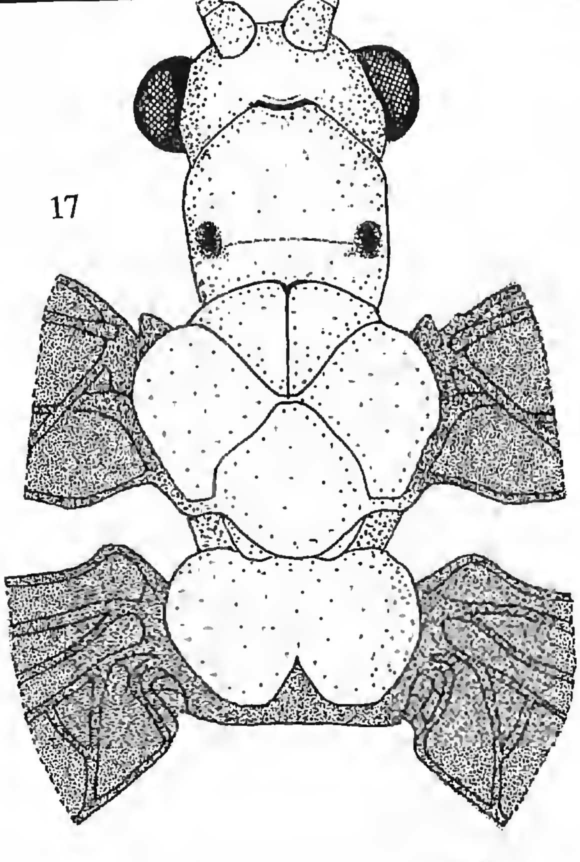
Figures 16–22. *Ceraeochrysa costaricensis,* NEW SPECIES. Figure 16. Right wings. Figure 17. Head and thorax, dorsal view. Figure 18. Head, frontal view. Figure 19. Apex of male abdomen, lateral view. Figure 20. Gonapsis, dorsal view. Figure 21. Male genitalia, lateral view. Figure 22. Male genitalia, caudal view.



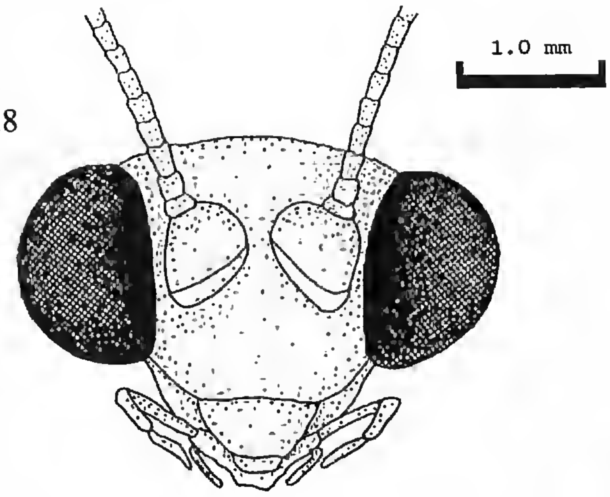
16



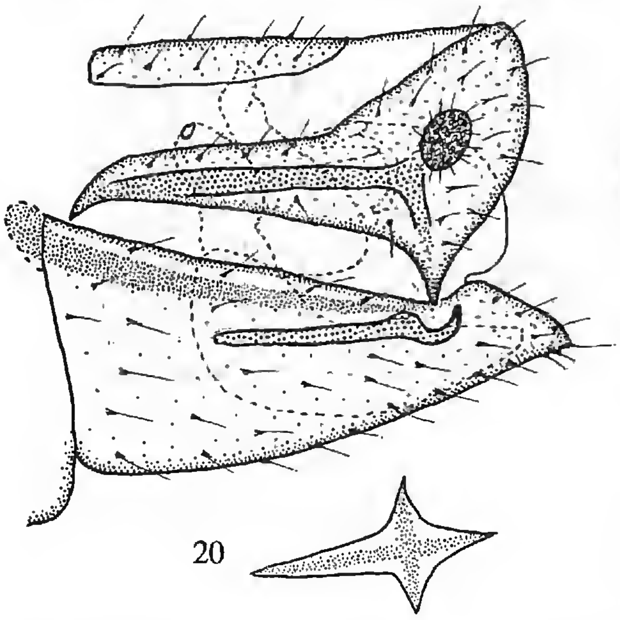
19



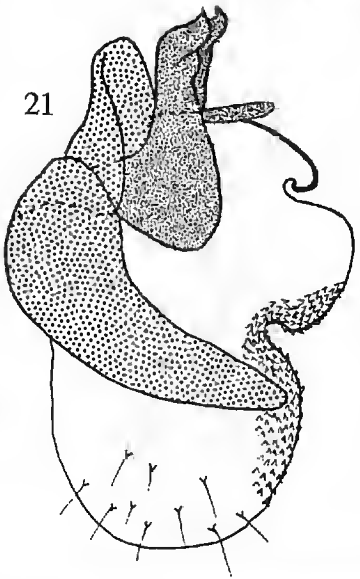
17



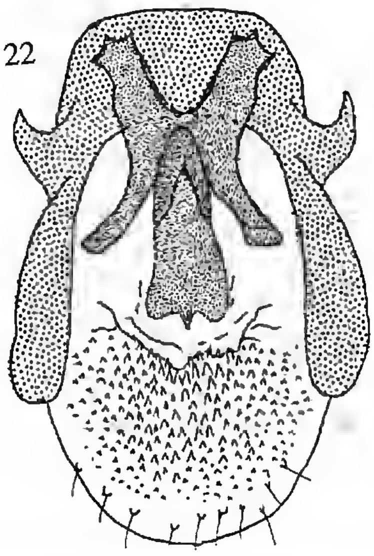
18



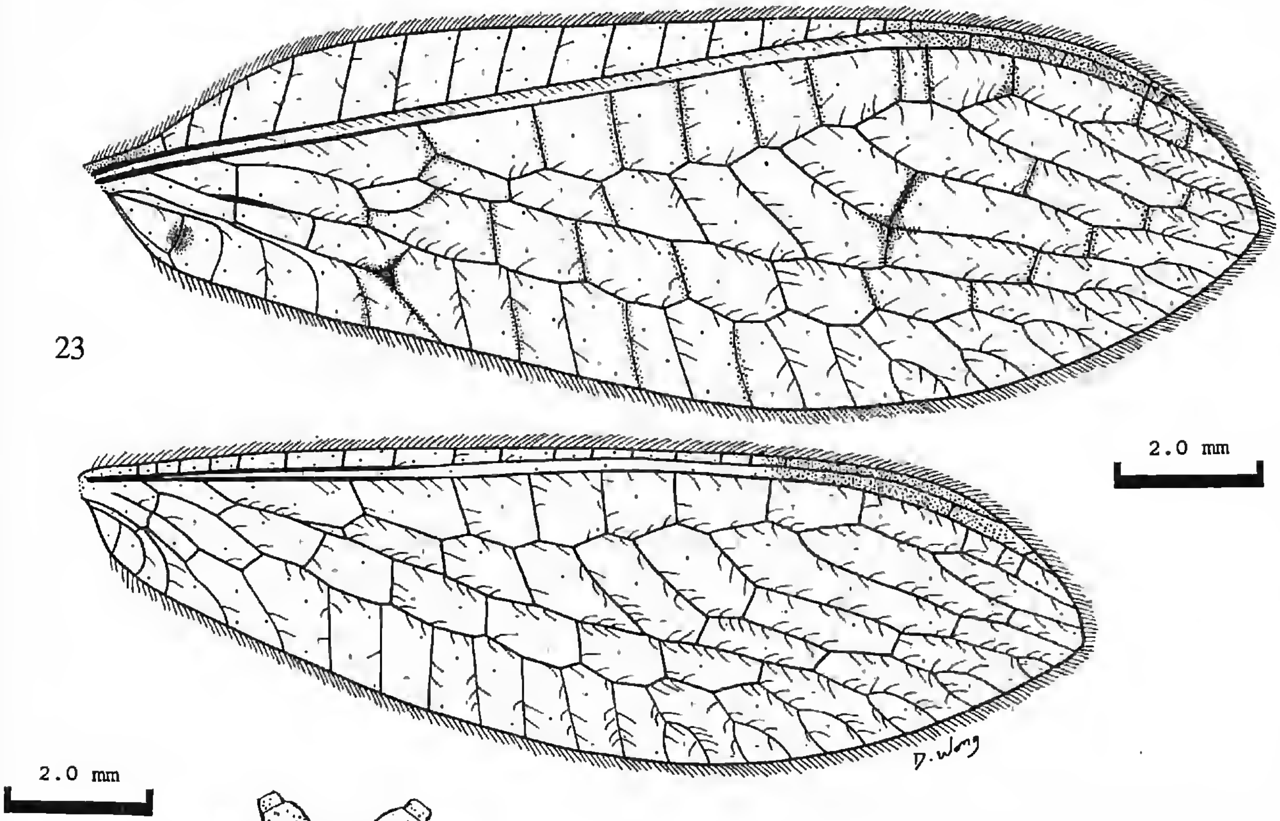
20



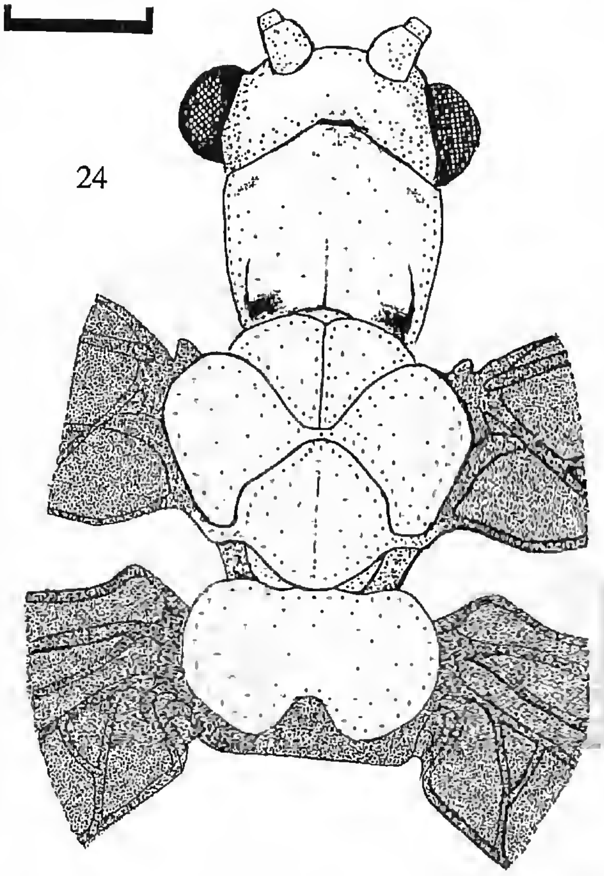
21



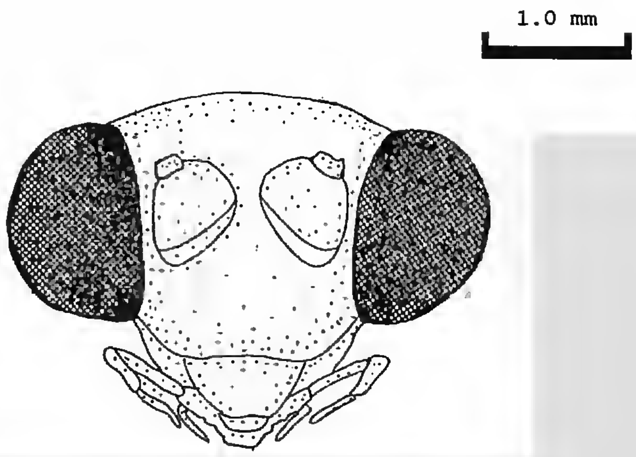
22

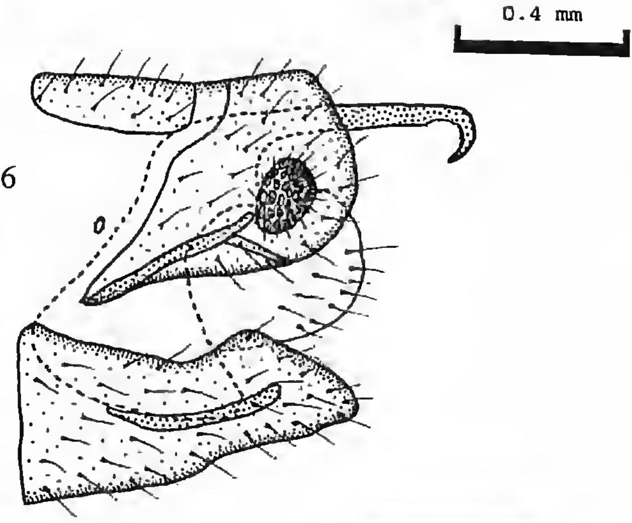


23



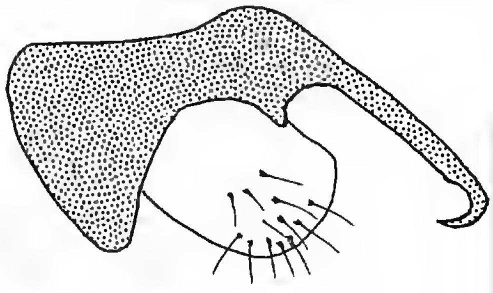
24



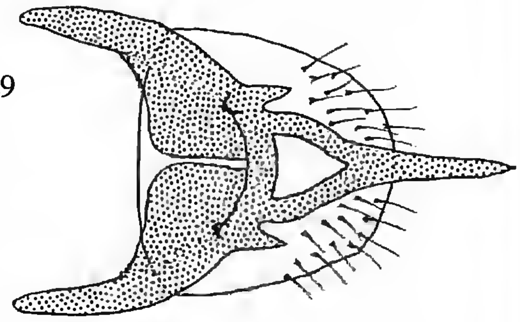


26

27



28



29

CuP. Interestingly, there is a second illusory maculate area; *Ceraeochrysa nigripedis* has a pair of dark spots laterally on the metanotum, while in *C. tauberae* the forewing 2A–3A crossvein spot reposes over much the same metanotal area when the wings are at rest—forming the illusion of a metanotal spot in this species as well. These species also differ in that *C. tauberae* has a very wide gonarcal arch (not narrow), and numerous gonosetae on the gonosaccus (not smooth membrane).

Etymology.—This species is named after Catherine A. Tauber, who is a noted authority on chrysopid biology and the taxonomy of their immature stages.

Material Examined.—See Type.

ACKNOWLEDGMENT

The author thanks Connie Yan, Victoria Saxe and Diane Wong for drawings of the head, thorax and wings of the four species. Kady and Maurice Tauber graciously donated the type specimen of *C. tauberae* to INBIO. Manuel Zumbado and the staff of INBIO provided many of the specimens studied, and Angel Solis provided access and equipment during visits to INBIO. I wish to thank George Gorman for logistical support within Costa Rica, as well as Helen Sparrow and Tom Sisk for providing assistance and logistical support at the Los Alturas Field Station during a collecting trip in 1991. Phillip A. Adams generously provided illustrations and background information about the genus *Ceraeochrysa.* The former chairman of the California Academy of Science's Entomology Department, Charles Griswold, provided funding and encouragement for the ongoing study of Costa Rican neuropterans, as did the California Academy of Sciences In-House Research Fund.

LITERATURE CITED

Adams, P. A. 1982. *Ceraeochrysa,* a new genus of Chrysopinae (Neuroptera) (Studies in New World Chrysopidae, Part II). Neuroptera International, 2: 69–75. 12 figures.

Adams, P. A. & N. D. Penny. 1987. Neuroptera of the Amazon Basin. Part 11a. Introduction and Chrysopini. Acta Amazônica, 15(1985): 413–479. 213 + 29 figures. 1 table.

Brooks, S. J. & P. C. Barnard. 1990. The green lacewings of the world: a generic review (Neuroptera: Chrysopidae). Bulletin of the British Museum of Natural History, Entomology, 59: 117–286. 578 figures. 1 table.

Received 26 Mar 1996; Accepted 4 Nov 1996.

←
Figures 23–29. *Ceraeochrysa tauberae,* NEW SPECIES. Figure 23. Right wings. Figure 24. Head and thorax, dorsal view. Figure 25. Head, frontal view. Figure 26. Apex of male abdomen, lateral view. Figure 27. Gonapsis, dorsal view. Figure 28. Male genitalia, lateral view. Figure 29. Male genitalia, dorsal view.

PAN-PACIFIC ENTOMOLOGIST
73(2): 70–78, (1997)

SIBUYANHYGIA, A NEW GENUS OF COLPURINI FROM THE PHILIPPINE REPUBLIC, WITH DESCRIPTIONS OF THREE NEW SPECIES (HETEROPTERA: COREIDAE)

HARRY BRAILOVSKY
Departamento de Zoología, Instituto de Biología, Universidad Nacional
Autónoma de México, Apdo Postal 70153, México 04510 D.F., México

Abstract.—One new genus (*Sibuyanhygia*) and three new species (*S. callejai, S. atra* and *S. sibulana*) collected in the Philippine Republic are described in the tribe Colpurini (Coreidae). Dorsal habitus illustrations and drawings of the male and female genitalia are provided. A key to the known genera of Colpurini from the Philippine Republic is given.

Key Words.—Insecta, Heteroptera, Coreidae, Colpurini, new genus, new species, Philippine Republic

---

Five genera and eighteen species of Colpurini have been described from the Republic of the Philippines. The genus *Carvalhygia* Brailovsky contains three species (*C. carvalhoi* Brailovsky, *C. milzae* Brailovsky and *C. nigra* Brailovsky). The genus *Hygia* Uhler holds three subgenera: *Colpura* Bergroth with two species (*C. obscuricornis* (Stål) and *C. pallidicornis* (Stål)), *Microcolpura* Breddin with one species (*M. denticollis* (Bergroth)), and *Sphinctocolpura* Breddin with five species (*S. dentifer* (Stål), *S. maculipes* (Stål), *S. obscuripes* (Stål), *S. pictipes* (Stål) and *S. punctipes* (Stål)). The genus *Homalocolpura* Breddin includes four species (*H. aploa* Brailovsky & Barrera, *H. leyteana* Brailovsky & Barrera, *H. parrilloi* Brailovsky & Barrera, and *H. sorbax* Bergroth). The genus *Kekihygia* Brailovsky has two species (*K. luzonica* Brailovsky, and *K. vasarhelyi* Brailovsky). The genus *Typhlocolpura* Breddin has one species (*T. vulcanalis* Bergroth) (Uhler 1861; Stål 1870; Breddin 1900; Bergroth 1916, 1918; Brailovsky & Barrera 1994; Brailovsky 1994, 1995).

The present paper adds one new genus and three new species. Striking features of this new genus are its humeral angles projected into conical teeth or strongly elevated lobes directed upward, ocelli well developed, head without a neck, and abdominal sternite VII of the female with plica and fissura.

KEY TO THE GENERA OF COLPURINI FROM THE PHILLIPPINE REPUBLIC

1. Abdominal sternite VII of the female without plica or fissura; antenniferous tubercle armed .... *Kekyhygia* Brailovsky
1′. Abdominal sternite VII of the female with plica and fissura; antenniferous tubercle unarmed 2
2(1′). Ocelli absent; postocular tubercle extremely reduced or absent ....*Carvalhygia* Brailovsky
2′. Ocelli present, sometimes hard to see; postocular tubercle well developed 3
3(2′). Body surface shining; ventral surface of tibiae armed; ventral surface of femora armed with two rows of long spines; rostrum remarkably long, extending to the apex of the last abdominal segment or beyond the abdomen .... *Homalocolpura* Breddin

3′. Body surface rather dull; ventral surface of tibiae unarmed; ventral surface of femora unarmed or with only few small spines; rostrum shorter 4
4(3′). Corium and clavus separated by claval suture; hemelytral membrane well developed . . . . *Hygia* Uhler
4′. Corium and clavus fused; hemelytral membrane reduced 5
5(4′). Humeral angles of the pronotum projected into conical lobes, strongly elevated and directed upward . . *Sibuyanhygia* Brailovsky NEW GENUS
5′. Humeral angles of the pronotum not exposed . . . *Typhlocolpura* Breddin

SIBUYANHYGIA BRAILOVSKY, *NEW GENUS*

Type Species.—*Sibuyanhygia sibulana* Brailovsky, NEW SPECIES.

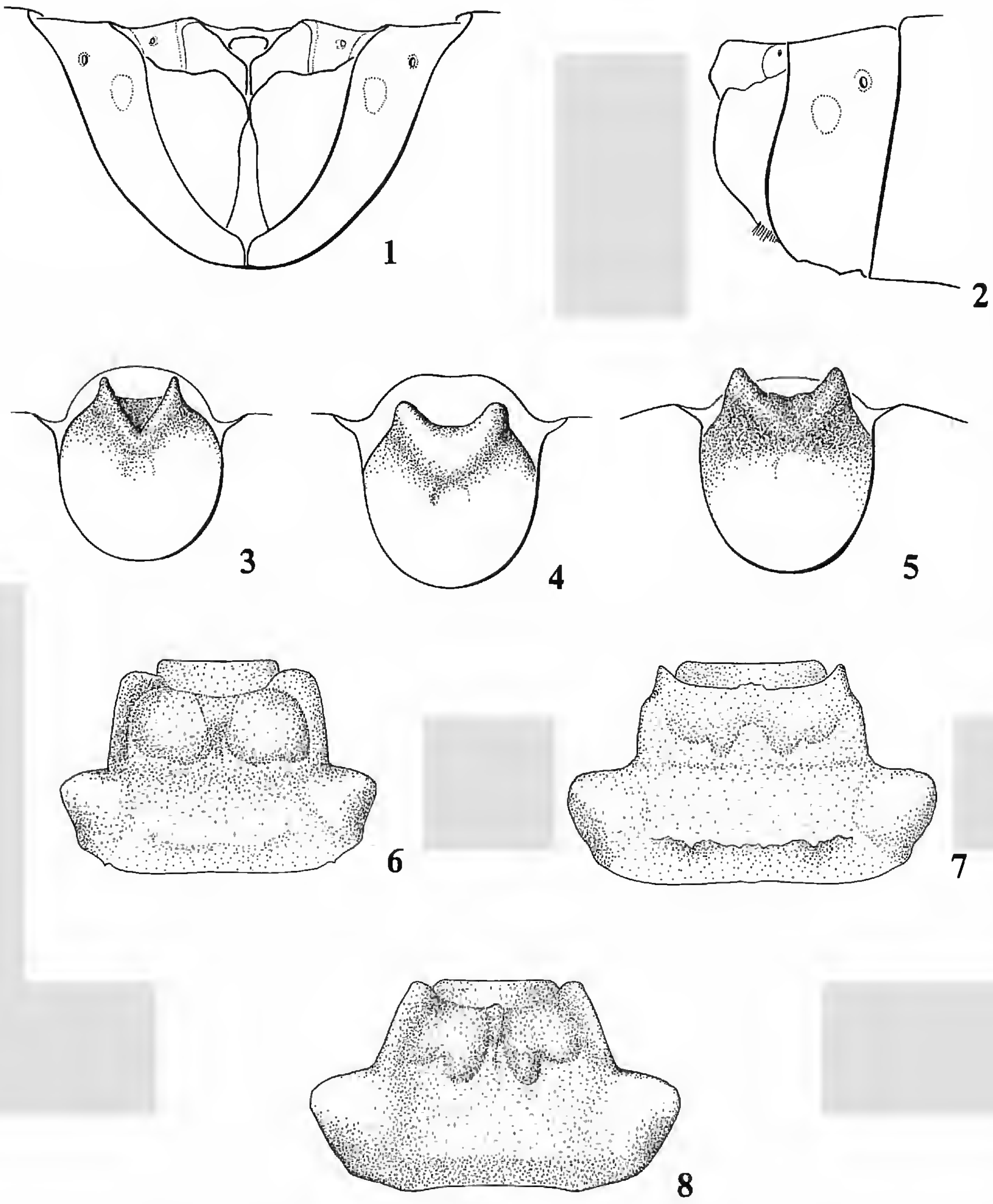
Description.—Head longer than wide, pentagonal, and dorsally slightly convex; tylus unarmed, apically globose, extending anteriorly to and laterally higher than jugae; jugum unarmed, thickened and shorter than tylus; antenniferous tubercle unarmed, quadrate, robust, apically truncated; side of head in front of eye unarmed, and obliquely straight; antennal segment I robust, thickest, slightly curved outward; segments II and III cylindrical and slender; segment IV fusiform; segment II the longest, IV the shortest, and III longer than I; ocelli moderately elevated; preocellar pit deep; eyes spherical and prominent; postocular tubercle protuberant, globose; buccula rounded, elevated, short, not projecting beyond antenniferous tubercle, with sharp anterior projection; rostrum reaching abdominal sternite V; genae unarmed; mandibular plate unarmed. Thorax. Pronotum: Wider than long, trapeziform, nondeclivent, and bilobate; anterior lobe longer than posterior lobe; collar wide; frontal angles produced forward as conical rounded teeth; humeral angles projected into rounded lobes, elevated, directed outward, and strongly higher than posterior pronotal disc; posterolateral border obliquely straight; posterior border straight or slightly concave; calli slightly convex (Figs. 6-8). Anterior lobe of metathoracic peritreme elevated and reniform; posterior lobe sharp, small. Legs: Femora armed with two subdistal short spines, and few more scattered along ventral surface; tibiae cylindrical, with longitudinal sulcus indistinct. Scutellum: Triangular, flat, longer than wide, with apex acute. Hemelytra: Brachypterous; clavus and corium fused; membrane reduced, reaching onto the middle third of abdominal tergum V or anterior third of VI, not overlapping, meeting along the midline or with only the inner portion of one membrane overlapping the inner portion of the other. Abdomen: Connexival segments elevated, with posterior angle complete, not extending on a short spine; abdominal sterna with medial furrow, projecting to posterior third of sternite V. Integument: Body surface rather dull. Head, pronotum, scutellum, clavus, corium, abdomen, and exposed parts of genital segments of both sexes usually with circular grayish-white farinose punctures, and each punctuation with short decumbent golden or silvery bristle-like setae; antennae, legs, and abdominal sterna with few long erect setae.

Male Genitalia.—Genital capsule. Posteroventral edge with a pronounced U-shaped concavity, enclosed by two medium sized arms (Figs. 3, 5) or by two robust arms (Fig. 4). Parameres. Shift robust, with anterior lobe slightly convex, and posterior lobe long and slender (Figs. 9–10).

Female Genitalia.—Abdominal sternite VII with plica and fissura; plica triangular, narrow, just reaching middle third of sternite VII; paratergite VIII short, square, with visible spiracle; paratergite IX longer than VIII, rectangular, with inner lobes curved to middle line and overlapping; gonocoxae I enlarged dorsoventrally, in lateral view with external face entire and convex, in caudal view open (Figs. 1–2). Spermatheca. Bulb spherical, duct coiled, with long membraneus duct (Fig. 11).

Diagnosis.—*Tachycolpura* Breddin, *Lobogonius* Stål, and *Sibuyanhygia* NEW GENUS, have each humeral angle projected into a conical tooth or a strong lobe, which is elevated, directed upward, and variable in length, buccula with sharp anterior or middle projection, ocelli well developed, antenniferous tubercle unarmed, and abdominal sternite VII of the female with plica and fissura.

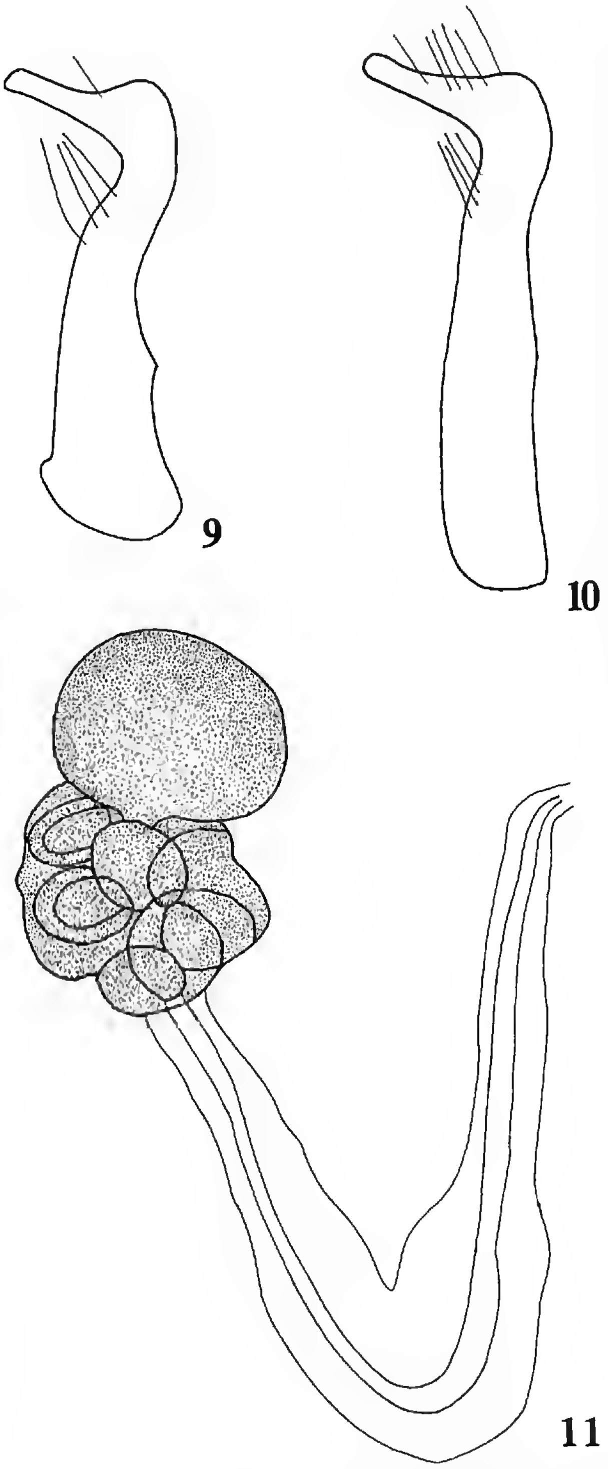
In *Lobogonius* the femora are unarmed, the scutellum before the middle is raised into two convex and obtuse tubercles, and the hemelytra are always macropter-



Figures 1–2. Female genital plates of *Sibuyanhygia sibulana* Brailovsky. Figure 1. Caudal view. Figure 2. Lateral view. Figures 3–5. Caudal view of the male genital capsule of *Sibuyanhygia* spp. Figure 3. *S. sibulana* Brailovsky. Figure 4. *S. atra* Brailovsky. Figure 5. *S. callejai* Brailovsky. Figures 6–8. Pronotum view of *Sibuyanhygia* spp. Figure 6. *S. sibulana* Brailovsky. Figure 7. *S. atra* Brailovsky. Figure 8. *S. callejai* Brailovsky.

ous. *Tachycolpura* like *Sibuyanhygia,* has the femora armed, the scutellum always flat, and the hemelytra are macropterous, brachypterous, or coleopteroid. *Tachycolpura* is easily distinguished by the narrow, moderately elongated body, with an average length from 16.48 to 18.25 mm, with the neck elongate, eventually narrowing basally, and antennal segment I is conspicuously longer than head length (Brailovsky et al. 1992). The body of *Sibuyanhygia* is shorter, relatively robust, with an average length from 10.60 to 12.30 mm, the head lacks a neck, and antennal segment I is shorter or slight longer than head length.

The genera of Colpurini previously known from the Phlippine Republic (*Carvalhygia, Homalocolpura, Kekihygia, Typhlocolpura,* and *Hygia* with three subgenera *Colpura, Microcolpura,* and *Sphinctocolpura*) have the humeral angles



Figures 9–11. *Sibuyanhygia sibulana* Brailovsky. Figures 9–10. Parameres. Figure 11. Spermatheca.

rounded, and not exposed. In *H. (Colpura) obscuricornis* (Stål) and *H. (Colpura) pallidicornis* (Stål), the humeral angles are slightly exposed but the genae are armed (in *Sibuyanhygia* unarmed). In *H. (Sphinctocolpura) pictipes* (Stål), the humeral angles are also slightly exposed, and the genae are unarmed, but the hemelytra is always macropterous and the femora are yellow with orange-brown spots. In *Sibuyanhygia* the hemelytra are brachypterous, and the femora are black or orange-brown, with only the basal joint yellow.

Distribution.—Only known from the Phlippine Republic.

Etymology.—Named for the Sibuyan Sea.

Sibuyanhygia sibulana Brailovsky, NEW SPECIES

(Figs. 1–3, 6, 9–11, 15)

Types.—Holotype, male; data: PHILIPPINE REPUBLIC. Mindanao, Santa Cruz Mts. (Taloon Trail), 915–1525 m, 13 Sep (without year), C.S. Clagg. Deposited in

The Natural History Museum, London. Paratypes: one female; data: PHILIPPINE REPUBLIC. Mindanao, Mt. Apo (Todaya Platau), 1525 m, 2 Sep (without year), C.S. Clagg. Deposited in The Natural History Museum, London. One female; data: PHILIPPINE REPUBLIC. Mindanao, Mt. Apo (Galog Riv.), 1830 m, 26 Sep (without year), C.S. Clagg. Deposited in The Natural History Museum, London. One male; data: PHILIPPINE REPUBLIC. Mindanao, Mt. Apo (Sibulan Riv.), 610 m, 8 Oct (without year), C.S. Clagg. Deposited in the "Colección Entomolgica del Instituto de Biología, UNAM, México." Three females; data: PHILIPPINE REPUBLIC. Mindanao, Mt. Apo (Mainit Riv.), 1830–1980 m, 10 Sep to 24 Oct (without year), C.S. Clagg. Two deposited in The Natural History Museum, London, the other in the "Colección Entomolgica del Instituto de Biología, UNAM, México." One female; data: PHILIPPINE REPUBLIC. Mindanao, Prov. Davao, E. slope Mt. Apo, 970–1070m, 22 Oct 1946, F.G. Werner (CNHM Philippine Zoological Exped. 1946–1947). Deposited in Field Museum Natural History, Chicago.

Description.—Male (holotype). Head, anterior lobe of pronotum, scutellum, connexival segments, dorsal abdominal segments I to VI and anterior third of VII, thorax, abdominal sterna, and genital capsule red-brown with following areas pale yellow to ochre: dorsal aspect of postocular tubercle with small discoidal spot, apex of scutellum, posterior edge of connexival segments III to VI, anterior lobe of metathoracic peritreme, and posterior edge of abdominal sterna V to VII; antennal segment I red-orange, and II to IV pale yellow, with basal joint of IV slightly darker; posterior lobe of pronotum, clavus and corium red-orange; hemelytral membrane creamy yellow, with veins darker; middle and posterior third of dorsal abdominal segment VII orange-hazel; rostral segments I and II light orange-hazel, and III and IV light yellow; coxae red-brown; trochanters yellow; fore femora light red-orange; middle femora light red-orange with basal joint yellow; hind femora light red-orange with dorsal longitudinal stripe pale yellow, running from the basal joint to the middle third; tibiae and tarsi light orange-yellow. *Structural characters.*—Pronotum: Humeral angles slightly elevated (Fig. 6). Hemelytra: Hemelytral membrane reaching anterior third of abdominal tergum V. Genital capsule: Posteroventral edge with pronounced U-shaped concavity, enclosed by two medium sized arms (Fig. 3). Parameres: Figs. 9–10.

Female.—Color: Similar to male. Connexival segments VIII and IX, abdominal terga VIII and IX, and genital plates red-brown. *Structural characters.*—Spermatheca: Fig. 11. Genital plates: Figs. 1–2.

Measurements.—First male, then female. Head length: 1.90 mm, 2.00 mm; width across eyes: 1.76 mm, 1.84 mm; interocular space: 1.04 mm, 1.08 mm; interocellar space: 0.46 mm, 0.48 mm; preocular distance: 1.22 mm, 1.18 mm; length antennal segments: I, 1.80 mm, 1.76 mm; II, 2.84 mm, 2.84 mm; III, 2.00 mm, 1.92 mm; IV, 1.54 mm, 1.60 mm. Pronotal length: 1.90 mm, 2.16 mm; width across frontal angles: 1.84 mm, 1.92 mm; width across humeral angles: 2.94 mm, 3.20 mm. Scutellar length: 1.08 mm, 1.32 mm; width: 1.04 mm, 1.26 mm. Total body length: 10.60 mm, 12.08 mm.

Variation.—1—Endocorial disc with or without red-brown discoidal spot. 2—Posterior edge of connexival segment VII yellow. 3—Abdominal tergum VII red-brown. 4—Posterior edge of pleural abdominal sterna III to VII ochre. 5—Connexival segments, and pleural abdominal sterna light red-brown with posterior edge yellow to ochre.

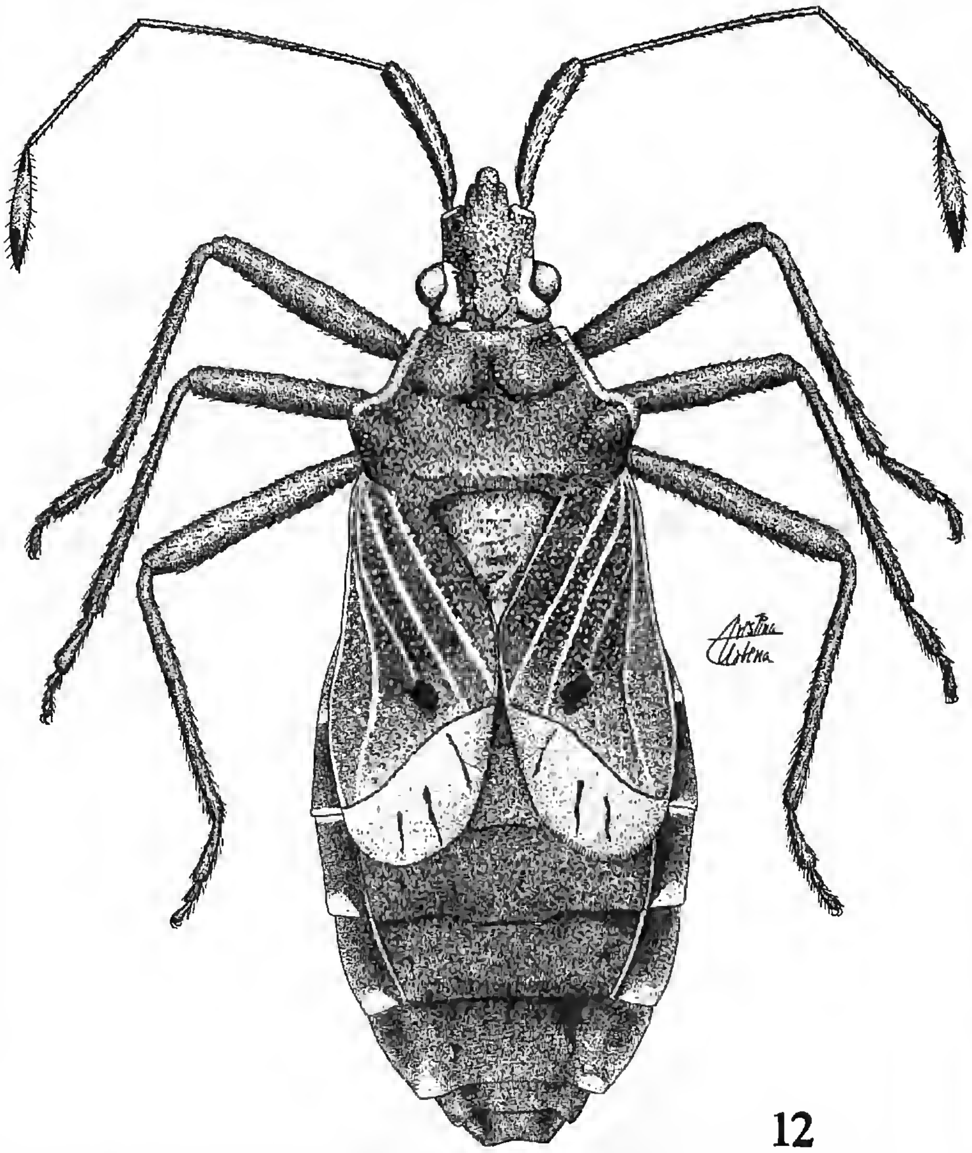
Etymology.—Named for the Sibulan River; a noun in apposition.

Material Examined.—See Types.

SIBUYANHYGIA ATRA BRAILOVSKY, NEW SPECIES

(Figs. 4, 7, 14)

Types.—Holotype, male; data: PHILIPPINE REPUBLIC. Mindanao Island, Mt. Apo (Agko), 1000 m, 5 Oct 1978, Shinji Nagal. Deposited in Field Museum Natural History, Chicago. Paratype: 1 female; data: same as holotype. Deposited in the "Colección Entomológica del Instituto de Biología, UNAM, México."



12

Figure 12. Dorsal view of *Sibuyanhygia callejai* Brailovsky.

Description.—*Male* (holotype). Coloration: Red-brown to black with following areas yellow to ochre: dorsal aspect of postocular tubercle with small discoidal spot, apex of scutellum, posterior third of connexival segments III to VII, anterior and posterior lobe of metathoracic peritreme, and posterior third of pleural abdominal sterna III to VII; antennal segment I red-brown, II to IV orange-hazel with basal joint of IV red-brown; hemelytral membrane creamy yellow with veins darker; rostral segments I to IV red-orange; coxae red-orange; trochanters yellow with apical third of I red-orange; fore femora red-brown; middle femora red-brown with basal joint yellow; hind femora red-brown with yellow longitudinal stripe running from basal joint to middle third; tibiae and tarsi red-orange. *Structural characters.*—Pronotum: Humeral angles conspicuously elevated and robust (Fig. 7). Hemelytra: Hemelytral membrane reaching anterior third of abdominal tergum VI. Genital capsule: Posteroventral edge with pronounced U-shaped concavity, enclosed by two robust arms (Fig. 4).

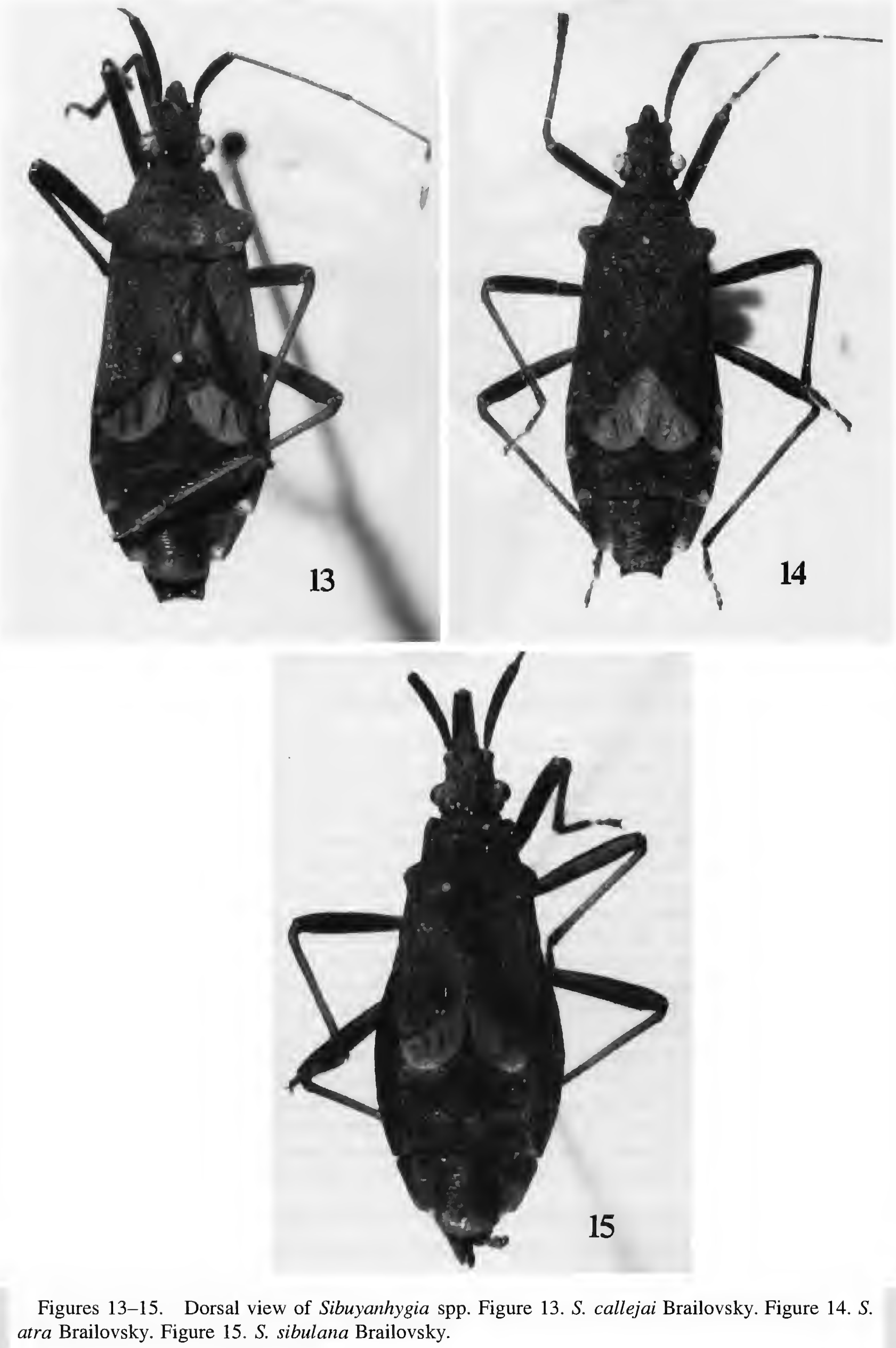
Female.—Color: Similar to male. Connexival segments VIII and IX, abdominal terga VIII and IX, and genital plates red-brown.

Measurements.—First male, then female. Head length: 1.96 mm, 2.02 mm; width across eyes: 1.88 mm, 1.86 mm; interocular space: 1.08 mm, 1.12 mm; interocellar space: 0.47 mm, 0.44 mm; preocular distance: 1.32 mm, 1.38 mm; length antennal segments: I, 2.08 mm, 2.08 mm; II, 3.00 mm, 3.08 mm; III, 2.12 mm, 2.20 mm; IV, 1.64 mm, 1.64 mm. Pronotal length: 2.08 mm, 2.12 mm; width across frontal angles: 1.76 mm, 1.80 mm; width across humeral angles: 3.44 mm, 3.52 mm. Scutellar length: 1.32 mm, 1.40 mm; width: 1.20 mm, 1.34 mm. Total body length: 11.70 mm, 12.15 mm.

Discussion.—Closely related to *S. sibulana* Brailovsky, but distinguished by the longer hemelytral membrane, more elevated humeral angles, mostly red-brown to black body, and longer and more robust arms on the posteroventral edge of male genital capsule (Figs. 3–4).

Etymology.—From the Latin, *"atra"*, meaning black.

Material Examined.—See Types.



Figures 13–15. Dorsal view of *Sibuyanhygia* spp. Figure 13. *S. callejai* Brailovsky. Figure 14. *S. atra* Brailovsky. Figure 15. *S. sibulana* Brailovsky.

SIBUYANHYGIA CALLEJAI BRAILOVSKY, NEW SPECIES
(Figs. 5, 8, 12, 13)

Types.—Holotype, Male; data: PHILIPPINE REPUBLIC. Negros Island, Parker Mt., col. Chapman (without date). Deposited in The Natural History Museum, London. Paratype: 1 female; data: same as holotype. Deposited in the "Colección Entomológica del Instituto de Biología, UNAM, México."

Description.—Male (holotype). Dorsal coloration: Head red-brown with tylus pale orange, and the area adjacent to eyes yellow; antennal segment I red-brown, II and III pale orange, and IV creamy yellow with basal joint pale orange and apical third dark yellow; pronotum, scutellum, clavus and corium pale orange with following areas yellow: anterolateral borders of the pronotum, external edge of humeral angles, and apex of scutellum; endocorium with red-brown discoidal spot near the apical margin; hemelytral membrane creamy yellow with veins brown; connexival segments dark brown with posterior third yellow; abdominal terga light red-brown with posterior third of VII yellow. Ventral coloration: Red-brown with following areas yellow: anterior lobe of metathoracic peritreme and anterior angle and posterior third of abdominal pleural margins III to VII; rostral segments orange-hazel; coxae red-brown; fore trochanter orange-hazel with basal joint yellow; middle trochanter yellow with orange-hazel reflections; hind trochanter yellow; fore femora red-orange; middle femora red-orange with basal joint yellow; hind femora red-orange with short yellow longitudinal stripe running from basal joint to anterior third; tibiae and tarsi light orange-yellow. *Structural characters.*—Pronotum: Humeral angles well developed, elevated, directed upward, and strongly higher than pronotal disc (Fig. 8). Hemelytra: Hemelytral membrane reaching middle third of abdominal tergum V. Genital capsule: Posteroventral edge with pronounced U-shaped concavity, enclosed by two short lateral lobes (Fig. 5).

Female.—Color: Similar to male. Connexival segments VIII and IX, abdominal terga VIII and IX, and genital plates red-brown with external edge of paratergite VIII and IX, and internal angle of gonocoxae I yellow.

Measurements.—Male first, then female. Head length: 1.84 mm, 2.02 mm; width across eyes: 1.70 mm, 1.88 mm; interocular space: 0.96 mm, 1.08 mm; interocellar space: 0.40 mm, 0.45 mm; preocular distance: 1.20 mm, 1.32 mm; length antennal segments: I, 1.92 mm, 2.00 mm; II, 2.90 mm, 3.04 mm; III, 2.00 mm, 2.04 mm; IV, 1.48 mm, 1.56 mm. Pronotal length: 1.88 mm, 2.08 mm; width across frontal angles: 1.64 mm, 1.80 mm; width across humeral angles: 3.40 mm, 3.64 mm. Scutellar length: 1.28 mm, 1.48 mm; width: 1.20 mm, 1.36 mm. Total body length: 11.15 mm, 12.30 mm.

Discussion.—Antennal segment IV of *S. callejai,* is creamy yellow with basal and apical third darker, and the anterolateral edge of pronotum and external edge of humeral angles yellow. In the other known species, antennal segment IV is yellow or orange and with only the basal joint darker, and the anterolateral edge and humeral angles are red-brown.

Sibuyanahygia callejai like *S. atra,* has the humeral angles well developed, elevated, directed upward and more strongly elevated than the pronotal disc, but the hemelytral membrane extends to the anterior edge of abdominal tergum V and the body is paler than *S. atra,* in which the hemelytral membrane extends to abdominal tergum VI.

Etymology.—Named for Dr. Ignacio Calleja Ahedo, distinguished Mexican odontologist.

Material Examined.—See Types.

ACKNOWLEDGMENT

I thank Janet Margerison-Knight (The Natural History Museum, London), and Phil Parrillo (Field Museum Natural History, Chicago) for the loan of specimens. Special thanks to Cristina Urbina, Cristina Mayorga and Ernesto Barrera (each of the Instituto de Biología, Universidad Nacional Autónoma de México) for the illustrations.

LITERATURE CITED

Bergroth, E. 1916. New and little known heteropterous Hemiptera in the United States National Museum. Proc. U.S. Natl. Mus., 51(2150): 215–239.

Bergroth, E. 1918. Studies in Philippine Heteroptera I. Phililipp J. Sci., 13: 43–126.

Brailovsky, H. 1994. One new genus and two new species of Colpurini (Heteroptera: Coreidae: Coreinae) from the Philippine Republic. Ann. Entomol. Soc. Amer., 87(6): 745–750.

Brailovsky, H. 1995. New genus and new species of Colpurini (Heteroptera: Coreidae) from the Philippine Republic. Proc. Entomol. Soc. Wash., 97(2): 250–257.

Brailovsky, H. and E. Barrera. 1994. The genus *Homalocolpura* Breddin and description of five new species (Hemiptera: Heteroptera: Coreidae: Colpurini). Zool. Med. Leiden 68: 55–72.

Brailovsky, H., E. Barrera, and W. Lopez-Forment. 1992. Revision of the genus *Tachycolpura* Breddin (Hemiptera: Heteroptera: Coreidae: Colpurini). Pan-Pacific Entomol., 68(2): 122–132.

Breddin, G. 1900. Materiae ad cognitionem subfamilae Pachycephalini (Lybantini olim). Ex Hemipteris-Heteropteris, Fam. Coreidae. Rev. Entomol. Caen, 19: 194–217.

Stål, C. 1870. Hemiptera insularum Philippinarum. Ofv. Kongl. Vet.-Akad. Forh., 7: 607–776.

Uhler, P.R. 1861. Rectification of the paper upon the Hemiptera of the North Pacific expedition. Proc. Acad. Natl. Sci. Phila., 1861: 286–287.

Received 1 Apr 1996; Accepted 18 Dec 1996

PAN-PACIFIC ENTOMOLOGIST
73(2): 79–92, (1997)

A REVIEW OF *LIPAROCEPHALUS* MÄKLIN (COLEOPTERA: STAPHYLINIDAE: ALEOCHARINAE) WITH DESCRIPTIONS OF LARVAE[1]

Kee-Jeong Ahn
Snow Entomological Museum, University of Kansas,
Lawrence, Kansas 66045

Abstract.—A systematic review of the aleocharine genus *Liparocephalus* Mäklin is presented. *Liparocephalus* Mäklin is redescribed, and three species (*L. brevipennis* Mäklin, *L. cordicollis* LeConte, *L. tokunagai* Sakaguti) are described. Late instar larvae of *L. cordicollis* are redescribed and late instar larvae of *L. brevipennis* and *L. tokunagai* are described for the first time. A key is provided for separation of both adults and late instar larvae of known species of *Liparocephalus,* and illustrations of diagnostic features are presented.

Key Words.—Insecta, Coleoptera, Staphylinidae, Aleocharinae, *Liparocephalus,* systematic review, intertidal.

Members of the genus *Liparocephalus* are confined to the rocky seashores of the Pacific Coast of Japan, Alaska, Canada, and U.S.A. Topp & Ring (1988) studied adaptations to the marine environment of *L. cordicollis* LeConte from the Pacific coast of Canada. This species is a predator on small chironomid larvae, and can respire when submerged in seawater. Adults of *L. cordicollis* can stabilize their body weight at different salinities by regulating osmotic pressure.

The genus *Liparocephalus* was first described and characterized by Mäklin (1853), who described *L. brevipennis* from the coast of Alaska. Later LeConte (1880) described *L. cordicollis* from Alaska and Sakaguti (1944) described *L. tokunagai* from the coast of Japan. The adults and larvae of *L. cordicollis* (incorrectly identified as *L. brevipennis*) were described by Saunders (1928) and Chamberlin & Ferris (1929). Moore (1956b) also discussed the larvae of *Liparocephalus.*

However, the genus *Liparocephalus* has not been clearly described in detail in spite of revisionary studies of the North American taxa (Moore 1956a). In addition, the late instar larvae of the *Liparocephalus* species should be described according to the appropriate technique developed recently (Ashe & Watrous 1984).

For these reasons, I redescribe *Liparocephalus* and *L. brevipennis, L. cordicollis,* and *L. tokunagai* and their associated late instar larvae. The described larvae were collected in association with adults of *L. brevipennis* in Alaska, *L. cordicollis* in Canada, and *L. tokunagai* in Japan, respectively. There were no other larvae or adults of any other aleocharine species present and larvae of other possible species of intertidal Aleocharinae known to me are distinctly different from these larvae. Therefore, I have described them as probable larvae of *L. brevipennis, L. cordicollis,* and *L. tokunagai.*

Depository Abbreviations.—California Academy of Sciences, San Francisco (CAS); Cornell University Insect Collections, Ithaca (CUIC); Field Museum of

---

[1] Contribution number 3164 from the Snow Entomological Museum (Natural History Museum, Division of Entomology), University of Kansas, Lawrence, KS 66045, U.S.A.

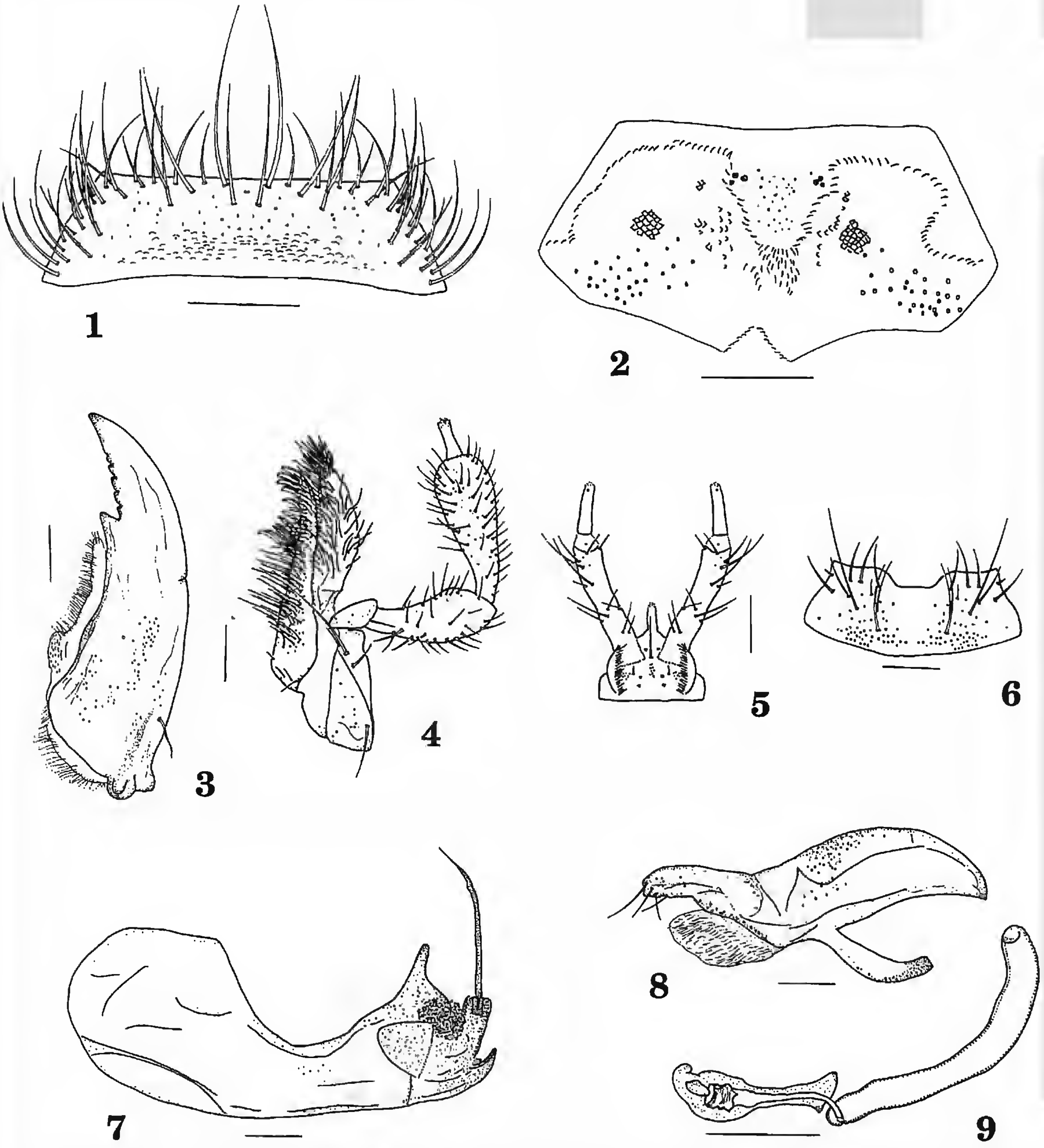
Natural History, Chicago (FMNH); Finnish Museum of Natural History, Helsinki, Finland (FMNHC); Snow Entomological Museum at the University of Kansas, Lawrence (KSEM); Museum of Comparative Zoology at Harvard University, Cambridge (MCZ); Natural History Museum and Institute, Chiba, Japan (NHMIC); National Museum of Natural History, Washington, D.C. (NMNH); Spencer Entomological Museum at the University of British Columbia, Vancouver, Canada (UBCZ); University of California at Riverside (UCR); James Entomological Collection at the Washington State University, Pullman (WSUC).

LIPAROCEPHALUS MÄKLIN

Liparocephalus Mäklin, 1853: 191; LeConte, 1861: 66; Casey, 1886: 229; 1893: 353; Fenyes, 1918: 106; Bernhauer & Scheerpeltz, 1926: 550; Chamberlin & Ferris, 1929: 143; Blackwelder, 1952: 222; Moore, 1956a: 116; Hatch, 1957: 149; Moore & Legner, 1975: 445, 1976: 531; Seevers, 1978: 171.

Type Species.—*Liparocephalus brevipennis* Mäklin. Designated by Fenyes (1918).

Description.—*Adult.* Length 3.8–5.2 mm. Body shape broad, robust and more or less convex, black to dark brown, pubescent with relatively long microsetae more or less densely and uniformly distributed. HEAD. Slightly deflexed, about as long as wide. Eyes small, 0.2 times length of head; without setae between facets. Tempora very long. Neck absent. Microsetae uniformly distributed. Antenna with 11 antennomeres; all antennomeres elongate. MOUTHPARTS. Labrum (Fig. 1) transverse, trapezoidal, ≈ 50–80 major setae distinct, additional setae present, sensilla indistinct on anterior margin of labrum, small pores scattered; epipharynx (Fig. 2) with ≈ 15 large lateral pores on each side and ≈10–20 small medial pores. Mandibles (Fig. 3) symmetrical, apex more or less acute and not curved downward; median tooth well developed, 4–5 internal teeth present between apex and median tooth; prostheca well developed, membranous with fibrils; 3 or 5 setae present laterally, most basal one largest. Maxilla (Fig. 4) with galea and lacinia elongate, almost equal in length; galea corneous, apex densely pubescent with long filiform setae, and many long setae uniformly distributed on dorsal surface; lacinia more or less acute, internal surface with comb of single row of about 11 well separated spines followed by several setae, many long setae uniformly distributed on dorsal surface; maxillary palpus with 4 articles, robust, article 3 incrassate distally and longer than article 2, article 4 narrowed distally with indistinct sensilla at apex, distinct filamentous sensilla at base. Labium (Fig. 5) with palpi of 2 articles, elongate, article 1 partially articulated, article 2 with indistinct sensilla at apex, much narrower and shorter than article 1; twin pores, median pore and distal pores present; ligula simple, elongate; one medial seta present or none on prementum; real pores, setal pores, and basal pores present; ≈ 10–16 pseudopores medially, and ≈6 pseudopores laterally; a pair of comb-like hypoglossae present. Mentum (Fig. 6) with v setae; more or less trapezoidal, anterior margin deeply emarginate, or anterior margin deeply truncate internally, posterior margin prolonged roundly, and apico-lateral margin with projecting knob. Submentum with numerous punctures and setae. THORAX. Pronotum about 0.8–0.9× as long as wide, narrowest at base and widest near apex; pattern of pubescence with setae subparallel, those on apical half of pronotum directed anteriorly, those on basal half directed posteriorly in a narrow median strip, others curve correspondingly (pattern G, Seevers 1978); microsetae uniformly distributed; two long filiform setae present on each side. Hypomera visible in lateral aspect. Mesocoxal cavities contiguous; mesosternal process very short, and more or less pointed. Metasternum shorter than width of mesocoxa. Legs with tarsal formula 4-4-5, tarsus with spatulate setae. Claws narrow, long, sickle-shaped. Scutellum more or less diamond-shaped. ELYTRA. 0.5–0.6× as long as pronotum; microsetae numerous, directed posteriorly, uniformly distributed; two long filiform setae present, 1 on disc and 1 on lateral margin. Hind wings absent. ABDOMEN. General shape broadest at segment VII or VIII; microsetae numerous, directed posteriorly, uniformly distributed. Tergites not impressed at base. Sternites not constricted at base. Tergite X broader than long, without major setae but with numerous additional setae. SECONDARY SEXUAL CHARACTERISTICS. Sternite VIII (Fig. 22) of male prolonged posteriorly as broad triangular projection. Female



Figures 1–9. Adult *Liparocephalus cordicollis*. Figure 1. Labrum, dorsal aspect. Figure 2. Epipharynx, dorsal aspect. Figure 3. Mandible, ventral aspect. Figure 4. Maxilla, dorsal aspect. Figure 5. Labium, dorsal aspect. Figure 6. Mentum, dorsal aspect. Figure 7. Median lobe, lateral aspect. Figure 8. Paramere, lateral aspect. Figure 9. Spermatheca, lateral aspect. Scale = 0.1mm.

sternite slightly prolonged. AEDEAGUS. Median lobe (Figs. 7, 23, 25). Parameres (Fig. 8). SPERMATHECA. (Figs. 9, 24, 26).

Diagnosis.—Among aleocharine general with 4-4-5 tarsal formula, members of *Liparocephalus* are recognized by the combination of: relatively long setae densely and uniformly distributed; all antennomeres elongate; eyes without setae between facets; labrum (Fig. 1) transverse with 50–80 major setae; mandibles (Fig. 3) almost symmetrical, with 4–5 large teeth between apex and median tooth; lacinia (Fig. 4) with setae distributed uniformly over dorsal surface; galea (Fig. 4) with setae distributed uniformly over dorsal surface; medial setae on labium (Fig. 5) one or none; mentum with v setae (Fig. 6); elytra shorter than pronotum; hind wings absent; mesocoxal cavities contiguous; tarsus with spatulate setae; tergites not impressed at base; distinctive secondary sexual characteristics (Fig. 22); and occurrence in the intertidal zone of rocky shores.

Distribution.—Alaska to California (USA) and Japan.

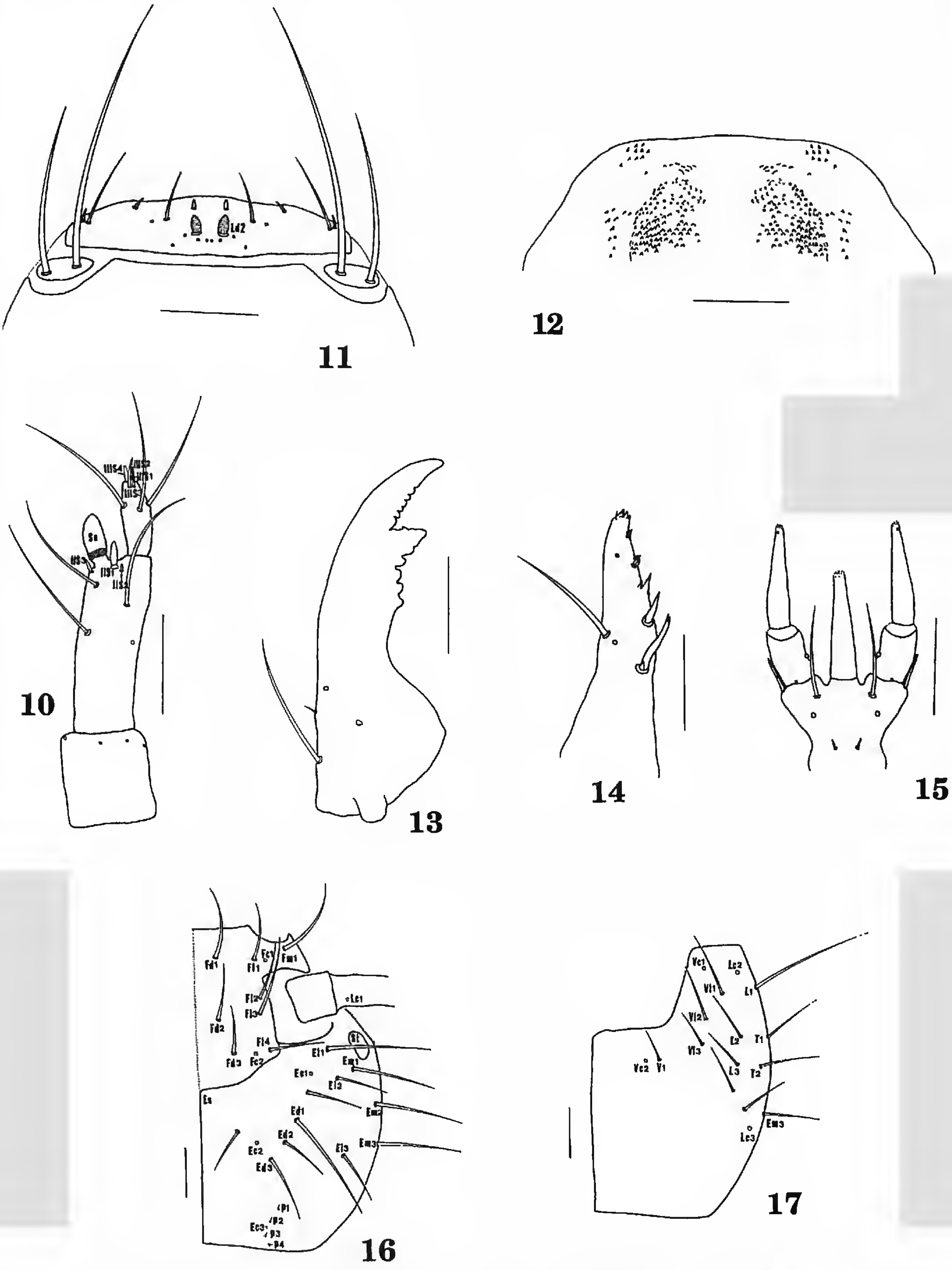
Late Instar Larva.—Length 3.0–3.4 mm. Body shape elongate, flattened, parallel-sided, dark brown in color. HEAD. (Figs. 16, 17) ≈ 0.9× as long as wide. One small stemma on each side. Ecdysial sutures distinct and complete from antennal fossae anteriorly to base of head posteriorly. Chaetotaxy as in Figs. 16 and 17. Antenna as in Figure 10, with 3 articles; article 1 elongate, ≈ 1.1–1.4× as long as wide, with 5 campaniform sensilla around apical margin; article 2 ≈ 1.4–2.0× length of article 1; article 3 ≈ 0.4× length of article 2; article 2 with 3 solenidia in addition to inflated, acorn-shaped and faintly fenestrate sensory appendage which is shorter than article 3; IIS1 spinose, short, ≈ 0.2–0.4× as long as IIS2; IIS2 elongate, digitiform, about as long as sensory appendage or shorter, IIS3 present; article 3 with 3 solenidia, IIIS3 long digitiform, IIIS4 present. MOUTHPARTS. Labrum (Fig. 11) narrow, with 4 distinct setae (Ld1–Ld2, Ll1, Lm2) and 4 additional setae on each side, campaniform sensilla absent; Ll1 and Lm2 on small lateral sclerite distinctly separated from main body of labrum by suture; seta Ld2 short, robust and inflated. Epipharynx as in Fig. 12. Mandibles (Fig. 13) more or less symmetrical, median tooth large, ≈ 5–10 serrations present on internal edge (absent or 4–5 between apex and median tooth, 4–5 between median tooth and base), 2 setae in basi-lateral half, distal seta very small and basal seta large and long. Maxilla with cardo broadly oval, with one seta near stipes; stipes narrow at base, not distinctly separated from mala, surface with 3 large setae, 2 on disk and 1 near lateral margin; mala (Fig. 14) with apex acute, 5 spinose setae on mesal region with large seta most basal, both right and left ones branched, several short spinules scattered on dorsal surface; maxillary palpus with 3 articles and basal crescentic palpifer; article 1 elongate, ≈ 1.6–2.3× as long as wide; article 2 ≈ 0.4–0.5× as long as article 1; article 3 ≈ 0.7–0.8× as long as article 1 and 2 together; article 3 with basal digitiform sensory appendage on external surface. Labium (Fig. 15) consisting of indistinctly separated prementum, mentum, and more or less broad and sclerotized submentum; ligula elongate; labial palpus with 2 articles, article 2 ≈ 2.0–2.3× as long as article 1; submentum with 1 pair of setae; mentum with 2 pairs of setae and 1 pair of campaniform sensilla; prementum with 2 pairs of setae and 1 pair of campaniform sensilla; 2–3 more or less sword-shaped spines present on antero-lateral margin of labium. THORAX. Pronotum (Fig. 18) transverse; chaetotaxy as in Fig. 18. Mesonotum (Fig. 19) transverse; chaetotaxy as in Fig. 19. Metanotum similar to mesonotum. Tarsus with 2 robust dorsal spines. ABDOMEN. Abdominal tergites I–VII transverse. Tergal gland reservoir (Fig. 20) slightly sclerotized, with distinctive pattern of internal hoop-like sclerotizations; 4 gland ducts in form of coiled tubules. Abdominal tergite IX (Fig. 21) with granulose integument. Urogomphus short, articulated, length of article ≈ 0.5–1.0× as long as postero-lateral prolongation of tergite IX, with minute seta ventrally and 1 long apical seta. Tergite X with 4 small, unsclerotized pygopodial hooks.

Diagnosis.—Larvae of *Liparocephalus* can be distinguished from all other described aleocharine larvae by the combination of: elongate antenna (Fig. 10) with sensory appendage shorter than article 3; narrow labrum (Fig. 11) without campaniform sensilla; maxilla with most basal seta on both right and left malar surfaces (Fig. 14) branched; urogomphus (Fig. 21) short, articulated, with minute setae ventrally, and 1 long seta arising from apex; tergite X with 4 small unsclerotized pygopodial hooks; and many additional setae (in comparison with standard patterns described by Ashe and Watrous) on head, pronotum, mesonotum and abdominal tergites.

KEY TO THE SPECIES OF *LIPAROCEPHALUS*

ADULTS

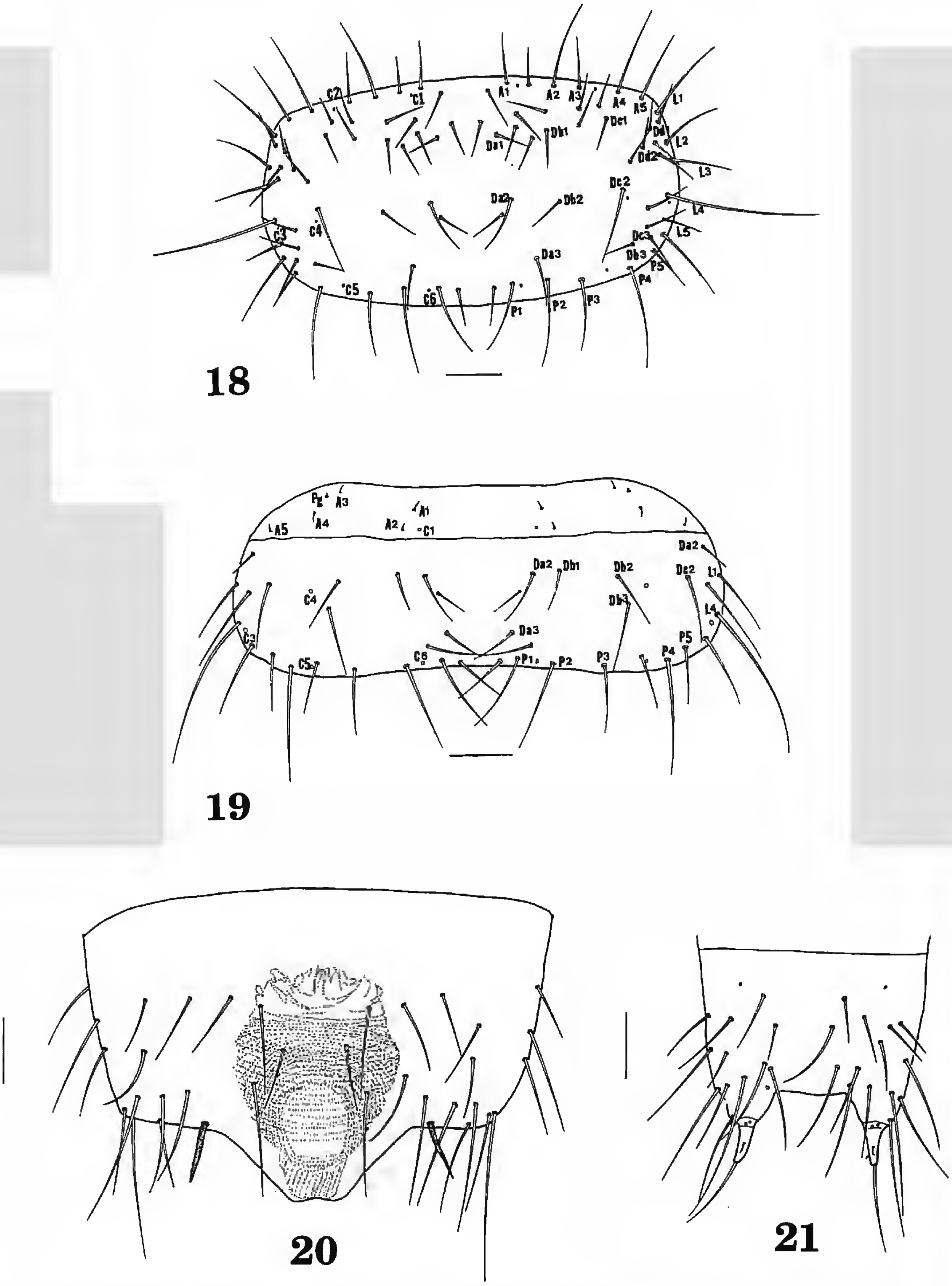
1. Mentum trapezoidal, anterior margin emarginate; male abdominal sternite VIII prolonged posteriorly as broad triangular projection, its median margin shorter than lateral margin (Fig. 22); median lobe as in Fig. 23; spermatheca as in Fig. 24; Alaska . . . . *L. brevipennis*



Figures 10–17. Late instar larva of *Liparocephalus cordicollis.* Figure 10. Antenna, dorsal aspect. Figure 11. Labrum, dorsal aspect. Figure 12. Epipharynx, dorsal aspect. Figure 13. Mandible, dorsal aspect. Figure 14. Mala, dorsal aspect. Figure 15. labium, dorsal aspect. Figure 16. Head, dorsal aspect. Figure 17. Head, ventral aspect. Symbols according to Ashe & Watrous (1984). Scale = 0.1mm.

1′. Mentum not trapezoidal, anterior margin deeply truncate internally, posterior margin prolonged, rounded, and apico-lateral margin with projecting knob (Fig. 6); male abdominal sternite VIII prolonged posteriorly as broad triangular projection and median margin longer than lateral margin; Alaska to California, Japan 2

2(1′). Color black or dark brown; median lobe as in Fig. 7; spermatheca as in Fig. 9; Alaska to California .... *L. cordicollis*

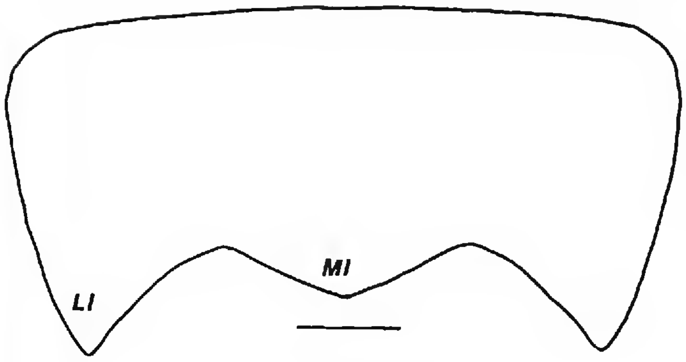


Figures 18–21. Late instar larva of *Liparocephalus cordicollis*. Figure 18. Pronotum, dorsal aspect. Figure 19. Mesonotum, dorsal aspect. Figure 20. Abdominal tergite VIII, dorsal aspect. Figure 21. Abdominal tergite IX, dorsal aspect. Symbols according to Ashe & Watrous (1984). Scale = 0.1mm.

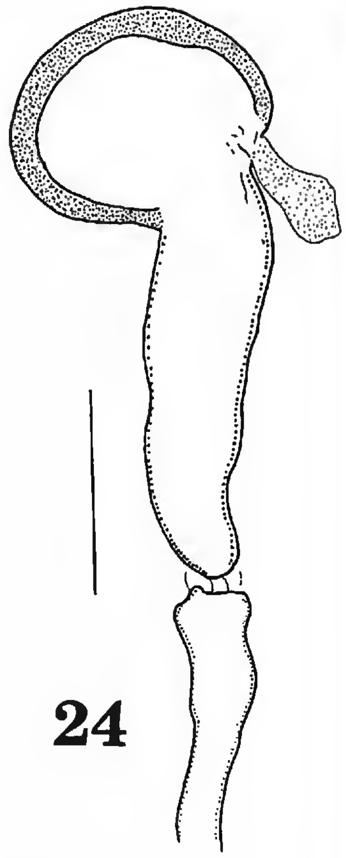
2′. Color brown; median lobe as in Fig. 25; spermatheca as in Fig. 26; Japan . . . . *L. tokunagai*

LATE INSTAR LARVAE

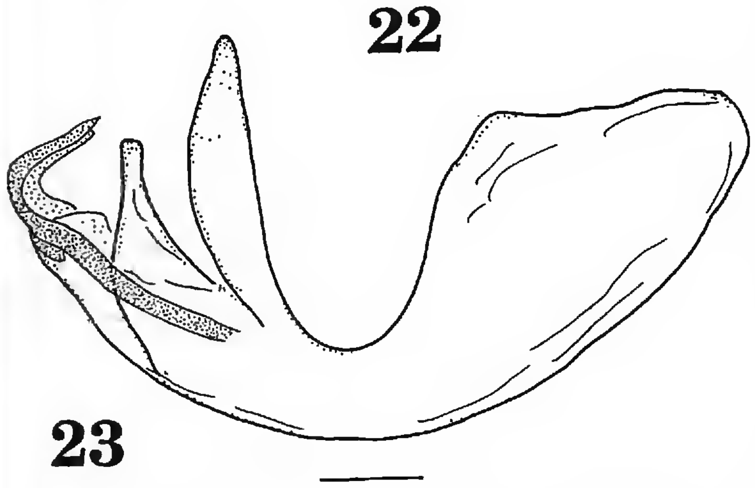
1. Head chaetotaxy complete (Ashe & Watrous 1984), additional setae absent; pronotal chaetotaxy complete, additional setae absent; mesonotal chaetotaxy complete, additional setae absent . . . . *L. tokunagai*



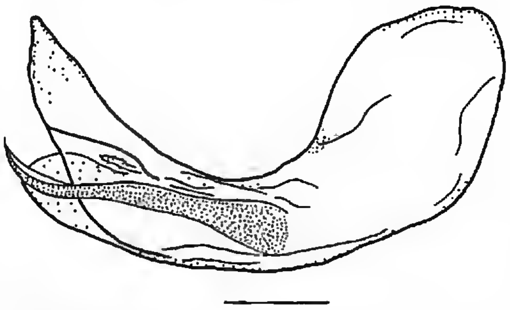
22



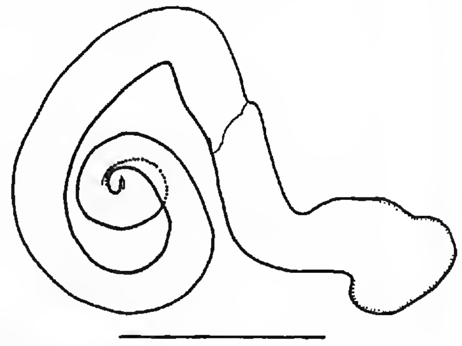
24



23



25



26

Figures 22–24. *Liparocephalus brevipennis*. Figure 22. Sternite VIII of male, dorsal aspect. Figure 23. Median lobe, lateral aspect. Figure 24. Spermatheca, lateral aspect. Figures 25–26. *Liparocephalus tokunagai*. Figure 25. Median lobe, lateral aspect. Figure 26. Spermatheca, lateral aspect. Ml: median lobe, Ll: lateral lobe. Scale = 0.1mm.

1′. Head chaetotaxy complete, additional setae present; pronotal chaetotaxy complete, additional setae present; mesonotal chaetotaxy complete, additional setae present 2

2(1′). Head chaetotaxy complete, 3 additional setae present; pronotal chaetotaxy complete, 3 additional setae present; mesonotal chaetotaxy complete; chaetotaxy of abdominal tergite I complete . . . . *L. brevipennis*

2′. Head chaetotaxy complete, 4 additional setae present (Figs. 16, 17); pronotal chaetotaxy complete, about 20 additional setae present (Fig. 18); mesonotal chaetotaxy complete, 6 additional setae present (Fig. 19); chaetotaxy of abdominal tergite I complete, many additional setae present . . . . *L. cordicollis*

LIPAROCEPHALUS BREVIPENNIS MÄKLIN

(Figs. 22–24)

Liparocephalus brevipennis Mäklin, 1853: 192; Bernhauer & Scheerpeltz, 1926; 550; Moore, 1956a: 117; Moore & Legner, 1975: 445.

Types.—*Liparocephalus brevipennis* Mäklin: Lectotype, here designated, in the collection of the Finnish Museum of Natural History (Helsinki, Finland), with labels as follows: "Chtagaluk, Constant, Holmberg; Mus. Zool. H:fors, Spec. typ. No. 2228, *Liparocephalus brevipennis* Mäklin; Lectotype, *Liparocephalus brevipennis* Mäklin, Desig. K. J. Ahn, 1995."

Description.—*Adult.* Length 4.2–4.4 mm. Body color black or dark brown. Head about as long as wide, infraorbital carina present. Ratio of length of compound eyes to length of head ≈ 0.2. Antennomeres all elongate. Labrum with 25–30 + 25–30 major setae; epipharynx with ≈ 10 medial pores. Mandible with 4 internal teeth between apex and median tooth. Labium with 1 medial seta on prementum, ≈ 10 pseudopores present medially. Mentum more or less trapezoidal, anterior margin deeply emarginate. Pronotum subquadrate, ≈ 0.9× as long as wide, long filiform setae absent from lateral margin. Elytra ≈0.9× as long as wide; ≈ 0.5× as long as pronotum, long filiform setae absent. Aedeagus. Median lobe (Fig. 23). Spermatheca. (Fig. 24).

Distribution.—Alaska.

Material Examined.—USA. ALASKA. *DILLINGHAM Co.:* Unalaska I., Dutch Harbor, Sep 1890, F. E. Blaisdell (FMNH, 4; CAS, 18); same loc., 9 Jul 1907, Van Dyke (CAS, 18); same except, 14 Aug 1907 (CAS, 1); same loc., F. E. Blaisdell (CAS, 4). *INLET Co.:* Clam Gulch St. Rec. area, 23 May 1994, K. J. Ahn, ex rock crevice on mud flat at low tide (KSEM, 15); Cook Inlet, Clam Culch, 23 Jul 1973, G. Schulte, ex rocky shore, polyhaline water among *Enteromorphia, Fucus* and barnacles (KSEM, 1); Homer, Coal Bay, 24 May 1994, K. J. Ahn, ex under rock at low tide (KSEM, 4). *SKAGWAY Co.:* Saldovia, 21 Jun 1899, T. Kincaid (NMNH, 9). *VALDEZ CORDOVA Co.:* Valdez, 1 Aug 1978, P., P.-H., Madaline & S. Arnaud, under intertidal rock (UCR, 5; CAS, 29). *UNKNOWN:* Wickham, Ft. Wrangel (NMNH, 1). *UNKNOWN:* (MCZ, 1).

Late Instar Larva.—Length 3.4 mm. General body shape elongate, flattened, parallel-sided, dark brown in color. HEAD. About 0.9 × as long as wide. Chaetotaxy of frontal, epicranial, temporal, lateral, and ventral regions complete (Fd1–Fd3, Fl1–Fl4, Fm1, Ed1–Ed3, El1–El3, Em1–Em3, T1–T2, L1–L3, Vl1–Vl4, and V1–V2 all present), 3 additional setae present (1 between Ed2 and Ed3, 2 more L setae), campaniform sensilla Fc1–Fc2, Ec1–Ec2, P1–P4, Lc1–Lc3, and Vc1–Vc2 present. Antenna with 3 articles; article 1 elongate, ≈ 1.4× as long as wide; article 2 ≈ 1.4× length of article 1; article 3 ≈ 0.4× length of article 2; sensory appendage shorter than article 3; IIS1 spinose, short, ≈ 0.4× as long as IIS2; IIS2 elongate, digitiform, shorter than sensory appendage. MOUTHPARTS. Mandibles with ≈ 10 serrations on internal edge (4–5 between apex and median tooth, 4–5 between median tooth and base). Maxilla with article 1 of maxillary palpus elongate, ≈ 1.6× as long as wide; article 2 ≈ 0.5× as long as article 1; article 3 ≈ 0.7× as long as article 1 and 2 together. Labial palpus with article 2 ≈ 2.3× as long as article 1. THORAX. Pronotum transverse; chaetotaxy with anterior, lateral, posterior and discal rows complete (A1–A5, L1–L5, P1–P5, Da1–Da3, Db1–Db3, Dc1–Dc3, and Dd1–Dd2 all present), 3 additional setae present (1 below Dd2, 1 between Dc3, P5, and L5, 1 between A1 and A2); campaniform sensilla C1–6 present. Mesonotum transverse; chaetotaxy with anterior, lateral, posterior and discal rows complete (A1–A5, L1 and L4, P1–P5, Da2–Da3, Db1–Db3, Dc2, and Dd2 all present); campaniform sensilla C1, C3, C4, C5, and C6 present. Metanotum similar to mesonotum. ABDOMEN. Chaetotaxy of abdominal tergite I with anterior, lateral, posterior and discal rows complete (A2, A4, A5, L1 and L4, P1–P5, Da2, Db2, Dc2, and Dd2 all present). Urogomphus slender, about as long as postero-lateral prolongation of tergite IX.

Diagnosis.—Larvae of *Liparocephalus brevipennis* can be distinguished from all other described *Liparocephalus* larvae by the combination of: antenna with IIS1 ≈ 0.4× as long as IIS2, IIS2 shorter than sensory appendage; urogomphus about as long as postero-lateral prolongation of tergite IX; head chaetotaxy complete, 3 additional setae present; pronotal chaetotaxy complete, 3 additional setae present; mesonotal chaetotaxy complete; and chaetotaxy of abdominal tergite I complete (in comparison with standard patterns described by Ashe & Watrous).

Material Examined.—USA. ALASKA *INLET CO.:* Clam Gulch St. Rec. area, 23 May 1994, K. J. Ahn, ex rock crevice on mud flat at low tide (KSEM, 4); Seward, 25 May 1994, K. J. Ahn, ex under boulder at mid-tide (KSEM, 10).

LIPAROCEPHALUS CORDICOLLIS LECONTE
(Figs. 1–21)

Liparocephalus cordicollis LeConte, 1880; 177; Casey, 1893: 354; Bernhauer & Scheerpeltz, 1926: 550; Chamberlin & Ferris, 1929: 143; Moore, 1956a: 118; Hatch, 1957: 149; Moore & Legner, 1975: 445.

Liparocephalus brevipennis, Casey, 1893: 354; Keen, 1897: 285, Fenyes, 1918: 106; Saunders, 1928: 543; Chamberlin & Ferris, 1929: 143.

Description.—Adult. Length 3.8–5.2 mm. Body color black or dark brown. Head about as long as wide, infraorbital carina present. Ratio of length of compound eyes to length of head ≈ 0.2. Antennomeres all elongate. Labrum (Fig. 1) with 35–40 + 35–40 major setae; epipharynx (Fig. 2) with 20 small medial pores. Mandible (Fig. 3) with 5 internal teeth between apex and median tooth. Labium (Fig. 4) with 1 medial seta or none on prementum, ≈ 16 pseudopores present medially. Mentum (Fig. 6) with anterior margin deeply truncate internally, posterior marginal prolongation rounded, and apicolateral margin with projecting knob. Pronotum subquadrate, ≈ 0.8× as long as wide, with long filiform setae 1 on disc and 1 on lateral margin. Elytra ≈ 0.8× as long as wide; ≈0.6× as long as pronotum, long filiform setae present. Aedeagus. Median lobe (Fig. 7). Paramere (Fig. 8). Spermatheca. (Fig. 9).

Distribution.—Alaska to California (Monterey Co.).

Material Examined.—USA. ALASKA. *KETCHIKAN Co.:* Prince of Wales Isl., Port Protection, 10-20 Aug 1951, B. Malkin (FMNH, 4); Prince of Wales Isl., Red Bay, 13-14 Sep 1951, B. Malkin (FMNH, 2). *PRINCE OF WALES OUTER WRANGELL Co.:* Kah Sheets Bay, Kupreanof Isl., 31 Aug 1951, B. Malkin (FMNH, 15); same except, 28 Aug 1951, (FMNH, 1). *SKAGWAY Co.:* Yakutat, 21 Jun 1899, T. Kincaid (MCZ, 1). *UNKNOWN:* Admiralty Isl., 25 Jun 1933, R. R. Sheppard (MCZ, 3). CALIFORNIA. *HUMBOLDT Co.:* Trinidad Head, Trinidad, Mar 1963, J. D. Pinto (UCR, 1); Samoa, Apr 1962, J. Pinto (UCR, 2). *MARIN Co.:* Rocky Point, 1mi. SE. of Stinson Beach, 1 Jun 1968, V. F. Lee (CAS, 2); Agate Beach, 30 Mar 1971, D. Giuliani (UCR, 2); Bolinas Point, 1.6 mi. due West of Bolinas, 10 Apr 1977, V. F. Lee (CAS, 7); Strawberry Point, Brickyard Park, 2 Apr 1978, V. F. Lee (CAS, 10); Angel Island State Park, Pt. Blunt, Sandy Beach, 29 May 1976, V. F. Lee (CAS, 1); Tomales Bay, 9 Sep 1912, Van Dyke (CAS, 32). *MENDOCINO Co.:* Needle Rock, 6 Oct 1974, D. Guiliani (UCR, 1). *MONTEREY Co.:* Pescadero Pt., 1 Aug 1968, W. G. Evans, ex intertidal on *Egregia* (KSEM, 1); same except, 1 Apr 1966, P. Schroeder (KSEM, 6); Asilomar Beach, 23 Feb 1967, W. G. Evans, ex just above *Porphyra* (KSEM, 1); Asilomar Beach (Moss?) Beach, 9 Jan 1967, W. G. Evans, ex in crevice (KSEM, 2); Bird Rock Beach, 9 Dec 1966, W. G. Evans, ex mid-tide crevice (KSEM, 1); Pacific Grove, Mussel Pt., 9 Dec 1966, W. G. Evans (KSEM, 2); Carmel, 4 Nov 1925, F. E. Blaisdell (CUIC, 1); same except, 12 Nov 1914, (FMNH, 1); same except, 10 Apr 1932, L. S. Slevin (CAS, 2); same except, 27 May 1922 (CAS, 6); same except, 15 Apr 1919 (CAS, 1); same except, 17 Feb 1929 (CAS, 1); same except, 3 Mar 1917 (CAS, 1); same except, 6 May 1914 (CAS, 3); same except, 16 Nov 1914 (CAS, 1); same except, 20 Jan 1915 (CAS, 1); same except, 12 Nov 1914 (CAS, 1); same except, 26 Oct 1914 (CAS, 1). *SANTA CRUZ Co.:* Año Nuevo Beach, 3 Apr 1953 (FMNH, 3). *SAN FRANCISCO Co.:* San Francisco, Baker Beach, 2 Apr 1967, V. F. Lee (CAS, 18); Cove West of Phelan Beach, 24 May 1978, V. F. Lee (CAS, 2). *SAN MATEO Co.:* Halfmoon Bay, 24 Jan 1925, A. Davis (KSEM, 5); same except, 9 Mar 1957 (FMNH, 1); same except, H. C. Fall (MCZ, 6); same except, 2 Jan 1929 (FMNH, 6); Pillar Point, 15 Oct 1966, V. F. Lee, low tide, intertidal rocks (CAS, 4); Frenchman's Reef, 22 Feb 1967, V. F. Lee (CAS, 7); Moss Beach, 16 May 1991, K. J. Ahn & J. S. Ashe, ex on rocks in the intertidal zone (KSEM, 8); same loc., 6 Jul 1966, W. G. Evans, ex in mid-tide crevice (KSEM, 1); same except, Aug, F. E. Blaisdell (FMNH, 1); same except, 7 Jul 1912 (CAS, 7); same except, 1 May 1910 (CAS, 6); same loc., 2 Oct 1950 (CAS, 1); same loc., Nov 1928, G. F. Ferris (CAS, 2); same loc., 27 Apr 1947, H. P. Chandler (CAS, 1). *SONOMA Co.:* Bodega Bay, 23 Nov 1973, W. G. Evans, ex high crevice (KSEM, 3); 7 May 1950, G. H. Hanna (CAS, 1); 27 Apr 1971, J. Hafernik (KSEM, 1); Bodega Marine Laboratory, Horseshoe Cove, 25 May 1975, V. F. Lee (CAS, 3);

Soberanes Pt., 4 Mar 1974, J. Norman, ex low tide crevice (KSEM, 3). *UNKNOWN.* (KSEM, 3). OREGON. *CLATSOP Co.:* Cannon Beach, 11 Jun 1927, E. C. Van Dyke (FMNH, 2; CAS, 9). *COOS Co.:* Squaw Isl., 19 Jun 1947, I. M. Newell (FMNH, 6). *CURRY Co.:* Pt. N. Cape Blanco, 7 Oct 1974, D. Giuliani (UCR, 1). *LANE Co.:* Winchester Bay, 13 Apr 1947, B. Malkin & I. M. Newell (FMNH, 2). *LINCOLN Co.:* 1 mi. N. Depoe Bay, 1 Aug 1970, S. R. Leftler (WSUC, 1); Agate Beach, 9 Jul 1925, W. J. Chamberlin (NMNH, 2); Charleston, 20 Jun 1947, G. Nelson (FMNH, 4); same except, 2 Jul 1947 (MCZ, 1); same except, 7 Jul 1947 (MCZ, 1); same except, 23 Jul 1947 (MCZ, 2). *UNKNOWN.* O. B. Johnson (WSUC, 2); (KSEM, 5). WASHINGTON. *CLALLAM Co.:* nr. Neah Bay, 9 Oct 1974, D. Giuliani (UCR, 4); Olympic Natl. Park, 28 Jul 1980, J. S. Ashe, ex intertidal on rocks (KSEM, 10); Salt Water Park, 17 Jun 1977, A. Borkent, ex among barnacles and mussels (KSEM, 1); Ilwaco, Jul 1917, A. L. Melander (FMNH, 1). *KING Co.:* Seattle, Alki Point, 16 Jul 1965, L. Russell (UCR, 2). CANADA. *BRITISH COLUMBIA:* Queen Charlotte Islands, Graham Island, Runnell Sound, 17 Jul 1988, J. S. Ashe, ex on rocks in intertidal zone (KSEM, 75); Massett, Keen (FMNH, 13); Queen Charlotte Islands, J. H. Keen (NMNH, 3); same loc., J. Fletcher (MCZ, 6); same loc., Liebeck (MCZ, 3); same loc., Hubbard & Schwarz (NMNH, 4); same loc., Rev. Keene (NMNH, 1); Massett (FMNH, 2; CAS, 26); Agate Beach near Toe Hill, 16 Jul 1988, J. S. Ashe, ex on rocks in the intertidal zone (KSEM, 3); Hope Isl., 13 Sep 1970, W. G. Evans, ex low tide crevice on beach (KSEM, 29); Vancouver, Wreck Beach, 24 Jul 1980, J. S. Ashe, ex wrack and intertidal zone (KSEM, 1); Vancouver Isl., Courtenay, 6 Mar 1932, H. C. Fall (MCZ, 1); Vancouver, 30 Jun 1951, H. Leech (UBCZ, 5; CAS, 8); same loc., 2 Apr 1952, G. J. Spencer (UBCZ, 6); same loc., 10 Mar 1931, K. Graham (UBCZ, 2); same except, 27 Feb 1932 (FMNH, 1); same except, 10 Mar 1931 (FMNH, 2); Indian R., 3 Jul 1931, H. B. Leech (UBCZ, 1; CAS, 4); Victoria, Vanc., Hubbard & Schwarz (NMNH, 5); Univ. British Columbia Campus, 3 Jul 1988, J. S. Ashe, ex on rocks (KSEM, 1); same loc., Tofino, Jun–Jul 1926, G. J. Spencer (UBCZ, 14); Jul 1926, Spencer (CAS, 1).

Late Instar Larva.—Length 3.0 mm. General body shape elongate, flattened, parallel-sided, dark brown in color. HEAD (Figs. 16, 17). About 0.9 × as long as wide. Chaetotaxy with setae of frontal, epicranial, temporal, lateral, and ventral regions complete (Fd1–Fd3, Fl1–Fl4, Fm1, Ed1–Ed3, El1–El3, Em1–Em3, T1–T2, L1–L3, Vl1–Vl4, and V1–V2 all present), 4 additional setae present (1 between Ed2 and Ed3, 1 between Ed1 and El2, 2 more L setae), campaniform sensilla Fc1–Fc2, Ec1–Ec2, P1–P4, Lc1–Lc3, and Vc1–Vc2 present. Antenna as in Figure 67, with 3 articles; article 1 ≈1.1× as long as wide; article 2 ≈ 2.0× length of article 1; article 3 ≈ 0.4× length of article 2; sensory appendage slightly shorter than article 3; IIS1 spiniform, short, ≈ 0.2× as long as IIS2, IIS2 elongate, digitiform, about as long as sensory appendage. MOUTHPARTS. Labrum as in Fig. 11. Epipharynx as in Fig. 12. Mandibles (Fig. 13) with ≈ 10 serrations on internal edge (4–5 between apex and median tooth, 4–5 between median tooth and base). Maxillary palpus with article 1 elongate, ≈ 2.3× as long as wide; article 2 ≈ 0.4× as long as article 1; article 3 ≈ 0.8× as long as article 1 and 2 together. Labium (Fig. 15) with article 2 of labial palpus ≈ 2.0× as long as article 1. THORAX. Pronotum (Fig. 18) transverse; chaetotaxy with anterior, lateral, posterior and discal rows complete (A1–A5, L1–L5, P1–P5, Da1–Da3, Db1–Db3, Dc1–Dc3, and Dd1–Dd2 all present), ≈ 20 additional setae present, campaniform sensilla C1–6 present. Mesonotum (Fig. 19) transverse; chaetotaxy with anterior, lateral, posterior and discal rows complete (A1–A5, L1 and L4, P1–P5, Da2–Da3, Db1–Db3, Dc2, and Dd2 all present), 6 additional setae present, campaniform sensilla C1, C3, C4, C5, and C6 present. Metanotum similar to mesonotum. ABDOMEN. Abdominal tergites I–VII transverse with many additional setae; tergite I chaetotaxy with anterior, lateral, posterior and discal rows complete (A2, A4, A5, L1 and L4, P1–P5, Da2, Db2, Dc2, and Dd2 all present). Urogomphus (Fig. 21) slender, about as long as postero-lateral prolongation of tergite IX.

Diagnosis.—Larvae of *Liparocephalus cordicollis* can be distinguished from all other described *Liparocephalus* larvae by the combination of: antenna (Fig. 10) with IIS1 ≈ 0.2× as long as IIS2; IIS2 almost as long as sensory appendage; urogomphus (Fig. 21) about as long as postero-lateral prolongation of tergite IX; head chaetotaxy complete, 4 additional setae present (Figs. 16, 17); pronotal chaetotaxy complete, about 20 additional setae present (Fig. 18); mesonotal chaetotaxy complete, 6 additional setae present (Fig. 19); and chaetotaxy of abdominal tergite I complete, many additional setae present (in comparison to standard patterns described by Ashe & Watrous).

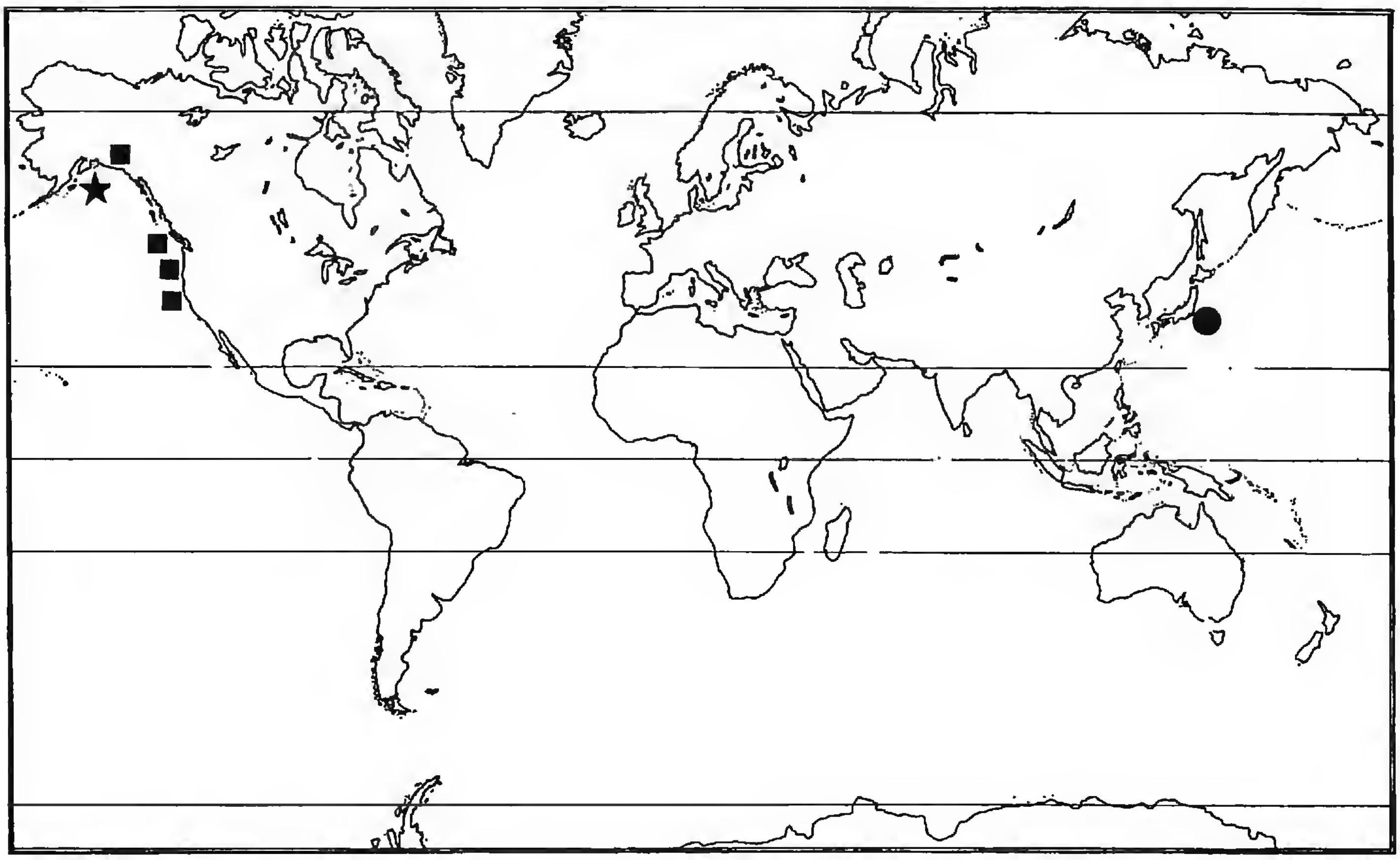


Figure 27. Distribution of *Liparocephalus brevipennis* (star), *L. cordicollis* (squares), and *L. tokunagai* (circle).

Material Examined.—USA. WASHINGTON. *CLALLAM Co.:* Olympic Natl. Park, 28 Jul 1980, J. S. Ashe, ex intertidal on rocks (KSEM, 3). CANADA. *BRITISH COLUMBIA:* Queen Charlotte Isls., Graham Isl., Toe Hill, 14 Jul 1988, J. S. Ashe, ex low intertidal on rocks (KSEM, 23).

LIPAROCEPHALUS TOKUNAGAI SAKAGUTI

(Figs. 25, 26)

Liparocephalus tokunagai Sakaguti, 1944: 20.

Description.—*Adult.* Length 4.9 mm. Body color brown, abdominal tergite VI black. Head more or less quadrate, as long as wide, lateral margin almost straight, infraorbital carina present, not reaching to maxilla. Ratio of length of compound eye to length of head ≈ 0.2. Antennomeres all elongate. Labrum with 35–40 + 35–40 major setae; epipharynx with 20 small medial pores. Mandible with 5 internal teeth between apex and median tooth. Labium without medial setae on prementum. Mentum anterior margin very deeply truncate internally, posterior margin rounded, and apico-lateral margin with projecting knob. Pronotum subquadrate, ≈ 0.8× as long as wide, long filiform setae present, 1 on disc and 1 on lateral margin. Elytra ≈ 0.9× as long as wide; ≈0.6× as long as pronotum, with long filiform setae. Aedeagus. Median lobe (Fig. 25). Spermatheca. (Fig. 26).

Distribution.—Japan.

Material Examined.—JAPAN. *SHIKOKU.* Aburatsubo Beach, Miura, Kanagawa, 19 May 1985, Y. Shibata (KSEM, 1); same loc., 3 Jul 1985 (KSEM, 1). *KYUSHU.* Kekura, Kagoshima, C. 31 Mar 1983, T. Sunose (NHMIC, 1).

Late Instar Larva.—Length 3.4 mm. General body shape elongate, flattened, parallel-sided. Color dark brown. HEAD. About 0.9× as long as wide. Chaetotaxy with frontal, epicranial, lateral, and ventral regions complete (Fd1–Fd3, Fl1–Fl4, Fm1, Ed1–Ed3, El1–El3, Em1–Em3, T1, L1–L3, Vl1–V14, and V1–V2 all present but T2 absent), campaniform sensilla Fc1–Fc2, Ec1–Ec2, P1–P4, Lc1–Lc3, and Vc1–Vc2 present. Antenna with 3 articles; article 1 elongate, ≈1.4× as long as wide; article 2 ≈1.5× length of article 1; article 3 ≈0.4× length of article 2; sensory appendage shorter than article 3; IIS1 spiniform, short, ≈0.2× as long as IIS2; IIS2 elongate, digitiform, shorter than sensory appendage. MOUTHPARTS. Mandibles with ≈5 serrations present on internal edge (all 5 between median tooth and base). Article 1 of maxillary palpus elongate, ≈1.9× as long as wide; article 2 ≈0.4× as long as article 1; article 3 ≈0.8× as long as article 1 and 2 together. Article 2 of labial palpus ≈2.0× as long as article 1. THORAX. Pronotum transverse; chaetotaxy with anterior, lateral, posterior and discal rows complete (A1–A5, L1–L5, P1–P5, Da1–Da3, Db1–Db3, Dc1–Dc3, and Dd1–Dd2 all present); campaniform sensilla C1–6 present. Mesonotum transverse; chaetotaxy with anterior, lateral, posterior and discal rows complete (A1–A5, L1 and L4, P1–P5 present, Da2–Da3, Db1–Db3, Dc2 and Dd2 all present); campaniform sensilla C1, C3, C4, C5, and C6 present. Metanotum similar to mesonotum. ABDOMEN. Abdominal tergites I–VII transverse; abdominal tergite I chaetotaxy with anterior, lateral, posterior and discal rows complete (A2, A4, A5, L1 and L4, P1–P5, Da2, Db2, Dc2, and Dd2 all present). Urogomphus slender, ≈0.5× as long as postero-lateral prolongation of tergite IX.

Diagnosis.—Larvae of *Liparocephalus tokunagai* can be distinguished from all other described *Liparocephalus* larvae by the combination of: antenna with IIS1 ≈ 0.2× as long as IIS2; IIS2 shorter than sensory appendage; urogomphus ≈ 0.5× as long as postero-lateral prolongation of tergite IX; and, chaetotaxy of head, pronotum, mesonotum and abdominal tergite I complete (in comparison to standard patterns described by Ashe & Watrous).

Material Examined.—JAPAN. *KYUSHU.* Kekura, Kagoshima, C. 31 Mar 1983, T. Sunose (NHMIC, 3).

DISCUSSION

Casey (1893) placed *Liparocephalus* in Bolitocharides based on the 4-4-5 tarsal formula and 11-articled antennae. He noted that *Liparocephalus, Diaulota,* and *Amblopusa* could be a well isolated group of genera among Bolitocharides based on their species distribution along the Pacific coast, elytra very short, tibiae short, devoid of lateral spinules, long sparse hairs present, and tarsi very short.

Fenyes (1918), who next mentioned *Liparocephalus,* placed it in the tribe Bolitocharini (group Liparocephali) based on the number of the tarsal joints (4-4-5), antennal articles (11), segments of the maxillary (4), and labial palpi (2 or indistinctly 3).

Bernhauer & Scheerpeltz (1926) and Hatch (1957) likewise classified the genus based on Casey's description and Fenyes's placement.

Chamberlin & Ferris (1929) compared the structure of members of *Liparocephalus, Diaulota,* and *Amblopusa* and described two species of *Liparocephalus.* However, Moore (1956a) revealed that they incorrectly identified *L. cordicollis* as *L. brevipennis.* He placed *Liparocephalus* in the subtribe Phytosi and made mention of the systematic relationships of *Liparocephalus* among the Phytosi.

The latest mention of this aleocharine genus was by Seevers (1978). He removed the subtribe Phytosina from the tribe Bolitocharini and raised it to tribal status (tribe Phytosini) placing *Liparocephalus* in it based primarily on tarsal formula (4-4-5), elytra shorter than pronotum, and hind wings absent.

From the time of its description, *Liparocephalus* Casey has been consistently classified with a number of other intertidal aleocharine genera in the tribe Phytosini, or its equivalent. However, Ahn & Ashe (1996) have shown that *Liparocephalus* and related genera represent a monophyletic lineage separated from *Phytosus* and related genera (= Phytosini) and should be placed in the tribe Liparocephalini.

I compared the structure of members of *Liparocephalus* to that of members of several intertidal phytosine genera. This examination revealed that the members of *Liparocephalus* comprise a well-supported monophyletic group. Cladistic analysis (Ahn & Ashe, 1996) indicates that members of *Liparocephalus* are sister group to the species of *Diaulota*. Within the *Liparocephalus* lineage, *L. cordicollis* + *L. tokunagai* show a sister group relationship to *L. brevipennis*.

ACKNOWLEDGMENT

I thank the following individuals and institutions for their contributions of this project: J. S. Ashe, Snow Entomological Museum at the University of Kansas; S. I. Frommer, University of California at Riverside; D. G. Furth, Museum of Comparative Zoology; E. R. Hoebeke, Cornell University Insect Collections; G. N. House, National Museum of Natural History, Washington, D.C.; D. Kavanaugh, California Academy of Sciences, San Francisco; J. Muona, Finnish Museum of Natural History, Helsinki, Finland; S.-I. Naomi, Natural History Museum and Institute, Chiba, Japan; K. M. Needham, Spencer Entomological Museum at the University of British Columbia, Vancouver, Canada; and A. F. Newton, Field Museum of Natural History, Chicago. R. S. Zack, James Entomological Collection at Washington State University, generously provided me with the opportunity to examine the collections including type series of species of *Liparocephalus* by arranging for the loan of specimens. I also thank James S. Ashe for reading and providing helpful suggestions on the manuscript. This research was supported by University of Kansas GRF grant 91-162, Snow Entomological Museum Development Fund and NSF Grant DEB-9521755 awarded to James S. Ashe.

LITERATURE CITED

Ahn, K. J. & J. S. Ashe. 1996. Phylogeny of the intertidal aleocharine tribe Liparocephalini (Coleoptera: Staphylinidae). Syst. Entomol., 21: 99–114.

Ashe, J. S. & L. E. Watrous. 1984. Larval chaetotaxy of Aleocharinae (Staphylinidae) based on a description of *Atheta coriaria* Kraatz. Coleopt. Bull., 38(2): 165–179.

Bernhauer, M. & O. Scheerpeltz. 1926. Coleopterorum Catalogus. Pars 82, Staphylinidae 6: 499–988.

Blackwelder, R. E. 1952. The generic names of the beetle family Staphylinidae with an essay on genotype. Bull. U.S. Nat. Mus., 200: 1–483.

Casey, T. L. 1886. Descriptive notices of North American Coleoptera, I. Bull. Calif. Acad. Sci., 2: 157–264.

Casey, T. L. 1893. Coleopterological notices V. Ann. N. Y. Acad. Sci., 7: 281–606.

Chamberlin, J. C. & G. F. Ferris. 1929. On *Liparocephalus* and allied genera (Coleoptera: Staphylinidae). Pan-Pac. Entomol., 5(3): 137–162.

Fenyes, A. 1918. Fam. Staphylinidae: subfam. Aleocharinae [facicle 173a, pp. 1–100]. *In* Genera Insectorum dirgés par P. Wytsman. Coleoptera. Burxelles.

Hatch, M. H. 1957. The beetles of the Pacific Northwest. Part II: Staphyliniformia. Univ. Wash. Publ. Biol., 16:1–384.

Keen, J. H. 1897. Three interesting Staphylinidae from Queen Charlotte Islands. Can. Entomol., 29: 285–287.

LeConte, J. L. 1880. Short studies of North American Coleoptera. Trans. Amer. Entomol. Soc., 12: 163–218.

Mäklin, F. G. 1853. Description of new taxa. *In* Mannerheim, C. Dritter Nachtrag der Aleutischen Ins. Bull. Soc. Imp. Nat. Moscou, 26: 95–269.

Moore, I. 1956a. A revision of the Pacific coast Phytosi with review of the foreign genera (Coleoptera: Staphylinidae). Trans. San Diego Soc. Nat. Hist., 12: 103–152.

Moore, I. 1956b. Notes on some intertidal Coleoptera with descriptions of the early stages (Carabidae, Staphylinidae, Malachiidae). Trans. San Diego Soc. Nat. Hist., 12: 207–230.

Moore, I. & E. F. Legner. 1975. A Catalogue of the Staphylinidae of America North of Mexico (Coleoptera). Univ. Calif. Div. Agric. Sci. Spec. Publ., 3015.

Moore, I. & E. F. Legner. 1976. Intertidal rove beetles (Coleoptera: Staphylinidae). *In* Marine insects (L. Cheng, editor). North Holland Publishers, Amsterdam. xix+581pp.

Sakaguti, K. 1944. A new intertidal rove-beetle from the Pacific coast of Japan. Trans. Kansai Entomol. Soc., 14: 20–21.

Saunders, L. G. 1928. Some marine insects of the Pacific coast of Canada. Ann. Entomol. Soc. Amer., 21(4): 521–545.

Seevers, C. H. 1978. A generic and tribal revision of the North American Aleocharinae (Coleoptera: Staphylinidae). Fieldiana: Zool., 71: 1–289.

Toop, W. & R. A. Ring. 1988. Adaptations of Coleoptera to the marine environment. II. Observations on rove beetles (Staphylinidae) from rocky shores. Can. J. Zool., 66: 2469–2474.

Received 13 Oct 1995; Accepted 10 Dec 1996

PAN-PACIFIC ENTOMOLOGIST
73(2): 93–99, (1997)

THE IMMATURE STAGES AND BIOLOGY OF THE CRANEFLIES *TOXORHINA CALEDONICA* AND *ELEPHANTOMYIA GARRIGOUANA* (DIPTERA: LIMONIIDAE)

C. Dennis Hynes
17 Cricket Hollow Run Clayton, North Carolina 27520

Abstract.—The larval and pupal stages of the craneflies *Toxorhina* (*Ceratocheilus*) *caledonica* Alexander and *Elephantomyia* (*Elephantomyia*) *garrigouana* Alexander are described. The habitat and certain biological behaviors of *Toxorhina* and *Elephantomyia* are noted. Similarities and differences in structure of the immature stages of the two genera are listed and their importance in the determination of relationships discussed. The characters support a close relationship of the two genera, and confirms the placement of the two genera within the Eriopterini. A possible error in the rearing of one species of *Elephantomyia* from South Africa is also discussed.

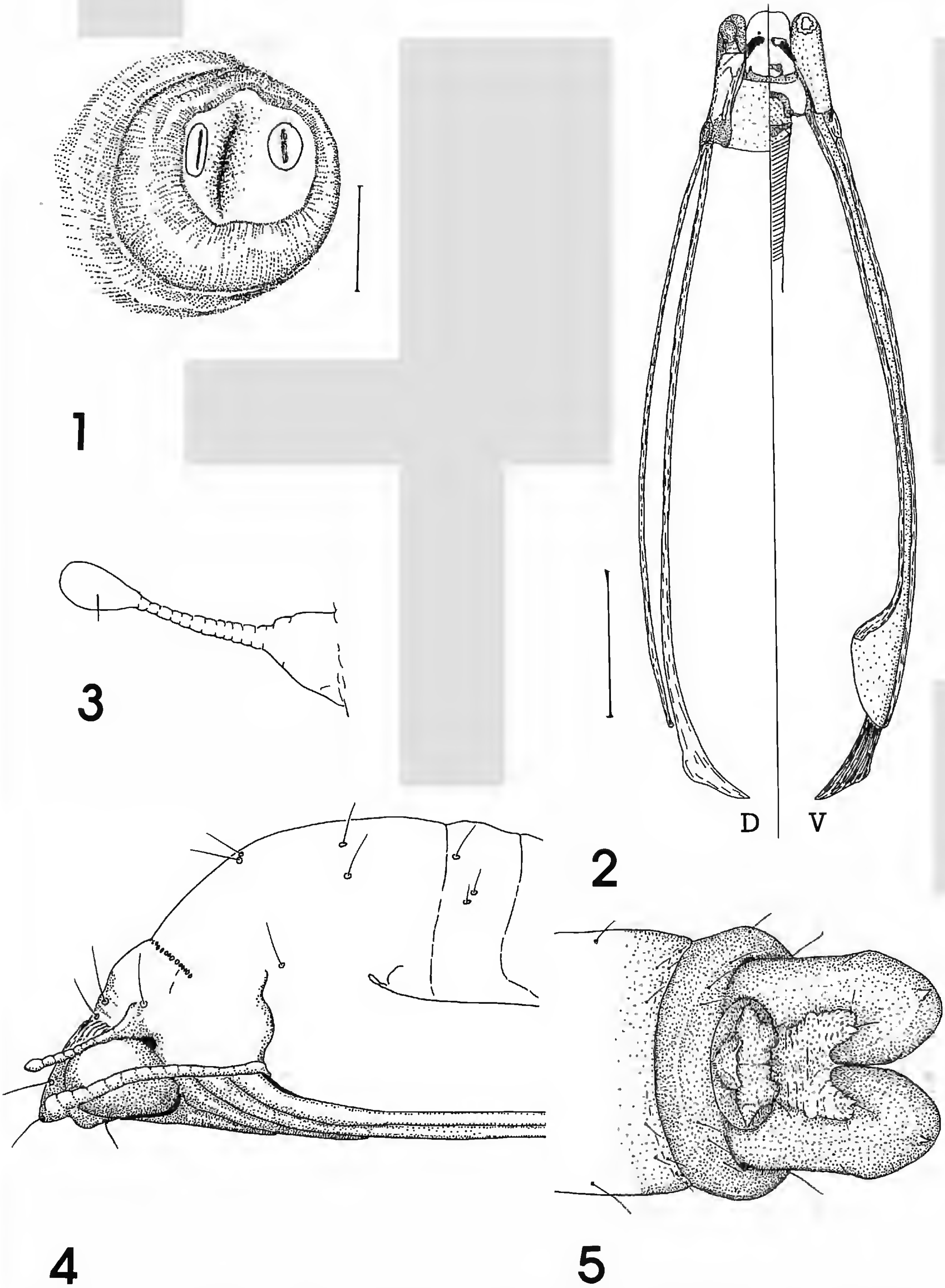
Key Words.—Insecta, Diptera, Cranefly, Limoniidae, *Toxorhina, Elephantomyia,* larva, pupa, relationship.

The relationship between the genera *Toxorhina* Loew and *Elephantomyia* Osten Sacken and their placement in the present hierarchy of the Limoniidae has been in question for some time. Using adult characters, Alexander (1921a, 1921b) considered these genera to be closely related and, on this supposition, placed both genera in the tribe Eriopterini. Later, Alexander (1923) had transferred the genus *Elephantomyia* to the tribe Hexatomini on the basis of its possession of tibial spurs. *Toxorhina,* without tibial spurs, remained in the Eriopterini. Subsequently, other species of *Elephantomyia* were discovered not having tibial spurs, and the subgenus *Elephantomyodes* (Alexander 1923) was erected to include these species. However, Alexander (1951) described *Elephantomyia* (*Elephantomyia*) *garrigouana* as lacking tibial spurs, yet placed it into the subgenus *Elephantomyia* rather than *Elephantomyodes* on the basis of wing venation. He failed to indicate the exact differences in wing venation that led him to this conclusion. This further confused relationships within *Elephantomyia* and also between *Elephantomyia* and *Toxorhina.* The confusion was compounded by a probable error by Wood's (1952) rearing of a South African species of *Elephantomyia.* Since the immature stages of *E.* (*Elephantomyia*) *westwoodi* O. S. had been described earlier (Alexander 1921a) and other species later (Bangerter 1934, Savchenko 1986, Wood 1952) it was hoped that discovery of the immature stages of the genus *Toxorhina* would supply information to clear up the matter.

In New Caledonia I found and reared the immature stages of *Toxorhina* (*Ceratocheilus*) *caledonica* Alexander. For comparison I include a description of the immature stages of *Elephantomyia* (*Elephantomyia*) *garrigouana* Alexander.

Toxorhina (*Ceratocheilus*) *caledonica* Alexander
(Figs. 1–5)

Larva.—Body cylindrical, cigar shaped posteriorly, tapering anteriorly, covered with dark setae giving body a gray velvet sheen. Spiracular disk (Fig. 1) without lobes, outer border a rounded collar, dorsomedial area slightly indented; face of disk and spiracles white. Spinous ventral creeping welts



Figures 1–5. *Toxorhina* (*Ceratocheilus*) *caledonica* Alexander; scale indicators (when present) are 0.1 mm. Figure 1. Spiracular disk, posterolateral view. Figure 2. Larval head capsule (d-dorsal, v-ventral). Figure 3. Mesothoracic breathing horn. Figure 4. Male pupa, anterior end, lateral view. Figure 5. Male pupa, posterior end, dorsal view.

on abdominal segments 6 and 7. Anal gills or lobes absent. Abdominal segment 10 a white mound with the anus at its anterior border. Both anus and mound (mound similarly shaped to, but definitely not a creeping welt and not spinous) covered by anterior flap of elongate, dark gray setae. Head capsule (Fig. 2): length from anterior tip of labrum to posterior margin of dorsal plate 0.51 mm; width at mandibular articulation 0.08 mm. Head very elongate, length/width ratio 6.4; dorsal and dorsolateral bar-like phragmata approximately same width, ventral bars slightly wider apically. Mandible slightly slanted or rotated from vertical plane, recurved distally, ending in small teeth. Area behind clypeus entirely membranous. Anterior portion of esophagus sclerotized, with riblike structures for a short distance posteriorly. Maxillae blunt; antennae short, terminal papilla same size as sclerotized basal segment. Length 9.3 mm; width at fourth abdominal segment 0.95 mm.

Pupa.—Body light brown, long, narrow. Antennal sheath lying directly across eye (Fig. 4). Small crest or row of folds between bases of antennae, another row at posterodorsal margin of eye; a large tubercle directed forward, ending in an elongate seta between antennal bases. Mesothoracic breathing horns (0.8–1.1 mm) extending laterally, slightly widened at base becoming narrower then again widening just before tip, constrictions along shaft, tip slightly enlarged, oval, flattened dorsoventrally (Fig. 3). Wing pads nearly black in more mature specimens. Mesothoracic leg sheaths slightly wider than others, ending just before posterior edge of abdominal segment 6, mesothoracic leg sheaths only slightly shorter; metathoracic sheaths much shorter, ending at no more than midlength of abdominal segment 6. Abdominal segments punctulate. Segments 2–7 with three rings, two narrow basal rings and one broad distal ring. Male cauda (Fig. 5) with segment 8 forming collar, folded over anterior edge of segment 9. Sternite 9 bulbous, smooth; tergite 9 with anterior oval area with two strong, rounded tubercles and two teeth, one extending laterad on each side. Sheaths of dististyles strongly recurved; a sharp tooth in angle of curvature bearing a strong seta, another short tooth on caudal edge. Length 6.9–7.0 mm; dextrosinistral and dorsoventral width at wing base 0.9–1.1 mm.

The description of *Toxorhina caledonica* is based on four larvae and three pupae, deposited in my collection.

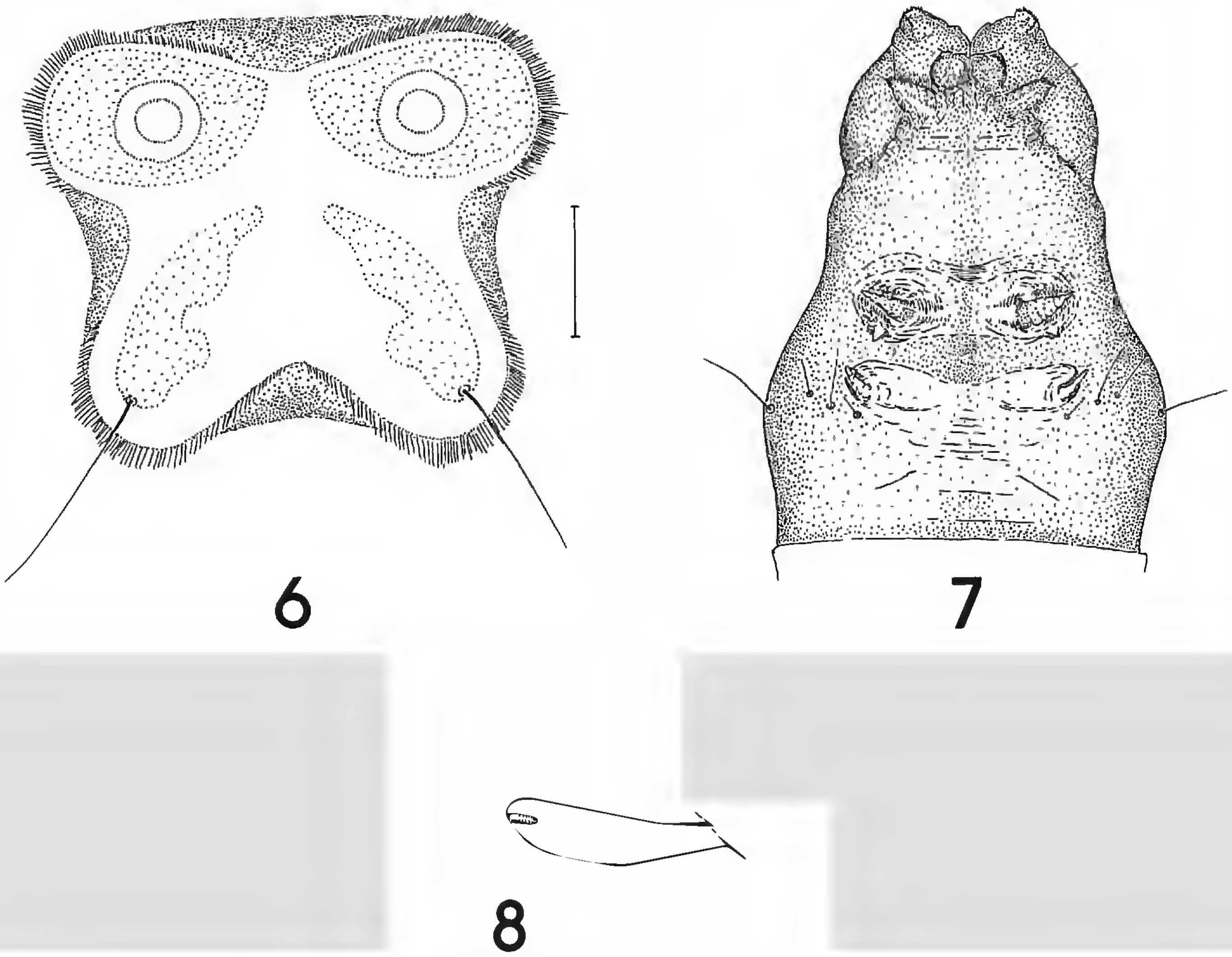
Specimens Examined.—NEW CALEDONIA: Riviere Bleue; 10-1788-1.1, 10-1788-1.2. To avoid confusion, these numbers represent my catalog number as well as the rearing cage number. This number also indicates the vial in which the reared specimens are found (month 10-day 17 of year 1988-microhabitat 1 and specimen or specimens reared .2) This format is followed throughout this paper.

Elephantomyia (Elephantomyia) Garrigouana Alexander
(Figs. 6–8)

Larva.—Body cylindrical, covered with closely appressed golden setae. Spinous ventral creeping welts present on abdominal segments 5, 6, and 7. Spiracular disk (Fig. 6) with 4 lobes, ventral ones slightly longer, each with an elongate, stout seta extending caudad; outer edge of all lobes with fringe of setae; face with light brown markings, spiracles gold. Anal gills or lobes absent. Abdominal segment 10 with anus at anterior border of small, white mound, both covered with a row of dense elongate setae originating along anterior edge of anus. Head capsule very slender, elongate, length 0.33–0.41 mm; width at mandibular articulation 0.05–0.06 mm; L/W ratio 6.3 to 6.5. Six "bars" or "rods" with membranes forming 3 plates; dorsal and ventral bars approximately same size, the dorsolateral ones more slender, becoming extremely thin at posterior end. Mandible slightly slanted or rotated from vertical axis, not recurved distally, ending in rounded teeth. Postclypeal area entirely membranous. Anterior portion of esophagus with sclerotized, riblike structures. Maxillae blunt; antennae short, terminal papilla larger than basal segment. Length 7.7–9.1 mm; width at fourth abdominal segment 0.7–0.79 mm.

Pupa.—Antennal sheaths lying across eyes. Mesothoracic breathing horn (0.30–0.37 mm) elongate, clavate, flattened laterally, extending cephalad (Fig. 8). Wing pads end at posterior edge of abdominal segment 2. Mesothoracic leg sheaths slightly enlarged at base, ending at three-quarters length of abdominal segment 5, mesothoracic sheaths slightly shorter, metathoracic sheaths still shorter. Dorsally, abdominal segment 9 bearing 4 sharply pointed lobes, anterior pair thinner than posterior pair. On caudal edge of each dististyle sheath a short, curved row of spines. Four lobes anterior to dististyle sheaths posterior pair spherical, anterior pair pointed, tips with several spinules and 2 seta directed laterad (Fig. 7). Length 5.1–5.4 mm; dextro-sinistral and dorso-ventral width at wing base 0.7–0.8 mm.

The description of *E. garrigouana* is based on twelve larvae and three pupae and are deposited in my collection.



Figures 6–8. *Elephantomyia* (*Elephantomyia*) *garrigouana* Alexander; scale indicator (when present) 0.1 mm. Figure 6. Spiracular disk. Figure 7. Male pupa, posterior end, dorsal view. Figure 8. Mesothoracic breathing horn.

Specimens Examined.—NEW CALEDONIA: Mont Mou; 10-1888-1.2, 11-1588-1.1. Riviere Blanc; 11-888-1.2. Riviere Bleue; 10-2788-1.5a, 11-1788-1.2 (See above for explanation of numbers).

BIOLOGY

Habitat.—The larvae of both *Toxorhina* (*Ceratocheilus*) *caledonica* and *Elephantomyia* (*Elephantomyia*) *garrigouana* were found in two general habitats. The first is rotting branches of trees (Myrsinaceae, probably *Rapanea*) beneath accumulations of twigs and leaves. Those of *T. caledonica* were taken from rotted wood that was slimy, not punky, indicating a much more advanced stage of decay than that in which the larvae of *E. garrigouana* were found.

The second habitat was rotting palm fronds. Larvae were located in a brown, syrupy liquid between the fibers of the petiole. The larvae of *T. caledonica* were found in the wet proximal areas of the petiole; those of *E. garrigouana* were found in drier, more distal areas of the petiole. The pupae of both species were found in dryer areas of both habitats.

Elephantomyia garrigouana was also found in punky wood Araiaceae (either *Myodocarpus,* or more probably *Schefflera*). The immature stages of *T. caledonica* were not found in this habitat.

Emergence.—The pupal period of both species was approximately seven days in ambient temperatures (range: 22–25° C). At emergence, the teneral adult of *T. caledonica,* is engorged with water and air and the abdomen is very elongated. The rostrum of the head at eclosion is short, and barely reaches back to the base of the wing. In five to ten minutes after complete emergence from the pupal case, the rostrum starts to elongate, becoming longer than the entire body. This is accomplished by hydrostatic pressure within the body before hardening of the exoskeleton.

Discussion

There are no differences between the larvae or pupae of *E. garrigouana* and *E. westwoodi* that would indicate that the presence or absence of the tibial spur (absent in the adult of the former) should lead to the erection of a new subgenus. In fact, the differences are so slight as to lead one to disregard the subgenus *Elephantomyodes* altogether, placing species with or without tibial spurs in the subgenus *Elephantomyia.*

The most obvious difference between the larvae of *Elephantomyia* and *Toxorhina* is found in the structure of the outer edge of the spiracular disk, i.e., the lack of discal lobes in *Toxorhina* and their presence in *Elephantomyia.* Both genera have an anal mound directly posterior to the anus and a transverse and heavy row of elongate setae forming a "flap" over the anus and the anal mound. Although similar in shape, the mound is definitely not a creeping welt and must serve the same purpose as the anal gills. Dissection reveals that gills are not retracted or present within the anal area of either genus. Also notable is the presence of ventral creeping welts on abdominal segments 5, 6 and 7 in *Elephantomyia,* but on only 6 and 7 in *Toxorhina.* Similarities indicating the close relationship of the two genera are numerous.

The head capsules are very similar in their structural features. All specimens of *E. garrigouana* and *T. caledonica,* as well as *E. westwoodi,* have head length/width ratios of well over 5.0. This ratio is taken as the length of the head from the anterior edge of the labrum to the posterior edge of the dorsal plate, divided by the width of the head capsule at the posterior or outer articulation of the mandibles. The measurement indicates the very slender appearance of the head capsule when compared to those of all other larvae of the Tipulomorpha, which have length/width ratios (from this measurement) under 4.0.

The antennal buttress in *Elephantomyia* and *Toxorhina* is elongate compared to that of other genera. The shape and relative size of the papilla to the basal segment of the antennae are nearly the same in both genera. The dorsolateral bar or rod-like phragmata is much thinner in *Elephantomyia.*

The mandibles are very small (about 0.02 mm long in *E. garrigouana*; 0.04 mm in *T. caledonica*) and slightly turned downward allowing for a scraping movement. Alexander (1921a) described the mandibles of *E. westwoodi* as pointed with the inner surface toothed. Specimens that I dissected have a rounded tip with additional teeth on the inner edge. The mandibular structure of *Toxorhina* is slightly more complex than that of *Elephantomyia,* but in both cases it indicates a scraping action in the procurement of food. The slight tilt to the mandibles perhaps explains their unusual position in Alexander's drawing (Alexander 1921a).

A striking resemblance between the two genera is the presence of the ribbed anterior portion of the esophagus. No other known genera within the Tipulomorpha have such ribbing. The closest approximation would be the spines in similar locations in some hexatomine groups. The purpose of this structure is unknown, but it may protect the forward portion of the esophagus from sharp edges found in the food ingested.

The structural similarities between the larval, pupal and adult forms of the two genera are summarized as follows. From the larvae: (1) the length/width ratio and shape of the head capsule; (2) the size and shape of the antennae; (3) the size and shape of the mandibles; (4) the tilt or slant of the mandibles; (5) the presence of ribbing in the forward part of esophagus; and (6) the structure of the anus, anal mound and covering setal "flap".

From the pupae: (1) the antennal sheath lying across the eye dividing the eye sheath into two parts, not across the dorsal border of the eye sheath as in most other tipulids; and (2) the similar ecological habitat.

The similarities of the immatures suggest that the two genera are closely related and should be placed in the same grouping of the hierarchy. I have already indicated in an earlier paper (Hynes 1993) that both should be placed in the Eriopterini. This suggestion ignores the presence or absence of tibial spurs. Without getting into a discussion of the differences between "key," "evolutionary," and "cladistic" characters, I feel that the character "tibial spur" as currently used is best removed from discussions of relationship.

Oosterbroek and Theowald (1991) infer that the genus *Elephantomyia* might be placed in limoniine groups. This is based on the immatures of one species, *E. aurantica,* supposedly reared by Wood (1952). Wood indicated that this species has a larva apparently limoniine in form, not eriopterine as in the other species he reared. Several aspects of this conclusion are disturbing. Such discussions are often accepted to a degree that details tend to take on the aura of undisputed data, and such must be avoided in this case. The primary reason is the reported condition of rearing the species. If one reads the account by Wood, the conclusion must be reached that other individuals did the rearing. Only one larva was reared to the pupal stage, and there is no mention as to whether this pupa was reared to adult. Also one must conclude that there was no attempt to control the medium in which the rearing was accomplished. When collecting, one finds other larvae, particularly the genus *Limonia,* in the same habitat as *Elephantomyia* and *Toxorhina.* Moreover, a given species is not necessarily found in only one habitat (see above). Care must be taken that the larva one wishes to rear is the only type of larva present. Failure to observe these cautions allows a large probability of error. But further than that, to allow that a gene complement could change so drastically (as in Wood's *Elephantomyia* larva), yet have no real effect on differentiation in later development (pupa and adult) is very improbable. Convergent evolution is an extremely rare event and in no case so perfectly matched in two of the three developmental stages. That someone made mistakes in rearing technique has a much greater probability and is far more believable. The rearing must be repeated, and in such a manner that there can be no doubt as its validity, i.e., a definite association of one larva to its pupa and subsequently to its adult. Until this is accomplished, suppositions on monophyly or polyphyly based on Wood's data on *E. aurantiaca* should not be made.

ACKNOWLEDGMENT

I am indebted to the biologists and staff of ORSTOM (French Institute of Scientific Research and Development through Cooperation), Noumea. I thank Jean Chazeau (ORSTOM, Noumea) for his support of efforts concerning crane-fly biology in New Caledonia. I also thank George W. Byers (Snow Museum, University of Kansas) for his suggestions and comments. Tentative identification of *Rapanea* was made by the botanical staff at ORSTOM, Noumea. I particularly wish to thank the Charles P. Alexander Fund of the Pacific Coast Entomological Society for partial payment of page charges for this publication.

LITERATURE CITED

Alexander, C. P. 1921a. The crane-flies of New York, Part II. Biology and Phylogeny. Cornell Univ. Memoirs, 38.

Alexander, C. P. 1921b. New or little-known crane-flies from the Amazonian region. Proc. Acad. Nat. Sci., Phil., pt. I: 39–103.

Alexander, C. P. 1923. Undescribed species of Japanese crane-flies (Tipulidae, Diptera). Part III. Ann. Entomol. Soc. Amer., 16: 57–76.

Alexander, C. P. 1951. New or little-known Tipulidae (Diptera). 89. Oriental-Australasian species. Ann. Mag. Nat. Hist., 12(4): 576–606.

Bangerter, H. 1934. Mucken-Metamorphosen. 6. Konowia, 13: 264–272.

Hynes, C. D. 1993. The crane-flies of New Caledonia (Diptera Tanyderidae, Tipulidae). *In* L. Matile, J. Najt & S. Tillier (eds.), Zoologia Neocaledonica, Vol. 3. Mem. Mus. natn. Hist. nat., 157: 73–121.

Oosterbroek, P. and Theowald, B. 1991. Phylogeny of the Tipuloidea based on characters of the larvae and pupae (Diptera, Nematocera), with an index to the literature except Tipulidae. Tijd. voor Entomol. 134: 211–267, figs., 1–180.

Savchenko, E. N. 1986. Limoniidae: Introduction, Pediciinae, Hexatominae. Fauna Ukraini, 14(2): 1379.

Wood, H. G. 1952. The crane-flies of the South-West Cape (Diptera, Tipuloidea). Ann. South African Museum, 39: 1–327.

Received 4 Dec 1996; Accepted 14 Nov 1996.

PAN-PACIFIC ENTOMOLOGIST
73(2): 100–102, (1997)

A NEW SPECIES OF THE GENUS *CERACLEA* STEPHENS (TRICHOPTERA: LEPTOCERIDAE) FROM ZELYONYI ISLAND (SOUTH KURIL ISLANDS)

Tatyana I. Arefina
Laboratory of Freshwater Hydrobiology, Institute of Biology and Soil Sciences,
Far Eastern Branch of Russian Academy of Sciences,
Vladivostok 690022, Russia.

Abstract.—*Ceraclea valentinae* NEW SPECIES from Zelyonyi Island (south Kuril Islands, Russia), belonging to the *Ceraclea* (*C.*) *fulva* group, is described and illustrated. This genus has not previously been recorded from Kuril Islands.

Keywords.—Insecta, Trichoptera, Leptoceridae, *Ceraclea,* Kuril Islands

---

A new caddisfly species, genus *Ceraclea,* was collected in 1994 from Zelyonyi Island, one of the southerly islands of the Kuril Islands archipelago. The specimen was collected during an expedition to the islands sponsored by the International Programs Division of the U.S. National Science Foundation and the Institute of Biology and Soil Sciences of Russian Academy of Sciences, Vladivostok. The genus *Ceraclea* has not previously been recorded from the Kuril Islands. The description of *Ceraclea valentinae* belonging to the *Ceraclea* (*C.*) *fulva* group (Morse 1975, Yang & Morse 1988), is presented here.

Ceraclea valentinae Arefina, NEW SPECIES

Types.—Holotype male; data: SOUTH KURIL ISLANDS (RUSSIA). Zelyonyi Island, western shore of Kamenskoye Lake, 6 Aug 1994, V. Teslenko; deposited: Zoological Institute of the Russian Academy of Sciences, Saint Petersburg.

Description.—Male (Holotype). Head and body brown with relatively long white and brown hairs intermixed. Forewing light yellow-brown, apically darker with light spots. Body length: 10.4 mm; forewing length: 13.2 mm. Male genitalia (Fig. 1): superior appendages almost semicircular, slightly fused basally, angled apically in dorsal view (Fig. 1b). Tergum X in lateral view (Fig. 1a) longer than superior appendages, upturned from middle, constricted apically, with rounded apex; in dorsal view tergum X broad at base, then abruptly tapering to distal part composed of setose triangular mesal lobe and pair of slender lateral lobes turned mesad from middle. The main body of inferior appendage (inf. app.) in lateral view straight, without ventro-basal lobe and with dark caudoventral surface; mesal ridge (me. rdg.) tapered apically, with two short strong spines on caudal surface (Fig. 1c); subapico-dorsal lobe (sap. do.) elongate, bent caudad from base (Fig. 1a); harpago (har.) slightly longer than subapico-dorsal lobe, each with subapical triangular projection (Fig. 1c). Phallobase (phb.) with short ventral apex; parameres (par.) short, angled about 90 degrees from middle, bent ventro-caudad (Fig. 1d).

Female.—Unknown.

Diagnosis.—Within the *C.* (*C.*) *fulva* group, *C. valentinae* belongs to the subgroup including *C. albimacula* (Rambur), *C. alboguttata* (Hagen), *C. fulva* (Rambur), *C. transversa* (Hagen), *C. latahensis* (Smith) (Morse 1975, Yang & Morse 1988) and *C. morsei* (Kumanski 1991). All enumerated species have an unique synapomorphy of stout spine(s) on the caudal mesal ridge surface of each inferior appendage. *C. valentinae* most closely resembles *C. albimacula, C. alboguttata*

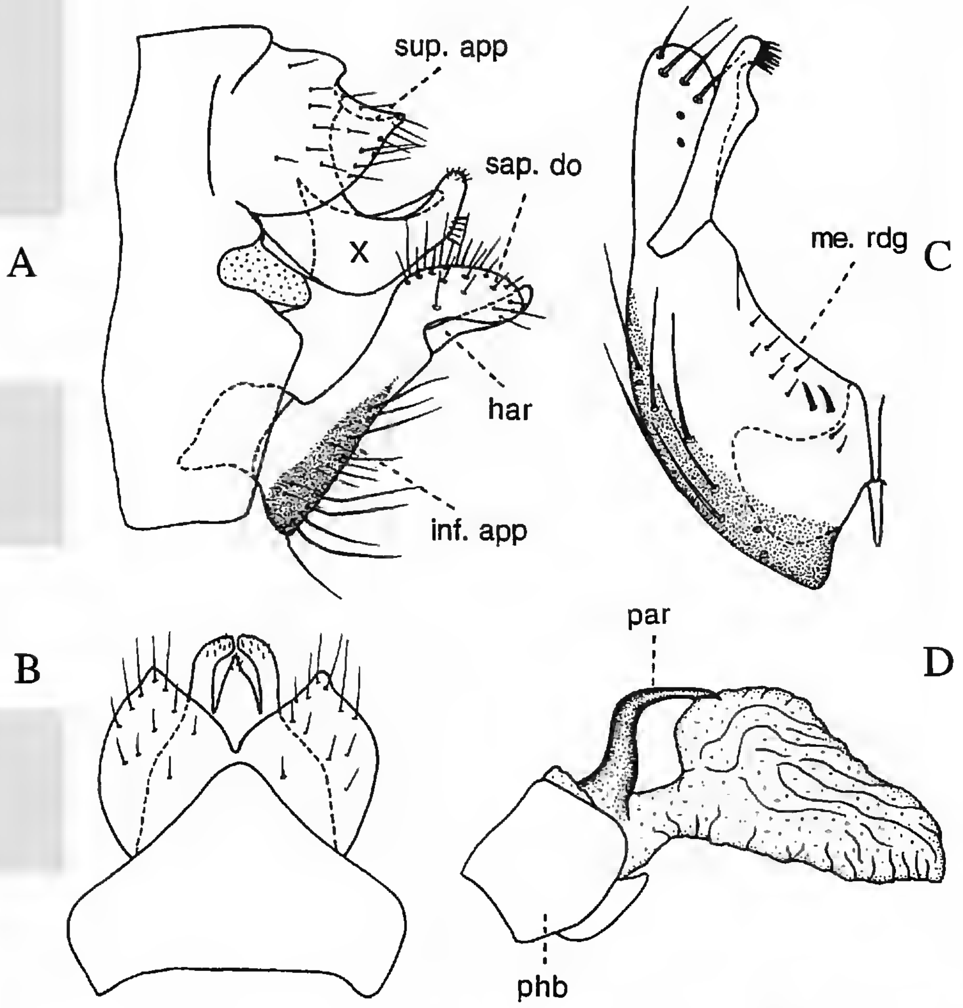


Figure 1. Male genitalia of *Ceraclea valentinae* NEW SPECIES in lateral (A) and dorsal (B) view; left inferior appendage (C) in ventro-caudal view; phallus (D) in lateral view. Abbreviations: har = harpago, inf. app. = inferior appendage, me. rdg. = mesal ridge of an inferior appendage, par = parameres, phb = phallobase; sap. do. = subapico-dorsal lobe of an inferior appendage, sup. app. = superior appendage, X = abdominal segment X.

and *C. fulva* in the broadly triangular subapical lobe of each harpago, in the short parameres and in the short stout spine(s) on the caudal mesal ridge surface of each inferior appendage. *C. latahensis, C. transversa* and *C. morsei* have single stout spines on the caudal mesal ridge surface, and these are much longer than the two spines in the new species. *C. valentinae* shares with *C. fulva* a pair of slender lateral lobes turned mesad of tergum X, and with *C. alboguttata* a similarly shaped triangular mesal lobe of tergum X. The superior appendages of the new species are shorter than tergum X and angled apically like those of *C. alboguttata* and *C. albimacula.* The new species shares with *C. albimacula* the dark caudo-ventral surface of the inferior appendage, and both species lack a baso-ventral lobe on each inferior appendage. *C. valentinae* differs from *C. albimacula* by its well developed triangular mesal lobe and unclavate lateral lobes of tergum X. The harpago is slightly longer than the subapico-dorsal lobe of each inferior appendage in the new species, but not in *C. albimacula.* The new species is distinguished from *C. alboguttata* and *C. fulva* by lacking a baso-ventral lobe on the inferior appendage, and from *C. fulva* by possessing an unbifid mesal lobe on tergum X. Tergum X in the new species extends well past the superior appendages, while in *C. fulva* tergum X is subequal to the superior appendages. *C. valentinae* differs from the other species mentioned above by possessing two short spines on the caudal mesal ridge surface and by having more strongly curved parameres.

Distribution.—Known only from the type locality in the south Kuril Islands.

Etymology.—The species is named in honor of Valentina Teslenko, a specialist in Plecoptera (Institute of Biology and Soil Sciences, Russian Academy of Sciences), the collector of the new species.

Material Examined.—See Type.

ACKNOWLEDGMENT

I sincerely thank John C. Morse, Professor of Entomology, Director of the Clemson University Arthropod Collection, for his valuable advice and confirmation of the legitimacy of the new species. My sincere thanks are due to Yuri A. Tshistjakov, Institute of Biology and Soil Science, Vladivostok, for critical reading of the manuscript, and to Noboru Minakawa, University of Washington, Seattle, for his kind help in preparation of the manuscript. The work described here was supported in part by the International Programs Division and the Biological Sciences Directorate (Biotic Surveys and Inventories Program) of the U.S. National Science Foundation, Grant No. DEB-9400821, Theodore W. Pietsch, principal investigator.

LITERATURE CITED

Kumanski, K. 1991. Studies on the fauna of Trichoptera (Insecta) of Korea. II. Family Leptoceridae. Historia naturalis bulgarica, 3: 49–71.

Morse, J. C. 1975. A phylogeny and revision of the caddisfly genus *Ceraclea* (Trichoptera, Leptoceridae). Contributions of the American Entomological Institute, 11: 1–97.

Yang, L. & J. C. Morse. 1988. *Ceraclea* of the People's Republic of China (Trichoptera: Leptoceridae). Contributions of the American Entomological Institute, 23: 1–69.

Received 15 Dec 1995; Accepted 4 Nov 1996

PAN-PACIFIC ENTOMOLOGIST
73(2): 103–109, (1997)

THE COSTA RICAN SPECIES OF *WESMAELIA* FOERSTER WITH DESCRIPTION OF A NEW SPECIES (HYMENOPTERA: BRACONIDAE: EUPHORINAE)

Scott Richard Shaw
Department of Plant, Soil, and Insect Sciences, University of Wyoming,
Laramie, Wyoming 82071-3354

Abstract.—*Wesmaelia pendula* Foerster is recorded for the first time from Costa Rica. A second species from Costa Rica, *Wesmaelia lizanoi* NEW SPECIES, is described and illustrated. A key to the two New World species is included.

Key Words.—Insecta, Braconidae, Euphorinae, *Wesmaelia,* Costa Rica, new species.

The genus *Wesmaelia* was described by Foerster (1862) in honor of the Belgian hymenopterist Constantin Wesmael, who made numerous contributions to our knowledge of braconid wasps during the 1830s. With its exceptionally long and slender first metasomal segment (Fig. 2), *Wesmaelia* is one of the most distinctive euphorine genera (S. Shaw 1985), but it is usually regarded as rather rare (M. Shaw & Huddleston 1991). For more than 125 years *Wesmaelia* has been known only by the type-species, *W. pendula* Foerster, but in recent years three additional species have been described in the Old World (Papp 1990; Belokobylskij 1992; Papp & Chou 1995). Only one of these four, the holarctic *W. pendula,* has been previously reported in North America (Marsh 1979). The hosts of most *Wesmaelia* are unknown, but *W. pendula* is recorded in the United States as a koinobiont endoparasitoid of the late instar nymphs and adults of nabid bugs of the genus *Nabis* (Muesebeck 1963; Marsh 1979; S. Shaw 1985, 1988, 1995; M. Shaw & Huddleston 1991).

Around 1989 I began a collaboration with Prof. Paul Hanson, of the Universidad de Costa Rica, to help develop a textbook to the Hymenoptera of Costa Rica. As a result of this effort, dozens of Malaise traps were operated at sites throughout the country, and many thousands of specimens of Braconidae were collected and prepared for study (Hanson & Gauld 1995). One of the unexpected surprises of this project was the discovery of the new species described in this paper. One male and two female specimens of *W. pendula* were also found at the Zurqui de Moravia site in San Jose Province, extending the known southern limit of distribution for this species from Mexico to central Costa Rica.

Materials and Methods

Wesmaelia species can be identified as members of the subfamily Euphorinae using the keys of S. Shaw (1995), Sharkey (1993), or M. Shaw & Huddleston (1991). Diagnosis of *Wesmaelia* follows that of S. Shaw (1985) and Papp & Chou (1995). Specimens can be determined as *Wesmaelia* using the keys of S. Shaw (1985), or Marsh et al. (1987). Specimens keyed through Marsh et al. (1987) will key to couplet 222. The genus is easily diagnosed by the slender first metasomal segment (Fig. 2), along with the forewing venation (as Fig. 3) with reduced M-Cu vein, strongly curved Rs, and no closed second submarginal cell.

The morphological terminology used here follows that of Shaw (1985, 1987), except for the wing venation terminology, which is adapted to conform to more recently adopted changes (Huber & Sharkey 1993). Microsculpture terminology follows that of Harris (1979). Body length was calculated by measuring from the front of the head (exclusive of the antennae) to the apex of the propodeum, and adding the measure of the metasomal length (exclusive of the ovipositor), thus avoiding the problem created by specimens that die with the metasoma flexed in various positions (see Figs. 2 & 4).

Abbreviations for specimen depositories are as follows: Rocky Mountain Systematic Entomology Laboratory, University of Wyoming, Laramie (RMSEL); Museo de Insectos, Universidad de Costa Rica, San Jose (MIUCR); and Instituto Nacional de Biodiversidad, Heredia (INBio).

KEY TO THE NEW WORLD SPECIES OF *WESMAELIA*

1a. Petiolate first metasomal tergum longer than mesosoma and strongly curved in lateral view (Fig. 2); mesosoma mostly black; females with 17–18 flagellomeres, males with 21–22 ..... *W. lizanoi* NEW SPECIES

1b. Petiolate first metasomal tergum shorter than mesosoma and less curved than in Fig. 2; mesosoma mostly orange except propodeum black; females with 25–33 flagellomeres, males with 25–29 .... *W. pendula*

WESMAELIA LIZANOI SHAW, NEW SPECIES
(Figs. 1–3)

Types.—Holotype, female; data: COSTA RICA. *SAN JOSE:* Zurqui de Moravia, 1600 m el, Oct-Dec 1990, P. Hanson, Malaise trap; deposited: Rocky Mountain Systematic Entomology Laboratory, University of Wyoming, Laramie. Paratypes: 3 females, 2 males, same data as holotype; 1 male, same data except Jan-Feb 1989; 1 male, same data except Mar 1989; 1 female, 2 males, same data except Jun 1990; 2 females, 2 males, same data except Jul 1990; 3 females, same data except Apr 1991; 1 male, same data except Jul 1991; 1 female, same data except Mar 1992; 2 females, same data except Apr 1992; 1 male, same data except May 1992; 1 male, same data except Jul 1992; 2 females, same data except Feb 1994; 3 females, same data except Apr 1994; 1 female, same data except Jun-Jul 1994; 1 female, same data except Jan 1995; 3 females, 8 males, same data except Mar 1995; 1 female, 2 males, same data except Jun 1995; 1 female, 2 males, same data except Aug 1995. 2 females, *HEREDIA:* Vara Blanca, Finca Georgina, 2100 m, Jul-Aug 1990, P. Hanson, Malaise trap; 7 females, same data except Mar-Apr 1990; 2 females, 4 males, same data except May-Jun 1990; 2 females, same data except Jul 1990. 1 female, *PUNTARENAS:* San Vito, Jardin Bot. Las Cruces, 1200 m, Dec 1988, P. Hanson, Malaise trap. Paratypes deposited: RMSEL, MIUCR, INBio.

Description of Holotype Female.—Body length 3.8 mm; forewing length 2.8 mm. Head as in Fig. 1, transverse, surface mostly smooth with moderately dense setae; temple highly polished and mostly devoid of setae; ocelli small, ocell-ocular distance 2.6× greater than lateral ocellus width; eyes ovoid, 1.8× taller than wide in anterior view; with inner margins nearly parallel, barely converging ventrally; antennal scape short, 1.6× longer than wide; antenna with 18 flagellomeres; basal flagellomeres long and slender, first flagellomere 5× longer than wide; apical flagellomeres more compact, apical flagellomere 1.7× longer than wide; median carina between antenna mostly effaced, indicated only

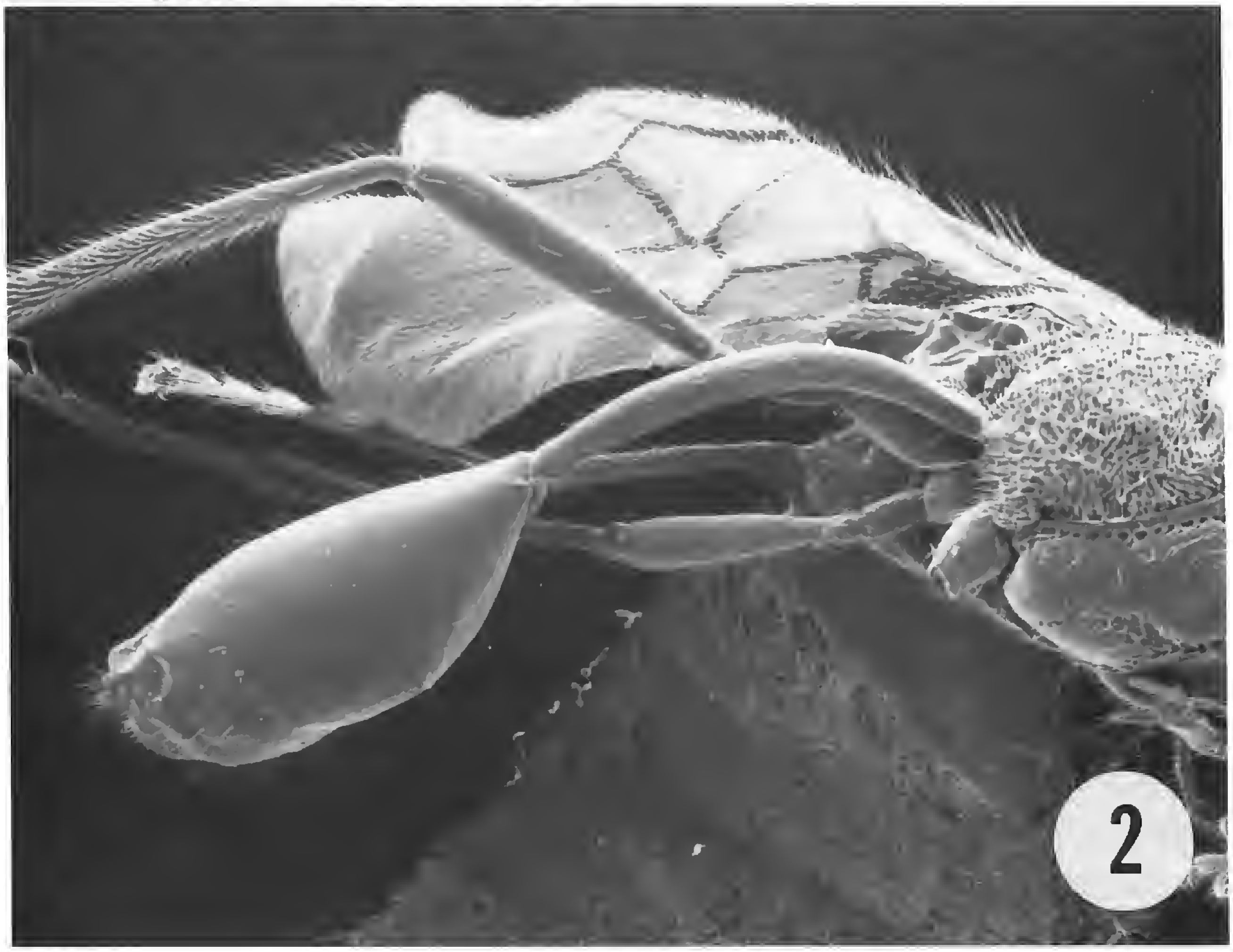


Figure 1. Head of *Wesmaelia lizanoi,* anterior view, antennae removed.

Figure 2. Posterior half of mesosoma and metasoma of *Wesmaelia lizanoi,* lateral view, right wing removed.

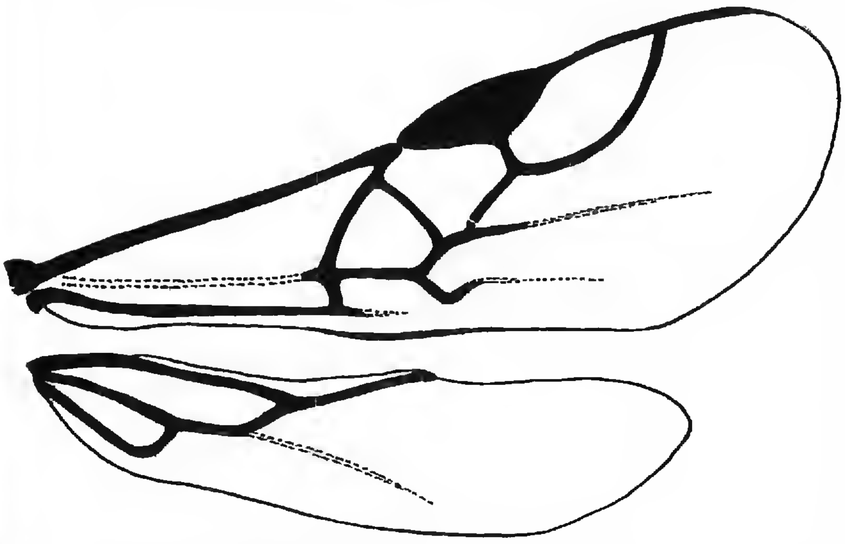


Figure 3. Wings of *Wesmaelia lizanoi.*

by trace rugulose sculpture; face 1.9× wider than tall; clypeus with lower margin rounded; malar space very narrow, 0.9× basal width of mandible; mandibles long and slender, nearly completely overlapping when closed. Mesosoma 1.4× longer than tall in lateral view; pronotum and prosternum mostly areolate-rugose; mesonotum and scutellar disc mostly smooth, except notauli foveate; mesopleuron mostly smooth and devoid of setae on medial disc, except antero-ventral sternaulus foveate; propodeum deeply excavated medially; propodeal sculpture finely areolate, except smooth area dorsad metasomal insertion delimited dorsally by a transverse carina; hind tibia with apical fringe of flat setae along inner margin; wings as in Figs. 2–3; pterostigma 2.7× longer than tall; vein Rs sharply curved, meeting wing margin well before apex; length of marginal cell along wing margin 0.75× pterostigma length. Metasoma as in Fig. 2, smooth, highly polished, and mostly devoid of setae except along posterior margins of posterior segments; petiolate first metasomal segment exceptionally long and slender, 8.4× longer than midpoint width in lateral view, longer than entire mesosoma, and strongly curved in lateral view (Fig. 2); metasoma beyond petiole with 6 visible segments, 2.7× longer than tall in lateral view, terga weakly sclerotized and somewhat indented posteromedially; hypopygium truncated, finely carinate medially; ovipositor sheath 4.4× longer than tall in lateral view; needle-like tip of ovipositor just visible beyond sheath apex. *Color:* Ocellar triangle, vertex posteriorly, mesosoma, petiolate first metasomal segment, metasomal terga 2 + 3, and ovipositor sheath dark brown to black; eyes silver; antenna, remainder of head, legs, and remainder of metasoma mostly light yellow-brown; membranous parts of metasoma white; wing membrane transparent; pterostigma and wing venation pale brown.

Diagnosis.—*Wesmaelia lizanoi* can be distinguished from related species by its unique combination of short antennae with 17–18 flagellomeres in the females, 21–22 flagellomeres in the males, eyes barely converging ventrally (Fig. 1), the exceptionally long and slender first metasomal segment (Fig. 2), and extensive black coloration on the top of the head, the entire mesosoma, and much of the metasoma.

Variation.—All variation noted is based on study of the paratypes. Females with body length 3.3–4.1 mm; forewing length 2.3–2.8 mm; antenna with 17–18 flagellomeres; light-colored parts of body varying from yellow-brown to pale brown-white or white; metasoma posteriorly and ventrally infused with varying amounts of dark brown pigment. Color of the face is more pure white in specimens from Vara Blanca, as compared with those from other sites. There is substantial variation in the apparent size of the metasoma beyond the petiolate first segment (varying from 2.7–4.1× longer than tall in lateral view), depending on the degree to which segments are telescoped outwards. The great length of the first metasomal segment, along with the telescoping capability of the remaining segments, allow the metasoma to swing ventrally and anteriorly, presumably allowing oviposition

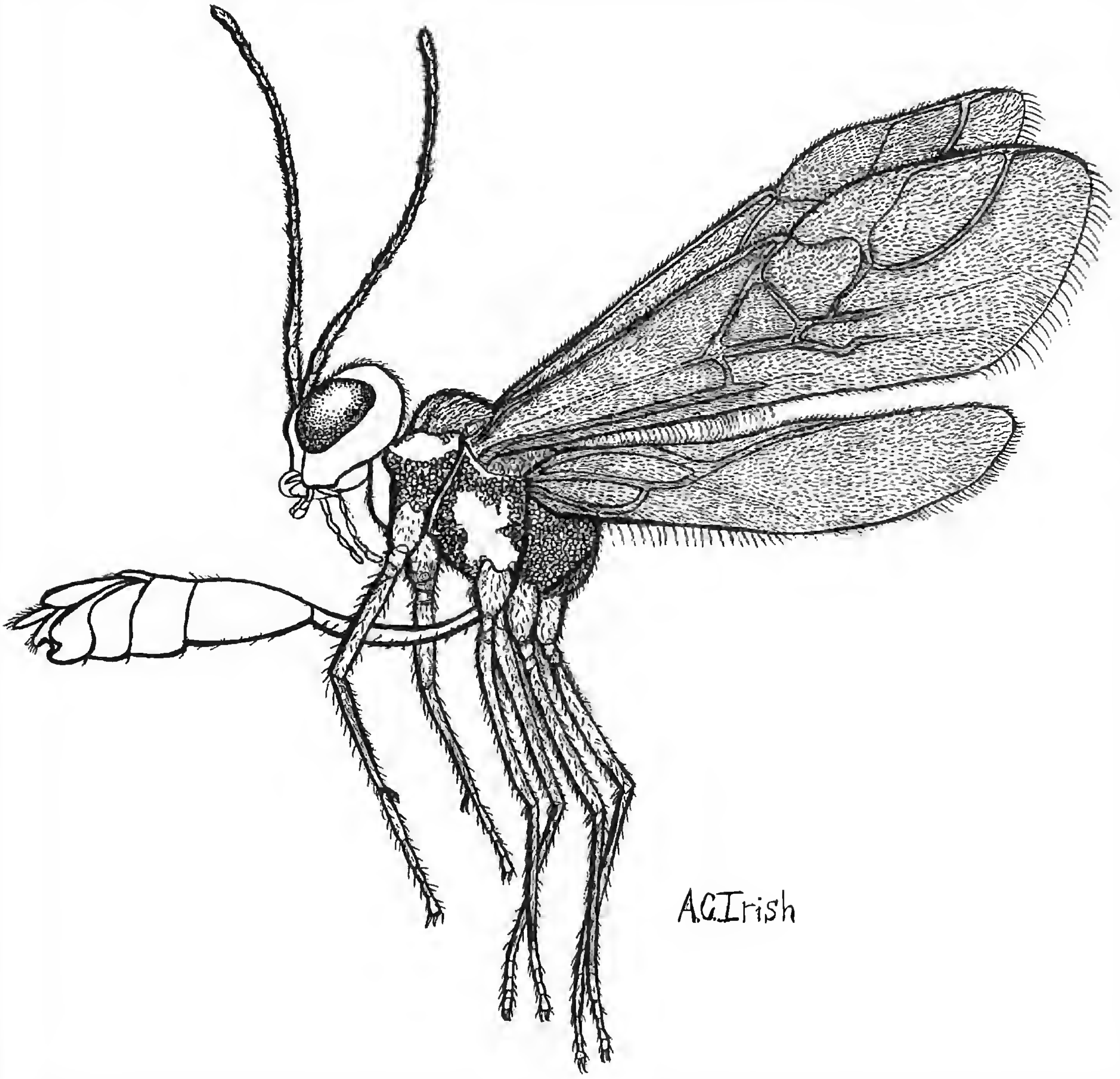


Figure 4. Lateral habitus of *Wesmaelia lizanoi* female, with metasoma advanced in ovipositional posture.

in front of the body of the wasp (Fig. 4). Several specimens died with the metasoma extended in this forward position.

Males with body length 2.9–3.7 mm; forewing length 2.4–3.0 mm; antenna with 21–22 flagellomeres; flagellum and metasoma much darker than in female, mostly dark brown to black; propodeal sculpture entirely finely areolate, lacking a smooth area above the metasomal insertion.

Distribution.—Known only from three Costa Rican sites in Heredia, San Jose, and Puntarenas Provinces, at elevations ranging from 1200 to 2100 meters. The site at Zurqui de Moravia is located on the main highway east from San Jose to Limon, just before the entrance to Braulio Carillo National Park, behind the La Fonda restaurant. The Zurqui Malaise trap has been situated for several years just over the crest of a grassy hill on the edge of (and overlooking) a moist primary cloud forest, rich in epiphytes. The site at Vara Blanca is located at Finca Georgina, a farm belonging to the president of the Dos Pinos dairy company. The Finca Georgina Malaise trap was situated on the edge of a strip of primary forest remaining in a ravine. The site at San Vito is located at the Jardin Botanica Las Cruces, also known as the Wilson Botanic Garden.

Biology.—The hosts of *W. lizanoi* are unknown, but if its habits are similar to *W. pendula,* then this new species also parasitizes late instar nymphs and adults of nabid bugs. Adults of *W. lizanoi* have been collected during almost every month of the year, indicating that this species is probably multivoltine.

Etymology.—This species is named in honor of Sr. Jorge Arturo Lizano, owner of the La Fonda restaurant, behind which the "Zurqui de Moravia" Malaise trap was situated. Through his courtesy many new insects have become known to science.

Material Examined.—See Types.

ACKNOWLEDGMENT

Special thanks to Paul Hanson for providing specimens and detailed information on the sites of the Malaise traps. Scanning electron microscopy for Figs. 1–2 was done by Paul Marsh. The habitus drawing (Fig. 4) was done by Ms. Amy Irish. This research was supported by grant DEB-930-0517 from the National Science Foundation.

LITERATURE CITED

Belokobylskij, S. A. 1992. *Wesmaelia* and *Syrrhizus* species (Hymenoptera, Braconidae, Euphorinae) in the Far East. Vest. Zool., 1992: 8–16 (in Russian).

Foerster, A. 1862. Synopsis der Familien und Gattuungen der Braconen. Verh. Naturh. Ver. Preuss. Rheinl. 19: 224–288.

Hanson, P. E. & I. D. Gauld. 1995. The Hymenoptera of Costa Rica. Oxford University Press, Oxford.

Harris, R. A. 1979. A glossary of surface sculpturing. Occas. Pap. Entomol. 28: 1–31.

Huber, J. T. & M. J. Sharkey. 1993. Structure. pp. 13–59. *In:* Goulet, H. & J. T. Huber (eds.), Hymenoptera of the World: An identificaiton guide to families. Centre for Land and Biological Resources Research, Ottawa, Ontario. Research Branch, Agriculture Canada, Publication 1894/E.

Marsh, P. M. 1979. Family Braconidae. pp. 144–313. *In:* Krombein, K. V., P. D. Hurd Jr., D. R. Smith, & B. D. Burks (eds.), Catalog of Hymenoptera in America North of Mexico. Smithsonian Institution Press, Washington, D.C.

Marsh, P. M., S. R. Shaw & R. A. Wharton. 1987. An identification manual for the North American genera of the Family Braconidae (Hymenoptera). Mem. Entomol. Soc. Wash., 13: 1–98.

Muesebeck, C. F. W. 1963. Host relationships of the Euphorinae (Hymenoptera: Braconidae). Proc. Entomol. Soc. Wash., 65: 306.

Papp, J. 1990. New braconid wasps (Hymenoptera: Braconidae) in the Hungarian Natural History Museum, 1. Ann. hist.-nat. Mus. natn. Hung., 82: 175–190.

Papp, J., & L-y. Chou. 1995. The genus *Wesmaelia* Foerster of Taiwan (Hymenoptera: Braconidae: Euphorinae). Chin. J. Entomol., 15: 345–354.

Sharkey, M. J. 1993. Family Braconidae. pp. 362–394. *In:* Goulet, H. and J. T. Huber (eds.). Hymenoptera of the World: An identification guide to families. Centre for Land and Biological Resources Research, Ottawa, Ontario. Research Branch, Agriculture Canada, Publication 1894/E.

Shaw, M. R. & T. Huddleston. 1991. Classification and biology of braconid wasps (Hymenoptera: Braconidae). Handbooks for the Identification of British Insects, Volume 7, Part 11. Royal Entomological Society of London.

Shaw, S. R. 1985. A phylogenetic study of the Subfamilies Meteorinae and Euphorinae (Hymenoptera: Braconidae). Entomography, 3: 277–370.

Shaw, S. R. 1987. *Orionis,* a new genus from Central America, with an analysis of its phylogenetic placement in the Tribe Euphorini (Hymenoptera: Braconidae). Syst. Entomol., 12: 103–109.

Shaw, S. R. 1988. Euphorine phylogeny: the evolution of diversity in host-utilization by parasitoid wasps (Hymenoptera: Braconidae). Ecol. Entomol., 13: 323–335.

Shaw, S. R. 1995. Braconidae. pp. 431–463. *In:* Hanson, P. E. and I. D. Gauld (eds.). The Hymenoptera of Costa Rica. Oxford University Press, Oxford.

Received 23 May 1996; Accepted 4 Nov 1996

PAN-PACIFIC ENTOMOLOGIST
73(2): 110–121, (1997)

POPULATION DENSITY AND DISPERSAL ABILITY IN DARWIN'S DARKLINGS: FLIGHTLESS BEETLES OF THE GALÁPAGOS ISLANDS[1]

T. L. FINSTON[2], S. B. PECK, AND R. B. PERRY[2]
Department of Biology, Carleton University
Ottawa, Ontario K1S 5B6 Canada

Abstract.—This study is the first to combine both field and genetic data to examine population structure in flightless beetles from the Galápagos Islands. Field studies were conducted on four species of tenebrionid beetles belonging to three genera, *Ammophorus* Gúerin-Méneville, *Blapstinus* Latreille, and *Stomion* Waterhouse. The dynamics of the beetle community at the study site, Tortuga Bay, Santa Cruz Island, were analyzed in an attempt to examine patterns of activity and to quantify species abundances, population sizes, densities and levels of individual vagility. Beetle activity was found to vary with temperature, precipitation and number of sunlight hours. Although the number of recaptures was low, densities in the quadrats ranged from eight *B. lugubris* Boheman per hectare to 1238 *S. laevigatum* Waterhouse per hectare. Individual vagility is shown to be low among *S. laevigatum*, the most abundant species at the study site, as the dispersion index (DI) showed that captures were aggregated in three of the four quadrats, suggesting little movement. In addition, beetle captures occurred more frequently than expected in internal traps, again revealing limited movement into or out of the quadrats. These results were confirmed by a separate analysis of genetic differentiation among demes of *S. laevigatum* which showed the number of migrants to be less than one per generation.

Key Words.—Insecta, Coleoptera, ecology, mark and recapture, population structure, tenebrionid beetles

The Galápagos Islands have provided striking examples of species radiations under conditions of allopatry. The role of geographic isolation in island archipelagoes has long been recognized in limiting gene flow and promoting reproductive isolation (Mayr 1963). Geographic isolation may also be imposed by life-history parameters such as low dispersal ability or flightlessness. Isolation may also result from habitat restriction, whereby populations are spatially separated by regions of unsuitable habitat (King 1987, Crouau-Roy 1989), or by host plant specificity (McCauley & Eanes 1987). Genetic studies on flightless insects (Zera 1981, Finston & Peck 1995) and birds (Baker et al. 1995) have revealed high levels of genetic differentiation among populations and low genetic variability.

The migration of individuals can be measured using both direct and indirect methods. Mark and recapture studies can be used to directly measure individual vagility and provide estimates of the number of migrants between demes. In particular, pitfall traps have commonly been used in population studies of surface dwelling insects, although their use is highly dependent upon a number of factors, including vagility of the organism under study, and ecological factors such as the influence of substrate type, vegetation and weather patterns on activity levels (Ahearn 1971, Thomas & Sleeper 1977). Alternately, population genetic structure

---

[1] Authors page charges partially offset by a grant from the C. P. Alexander Fund, Pacific Coast Entomological Society.

[2] Current Address: Department of Zoology, University of Guelph, Guelph, Ontario, Canada N1G 2W1.

can be measured, and the amount of gene flow and migration inferred. Investigations into the role of limited vagility may provide an insight into patterns of microevolutionary change. The extent of isolation and gene flow among spatially separated populations determines the potential for phenotypic and genetic differentiation. Indeed, speciation is most active where geographic barriers are greatest-among insular habitats (Mayr 1942, 1966).

Prior work on species radiations in the Galápagos Islands has focused on the vertebrate fauna (Van Denbergh 1914, Hendrickson 1966, Lack 1968, Grant 1986), however, the invertebrate fauna also provides striking examples of species radiations (Coppois 1984, Peck & Kukalova-Peck 1990). In particular, the Galápagos supports a rich assemblage of tenebrionid (darkling) beetles. Darkling beetles are often abundant members of surface dwelling communities in arid and semi-arid environments (Crawford 1990). Tenebrionid species occur sympatrically in arid regions all over the world (Thomas 1983), and most are flightless, night active members of these communities (Doyen & Tschinkel 1974). A total of 51 species are known in 14 genera from the Galápagos Islands. Most notable are Darwin's darklings, *Ammophorus* Gúerin-Méneville, *Blapstinus* Latreille, and *Stomion* Waterhouse, three genera containing 38 described species of flightless, ground-dwelling beetles (Peck & Kukalova-Peck 1990). Collectively, this group represents the largest radiation of beetle species in the archipelago. Four of these species, belonging to all three genera, were found sympatrically at a single site, and were the focus of this study. The present study represents the first attempt to quantify population sizes, densities, species abundances and beetle activity in a tenebrionid community in the Galápagos Islands, and provides the first examination of dispersal ability in a Galápagos insect, employing both field and population genetic data.

MATERIALS AND METHODS

The present study involved two field components: a mark and recapture study, and a weekly transect study. The field site was the dune area located at Tortuga Bay on the island of Santa Cruz, Galápagos. Beetles were identified using the key of Van Dyke (1953). Field work took place March to July, 1992.

Mark and Recapture Study.—In order to assess species assemblages, population sizes and densities, and dispersal ability, four separate quadrats were arranged, each consisting of five rows of five traps. Each trap was 2 m from any other trap in a quadrat, and consisted of small, unbaited cylindrical plastic containers 10 cm in diameter and 6 cm deep. Each trap was equipped with a cover which was used to close the traps and a coarse wire screen (used when the traps were open) to prevent beetle predation by birds and lizards. Each quadrat covered 64 m^2. The quadrats were arranged as in Fig. 1, such that each quadrat was situated in the corner of a 32 m × 102 m rectangle.

The vegetation was not homogeneous over the entire study area; the quadrats differed both in plant species present and in the proportion of ground covered by vegetation. The plant composition in order of abundance for each quadrat is as follows, with the estimated percent of ground cover noted in brackets: I. *Scaevola plumieri*, *Ipomoea pes-caprae*, *Sesuvium portulacastrum*, *Heliotropium sp.*, some grasses (80%); II. *Scaevola plumieri*, *Ipomoea pes-caprae*, *Sesuvium portulacastrum*, *Prosopis juliflora* (90%); III. *Scaevola plumieri*, *Sesuvium portulacastrum*,

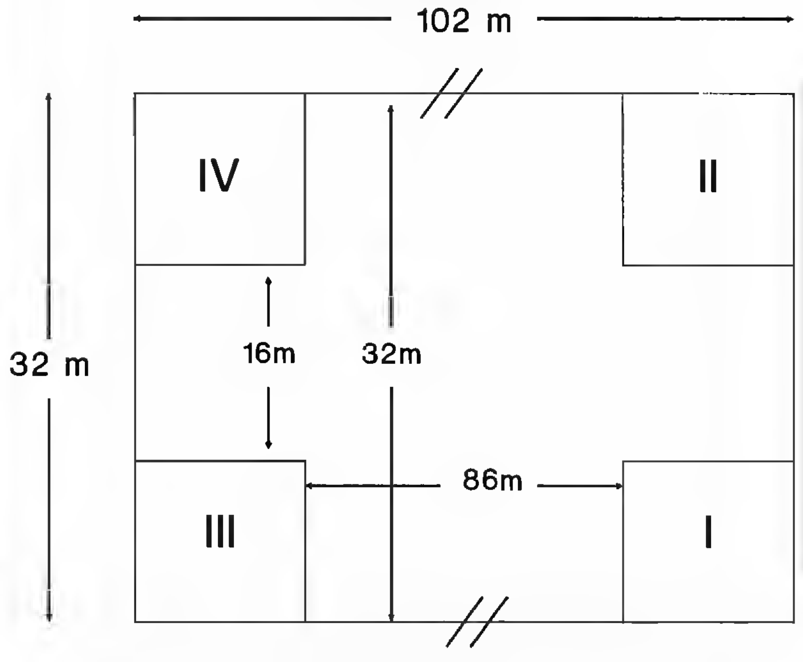


Figure 1. Arrangement of traps and quadrats used in the mark and recapture study.

Ipomoea pes-caprae, *Heliotropium sp.* (60%); IV. *Heliotropium sp.*, *Tiquilia darwinii*, *Cryptocarpus pyriformis*, *Prosopis juliflora* (15%).

The traps were opened for a twelve hour period, from dusk to dawn, at five day intervals from 15 Jun to 8 Jul 1992. Individuals caught in the traps were recorded by quadrat and trap number, and marked with a dot of white typing correction fluid in the corner of the elytron which corresponded to the quadrat in which it was caught. Thus, recaptured individuals could be identified with respect to their original quadrat of capture. The beetle was then released at the site of capture. Estimates of population size (N) were calculated for those quadrats in which marked beetles were recaptured using the geometric model described by Thomas & Sleeper (1977):

$$N = M/[1 - (M/t)];\ s^2 = M^2t(t - r)/r^3$$

where M = number of individuals marked; r = number of individuals recaptured, and t = total number of captures (= total number marked + recaptures). This model was chosen because it does not assume equal catchability rates among individuals, and minimizes stochastic events by permitting the use of cumulative results. Population density was calculated by dividing N by the unit area in hectares.

The dispersion index (DI) was calculated for *S. laevigatum* Waterhouse only, the most abundant beetle in the quadrat area. The DI (variance/mean) approximates unity when individuals are randomly distributed; a higher DI suggests aggregations of individuals (Fowler & Cohen 1990). A chi-square analysis was used to test the random distribution of individuals in each of the four quadrats. In addition, a chi-square test of the observed and expected number of captures (assuming a uniform distribution) from peripheral and internal traps was performed as a further inspection of the dispersal habits of *S. laevigatum*.

Transect Census.—As an independent assessment of community assemblages and beetle activity, a 100 m transect was marked along a one m wide foot trail which crossed the littoral and arid vegetation zones. The substrate changed from a fine white marine sand to volcanic rock approximately 20 m from the start of the transect. Sampling took place every five days and continued for eight weeks, from 8 May to 7 Jul 1992. Baits of 5 gm of dry oatmeal were laid out at 2 m intervals at dusk, such that each bait site covered approximately 2 m^2. The transect was inspected one hour later, beginning at the site closest to the beach. The numbers of individuals of each species belonging to the three tenebrionid genera were recorded for each bait site. In order to examine the effects of local climatic conditions on species abundance and activity, weather data collected at the Charles Darwin Research Station was used for analysis. The research station lies approximately 2 km from the study site at Tortuga Bay, and is thus representative of the climatic conditions at the study site. Data included in this analysis were temperature and humidity at 18:00 h, total precipitation, number of hours of sunlight, and minimum and maximum temperatures for the day in which the count was made. In addition, the total precipitation for the seven day period preceding each sampling date was used. Pearson correlations and their corresponding probabilities were calculated between these ecological data, and weekly species richness (number of different species found in the evening's collection) and individual species abundances using the CORR module in SYSTAT (Wilkinson 1988).

Genetic Analysis.—Stomion laevigatum were collected from the following 5 sites on 4 different islands: Caamaño-sea lion beach (CAAM); Isabela-Alcedo Rim (ARIM), Tagus Cove (TAGU); Santa Cruz-Tortuga Bay (BTOR) Santiago-Playa Espumilla (SANT). Where possible, 44 individuals were analyzed for variation at eight polymorphic enzyme loci using cellulose acetate electrophoresis (Hebert & Beaton 1993). The loci analyzed were as follows: hexokinase (*Hk-2*), mannose-6-phosphate isomerase (*Mpi*), phosphoglucomutase (*Pgm-1*), peptidase-A (*Pep*, utilizing phe-pro), supernatant and mitochondrial glutamate oxaloacetate transamerase (*Got-s*, *Got-m*), 6-phosphogluconate dehydrogenase (*6pgdh*), and phosphoglucose isomerase (*Pgi*). Genetic analyses were carried out using BIOSYS-1 (Swofford & Selander 1991) unless otherwise indicated. Allele frequencies were calculated for each site, and Wright's F-statistics were analyzed hierarchically such that gene frequency divergence could be measured among demes on the same island as well as among demes on different islands. (Wright 1940). Two models of gene flow were employed to obtain estimates of the number of migrants between demes. Wright's F-statistics were used to calculate the number of migrants using the following formula:

$$F_{ST} = 1/(4N_m + 1)$$

where N_m = the effective number of migrants per generation. Slatkin's rare alleles model (Slatkin 1985, 1987) was used to directly estimate the number of migrants between demes using the frequency of unique alleles as indicators of gene flow:

$$\ln [p(1)] = a\ln(N_m) + b,$$

where $p(1)$ is the average frequency of alleles found only in single populations and a and b are constants that depend on the population size. In order to use Slatkin's constants which were based on a sample size of 25, N_m was multiplied by the ratio 25/n where n is the mean sample size of those populations possessing unique alleles (Slatkin 1985, 1987).

RESULTS

Mark and Recapture Study.—Four species, *Ammophorus bifoveatus* Waterhouse, *Blapstinus lugubris* Boheman, *B . spatulatus* Van Dyke, and *Stomion lae-*

Table 1. The total number of individuals marked/recaptured for each species for all four quadrats.

Week	*A. bifoveatus*	*B. lugubris*	*B. spatulatus*	*S. laevigatum*
1	7/0	0/0	22/0	36/0
2	20/0	0/0	30/1	42/0
3	5/0	0/0	28/1	44/0
4	2/0	0/0	19/1	25/0
5	3/1	1/0	10/0	24/0
Total	37/1	1/0	119/3	171/0

vigatum were found at the study site. Of the 328 beetles captured, marked, and released, only four were recaptured (Table 1). A single individual of *A. bifoveatus*, three individuals of *B. spatulatus*, and no individuals of *S. laevigatum* or *B. lugubris* were recaptured. All four individuals were recaptured in their original quadrat of capture. Population sizes obtained from the model presented by Thomas & Sleeper (1977) are not reported here, as the estimates resulted in standard deviations which approached or exceeded the estimates themselves. Because of the poor recapture rate, population density was instead calculated each week by dividing the total number of individuals of each species in a quadrat by the unit area (64 m^2). The arithmetic mean over all four quadrats was then calculated over all weeks. Density estimates ranged from 8 *B. lugubris* per hectare to 1340 *S. laevigatum* per hectare (Table 2).

The DI showed that *S. laevigatum* captures were not random in three of the four quadrats, as this ratio approximated unity only in quadrat I (Table 3). Some traps caught large numbers of beetles, while others caught no beetles over the course of the study. Tests of distribution models showed that aggregation of beetles occurred in quadrats II, III and IV. Quadrat I fitted neither a Poisson nor a binomial distribution, although its chi-square value (8.00) was very close to the critical value (7.81) for acceptance of the random (Poisson) distribution model. Furthermore, a chi-square test showed significant deviations between the number of observed and expected captures in both peripheral and internal traps. Beetle catches occurred more frequently than expected in the internal traps and less frequently in the peripheral traps in three of the four quadrats (Table 4).

The number of captures per quadrat was not found to be significantly related to the estimated amount of vegetation cover (Pearson correlation = 0.765, P = 0.235), but the greatest number of captures did come from quadrats I and II,

Table 2. Weekly density estimates (per hectare) for four tenebrionid species averaged over each of four quadrats.

Week	*S. laevigatum*	*B. lugubris*	*B. spatulatus*	*A. bifoveatus*
1	1410	0	860	270
2	1640	0	1170	780
3	1220	0	1090	190
4	980	0	740	80
5	940	40	390	120
Mean (±SD)	1340 (294.5)	8 (17.9)	850 (309.8)	288 (284.4)

Table 3. Mean number of catches per trap ($\bar{x}$), standard deviation (SD), dispersion index (DI) and chi-square values (χ^2) for random (Poisson) and aggregated (binomial) distribution model tests for each of four quadrats in the mark and recapture study. * = $P < 0.05$.

Quadrat	$\bar{x}$	SD	DI	Poisson χ^2 (df)	Binomial χ^2 (df)
I	1.80	1.83	1.02	8.00* (3)	8.93* (2)
II	3.44	5.24	1.52	25.98* (9)	8.72 (8)
III	0.60	0.92	1.53	6.32* (2)	2.04 (1)
IV	1.12	1.69	1.51	14.10* (4)	7.67 (3)

which were estimated to be 80% and 90% vegetated, respectively. The fewest captures came from quadrats III and IV, which were an estimated 60% and 15% vegetated, respectively. *Stomion laevigatum* was the most abundant species in all four quadrats. *Ammophorus bifoveatus* and *B. spatulatus* were particularly rare in the less vegetated quadrats. No *A. bifoveatus* were captured in quadrat III and *S. laevigatum* was more than four times more abundant than *B. spatulatus*. In quadrat IV, *S. laevigatum* was twenty-seven times more abundant than *B. spatulatus* and fourteen times more abundant than *A. bifoveatus*. *Blapstinus lugubris* was captured only once, in quadrat II.

Transect Census.—The four species found in the quadrat area, *A. bifoveatus*, *B. lugubris*, *B. spatulatus*, and *S. laevigatum* were also found along the transect. A total of 1199 beetles were encountered, with *B. spatulatus* and *A. bifoveatus* being most common (Table 5). In contrast to the mark and recapture site, *S. laevigatum* was the least abundant species encountered. Evening beetle counts ranged from two to 208 individuals, and the number of species observed ranged from one to four.

Correlation of species abundance and richness with seven environmental conditions showed significant but negative correlations for several variables (Table 6). For example, the number of individuals of *B. spatulatus* and *A. bifoveatus* were negatively correlated with maximum daily temperature, temperature at 18:00 h, the days' precipitation, hours of sunlight during the day, and the total precipitation for the week preceding the sampling date. In contrast, the number of different species observed in a sample was shown to be positively correlated with percent relative humidity. The days' minimum temperature showed no effect on species abundance or diversity. The numbers of *S. laevigatum* and *B. lugubris* were not correlated with any measured environmental conditions.

Table 4. Chi-square test of number of expected versus number of observed captures in internal and peripheral traps for four quadrats. * = $P < 0.05$. df = 1.

	Internal			Peripheral		
Quadrat	Obs.	Exp.	χ^2	Obs.	Exp.	χ^2
I	13	16.2	0.632	32	28.8	0.356
II	43	31.2	5.38	41	53.8	3.03
III	7	5.4	0.474	8	9.6	0.267
IV	12	10.1	0.366	16	17.9	0.206
Total			6.852*			3.859*

Table 5. The number of individuals of each of four species of tenebrionids counted at the Tortuga Bay transect site on Santa Cruz Island, Galápagos.

Week	*S. laevigatum*	*B. lugubris*	*B. spatulatus*	*A. bifoveatus*
1	2	0	0	0
2	9	4	37	37
3	4	44	58	96
4	1	0	53	74
5	5	19	65	73
6	1	14	80	112
7	1	8	89	110
8	2	19	69	113
Totals	25	108	451	615

Genetic Analysis.—Although there were no allelic substitutions among sites at any of the eight loci surveyed for *S. laevigatum*, allele frequencies did differ among sites (Table 7). Genetic differentiation was substantial among demes at both hierarchical levels, where on average, nearly 40% of the total observed variation in allele frequencies was due to variation among demes, whether on the same island or on different islands (Table 8). Approximately 60% of the variation resulted from differences within demes (1-F_{ST}). Both models of gene flow produced migration estimates of considerably less than one migrant per generation among demes (Table 8). Wright's model produced an estimate of 0.429 migrants per generation among demes on the same island and 0.383 migrants per generation among demes on different islands. Similarly, Slatkin's model produced an estimate of 0.417 migrants per generation among demes on different islands.

DISCUSSION

The utility of pit-fall traps in mark and recapture studies for the estimation of population sizes has fallen under scrutiny (e.g. Southwood 1966, Thomas & Sleeper 1977). Many non-random effects such as changes in activity patterns or abundance of populations, and biases introduced by the trapping methodology, may affect catchability and population size estimates. However, these effects can be overcome when the proper precautionary measures are observed, such as main-

Table 6. Pearson correlation coefficients for individual species' abundances and species richness and seven environmental variables. T = temperature at 18:00, PP = daily precipitation, H = relative humidity at 18:00, SOL = number of sunlight hours, TMAX = maximum daily temperature, TMIN = minimum daily temperature, TPP = total precipitation in the week preceding the collection, TI = total number of individuals in the collection, TS = total number of species in the collection. * = $P < 0.05$.

Factor	T	PP	H	SOL	TMAX	TMIN	TPP
Taxon							
S. laevigatum	0.38	−0.16	0.39	0.38	0.48	0.25	−0.07
B. lugubris	−0.23	−0.38	0.07	−0.35	−0.35	0.11	−0.36
B. spatulatus	−0.93*	−0.82*	0.52	−0.73*	−0.96*	−0.68	−0.86*
A. bifoveatus	−0.87*	−0.77*	0.37	−0.76*	−0.96*	−0.52	−0.81*
TI	−0.85*	−0.80*	0.42	−0.74*	−0.94*	−0.51	−0.84*
TS	−0.70	−0.94*	0.71*	−0.51	−0.70	−0.46	−0.93*

Table 7. Allele frequencies for five populations of *S. laevigatum*. *n* = sample size.

Pop.	SANT	BTOR	CAAM	TAGU	ARIM
n	44	44	42	43	44
HK-2					
3	0.989	0.977	1.000	1.000	1.000
4	0.011	—	—	—	—
5	—	0.023	—	—	—
MPI					
2	0.034	—	—	0.012	—
3	0.375	—	0.012	—	0.080
4	0.580	0.372	0.666	0.928	0.920
5	0.011	0.581	0.012	0.060	—
6	—	0.047	0.310	—	—
PGM-1					
1	0.011	0.011	—	—	—
2	0.011	0.034	—	0.058	—
3	0.967	0.921	0.857	0.907	0.989
4	0.011	0.034	0.143	0.035	0.011
PEP					
2	—	0.284	0.119	0.081	0.080
3	0.989	0.693	0.881	0.919	0.920
4	0.011	—	—	—	—
5	—	0.023	—	—	—
GOT-M					
2	0.625	—	0.488	0.907	0.909
3	0.375	0.405	0.512	0.093	0.091
4	—	0.595	—	—	—
GOT-S					
1	0.012	—	—	—	—
2	0.035	—	—	—	—
3	0.720	0.667	—	—	—
4	0.233	0.333	0.561	—	0.966
5	—	—	0.439	1.000	0.034
6PGDH					
2	—	0.035	0.012	0.012	—
3	1.000	0.930	0.988	0.163	0.068
4	—	0.035	—	0.826	0.898
5	—	—	—	—	0.034
PGI					
1	—	0.023	—	—	—
2	0.125	0.080	—	0.186	0.011
3	0.546	0.874	1.000	0.791	0.989
4	0.295	0.023	—	—	—
5	0.034	—	—	0.023	—

taining uniform trap size and distance between traps, as well as using unbaited traps (Thomas & Sleeper 1977). Moreover, some surface-dwelling arthropods, such as tenebrionids, may be particularly amenable to pit-fall trapping techniques. This method was shown to be most effective in evaluating changes in population

Table 8. Estimates of the number of migrants per generation using two models of gene flow. F_{ST} = Wright's F-statistic, N_m = number of migrants.

Subgroup (S)	Total group (T)	F_{ST}	N_m (Wright)	N_m (Slatkin)
Site	island	0.368	0.429	—
Site	total	0.395	0.383	0.417

behaviour, density, and dispersal, but least effective at obtaining estimates of population size (Ahearn 1971). The number of recaptures in the present study was too few to allow a reliable estimation of population size for any of the species, therefore, distribution, population density and vagility of the beetles were all examined in the quadrats using the total number of captures.

Capture success may have been a function of both trapping methodology and patterns of beetles activity and abundance. For example, mortality rates may have been higher in marked beetles, that is, the correction fluid may have been toxic (although no dead, marked beetles were found in the study area), or they may have been more visible to predators. Alternately, the mark may have rubbed off during the course of the study as the beetle brushed against vegetation or sand while scavenging, although marked beetles held in captivity during the course of the study did not lose their markings (pers. obs.). Individual ranges may have been larger than the area covered by the four quadrats. Beetles, once marked, may have wandered out of the area. Finally, weekly patterns of beetle activity may also have been a contributing factor. Beetle activity on any given day may be affected by temperature, relative humidity, moon phase, recent rainfall, or amount of cloud cover (Thomas 1979). Indeed, the results of the transect study suggested that for at least two species, sand temperature and humidity may affect beetle activity and therefore recapture success. The highest number of evening sightings occurred following days with the lowest number of sunlight hours (less than five hours), perhaps as a result of lowered sand surface temperatures. In addition, the greatest species richness was noted on evenings with the greatest degree of daytime relative humidity, suggesting that cooler temperatures and some moisture favoured beetle activity. However, beetle activity was greatly reduced during heavy rains, such as on the first evening of collection.

Density estimates made from the total capture data were generally lower but in accordance with estimates for tenebrionids from other mark and recapture studies, ranging from 8–1340 beetles/hectare. Ahearn (1971) found the average density for five tenebrionid species to be about 1700 beetles/hectare at a site in South Mountain Desert Park in Phoenix, Arizona. Thomas & Sleeper (1977) found a range of 96–2755 beetles/hectare for six species in Rock Valley, Nevada. Similarly, Thomas (1979) found approximately 1000 beetles/hectare for the two most abundant species over a two year period in the Mojave Desert.

The results of this study further suggested that Darwin's darklings may have limited vagility. If individuals had large ranges, or good dispersal tendency, we would expect to capture some beetles in a quadrat different from that in which they were marked, or outside the quadrats. However, of the four beetles which were recaptured, each was found in the same quadrat in which it was marked. In addition, active searches in the area surrounding the quadrats produced no marked beetles. Because each beetle was recaptured in its original quadrat of capture, no direct estimates of displacement distances could be made. However, the DI for *S. laevigatum* showed that beetles tended to be aggregated in three of the four quadrats, suggesting little movement, although the use of pheromones as attracting agents cannot be discounted in explaining the observed aggregations. In addition, an analysis of the number of beetles trapped in peripheral and internal traps showed that more beetles were trapped in the internal traps than the peripheral traps. If populations were vagile, we would expect to trap more beetles in the peripheral traps, as beetles move in from the surrounding area. Doyen & Tschinkel (1974) found vagility to be low among some tenebrionid species in their study in the Chiricahua Mountains; beetles were frequently recaptured in the same or a nearby quadrat as that in which they were marked, and taxa which showed the greatest levels of aggregation were those which were least vagile. The comparatively low number of *S. laevigatum* at the near-by transect site also suggests that this taxon is limited in its range. These results were confirmed by an analysis of genetic differentiation among demes. Estimates of the number of migrants among demes using both Wright's F-statistics and Slatkin's rare alleles model for *S. laevigatum* showed dispersal to be very low, revealing less than one migrant per generation for both models (Finston & Peck 1995).

The dispersal ability of individuals of a species is largely responsible for the establishment and maintenance of geographical isolates (Mayr 1966:565). Darwin's darklings show narrow distributions; each species is found on only one or a few geographically close islands (Van Dyke 1953). The flightless condition of the beetles limits their dispersal ability, particularly across water gaps. Peck (1994a,b) showed that various Coleoptera are occasionally present as aerial plankton or as pleuston between islands in the archipelago. Darwin's darklings, however, range from 5–10 mm and are larger than the small-bodied Coleoptera typically found as aerial plankton. It is likely that only single or few founding individuals, carried as sea surface pleuston, were responsible for the colonization of new islands. Although the Galápagos climate is semi-arid, it is seasonal, having both a wet and a dry season. Nevertheless, as with other, more stable tropical habitats, there may be little pressure for seasonal movement of beetles in search of favourable habitats. Furthermore, the highly stratified vegetation zones of the islands (Wiggins & Porter 1971) may pose geographical barriers for tenebrionid beetles, which are largely restricted to the littoral and arid zones (Van Dyke 1953, Finston 1993). This, and a previous study (Finston & Peck 1995) showed that dispersal ability and gene flow are limited even on a local scale; the number of migrants between populations was less than one per generation between populations on the same island. The potential for few founders and limited subsequent movement of flightless beetles provides a model for the establishment and maintenance of geographical isolation of populations. Such isolation is necessary for microevolutionary change- localized differentiation through both adaptation and stochastic events such as founder effects and genetic drift- and ultimately, speciation.

ACKNOWLEDGMENT

F. Cepeda and A. Izurieta, Superintendents, Galápagos National Park (Department of Forestry, Ministry of Agriculture, Republic of Ecuador) issued scientific research permits. Field logistical support and meteorological data were provided by the Charles Darwin Research Station, Santa Cruz Island, D. Evans, and C. Blanton, Directors. Field work was partially supported by a research grant to SBP from the Natural Sciences and Engineering Research Council of Canada and an OGS award to TLF. Field sampling was aided by Sandra Abedrabbo, Joyce Cook, Moraima Inca, Bernard Landry, Ricardo Palma, and Eduardo Villema. The manuscript was improved by comments from Margaret Beaton, Konjev Desender, Chris Wilson, and several anonymous reviewers.

LITERATURE CITED

Ahearn, G. A. 1971. Ecological factors affecting population sampling of desert tenebrionid beetles. Amer. Midl. Nature., 86: 385–406.

Baker, A. J., C. H. Daugherty, R. Colbourne, & J. L. McLennan. 1995. Flightless brown kiwis of New Zealand possess extremely subdivided population structure and cryptic species like small mammals. Proc. Natl. Acad. Sci., USA. 92: 8254–8258.

Coppois, G. 1984. Distribution of bulimulid snails on the northern slope of Santa Cruz Island, Galápagos Islands. Biol. J. Linn. Soc., 21: 217–227.

Crawford, C. S. 1990. Scorpions, Solifugae, and associated desert taxa. *In* Dindal, D. L. (ed.). Soil Biology Guide. John Wiley and Sons, New York.

Crouau-Roy, B. 1989. Population studies on an endemic troglobitic beetle: geographical patterns of genetic variation, gene flow and genetic structure compared with morphometric data. Genetics, 121: 571–582.

Doyen, J. T., & W. F. Tschinkel. 1974. Population size, microgeographic distribution and habitat separation in some tenebrionid beetles (Coleoptera). Ann. Entomol. Soc. Amer., 67: 617–626.

Finston, T. L. 1993. Evolution of the genus *Stomion* (Coleoptera: Tenebrionidae) in the Galápagos Islands. M. Sc. thesis, Carleton University.

Finston, T. L. & S. B. Peck. 1995. Population structure and gene flow in *Stomion*: a species swarm of flightless beetles of the Galápagos Islands. Heredity, 75: 390–397.

Fowler, J. & L. Cohen. 1990. Practical Statistics for Field Biology. Open University Press, Milton Keynes, Philadelphia.

Grant, P. R. 1986. Ecology and evolution of Darwin's Finches. Princeton University Press, Princeton, NJ.

Herbert, P. D. N., & M. J. Beaton. 1993. Methodologies for Allozyme Analysis using Cellulose Acetate Electrophoresis, 2nd edn. Helena Laboratories, Beaumont, TX.

Hendrickson, J. R. 1966. The Galápagos Tortoises, *Geochelone* Fitzinger 1835 (*Testudo* Linnaeus 1758 in part). *In* Bowman, R. I. (ed.), Proceedings of the Symposium of the Galápagos International Scientific Project. University of California Press, Berkeley and Los Angeles.

King, P. S. 1987. Macro- and microgeographic structure of a spatially isolated beetle species in nature. Evolution, 41: 401–416.

Lack, D. 1968. Darwin's Finches- an essay on the general biological theory of evolution. Peter Smith Publishers, Glouster, Mass.

Mayr, E. 1942. Systematics and the origin of species. Columbia University Press, New York.

Mayr, E. 1963. Animal Species and Evolution. The Belknap Press of Harvard University Press. Cambridge, Mass.

McCauley, D. E. & W. F. Eanes. 1987. Hierarchical population structure analysis of the milkweed beetle, *Tetraopes tetraophthalmus* (Forster). Heredity, 58: 193–201.

Peck, S. B. 1994a. Aerial dispersal of insects between and to islands in the Galápagos archipelago, Ecuador. Ann. Entomol. Soc. Amer., 87: 218–224.

Peck, S. B. 1994b. Sea-surface (pleuston) transport of insects between islands in the Galápagos archipelago, Ecuador. Ann. Entomol. Soc. Amer., 87: 576–582.

Peck, S. B. & J. Kukalova-Peck. 1990. Origin and biogeography of the beetles (Coleoptera) of the Galápagos Archipelago, Ecuador. Can. J. Zool., 68: 1617–1638.

Slatkin, M. J. 1985. Rare alleles as indicators of gene flow. Evolution, 39: 53–65.

Slatkin, M. J. 1987. Gene flow and the geographic structure of natural populations. Science, 236: 787–792.

Southwood, T. R. E. 1966. Ecological Methods. Butler & Tanner, Ltd. London.

Swofford, D. L. & R. B. Selander. 1991. BIOSYS-1. A Computer Program for the Analysis of Allelic Variation in Genetics. Department of Genetics and Development, University of Illinois at Urbana-Champaign, Urbana, IL.

Thomas, D. B. 1979. Patterns in the abundance of some tenebrionid beetles in the Mojave Desert. Environ. Entomol., 8: 568–574.

Thomas, D. B. 1983. Tenebrionid beetle diversity and habitat complexity in the eastern Mojave Desert. The Coleopterists Bull., 37: 135–147.

Thomas, D. B. & E. L. Sleeper. 1977. The use of pit-fall traps for estimating the abundance of arthropods, with special reference to the Tenebrionidae (Coleoptera). Ann. Entomol. Soc. Amer., 70: 242–248.

Van Denbergh, J. 1914. The gigantic land tortoises of the Galápagos archipelago. Proc. Calif. Acad. Sci., 1: 7–288.

Van Dyke, E. C. 1953. The Coleoptera of the Galápagos Islands. Occas. Papers Calif. Acad. Sci., 22: 1–181.

Wiggins, I. L. & D. M. Porter. 1971. Flora of the Galápagos Islands. Stanford University Press. Stanford, California.

Wilkenson, L. 1988. SYSTAT: The System for Statistics. SYSTAT, Evanston, IL.

Wright, S. 1940. Isolation by distance. Am. Nat., 74: 232–248.

Zera, A. J. 1981. Genetic structure of two species of waterstriders (Gerridae: Hemiptera) with differing degrees of winglessness. Evolution, 35: 218–225.

Received 30 Apr 1996; Accepted 1 Sep 1996.

PAN-PACIFIC ENTOMOLOGIST
73(2): 122–126, (1997)

A NEW SPECIES OF *LITOPROSOPUS* (LEPIDOPTERA: NOCTUIDAE) FROM BAJA CALIFORNIA, MEXICO

John W. Brown[1] and David K. Faulkner
Entomology Department, San Diego Natural History Museum, P.O. Box 1390,
San Diego, California 92112

Abstract.—*Litoprosopus bajaensis* Brown and Faulkner, NEW SPECIES, a taxon endemic to the northern portion of the Vizcaino Desert, Baja California, Mexico, is described and illustrated. The description is based on six specimens (two males and four females) collected between 31 March and 1 May (1975–1985). The combination of the long curved ampulla, short third segment of the labial palpus, and pale fawn-gray forewing color separate *L. bajaensis* from all other species of *Litoprosopus.*

Key Words.—Insecta, Lepidoptera, Noctuidae, *Litoprosopus bajaensis,* Baja California.

Although our knowledge of the lepidopterous fauna of the peninsula of Baja California, Mexico, has increased dramatically over the last ten years (e.g., Brown & Donahue 1989, Brown, Real & Faulkner 1992, Eichlin 1993), considerable portions of the fauna remain poorly studied. Numerous endemic taxa are undescribed, and published information is lacking for several major groups (e.g., microlepidoptera, Arctiidae, Noctuidae). This paper describes a new species of *Litoprosopus* (Noctuidae) from the northern portion of the Vizcaino Desert. The new species is geographically isolated and morphologically distinct from its congeners.

Dissection methodology followed that presented in Clarke (1941). Terminology for structures of the genitalia follows Eichlin (1975).

Depositories and Abbreviations.—Specimens of *Litoprosopus* were borrowed from the following collections: Natural History Museum of Los Angeles County (LACM); University of California, Berkeley (UCB); and San Diego Natural History Museum (SDNHM). Comparative material was borrowed from The Natural History Museum, London, England; National Museum of Natural History, Washington, D.C.; American Museum of Natural History, New York, New York; and Carnegie Museum of Natural History, Pittsburgh, Pennsylvania.

Litoprosopus bajaensis Brown & Faulkner, NEW SPECIES
(Figs. 1–3)

Type Material.—Holotype: male: MEXICO: *BAJA CALIFORNIA:* 1.6 km (1 mi) E of Santa Inez, 6 Apr 1985, D. K. Faulkner, UV light (SDNHM). Five paratypes as follows: MEXICO: *BAJA CALIFORNIA:* 5 km N of Catavina, 2 females, 1 May 1975, E. M. Fisher (LACM); 16 km (10 mi) SE of El Rosario, 1 male, 31 Mar 1976, black light trap (UCB); 1.6 km (1 mi) E of Santa Inez, 2 females, 6 Apr 1985, D. K. Faulkner (SDNHM).

Description.—*Adult Male. Head*: Frons sparsely scaled below mid-eye; vertex long-scaled, pale fawn-gray. Ocelli small. Labial palpus strongly upturned, pale fawn-gray; segment III short and blunt, approximately 0.25 times length of segment II. *Thorax:* Smooth-scaled, densely clothed in fawn-gray

---

[1] Current Address: USDA, Systematic Entomology Laboratory, c/o National Museum of Natural History, Washington, D.C. 20560

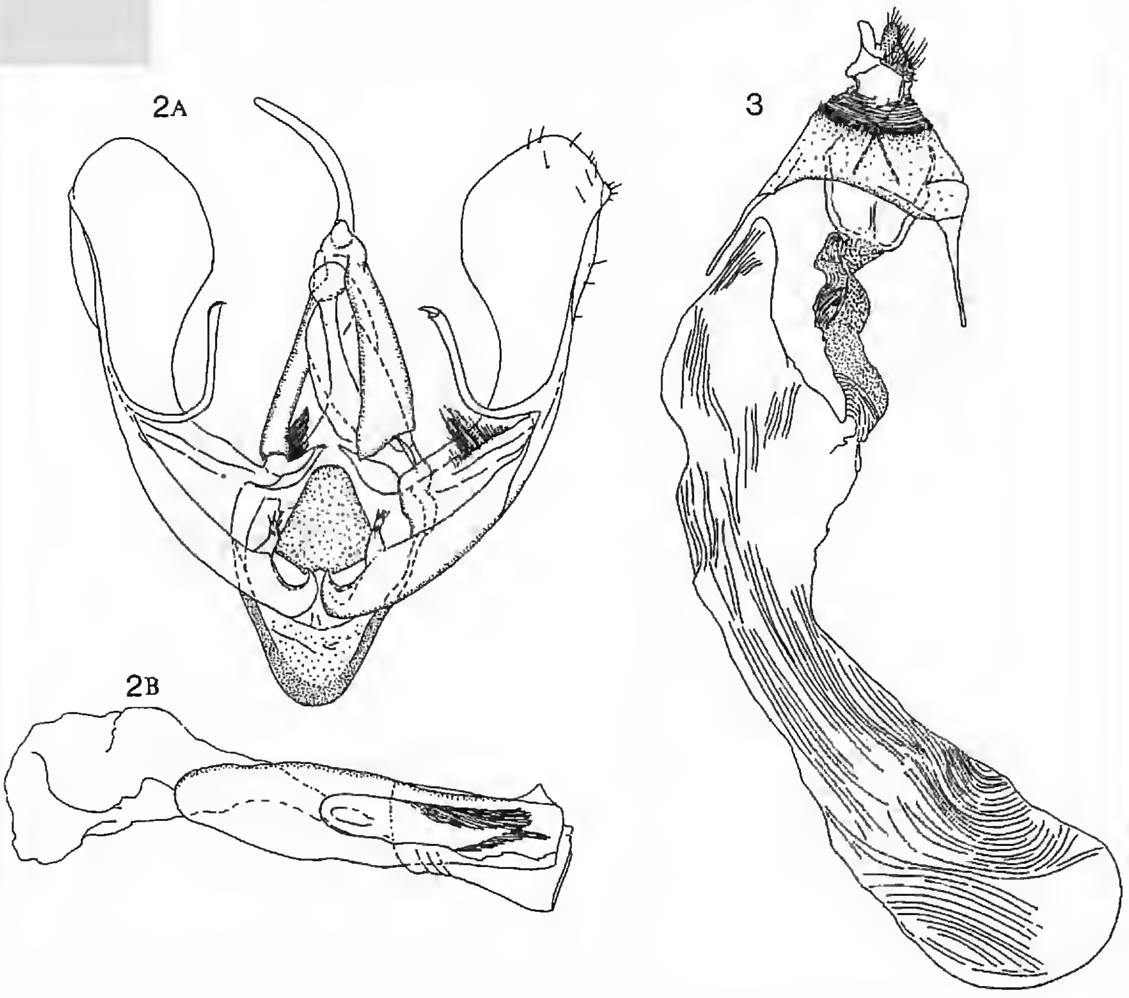
Figure 1. Adult female of *Litoprosopus bajaensis.*

scales. *Forewing:* Length 20–22 mm ($\bar{x}$ = 21; *n* = 2) (Fig. 1). Uniform pale fawn-gray above, with few small brown specks in basal half of discal cell. Underside glossy pale tan. *Hindwing:* White above, with fawn-brown border and faint mottling; "eye-spot" at margin comprised of a pair of small, dark brown, subrectangular spots between veins 1A + 2A − CuP and CuP − CuA_2. Underside glossy white. *Genitalia:* As in Fig. 2 (drawn from JWB slide no. 136, Baja California, Mexico; *n* = 1). Uncus long, slender, nearly uniform in width, but attenuate distally. Tegumen narrow. Juxta trapezoidal. Valva long, broadest distally, narrowest subbasally. Sacculus with broadly hook-shaped base, subtended distally by long, narrow digitate process; broad basal portion of sacculus attenuate at approximately 0.4 distance from base to apex; long, narrow, curved ampulla from sacculus approximately 0.5 distance from base to apex, arising from narrow, strongly sclerotized portion of sacculus; sacculus ending near apex of valva with several small warts bearing setae. Aedeagus moderately long, broad; two large patches of scobination in basal portion of vesica.

Adult Female.—Essentially as described for male. Forewing length 19–24 mm ($\bar{x}$ = 21; *n* = 4). *Genitalia:* As in Fig. 3 (drawn from JWB slide no. 137, Baja California, Mexico; *n* = 2). Papillae anales simple, unmodified. Sterigma a sclerotized band; ostium bursae represented by a strong cup-shaped process. Ductus bursae with dense patches of scobination posteriorly, lines of sclerotization anteriorly. Corpus bursae long, moderately narrow, unsclerotized, with large region caudal to attachment of ductus bursae ("apex" sensu Eichlin 1975). Ductus seminalis from posterior portion of apex.

Diagnosis.—Litoprosopus bajaensis can be distinguished superficially from all other species of *Litoprosopus* by its nearly uniform pale fawn-gray forewing color. Most species in the genus are characterized by varying shades of brown on the forewing, usually with some lighter or darker mottling. The closest species geographically, *L. coachella* Hill, has a pale tan-ocherous forewing, with traces of two, narrow, brown, curved lateral bands. The two apparently are allopatric, with *L. coachella* restricted to southern California and *L. bajaensis* restricted to the Vizcaino Desert of Baja California, Mexico.

The male genitalia of *L. bajaensis* can be distinguished from *L. futilis* (Grote & Robinson), *L. confligens* (Walker), and *L. coachella* by its longer and more strongly curved process from the ampulla, which is reminiscent of *L. puncticosta* Hampson and *L. bahamensis* Hampson, both from the Caribbean. *Litoprosopus bajaensis* can be distinguished from the latter two by its longer region of subbasal constriction of the valva and the warty bases of setae at the distal end of the sacculus.



Figures 2–3. Genitalia of *Litoprosopus bajaensis*. Figure 2a. Male, valvae spread. Figure 2b. Aedeagus removed. Figure 3. Female.

The third segment of the labial palpus is short (approximately 0.25 the length of the second segment) and blunt in *L. bajaensis*. This is similar to *L. confligens* but differs from all other species examined in which the third segment is 0.6–0.8 times as long as the second.

Distribution and Life History.—*Litoprosopus bajaensis* is known only from the northern portion of the Vizcaino Desert in Baja California, Mexico. Capture records extend from 10 km SE of El Rosario to just north of Catavina (Fig. 4); all specimens ($n = 6$) were collected between 31 March and 1 May (1975–1985). Since adults of *L. coachella* have been collected from April through October, it is likely that *L. bajaensis* has a considerably longer flight period than the available records suggest. Based on life history information of *L. coachella* (e.g., Comstock 1933, 1956; Flock 1951), it is suspected that larvae of *L. bajaensis* feed on the flowers, buds, and possibly fruits of fan palms in the genus *Washingtonia* (Arecaceae), two species of which occur within its range—*W. filifera* (Linden) Wendl. and *W. robusta* Wendl. (Wiggins 1980).

Discussion.—Poole (1989) included seven species in *Litoprosopus*: *bahamensis, coachella, confligens, futilis, haitiensis, hatuey* (Poey), and *punticosta*. We have examined the types of all but *L. hatuey*; it is likely that all are distinct species. The type of *hatuey* may be deposited in a collection in Cuba, but we were unable to locate it. This is particularly troubling because it is the type species of the genus.

Species of *Litoprosopus* are distributed from the southern United States (i.e., Florida, Georgia, Texas, Arizona, California) south through Central America, with a few records from northern South America. Although most exhibit a compara-

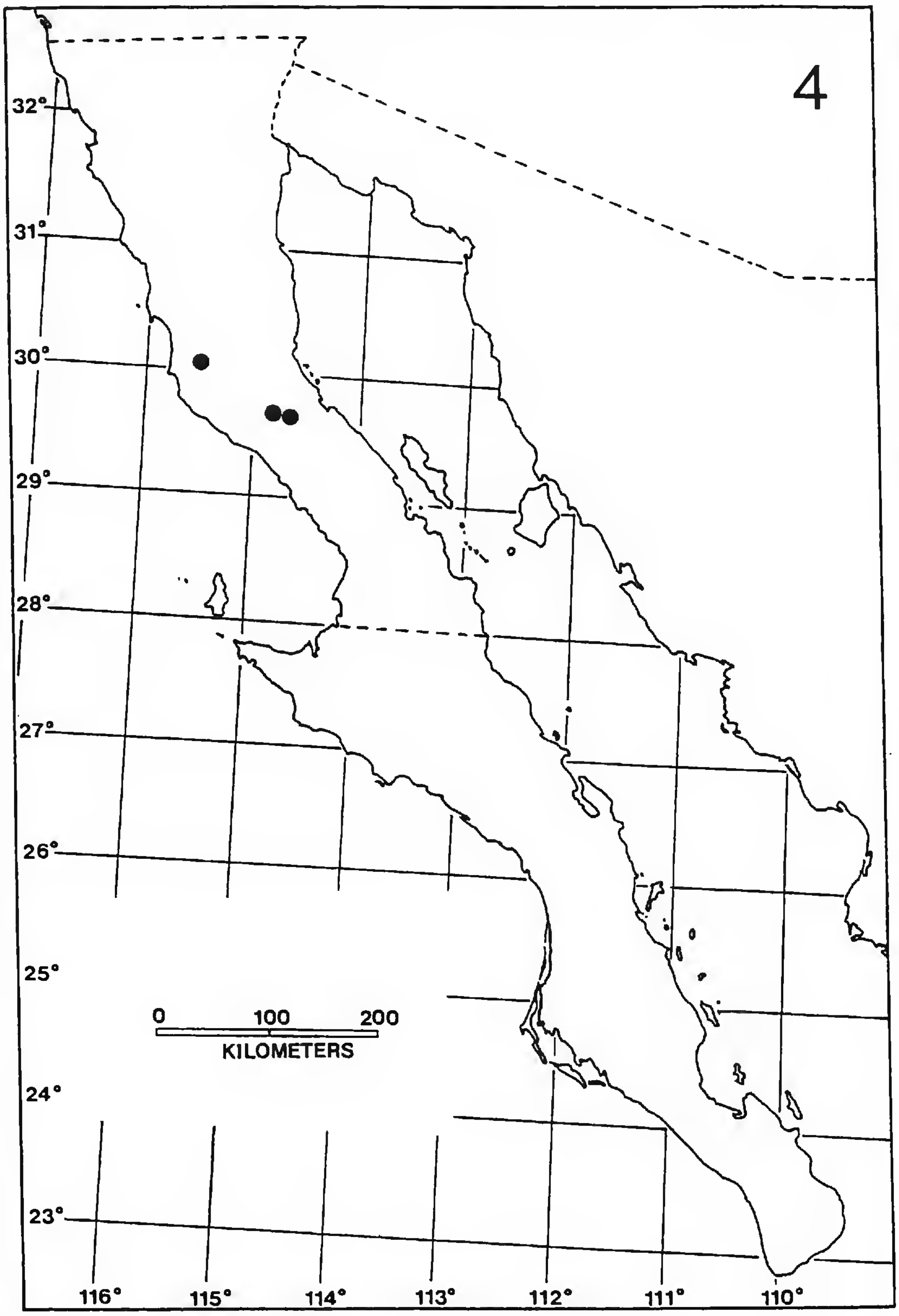


Figure 4. Geographical distribution of *Litoprosopus bajaensis.*

tively limited distribution, *L. confligens* ranges from southern Florida to South America.

The phylogenetic position of the genus within the Noctuidae is unresolved, and species level problems may be present in the Caribbean region (including Florida). The paucity of material from this region inhibits our ability to discriminate between intraspecific variation and interspecific differences.

Material Examined.—See Types.

ACKNOWLEDGMENT

We thank the following for allowing us to examine specimens in their care: Robert W. Poole, United States National Museum of Natural History, Washington, D.C.; John E. Rawlins, Carnegie Museum of Natural History, Pittsburgh, Pennsylvania; Jerry A. Powell, Essig Museum of Entomology, University of California Berkeley; Julian P. Donahue, Natural History Museum of Los Angeles County, Los Angeles, California; James Miller, American Museum of Natural History, New York, New York; and Ian Kitching, The Natural History Museum, London, England. We thank R. Poole and J. Rawlins for encouragement, assistance, and discussions.

LITERATURE CITED

Brown, J. W. & J. P. Donahue. 1989. The Sphingidae (Lepidoptera) of Baja California, Mexico. J. Lepid. Soc., 43: 184–209.

Brown, J. W., H. G. Real & D. K. Faulkner. 1992. Butterflies of Baja California, Mexico. Lepidoptera Research Foundation, Beverly Hills, California.

Clarke, J. F. G. 1941. The preparation of the genitalia of Lepidoptera. Bull. Brooklyn Entomol. Soc., 36: 149–161.

Comstock, J. A. 1933. Studies in Pacific Coast Lepidoptera. Bull. South. Calif. Acad. Sci., 32: 113–120.

Comstock, J. A. 1956. Is this a new, and giant clothes moth? Bull. South. Calif. Acad. Sci., 55: 51–53.

Eichlin, T. D. 1975. Guide to the adult and larval Plusiinae of California (Lepidoptera: Noctuidae). Occas. Pap. Entomol., Calif. Dept. Food & Agri. No. 21.

Eichlin, T. D. 1993. Clearwing moths of Baja California. Trop. Lepid., 3: 135–150.

Flock, R. A. 1951. Damage to household goods by the fan palm caterpillar. J. Econ. Entomol., 44: 260–261.

Poole, R. 1989. Lepidopterorum Catalogus (new series), fascicle 118: Noctuidae. E. J. Brill/Flora and Fauna Publ., Leiden, The Netherlands. Three volumes, xii + 1341 pp.

Wiggins, I. L. 1980. Flora of Baja California. Stanford University Press, Stanford.

Received 22 Apr 1996; Accepted 16 Dec 1996

PAN-PACIFIC ENTOMOLOGIST
73(2): 127–134, (1997)

THE NAUCORIDAE (HETEROPTERA) OF SOUTHERN THAILAND

Robert W. Sites,[1] Becky J. Nichols,[1] and Surakrai Permkam[2]
[1]Wilbur R. Enns Entomology Museum, Department of Entomology,
University of Missouri, Columbia, Missouri 65211;
[2]Faculty of Natural Resources, Prince of Songkla University, Hat Yai, Thailand

Abstract.—In January 1995, the southernmost seven provinces of Thailand were surveyed for their naucorid fauna. Eight species representing five genera and four subfamilies were collected from waterfalls, streams, and ponds. An annotated list of taxa and illustrated taxonomic key are presented.

บทคัดย่อ - เดือนมกราคม ๒๕๓๘ ได้ทำการสำรวจมวนตะพาบน้ำ ในพื้นที่ ๗ จังหวัดภาคใต้ตอนล่างของประเทศไทย พบมวนดังกล่าว ๘ ชนิด ซึ่งจัดอยู่ใน ๕ สกุล และ ๔ วงศ์ย่อย โดยเก็บตัวอย่างจากบริเวณน้ำตก ลำธาร และแหล่งน้ำขังอื่นๆ คำอธิบายรายละเอียดของแมลงแต่ละชนิด และรูปวิธาน ได้นำเสนอในที่นี้

Key Words.—Insecta, Naucoridae, Thailand, fauna, aquatic

Tropical peninsular Thailand is topographically diverse with many mountain ranges and associated waterfalls and streams. These numerous aquatic systems as well as vegetated ponds harbor a diverse aquatic insect fauna. The composition of lotic insect communities in southern Thailand is shaped in part by natural biogeographic distributions as well as by disturbances from a variety of natural and anthropogenic origins. Scouring monsoons occur primarily from October through December; however, rainfall occurs throughout the year with an average of approximately 432 cm per year (Nuttonson 1963), and a recorded high of 660 cm (Pendleton 1962). Most streams of peninsular Thailand have their origins in the forested mountains. Although extensive deforestation occurred in the 1970's and 1980's, resulting in the removal of riparian vegetation, the government banned commercial logging in 1989, affording greater protection for these aquatic systems and associated organisms. In addition, use of streams for personal hygiene and for the disposal of acids during the commercial production of rubber contributes to the presence or absence of particular members of the aquatic insect community.

Naucoridae constitutes a family of predacious aquatic Heteroptera which is known to inhabit a wide variety of lotic and lentic situations. This family is most speciose in both the New and Old World tropics, although representatives also occur in temperate regions. Naucorids are considered keystone consumers (Sites & Willig 1991); thus, they constitute an important component of the trophic web of aquatic systems, particularly of tropical streams (Sites in press). Riparian deforestation has been reported to potentially have a substantial effect on populations of Naucoridae by resulting in increased densities (Polhemus & Polhemus 1988, Sites in press).

Although most treatments of Naucoridae are of taxonomic focus, several faunal lists are available for regions of Southeast Asia, including Sri Lanka (Mendis & Fernando 1962), India (Tonapi 1959, and references therein), Indonesia (Nieser

& Chen 1991, 1992), peninsular Malaysia (Fernando & Cheng 1963), the Philippine Islands (Usinger 1937), India, Sri Lanka, and Burma (Distant 1911), and Sumatra, Java, and Bali (Lundblad 1933). No naucorid species are given in the list of insects of southern Thailand (Chinajariyawong et al. 1986). Herein, we present an annotated list of naucorid species collected in southern Thailand and an illustrated taxonomic key.

FIELD COLLECTIONS

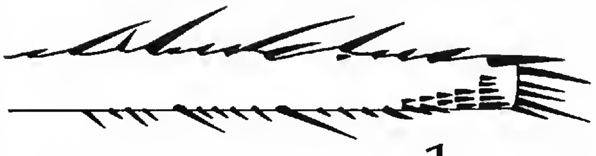
Thirty collections were made in the southernmost seven provinces of Thailand (Narathiwat, Pattani, Phattalung, Satun, Songkhla, Trang, Yala), including, in some cases, in national parks (with permission). Because of political instability, collecting was not conducted in extreme southeastern Narathiwat Province. This area is mountainous with waterfalls and streams, and holds promise as harboring species not included herein. Collecting was performed with an aquatic D-net. In streams, the substrate was kick-sampled, allowing the current to carry organic debris, including insects, into the net. Along stream margins and in ponds, vegetation was swept with the D-net. All insects were placed into 80% ethyl alcohol.

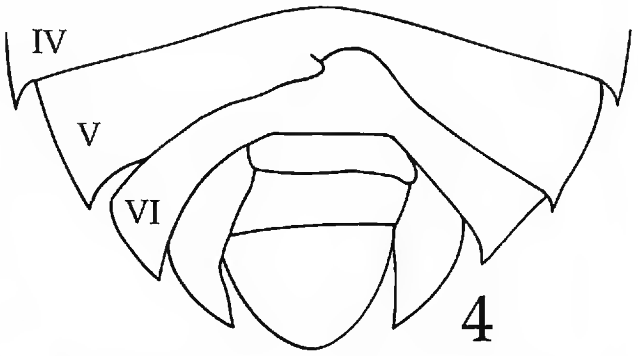
It is common for more than one species of naucorid (even congeners) to be present in a particular body of water. For some species, both sexes are required for accurate identification. Further, other taxa such as the common lotic genus, *Aphelocheirus*, are polymorphic with respect to wing development. Therefore, when possible, series of specimens should be collected to sufficiently characterize the species and maximize the likelihood of obtaining accurate specific determinations. Voucher specimens have been deposited in the museum of the Department of Pest Management, Faculty of Natural Resources, Prince of Songkla University (PSU), Hat Yai, Thailand; and the Wilbur R. Enns Entomology Museum, University of Missouri, Columbia, Missouri. Although we collected more species than expected from the region based on the literature, the possibility exists that additional species may be found in southern Thailand. Therefore, this key may require modification in the future if additional species are discovered.

KEY TO THE ADULTS OF NAUCORIDAE OF SOUTHERN THAILAND

Identification of species of *Aphelocheirus* requires the distinction between male and female individuals. Males are asymmetrical in the terminal abdominal sterna, whereas females are symmetrical.

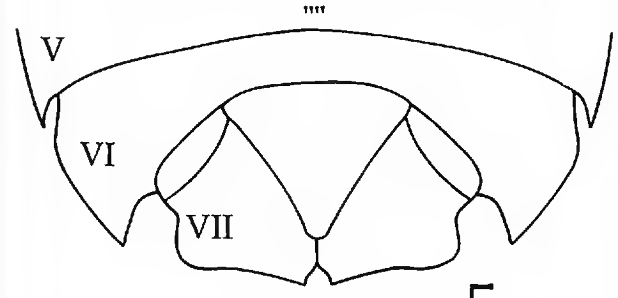
1a Labium reaching posteriorly at most to prothoracic coxae; antennae short, not reaching lateral margins of head 2
1b Labium extending posteriorly to near mesothoracic coxae; antennae long, extending past lateral margins of head 5
2a(1a) Posterior margin of pronotum with lateral ¼ widely separated from anterior margin of mesothorax and hemelytra; ≥ 13 mm in length .... *Gestroiella limnocoroides* Montandon
2b Posterior margin of pronotum closely appressed to anterior margin of mesothorax and hemelytra; < 13 mm in length 3
3a(2b) Prothoracic leg with pretarsus with single minute claw; protarsus one-segmented .... *Naucoris scutellaris* Stål


1

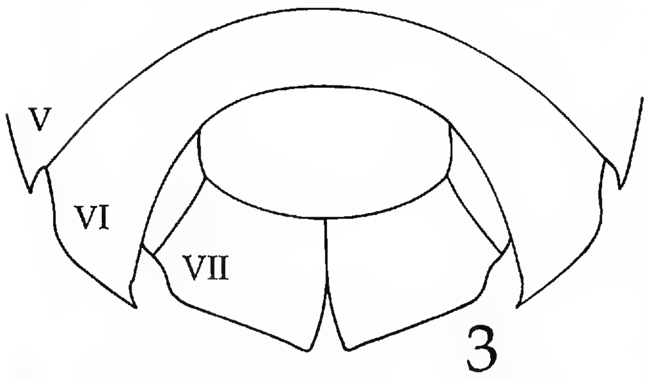


4

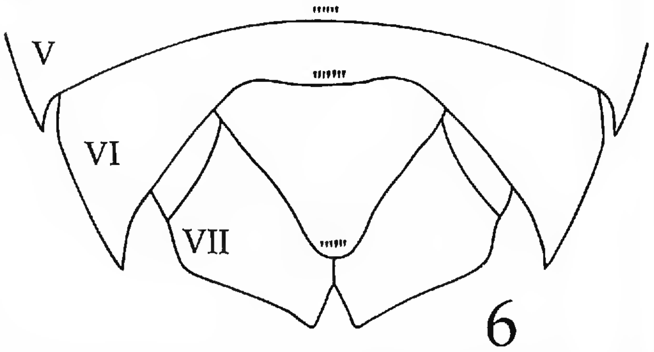

2



5



3



6

Figure 1. Distal end of metatibia of *Heleocoris.*
Figure 2. Distal end of metatibia of *Ctenipocoris asiaticus.*
Figure 3. Subgenital plate of female *Aphelocheirus grik.*
Figure 4. Abdominal sternite V of male *Aphelocheirus grik.*
Figure 5. Subgenital plate of female *Aphelocheirus femoratus.*
Figure 6. Subgenital plate of female *Aphelocheirus malayanus.*

3b Prothoracic leg with pretarsus with two conspicuous claws; protarsus two-segmented (one-segmented in *Heleocoris* females) 4

4a(3b) Metatibia ventrally with subapical, stout, parallel spines arranged in two or more rows (Fig. 1); fringe of natatorial hairs on mesal surface of metatibia dense, without gaps between hairs ..... *Heleocoris* spp.

4b Metatibia with circlet of stout, divergent, subapical spines, not arranged in rows (Fig. 2); fringe of hairs on mesal surface with gaps between hairs .... *Ctenipocoris asiaticus* Montandon

5a(1b) Female with subgenital plate truncate (Fig. 3); male with tab projecting from posterior margin of abdominal sternite V (Fig. 4); never with raised, brown patch on hind trochanter and base of femur .... *Aphelocheirus grik* Polhemus & Polhemus

5b Female with subgenital plate triangular (Figs. 5, 6); male with or without weakly developed tab on abdominal sternite V; if tab is present, then with raised, brown patch on hind trochanter and base of femur 6

6a(5b) Male with hind trochanter and base of femur each bearing well-defined, raised, brown patch; female with posterolateral angle of tergite VII 90° (Fig. 5), subgenital plate without peg-like setae, although hair-like setae present, peg-like setae near posterior margin at midline of sterna IV-V and occasionally VI .... *Aphelocheirus femoratus* Polhemus & Polhemus

6b Male with hind trochanter and base of femur devoid of well-defined brown patch, although poorly-defined dark streak may occur over much of femur; female with posterolateral angle of tergite VII ca. 130°, 4-6 peg like setae near apex of subgenital plate (may be difficult to see) (Fig. 6), peg-like setae also near posterior margin at midline of sterna IV-VI .... *Aphelocheirus malayanus* Polhemus & Polhemus

ANNOTATED LIST OF TAXA

SUBFAMILY APHELOCHEIRINAE

GENUS *APHELOCHEIRUS*

Three species of *Aphelocheirus* were collected from southern Thailand. Five additional species have been recorded from northern Thailand (Polhemus & Polhemus 1988) but have not been recorded from the peninsular part of the country. Species in this genus are represented by brachypterous and macropterous forms. The subfamily is represented by only the genus *Aphelocheirus* and is considered by some to represent a distinct family level taxon (Štys & Jansson 1988, and citations therein).

Aphelocheirus femoratus Polhemus & Polhemus

Aphelocheirus femoratus Polhemus & Polhemus 1988: Raffles Bull. Zool. 36: 214–216.

Diagnosis.—The male is distinctive in having well-defined brown patches on the hind trochanters and bases of the hind femora. The seventh abdominal terga of the female have posterolateral angles of 90° and the subgenital plate is triangular. Brachypterous and macropterous forms are consistent in expression of the diagnostic characters.

Discussion.—This species occurs in gravel and rocky substrates of streams. This is the most common *Aphelocheirus* species in southern Thailand, and has been recorded from peninsular Malaysia north to Chiang Mai Province in northern Thailand (Polhemus & Polhemus 1988). This species occurred syntopically with *A. grik* at Banglang National Park and 9 km N Than To, *Heleocoris* sp. nr Srisakhon, and *Gestroiella limnocoroides* at Ton Nga Chang.

Material Examined.—NARATHIWAT: stream 14 km W of Srisakhon, 15 Jan 1995, L-77 (11 brachypterous males, 1 macropterous male, 4 brachypterous females, 7 macropterous females, 46 nymphs); stream below Bacho Waterfall, 15 Jan 1995, L-78 (5 brachypterous males, 4 brachypterous females, 57 nymphs). *SONGKHLA:* stream from Ton Plieuw, 7 Jan 1995, L-62 (17 brachypterous males, 9 brachypterous females, 13 nymphs); same locality, 8 Jan 1995, L-64 (2 brachypterous males, 2 brachypterous females, 2 nymphs); Ton Nga Chang National Park, stream at Buddhist temple, 6 Jan 1995, L-59 (1 macropterous male, 7 nymphs); same locality, 7 Jan 1995, L-60 (14 brachypterous males, 14 brachypterous females, 13 nymphs); same locality, 8 Jan 1995, L-65 (15 brachypterous males, 10 brachypterous females, 33 nymphs); same locality, 30 Jan 1995, L-81 (13 brachypterous males, 11 brachypterous females, 6 nymphs); Ton Nga Chang National Park, waterfall levels 2 and 3, 6 Jan 1995, L-66 (1 macropterous male, 1 brachypterous female, 1 nymph). *YALA:* Banglang National Park, Than To, 14 Jan 1995, L-73 (7 brachypterous males, 4 brachypterous females); 9 km N of Than To, 15 Jan 1995, L-76 (1 macropterous male).

Aphelocheirus grik Polhemus & Polhemus

Aphelocheirus grik Polhemus & Polhemus 1988: Raffles Bull. Zool. 36: 218–220.

Diagnosis.—The male has a tab extending from the posterior margin of abdominal sternite V and lacks the raised brown patches characteristic of *A. femoratus*. The female is easily recognized by the truncate subgenital plate. Brachypterous and macropterous forms are consistent in expression of these diagnostic characters.

Discussion.—This species occurs in gravel and rocky substrates of streams and has been recorded from peninsular Malaysia north to Chiang Mai Province in northern Thailand (Polhemus & Polhemus 1988). This species occurred syntopically with *A. femoratus* at Banglang National Park and near Than To, and *A. malayanus* near Khao Ka Chong.

Material Examined.—TRANG: ca. 10 km E of Khao Ka Chong National Park on hwy 4, 12 Jan 1995, L-69 (1 macropterous male). *YALA:* Banglang National Park, Than To, 14 Jan 1995, L-73 (1 macropterous male, 1 brachypterous female, 4 macropterous females); 9 km N of Than To, 15 Jan 1995, L-76 (14 brachypterous males, 13 brachypterous females).

Aphelocheirus malayanus Polhemus & Polhemus

Aphelocheirus malayanus Polhemus & Polhemus 1988: Raffles Bull. Zool. 36: 216–218.

Diagnosis.—This species is similar to *A. femoratus* although it is slightly larger. The male lacks the raised brown patches characteristic of *A. femoratus* and the tab on abdominal sternite V characteristic of *A. grik*. The female has a triangular subgenital plate with 4-6 obscure peg-like setae near the apex, and the posterolateral angle of tergum VII is ca. 130°. Brachypterous and macropterous forms are consistent in expression of these diagnostic characters.

Discussion.—This species occurs in the gravel and rocky substrates of streams and previously was known only from peninsular Malaysia. This is the first record of *A. malayanus* from Thailand and it occurred syntopically with *A. grik*.

Material Examined.—TRANG: ca. 10 km E of Khao Ka Chong National Park on hwy 4, 12 Jan 1995, L-69 (4 brachypterous males, 6 brachypterous females, 4 macropterous females, 16 nymphs).

SUBFAMILY CHEIROCHELINAE

GENUS *GESTROIELLA*

Gestroiella limnocoroides Montandon

Gestroiella limnocoroides Montandon 1897: Ann. Mus. Civ. Storia Nat. Genova 17: 371–372.

Diagnosis.—This species is the largest known naucorid in southern Thailand. Length ranges from 13–17 mm, although specimens from other regions of Southeast Asia are considerably larger. The posterior margin of the pronotum is widely separated from the anterior margin of the mesonotum and embolia of the hemelytra. The lateral margins of the head and pronotum are markedly straight and convergent.

Discussion.—This species occurs in the gravel and rocky substrate of streams. We also collected specimens from rock pools of the waterfall which were discontinuous from the main body of water. This record represents the southernmost known extent of the range of *G. limnocoroides* and the nearest known population is at Chiang Mai in northern Thailand. This species occurred syntopically with *A. femoratus* at Ton Nga Chang. The specific status of this population is equivocal because this genus is in need of revision.

Material Examined.—SONGKHLA: Ton Nga Chang National Park, stream at Buddhist temple, 6 Jan 1995, L-59 (9 nymphs, 1 exuviae); same locality, 7 Jan 1995, L-60 (12 nymphs); same locality, 8 Jan 1995, L-65 (1 male, 10 nymphs); same locality, 30 Jan 1995, L-81 (1 male, 26 nymphs); same locality, waterfall levels 2 and 3, 6 Jan 1995, L-66 (1 female, 14 nymphs).

SUBFAMILY LACCOCORINAE

GENUS *CTENIPOCORIS*

***Ctenipocoris asiaticus* Montandon**

Ctenipocoris asiaticus Montandon 1897: Ann. Mus. Civ. Storia Nat. Genova 17: 374–376.

Diagnosis.—In most somatic characters, this genus resembles *Heleocoris,* although it is smaller and the degree of spination of the hind legs is characteristic of *Ctenipocoris*. Specifically, a whorl of spines encircles the distal end of the hind femur, whereas in *Heleocoris* several rows of parallel spines are located ventrally at the distal end. Also, the spines of *Ctenipocoris* are stouter than in *Heleocoris*.

Discussion.—This species is rare, seldom collected in series, and generally occurs in ponds or in vegetation along the quiet margins of streams. The only specimen collected occurred syntopically with *Naucoris scutellaris* in vegetated ponds on the campus at Prince of Songkla University in Hat Yai.

Material Examined.—SONGKHLA: Hat Yai, PSU campus, 5 Jan 1995, vegetated ponds, L-56 (1 male).

Genus *Heleocoris*

Diagnosis.—Members of the subfamily Laccocorinae all have the prothoracic pretarsus with two claws (Usinger 1941). The prothoracic tarsal segmentation is sexually dimorphic in *Heleocoris*: Males have two segments whereas females have only one. In *Ctenipocoris*, both sexes have two segments. Spination of the hind femur will distinguish species in this genus from *Ctenipocoris*. Specifically, two or more rows of parallel spines are located ventrally at the distal end of the hind femur in *Heleocoris*, whereas a whorl of spines encircles the distal end of the hind femur in *Ctenipocoris*. Also, the spines of *Heleocoris* are not as stout as in *Ctenipocoris*.

Discussion.—Two species of *Heleocoris* were collected in southern Thailand. Because of the lack of availability of authoritatively identified comparative material in major collections, these two species are not reliably identifiable. In addition, because of the dire need for taxonomic revision (Nieser & Chen 1992), these species possibly will be removed from *Heleocoris* because the type species of this genus is African, and differences exist between the African and Asian species (J. T. Polhemus, personal communication). One species (sp. A, which may be *H. ovatus* Montandon) was common when present, occurring in vegetated stream margins and very shallow, slow riffles (< 5 cm depth). Species B was collected on only one occasion and was in a leaf pack in the plunge pool of a small waterfall.

Material Examined.—SPECIES A: *NARATHIWAT:* stream 14 km W of Srisakhon, 15 Jan 1995, L-77 (29 males, 33 females, 5 nymphs); stream below Bacho Waterfall, 15 Jan 1995, L-78 (1 female, 3 nymphs). *YALA:* Banglang National Park, Than To, 14 Jan 1995, L-73 (4 males, 5 females, 2 nymphs); 9 km N of Than To, 15 Jan 1995, L-76 (19 males, 14 females). SPECIES B: *SONGKHLA:* Hat Yai, stream on PSU campus, leaf pack of plunge pool at base of waterfall, 5 Jan 1995, L-57 (1 female, 1 nymph).

SUBFAMILY NAUCORINAE

GENUS *NAUCORIS*

***Naucoris scutellaris* Stål**

Naucoris scutellaris Stål 1860: Kongl. Sv. Freg. Eugenies Jord. 266.

Diagnosis.—This is the smallest of the naucorids in southern Thailand (length, 6.5–7.5 mm). The underside, particularly that of the legs, is conspicuously speckled with dark brown spots. The forelegs have the tarsus one-segmented and pretarsus with one claw. The labium is short, barely reaching the fore coxae.

Discussion.—This species is a common inhabitant of ponds and vegetated stream margins throughout southern Thailand. The known range of this species extends from Java to India (La Rivers 1971) and includes Thailand (Nieser & Chen 1992).

Material Examined.—PHATTALUNG: Khao Chai Son, pond nr hot springs, 12 Jan 1995, L-71 (8 nymphs). *SONGKHLA:* reservoir at end of stream from Ton Plieuw, 7 Jan 1995, L-61 (1 female, 2 nymphs); Hat Yai, PSU campus, vegetated ponds, 4 Jan 1995, L-55 (1 male); same locality, 8 Jan 1995, L-67 (1 male, 1 female, 2 nymphs); same locality, 30 Jan 1995, L-83 (1 male, 2 females, 2 nymphs); Ton Nga Chang National Park, stream at Buddhist temple, 7 Jan 1995, L-60 (1 male). *YALA:* Banglang National Park, Than To, 14 Jan 1995, L-73 (2 males, 6 females); 9 km N of Than To, 15 Jan 1995, L-76 (2 males, 1 female).

ACKNOWLEDGMENT

We are very grateful to Prasert Chitapong and Soontorn Pipithsangchan (Prince of Songkla University) for logistical support in Thailand. We thank Wasant Atisabda for assistance with the Thai abstract, and J. T. Polhemus for assistance with identifications and for reviewing this manuscript. We also thank Michael Nolan, University of Missouri, for providing partial support for this research, including the International Agriculture Programs in the College of Agriculture, Food, and Natural Resources for RWS and the Brown Fellowship for BJN. Partial funding for RWS also was provided by MU project PSSL0232. This is Missouri Agricultural Experiment Station journal series paper 12,425.

LITERATURE CITED

Chinajariyawong, A., J. Pecharat, S. Kritsaneepaiboon & S. Permkhamm. 1986. Scientific and common names of insects in southern Thailand. Thai-Australian Prince of Songkla University Project, Faculty of Natural Resources, 39 p.

Distant, W. L. 1911. The fauna of British India, including Ceylon and Burma (Rhynchota). 5: i-xii, 1–362. Taylor & Francis, London.

Fernando, C. H. & L. Cheng. 1963. A guide to Malayan water bugs (Hemiptera-Heteroptera) with keys to the genera. Dept. Zoology, Univ. Singapore, 31 pp. unpublished document.

La Rivers, I. 1971. Studies of Naucoridae (Hemiptera). Biol. Soc. Nevada Mem. 2. iii + 120 p.

Lundblad, O. 1933. Zur Kenntnis der aquatilen und semi-aquatilen Hemipteren von Sumatra, Java und Bali. Arch. Hydrobiol. suppl. 12, 1-195; 263–489, 21 Taf.

Mendis, A. S. & C. H. Fernando. 1962. A guide to the freshwater fauna of Ceylon. Bull. Fish. Res. Stn. Ceylon 12, 160 p.

Montandon, A. L. 1897. Viaggio di Leonardo Fea in Birmania e regioni Vicine LXXV. Hemiptera Cryptocerata. Annali del Museo Civico di Storia Naturale di Genova, 17(2): 365–377.

Nieser, N. & P. Chen. 1991. Naucoridae, Nepidae and Notonectidae, mainly from Sulawesi and Pulau Buton (Indonesia). Tijdschr. Entomol., 134: 47–67.

Nieser, N. & P. Chen. 1992. Notes on Indonesian waterbugs (Nepomorpha & Gerromorpha). Storkia, 1: 30–40.

Nuttonson, M. Y. 1963. The physical environment and agriculture of Thailand. A study based on field survey data and on pertinent records, material, and reports. Am. Inst. Crop Ecol., Washington D.C., 256 p.

Pendleton, R. L. 1962. Thailand. Aspects of landscape and life. Am. Geograph. Soc. Handbook, Duell, Sloan and Pearce, New York.

Polhemus, D. A. & J. T. Polhemus. 1988. The Aphelocheirinae of tropical Asia (Heteroptera: Naucoridae). Raffles Bull. Zool. (1989), 36: 167–300.

Sites, R. W. (in press). Economic importance of Naucoridae. *In:* C. W. Schaefer & A. R. Panizzi [eds.], Heteropterans of economic importance.

Sites, R. W. & M. R. Willig. 1991. Microhabitat associations of three sympatric species of Naucoridae. Environ. Entomol., 20: 127–134.

Stål, C. 1860. Zoologi. I. Insecta. Hemiptera. Kongl. Sv. Freg. Eugenies Jord., etc. Vettens. Lakt. II. 2(1): 219–299, Norstedt & Söner, Stockholm.

Štys, P. & A. Jansson. 1988. Check-list of recent family-group and genus-group names of Nepomorpha (Heteroptera) of the world. Acta Entomol. Fennica, 50: 1–44.

Tonapi, G. T. 1959. Studies on the aquatic insect fauna of Poona (aquatic Heteroptera). Proc. Nat. Inst. Sci. India (B), 25: 321–332.

Usinger, R. L. 1937. The Naucoridae of the Philippine Islands (Hemiptera). Philip. J. Sci. (1938), 64: 299–311.

Usinger, R. L. 1941. Key to the subfamilies of Naucoridae with a generic synopsis of the new subfamily Ambrysinae (Hemiptera). Ann. Entomol. Soc. Am., 34: 5–16.

Received 3 Jan 1996; Accepted 26 Sep 1996.

PAN-PACIFIC ENTOMOLOGIST
73(2): 135–136, (1997)

Scientific Note

APHODIUS ALTERNATUS HORN (APHODIINAE: SCARABAEIDAE), FIRST RECORD OF A SEMIAQUATIC SCARAB BEETLE

Aphodius alternatus Horn belongs to a species group that is associated with moist habitats, generally along lake or stream margins (Gordon, R. 1977. Proc. Entomol. Soc. Wash; 79: 157–167) and are characterized by males that exhibit a large, down-curved laterally flattened anterior tibial spur (Horn, G. H. 1887. Trans. Amer. Entomol. Soc; (Philadelphia), 14: 1–110).

Aphodius alternatus has been reported from moist habitats along stream, pond, slough, and prairie pothole margins (Gordon 1977) and is widespread in distribution. It is recorded from Alberta, British Colombia, and Manitoba in Canada, and is reported from California, Colorado, Idaho, Iowa, Michigan, Montana, Nevada, North Dakota, Oregon, South Dakota, Utah, Washington, Wisconsin, and Wyoming in the United States.

While studying vernal pool invertebrates, I occasionally collected *A. alternatus* floating on the surface or clinging to floating vegetation. These beetles were never common, and I initially believed them to have fallen into the pools inadvertently. When sampling over a larger geographic range, pools were located in which *A. alternatus* occurred in larger numbers (12 to 14 per square meter).

Aphodius sp. collected from droppings of nearby range cattle and the droppings chambers of the local ground squirrels and gophers and were found to be different species.

Aphodius alternatus were observed and collected from California grassland vernal pools from Shasta County south to Tulare and Monterey Counties. The biology of *A. alternatus* was observed in Shasta, Tehama, Placer, Sacramento, and Monterey Counties. Field observations were made from first appearance in January until the beetles died at the end of the vernal pool season.

Adults first appeared in vernal pools near the end of January. They were found clinging to floating vegetation, with one side of the abdomen exposed to air. When dislodged from the floating substrate, a beetle would reorient itself, dorsum up, flail its legs in a similar, although slower fashion as is observed in beetles of the family Hydrophilidae, and propel itself to another holdfast. Adults often let go of the vegetation to "swim" to another floating plant.

Aphodius alternatus were observed feeding on insects that had fallen into the pools and drowned; however, the beetles were often forced away from their food by the large numbers of aquatic gastropods (*Physatella* sp. and *Lymnaea* sp.), and numerous turbellarians also feeding on dead insects.

On warm, calm days at the end of March and into April, adults climbed as high as possible onto emergent vegetation, and then flew away. The beetles flew up to a height of 1.5–2 m in a slow zig-zag pattern. They then flew straight to another pool, paused about 0.5 m above the water surface, closed their wings and dropped into the water. During the zig-zag searching flight, the beetles flew back and forth over a 3 m wide area for a distance of up to 30 meters to find a pool. Some beetles were observed flying across approximately 144 m^2 in five minutes. When the beetles located a pool, their flight speed increased to almost 1 m per second. Flight was observed only on still sunny days, with air temperatures at or above 17° C.

Mating occurred on the surface of the pools, when air temperatures rose above 19.5° C and the water temperature reached 10° C. Pairs in copula were only observed clinging to floating vegetation. Egg deposition was not observed.

Toward the end of April, the vernal pools begin evaporating. As the pools dried, invertebrates and amphibian larvae were concentrated into the deeper parts of the pool where they eventually died. Adult *A. alternatus* were observed to feed actively in these deposits of carrion which varied in weight from 2 to 26 g. *Aphodius alternatus* densities varied greatly between deposits, with no apparent relationship between the numbers of beetles and the weight or size of carrion. No movement of *A. alternatus* between carrion deposits was observed.

At various times after the drying of the pools, both carrion and soil samples were taken and sieved in an attempt to find *A. alternatus* larvae. Samples were collected from ten pools in which *A. alternatus* had previously been collected in large numbers. Soil samples were taken from beneath the carrion, various sites within the pools, from pool margins, and from areas between pools. Fifteen soil samples were taken per pool, along with a variable number of carrion samples depending on the number of carrion deposition sites within the pool. In only one sample, from Shasta County, was there an aphodine larva, which died before pupating.

Gordon (1977) reported that extensive variation occurs in *A. alternatus* throughout its range and that the species is made up of numerous disjunct populations. This is probable in California as populations seem to be restricted to specific vernal pool complexes.

Acknowledgment.—*A. alternatus* were identified by Robert Gordon, Systematic Entomology Laboratory, Smithsonian Institute.

D. Christopher Rogers, *Jones & Stokes Associates, Inc. 2600 V Street, Sacramento CA, 95818-1914. (916)737-3000.*

Received 15 May 1996; Accepted 24 Dec 1996.

PAN-PACIFIC ENTOMOLOGIST
73(2): 137–140, (1997)

Scientific Note

DISTRIBUTIONAL LIMITS OF EUGLOSSINE AND MELIPONINE BEES (HYMENOPTERA: APIDAE) IN NORTHWESTERN MEXICO

Euglossine and meliponine bees are predominantly distributed within the American tropics (Dressler, R.L. 1982. Ann. Rev. Ecol. Syst., 13: 373–384; Roubik, D.W. 1989. Ecology and Natural History of Tropical Bees. Cambridge, Univ. Press). Despite the extensive collections of euglossine bees with chemical baits, few extra-tropical records have been reported (Moure, J.S. 1967. At. Simp. Biota Amazôn., 5: 395–415; Kimsey, L.S. & Dressler, R.L. 1986. Pan-Pacific Entomol., 62: 229–236; Kimsey, L.S. 1987. Syst. Entomol., 12: 63–72). Nevertheless, some species occur outside the geographic tropics. In South America there are reports of euglossine and meliponine bees as far south as 32° S (Moure 1967. Wittmann, D., Hoffmann, M. & Scholz, E. 1988. Entomol. Generalis, 14: 53–60), but in the Northern Hemisphere it has been thought, until recently, that their distribution was restricted to about 25° N (Roubik 1989), in the Sierra Madre Oriental and central México. During the summers of 1991 and 1993 to 1995 bee collections have been made in several localities in southern Sonora, México (Table 1). These include *Nannotrigona perilampoides* (Cresson), and *Euglossa viridissima* Friese. The former has been collected in wild nests in trunks of *Ipomoea arborescens* (Humb. & Bonpl. ex Willd.) G. Don in the Sierra de Alamos, and from domestic hives kept by Rafael Figueroa at his carpentry in Alamos, Sonora. Male and female specimens of *Eg. viridissima* have been collected visiting flowers of *Tecoma stans* (L.) Juss ex H.B.K. and *Thevetia peruviana* (Pers.) Scum ex Engler & Prantl. However, other plants known to be visited and pollinated almost strictly by euglossine bees are present in the area. These include a large complement of orchids, tropical trees, and vines like *Dalechampia scandens* L. (Armbuster, W.S. & Webster, G.L. 1979. Biotropica, 11: 278–283) that are known to be used by euglossine and meliponine bees as food, and also as fragrance and resin sources for attraction and nest building. Males of euglossine bees were also lured with fragrances of eugenol, methyl salycilate, vanillin, and eucalyptol. However, in this study they were only attracted to eugenol.

The area where the bees have been collected is abrupt, with a broken topography dissected by numerous streams, some of them in deeply incised canyons. The vegetation consists of tropical deciduous forest and ecotones to Foothills Thornscrub and Sonoran Desert in the lowlands, and oak woodlands and pine-oak forests on the upper elevations (Gentry, H.S. 1942. Rio Mayo Plants. Carnegie Inst. Washington. Publ. 527; Búrquez, A., Martínez-Yrízar, A. & Felger, R.S. 1996. *In*: Biodiversity and Conservation in the Sonoran Desert. Robichaux, R.H. [ed.] Univ. Arizona Press). The capture of specimens of *Eg. viridissima* in southern Sonora, and the occasional reports of other Euglossini in NW Mexico, places the northern Sierra Madre Occidental in the states of Sonora and Chihuahua, as the present absolute northern limit for viable populations of this neotropical group of bees. The repeated collection of male and female individuals of *Eg. viridissima*,

Table 1. Tropical taxa collected near Alamos, Sonora, México or farther north (see Fig. 1). Taxa are ordered by collection date and plant visited. All specimens deposited at the reference collection of Estación Regional Noroeste, Centro de Ecología, UNAM. Elev = elevation in meters. *n* = number of individuals, M = male, F = female. TDF = Tropical deciduous forest.

Taxon Date	Collected on	Locality	Elev	*n*	Habitat
Euglossa viridissima					
03 Sep 1991	Eugenol bait	Sierra de Alamos (E side)	400	1M	TDF
04 Sep 1991	*Thevetia peruviana*	Alamos	400	1F	town garden
17 May 1991	Eugenol bait	Sierra de Alamos (E side)	750	6M	TDF
26 Oct 1994	*Thevetia peruviana*	Alamos	400	1M	town garden
26 Oct 1994	*Thevetia peruviana*	Yocojihua	350	2M 1F	TDF/thornscrub
30 Oct 1995	*Tecoma stans*	Piedras Verdes	190	1M 2F	town garden
30 Oct 1995	Eugenol bait	Sierra Alamos (N side)	500	1M	TDF
30 Oct 1995	*Thevetia peruviana*	Yocojihua	350	2M 1F	town garden
30 Oct 1995	Eugenol bait	Sierra de Alamos (E side)	750	2M	TDF
Eulaema polychroma					
04 Sep 1991	*Martynia annua*	Arroyo Alamos (2 km E)	450	1	TDF
30 Oct 1995	*Tecoma stans*	Alamos	400	2	town garden
Nannotrigona perilampoides					
30 May 1992	domestic hive	Alamos	400	12	TDF/thornscrub
30 May 1992	nest	Sierra de Alamos (E side)	750	60	TDF
30 Oct 1995	nest	Sierra de Alamos (E side)	800	5	TDF
Mesocheira bicolor					
30 Oct 1995	*Tecoma stans*	Piedras Verdes	190	1	town garden
Mesoplia sp.					
23 Abr 1990	*Vitex mollis*	Tonichi	250	1	thornscrub
13 Ago 1991	*Antigonon leptopus*	El Gavilán (E Hermosillo)	325	1	thornscrub
Xylocopa guatemalensis					
17 May 1991	*Martynia annua*	Sierra de Alamos (E side)	750	1	TDF
Xylocopa muscaria					
17 May 1991	*Martynia annua*	Sierra de Alamos (E side)	750	1	TDF

the lack of wear on their wings, and the presence of extensive tropical vegetation, along the sierran foothills indicate that these are members of persistent bee populations, rather than long-distance transient vagrants. The collection of *N. perilampoides* at their nests and domestic hives, confirms their presence and use farther north than previously reported (Schwarz, H. F. 1949. An. Inst. Biol. Mex., XX: 357–370). Other bee species found in the region near their extreme northern distribution are: *Partamona bilineata* (Say) [see Rozen, J. 1992. Melissa, 5: 1–2], *Eufriesea caerulescens* (Lepeletier) [reported in Kimsey. & Dressler 1986. at Maguarichic, Chihuahua, but close by is Maguarichi, Sonora, both in the Río Fuerte drainage], *Eulaema polychroma* (Mocsáry), *Mesoplia* sp., *Mesocheira bicolor* Fabricius, *Xylocopa muscaria* Fabricius and *X. guatemalensis* Cockerell (this report, Table 1). The occurrence of these strictly tropical bee species, add support to the remarkable deep intrusion of tropical elements along the Pacific

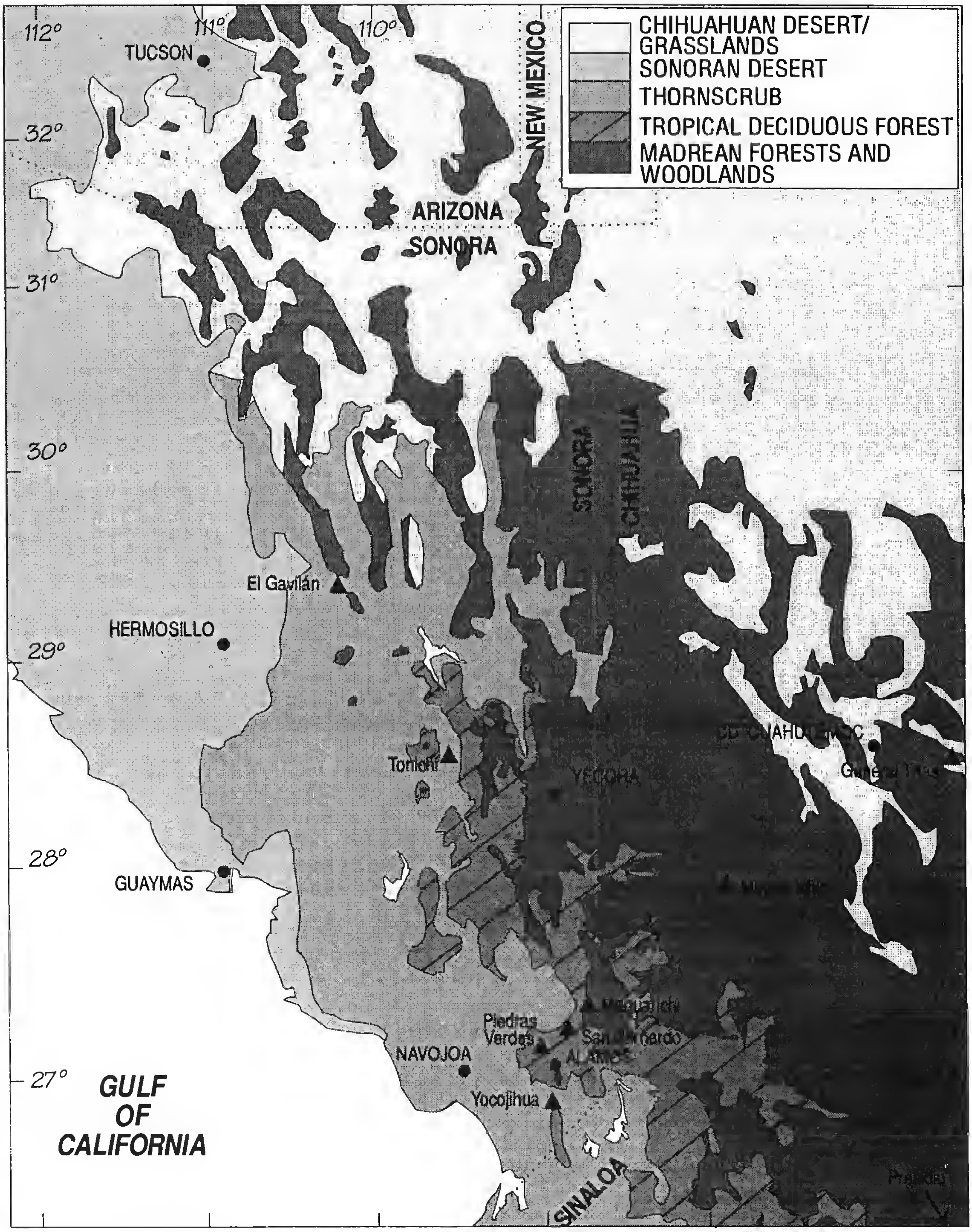


Figure 1. Diagram showing the vegetation of NW México-SW USA. Triangles show the collection sites mentioned in this report.

coast of Mexico far north of the tropic line. This phenomenon is also evident by the numerous strictly tropical plant taxa extending their ranges northwards along the same region (Gentry 1942, P. Jenkins pers. com.).

Euglossine and meliponine bees, as happen with other tropical bees, probably follow the tropical vegetation corridors along the Sierra Madre Oriental and Sierra Madre Occidental. The most northerly tropical communities (tropical deciduous forest), are present on the western face of the Sierra Madre Occidental (Gentry 1942; Rzedowsky, J. 1978. Vegetación de México. Limusa, México). These reach their northernmost occurrence in eastern Sonora, at the Pacific side of the Sierra, developing as an extensive vegetation belt between the Sonoran Desert and the oak Madrean Woodlands, or as isolated patches along the deep sierran canyons (Figure 1; Búrquez et al. 1996). An extreme example of dispersal along the Sierra Madre biological corridors was the recent report of a single male of *E. polychroma* in the Sonoran Desert captured near Tucson, Arizona that probably strayed from populations from the Sierra Madre Occidental (Minckley, R. L. & Reyes, S. G. 1995. J. Kansas Entomol. Soc., 69: 102–104).

Some euglossine bee species, although almost strictly tropical follow these tropical corridors in both hemispheres. Species at their extreme distribution range include *Eufriesea chalybaea* (Friese) that reaches 32° S, near Córdoba, Argentina (Moure 1967), *Ef. violacea* (Blanchard), *Eu. nigrita* Lepeletier, *Eg. cordata* (L.), *Eg.* sp. indet., and *Ef.* sp. indet., near Rio Grande do Sul, Brazil (ca. 30° S; Wittmann *et al.* 1988.), while in the Northern Hemisphere, *Ef. mexicana* (Mocsáry) has been collected at Presidio, Durango, México (25° N), and *Ef. caerulescens* (but perhaps the reputed synonym, *Ef. simillima* [Moure & Michener in Moure] D. Yanega pers. com.) has been collected near General Trías, México at 29° N (Rozen 1992, Minckley & Reyes 1995., Kimsey & Dressler 1986). The Sonoran collections of *Eg. viridissima* and *N. perilampoides* (this report) sets the distribution of the genera up to 27° N. However, it is probable that these species extend along the tropical deciduous forests in areas northward up to 29° N. *Eu. polychroma* collected at 32° N (Minckley & Reyes 1995.) is the absolute northernmost range of any euglossine bee, but as Minckley & Reyes (1995) have noted, persistent populations might be farther south, in the Pacific slope of the Sierra Madre Occidental in Southern Sonora, where their reproductive populations may live sympatrically along with other euglossine and meliponine species.

Acknowledgment.—Bob Minckley provided encouragement and revised previous versions of the manuscript. Two anonymous reviewers gave useful criticisms. G. Eickwort+, B. Alexander+, R. Ayala, T. Griswold, R. McGinley, D. Michener, W. LaBerge, J. Rozen, D. Roubik and other PCAM members introduced me to bees. S. Meyer called my attention on the presence of domestic meliponine hives in the Alamos region. To all of them I am grateful.

Alberto Búrquez, *Centro de Ecología, Universidad Nacional Autónoma de México, Apartado Postal 1354, Hermosillo, Sonora 83000, México.*

Received 20 Jun 1996; Accepted 1 Sep 1996.

PAN-PACIFIC ENTOMOLOGIST
Information for Contributors

See volume 66(1): 1–8, January 1990, for detailed general format information and the issues thereafter for examples; see below for discussion of this journal's specific formats for taxonomic manuscripts and locality data for specimens. Manuscripts must be in English, but foreign language summaries are permitted. Manuscripts not meeting the format guidelines may be returned. Please maintain a copy of the article on a word-processor because revisions are usually necessary before acceptance, pending review and copy-editing.

Format. — Type manuscripts in a legible serif font IN DOUBLE OR TRIPLE SPACE with 1.5 in margins on one side of 8.5 × 11 in, nonerasable, high quality paper. THREE (3) COPIES of each manuscript must be submitted, EACH INCLUDING REDUCTIONS OF ANY FIGURES TO THE 8.5 × 11 IN PAGE. Number pages as: title page (page 1), abstract and key words page (page 2), text pages (pages 3+), acknowledgment page, literature cited pages, footnote page, tables, figure caption page; place original figures last. List the corresponding author's name, address including ZIP code, and phone number on the title page in the upper right corner. The title must include the taxon's designation, where appropriate, as: (Order: Family). The ABSTRACT must not exceed 250 words; use five to seven words or concise phrases as KEY WORDS. Number FOOTNOTES sequentially and list on a separate page.

Text. — Demarcate MAJOR HEADINGS as centered headings and MINOR HEADINGS as left indented paragraphs with lead phrases underlined and followed by a period and two hypens. CITATION FORMATS are: Coswell (1986), (Asher 1987a, Franks & Ebbet 1988, Dorly et al. 1989), (Burton in press) and (R. F. Tray, personal communication). For multiple papers by the same author use: (Weber 1932, 1936, 1941; Sebb 1950, 1952). For more detailed reference use: (Smith 1983: 149–153, Price 1985: fig. 7a, Nothwith 1987: table 3).

Taxonomy. — Systematics manuscripts have special requirements outlined in volume 69(2): 194–198; if you do not have access to that volume, request a copy of the taxonomy/data format from the editor before submitting manuscripts for which these formats are applicable. These requirements include SEPARATE PARAGRAPHS FOR DIAGNOSES, TYPES AND MATERIAL EXAMINED (INCLUDING A SPECIFIC FORMAT), and a specific order for paragraphs in descriptions. List the unabbreviated taxonomic author of each species after its first mention.

Data Formats. — All specimen data must be cited in the journal's locality data format. See volume 69(2), pages 196–198 for these format requirements; if you do not have access to that volume, request a copy of the taxonomy/data format from the editor before submitting manuscripts for which these formats are applicable.

Literature Cited. — Format examples are:

Anderson, T. W. 1984. An introduction to multivariate statistical analysis (2nd ed). John Wiley & Sons, New York.

Blackman, R. L., P. A. Brown & V. F. Eastop. 1987. Problems in pest aphid taxonomy: can chromosomes plus morphometrics provide some answers? pp. 233–238. *In* Holman, J., J. Pelikan, A. G. F. Dixon & L. Weismann (eds.). Population structure, genetics and taxonomy of aphids and Thysanoptera. Proc. international symposium held at Smolenice Czechoslovakia, Sept. 9–14, 1985. SPB Academic Publishing, The Hague, The Netherlands.

Ferrari, J. A. & K. S. Rai. 1989. Phenotypic correlates of genome size variation in *Aedes albopictus*. Evolution, 42: 895–899.

Sorensen, J. T. (in press). Three new species of *Essigella* (Homoptera: Aphididae). Pan-Pacif. Entomol.

Illustrations. — Illustrations must be of high quality and large enough to ultimately reduce to 117 × 181 mm while maintaining label letter sizes of at least 1 mm; this reduction must also allow for space below the illustrations for the typeset figure captions. Authors are strongly encouraged to provide illustrations no larger than 8.5 × 11 in for easy handling. Number figures in the order presented. Mount all illustrations. Label illustrations on the back noting: (1) figure number, (2) direction of top, (3) author's name, (4) title of the manuscript, and (5) journal. FIGURE CAPTIONS must be on a separate, numbered page; do not attach captions to the figures.

Tables. — Keep tables to a minimum and do not reduce them. Table must be DOUBLE-SPACED THROUGHOUT and continued on additional sheets of paper as necessary. Designate footnotes within tables by alphabetic letter.

Scientific Notes. — Notes use an abbreviated format and lack: an abstract, key words, footnotes, section headings and a Literature Cited section. Minimal references are listed in the text in the format: (Bohart, R. M. 1989. Pan-Pacific. Entomol., 65: 156–161.). A short acknowledgment is permitted as a minor headed paragraph. Authors and affiliations are listed in the last, left indented paragraph of the note with the affiliation underscored.

Page Charges. — PCES members are charged $35.00 per page, for the first 20 (cumulative) pages per volume and full galley costs for pages thereafter. Nonmembers should contact the Treasurer for current nonmember page charge rates. Page charges do not include reprint costs, or charges for author changes to manuscripts after they are sent to the printer. Contributing authors will be sent a page charge fee notice with acknowledgment of initial receipt of manuscripts.

THE PAN-PACIFIC ENTOMOLOGIST
Volume 73 April 1997 Number 2

Contents

SCIENTIFIC NOTES

The PAN-PACIFIC ENTOMOLOGIST

Volume 73 July 1997 Number 3

Published by the PACIFIC COAST ENTOMOLOGICAL SOCIETY
in cooperation with THE CALIFORNIA ACADEMY OF SCIENCES
(ISSN 0031-0603)

The Pan-Pacific Entomologist

Published quarterly in January, April, July, and October with Society Proceedings usually appearing in the October issue. All communications regarding nonreceipt of numbers should be addressed to: Vincent F. Lee, Managing Secretary; and financial communications should be addressed to: Julieta F. Parinas, Treasurer; at: Pacific Coast Entomological Society, Dept. of Entomology, California Academy of Sciences, Golden Gate Park, San Francisco, CA 94118-4599.

Application for membership in the Society and changes of address should be addressed to: William Hamersky, Membership Committee chair, Pacific Coast Entomological Society, Dept. of Entomology, California Academy of Sciences, Golden Gate Park, San Francisco, CA 94118-4599.

Manuscripts, proofs, and all correspondence concerning editorial matters (but not aspects of publication charges or costs) should be sent to: Dr. Robert V. Dowell, Editor, Pan-Pacific Entomologist, California Dept. of Food & Agriculture, 1220 N St., Sacramento, CA 95814. See the back cover for Information-to-Contributors, and volume 66(1): 1–8, January 1990, for more detailed information. Information on format for taxonomic manuscripts can be found in volume 69(2): 194–198. Refer inquiries for publication charges and costs to the Treasurer.

The annual dues, paid in advance, are $25.00 for regular members of the Society, $26.00 for family memberships, $12.50 for student members, or $40.00 for institutional subscriptions or sponsoring members. Members of the Society receive *The Pan-Pacific Entomologist.* Single copies of recent numbers or entire volumes are available; see 72(4): 247 for current prices. Make checks payable to the *Pacific Coast Entomological Society.*

Pacific Coast Entomological Society

THE PAN-PACIFIC ENTOMOLOGIST (ISSN 0031-0603) is published quarterly for $40.00 per year by the Pacific Coast Entomological Society, ℅ California Academy of Sciences, Golden Gate Park, San Francisco, CA 94118-4599. Periodicals postage is paid at San Francisco, CA, and additional mailing offices. POSTMASTER: Send address changes to the Pacific Coast Entomological Society, ℅ California Academy of Sciences, Golden Gate Park, San Francisco, CA 94118-4599.

This issue mailed 31 July 1997

The Pan-Pacific Entomologist (ISSN 0031-0603)
PRINTED BY THE ALLEN PRESS, INC., LAWRENCE, KANSAS 66044, U.S.A.

PAN-PACIFIC ENTOMOLOGIST
73(3): 141–151, (1997)

OSMIA (HYMENOPTERA: MEGACHILIDAE) DIVERSITY AT A SITE IN CENTRAL COASTAL CALIFORNIA

John F. Barthell[1,2], Terry L. Griswold[3], Gordon W. Frankie[1], & Robbin W. Thorp[4]

[1] Division of Entomology, University of California, Berkeley, California 94720
[3] USDA–ARS Bee Biology & Systematics Lab, Utah State University, Logan, Utah 84322
[4] Department of Entomology, University of California, Davis, California 95616

Abstract.—Thirty species of the megachilid bee genus *Osmia* were recorded at a research reservation in central coastal California during two survey periods: 1937–43 and 1987–92. Diversity remained constant at 23 species between surveys. However, cumulative diversity increased from 23 to 30 species. The total number of species at this geographic locale is relatively high when compared with nine other surveys but is most typical of diversities found at other montane, mid-elevation latitudes. Differences between study periods suggest that long-term surveys are required to accurately assess species diversity.

Key Words.—Insecta, Hymenoptera, Megachilidae, *Osmia*, species diversity.

Studies of biodiversity often rely upon knowing numbers of species, information that is critical to testing some of the most frequently discussed hypotheses in basic and applied ecology, including island biogeography and species/area relationships (reviewed in Williamson 1981, MacArthur & Wilson 1967). Within the Apoidea, taxonomic summaries for broad geographic regions have been assembled (Michener et al. 1994, Ayala et al. 1993, Roubik 1989, Westrich 1989a & b, Rust et al. 1983, Tepedino 1982, Michener 1979, Moldenke 1976, Stephen et al. 1969), but fewer studies seek to determine local species diversity in preserved, natural settings (e.g. Thorp et al. 1994, Thorp & Gordon 1992, Ayala 1988, Rust et al. 1985).

We surveyed such a region for the solitary bee genus *Osmia.* This group represents the fifth largest genus of bees in North America, containing approximately 130 species (Rust 1974). Like other genera in the family Megachilidae, many species use pre-existing cavities in their environment for nesting. This trait makes them amenable to studies that use artificial nesting sites, including trap-nests (Krombein 1967). The present study concerns collections made by hand during two historical periods and at a single locale, the Hastings Natural History Reservation (Hastings). Our objectives were two-fold. First, we wished to gain a relatively complete record of *Osmia* species at a preserved site in California. Secondly, we wanted to compare collection results from two survey periods (1937–43 and 1987–92) for differences.

Materials and Methods

Study Site.—The Hastings Natural History Reservation (Hastings) is located 42 km SE of Carmel in the Santa Lucia foothills of Monterey County, California (36°23′ N, 121°33′ W). Hastings is part of the University of California Natural Reserve System and is managed through the Museum of Vertebrate Zoology (U.C. Berkeley). It originally encompassed 664 ha. of land when established in 1937

---

[2] Current Address: Department of Biology, University of Central Oklahoma, Edmond, Oklahoma 73034.

and currently covers 914 ha., ranging in elevation from 467–953 m (Griffin 1988). Griffin (1974, 1990) describes six major plant communities at Hastings with 90 of the 576 plant species (15%) being introduced (Knops et al. 1995).

Early research at Hastings was directed by the resident zoologist Jean M. Linsdale who helped to accumulate a wealth of information on the natural history and species composition of the reserve (Linsdale 1947). Several taxonomic surveys were produced, including an extensive insect collection made by C. D. Michener in the late 1930s. The rediscovery of a portion of this collection in metal storage cabinets during the late 1980s coincided with our efforts to survey bee species at Hastings and other California sites (Thorp et al. 1992). Here we compare *Osmia* diversity at Hastings between the two survey periods as well as its overall diversity to other North American surveys.

Collections were made primarily with a hand-held insect net with the date recorded for each specimen. Some specimens collected during the early survey period (1937–43) were stored in gelatin capsules and held in glassine envelopes with labelled, 7.6 cm × 21.7 cm index cards. These latter specimens were later mounted on insect pins to facilitate species determination. Other specimens from that period were deposited in the Snow Entomology Museum (SEM) at the University of Kansas. These specimens were re-examined for this study and later redeposited at SEM. Specimens from the most recent survey will be deposited at University of California (Berkeley and Davis campuses) entomological museums.

Host plant associations were recorded for specimens during both survey periods, but most often during the second one. When possible, pollen sources were determined by observation of foraging female bees and microscopic comparison of pollen taken from flower and bee specimens.

Results and Discussion

A total of 377 *Osmia* specimens were collected during the first survey period (1937-1943). Most (360) were collected during 1938 with only four specimens from 1939, 12 from 1940 and one from 1943 (none in 1937, 1941 and 1942). During the 1987–92 period, 602 *Osmia* specimens were collected, most of these during the last two years of the study, 1991 (227) and 1992 (222); fifteen specimens were collected during 1987, none during 1988, 52 during 1989 and 86 during 1990. During both survey periods, 23 *Osmia* species were documented. Seven species were unique to each survey, with a total of 30 species overall (Table 1).

Geographic Comparisons of Diversity.—*Osmia* species diversity at Hastings is relatively high. The 30 species collected there represent over 20% of the 130 species estimated for North America by Rust (1974) and 10 of the 12 subgenera (excepting *Diceratosmia* and *Nothosmia*). Despite its relatively small size (914 hectares), Hastings has over one-third (27 of 75) of the *Osmia* species estimated in California by Moldenke & Neff (1974).

A comparison of our results with nine other North American surveys that include *Osmia* (Table 2) confirms the generalization that *Osmia* represent "boreal" species (Linsley 1958). The five most diverse *Osmia* locales (including Hastings) were at higher elevations (> 450 m) with substantial grassland/meadow components. The combined studies of Thorp et al. (1994) and Rust et al. (1985) yielded one-third as many *Osmia* species on Santa Cruz Island (off the coast of southern California) as in this survey, even though Hastings represents < 1% of the area

Table 1. A comparison of *Osmia* species collected during two study periods at the Hastings Natural History Reservation: 1937–43 and 1987–92.

	Collection period			
	1937–43		1987–92	
Species	Pres.*	(No., %)	Pres.*	(No., %)
Osmia (Acanthosmioides) nifoata Cockerell	●	(7, 1.9)	●	(16, 2.7)
Osmia (Centrosmia) bakeri Sandhouse	○	(0, 0.0)	●	(16, 2.7)
Osmia (Cephalosmia) californica Cresson	○	(0, 0.0)	●	(4, 0.7)
Osmia (Cephalosmia) montana Cresson	●	(15, 4.0)	○	(0, 0.0)
Osmia (Chalcosmia) coloradensis Cresson	●	(2, 0.5)	○	(0, 0.0)
Osmia (Chalcosmia) texana Cresson	●	(1, 0.3)	●	(30, 5.0)
Osmia (Chenosmia) aglaia Sandhouse	●	(19, 5.0)	●	(65, 10.8)
Osmia (Chenosmia) calla Cockerell	●	(2, 0.5)	○	(0, 0.0)
Osmia (Chenosmia) clarescens Cockerell	●	(2, 0.5)	○	(0, 0.0)
Osmia (Chenosmia) cyanopoda Cockerell	○	(0, 0.0)	●	(2, 0.3)
Osmia (Chenosmia) granulosa Cockerell	●	(10, 2.7)	●	(9, 1.5)
Osmia (Chenosmia) kincaidii Cockerell	●	(4, 1.1)	●	(5, 0.8)
Osmia (Chenosmia) laeta Sandhouse	●	(12, 3.2)	●	(28, 4.7)
Osmia (Chenosmia) pusilla Cresson	●	(1, 0.3)	○	(0, 0.0)
Osmia (Chenosmia) regulina Cockerell	●	(29, 7.7)	●	(17, 2.8)
Osmia (Chenosmia) trevoris Cockerell	○	(0, 0.0)	●	(5, 0.8)
Osmia (Chenosmia) tristella Cockerell	●	(2, 0.5)	●	(6, 1.0)
Osmia (Chenosmia) zephyros Sandhouse	○	(0, 0.0)	●	(7, 1.2)
Osmia (Euthosmia) glauca (Fowler)	●	(193, 51.2)	●	(55, 9.1)
Osmia (Monilosmia) albolateralis Sandhouse	●	(5, 1.3)	●	(2, 0.3)
Osmia (Monilosmia) atrocyanea (Cockerell)	●	(8, 2.1)	●	(101, 16.8)
Osmia (Monilosmia) brevis Cresson	●	(4, 1.1)	●	(8, 1.3)
Osmia (Monilosmia) cara Cockerell	●	(1, 0.3)	○	(0, 0.0)
Osmia (Monilosmia) cyanella Cockerell	●	(21, 5.6)	●	(41, 6.8)
Osmia (Monilosmia) gabrielis Cockerell	●	(8, 2.1)	●	(13, 2.2)
Osmia (Mystacosmia) nemoris Sandhouse	●	(21, 5.6)	●	(25, 4.2)
Osmia (Osmia) lignaria Cresson	●	(8, 2.1)	●	(145, 24.1)
Osmia (Osmia) ribifloris Michener	○	(0, 0.0)	●	(1, 0.2)
Osmia (Trichinosmia) latisulcata Michener	●	(1, 0.3)	○	(0, 0.0)
Osmia (Unassigned) *claremontensis* Michener	○	(0, 0.0)	●	(1, 0.2)
Osmia undetermined specimens	—	(1, 0.3)	—	(0, 0.0)
Totals	23	(377, 100.2)	23	(602, 100.2)

* Species presence (●) or absence (○).

of the island. This result probably reflects the fact that Santa Cruz Island is species-poor relative to the mainland bee fauna (Thorp et al. 1994). The latitudinal extremes of Alaska (Armbruster & Gunn 1989) and Mexico (Ayala 1988) show little *Osmia* diversity as do the surveys conducted at Nevada and Utah sand dune habitats (Rust et al. 1983, Griswold, unpublished data).

Differences Between Surveys at Hastings.—*Osmia lignaria* Cresson was the most frequently collected species during the 1987–92 period (24% of the collection) while *Osmia glauca* was most common during the 1937–43 survey (193 of 377 specimens). All but one of the latter species were collected on the same day, 1 Jun, in 1938. Relatively few (eight) *O. lignaria* were collected during the early survey period, an artifact of a delayed initiation of the survey. The least common species in the current survey were *Osmia ribifloris* and *Osmia claremontensis*

Table 2. A comparison of selected North American faunal surveys that include *Osmia* species.

Survey citation	Locale (disjunct sites) Habitat types	Years	Latitude	Elevation (m)	Method	No. subgenera Total (shared†)	No. spp. Total (shared†)
Armbruster & Gunn (1989)	USA—Alaska (32) variable–interior arctic	8	64.0–70.0° N	unreported	Net	2 (2)	4 (0)
Griswold (unpub.)	USA—Idaho (1) montane meadow	2	42.0–43.0° N	1768	Malaise	7 (7)	28 (13)
Tepedino (1982)	USA—Wyoming (2) shortgrass prairie	3	41.0–42.0° N	2250–2425	Net	7 (7)	20 (8)
Griswold (unpub.)	USA—California (4) montane meadow	3	40.0–41.0° N	1342–2286	Net	8 (7)	34 (17)
Griswold (unpub.)	USA—Nevada (5) montane meadow	3	40.0–41.0° N	2316–3109	Net	5 (5)	20 (7)
Rust et al. (1983)	USA—Nevada (2) sand dunes	2	39.0–40.0° N	1250–1400	Net	1 (1)	1 (0)
Griswold (unpub.)	USA—Utah (8) sand dunes	6	38.0–39.0° N	1372–1585	Net	5 (4)	7 (1)
Current study	USA—California (1) coastal foothill	10	36.0–37.0° N	467–953	Net	10 (−)	30 (−)
Thorp et al. (1994)[1]	USA—California (1) variable–island	5	33.5–34.5° N	0–753	Net	4 (4)	10 (9)
Ayala (1988)	MEX—Jalisco (1) seasonal lowland	5	19.0–20.0° N	unreported	Net	− (−)	0 (−)

[1] Based upon the work of Rust et al. (1985) which includes additional years of collections.

† Number shared with current study.

whereas *O. cara*, *O. pusilla*, *O. latisulcata* and *O. texana* were the rarest of the original survey (all species represented by a single specimen). Fifteen species from the current survey were represented by ≤ 20 specimens, including all 7 species not recorded during the original collection period.

Although most species undetected between surveys were relatively rare or inconspicuous, the absence of *O. coloradensis* and *O. montana* in the recent survey is enigmatic. Both are well documented in California (Rust 1974) and are relatively large in size with a dark metallic appearance that makes them especially conspicuous to collectors. Both species prefer asteraceous pollen (Hurd 1979) and we have collected the closely related *Osmia californica* and *Osmia texana* from the thistle species *Cirsium occidentale*. Nectar sources such as *Salvia mellifera* and *Vicia villosa* were also monitored without encountering either *Osmia* (see Appendix). If either of these species were at Hastings during the current survey, they were in such low numbers as to be undetectable.

There may be several explanations for the apparent absence of species between survey periods. First, naturally occurring factors such as annual host plant variation could produce temporary declines in bee population levels. Bloom intensity of *Lupinus nanus* can vary 11-fold between years at Hastings, for example, potentially influencing those bee species that require its pollen (Knops & Barthell 1996). Population fluctuations may also reflect parsivoltinism, a condition in some *Osmia* species that delays emergence (Torchio & Tepedino 1982). The current survey was conducted during consecutive years, however, and we are likely to have encountered such species if they inhabited Hastings in high numbers.

Most plant species introductions occurred well before the first complete floral survey conducted at Hastings (Linsdale 1955). Knops et al. (1995), indicate that very early agricultural practices (≈ 1800s) have profoundly altered plant communities at Hastings. Over 28% of the grassland and 19% of the herbaceous communities, both important sources of host plants, are now alien species. How these long-term introductions have influenced *Osmia* is difficult to ascertain. Although bee species were collected from introduced host plants, most of these species were already at Hastings when the original survey was conducted.

Ten fires are known to have at least minimally affected Hastings in this century, seven since the reserve was established (Griffin 1988). In total, they affected ≈ 206 hectares of the current reserve property and 88 ha (≈ 13%) of the original property. The extensive "Marble Cone" fire of 1977 did not reach Hastings but did alter nearby plant communities by producing an abundance of herbaceous species (Talley & Griffin 1980). This may have influenced pollen and nectar availability to bees, but there is no direct evidence of this occurring. Such fires also consume dead trees and limbs which might otherwise be used for nesting sites. There is little evidence that burns have had a serious effect on the availability of downed wood, however.

Species diversity has remained constant at Hastings between surveys (23 species) although cumulative species diversity has increased. Each survey had seven unique species, suggesting that species may become alternately present (detectable) and absent (undetectable) in the environment over time. The absence of conspicuous species such as *Osmia montana* and *Osmia coloradensis* in the most recent survey indicates that these absences are not necessarily an artifact of different collectors, underscoring the need for long-term surveys to better estimate species diversity.

ACKNOWLEDGMENT

We thank A. Barthell, K. Delate, D. Fruitt, J. Knops, M. Prentice and R. Stone for field assistance and H. Daly, F. Pitelka, M. Stromberg and D. Wood for their logistical support. Charles Michener collected most of the material in the early survey and loaned us that portion of the material housed in the Snow Entomological Museum, University of Kansas. The staff of Hastings Natural History Reservation (University of California, Berkeley) provided advice and an enthusiastic atmosphere for our research efforts. Earlier drafts of the manuscript were evaluated by H. Daly, T. Duncan, C. Michener, F. Parker and N. Williams. Valuable botanical discussions were provided by J. Griffin and J. Knops. The research was supported by the U.C. Agricultural Experiment Station and through dissertation support to JFB by a U.C. Natural Reserve System Grant and the U.C. Entomology Department's Walker Fund. Posthumously, we thank J. Linsdale who, with help from numerous assistants, oversaw collection and curation of specimens at Hastings. This paper was presented as part of a memorial symposium in honor of George Eickwort held at Cornell University in April of 1995.

LITERATURE CITED

Armbruster, W. S. & D. A. Gunn. 1989. The solitary bee fauna (Hymenoptera: Apoidea) of interior and arctic Alaska: flower associations, habitat use, and phenology. J. Kansas Entomol. Soc., 62: 468–483.

Ayala, R. 1988. Abejas silvestres de Chamela, Jalisco, Mexico. Fol. Entomol. Mex., 77: 395–493.

Ayala, R., T. Griswold & S. Bullock. 1993. pp. 179–227. The native bees of Mexico. *In* Ramamoorthy, T. P., R. Bye & A. Lot (eds.). Biological diversity of Mexico: Origins and distribution. Oxford Univ. Press, New York.

Griffin, J. R. 1974. Botanical resources of the Hastings reservation, Monterey county, California. Madroño, 22: 329–333.

Griffin, J. R. 1988. A natural history of Hastings reservation. Report Number 1. Hastings Natural History Reservation, Museum of Vertebrate Zoology, Natural Reserve System, University of California.

Griffin, J. R. 1990. Flora of Hastings Reservation Carmel Valley, California. Report No. 2. Hastings Natural History Reservation, Museum of Vertebrate Zoology, Natural Reserve System, University of California.

Hurd, P. D., Jr. 1979. Superfamily Apoidea. pp. 1741–2209. *In* K. V. Krombein, P. D. Hurd, Jr., D. R. Smith & B. D. Burks, (eds.). Catalog of Hymenoptera in America North of Mexico, Volume 2, Apocrita. Smithsonian Institution Press, Washington, D. C.

Knops, J. M. H. & J. F. Barthell. 1996. Flower abundance in a population of sky lupine (*Lupinus nanus*) over three years in central coastal California. Madroño, 43: 85–92.

Knops, J. M. H., J. R. Griffin & A. C. Royalty. 1995. Introduced and native plants at the Hastings Reservation, central coastal California: a comparison. Biol. Conservation, 71: 115–123.

Krombein, K. V. 1967. Trap-nesting wasps and bees: life histories, nests, and associates. Smithsonian Press, Washington, D.C.

Linsdale, J. M. 1947. The Francis Simes Hastings Natural History Reservation 1937–47. University of California, Berkeley.

Linsdale, J. M. 1955. Check list of ferns and seed plants of the Frances Simes Hastings Natural History Reservation. Leaf. West. Bot., 7: 201–218.

Linsley, E. G. 1958. The ecology of solitary bees. Hilgardia, 27: 543–599.

MacArthur, R. H. & E. O. Wilson. 1967. The theory of island biogeography. Princeton University Press, Princeton.

Michener, 1979. Biogeography of the bees. Ann. Missouri Bot. Gard. 66: 277–347.

Michener, C. D., R. J. McGinley & B. N. Danforth. 1994. The bee genera of North and Central America (Hymenoptera: Apoidea). Smithsonian Institution Press, Washington, D. C.

Moldenke, A. R. 1976. California pollination ecology and vegetation types. Phytologia, 34: 147–178.

Moldenke, A. R. & J. L. Neff. 1974. The bees of California: a catalogue with special relevance to pollination and ecological research. Technical Report 74-3 (Part III of 3). Board of Studies in Biology, University of California, Santa Cruz.

Roubik, D. W. 1989. Ecology and natural history of tropical bees. Cambridge University Press, Cambridge, Massachusetts.

Rust, R. W. 1974. The systematics and biology of the genus *Osmia*, Subgenera *Osmia*, *Chalcosmia*, and *Cephalosmia* (Hymenoptera: Megachilidae). Wasmann J. Biol., 32: 1–93.

Rust, R. W., L. M. Hanks & R. C. Bechtel. 1983. Aculeata Hymenoptera of Sand Mountain and Blow Sand Mountains, Nevada. Great Basin Naturalist., 43: 403–408.

Rust, R., A. Menke & D. Miller. 1985. A biogeographic comparison of the bees, sphecid wasps, and mealybugs of the California channel islands (Hymenoptera, Homoptera). pp. 29–58. *In* Menke, A. S. & D. R. Miller (eds.). Entomology of the California Channel Islands: Proceedings of the First Symposium, Santa Barbara Museum of Natural History.

Stephen, W. P., G. E. Bohart & P. F. Torchio. 1969. The biology and external morphology of bees. Oregon State University Press, Corvallis, Oregon.

Talley, S. N. & J. R. Griffin. 1980. Fire ecology of a montane pine forest, Junipero Serra Peak, California. Madroño, 27: 49–60.

Tepedino, V. J. 1982. Flower visitation and pollen collection records for bees of high altitude shortgrass prairie in southeastern Wyoming. Southwestern Entomol., 7: 16–25.

Thorp, R. W. & D. M. Gordon. 1992. Biodiversity and pollination biology of bees in coastal nature preserves. pp. 105–111. *In* Turner, H. M. (ed.), Proc. Symp. Biodiversity of NW Calif. (28–30 Oct. 1991, Santa Rosa). Univ. of Calif. DANR Publ. Wildland Research Center, Berkeley, CA Rept. 29.

Thorp, R. W., G. W. Frankie, J. Barthell, D. Gordon, L. Newstrom, T. Griswold, J. Schmidt & S. Thoenes. 1992. Ecological Research. Long-term studies to gauge effects of invading bees. Cal. Ag., 46: 20–23.

Thorp, R. W., A. M. Wenner & J. F. Barthell. 1994. Flowers visited by honey bees and native bees on Santa Cruz Island. In Halverson, W. L. & G. J. Maender (eds.). Fourth California Islands Symposium: Update on the Status of Resources. Santa Barbara Museum of Natural History, Santa Barbara, California.

Torchio, P. F. & V. J. Tepedino. 1982. Parsivoltinism in three species of *Osmia* bees. Psyche, 89: 221–238.

Westrich, P. 1989a. Die Wild-Bienen-Württembergs. Allgemiener Teil: Lebensraüme, Ökologie und Schutz. Stuttgart, pp. 5–431.

Westrich, P. 1989b. Die Wild-Bienen-Württembergs. Spezieller Teil: die Gattungen und Arten. Stuttgart, pp. 437–972.

Williamson, M. H. 1981. Island populations. Oxford University Press, Oxford.

Received 28 Aug 1996; Accepted 6 Jan 1997.

Appendix. Flower visitation records of *Osmia* species for which records are available.

		O. (*Acanth.*) *nifoata*	*O.* (*Centr.*) *bakeri*	*O.* (*Cephal.*) *californica*	*O.* (*Chalc.*) *texana*	*O.* (*Chen.*) *aglaia*	*O.* (*Chen.*) *cyanopoda*	*O.* (*Chen.*) *granulosa*	*O.* (*Chen.*) *kincaidii*	*O.* (*Chen.*) *laeta*	*O.* (*Chen.*) *regulina*	*O.* (*Chen.*) *trevoris*	*O.* (*Chen.*) *tristella*	*O.* (*Chen.*) *zephyros*	*O.* (*Euth.*) *glauca*	*O.* (*Monil.*) *albolateralis*	*O.* (*Monil.*) *atrocyanea*	*O.* (*Monil.*) *brevis*	*O.* (*Monil.*) *cyanella*	*O.* (*Monil.*) *gabrielis*	*O.* (*Mystac.*) *nemoris*	*O.* (*Osmia*) *lignaria*	*O.* (*Osmia*) *ribifloris*	*O.* (None) *claremontensis*
Amaryllidaceae																								
Triteleia ixoides (S. Watson) E. Greene	♀	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—
	♂	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Asteraceae																								
Centaurea melitensis L.*	♀	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—
	♂	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Cirsium occidentale (Nutt.) Jepson	♀	—	—	2†	18†	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	♂	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Boraginaceae																								
Plagiobothrys nothofulvus (A. Gray) A. Gray	♀	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—
	♂	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Brassicaceae																								
Cardamine californica (Torrey & A. Gray) E. Greene	♀	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	♂	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—
Caprifoliaceae																								
Lonicera interrupta Benth.	♀	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—
	♂	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ericaceae																								
Arbutus menziesii Pursh	♀	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	5	1	—
	♂	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Appendix. Continued.

		O. (*Acanth.*) *nifoata*	*O.* (*Centr.*) *bakeri*	*O.* (*Cephal.*) *californica*	*O.* (*Chalc.*) *texana*	*O.* (*Chen.*) *aglaia*	*O.* (*Chen.*) *cyanopoda*	*O.* (*Chen.*) *granulosa*	*O.* (*Chen.*) *kincaidii*	*O.* (*Chen.*) *laeta*	*O.* (*Chen.*) *regulina*	*O.* (*Chen.*) *trevoris*	*O.* (*Chen.*) *tristella*	*O.* (*Chen.*) *zephyros*	*O.* (*Euth.*) *glauca*	*O.* (*Monil.*) *albolateralis*	*O.* (*Monil.*) *atrocyanea*	*O.* (*Monil.*) *brevis*	*O.* (*Monil.*) *cyanella*	*O.* (*Monil.*) *gabrielis*	*O.* (*Mystac.*) *nemoris*	*O.* (*Osmia*) *lignaria*	*O.* (*Osmia*) *ribifloris*	*O.* (None) *claremontensis*
Fabaceae																								
Lotus scoparius (Nutt.) Ottley	♀	1	—	—	—	41†	2	—	—	15†	12†	—	—	—	—	—	10	—	1	2	—	—	—	—
	♂	1	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Lupinus nanus Benth.	♀	—	—	—	—	—	—	—	—	—	—	3	1	3	—	—	8†	—	—	—	1	35†	—	—
	♂	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Melilotus indica (L.) All.*	♀	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	♂	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Robinia pseudo-acacia L.*	♀	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—
	♂	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Trifolium sp.	♀	1	—	—	—	—	—	—	—	—	7	—	—	—	—	1	—	—	—	—	—	—	—	—
	♂	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Vicia villosa Roth*	♀	15	—	—	—	—	—	—	1	—	3†	2	—	3	—	1	49	1	1	9	14	3	—	—
	♂	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	8	—	—	2	1	—	—	—
Hydrophylliaceae																								
Pholistoma auritum (Lindley) Lilja	♀	—	—	—	—	—	—	—	1	—	—	—	—	—	4	—	1	—	—	—	—	14	—	—
	♂	—	—	—	—	—	—	—	1	—	—	—	—	—	1	—	—	—	—	—	—	2	—	—
Nemophila menziesii Hook. & Arn.	♀	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	♂	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	20	—	—
Labiatae																								
Rosmarinus sp.*	♀	—	—	—	—	—	—	—	—	—	—	—	—	—	4	—	—	—	—	—	1	—	—	—
	♂	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	10	—	—

Appendix. Continued.

		O. (*Acanth.*) *nifoata*	*O.* (*Centr.*) *bakeri*	*O.* (*Cephal.*) *californica*	*O.* (*Chalc.*) *texana*	*O.* (*Chen.*) *aglaia*	*O.* (*Chen.*) *cyanopoda*	*O.* (*Chen.*) *granulosa*	*O.* (*Chen.*) *kincaidii*	*O.* (*Chen.*) *laeta*	*O.* (*Chen.*) *regulina*	*O.* (*Chen.*) *trevoris*	*O.* (*Chen.*) *tristella*	*O.* (*Chen.*) *zephyros*	*O.* (*Euth.*) *glauca*	*O.* (*Monil.*) *albolateralis*	*O.* (*Monil.*) *atrocyanea*	*O.* (*Monil.*) *brevis*	*O.* (*Monil.*) *cyanella*	*O.* (*Monil.*) *gabrielis*	*O.* (*Mystac.*) *nemoris*	*O.* (*Osmia*) *lignaria*	*O.* (*Osmia*) *ribifloris*	*O.* (None) *claremontensis*
Lamiaceae																								
Marrubium vulgare L.*	♀	—	—	—	—	5	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	♂	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Salvia mellifera E. Greene*	♀	—	—	2	—	5	—	6	—	2	—	—	2	—	—	—	2	2	5	—	—	5	—	—
	♂	—	—	—	8	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—
Stachys bullata Benth.	♀	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	1	1	—	—	—	—	—
	♂	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Thymus sp.*	♀	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	♂	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—
Onagraceae																								
Clarkia unguiculata Lindley	♀	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	♂	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Oxalaceae																								
Oxalis pes-caprae L.*	♀	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	♂	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	17	—	—
Polygonaceae																								
Eriogonum fasciculatum Benth.	♀	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—
	♂	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Rhamnaceae																								
Rhamnus californica Esch.	♀	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—
	♂	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Appendix. Continued.

		O. (*Acanth.*) *nifoata*	*O.* (*Centr.*) *bakeri*	*O.* (*Cephal.*) *californica*	*O.* (*Chalc.*) *texana*	*O.* (*Chen.*) *aglaia*	*O.* (*Chen.*) *cyanopoda*	*O.* (*Chen.*) *granulosa*	*O.* (*Chen.*) *kincaidii*	*O.* (*Chen.*) *laeta*	*O.* (*Chen.*) *regulina*	*O.* (*Chen.*) *trevoris*	*O.* (*Chen.*) *tristella*	*O.* (*Chen.*) *zephyros*	*O.* (*Euth.*) *glauca*	*O.* (*Monil.*) *albolateralis*	*O.* (*Monil.*) *atrocyanea*	*O.* (*Monil.*) *brevis*	*O.* (*Monil.*) *cyanella*	*O.* (*Monil.*) *gabrielis*	*O.* (*Mystac.*) *nemoris*	*O.* (*Osmia*) *lignaria*	*O.* (*Osmia*) *ribifloris*	*O.* (None) *claremontensis*
Rosaceae																								
Cydonia sp.*	♀	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	♂	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	9	—	—
Scrophulaceae																								
Collinsia heterophylla Buist	♀	—	10†	—	—	3	—	1	1	4†	4	—	3†	—	15†	1†	8†	3†	29†	—	8	15†	—	—
	♂	—	5	—	—	5	—	1	—	3	1	—	1	—	4	—	5	2	3	—	—	—	—	1
Verbenaceae																								
Verbena lasiostachys Link	♀	—	—	—	—	2	—	—	1	—	—	—	—	—	1	—	—	—	1	—	2	—	—	—
	♂	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Violaceae																								
Viola pedunculata Torrey & A. Gray	♀	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—
	♂	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

* Introduced plant species.
† Confirmed pollen source.
"—" = no records.

PAN-PACIFIC ENTOMOLOGIST
73(3): 152–155, (1997)

A NEW SPECIES OF *ENICOSCOLUS* (DIPTERA: BIBIONIDAE) FROM BRAZIL, WITH ADDITIONAL DISTRIBUTION RECORDS FOR THE GENUS

Scott Fitzgerald
Colorado State University, Department of Entomology,
Fort Collins, CO 80523

Abstract.—A new species of the rare bibionid genus *Enicoscolus* is described from Brazil and a holotype female is designated. Characters separating *Enicoscolus hardyi* new species from the three other known *Enicoscolus* species are summarized. Illustrations to distinguish the three New World species and a key to the world species are provided. New range extentions and seasonal distribution are also given for the New World species.

Key Words.—Insecta, Diptera, Bibionidae, *Enicoscolus*, new species, Mexico, Brazil.

The bibionid genus *Enicoscolus* Hardy was erected for two species, *E. brachycephalus* Hardy and *E. dolichocephalus* Hardy, represented by five females collected in the state of Morelos, Mexico (Hardy 1961). An additional species, *E. collessi* Hardy, was added to the genus, represented by one female, from Queensland, Australia (Hardy 1962). Hardy (1982) reports three additional females of *E. collessi* from the island of New Guinea, which brings the number of known specimens of the genus to a total of nine females. No fossils of *Enicoscolus* are known. An examination of neotropical material from various institutions produced an additional seventeen females, one representing a new species from Brazil.

Because the genus was previously known from the Australian region and Mexico, the discovery of a new species of *Enicoscolus* from South America was expected (Hardy 1962) and provides additional support for an ancient Antarctic land connection between the Australian and South American land masses. However, without a phylogeny only speculation can be made as to the origin of the genus, dispersal events, and the order of vicariance events that may have led to its present-day distribution. A Gondwanian distribution makes it possible that the genus may be found in Africa, and due to its scarcity and small size, additional unknown species seem likely.

Males of *Enicoscolus* are unknown. With the exception of brachypterous *Penthetria funebris* Meigen, no other bibionids are known to be apterous, brachypterous, or parthenogenetic. There is a possibility that *Enicoscolus* may exhibit one of these derived states, making males either difficult to collect or absent.

Depositories.—California Academy of Sciences, San Francisco (CASC); Canadian National Collection, Ottawa (CNCI); Essig Museum of Entomology, University of California, Berkeley (EMEC); Utah State University, Logan (EMUS); Snow Entomological Museum, University of Kansas, Lawrence (SEMC); The Bohart Museum of Entomology, University of California, Davis (UCDC); University of California, Riverside (UCRC); Coleccion Entomologica, Instituto de Biologia, Universidad Nacional Autonoma de Mexico (UNAM); United States National Museum of Natural History, Washington, D.C. (USNM). Terminology of morphology follows McAlpine (1981).

KEY TO THE SPECIES OF ENICOSCOLUS

1a Rostrum developed (Fig. 3); Mexico .... *dolichocephalus*
1b Rostrum undeveloped (Figs. 1 & 2) 2
2a(1b) Apical segment of palpus short (see Hardy 1962: 784, fig. a); Australian region .... *collessi*
2b Apical segment of palpus long (Fig. 1 & see Hardy 1961: 83, fig. 1); Mexico and Brazil 3
3a(2b) Dorsum of thorax orange; shape of head as Fig. 1; hind basitarsus slender, elongate, relative to tarsomeres 2 and 3 (Fig. 4); Brazil .... *hardyi*
3b Dorsum of thorax black; shape of head as Fig. 2; hind basitarsus not so slender, elongate, relative to tarsomeres 2 and 3 (Fig. 5); Mexico .... *brachycephalus*

Enicoscolus hardyi Fitzgerald, NEW SPECIES
(Figs. 1, 4)

Type.—Holotype female. BRAZIL. West border, Mato Grosso, May 1931, R.C. Shannon; deposited: Snow Entomological Museum, University of Kansas (SEMC). Flagellum of one antenna, one hind leg, and apical two tarsal segments of the remaining hind leg missing.

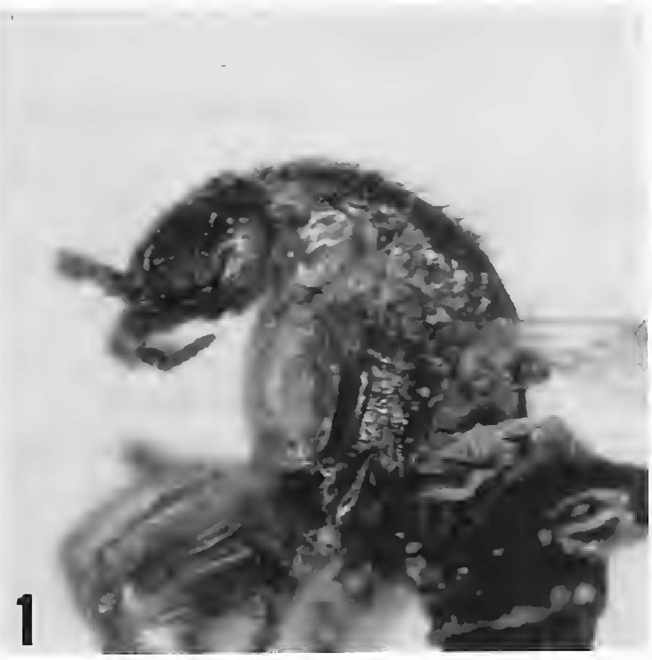
Female.—Entirely orange-yellow with the exception of brown-orange abdomen and black occiput. Head: Antennae capitate. Antenna with six or seven flagellomeres (apical segments difficult to distinguish); first two flagellomeres easily distinguishable, remaining flagellomeres composing a capitate knob. Palpus four- or five- segmented (basal segments difficult to distinguish). Apical palpal segment elongate, 1.5 × length of preceding segment (Fig. 1). Rostrum undeveloped (Fig. 1). Thorax: Mesonotum anteriorly (presuturally) setose, posteriorly (postsuturally) with setae in dorsocentral rows and laterally. Wing: About 2.5 mm long, anterior veins orange to light brown, posterior veins and stigma concolorous with membrane. Membrane with microtrichia. Basal portion of Rs subequal to r-m cross vein. Legs: Fore tibia with anterior spur rudimentary, posterior spine strongly developed. Hind basitarsus slender, elongate ($\approx$ 0.5 mm), as long as next two segments combined (Fig. 4). Hind tibial spurs short, slender, flat, apically rounded.

Male.—Unknown.

Diagnosis.—*Enicoscolus hardyi* can be separated from other *Enicoscolus* species by the undeveloped rostrum (Fig. 1), elongate apical segment of the palpus (Fig. 1), orange thorax, hind basitarsus more slender, elongate relative to tarsomeres two and three (Fig. 4), and geographic occurrence (distribution; Brazil). *Enicoscolus dolichocephalus* differs by the developed rostrum (Fig. 3), apical segment of palpus short, hind basitarsus not so slender, elongate, relative to tarsomeres two and three (Fig. 6), and known only from Mexico. *Enicoscolus collessi* differs by the apical segment of palpus short (see Hardy 1962: 784, fig. a), dorsum of the thorax black, and known only from the Australian region. *Enicoscolus hardyi* is most similar to *E. brachycephalus*, but the latter species differs by general shape of the head (compare Figs. 1 and 2), dorsum of the thorax black, hind basitarsus not so slender, elongate, relative to tarsomeres two and three (Fig. 5), and known only from Mexico.

Etymology.—The specific name honors Elmo Hardy, University of Hawaii, whose comprehensive works on world Bibionidae have made further studies of the family possible.

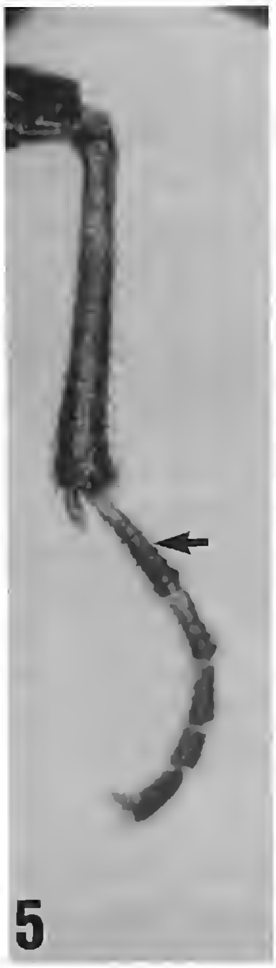
Material Examined.—See Type.


1


2


3


4


5


6

Figures 1–3. *Enicoscolus* spp., female head, lateral view. Figure 1. *E. hardyi*. Figure 2. *E. brachycephalus*. Figure 3. *E. dolichocephalus*.

Figures 4–6. *Enicoscolus* spp., hind leg (arrow indicates basitarsus). Figure 4. *E. hardyi*. Figure 5. *E. brachycephalus*. Figure 6. *E. dolichocephalus*.

Enicoscolus brachycephalus Hardy
(Figs. 2, 5)

Enicoscolus brachycephalus Hardy 1961: 82.

Type Material Examined.—Holotype female; MEXICO. *MORELOS*: Yautepec, 29 Oct 1956, R. & K. Dreisbach; deposited USNM.

This species was previously represented by two females collected from Morelos, Mexico, in September and October (Hardy 1961). The following additional records expand the geographic distribution of the species about 1,140 km northwestward to southern Chihuahua, Mexico, and expand the seasonal distribution of the species from July-November.

Other Specimens Examined.—MEXICO. *CHIHUAHUA*: 4.8 km W of Santa Barbara, 22 Jul 1967, 1 female (UCDC). *JALISCO*: Guadalajara, 2 Oct 1966, G.E. & A.S. Bohart, 1 female (EMUS). *MORELOS*: Cuernavaca, Nov 1944, N.H.L. Krauss, 2 females (USNM). *PUEBLA*: river E of Tepexco, 1250 m, Highway 160, 24 Aug 1977, E.I. Schlinger, 1 female (EMEC); narrow canyon 8 km S of Tecamachalco, 2103 m, flight trap, 10 Aug 1967, M.E. Irwin, 3 females (UCRC). *VERACRUZ*: Nov 1963, N.H.L. Krauss, 1 female (USNM).

Enicoscolus dolichocephalus Hardy
(Figs. 3, 6)

Enicoscolus dolichocephalus Hardy 1961: 82.

Type Material Examined.—Holotype female; MEXICO. *MORELOS*: Tepoztlan, 20 Oct 1957, R. & K. Dreisbach; deposited USNM.

This species was previously represented by three females collected from Morelos, Mexico, in October (Hardy 1961). The following additional records of this species extend the geographic distribution 1,425 km northwestward to Sonora, Mexico, and expand the seasonal distribution from September–October.

Other Material Examined.—MEXICO. *MORELOS*: 19.2 km E of Cuernavaca, 1310 m, 14 Aug 1954, J.G. Chillcott, 1 female (CNCI); Canon de Lobos, 6 Sep 1976, J.M. Pino, 1 female (UNAM); Canon de Lobos, 6–11 Sep 1976, J. Butze, 1 female (UNAM); (MORELOS?), Highway 95D, km 62, 3.2 km SE of LaPera, (lava beds), 30 Oct 1973, C.W. O'Brien, 1 female (CASC). *NAYARIT*: Tepic, 15–17 Sep 1953, B. Malkin, 1 female (CASC). *SONORA*: Alamos, 7 Sep 1970, G.E. & R.M. Bohart, 2 females (EMUS).

ACKNOWLEDGMENT

I sincerely thank Boris C. Kondratieff, Colorado State University, for support of this research and a critical review of the manuscript. I thank Paul Arnaud, Jr., California Academy of Sciences; Cheryl B. Barr, University of California, Berkeley; Robert W. Brooks, University of Kansas, Atilano Contreras-Ramos, Coleccion Entomologica, Instituto de Biologia, Universidad Nacional Autonoma de Mexico; Jeff Cumming, Canadian National Collection; Saul I. Frommer, University of California, Riverside; Wilford J. Hanson, Utah State University; S. L. Heydon, University of California, Davis; and F. Christian Thompson, Systematic Entomology Laboratory, USDA, for the loan of material. My visit to the United States National Museum of Natural History was supported by the Samuel Wendell Williston Diptera Research fund and my visit to the Coleccion Entomologica, Instituto de Biologia, Universidad Nacional Autonoma de Mexico was supported by the Dipterology Fund. I thank Atilano Contreras-Ramos for his hospitality during my visit to the Instituto de Biologia, Universidad Nacional Autonoma de Mexico.

LITERATURE CITED

Hardy, D. E. 1961. Notes and descriptions of exotic Bibionidae. Proc. Entomol. Soc. Wash. 63: 81–99.

Hardy, D. E. 1962. A remarkable new bibionid fly from Australia. Pac. Insects 4: 783–785.

Hardy, D. E. 1982. The Bibionidae (Diptera) of Australia. Aust. J. Zool. 30: 805–855.

McAlpine, J. F. 1981. Morphology and terminology—adults. [Chapter] 2. pp. 9–63. *In* McAlpine J. F., B. V. Peterson, G. E. Shewell, H. J. Teskey, J. R. Vockeroth, and D. M. Wood. Manual of Nearctic Diptera. Vol. 1. Agriculture Canada Monograph 27.

Received 24 Jul 1996; Accepted 20 Mar 1997.

PAN-PACIFIC ENTOMOLOGIST
73(3): 156–167, (1997)

NEW SPECIES OF *DIOXYPTERUS* FAIRMAIRE FROM TONGA AND FIJI, WITH NEW DISTRIBUTION RECORDS, A TRIBAL REASSIGNMENT, AND KEY TO THE SPECIES OF THE REGION (COLEOPTERA: ELATERIDAE)

Paul J. Johnson
Insect Research Collection,
South Dakota State University,
Brookings, South Dakota, 57007

Abstract.—*Dioxypterus tonga* NEW SPECIES and *D. eua* NEW SPECIES are described from Tonga and are the first species of *Dioxypterus* reported from east of Fiji. *Dioxypterus beaveri* NEW SPECIES is described and *D. ovalauensis* Van Zwaluwenburg newly recorded from Viti Levu, Fiji. *Dioxypterus* is removed from the Hemirhipini (Agrypninae) and reassigned to the Dicrepidiini (Elaterinae). A key to the species of Fiji and Tonga is provided.

Key Words.—Insecta, Elateridae, *Dioxypterus*, taxonomy, Tonga, Fiji.

Dioxypterus Fairmaire is a moderately diverse genus of 31 species, including those herein described. Species of this genus are restricted to the south-central Pacific, from northeastern Papua New Guinea, through the Bismarck and Solomon archipelagos, south to Tanna I., Vanuatu, and east to Fiji. Here, two species are reported from Tonga for the first time, both previously undescribed. In addition, a new species is also described from Viti Levu, Fiji, and *D. ovalauensis* Van Zwaluwenburg is newly reported from Viti Levu.

Adult *Dioxypterus* are readily recognized by their fusiform body that usually appears humped in profile at the elytral base, attenuate and acuminate elytra, antennae short and serrate reaching only to pronotal posterior margin, a frontal margin that is often incompletely carinate medially, closed pronotosternal sutures, and a prosternal process that is greatly expanded and bidentate posteriorly. This form of prosternal process is known only from the species of *Dioxypterus*, the Melanesian *Symphostethus* Schwarz, and the neotropical *Ypsilosthetus semiotulus* Candèze. Among the South Pacific elaterids, *Dioxypterus* species are distinctive and are not usually confused with other click beetles.

The genus was diagnosed by Fairmaire (1881) with four Fijian species originally attributed. Hyslop (1921) designated *D. nigrotransversus* Fairmaire as type species. Neither Schwarz (1902) nor Van Zwaluwenburg (1933, 1940) provided revised generic diagnoses of the genus while describing many of the valid species. Because of this lack of discreet characterization a redescription including the salient traits of generic value is presented below.

In the following descriptions, mensural traits given are length and width. Body length is measured from the frontal margin to elytral apex, and width measured at the elytral humeri. Antennal and tarsal segment length ratios are measured along the dorsum of each segment. The ocular index is also used (Campbell & Marshall 1964). Terminology for genital structures follows Lawrence & Britton (1991), and wing venation terminology follows Kukalová-Peck & Lawrence (1993). Geographic names follow Motteler (1986).

Depositories—Holotypes are deposited at the Bernice P. Bishop Museum, Honolulu (BPBM). Additional specimens are deposited at BPBM or in the author's personal collection (PJJC).

DIOXYPTERUS FAIRMAIRE

Fairmaire's (1881) original description lacked nearly all characteristics of value for modern interpretation of click beetle relationships. Since no subsequent author has provided a revised generic characterization one is presented here to facilitate future studies.

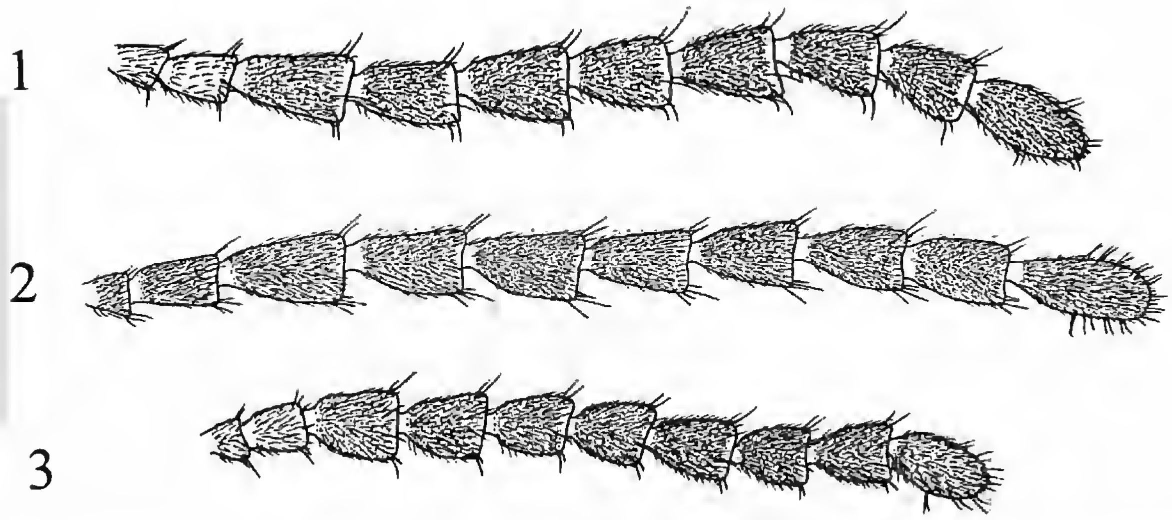
Redescription.—Body fusiform; dorsum shallowly convex, venter strongly convex. Head convex on frons; supra-antennal ridges obtuse to subcarinate, anteromedially directed, conjoined medially to form a complete and usually subcarinate fronto-clypeal margin; antenna 11-segmented, serrate from segment 4; mandible strongly arcuate ectally; maxillary and labial palps with ultimate segment elongate, narrowly subsecuriform. Prothorax with pronotum trapezoidal, basal incisures absent, hind angles bicarinate dorsally; pronotosternal sutures closed anteriorly, mesal margin of hypomeron with a narrow polished and flattened bead; prosternal intercoxal process broadly, dorsoventrally arcuate posteriorly. Mesosternum with sides of median fossa subvertically declivous; mesepimeron and mesepisternum reaching coxal cavity. Meso-metasternal suture connate, with or without surface trace. Elytra attenuate, apices mucronate as an extension of strial interval 3, intervals flat to shallowly convex, striae shallowly impressed and with small punctures. Metathoracic wings with RP_1, RP_2 and RP_3 apical sclerotizations, CuA_2-CuA_{3+4} crossvein present, CuA_1-MP_{3+4} juncture proximal of MP_3-MP_4 fork. Legs proportionately long, slender, femur and tibia subequal in length; tarsus with segment 1 long, ≥ 2X length of segment 2, segments 2–4 or 3–4 with densely setose membranous pads ventrally, segment 4 with setose pad extended anteroapically and briefly divided; pretarsal claw simple, asetose. Male with abdominal ventrite 5 broadly rounded or subtruncately lobed. Female with abdominal ventrite 5 broadly, shallowly emarginate, with or without a median subtruncate lobe. Aedeagus with lateral lobe hooked apically, and with a single or only a few apical setae. Gonocoxites slender, lightly sclerotized; styli elongate; bursa copulatrix trisaccate with a heavily sclerotized and spinose collar.

Dioxypterus eua Johnson, NEW SPECIES

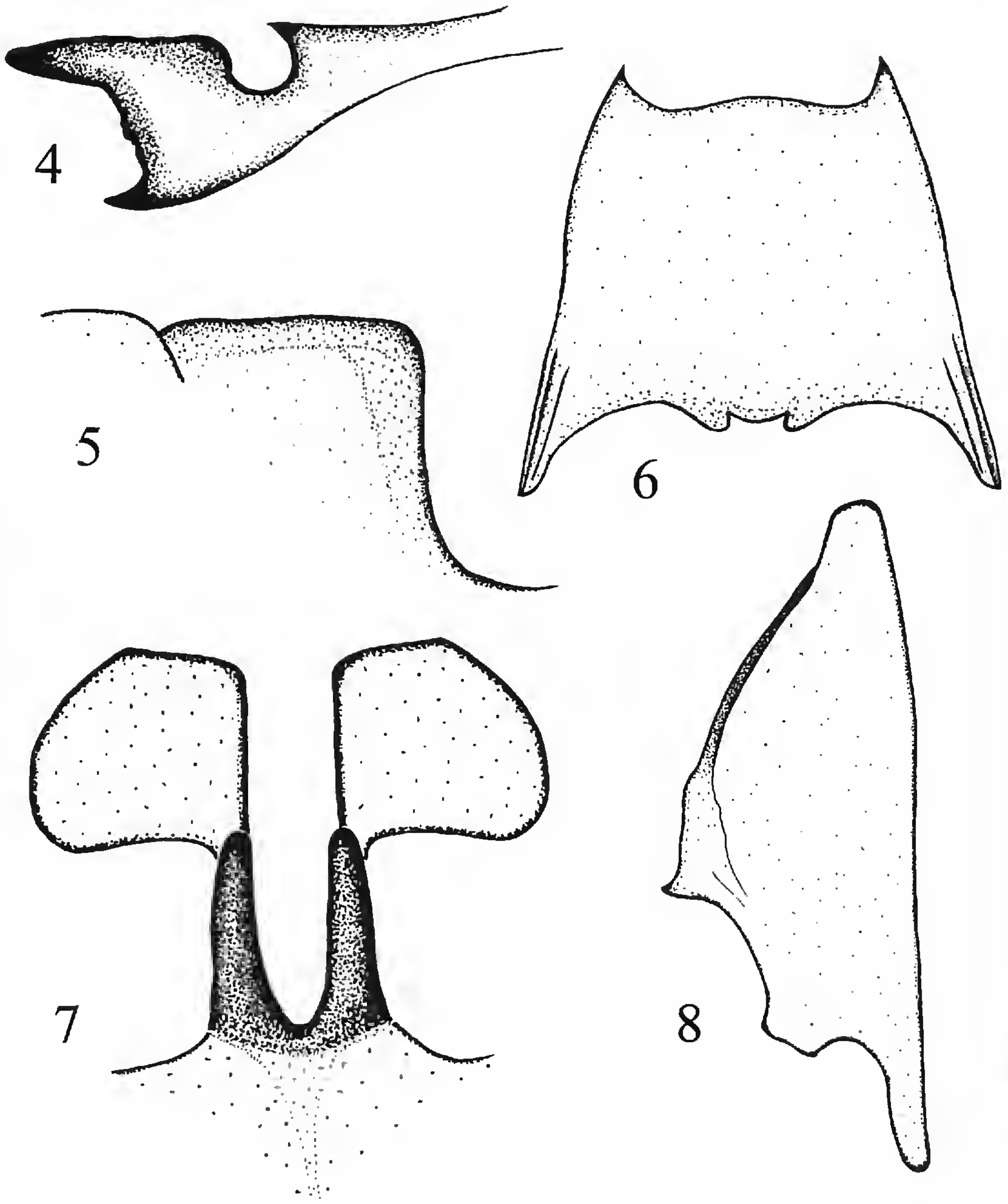
(Figs. 1, 8–9, 11–13, 15, 17, 19, 21)

Types.—Holotype, male; data: TONGA. *EUA I.*: Hafu, 100–200 m, Feb 1972, N.L.H. Krauss; deposited: Bernice P. Bishop Museum, Honolulu. Paratypes: Hafu, 150–200 m, Feb 1969, N.L.H. Krauss, 1 female; Pangai, 0–100 m, Jan 1979, N.L.H. Krauss, 1 male; hills above Pangai, 100–300 m, Jan 1979, N.L.H. Krauss, 1 male; Parker's Hill area, 200–300 m, Mar 1969, N.L.H. Krauss, 1 female; Ohonua, Feb 1956, N.L.H. Krauss, 1 female. Paratypes deposited: Bernice P. Bishop Museum, Honolulu.

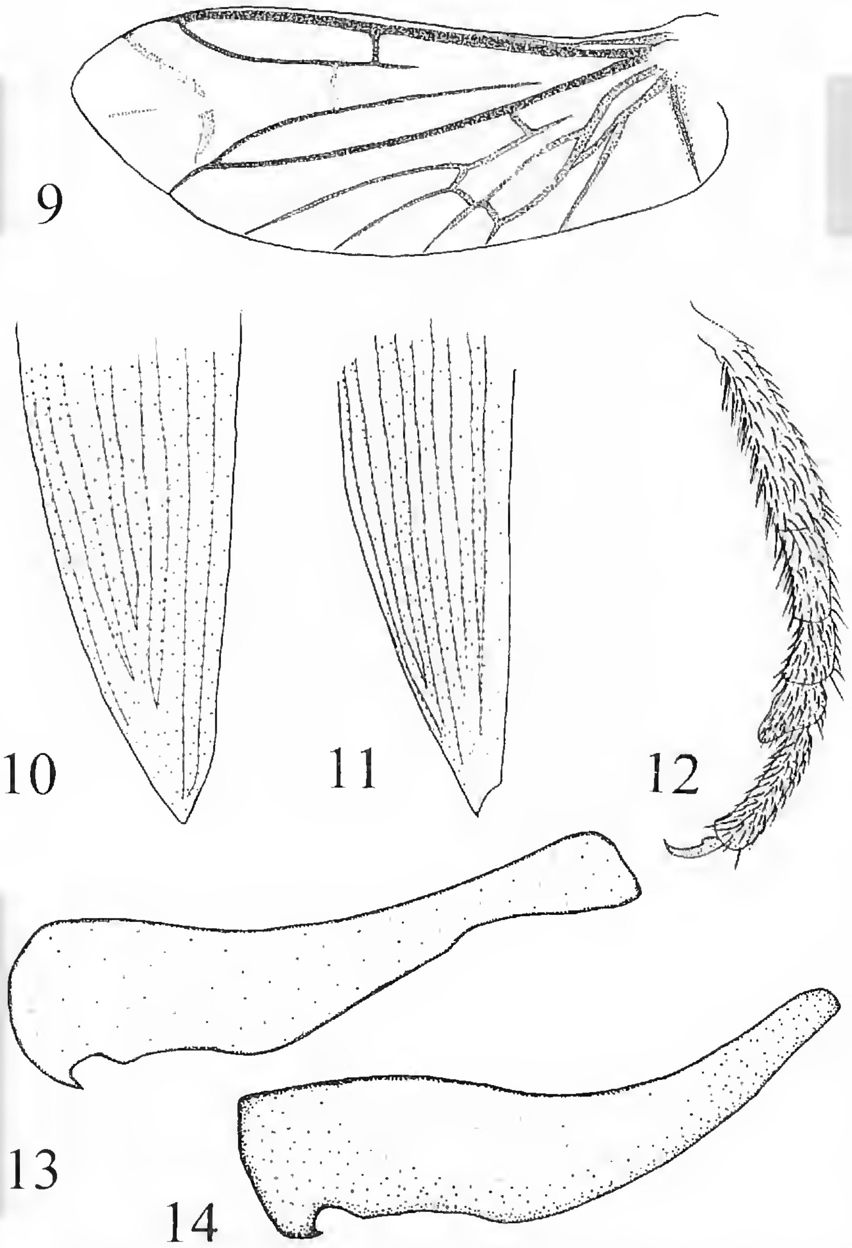
Description.—Length 9.1–11.6 mm, width 2.8–3.4 mm; body flavotestaceous, with castaneous highlights, the following structures and patterns piceous: a pair of bifurcate vittae on frons and median spot on frontal margin, anterolateral portions and hind angles of pronotum, anterior third of hypomeron, prosternum, elevated rim of mesosternal fossa, mediolateral portions of metasternum, medial margin of metacoxa, sutural margins of ventral sclerites, and humeral region and strial punctures of elytra. Antennae and legs brunneous. Pubescence aurantaceous, moderately-dense, forming a pair of whorls on pronotal disc. Head evenly, moderately-sparsely, finely punctured; ocular index = 66; supra-antennal ridges subcarinate, shallowly arcuate over antennal fossa, then transverse, evanescently conjoined medially; clypeal region obsolescent, coarsely punctured. Antenna (Fig. 1) short, reaching to apex of pronotal hind angle; segment 2 short, segment 3 subcylindrical; segments 4–10 short, serrate; segment 2–11 length ratio = 1.0:1.2:2.0:1.8:1.8:1.8:1.9:1.8:1.8:2.2. Labrum broadly rounded anteriorly, slightly transverse, coarsely punctured. Pronotum with medial length 0.83X width across hind angles at posterior margin, moderately-sparsely and finely punctured on disc, becoming denser and coarser anterolaterally; lateral margin carinate, remaining distinct to anterior margin; hind angles nar-



Figures 1–3. *Dioxypterus* species, antenna. Figure 1. *D. eua*. Figure 2. *D. tonga*. Figure 3. *D. beaveri*.



Figures 4–8. *Dioxypterus* species. Figure 4. *D. beaveri*, prosternal process, lateral aspect; Figure 5. *D. tonga*. mesosternal profile, posterior portion. Figure 6. *D. tonga*, pronotum. Figure 7. *D. tonga*, mesosternum, ventral aspect. Figure 8. *D. eua*, left hypomeron.



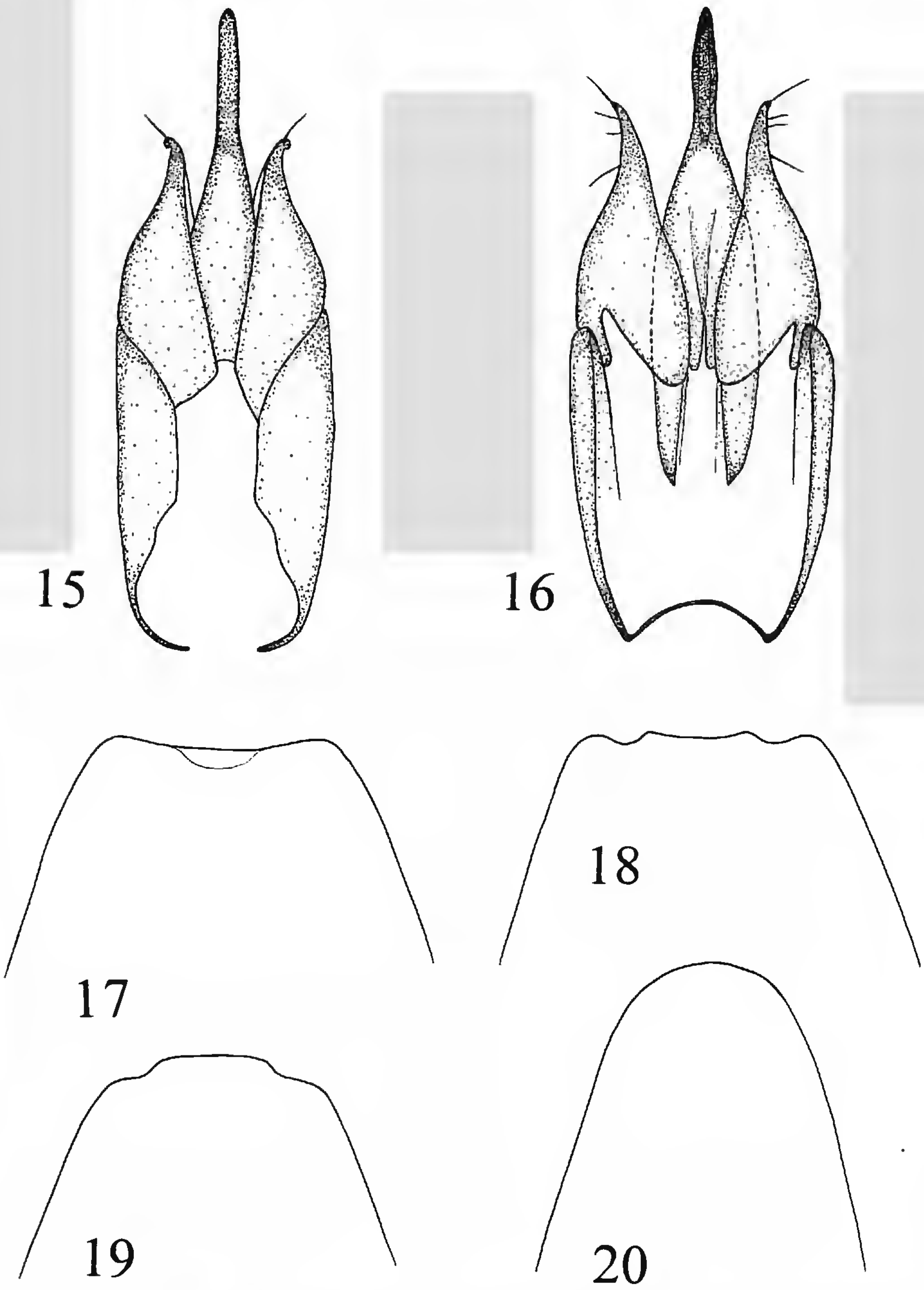
Figures 9–14. *Dioxypterus* species. Figure 9. *D. eua*, metathoracic wing. Figure 10. *D. tonga*, elytral apex. Figure 11. *D. eua*, elytral apex. Figure 12. *D. eua*, metatarsus. Figure 13. *D. eua*, metacoxal lamina. Figure 14. *D. tonga*, metacoxal lamina.

rowly rounded at apex, dorsal carinae subequal in length, anterior ends terminating abruptly. Hypomeron (Fig. 8) moderately-sparsely, shallowly punctured; mesal margin with narrow, flattened, polished, sparsely punctured bead widening posteriorly; posterior margin with median, subquadrate lobe. Prosternum with punctures fine, shallow; anterior lobe broadly arcuate; intercoxal process arcuate, compressed, acute at apex, expanded dorsally and subvertical posteriorly. Mesosternum with sides of median fossa slightly elevated, subvertically declivous; fossa narrowly U-shaped in ventral aspect; mesepisternum narrowly rounded at mesocoxal cavity. Elytral apex (Fig. 11) acute, shallowly arcuate mesally. Metathoracic wing (Fig. 9) with radial cell large; RP_1, RP_2, and RP_3 not conjoined, RP_2 obsolescent. Metasternum finely, shallowly, moderately-densely punctured; connate with mesosternum, sutural trace absent; midline shallowly engraved throughout; coxal lamina (Fig. 13) shallowly sinuate posteriorly; tarsus (Fig. 12) with segment length ratio = 1.0:0.4:0.3:0.2:0.5, segment 4 obliquely extended ventroapically.

Male.—Abdominal ventrite 5 (Fig. 19) with median subrectangular lobe at apex. Aedeagus (Fig. 15) with median lobe subparallel apically, apex obtuse; lateral lobe strongly narrowing at midlength, narrow and hooked at apex, with single seta at apex.

Female.—Abdominal ventrite 5 (Fig. 17) emarginate and shallowly impressed at apex. Bursa copulatrix as in Fig. 21.

Diagnosis.—This species is similar in size and coloration to *D. ovalauensis* Van Zwaluwenburg, from Fiji. These two can be separated by color pattern, distribution, and genital morphology, as given in the key, below.



Figures 15–20. *Dioxypterus* species. Figure 15. Aedeagus of *D. eua*, dorsal aspect. Figure 16. Aedeagus of *D. tonga*, dorsal aspect. Figure 17. *D. eua*, female ventrite 5, outline of apex. Figure 18. *D. beaveri*, female ventrite 5, outline of apex. Figure 19. *D. eua*, male ventrite 5, outline of apex. Figure 20. *D. tonga*, male ventrite 5, outline of apex.

Etymology.—Named after the island of provenance, Eua, and treated as a noun in apposition.

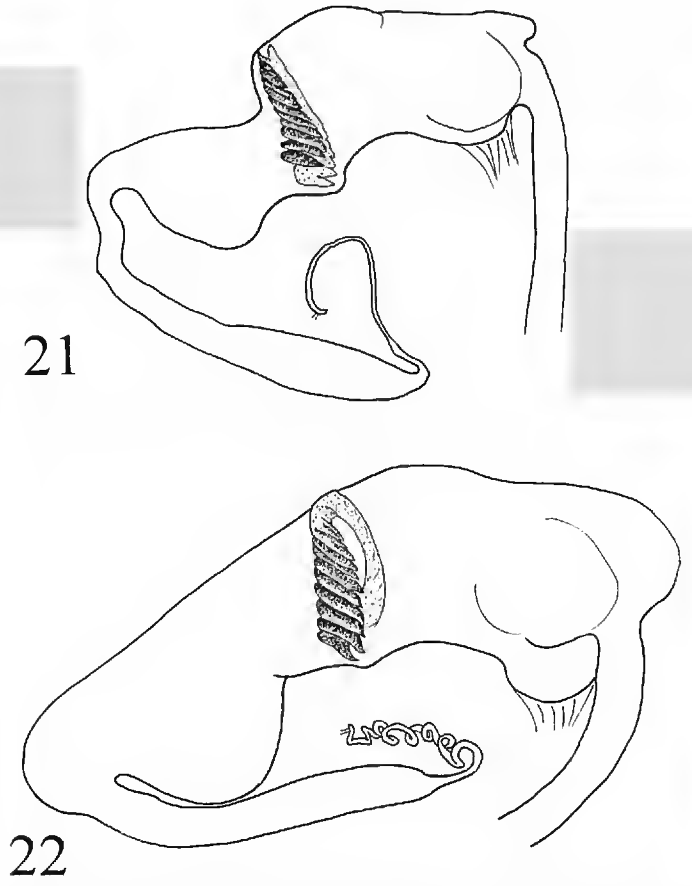
Distribution.—Known only from Eua Island.

Material Examined.—See Types.

Dioxypterus tonga Johnson, NEW SPECIES
(Figs. 2, 5–7, 14, 16, 20)

Type.—Holotype, male; data: TONGA. *EUA I*, Hafu, 100–200 m, Feb 1972, N.L.H. Krauss; deposited: Bernice P. Bishop Museum, Honolulu.

Description.—Length 18.2 mm, width 5.9 mm; Body brunneotestaceous, with infuscate highlights; frons with a pair of narrow infuscate maculae between eyes, pronotum with large infuscate lateral maculae extending along margins and hind angles and narrowly conjoined along anterior margin, midline and posterior third brunneotestaceous; scutellum brunneotestaceous; elytra brunneotestaceous, except narrowly infuscate striae. Pubescence aurantaceous, moderately-dense, directed posteriorly ex-



Figures 21–22. *Dioxypterus* species, bursa copulatrix and accessory gland duct. Figure 21. *D. eua.* Figure 22. *D. beaveri.*

cept as follows: directed anteriorly on head, pronotum with two discal whirls and setae directed anteriorly on anterior half and laterally on sides. Head evenly, moderately-sparsely, finely punctured; ocular index = 59; frontal margin obtuse, not cariniform, supra-antennal portion shallowly arcuate over each antennal fossa, median portion transverse; clypeal region obsolescent, coarsely punctured. Antenna (Fig. 2) short, reaching apex of pronotal hind angle; segment 2 short, segment 3 subcylindrical, segments 4–10 serrate; segments 2–11 length ratio = 1.0:1.8:2.5:2.4:2.4:2.0:2.0:2.0:2.0:2.9. Labrum broadly rounded anteriorly, slightly transverse, finely punctured. Pronotum (Fig. 6) with medial length 0.76X width across hind angles at posterior margin, moderately-sparsely and finely punctured on disc, denser and coarser anterolaterally; lateral margin carinate, evanescent anteriorly; hind angles narrowly rounded at apex, lateral dorsal carina 1.8X length of mesal carina, anterior ends of carinae obsolescent. Hypomeron coarsely, umbilicately punctured; mesal margin with moderately broad, flattened, polished, sparsely punctured anteriorly; posterior margin with median, subquadrate lobe. Prosternum with punctures shallowly umbilicate; anterior lobe broadly, shallowly arcuate; intercoxal process shallowly arcuate, compressed, obtuse at apex, expanded dorsally and broadly concave posteriorly. Mesosternum (Figs. 5, 7) with sides of median fossa strongly elevated, subvertically declivous; fossa narrowly V-shaped in ventral aspect; mesepisternum truncate at mesocoxal cavity. Elytral apex evenly attenuate, oblique mesally. Metathoracic wing similar to preceding species. Metasternum finely, shallowly, moderately-densely punctured; connate with mesosternum with partial sutural trace present laterally; midline shallowly engraved throughout; coxal lamina (Fig. 14) arcuate posteriorly; tarsus with segment 4 extended ventroapically, segment length ratio = 1.0:0.6:0.4:0.3:0.8.

Male.—Abdominal ventrite 5 evenly rounded apically (Fig. 20). Aedeagus (Fig. 16) with median lobe narrow, attenuate at apex; lateral lobes strongly narrowing, arcuate laterally, and with 4 subapical setae.

Female.—Unknown.

Diagnosis.—This specimen is distinct from all known species of *Dioxypterus* in the combination of its size, coloration, pubescence, aedeagal morphology, and distribution. Only *D. gressitti* Van Zwaluwenburg is similar in size and general coloration, but differs considerably in most other traits and is only known from Guadalcanal, Solomon Islands. *Dioxypterus tonga* lacks immediate known affinities and possesses certain characteristics which are tentatively regarded as ancestral in expression, such as the ecarinate frontal margin, integument and pubescence lacking discrete patterns and contrasting coloration, meso-metasternal suture with surface trace restricted to lateral portions, and male abdominal ventrite 5 evenly rounded at apex.

Etymology.—Named after the country of origin, Tonga, and is treated as a noun in apposition.

Distribution.—Known only from Eua Island.

Material Examined.—See Type.

Dioxypterus beaveri Johnson, NEW SPECIES
(Figs. 3–4, 11, 18, 22)

Type.—Holotype, female; data: FIJI. *VITI LEVU*, Savura Creek, 1–7 Sep 1981, malaise trap, luminous, 39 09, R.A. Beaver; deposited: Bernice P. Bishop Museum, Honolulu.

Description.—Length 11.0 mm, width 3.1 mm; integument of head and antennal segments 4–11 piceous, and pronotum, elytra and most of venter brunneopiceous, with antennal segments 1–3, labrum, anterior lobe of prosternum, hypomeron, mesosternum, mesepisternum, epipleuron, and medio-basal portion of elytra testaceous, legs infuscate. Sculpture of small, simple, moderately-dense punctures, sparse on hypomeron. Pubescence long, directed laterally from median line on pronotum, otherwise longitudinally arranged; color is generally pale testaceous, but matches ground color to form a transverse, midlength elytral fascia and apico-lateral inverted "L" pattern. Head with supra-antennal ridges obtuse, shallowly arched, obsolete medially; frontal margin coarsely punctate medially; clypeal region narrow, coplanar with frons, not separated by ridge or carina medially; ocular index = 62. Antenna (Fig. 3) short, reaching posterior margin of pronotum; segment 2 subquadrate, segment 3 subcylindrical, segments 4–10 serrate; segments 2-11 length ratio = 1.0:1.4:2.1:1.9:1.9:1.9:1.9:1.9:1.9:2.4. Labrum broadly rounded anteriorly. Pronotum with medial length 0.84X width across hind angles at posterior margin, moderately-sparsely and finely punctured on disc, becoming denser and coarser laterally; lateral margin carinate; hind angles narrowly rounded at apex, lateral dorsal carina 1.4X length of mesal carina, strongly elevated and slightly reflexed laterally. Hypomeron sparsely set with shallow and small to moderate sized punctures; mesal margin with moderately broad, flattened and polished, slightly elevated bead and a narrow sulcus adjacent to bead; posterior margin with median, subquadrate lobe. Prosternum punctured as hypomeron; anterior lobe broadly, evenly arcuate; intercoxal process (Fig. 4) strongly arcuate, compressed, acute at apex, expanded dorsally and subvertical posteriorly. Mesosternum with sides of median fossa strongly elevated, subvertically declivous; fossa narrowly V-shaped in ventral aspect; mesepisternum narrowly adjacent to mesocoxal cavity. Elytral apex similar to Fig. 11. Metathoracic wing similar to that of preceding species. Metasternum finely and sparsely punctured; connate with mesosternum, without trace of suture; midline shallowly engraved throughout; coxal lamina similar to Fig. 14, shallowly sinuate posteriorly; tarsus with segment 4 extended ventroapically, segment length ratio = 1.0:0.4:0.3: 0.2:0.5.

Female.—Abdominal ventrite 5 (Fig. 18) with transverse, rectangular, median projection at apex. Bursa copulatrix as in Fig. 22.

Male.—Unknown.

Diagnosis.—This species differs from other described Fijian *Dioxypterus* by its relatively small size, dark dorsal integument, and the rectangular apical projection on ventrite 5 of the female. This species is most similar to *D. vagepictus* Fairmaire in general coloration and patterns of pubescence on the elytra, but is readily distinguished by the dark and unicolorous pronotum of *D. beaveri*, versus a testaceous pronotum with 2 longitudinal piceous vittae on the disc of *D. vagepictus*.

Etymology.—Named in honor of Roger A. Beaver, Chiang Mai, Thailand, in gratitude for collecting this interesting specimen and his contributions to coleopterology.

Material Examined.—See Type.

Dioxypterus ovalauensis Van Zwaluwenburg

Dioxypterus ovalauensis was originally described (Van Zwaluwenburg 1933) from Ovalau, Fiji. There are no subsequent island records published for this species. Specimens were examined from two localities on Viti Levu and these represent a new island record for this species.

Material Examined.—FIJI. *VITI LEVU*: Navai, 700–800 m, 29 Sep 1970, N.L.H. Krause, 1 male (deposited BPBM); Colo-i-suva, 3–6 Mar 1963, C.M. Yoshimoto, 1 female (deposited BPBM); Savura Creek, 3–9 Apr 83, malaise trap, 58 40, R.A. Beaver; 1 female (deposited PJJC).

KEY TO THE SPECIES OF *DIOXYPTERUS* FROM TONGA AND FIJI

1a. Small, ≤15.0 mm in length; elytra bicolored, with maculae and bands 2

1b. Size large, ca. 18.0 mm in length; elytra bruneotestaceous; pubescence golden; Tonga: Eua I .... *tonga* NEW SPECIES

2a (1a). Body flavous to orange; tarsi, pronotal hind angles, elytral maculae piceous to black 3

2b. Body testaceous, brunneous or brunneopiceous; elytra with flavous or brunneous maculae or bands 7

3a (2a). Pronotal disc unicolorous, hind angles piceous; elytral ground color same as on venter and pronotum 4

3b. Pronotum flavous, disc with pair of longitudinal infuscate vittae; elytral ground color flavobrunneous, with 3 oblique infuscate bands; Fiji: Viti Levu .... *vagepictus* Fairmaire

4a (3a). Elytral basal half concolorous with pronotum, piceous to black in apical half, apical quarter with triangular patch of testaceous pubescence 5

4b. Elytra orange in basal half, brunneous in apical third with testaceous pubescence, a transverse black band at midlength, and an oblique black band from humerus to suture and along suture to transverse band; Fiji: Viti Levu ...... *nigrotransversus* Fairmaire

5a (4a). Elytra lacking transverse band and postscutellar patch, anterior margin of apical black area emarginate 6

5b. Elytra with angulate transverse band at apical third; postscutellar area infuscate; Fiji: Viti Levu .... *muiri* Van Zwaluwenburg

6a (5a). Elytra with anterior margin of apical black area semicircularly emarginate; integument with apical triangular area piceous; Fiji: Taveuni .... *taveuni* Van Zwaluwenburg

6b. Elytra with anterior margin of apical black area cordately emarginate; integument with apical triangular area rufous; Fiji: Wakai .... *wakayensis* Van Zwaluwenburg

7a (2b). Elytra with base flavous between humerus and scutellum, and with angulate transverse, brunneous bands at midlength and apical third 8

7b. Elytra concolorous, with an oblique series of spots of pallid pubescence at midlength and a transverse band of pallid setae at apical third 10

8a (7a). Elytral intervals flat, midlength macula forming a band reaching suture; pronotum infuscate, hind angles piceous; Fiji: Viti Levu 9

8b. Elytral intervals shallowly convex, midlength macula reaching medially to interval 5 or 6; pronotum pale with infuscate maculae on disc, hind angles pale; Tonga: Eua ...... *eua* NEW SPECIES

9a (8a). Length 11.0 mm; pronotum dark infuscate to piceous on disc; elytra with piceous integumental color beneath pubescence of anterior band and apical third .... *beaveri* NEW SPECIES

9b. Length 12.9–14.2 mm; pronotum flavous with infuscate highlights; elytra with brunneoflavous integument beneath pubescence of anterior band and apical third .... *flexuosus* Fairmaire

10a (7b). Larger, 13–14 mm in length; scutellum and elytral bases dark; elytra with anterolateral midlength spot circular and discrete from intervals 6 to 8; Fiji: Viti Levu .... *guttulatus* Fairmaire

10b. Smaller, 10–12 mm in length; anterior one-half of scutellum and base of elytral interval 3 flavous; elytra with anterolateral midlength spot transverse from interval 6 and reaching costal margin; Fiji: Ovalau, Viti Levu ..... *ovalauensis* Van Zwaluwenburg

Discussion

Candèze (1891) assigned *Dioxypterus* to his broadly inclusive "Ludiites." Schwarz (1902) placed the genus in his "Chalcolepidiites" (= Hemirhipini), based on the fusion of the meso- and metasterna and lack of a sutural trace between the mesocoxae. On this same character, Van Zwaluwenburg (1959) arranged the genus in Campsosterninae, the latter a synonym of Oxynopterini. However, the relative degree of fusion and disappearance of surface traces of the meso-metasternal suture is highly variable within many elaterid lineages (e.g., Laurent 1961, Casari-Chen 1985), and is undoubtedly convergently derived.

In general, relationship extrapolation and suprageneric taxonomic assignment of taxa within the family is most reliably based on larval structure (e.g., Hyslop 1917, Ôhira 1962, Dolin 1978, Calder et al. 1993). Unfortunately, larvae attributable to any *Dioxypterus* species remain unknown. Based on salient adult traits given in the generic redescription above and notably the lack of setae on the tarsal claws, morphology of mesonotal sclerites (Gurjeva, 1974), and wing venation (Dolin, 1976), *Dioxypterus* properly belongs in Elaterinae. A further assignment to Dicrepidiini is based on the head capsule having a convex frons, the frontal carina conjoint with the supra-antennal carinae, closed pronotosternal sutures, and the tarsi with ventral setal pads and an ventroapical extension of segment 4. Assignment to Elaterinae, Dicrepidiini, is a new classificatory arrangement.

Described species of *Dioxypterus* can be placed in two taxonomic groups based on coloration patterns and generally on indigenous distribution. The first group, Group I, including the new Tongan species, contains those species that are cryptically colored of dingy browns and yellows, often forming bands and maculae.

Structurally, these species possess an incomplete frontal carina, the meso-metasternal suture is incompletely connate and there remains a traceable intercoxal suture line or groove. These species have a more southerly distribution and are found throughout Fiji, Tonga and Vanuatu, generally being endemic to either a single island or a local archipelago. Species of this group are known from the Solomon Islands, but only on Guadalcanal.

The second species group, Group II, exhibits contrasting bright red to orange on black patterns that may be aposematic coloration. In contrast to the species in Group I these tend to possess derived characteristics such as a complete frontal carina, and connate meso-metasterna with the intercoxal suture absent and usually untraceable at the surface. Most of these species are each found on one or more islands throughout the Solomon and Bismarck archipelagos, and northeasternmost Papua New Guinea, but there is one species in each of Fiji and Vanuatu.

In general, the diagnostic traits of the first species group are relatively ancestral in their expression, while those of the second species group are relatively derived. The pattern of generalized relationship and distribution is noted here because of its additive importance with that of other taxa noted below to Fijian regional biogeography. The species of Group I indicate that ancestral character states are found in those species endemic to the Fijian Region. This region contains an unusually high concentration of isolated taxa and ancestral characteristics within Elateridae. Further, the few Group II taxa in Fiji and their absence from Tonga suggest some degree of parapatric speciation between the two species groups.

The biotic similarity of Tonga with Fiji and the shared geological history (Ewart, 1988) of both archipelagos made the discovery of *Dioxypterus* species from Tonga predictable. Previous insect faunal conclusions of a largely Fiji-derived biota in Tonga were made for cicadas (Duffels 1988), barklice (Thornton 1981a-b), and butterflies (Miller & Miller 1993). Similarly, Tonga shares with Fiji and Vanuatu a number of click beetle genera, such as *Dioxypterus*, that are either endemic (*Photophorus* Candèze, *Hifo* Candèze, *Conobajulus* Van Zwaluwenburg) to the Fijian region, or have numerous species endemic to the region with species pairs shared between islands and archipelagoes (i.e. *Simodactylus* Candèze, *Pacificola* Van Zwaluwenburg, *Tetrigus* Candèze). The species of this latter set of taxa express character states that are ancestral in the Fijian region, relative to congenerics elsewhere in the South Pacific region. As noted above, the species of *Dioxypterus* follow this latter pattern with those species expressing the most intragenerically derived character states found in the Solomon Islands and Papua New Guinea. Overall, the distributions of *Dioxypterus* species and other endemic taxa correspond quite well with proposed phytogeographic segregation of the Fijian region (e.g., Takhtajan, 1986) and generalized Outer Melanesian Island Arc distributions (e.g., Holloway 1984, Polhemus 1995).

Though there is not a phylogenetically established sister genus for *Dioxypterus*, potential candidates are *Symphostethus* Schwarz (7 species in the Solomon Is. and Papua New Guinea) and the monobasic and neotropical *Ypsilosthetus* Candèze. All three genera share traits involving unique prosternal and mesosternal morphology, with *Dioxypterus* and *Ypsilosthetus* being more similar in elytral structure and pubescence style. A potential sister group for these three genera remains unresolved.

This latter genus pairing is similar to four other South Pacific/neotropical generic pairs of click beetles: the Tongan *Hifo* Candèze with the Brasilian *Cryptolamprus* Costa (Costa 1984), *Photophorus* Candèze from Fiji and Vanuatu with Meso-American *Ignelater* Costa (Costa 1975), the Fijian *Propsephus* Candèze with neotropical *Dipropus* Eschscholtz and the Fijian *Conobajulus* Van Zwaluwenburg with the neotropical *Chalcolepis* Candèze. The *Hifo/Cryptolamprus* and *Photophorus/Ignelater* associations are particularly intriguing as the Fijian Region species of *Hifo* and *Photophorus* are the only bioluminescent elaterids known outside of the neotropics. With Indomalesian and Australian affinities lacking for any of the Fijian endemic genera, their unusual apparent neotropical phylogenetic associations demand further attention as they suggest that these biogeographically uniques are most likely Gondwanian faunal relics.

ACKNOWLEDGEMENT

Thanks are extended to G. A. Samuelson, Bishop Museum, Honolulu, and R. A. Beaver, University of the South Pacific, Suva, for the loan of specimens; and to the faculty and staff of the B. P. Bishop Museum, especially S. E. Miller, G. A. and S. Samuelson, and G. Nishida, for their support and assistance during museum visits. Travel and support was provided by the Ernst Mayr Grant Committee, Museum of Comparative Zoology, Harvard University, and the Valentine Property Fund, B. P. Bishop Museum. Authorized as South Dakota Agricultural Experiment Station article No. 3004.

LITERATURE CITED

Calder, A. A., J. F. Lawrence and J. W. H. Trueman. 1993. *Austrelater*, gen. nov. (Coleoptera: Elateridae), with a description of the larva and comments on elaterid relationships. Invert. Taxon., 7: 1349–1394.

Campbell, J. M. & J. D. Marshall. 1964. The ocular index and its application to the taxonomy of the Alleculidae (Coleoptera). Coleopts. Bull., 18: 42.

Candèze, E. 1891. Catalogue methodique des Elaterides connus en 1890. H. Vaillant-Carmanne, Liege.

Casari-Chen, S. A. 1985. Sistemática e evolução dos Hemirhipini neotropicais (Pyrophorinae, Elateridae, Coleoptera). Rvta. bras. Entomol., 29: 383–423.

Costa, C. 1975. Systematics and evolution of the tribes Pyrophorini and Heligmini, with description of Campyloxeninae, new subfamily (Coleoptera, Elateridae). Arq. Zool., 26: 49–190.

Costa, C. 1984. On the systematic position of *Hifo* Candèze, 1881 (Elateridae, Coleoptera). Rvta. bras. Entomol., 28: 399–402.

Dolin, V. G. 1976. Wing venation in click beetles and its significance for the taxonomy of the family. Zool. Zhur., 54(11): 1618–1633. (1976 Engl. transl. by Dept. Secretary of State., Transl. Bur., Ottawa).

Dolin, V. G. 1978. Table for identification of click beetles of the USSR fauna. Urozhai, Kiev, 127p. (1981 Engl. transl. for U.S.D.A. and N.S.F. by Al-Ahram Center Sci. Transl.)

Duffels, J. P. 1988. The cicadas of the Fiji, Samoa and Tonga Islands, their taxonomy and biogeography (Homoptera, Cicadoidea). Entomonograph, Vol 10. E. J. Brill, Leiden.

Ewart, A. 1988. Geological history of the Fiji-Tonga-Samoan region of the S. W. Pacific, and some palaeogeographic and biogeographic implications. *In* J. P. Duffels (see above).

Fairmaire, L. 1881. Diagnoses de Coléoptères de la Mélanesie. Naturaliste, 1: 406–407.

Gurjeva, E. L. 1974. The thorax of click beetles (Coleoptera, Elateridae) and significance of its characters for the system of the family. Entomol. Obozr., 53: 96–113.

Holloway, J. D. 1984. Lepidoptera and the Melanesian Arcs. *In* F. J. Radovsky, P. H. Raven, & S. H. Sohmer (eds.). Biogeography of the Tropical Pacific. Bish. Mus. Spec. Publ., No. 72.

Hyslop, J. A. 1917. The phylogeny of the Elateridae based on larval characters. Ann. Entomol. Soc. Amer., 10: 241–256.

Hyslop, J. A. 1921. Genotypes of the elaterid beetles of the world. Proc. U.S. Nat. Mus., 58: 621–680.

Kukalová-Peck, J. & J. F. Lawrence. 1993. Evolution of the hind wing in Coleoptera. Can. Entomol., 125: 181–258.

Laurent, L. 1961. Sur la suture méso-métasternale chez les Elateridae (Coleoptera). Bull. Soc. Roy. Sci., Liège, 30: 68–71.

Lawrence, J. F. & E. B. Britton. 1991. Coleoptera (Beetles), pp. 543–683. *In* CSIRO, Insects of Australia (2nd ed.), Vol. 2. Melbourne University Press, Melbourne.

Miller, J. Y. & L. D. Miller. 1993. The butterflies of the Tonga Islands and Niue, [and] Cook Islands, with the descriptions of two new subspecies. Bish. Mus. Occas. Pap. No. 34.

Motteler, L. S. 1986. Pacific island names. Bish. Mus. Misc. Publ. 34.

Ôhira, H. 1962. Morphological and taxonomic study on the larvae of Elateridae in Japan. Entomological Laboratory, Aichi Gakugei University, Ikaxaki City.

Polhemus, D. A. 1995. Two new species of *Rhagovelia* from the Philippines, with a discussion of zoogeographic relationships between the Philippines and New Guinea (Heteroptera: Veliidae). J. N. Y. Entomol. Soc., 103: 55–68.

Schwarz, O. 1902. Neue Elaterides aus dem tropischen Asien, den malayischen Inseln und den Inseln der Südsee. Deuts. Entomol. Zeits., 1902(Heft II): 305–350.

Takhtajan, A. 1986. Floristic regions of the world. University of California Press, Berkeley.

Thornton, I. W. B. 1981a. Psocoptera of the Fiji Islands. Pac. Ins. Mon. No. 37: 1–105.

Thornton, I. W. B. 1981b. Psocoptera of the Tongan Archipelago. Pac. Ins. Mon. No. 37: 106–135.

Van Zwaluwenburg, R. H. 1933. New Elateridae (Col.) from Melanesia. Stylops, 2: 176–185.

Van Zwaluwenburg, R. H. 1940. New species and new records of elaterid beetles from the Pacific. Occas. Pap. Bern. P. Bish. Mus., 16: 91–130.

Van Zwaluwenburg, R. H. 1959. Some type designations, with notes on Pacific Elateridae (Coleoptera). Pac. Ins., 1: 347–414.

Received 29 Apr 1996; Accepted 12 Mar 1997.

PAN-PACIFIC ENTOMOLOGIST
73(3): 168–171, (1997)

A NEW SOUTHERN NEVADA SPECIES OF *AEGIALIA* (*AEGIALIA*) (COLEOPTERA: SCARABAEIDAE: APHODIINAE)

Robert D. Gordon[1] and Richard W. Rust[2]
[1] P.O. Box 65, Willow City, ND 58384
[2] Biology Department, University of Nevada, Reno, NV 89557

Abstract.—A new species, *Aegialia* (*Aegialia*) *knighti* Gordon and Rust is described and illustrated. *Aegialia knighti* is from an isolated sand dune in southern Nevada and constitutes the fifth member in a flightless, inland clade of North American *Aegialia*.

Key Words.—Insecta, Scarabaeidae, *Aegialia*, psammophilous, Southern Nevada.

The genus *Aegialia* is represented by 30 species in North America (Gordon & Cartwright 1988, 1977; Gordon 1990). *Aegialia* are cold-adapted fossorial detritivores with both adult and larval stages active in the winter. They are psammophiles, found on coastal dune systems, inland dunes, or wherever the substrate is generally sandy such as river banks, lake shores and deltas (Brown 1931; Jerath & Ritcher 1959; Jerath 1960; Stebnicka 1977; Gordon & Cartwright 1977, 1988; Rust & Hanks 1982; Gordon 1990).

Here we describe a new species of *Aegialia* (*Aegialia*) from an isolated sand dune in southern Nevada.

AEGIALIA (*AEGIALIA*) *KNIGHTI*, NEW SPECIES

Types.—Holotype male (Figs. 1a, 2a) deposited in United States National Museum (USNM), Washington, DC, data: NEVADA. *CLARK Co.*: Logandale-Overton Exchange, R67E-T14S, 28 Dec 95, J. B. Knight, S. O. Cichowlaz. Allotype, female (Fig. 2b) deposited USNM, same data as holotype. Paratypes, 22 specimens—same data as holotype; 27 specimens data: NEVADA. *CLARK Co.*: Logandale-Overton Exchange, R67E-T14S, 17 Dec 1995, J. B. Knight, S. O. Cichowlaz. Ten paratypes are in the USNM, 4 in the Nevada State Department of Agriculture collection in Reno, Nevada, 10 in the California Academy of Sciences, San Francisco, 10 in the Natural History Museum, London, England, 10 in the University of Nebraska collection in Lincoln, Nebraska and 5 in the California State Department of Food and Agriculture collection in Sacramento, California.

Description.—Holotype. Male (Figs. 1a, 2a) length 4.3 mm, greatest width 2.4 mm. Form oval, convex, broad posteriorly. Color pale yellowish red except mouthparts and tibial spurs reddish brown to black and ventral surfaces lighter in color, exoskeleton translucent. Pubescence straw-yellow to golden-yellow, setae on legs bright golden-yellow. Head shiny, weakly alutaceous, some small, widely separated punctures in central area; clypeus weakly emarginate; gena slightly produced. Pronotum shiny, smooth, some shallow widely separated punctures throughout, posterior marginal line well developed. Elytron smooth, shiny, intervals nearly flat, finely punctate, punctures separated by twice a punctures width. Metasternum shiny, with fine punctures centrally becoming alutaceous laterally, lacking medial impunctate area. Hindwing reduced to very small lobe. Front tibia with middle and basal teeth narrowly acute, middle longer than apical tooth (Fig. 1a). Middle tibia with two well developed transverse ridges, without surface denticles, tibial spurs narrow, acute, outer spur longer and subequal to first three tarsal segments. Hind tibia with two transverse ridges, basal ridge only

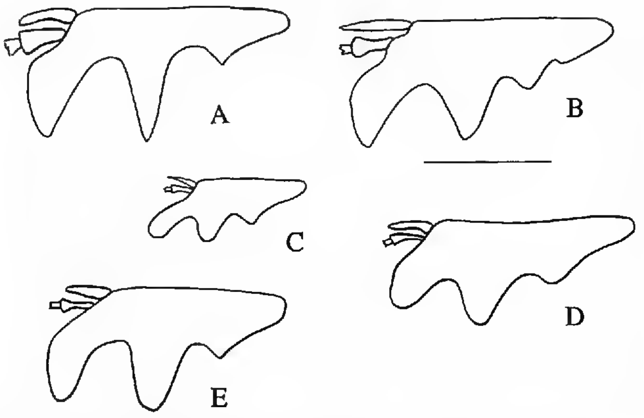


Figure 1. Fore tibia of inland, flightless North America *Aegialia* species. A. *A. knighti.* B. A. *magnifica.* C. *A. concinna.* D. *A. crescenta.* E. *A. hardyi.* Measurement line = 0.5 mm.

formed half way across tibia, transverse ridges and apical ridge with small broad setae; tibial spurs broadly spatulate, outer spur longer and subequal to first and second tarsal segments. Male genitalia as in Fig. 2a. Allotype.—Similar to male except length 4.4 mm, greatest width 2.5 mm. Female genital plate as in Fig. 2b.

Diagnosis:—Aegialia knighti is extremely similar to *A. magnifica* and will key to *A. magnifica* in Gordon & Cartwright (1988). *Aegialia knighti* differs from *A. magnifica* in being smaller (3.6 to 4.5 versus 4.4 to 5.9 mm in length and 2.1 to 2.4 versus 2.4 to 3.2 mm in greatest width), color pale yellow-red versus red, in having the basal and middle front tibial teeth acute (figs, 1a, 1b), in having broad setae on the hind tibial ridges versus lacking setae, and in lacking a median impunctate area on the central metasternum. The male and female genitalia are very different from *A. magnifica* (figs. 2a, 2b) and are more similar to *A. crescenta* (figs. 26, 29 in Gordon and Cartwright 1988). The key to *Aegialia* (*Aegialia*) (Gordon and Cartwright 1988) must be modified as follows:

11. Color pale red to pale yellow-red; head smooth, lacking tubercles, granules, or coarse punctations (fig. 16) 11A
Color dark brown to nearly black (except *concinna*); head rough, with coarse granules, punctations, or rugae 12
11A. Color pale red; large, 4.4–5.9 mm long and 2.4–3.2 mm greatest width; front tibial teeth rounded, not acutely pointed .... *A. magnifica*
Color pale yellow-red; small, 3.6–4.5 mm long and 2.1–2.4 mm greatest width; front tibial basal and middle teeth acutely pointed ... *A. knighti*

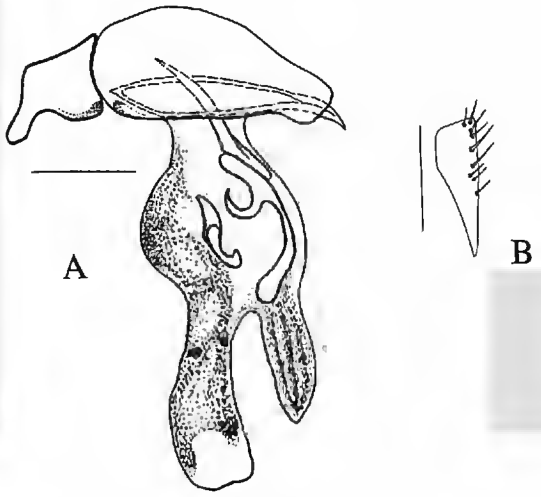


Figure 2. Genitalia of *Aegialia knighti.* A. Male. B. Female. Measurement lines = 0.25 mm.

Aegialia knighti is closely associated with and a member of the inland dune, reduced wing and flightless clade identified by Porter & Rust (1996). Its close resemblance to *A. magnifica* suggests they may be sister species, but a cladistic analysis is required to know the relationship of clade members, particularly because the genitalic structures of *A. knighti* are not closely similar to those of *A. magnifica* but are strikingly like those of *A. crescenta* and *A. hardyi.* The male internal sac of *A. knighti* has the same number of sclerites as does *A. crescenta* and the form of these sclerites, especially the large primary sclerite, is little different from that of *A. crescenta* and *A. hardyi. Aegialia knighti* has the female genital plate shaped like that of *A. hardyi* except with the apex obliquely angled rather than truncated as in *A. hardyi.*

Variation.—Length ranges from 3.6 to 4.5 mm and greatest width from 2.1 to 2.5 mm.

Habitat.—*Aegialia knighti* was collected from low, red sand hills and sand blow-outs in an area of approximately 12 km^2 that extends south of Mormon Mesa ridge and north and east of the Meadow Valley Wash-Wieser Wash-Muddy River drainage system from the Logandale-Overton exchange on Interstate 90 southward approximately 6 km to Logandale, Nevada. The Mojave Desert vegetation in the area is characterized by Creosote Bush (*Larrea tridentata* Nuttall), Mojave Yucca (*Yucca schidigera* Roezl ex Ort.), White Bur Sage (*Ambrosia dumosa* Payne), Brittlebush (*Encelia farinosa* A. Gray), species of *Opuntia* cactus, and species of *Atriplex.* The area ranges in elevation from 550m at the Logandale-Overton exchange to 450m near Logandale. The area receives approximately 9.5 cm of precipitation per year, which may fall in any month. The area has a mean annual temperature of 18° C with a mean minimum winter temperature of −4° C and mean summer maximum temperature of 40° C (Houghton et al. 1975).

Biology.—*Aegialia knighti* was collected by sifting sand from beneath *Ephedra* plants. No adults were observed on the surface sand during any of the three visits. Larvae were not obtained. *Aegialia knighti* appears to be very sensitive to soil moisture during the winter activity period. When the sand hills were first visited, the sand was moist a few centimeters below the surface and the individuals were very easy to collect. The sand hills were visited again on 28 Dec 1995 and a second series of specimens was easily obtained. The area was visited a third time on 16 Jan 1996 and only two individuals were collected by sifting sand. The sand hills had become dry and moist sand was not found until a depth of one meter was reached, much sand was sifted to procure the two individuals.

Etymology.—We name this species for Jeff Knight who collected the new species and is continuing to study and collect the insects of Nevada.

Material examined.—2 specimens data: NEVADA. *CLARK Co.*: 1 mi E of Logandale, 36°36′31.2″ N, 114°27′44.3″ W, Jan 12 1996, J. B. Knight, in the collection of the Nevada State Department of Agriculture.

ACKNOWLEDGMENT

We thank Jeff Knight and Scott Cichowlaz for their efforts in collecting *Aegialia knighti*, Dave Carlson, Sacramento, California for reviewing the manuscript, and Peter Brussard and the Nevada Biodiversity Initiative for providing partial funding.

LITERATURE CITED

Brown, W. J. 1931. A revision of the North American Aegialiinae (Coleoptera). Can. Entomol., 63: 9–19.

Cornell, J. F. 1967. Description of the larva of *Aegialia browni* Saylor. (Coleoptera: Scarabaeidae, Aphodiinae). Pan-Pac. Entomol., 43: 189–192.

Gordon, R. D. & O. L. Cartwright. 1977. Four new species of *Aegialia* (s. str.) (Coleoptera: Scarabaeidae) from California and Nevada sand dunes. J. Wash. Acad. Sci., 67: 42–48.

Gordon, R. D. & O. L. Cartwright. 1988. North American representatives of the tribe Aegialiini (Coleoptera: Scarabaeidae: Aphodiinae). Smithsonian Contr. Zool. 461: 1–37.

Gordon, R. D. 1990. A new species of *Aegialia* (*Aegialia*) (Coleoptera: Scarabaeidae: Aphodiinae) from southern Arizona and new data on North American *Aegialia*. Coleopt. Bull., 44: 271–273.

Houghton, J. G., C. M. Sakamoto & R. O. Gifford. 1975. Nevada's weather and climate. Nevada Bur. Mines Geol. Spec. Publ. 2: 1–78.

Jerath, M. L. 1960. Notes on the larvae of nine genera of Aphodiinae in the U.S. (Coleoptera: Scarabaeidae). Proc. U.S. Nat. Mus. 3245.

Jerath, M. L. & P. O. Ritcher. 1959. Biology of Aphodiinae with special reference to Oregon. Pan-Pac. Entomol., 35: 169–175.

Porter, J. L. & R. W. Rust. 1996. Genetic variation within populations of five species of *Aegialia* (Coleoptera: Scarabaeidae). Ann. Entomol. Soc. Amer. 89: 710–721.

Rust, R. W. & L. M. Hanks. 1982. Notes on the Biology of *Aegialia hardyi* Gordon and Cartwright (Coleoptera: Scarabaeidae). Pan-Pac. Entomol., 58: 319–325.

Stebnicka, Z. 1977. A revision of the Tribe Aegialiini (Coleoptera: Scarabaeidae, Aphodiinae). Acta Zool. Crac., 22: 397–506.

Received 10 Oct 1996; Accepted 21 Jan 1997.

PAN-PACIFIC ENTOMOLOGIST
73(3): 172–183, (1997)

FORAGING ACTIVITY, TRAILS, FOOD SOURCES AND PREDATORS OF *FORMICA OBSCURIPES* FOREL (HYMENOPTERA: FORMICIDAE) AT HIGH ALTITUDE IN COLORADO

JOHN R. CONWAY
Department of Biology, University of Scranton,
Scranton, Pennsylvania 18510

Abstract.—The thatching ant, *Formica obscuripes* Forel, was studied at high altitude in Colorado by marking workers and flagging trails. Mounds had 1–5 trails up to 53.6 m long. Seventeen mounds had trails going to a Douglas fir tree (*Pseudotsuga* sp.). Activity at trail checkpoints varied from 0–171 ants per minute during the day. Ants marked on one mound were found on as many as 24 other mounds up to 77.9 m away. Ants were observed on 12 plant species and tended aphids on nine of them. Leaf clusters on mountain snowberry (*Symphoricarpos rotundifolius* A. Gray) and Saskatoon serviceberry (*Amelanchier alnifolia* Nuttall) contained up to 1163 aphids/cluster and predaceous insect larvae. Ants also tended treehoppers, scale insects, mealybugs and galls on plants. Ants were seen feeding on an owl carcass, but usually scavenged dead insects. A bear cub was observed excavating mounds. The results are compared to other studies of this species.

Key Words.—Insecta, *Formica obscuripes*, thatching ant, Colorado, foraging, trails.

Formica obscuripes Forel, is a species of the *Formica rufa* group (Weber 1935) that ranges from northern Indiana and Michigan westward across the United States and southern Canada. It is an abundant ant in western North America, especially in semi-arid sagebrush areas and has been found at altitudes up to 3,170 m in Nevada (Wheeler & Wheeler 1986) and 2,896 m in Colorado (Gregg 1963).

My study compared *F. obscuripes* predation, trails, foraging activity, and food sources at high altitude in Colorado with studies in other areas (McCook 1884; Jones 1929; Cole 1932; Weber 1935; King & Sallee 1953, 1956; Talbot 1959; 1972; Gregg 1963; Kannowski 1963; Windsor 1964; Bradley 1972, 1973a, 1973b; Clark & Comanor 1972; Knowlton 1975; Herbers 1977, 1978, 1979a, 1979b; Inouye & Taylor 1979; Wheeler & Wheeler 1983, 1986; Henderson & Akre 1986; O'Neill 1988; Seibert 1992; McIver & Loomis 1993; McIver & Steen 1994).

MATERIALS AND METHODS

The study site was in Gunnison County, Colorado, N of Blue Mesa Reservoir and W of Soap Creek road (N 38 30.350′, W 107 19.602′) at an altitude of 2560 m. Field observations were conducted from 5–6 Aug 1990; 20 Jun–11 Oct 1992; 28 Jun–16 Aug 1993; 29 Jun–31 Jul and 14–16 Aug 1994; 3, 29–31 Jul and 15–16 Aug 1995, and 1–4, 18–19 Aug 1996. Eighty-five mounds were mapped in a study area (64.6 m × 114 m) using a surveyor's transect and compass. The area, dominated by big sagebrush (*Artemesia tridentata* Nuttall), is adjacent to a quaking aspen grove (*Populus tremuloides* Michaux). Other plants in the study area were *Chrysothamnus nauseosus* (Pallas) Britton (rubber rabbitbrush), *Purshia tridentata* (Pursh) De Candolle (antelope bitterbrush), *Lupinus argenteus* Pursh (silvery lupine), *Symphoricarpos rotundifolius* A. Gray (mountain snowberry), *Rosa woodsii* Lindley (Woods rose), *Urtica gracilis* Aiton (stinging nettle), *Penstemon* *strictus* Bentham (Mancos penstemon), *Ipomopsis aggregata* (Pursh) Grant ssp. *aggregata* (trumpet gilia), one Saskatoon serviceberry tree, *Amelanchier alnifolia* var. *pumila*, and one Douglas fir tree, *Pseudotsuga* sp.

Hundreds of workers were individually marked on eight mounds and five plants in 1992–1993 with a fine-tipped brush and model airplane paint. Thousands more were marked by spraying five mounds in 1994 and one mound in 1996 with acrylic enamel. These marking techniques did not seem to adversely affect many workers (O'Neill 1988). Trails were delineated with sprinkler flags. The terms "nest" and "mound" are used synonymously.

RESULTS

Carnivorous, Insectivorous, and Herbivorous Habits.—Although workers were observed feeding on a small owl carcass on 6–8 Jul 1993, they usually scavenged dead arthropods from late June to October. Beetles were common prey. Workers occasionally attacked and carried live insects, but did not pursue some observed on their mounds, such as aphids, a mealybug, a beetle, a spider, and another ant species.

Workers were seen with plant material at three mounds: a sagebrush leaf, a sagebrush gall, and a red flower.

Predation.—Seventeen mounds were found disturbed or excavated in the summers of 1993–1995. On 6 Jul 1993, a bear cub was observed digging about 25 cm into one mound and about 15 cm into another mound, presumably feeding on workers and brood. Nests recovered and one mound was largely rebuilt two weeks later.

Trails.—Well-defined trails lead from mounds to plants and/or to other mounds. Workers carried twigs, insects and spiders, nestmates, callows, wingless queens, larvae, and pupae on the trails.

Each of the mounds studied (n = 10) had 1–5 main trails. Three mounds had branching trails: two mounds had a single branch off a trail; the third mound had two branching trails. Trails (n = 35) from these mounds ranged from 0.6–44.8 m long (mean = 7.1 m). The greatest decline in trail number for a mound over the years was from four in 1992 to one in 1994. The mound was abandoned in 1995.

Marking Experiments.—Marking experiments and trails suggest that some mounds are related. Mounds #8 and #9 were connected by a trail and workers marked on mound #9 were found on mound #8. A trail ran between mounds #80 and #81 and workers marked on each mound were found on both. In addition, workers marked on a nearby Saskatoon serviceberry appeared on both mounds and both mounds had trails to the same sagebrush.

Workers marked on a particular mound were found on vegetation and other mounds. For example, mound #9 workers were found on nine mounds 4.3–14.6 m away and on vegetation up to 8.2 m away.

Circadian Activity.—Workers were seen leaving mounds as early as 06:40 and as late as 20:45 h in June 1992, but mound activity fluctuated greatly during the day. Mounds were active from 07:48 to approximately 11:00 h from 1 Jul–16 Aug 1993, although activity sometimes subsided as early as 10:45 and sometimes not until noon. Mound activity increased again from 13:45 to 18:40 h. It was not determined if mound activity was related to changes in temperature, sunlight, or other environmental factors.

Trail activity also changed during the day. Ant activity monitored for seven days in July 1994 at four checkpoints along two trails to the Douglas fir, fluctuated from 0–171 ants/min. Trail activity at the checkpoints was generally high in the morning from 07:31–11:17 h, but declined from 10:12–17:05 h. Activity increased and was high again later in the day from 17:07–18:59 h. At three of four checkpoints, the highest trail counts (165–171 ants/min) occurred from 17:17–18:07 h. The highest count at the fourth checkpoint (117 ants/min) occurred in the morning at 09:03 h.

Trails to Douglas fir.—Trails to the Douglas fir tree varied over the years. Workers marked on the trunk in 1993 were observed on or near five mounds 4.0–15.1 m away. In 1994, 17 mounds, 3.8–53.6 m away (mean = 15.3 m), were connected to the Douglas fir by nine trails. Four of these trails led to single mounds, four led to two mounds, and one trail went to four mounds and branched to a fifth mound. Ants marked on the most distant mound from the tree, #70, were found on 24 other mounds up to 77.9 m away (mound O) (Fig 1).

In 1996, ten trails led to the Douglas fir from 17 mounds 4.1–52.6 m away (mean = 15.7 m). Six trails went to single mounds, three led to two mounds, and one trail led to five mounds. Six 1994 mounds (#68, 70, 94, J, M, O) no longer had trails to the tree, but six different mounds did. The longest trail came from a mound (#65) 52.6 m away that passed through two unidentified mounds and two old mounds (#84, #48) on its way to the tree (Fig 1). Ants marked on mound #65 were subsequently found on four mounds; three with trails leading to the tree.

Every year ants went into thatch at the base of the Douglas fir tree and onto the branches to tend aphids. Some workers coming down the trunk had swollen gasters and one was carrying an aphid. Ants collected insects on the tree: one was observed pursuing a small beetle and others carried small flies. Ants died while foraging; over a 20 minute period, six ants were seen carrying dead coworkers or their remains on the trunk. A number of dead ants were also found mired in tree resin.

Foraging on Plants.—Workers were observed on 12 plants in the area from late June to October: quaking aspen, Douglas fir, Rocky Mountain penstemon, silvery lupine, rubber rabbitbrush, big sagebrush, Saskatoon serviceberry, mountain snowberry, stinging nettles, Woods rose, russian thistle, and redroot buckwheat.

Ants tended aphids on nine of these plants (Table 1), but were seen most commonly on big sagebrushes which were heavily infested with aphids and visited by large numbers of ants. Some aphid locations were unusual. One aphid site was inside a curled leaf gall produced by Eriophyid mites on a quaking aspen. Large numbers of aphids were also in leaf clusters on Saskatoon serviceberry (Table 2) and mountain snowberry (Table 3). Mountain snowberry leaf clusters were 2–3 cm in diameter and one bush had at least eight leaf clusters.

Workers also tended other insects, such as psylloidea on Saskatoon serviceberry, treehoppers on rubber rabbitbrush and stinging nettles, scale insects on rubber rabbitbrush and big sagebrush, dipteran galls on big sagebrush, and mealybugs on big sagebrush and stinging nettles (Table 1).

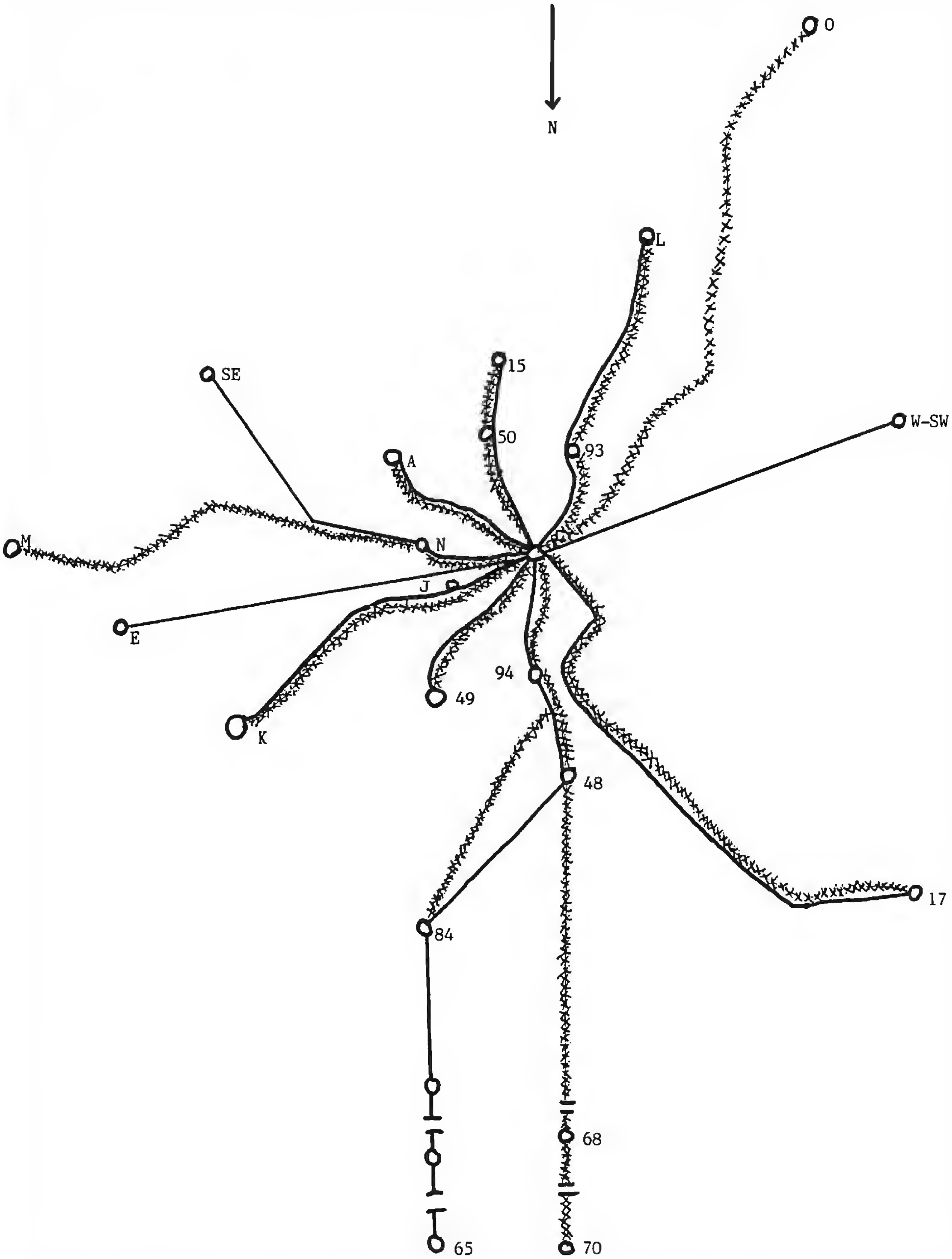


Figure 1. Trails from *Formica obscuripes* mounds to a Douglas fir tree in the summers of 1994 and 1996 at Soap Creek, Colorado study site. xxxx 1994 trails, —— 1996 trails, Scale: 1 cm = 2.2 m.

DISCUSSION

Carrion feeding appears rare in this species. Colorado ants fed on a small owl carcass and Weber (1935) reported ants feeding on Richardson ground squirrel carcasses, *Citellus richardsonii* (Sabine), placed on a mound.

Ants carried a variety of arthropods back to nests in Colorado as noted by others (Cole 1932; Weber 1935; Bradley 1973a, 1973b; O'Neill 1988; McIver & Steen 1994). Beetles were common prey in Colorado, but others reported the most common prey to be orthopterans (Weber 1935) or terrestrial isopods, leafhoppers, lepidopteran larvae and ants (O'Neill 1988). O'Neill (1988) noted ants bringing back living arthropods as I observed.

Colorado ants brought dead and live aphids to their mounds. Seibert (1992) also noted ants commonly carried dead aphids to their colonies, but Weber (1935) reported no aphids were taken to the nests.

Workers were observed with plant material at three Colorado mounds, but were not seen carrying seeds into mounds as reported by Cole (1932). Nor were yucca seeds found in the thatch and refuse piles as noted by Windsor (1964). Weber (1935) found no evidence of ants using plants as food.

Bradley (1973b) reported bear excavation of mounds as observed in this study. Other predators that have been recorded are kingbirds (*Tyrannus tyrannus* (L.) and *T. verticalis* Say), flickers (*Colaptes auratus borealis* Ridgw.), the common crow (*Corvus brachyrhynchos* Brehm), toads (*Bufo hemiophrys* Cope and *B. woodhousei* Girard) (Weber 1935), and six species of spiders (McIver & Loomis 1993).

Colorado mounds had one to five trails. Some trails branched and some trails changed during the season and from year to year as noted by O'Neill (1988).

The longest trails, 44.8 m (between mounds) and 53.6 m (between a mound and a plant), went farther than those (1–21.5 m) reported by Weber (1935), Herbers (1977), Henderson & Akre (1986), and McIver & Loomis (1993), but were shorter than the 135 m trail connecting nests reported by O'Neill (1988). The ten trails to the Douglas fir tree from 17 different mounds were greater than previously reported to a plant.

Henderson & Akre (1986) and O'Neill (1988) found that trails from several mounds frequently overlapped. O'Neill (1988) reported a system of two long parallel trails and branches serving 23 nests. In general, this did not occur in Colorado, except for some trails to the Douglas fir tree. One such trail connected five mounds.

Colonies are known to be polydomous and to reproduce by budding. I found small secondary mounds around plants along the trails from large primary mounds as noted by Herbers (1979b). Secondary mounds may become a new primary nest, serve as a refuge for aphids and ant tenders from summer heat and/or radiation, or provide a place where tenders transfer honeydew to larger ants for transport back to the primary nest (Weber 1935, Seibert 1992, McIver & Steen 1994). Henderson & Akre (1986) saw one colony relocate to a new nest site (presumably a secondary mound) 1 meter away over a period of about two weeks. They also found a secondary mound 20 m from the primary nest, which is about 5 m farther than the ones I located in Colorado.

Although Colorado workers generally followed the same trail each day as reported by Herbers (1977), marked ants were sometimes found off trails and on different trails. The maximum distance traveled by a marked worker between mounds was 77.9 m, farther than the 47.6 m reported by Weber (1935), but less than the 135 m of O'Neill (1988). I recovered ants marked on a single mound

Table 1. Insects and growths tended by *Formica obscuripes* on plants at Soap Creek, Colorado study site (*) compared to reports in literature.

Aphids (Homoptera—F. Aphididae)	
Big sagebrush—*Artemisia tridentata* Nutt	
Pleotrichophorus pseudoglandulosus (Palmer) *Aphis* sp.	*
Aphis artemisicola Will. *Aphis hermistonii* Wil. *Aphis oregonensis* Wil. *Macrosiphum frigidae* Oest.	Jones (1929)
Aphis spp. *Aphis minuta* *Macrosiphum* spp.	Knowlton (1975)
Unident. spp.	McIver & Loomis (1993); McIver & Steen (1994)
Quaking aspen—*Populus tremuloides* Michaux	
Unidentified spp. *Pterocomma populifoliae* (Fitch)	*
Chaitophorus sp. *Chaitophorus populicola* Thos.	Jones (1929)
Neothasmia populicola (Thos.)	Weber (1935)
Lupine—*Lupinus argenteus* Pursh	
Aphis lupini Gillette & Palmer	*
Mountain snowberry—*Symphoricarpos rotundifolius* Gray	
Unident. spp. *Cedoaphis incognita* Hottes & Frison *Brevicoryne symphoricarpi* (Thomas)	*
Saskatoon serviceberry—*Amelanchier alnifolia* var. *pumila*	
Unident. spp. *Aphis* sp. *Nearctaphis sensoriata* (Gillette & Bragg)	*
Stinging nettles—*Urtica gracilis* Aiton	
Unident. spp. *Aphis* sp.	*
Woods rose—*Rosa woodsii* Lindley	
Maculolachnus submacula (Walker) Unident. spp.—F. Aphididae (probable)	*
Douglas-fir—*Pseudotsuga* sp.	
Cinara pseudotaxifoliae Palmer	*
Lachnus splendens Gill. & Pal. on *P. taxifolia* (Poir.)	Jones (1929)
Rubber rabbitbrush—*Chrysothamnus nauseosus* (Pallas) Britton	
Unident. spp.	*
Psylloidea (Homoptera—F. Triozidae)	
Saskatoon serviceberry—*Amelanchier alnifolia* var. *pumila*	
Probable *Trioza* sp.	*

Table 1. Continued.

Treehoppers (Homoptera—F. Membracidae)	
Rubber rabbitbrush—*Chrysothamnus nauseosus* (Pallas)	
Publilia modesta Uhler—nymphs and adults	*
Unident. spp.	McIver & Loomis (1993); McIver & Steen (1994)
Stinging nettles—*Urtica gracilis* Aiton	
Unident. spp.	*
Scale insects (Homoptera—F. Coccidae)	
Rubber rabbitbrush—*Chrysothamnus nauseous* (Pallas)	
Unident. spp.	*
Big sagebrush—*Artemisia tridentata* Nutt	
Parthenolecanium sp.	*
Mealybugs (Homoptera—F. Pseudococcidae)	
Big sagebrush—*Artemisia tridentata* Nutt	
Amonosterium lichtensioides (Cockerell)	*
Stinging nettles—*Urtica gracilis* Aiton	
Unident. spp.	*
Dipteran galls—(Diptera—F. Cecidomyiidae)	
Big sagebrush—*Artemisia tridentata* Nutt	
Rhopalomyia pomum Gagne	*
Two unidentified growths (one containing aphids and other insects)	
Rubber rabbitbrush—*Chrysothamnus nauseosus* (Pallas)	*

on as many as 24 surrounding mounds. O'Neill (1988) found ants from eight nests on 29 other nests.

Colorado trail and mound activity varied during the day. Activity at trail checkpoints varied from 0–171 ants/minute; the latter being the highest rate reported for this species. Activity was generally high in the morning and later in the afternoon and decreased from 10:12–17:05 h, a somewhat longer duration than the 11:00–15:00 h reported by Weber (1935). As he noted, high temperatures and direct sunlight probably curtail summer midday activity. The greatest Colorado trail activity was from 17:17–18:07 h at three checkpoints; a fourth checkpoint had the greatest activity in the morning as reported by Weber (1935). Henderson & Akre (1986) noted a different circadian pattern; fairly constant foraging from 05:00–23:00 h, but little activity from 23:00–05:00 h.

I observed ants on 12 plant species and tending aphids on nine of them. Gregg (1963) also reported aphid-tending on a variety of Colorado plants. Jones (1929) listed 9 genera and 31 species of aphids on 22 plant genera in Colorado, but many of the plants and aphids differed from the ones in our study.

Colorado ants tended aphids, *Aphis* sp. and *Pleotrichophorus pseudoglandulosus* (Palmer), on big sagebrush. Although others observed ants on sagebrush (Cole 1932, Weber 1935, McIver & Steen 1994) and tending *Aphis* spp. (Jones 1929, Knowlton 1975), different aphids were also reported, such as *Macrosiphum*

Table 2. Four Saskatoon Serviceberry (*Amelanchier alnifolia* var. *pumila*) leaf clusters tended by *Formica obscuripes* at Soap Creek, Colorado study site (2560 m).

Cluster 1:	10 leaves
	24 workers
	403 wingless aphids (Homoptera)
	F. Aphididae
	Unidentified immature specimens
	Nearctaphis sensoriata (Gillette & Bragg)
	Ladybird larvae (Coleoptera)
	F. Coccinellidae
	Small wasp (Hymenoptera)
	F. Charipidae
	Lytoxysta brevipalpis Kieffer
	Parasitic hymenopteran larva
	Dipteran larvae (Diptera)
	F. Chamaemyiidae
Cluster 2:	7 leaves and 12 berries
	7 workers
	24 aphids (Homoptera)
	F. Aphididae
	Unidentified immature specimens
	F. Triozidae
	Probable *Trioza* sp.
Cluster 3:	8 leaves
	5 workers
	63 wingless aphids (Homoptera)
	F. Aphididae
	Unidentified immature specimens
	Nearctaphis sensoriata (Gillette & Bragg)
	1 ladybird larva (Coleoptera)
	F. Coccinellidae
	Scymnus sp.
Cluster 4:	8 leaves + 4 buds
	5 workers
	190 aphids (1 winged)
	Dipteran larvae (Diptera)
	F. Cecidomyiidae
	Unidentified larvae
	Bremia sp.

spp. (Jones 1929, Knowlton 1975) (Table 1) and *Bipersona* sp. (on an unidentified sagebrush species) (Weber 1935).

I saw ants tending the aphid, *Pterocomma populifoliae* (Fitch) on quaking aspen in Colorado, but others reported species in the genera *Chaitophorus* (Jones 1929) and *Neothasmia* (Weber 1935) (Table 1).

Colorado ants tended the aphid, *Cinara pseudotaxifoliae* Palmer, on Douglas fir, but Jones (1929) reported *Lachnus splendens* Gillette & Palmer on *Pseudotsuga taxifolia* (Poiret) (Table 1).

Colorado ants tended aphids on plants not reported in the literature, such as silvery lupine, stinging nettle, Saskatoon serviceberry, mountain snowberry and

Table 3. Three Mountain snowberry (*Symphoricarpos rotundifolius* Gray) leaf clusters tended by *Formica obscuripes* at Soap Creek, Colorado study site (2560 m).

Cluster 1:	93 leaves
	11 workers
	1163 aphids (50 winged) (Homoptera)
	F. Aphididae
	Unidentified immatures
	Cedoaphis incognita Hottes & Frison
	Brevicoryne symphoricarpi (Thomas)
	Thrips (2 adults and larvae) (Thysanoptera)
	F. Thripidae
	1st instar larva
	Frankliniella occidentalis (Perande) adults
	Frankliniella sp. larva
	Ladybird larvae (Coleoptera)
	F. Coccinellidae
	Dipteran larvae (Diptera)
	F. Chamaemyiidae and possible F. Chamaemyiidae
	F. Cecidomyiidae
	Lestodiplosis sp.
Cluster 2:	84 leaves
	40 workers
	707 aphids (28 winged) (Homoptera)
	F. Aphididae
	Unidentified immatures
	Cedoaphis incognita Hottes & Frison adults
	Ladybird larvae (Coleoptera)
	F. Coccinellidae
	Scymnus sp.
	Dipteran larvae and pupae (Diptera)
	F. Chamaemyiidae—pupae; poss. larvae
	F. Cecidomyiidae
	Lestodiplosis sp.
Cluster 3:	101 leaves
	9 workers
	906 aphids (36 winged) (Homoptera)
	F. Aphididae
	Unidentified immatures
	Cedoaphis incognita Hottes & Frison
	Ladybird larvae (Coleoptera)
	F. Coccinellidae
	Scymnus sp.
	Small wasp (Hymenoptera)
	F. Figitidae or F. Charipidae
	Dipteran larvae (Diptera)
	F. Cecidomyiidae
	Lestodiplosis sp.
	F. Syrphidae
	Syrphinae

Woods rose. McIver & Loomis (1993) and McIver & Steen (1994) reported workers foraging for honeydew on different lupine species (*Lupinus caudatus* Kellogg), but the insect was not identified.

Others noted ants tending aphids on the same genera as the Woods rose (*Rosa*) and mountain snowberry (*Symphoricarpos*) in Colorado (Weber 1935). Wheeler & Wheeler (1986) even noted the same two species of aphids on another species of *Symphoricarpos* that were on mountain snowberry in Colorado.

Knowlton (1975) reported the same aphid genus, *Pleotrichophorus* sp., on *Chrysothamnus*, that I found on big sagebrush in Colorado. This is not surprising, as it is known that one ant species may tend the same aphid species on different host plants (Jones 1929).

A new finding in Colorado was the large numbers of aphids (up to 1163) and other insects in Saskatoon serviceberry and mountain snowberry leaf clusters (Tables 2 and 3). Aphids have been reported to cause leaves to curl and have been found under curled leaves (Jones 1929, Weber 1935), but it is unclear if leaf cluster formation is due to aphid or ant activity.

The role of other insects in Colorado leaf clusters, such as a psylloidea, small wasps (F. Charipidae and possible F. Figitidae), and a parasitic hymenopteran larva are unclear. Dipteran larvae (F. Chamaemyiidae, F. Cecidomyiidae, F. Syrphidae), ladybird larvae (F. Coccinellidae), and thrip larvae and adults (F. Thripidae) in the clusters probably preyed on aphids (Tables 2 and 3). Jones (1929) suggested that ants may protect aphids from many natural enemies, such as chalcids, syrphids, coccinellids and chrysopids.

Workers tended treehopper nymphs and adults of *Publilia modesta* Uhler on rubber rabbitbrush in Colorado. Others have also noted ants tending Membracids (Wheeler 1910, Cole 1932) and collecting honeydew on rubber rabbitbrush (McIver & Loomis 1993, McIver & Steen 1994) (Table 1). O'Neill (1988) reported the membracids, *Campylenchia latipes* Say and *Publilia modesta* (Uhler), being tended on Canada thistle (*Cirsium arvense*) and chokecherry (*Prunus virginiana*).

Colorado ants also tended scale insects on rubber rabbitbrush and big sagebrush, dipteran leaf galls on big sagebrush, mealybugs on big sagebrush and stinging nettles, and two unidentified growths on rubber rabbitbrush (one housing aphids and other insects) (Table 1). They probably collected honeydew from all the above, except the dipteran galls. Further research is needed to determine if they harvest emerging flies from the latter.

Thus, as Seibert (1992) noted, *F. obscuripes* is not dependent on any one mutualistic partner. It has many nectar sources including coccids (Bradley 1973a, Seibert 1989, McIver & Steen 1994) and extrafloral nectar (Tilman 1978, Inouye & Taylor 1979, Seibert 1989).

ACKNOWLEDGMENT

Support for this research was provided by grants in 1993–1994 from the Howard Hughes Medical Institute through the Undergraduate Biological Sciences Education Program to the following University of Scranton students: John Bridge, Tom Sabalaske, Anthony Musingo, and Jeanne Rohan. I thank the Systematic Entomology Laboratory in Beltsville, Maryland and John T. Sorensen, Insect Taxonomy Laboratory, California Department of Food & Agriculture, Sacramento, California for identification of insect specimens. The Forest Service in Gunnison, Colorado identified plants.

Literature Cited

Bradley, G. A. 1972. Transplanting *Formica obscuripes* and *Dolichoderus taschenbergi* (Hymenoptera: Formicidae) colonies in Jack Pine stands of southeastern Manitoba. Can. Ent., 104: 245–249.

Bradley, G. A. 1973a. Effect of *Formica obscuripes* (Hymenoptera: Formicidae) on the predator-prey relationship between *Hyperaspis congressis* (Coleoptera: Coccinellidae) and *Toumeyella numismaticum* (Homoptera: Coccidae). Can. Ent., 105: 1113–1118.

Bradley, G. A. 1973b. Interference between nest populations of *Formica obscuripes* and *Dolichoderus taschenbergi* (Hymenoptera: Formicidae). Can. Ent., 105: 1525–1528.

Clark, W. H. & P. L. Comanor. 1972. Flights of the western thatching ant, *Formica obscuripes* Forel, in Nevada. Great Basin Nat., 32: 202–207.

Cole, A. C., Jr. 1932. The thatching ant, *Formica obscuripes* Forel. Psyche, 39:30–33.

Conway, J. R. 1996. Nuptial, pre-, and postnuptial activity of the thatching ant, *Formica obscuripes* Forel, in Colorado. Great Basin Nat., 56: 54–58.

Gregg, R. E. 1963. The ants of Colorado. University of Colorado Press. Boulder, Colorado.

Henderson, G. & R. D. Akre. 1986. Biology of the myrmecophilous cricket, *Myrmecophilia manni* (Orthoptera: Gryllidae). J. Kans. Ent. Soc., 59: 454–467.

Herbers, J. M. 1977. Behavioral constancy in *Formica obscuripes*. Ann. Ent. Soc. Am., 70: 485–486.

Herbers, J. M. 1978. Trends in sex ratios of the reproductive broods of *Formica obscuripes*. Ann. Ent. Soc. Am., 71: 791–793.

Herbers, J. M. 1979a. Caste-biased polyethism in a mound-building ant species. Amer. Midl. Nat., 101: 69–75.

Herbers, J. M. 1979b. The evolution of sex-ratio strategies in hymenopteran societies. Amer. Nat., 114: 818–834.

Inouye, D. W. & O. R. Taylor. 1979. A temperate region plant-ant-seed predator system: consequences of extra floral nectar secretion by *Helianthella quinquenervis*. Ecology, 60: 1–7.

Jones, C. R. 1929. Ants and their relation to aphids. Bull. Colo. Agr. Exp. Sta., 341: 1–96.

Kannowski, P. B. 1963. The flight activities of formicine ants. Symp. Genet. Biol. Ital., 12: 74–102.

King, R. L. & R. M. Sallee. 1953. On the duration of nests of *Formica obscuripes* Forel. Proc. Iowa Acad. Sci., 60: 656–659.

King, R. L. & R. M. Sallee. 1956. On the half-life of nests of *Formica obscuripes* Forel. Proc. Iowa Acad. Sci., 63: 721–723.

Knowlton, G. F. 1975. Ants of Curlew Valley, Utah and Idaho. Utah State University Ecology Center. Terrestrial Arthropod Series No. 13: 1–10.

McCook, H. C. 1884. The rufous or thatching ant of Dakota and Colorado. Proc. Acad. Nat. Sci. Phila. Part 1: 57–65.

McIver, J. D. & C. Loomis. 1993. A size-distance relation in Homoptera-tending thatch ants (*Formica obscuripes*, *Formica planipilis*). Insect. Soc., 40: 207–218.

McIver, J. D. & T. Steen. 1994. Use of a secondary nest in great basin desert thatch ants (*Formica obscuripes* Forel). Great Basin Nat., 54: 359–365.

O'Neill, K. M. 1988. Trail patterns and movement of workers among nests in the ant *Formica obscuripes* (Hymenoptera: Formicidae). Psyche, 95: 1–13.

Seibert, T. F. 1989. Foraging on insect mutualists by the thatching ant *Formica obscuripes*: interspecific and intraspecific mechanisms and implications. Ph.D. dissertation, University of Illinois, Urbana.

Seibert, T. F. 1992. Mutualistic interactions of the aphid *Lachnus allegheniensis* (Homoptera: Aphididae) and its tending ant *Formica obscuripes* (Hymenoptera: Formicidae). Ann. Ent. Soc. Am., 85: 173–178.

Talbot, M. 1959. Flight activities of two species of ants of the genus *Formica*. Amer. Midl. Nat., 61: 124–132.

Talbot, M. 1972. Flights and swarms of the ant *Formica obscuripes* Forel. J. Kans. Ent. Soc., 45: 254–258.

Tilman, D. 1978. Cherries, ants and tent caterpillars: timing of nectar production in relation to susceptibility of caterpillars to ant predation. Ecology, 59: 686–692.

Weber, N. A. 1935. The biology of the thatching ant *Formica obscuripes* Forel in North Dakota. Ecol. Monogr., 5: 165–206.

Wheeler, W. M. 1910. Ants; their structure, development and behavior. Columbia University Press.

Wheeler, G. C. & J. N. Wheeler. 1983. The ants of North Dakota. Nat. Hist. Mus. Los Ang. Cty., Los Angeles, CA.

Wheeler, G. C. & J. N. Wheeler. 1986. The ants of Nevada. Nat. Hist. Mus. Los Ang. Cty., Los Angeles, CA.

Windsor, J. K. 1964. Three Scarabaeid genera found in nests of *Formica obscuripes* Forel in Colorado. Bull. South. Calif. Acad. Sci., 63:205–209.

Received 28 Sep 1996; Accepted 17 Apr 1997.

PAN-PACIFIC ENTOMOLOGIST
73(3): 184–185, (1997)

Scientific Note

AN OUTBREAK OF THE MOTH *ACHAEA SERVA* (FABR.) ON THE MANGROVE *EXCOECARIA AGALLOCHA* (L.)

There have been several reports of lepidopteran larvae causing damage to the foliage of mangroves. One noteworthy case occurred in 1983 when between 5–10 km^2 of *Excoecaria agallocha* (L.) near Belawan in Northern Sumatra, Indonesia, was almost completely defoliated by caterpillars of the noctuid moth *Ophiusa melicerta* (Fabr.) (Whitten A. J. & S. J. Damanik, 1986. Biotropica, 18: 176). Whitten & Damaniks' report is intriguing because *E. agallocha* has also been recorded as having one of the lowest levels of leaf damage among mangroves and it has been suggested that *E. agallocha* is relatively resistant to attack by herbivorous insects because it produces a toxic sap (Robertson, A. I. 1991. Aust. J. Ecol., 16: 433–443).

Excoecaria agallocha is common within the landward margins of mixed mangrove stands along the banks of the Fitzroy River, Central Queensland, Australia, as far inland as Rockhampton (23°23′S, 150°31′E). During April 1995 we noticed that the *E. agallocha* within a strip at least 10 km long downstream from Rockhampton were almost completely defoliated. We surveyed the forest in April 1995 and found the mud beneath the *E. agallocha* trees littered with chewed fragments of leaf and numerous caterpillars of the noctuid moth *Achaea serva* (Fabr.) eating the few leaves remaining on the trees.

Within the area of defoliation we also found 3 separate patches, each of which was less than 60 m^2, where *E. agallocha* showed little or no leaf damage or defoliation. Fresh groundwater (salinity less than 2‰) was running into the mangrove forest from the landward edge of each patch, the boundary of which followed the extent of obvious freshwater seepage and was sharply defined; trees with almost undamaged foliage occurred within 1–2 m of completely defoliated ones. No other patches of freshwater input were found within the defoliated area.

Caterpillars of *A. serva* were present on the undefoliated trees, but stopped feeding and often fell to the ground within a few seconds of starting to feed; the leaves from these trees were rigid and oozed a copious watery latex when snapped across the midrib. In contrast, caterpillars feeding on leaves remaining on almost completely defoliated trees usually consumed the entire leaf apart from the midrib; the leaves were limp and produced little or no latex when snapped.

This may be another example of the outbreak of an herbivorous insect on plants which have become more attractive or susceptible to attack due to drought stress (e.g. White, T. C. R. 1993. The inadequate environment. Springer-Verlag, Berlin). From 1993–1995 there was a severe drought in Central Queensland coinciding with the 1993–95 El Nino Southern Oscillation event (Anonymous. 1995. Monthly weather review for Queensland. Australian Bureau of Meterology, Canberra), and we suggest this drought resulted in reduced toxin production by *E. agallocha* and hence the outbreak of *A. serva*. Furthermore, the outbreak of *Ophiusa melicerta* on *E. agallocha* in Indonesia reported by Whitten & Damanik (1986) occurred in January 1983; the year following one of the most extreme El Nino-Southern Oscillation events ever recorded, during which there was severe and widespread drought in Indonesia (Gill A. E. & E. M. Rasmusson. 1983. Nature, 306: 229–234).

The current El Nino event appears to have ended and rainfall during the southern hemisphere winter–spring of 1995 (June–November) in Rockhampton was significantly greater than in the same seasons of the previous year (Anonymous 1995). The defoliated *E. agallocha* have grown new leaves and no adults, pupae or caterpillars of *A. serva* were found during subsequent surveys in September 1995 or April 1996.

We think our observations are noteworthy for two reasons. First, they have resulted in an hypothesis which can explain two outbreaks of noctuids on *E. agallocha*. Second, considering that *A. serva* has been reported on castor, *Ricinus communis* L. (Common, I. F. B. 1990. Moths of Australia. Melbourne University Press, Melbourne), the outbreak on *E. agallocha* emphasises that species which have become more susceptible to herbivores due to drought stress may temporarily increase the effective host range (and thus perhaps the population density) of polyphagous pests of commercial crops. We intend to continue monitoring *E. agallocha* in Rockhampton because a future drought may provide an opportunity to test the above-mentioned hypothesis by experimentally irrigating parts of the mangrove swamp.

Acknowledgment.—The Rockhampton City Council allowed access to the mangrove forest and Dr. Bob Newby identified *Achaea serva.*

Stephen C. McKillup and Ruth V. McKillup, *Department of Biology, Central Queensland University, Rockhampton, Queensland 4702 Australia.*

Received 1 Jul 1996; Accepted 30 Sep 1996.

PAN-PACIFIC ENTOMOLOGIST
73(3): 186–189, (1997)

Scientific Note

HESPEROPSIS GRACILIAE (MacNEILL) (LEPIDOPTERA: HESPERIIDAE) FLIGHT BETWEEN HOSTPLANTS AND *PROSOPIS GLANDULOSA* TORREY

MacNeill's sootywing skipper, *Hesperopsis graciliae* (MacNeill), is a small (wingspread ≈ 23 mm) dark-gray butterfly found along the lower Colorado River and near the river along its tributaries in southeastern California, western Arizona, southern Nevada, and southern Utah (Scott, J. A. 1986. The butterflies of North America: a natural history and field guide. Stanford Univ. Press, Stanford, Calif.). Flights of *H. graciliae* occur from April to October in two (Emmel, T. C. & J. F. Emmel. 1973. The butterflies of southern California. Nat. His. Mus. Los Angeles Co., Sci. Series, 26: 1–148.) or three (Austin, G. T. & A. T. Austin. 1980. J. Res. Lepidoptera, 19: 1–63.) generations. Larvae of *H. graciliae* feed only on *Atriplex lentiformis* (Torrey) (Chenopodiaceae), a shrub found in dense clumps along lower Colorado River drainages (Emmel & Emmel 1973) that is halophytic and typically dioecious (Turner, R. M., J. E. Bowers & T. L. Burgess. 1995. Sonoran desert plants: an ecological atlas. Univ. Ariz. Press, Tucson.). *Hesperopsis graciliae*, however, is only sporadically encountered compared with the distribution of its larval host (Austin & Austin 1980). The apparent rarity of this butterfly, and concern over habitat destruction due to urban and agricultural development, has afforded *H. graciliae* the global rank of 'G3?' (L. Jaress, Ariz. Game & Fish Dept., Phoenix, personal communication), indicating that the conservation status of the species is uncertain but currently considered as rare or uncommon but not imperiled (Master, L. L. 1991. Conservation Biol., 5: 559–563.).

The rarity of *H. graciliae* compared with that of *A. lentiformis* suggests that factors other than larval-host availability influence its occurrence. One such factor may be the availability of a food source for *H. graciliae* adults. *Hesperopsis graciliae* adults must forage on other plant species, because *A. lentiformis* is wind-pollinated (Turner et al. 1995) and does not produce nectar, and foraging flights between plant species would be expected. However, *H. graciliae* adults are reported as seldom straying from the cover of their hostplants (Howe, W. H. [ed.]. 1975. The butterflies of North America. Doubleday & Co., Garden City, New York.). The present study describes and analyzes flights by *H. graciliae* between *A. lentiformis* and honey mesquite, *Prosopis glandulosa* Torrey (Fabaceae), a riparian plant of the lower Colorado River not used by *H. graciliae* larvae.

The study site was located on the upper floodplain along the southern edge of the Bill Williams River 3 km east of Lake Havasu, a Colorado River reservoir, at the northern boundary of La Paz County, Arizona. The site lies within the Sonoran Desert biome (Turner, R. M. & D. E. Brown. 1982. Sonoran desertscrub. pp. 181–221. *In* Brown, D. E. [ed.]. Biotic communities of the American Southwest—United States and Mexico. Desert Plants 4 [1–4].) at an elevation of 150 m. Precipitation (measured 19 km south near Parker, Ariz.) during the previous 12 mos (20 mm) had been 21% of the annual average (97 mm, Turner & Brown 1982). Principal vegetation at the site is *A. lentiformis*, *Acacia greggii* Gray, *Pluchea sericea* (Nutt.), *Cercidium* sp., *P. glandulosa*, and *Salix gooddingii* Ball. *Hesperopsis graciliae* flights were observed between a 14 m × 5.5 m × 3 m high closed-canopy patch of *A. lentiformis* male and female plants and a 16 m × 13 m × 6 m high closed-canopy patch of clumped *P. glandulosa.* The edges of the *A. lentiformis* and *P. glandulosa* canopies were 4.0 m apart and separated by a dirt and gravel road that traversed the site from east to west. The north edge of the road transected 4.6 m of the *A. lentiformis* canopy, and the south edge of the road transected 9.8 m of the *P. glandulosa* canopy. The *P. glandulosa* was not in flower.

Hesperopsis graciliae flights between the plant canopies were observed, beginning at approximately 0930 MST, for 4 hrs on 17 and 20 Sep and for 2.5 hrs on 24 Sep 1996. A line of 5-cm diam. rocks 2 m apart was placed along the center of the road, and the time was recorded when a *H. graciliae* was observed flying across the line of rocks en route to either the *A. lentiformis* or *P. glandulosa.* Air temperature at the site was recorded hourly and averaged 30.8, 30.6, and 34.4° C on the three dates, respectively. Two *H. graciliae* adults (1 male and 1 female) were collected from the *A. lentiformis* on 26 September, verified as to species (G. Austin, Nev. St. Mus., Las Vegas, personal communication), and deposited as voucher specimens at the University of Arizona Insect Museum, Tucson.

The number of *H. graciliae* flights to *A. lentiformis* and to *P. glandulosa* on each date was compared against an expected proportion of 1:1 using a χ^2 test. The sequence of flight directions observed on each date was analyzed with a runs test (Sokal, R. R. & F. J. Rohlf. 1981. Biometry [2nd ed]. W. H. Freeman & Co., New York.), a nonparametric method that uses the t_s-distribution to test if an observed sequence of dichotomized events, in this case flight to *A. lentiformis* or to *P. glandulosa*, departs from random. Significant ($P < 0.05$), positive values of t_s (>1.960) indicate flight directions that alternate in sequence, whereas negative values of t_s (<-1.960) indicate sequences with each flight direction tending to repeat. In addition to performing runs tests on observed sequences of flight direction, runs tests were performed on sequences of flight direction after shifting the observed times of flight to *A. lentiformis* earlier by 1, 2, 3, 4, and 5 min. Shifting the time of flight allowed determining if flights to *A. lentiformis* were delayed behind those to *P. glandulosa* by a constant interval on each date.

A total of 267 flights by *H. graciliae* was observed between the *P. glandulosa* and *A. lentiformis* canopies during the 10.5 hrs that the site was monitored (Table 1). *Hesperopsis graciliae* flew close to the ground, rarely exceeding a height of 20 cm, when traversing the open area between the plants and exhibited the fluttering, bouncy pattern as has been previously described (MacNeill, C. D. 1970. Entomol. News, 81: 177–184, Ferris, C. D. & F. M. Brown [eds.]. 1981. Butterflies of the Rocky Mountain states. Univ. of Okla. Press, Norman.). Flights to *P. glandulosa* were slower and with more wandering than those to *A. lentiformis*, and therefore more easily observed. Although *H. graciliae* flying to *A. lentiformis* frequently landed near the periphery of the plant canopy, few adults flying to *P. glandulosa* similarly landed; most adults instead continued their flight into the interior of *P. glandulosa*'s comparatively less-dense canopy.

The number of flights to *A. lentiformis* compared with those to *P. glandulosa* did not differ significantly ($P > 0.05$) within each date (Table 1). Across all three dates, the median time interval between successive flights to *P. glandulosa* was

Table 1. Frequency and interval of *Hesperopsis graciliae* flights between *Prosopis glandulosa* and *Atriplex lentiformis.*

Date	Plant species flown to	No. of flights	χ^2	Interval between successive flights (min)	
				Median	Range
17 Sept.	*P. glandulosa*	74	1.69[a]	2.42	0.08–11.42
	A. lentiformis	59		3.21	0.08–15.92
20 Sept.	*P. glandulosa*	51	3.40[a]	2.92	0.08–18.17
	A. lentiformis	34		4.50	0.08–21.50
24 Sept.	*P. glandulosa*	29	1.65[a]	3.75	0.08–21.92
	A. lentiformis	20		4.17	0.17–28.00

[a] No. of flights compared; n.s. (1 df, $P > 0.05$).

2.83 min, and the median time interval between successive flights to *A. lentiformis* was 3.58 min. The median time interval between successive flights to either plant species was 1.33 min across all three dates.

The observed sequence of *H. graciliae* flight direction, to *A. lentiformis* or to *P. glandulosa,* did not depart from random on any of the dates sampled (Table 2). Alternating sequences in flight direction were detected after the observed times of flight to *A. lentiformis* were shifted earlier by 2 min on 17 September, by 4 min on 20 September, and by 1 min and 2 min on 24 September. Observed flights to *A. lentiformis* therefore were delayed behind observed flights to *P. glandulosa* by a constant interval on each date. The interval corresponding to the delay, however, varied between dates. Flights to *A. lentiformis* occurred approximately 3 min later than flights to *P. glandulosa* after averaging the delays (2, 4, and 1.5 min) across dates. A maximum of 6, 5, and 4 flights consecutively in the same direction was observed on the three dates, respectively.

In contrast to previous descriptions of *H. graciliae* as a weak flyer preferring to remain within foliage (MacNeill 1970, Howe 1975), the present study found the species frequently (approx. once every 1.3 min) flying across a 4 m span of open terrain that separated larval-host and non-host plants. The frequent flights by *H. graciliae* between plant canopies, lack of significant difference between the number of flights to *A. lentiformis* compared with those to *P. glandulosa,* and sequences of alternating flight direction detected between the plant canopies, indicate that individual *H. graciliae* adults were repetitively flying back and forth between the two plant species. The maximum number of flights consecutively in

Table 2. Values of t_s testing if sequences of *Hesperopsis graciliae* flight direction, to *Prosopis glandulosa* or to *Atriplex lentiformis,* deviate from random.[a]

Date	Observed flight direction sequence	Flight direction sequence after shifting times of flight to *A. lentiformis* earlier				
		Shift of 1 min	Shift of 2 min	Shift of 3 min	Shift of 4 min	Shift of 5 min
17 Sept.	1.648	1.295	2.177[b]	0.414	1.472	0.061
20 Sept.	1.638	1.865	0.273	1.410	2.320[b]	0.955
24 Sept.	0.996	2.790[c]	2.192[b]	0.996	−0.798	0.398

[a] Runs test for dichotomized data (Sokal & Rohlf 1981).

[b] Alternating sequence in flight direction (df = ∞, $P < 0.05$).

[c] Alternating sequence in flight direction (df = ∞, $P < 0.02$).

the same direction (4-6 across dates) therefore provides an estimate of the insect's minimum population density on the *A. lentiformis*, and the average 3-min delay between flights to and from the *P. glandulosa* represents the time spent by *H. graciliae* at that plant species.

The benefit gained by *H. graciliae* repetitively flying from hostplants to *P. glandulosa* is not clear. For example, the insects may have been flying into *P. glandulosa*'s shaded interior for thermoregulation, the flights may have been associated with mate finding and reproduction, or the insects may have been searching for additional hostplants. I suggest that the observed flights represent foraging behavior by *H. graciliae*, an hypothesis supported by the presence of extrafloral nectaries on *P. glandulosa* (Pemberton, R. W. 1988. Madroño, 35: 238–246.). I found one nectary located between each of the paired, primary leaflets and several nectaries along the rachis between the secondary leaflets (see Hickman, J. C. [ed.]. 1993. The Jepson manual: higher plants of California. Univ. of Calif. Press, Berkeley.). Leaf-rachis nectaries from the *P. glandulosa* examined under magnification were exuding nectar, and *H. graciliae* were observed landing on the secondary leaflets. However, these observations were infrequent due to the difficulty of tracking the insects once they entered the *P. glandulosa* canopy, and the insect's small size and tendency to land on interior foliage prevented observing if their proboscises were extended and in contact with leaf-rachis nectar.

The hypothesis that *H. graciliae* were foraging at *P. glandulosa* extrafloral nectar is supported by the insect's opportunistic feeding as an adult. They have been reported to feed at flowers of an exotic weed, *Tamarix pentandra* Pallas (= *T. ramosissima*) (Tamaricaceae), a crop (alfalfa), *Medicago sativa* L. (Fabaceae), and a native plant, *Heliotropium curassavicum* L. (Boraginaceae) (Austin & Austin 1980). During the present study, I observed *H. graciliae* feeding at flowers of *Bebbia juncea* (Benth.) (Asteraceae) ≈ 0.25 km from the study site and the only insect-pollinated plants in flower in the vicinity. Adult Lepidoptera will feed on extrafloral nectar, and extrafloral nectar has been suggested to provide nectar-feeding insects an alternative food source when other sources are rare (Rogers, C. E. 1985. Bull. Entomol. Soc. Amer., 31: 15–20.). Alternative food sources may be important to *H. graciliae*, because floral nectar would be less abundant during the insect's fall flight. Additional effort is needed to determine if *H. graciliae* were foraging when repetitively flying to *P. glandulosa* or if the observed flights were due to other physiological demands, the significance of *P. glandulosa* extrafloral nectar as a food source to *H. graciliae* adults, and the influence of *P. glandulosa* on the insect's distribution and abundance.

Acknowledgment.—The author is grateful to the U.S. Fish and Wildlife Service for granting permission allowing the study to take place on their lands.

W. D. Wiesenborn, *U.S. Bureau of Reclamation, P.O. Box 61470, Boulder City, Nevada 89006-1470.*

Received 20 Nov 1996; Accepted 26 Feb 1997.

PAN-PACIFIC ENTOMOLOGIST
73(3): 190–191, (1997)

Scientific Note

HOST RANGE EXPANSION OF *HELCOSTIZUS RUFISCUTUM* CUSHMAN (HYMENOPTERA: ICHNEUMONIDAE) TO *PHORACANTHA SEMIPUNCTATA* FABR. (COLEOPTERA: CERAMBYCIDAE) IN CALIFORNIA

The eucalyptus longhorned borer, *Phoracantha semipunctata* Fabr., was first discovered in southern California in 1984, and during the last decade has decimated eucalyptus stands as it has spread throughout the southern counties, northwards through the San Joaquin and Sacramento Valleys and up the California coast (Scriven, G. T., E. L. Reeves & R. F. Luck. 1986. Calif. Agric., 40: 4–6; Paine, T. D., J. G. Millar & L. M. Hanks. 1995. Calif. Agric., 49: 34–37). Prior to this introduction, there were no North American *Phoracantha* species. As part of a biological control program aiming to limit damage caused by *P. semipunctata*, we have imported and introduced from Australia several species of braconid parasitoids of *Phoracantha* larvae (Paine et al. 1995). In particular, the parasitoid *Syngaster lepidus* Brullé showed promise of establishing at a site in Santa Barbara County, with several hundred wasps emerging from a single borer-infested tree a few months after release of 4,500 lab-reared wasps in summer 1994. On 11 Nov 1995, we monitored establishment of this parasitoid by looking under the bark of *Eucalyptus globulus* LaBillardière logs for the symmetrically oblong cocoons at the ends of *P. semipunctata* feeding galleries, but instead discovered a considerable number of very different, irregularly-shaped cocoons (one per borer gallery). Nine ichneumonid parasitoids of the species *Helcostizus rufiscutum* Cushman emerged from these cocoons in the laboratory (5 females and 4 males). *Helcostizus rufiscutum* is native to California and has apparently expanded its host range to become either a primary parasitoid of *P. semipunctata* or a secondary parasitoid of *S. lepidus.* Voucher specimens of *H. rufiscutum* have been placed in the Entomology Teaching and Research Museum at the University of California, Riverside.

Helcostizus rufiscutum belongs to the subfamily Cryptinae and tribe Hemitelini, other species of which are parasitic on cocoons of small insects in several insect groups, including Coleoptera and braconids (Townes, H. 1983. Mem. Am. Entomol. Inst., 35: 1-281). That the natural hosts of *H. rufiscutum* are apparently wood-boring larvae or their parasitoids is indicated by emergence of adult parasitoids from logs of the coniferous trees Monterey Cypress (*Cupressus macrocarpa* Gordon) and Douglas Fir (*Pseudotsuga menziesii* [Mirbel] Franco) as well the woody angiosperm poison oak (*Toxicodendron diversilobum* [Torrey & A. Gray] E. Green) (Townes 1983). It is clear that *P. semipunctata* was the host in Santa Barbara because *S. lepidus* was too rare at the site to account for the abundance of *H. rufiscutum.* For example, an intensive search of the study site on 11 Nov 1995 yielded only a single empty *S. lepidus* cocoon among hundreds of borer larvae. On 6 Aug 1996, we saw no evidence of *S. lepidus*, but counted 47 *H. rufiscutum* cocoons and 11 borer larvae (a parasitism rate of 81%). Moreover, we have tested the ability of *H. rufiscutum* to develop on *P. semipunctata* larvae in the laboratory; caged adult females readily oviposited on borer larvae through the bark of eucalyptus logs, and adult parasitoids emerged about 1 month later. Although all the parasitoids that emerged were males, this sex bias was likely due to either inhibition of mating behaviors in lab cages or to the size of host larvae that were provided. Field-collected cocoons yielded both sexes.

Host range expansion by *H. rufiscutum* is probably the result of a combination of factors. First, adult *H. rufiscutum* may search for a potentially broad range of borer hosts in a variety of habitats, as indicated by its being collected from a diversity of woody plant types. Second, location of the cryptic host insects is apparently mediated primarily by acoustic or vibrational cues that are detected by organs in the swollen front tibiae of females (J. Luhman, pers. comm.), and these cues may be similar for different borer species. Third, natural hosts and habitats were in close proximity to eucalyptus trees and slash infested with *P. semipunctata* larvae; all of the woody plant species from which this parasitoid has been reared (Monterey Cypress, Douglas fir, Poison Oak) occur in Santa Barbara County (Hickman, J. C. 1993. The Jepson Manual. Univ. of California Press). However, it is not known which species of wood borers are the native hosts. One possibility is *Xylotrechus nauticus* (Mannerheim) which commonly infests a wide variety of woody hosts (Linsley, E. G. 1964. Univ. Calif. Pub. Entomol., 22: 1-197). *Xylotrechus nauticus* larvae also feed in eucalyptus logs (Solomon, J. D. 1995. U.S.D.A. For. Serv. AH-706), and may occur in the same host logs as *P. semipunctata* (LMH, pers. obs.), suggesting a simple behavioral mechanism leading to parasitism of this introduced borer. Feeding galleries of *X. nauticus* may be distinguished from those of later instar *P. semipunctata* by their narrower breadth.

In Santa Barbara, *H. rufiscutum* apparently parasitizes a significant proportion of *P. semipunctata* larvae and so may play an important role in reducing borer populations. This parasitoid may also attack a congeneric borer species, *P. recurva*, which has been recently discovered in the state, but only in Orange, Riverside and San Bernardino Counties to date (C. Campbell & L. Hanks, unpublished data). Because *H. rufiscutum* is a native parasite and is broadly distributed in California (Townes 1983), fortuitous host range expansion may provide additional mortality of *Phoracantha* throughout the state.

Acknowledgment.—We thank Dr. John Luhman, Minnesota Department of Agriculture, for identifying the parasitoid specimens and reviewing the manuscript.

Lawrence M. Hanks, *Department of Entomology, University of Illinois, 320 Morrill Hall, 505 South Goodwin Ave., Urbana, IL 61801.*

Christopher Campbell, Timothy D. Paine, and Jocelyn G. Millar, *Department of Entomology, University of California, Riverside, CA 92521.*

Received 17 Dec 1996; Accepted 26 Feb 1997.

PAN-PACIFIC ENTOMOLOGIST
73(3): 192–196, (1997)

PROCEEDINGS OF THE PACIFIC COAST ENTOMOLOGICAL SOCIETY, 1996

FIVE HUNDRED TWENTY-THIRD MEETING

The 523rd meeting of the Pacific Coast Entomological Society was held on 19 Jan 1996 at 8:00 PM in the Morrison Auditorium of the California Academy of Sciences in Golden Gate Park, San Francisco with President-Elect Warren E. Savary presiding.

Ms. Barbara Deutsch presented a note on the migration of Monarch butterflies in North America and Mr. Curtis Y. Takahashi of the California Department of Food and Agriculture announced seasonal employment opportunities with the County of San Mateo and State of California Department of Food and Agriculture.

The featured speaker, Dr. Norman D. Penny of the California Academy of Sciences presented a slide lecture entitled "The Neuropterists' Contribution to the Costa Rican All Biotic Inventory". Dr. Penny discussed the tremendous diversity and species counts of Neuroptera that have been inventoried in over five years of extensive collecting in Costa Rica. The inventory reveals that Costa Rica has disproportionately high numbers of species diversity per area when compared with other areas outside of the country. The meeting was concluded at 9:05 PM and was followed by a social hour in the Department of Entomology Conference Room.

The following 39 persons were present: (30 members) P.H. Arnaud Jr., C.B. Barr, T.S. Briggs, R.M. Brown, R.L. Cable, H.K. Court, C.K. Griswald, A. Hom, A.S. Hunter, D.H. Kavanaugh, R.L. Langston, V.F. Lee, J.F. Parinas, D.R. Parks, A.M.L. Penny, D.A. Piechnik, K.A. Reynolds, J.M. Ribardo, K.J. Ribardo, D.C. Russel, L.S. Saul-Gershenz, W.E. Savary, K.A. Schick, N.M. Schiff, J. Schweikert, M. Sharp, C.Y. Takahashi, D. Ubick, and S.E. Vaughn; (9 guests) G.R. Almany, M.M. Arnaud, J.E. Court, M. Hurley, T. Pape, W.E. Rauscher, J. Schick, S. Smelter, and 1 illegible signature.

FIVE HUNDRED TWENTY-FOURTH MEETING

The 524th meeting of the Pacific Coast Entomological Society was held on 16 Feb 1996 at 8:00 PM in the Morrison Auditorium of the California Academy of Sciences in Golden Gate Park, San Francisco with President-Elect Warren E. Savary presiding.

Mr. Vincent F. Lee of the California Academy of Sciences announced that the first issue of the Pan-Pacific Entomologist was published on 12 Feb 1996 and is back on schedule. Mr. Lee also announced that the Pacific Branch of the American Association for the Advancement of Science will be held at San Jose State University on June 23 through 27.

Dr. Charles Griswald of the California Academy of Sciences announced that the International Congress of Arachnology will meet in July of 1998 in Chicago, Illinois.

Mr. Warren E. Savary of the Department of Agriculture announced that workshops on the future of San Francisco's Glen Canyon Park is requesting participation from the Pacific Coast Entomological Society, and Ms. Theresa Meickle presented a slide note illustrating the aesthetics of macro photographed sawfly frass.

The featured speaker, Dr. Nathan Schiff of the US Department of Agriculture-ARS, Albany presented a slide lecture entitled "Sawfly Biology; Dabblings of a Naturalist Turned Entomologist". Dr. Schiff provided entertaining insights into the phylogeny of sawflies as well as detailing the biology of the only true phytophagous Hymenoptera.

The meeting was adjourned at 9:35 PM and was followed by a social hour in the Department of Entomology Conference Room.

The following 37 persons were present: (29 members) P.H. Arnaud Jr., C.B. Barr, T.S. Briggs, R.M. Brown, R.L. Cable, H.K. Court, C.K. Griswald, A. Hom, A.S. Hunter, D.H. Kavanaugh, R.L. Langston, V.F. Lee, J.F. Parinas, D.R. Parks, A.M.L. Penny, D.A. Piechnik, K.A. Reynolds, J.M. Ribardo, K.J. Ribardo, L.S. Saul-Gershenz, W.E. Savary, K.A. Schick, N.M. Schiff, J. Schweikert, M. Sharp, C.Y. Takahashi, D. Ubick, and S.E. Vaughn; (8 guests) G.R. Almany, M.M. Arnaud, J.E. Court, M. Hurley, T. Pape, W.E. Rauscher, and J. Schick.

THE FIVE HUNDRED TWENTY-FIFTH MEETING

The 525th meeting of the Pacific Coast Entomological Society was held on 15 Mar 1996 at 8:00 PM in the Morrison Auditorium of the California Academy of Sciences in Golden Gate Park, San Francisco with President-Elect Warren E. Savary presiding.

Dr. Norman D. Penny of the California Academy of Sciences Announced that the auditor of the Society, H. Vannoy Davis found all business matters in order for 1995. Dr. Penny also announced that the Insect Fair at the Los Angeles Arboretum will be held on 18 May 1996. This is the largest insect fair in the United States.

Mr. Curtis Y. Takahashi of the California Department of Agriculture announced that the Insect Fair at Sanborn Park in Santa Clara County will be held on 18 May 1996 and Ms. Leslie Saul-Gershenz of the San Francisco Insect Zoo announced that a training workshop entitled "Managing and Working in Insectariums" will be held on the same day in Denver, Colorado.

Dr. Nathan Schiff of the Department of Agriculture-ARS, exhibited a living specimen of *Timema californica*.

The featured speaker, Mr. Norman E. Gershenz of the Center for Ecosystems Survival, presented an engaging slide lecture entitled "Conservation Strategies for the 21st Century". Mr. Gershenz described how conservation efforts have historically concentrated on a single species and how current strategies have evolved to include systemic habitat conservation. With this in situ approach, Mr. Gershenz outlined the socio-economic factors that necessitate a conservation partnership in country with residents forming a more effective conservation effort. The meeting was adjourned at 9:05 PM and was followed by a social hour in the Department of Entomology Conference Room.

The following 30 persons were present: (25 members) P.H. Arnaud Jr., L.G. Bezark, T.S. Briggs, S.V. Fend, C.E. Griswold, W. Hamersky, A. Hom, J. Honda, R.L. Langston, D.L. Mead, T. Meikle, J.F. Parinas, D.R. Parks, A.M.L. Penny, N.D. Penny, S. Renkes, R.G. Robertson, E.S. Ross, W.E. Savary, N.M. Schiff, J. Schweikert, F.A.H. Sperling, C.Y. Takahashi, D. Ubick, and S.E. Vaughn; (5 guests) M.M. Arnaud, B. Landry, K. Norton, W.E. Rauscher, and D.T. Wyatt.

FIVE HUNDRED TWENTY-SIXTH MEETING

The 526th meeting of the Pacific Coast Entomological Society was held on 19 Apr 1996 at 8:00 PM in the Morrison Auditorium of the California Academy of Sciences in Golden Gate Park, San Francisco with President Wojciek J. Pulawski presiding.

Mr. Vincent F. Lee of the California Academy of Sciences announced the availability of The Insect Study Source Book published by the Young Entomologists' Society. The Source book catalogs instructional videos and other entomological listings.

Ms. Jeanette McNicol of San Jose State University announced that the annual Arroy Seco overnight collection trip sponsored by the SJSU Entomology Club will be held on 27 Apr 1996.

The featured speaker, Dr. David H. Kavanaugh of the California Academy of Sciences presented a slide lecture entitled "In Search of Old World Relatives of Nearctic Carabid Beetles in Central Siberia, Lake Baikal Region". Dr. Kavanaugh detailed the logistical difficulties and the cultural experiences encountered while traveling to the Lake Baikal region and surrounding mountain ranges as well as demonstrating the phylogenetic similarities of carabids found in Siberia with those found in Western Europe and North America. The meeting was adjourned at 9:45 PM and was followed by a social hour in the Department of Entomology Conference Room.

The following 30 persons were present: (25 members) P.H. Arnaud Jr., L.G. Bezark, T.S. Briggs, S.V. Fend, C.E. Griswold, W. Hamersky, A. Hom, J. Honda, R.L. Langston, D.L. Mead, T. Meikle, J.F. Parinas, D.R. Parks, A.M.L. Penny, N.D. Penny, S. Renkes, R.G. Robertson, E.S. Ross, W.E. Savary, N.M. Schiff, J. Schweikert, F.A.H. Sperling, C.Y. Takahashi, D. Ubick, and S.E. Vaughn; (5 guests) M.M. Arnaud, B. Landry, K. Norton, W.E. Rauscher, and D.T. Wyatt.

FIVE HUNDRED TWENTY-SEVENTH MEETING

The 527th meeting of the Pacific Coast Entomological Society was held on 17 May 1996 at 8:00 PM in the Morrison Auditorium of the California Academy of Sciences in Golden Gate Park, San Francisco with President Wojciek J. Pulawski presiding.

Mr. Patrick Craig presented a slide of an unidentified arthropod, encased in Lebanese amber for identification. After much speculation, inconclusive identification resulted.

The featured speaker, Dr. Charles Griswald of the California Academy of Sciences presented a slide lecture entitled "Spider Webs Through Space and Time". Dr. Griswald presented an overview of spider biology involving silk production and web formation as a means of determining phylogenetic relationships of arachnids. The convergence hypothesis explained by Dr. Griswald differs from previous systematic theory in that the webs of spiders are viewed as behavioral extensions rather than architectural or structural compositions. The meeting was adjourned at 9:25 PM and was followed by a social hour in the Department of Entomology Conference Room.

The following 46 persons were present: (34 members) R.A. Aalbu, P.H. Arnaud Jr., C.B. Barr, L.G. Bezark, J. Brandriff, T.S. Briggs, K.W. Brown, R.M. Brown, H.K. Court, P.R. Craig, B. Deutsch, C.E. Griswald, R.E. Hill, A.S. Hunter, B. Keh, C.Y. Kitayama, R.L. Langston, V.F. Lee, D.L. Mead, T. Meikle, W.J. Pulawsk, A.E. Rackett, K.M. Reynolds, R.G. Robertson, W.E. Savary, K.N. Schick, N.M. Schiff, J. Sweikert, H.I. Scudder, E.L. Smith, F.A.H. Sperling, D. Ubick, S.E. Vaughn, and D.T. Wyatt; (12 guests) D. Aalbu, V. Ahrens-Pulawski, M.M. Arnaud, J. Baker, I. Brown, J.E. Court, D. Kitayama, K. Kitayama, R. Kitayama, K. Norton, W.E. Rauscher, and S. Stone.

FIVE HUNDRED TWENTY-EIGHTH MEETING

The 528th meeting of the Pacific Coast Entomological Society was held on 20 Sep 1996 at 8:00 PM in the Goethe Room of the California Academy of Sciences in Golden Gate Park, San Francisco with President Wojciek J. Pulawski presiding.

Dr. Nathan Schiff of the Department of Agriculture-ARS presented an exhibit of a sawfly (*Eurocerus*), a buprestid (*Melanophila*), and a cerambicid that were collected while posing as a Department of Forestry firefighter in Northern California and Mr. Ron Robinson presented a slide note of noctuid moths collected "in photo" during the summer.

The featured speaker, Dr. Thomas Briggs, Research Associate at the California Academy of Sciences presented a slide lecture entitled "The New Melones Cave Invertebrate Transplant". Dr. Briggs chronicled the details of the search, selection, and transplantation of invertebrates prior to the construction of the New Melones dam and subsequent flooding of the area. The New Melones Reservoir now covers the habitat from which the invertebrates transfer took place. The meeting was adjourned at 9:15 and concluded with a social hour held in the Department of Entomology Conference Room.

The following 46 persons were present: (34 members) R.A. Aalbu, P.H. Arnaud Jr., C.B. Barr, L.G. Bezark, J. Brandriff, T.S. Briggs, K.W. Brown, R.M. Brown, H.K. Court, P.R. Craig, B. Deutsch, C.E. Griswald, R.E. Hill, A.S. Hunter, B. Keh, C.Y. Kitayama, R.L. Langston, V.F. Lee, D.L. Mead, T. Meikle, W.J. Pulawsk, A.E. Rackett, K.M. Reynolds, R.G. Robertson, W.E. Savary, K.N. Schick, N.M. Schiff, J. Sweikert, H.I. Scudder, E.L. Smith, F.A.H. Sperling, D. Ubick, S.E. Vaughn, and D.T. Wyatt; (12 guests) D. Aalbu, V. Ahrens-Pulawski, M.M. Arnaud, J. Baker, I. Brown, J.E. Court, D. Kitayama, K. Kitayama, R. Kitayama, K. Norton, W.E. Rauscher, and S. Stone.

FIVE HUNDRED TWENTY-NINTH MEETING

The 529th meeting of the Pacific Coast Entomological Society was held on 18 Oct 1996 at 8:00 PM in the Morrison Auditorium of the California Academy of Sciences in Golden Gate Park, San Francisco with President Wojciek J. Pulawski presiding.

Ms. Cheryl Barr of the University of California, Berkeley announced that she has a companion ticket available for half price to the Entomological Society of America National Meeting to be held in Louisville, Kentucky.

Mr. Vincent F. Lee of the California Academy of Sciences announced that the books "Australian Orthpteroids" and "Insect Musicians and Cricket Champions" will be on display during the social hour following the meeting.

Dr. Nathan Schiff of the US Department of Agriculture-ARS presented a larval specimen of *Nudiprion* collected on white fir in the Yuba Pass of California, and Dr. Kirby Brown displayed a basket decorated with images of butterflies obtained from the Pitt River region of northeastern California.

The featured speaker, Dr. Bernard Landry of the University of California, Berkeley presented a slide lecture entitled "The Lepidoptera of the Galapagos Islands". In highlighting the zoogeographical history of the islands, Dr. Landry described probable patterns of insect colonization and described the low diversity of fauna encountered while collecting. The meeting was adjourned at 9:15 PM and was followed by a social hour held in the Department of Entomology Conference Room.

The following 56 persons were present: (41 members) R.A. Aalbu, P.H. Arnaud Jr., C.B. Barr, T.S. Briggs, K.W. Brown, R.M. Brown, M.S. Caterino, L.W. Currie Jr., B. Deutsch, W.A. Doolin, E.M. Fisher, C.E. Griswald, W. Hammersky, L.A. Irons, M.A. Isaak, B. Landry, R.L. Langston, F.F. Lee, D.L. Mead, T.C. Meikle, M.H. Niehoff, L.A. Norton, S.T. O'Keefe, J.F. Parinas, A.M.L. Penny, N.D. Penny, J.A. Powell, W.J. Pulawski, A.E. Rackett, J.L. Rasgon, W.E. Savary, N.M. Schiff, J.S. Schweikert, H.I. Scudder, F.A.H. Sperling, R.E. Stecker, C.Y. Takahashi, D. Ubick, S.E. Vaughn, J.D. Wells, and R.L. Zuparkko; (15 guests) V. Ahrens-Pulawski, M.M. Arnaud, S.A. Brown, S.M. Covarrubias, B. Deutsch, D.D. Giuliani, D.E. Kain, J.J. Kruse, J. Myatt, S.G. Nguyen, R.D. Reed, A. Schedlock, R.M. Shelly, L.A. Swenson, and L. Volpe.

FIVE HUNDRED THIRTIETH MEETING

The 530th meeting of the Pacific Coast Entomological Society was held on 15 Nov 1996 at 8:00 PM in the Morrison Auditorium of the California Academy of Sciences in Golden Gate Park, San Francisco with President Wojciek J. Pulawski presiding.

Dr. Pulawski announced the appointments of Dr. Paul H. Arnaud Jr., Dr. Norman D. Penny, and Ms. Cheryl B. Barr to the Nominations Committee and Mr. H. Vannoy Davis, Ms. Helen Court, and Mr. Jere Schweikert to the Audit Committee.

Dr. Edward L. Smith presented a detailed note on the evolutionary modifications of cerci in some Apteragota, Ephemeroptera, and Odonata and Mr. Ron Robinson presented a slide note capturing wood-boring craneflies *in copula*. The sequence of slides show the female dragging the engaged male into a bored hole of a dead Bay tree.

The featured speaker, Dr. Wojciek J. Pulawski of the California Academy of Sciences presented a slide lecture entitled "The Biological Evolution of Hymenoptera". Dr. Pulawski discussed the structural and behavioral development of Hymenoptera from the most basal vegetarian Symphyta up through to the origin of sociality of the Apocrita. The development of the acuneates was illustrated especially well by Dr. Pulawski's slides. The meeting was adjourned at 10:15 PM and was followed by a social hour held in the Department of Entomology Conference Room.

The following 37 persons were present: (27 members) R.A. Aalbu, C.B. Barr, L.G. Bezark, K.W. Brown, A.I. Cognato, H.K. Court, C.E. Griswald, W. Hamersky, A. Hom, R.L. Langston, V.F. Lee, T.C. Meikle, D.R. Parks, A.M.L. Penny, N.D. Penny, J.A. Powell, W.J. Pulawski, A.E. Rackett, J.L. Rasgon, K.M. Reynolds, K.J. Ribardo, J.S. Schweikert, E.L. Smith, D. Ubick, S.E. Vaughn, J.D. Wells, and R.L. Zuparko; (10 guests) V. Ahrens-Pulawski, T.J. Bernot, D. Bunn, J.E. Court, C.D. Dailey, B. Kepner, D. Povolny, D. Ross, V. Van Wly, and S. Wilson.

FIVE HUNDRED THIRTY-FIRST MEETING

The 531st meeting of the Pacific Coast Entomological Society was held on 13 Dec 1996 at 8:00 PM in the Blakeslee Conference Room of San Francisco State University, San Francisco with President Warren E. Savary presiding.

Dr. Paul H. Arnaud Jr. of the California Academy of Sciences announced the acquisition, by the Academy, of specimens from the estate of Dr. Donald Denning. Dr. Arnaud also reported on behalf of the Nominations Committee. The following members were voted on and approved as officers for 1997:

Mr. Warren Savary, President
Dr. William Shepherd, President-Elect
Ms. Julieta F. Parinas, Treasurer
Mr. Vincent F. Lee, Managing Secretary
Mr. Stanley E. Vaughn, Recording Secretary

Mr. Vincent F. Lee of the California Academy of Sciences reported that membership totaled 372 and Dr. Susan B. Opp of California State University, Hayward reported that all issues of the Pan-Pacific Entomologist were published on schedule in 1996.

Ms. Leslie Saul-Gershenz of the San Francisco Insect Zoo announced that the Entomological Society of America has a page on the World Wide Web as well as an entomology site by the Iowa State Teachers' Association. Ms. Saul-Gershenz also announced the completion of Dynastinae in the All Taxa Survey of Costa Rica.

Mr. Curtis Y. Takahashi of the California Department of Food and Agriculture presented, as an exhibit, some towels designed with images of insects and flowers.

The featured speaker, Dr. John E. Hafernik of San Francisco State University presented a slide lecture entitled "The Re-introduction of the Damselfly *Ishnera gemina* in Glen Canyon". Dr. Hafernik described the natural history of Glen Canyon and detailed past and present biological conservation techniques in reintroducing the damsilfly to the area. Initially, during re-introduction, populations of Ishnera exhibited increased mortality. Currently, however the emergence of new cohorts is approaching previous recapture levels, indicating the possibility of a reestablished population. The meeting was adjourned at 9:45 PM.

The following 30 persons were present: (17 members) M.M. Arnaud, P.H. Arnaud Jr., B. Deutsch, J.G. Edwards, N.E. Gershenz, J.E. Hafernik, B. Landry, V.F. Lee, S.B. Opp, J.L. Rasgon, K.M. Reynolda, L. Saul-Gershenz, W.E. Savary, N.A. Schiff, C.Y. Takahashi, S.E. Vaughn, and J.D. Wells; (13 guests) M. Brewer, J. Conner, R.A. Cruib, T. Dockery, J. Gulbranser, G. Hannon, A. LeMon, S. LeMon, D.A. Piechnik, W.A. Rauscher. C. Risden, R. Rozman, and E. Valdivia.

PAN-PACIFIC ENTOMOLOGIST
73(3): 197–198, (1997)

PACIFIC COAST ENTOMOLOGICAL SOCIETY NOTES TO THE FINANCIAL STATEMENTS YEAR ENDED SEPTEMBER 30, 1996

SUMMARY OF SIGNIFICANT ACCOUNTING POLICIES

Accounting Method

Income and expenses are recorded by using the cash basis of accounting.

Note from the Treasurer

The Pan-Pacific Entomologist, the journal of the Pacific Coast Entomological Society, is published quarterly. However, due to editorial delays, the issues are often not published and charged to the Society on schedule. This explains the abnormal fluctuation in publishing costs.

Capital Expenditures

Annual capital expenditures of $5,000 or less are charged to expense.

Marketable Securities

American Telephone & Telegraph Co., Pacific Telesis Group and Air Touch Communications common stocks are carried at market value. Increases and decreases in value are reflected in income.

As of Sept. 30, 1996 AT & T Corp. issued one share of Lucent Technologies Inc. capital stock for every 3 shares of AT & T Corp. shares owned plus cash for fractional shares. This distribution of 25 shares of Lucent Technologies Inc. is reflected in these statements as an increase in value of captial stock owned of $1147.

Income Tax

The Society is exempt from Federal Income and California franchise tax.

As Chairman of the Accounting and Tax Committee, and in accordance with the Society's bylaws, I have reviewed the financial records of the Society but have not made an audit of them.

During the course of this review, nothing was noted which indicated any material inaccuracy in the financial statements.

H. Vannoy Davis
Chairman of the Accounting and Tax Committee

PACIFIC COAST ENTOMOLOGICAL SOCIETY

STATEMENT OF INCOME, EXPENDITURES AND CHANGES IN FUND BALANCES

YEARS ENDED SEPTEMBER 30, 1996 AND 1995

	1996	1995
Income		
Dues and subscriptions	$ 17,808	$ 17,066
Reprints and miscellaneous	15,681	10,421
Interest	3,815	3,730
Dividends	700	681
Increase (Decrease) in value of capital stock:		
American Telephone & Telegraph Company	(1,080)	940
Pacific Telesis Group and Air Touch Communications	(33)	528
Lucent Technologies (see note)	1,147	
Total Income	**$ 38,038**	**$ 33,366**
Expenditures		
Publication costs—Pan-Pacific Entomologist	$ 30,478	$ 25,590
Reprint costs	3,098	2,614
Postage, newsletter and miscellaneous expenses	1,215	1,274
Total Expenditures	**$ 34,791**	**$ 29,478**
Increase in fund balances	$ 3,247	$ 3,888
Fund balances October 1, 1996 and 1995	133,258	129,370
Fund balances September 30, 1996 and 1995	**$136,505**	**$133,258**

STATEMENT OF ASSETS AS OF SEPTEMBER 30, 1996 AND 1995

	1996	1995
Cash in bank		
Commercial account	$ 17,475	$ 17,914
Special Funds:		
General Fund—Wells Fargo Bank	5,060	4,942
C. P. Alexander Fund—Capital Preservation Fund	57,413	54,711
Fall Memoir Fund—Wells Fargo Bank	35,060	34,228
Total cash in bank and special funds	**$115,008**	**$111,795**
Capital Stock (at market value)		
American Telephone & Telegraph Co., 80 shs.	4,180	5,260
Lucent Technologies, 25 shs.	1,147	
Pacific Telesis Group, 264 shs.	8,877	8,118
Air Touch Communications, 264 shs.	7,293	8,085
	21,497	21,463
Total Assets	**$136,505**	**$133,258**

PAN-PACIFIC ENTOMOLOGIST
73(3): 199, (1997)

1996 SPONSORING MEMBERS OF THE PACIFIC COAST ENTOMOLOGICAL SOCIETY

Ernest Anderson
Paula & Robert Buickerood
Bryan K. Eya
E. Eric Grissell
Teresa C. Meikle & Charles E. Griswold
John E. Hafernik Jr.
Frank T. Hovore
Calvert E. Norland
Harry W. Oswald
Richard L. Penrose
Albert E. Rackett
Norman E. Gershenz & Leslie S. Saul
Warren E. Savary
Harvey I. Scudder
Frank E. Skinner
Edward L. Smith
Thomas J. Zavortink

PAN-PACIFIC ENTOMOLOGIST
73(3): 200, (1997)

Editorial Policy Change

Beginning with manuscripts submitted after 1 January 1998, The Pan-Pacific Entomologist will require that voucher specimens for all articles be deposited in a properly maintained collection accessible to other scientists. This policy represents a departure in tradition for non-taxonomic studies that is necessitated by the rapid discovery of numerous cryptic species and species complexes. These situations make it imperative that future scientists be able to confirm exactly what species was studied in past papers. The uncertainty surrounding whether older studies used *Bemisia tabaci* (Gennadius) or *Bemisia argentifolii* (Bellows & Perring) is a good example of a situation that could have been avoided if voucher specimens were available. Similar confusion surrounds older studies of *Bactrocera dorsalis* (Hendel) from numerous locations, several *Rhagoletis* species and numerous aphids. The location at which the voucher specimen(s) have been deposited and the coding necessary to access them shall be noted in the Materials and Methods section of the article or the text of the scientific note.

PAN-PACIFIC ENTOMOLOGIST
Information for Contributors

See volume 66(1): 1–8, January 1990, for detailed general format information and the issues thereafter for examples; see below for discussion of this journal's specific formats for taxonomic manuscripts and locality data for specimens. Manuscripts must be in English, but foreign language summaries are permitted. Manuscripts not meeting the format guidelines may be returned. Please maintain a copy of the article on a word-processor because revisions are usually necessary before acceptance, pending review and copy-editing.

Format. — Type manuscripts in a legible serif font IN DOUBLE OR TRIPLE SPACE with 1.5 in margins on one side of 8.5 × 11 in, nonerasable, high quality paper. THREE (3) COPIES of each manuscript must be submitted, EACH INCLUDING REDUCTIONS OF ANY FIGURES TO THE 8.5 × 11 IN PAGE. Number pages as: title page (page 1), abstract and key words page (page 2), text pages (pages 3+), acknowledgment page, literature cited pages, footnote page, tables, figure caption page; place original figures last. List the corresponding author's name, address including ZIP code, and phone number on the title page in the upper right corner. The title must include the taxon's designation, where appropriate, as: (Order: Family). The ABSTRACT must not exceed 250 words; use five to seven words or concise phrases as KEY WORDS. Number FOOTNOTES sequentially and list on a separate page.

Text. — Demarcate MAJOR HEADINGS as centered headings and MINOR HEADINGS as left indented paragraphs with lead phrases underlined and followed by a period and two hypens. CITATION FORMATS are: Coswell (1986), (Asher 1987a, Franks & Ebbet 1988, Dorly et al. 1989), (Burton in press) and (R. F. Tray, personal communication). For multiple papers by the same author use: (Weber 1932, 1936, 1941; Sebb 1950, 1952). For more detailed reference use: (Smith 1983: 149–153, Price 1985: fig. 7a, Nothwith 1987: table 3).

Taxonomy. — Systematics manuscripts have special requirements outlined in volume 69(2): 194–198; if you do not have access to that volume, request a copy of the taxonomy/data format from the editor before submitting manuscripts for which these formats are applicable. These requirements include SEPARATE PARAGRAPHS FOR DIAGNOSES, TYPES AND MATERIAL EXAMINED (INCLUDING A SPECIFIC FORMAT), and a specific order for paragraphs in descriptions. List the unabbreviated taxonomic author of each species after its first mention.

Data Formats. — All specimen data must be cited in the journal's locality data format. See volume 69(2), pages 196–198 for these format requirements; if you do not have access to that volume, request a copy of the taxonomy/data format from the editor before submitting manuscripts for which these formats are applicable.

Literature Cited. — Format examples are:

Anderson, T. W. 1984. An introduction to multivariate statistical analysis (2nd ed). John Wiley & Sons, New York.

Blackman, R. L., P. A. Brown & V. F. Eastop. 1987. Problems in pest aphid taxonomy: can chromosomes plus morphometrics provide some answers? pp. 233–238. *In* Holman, J., J. Pelikan, A. G. F. Dixon & L. Weismann (eds.). Population structure, genetics and taxonomy of aphids and Thysanoptera. Proc. international symposium held at Smolenice Czechoslovakia, Sept. 9–14, 1985. SPB Academic Publishing, The Hague, The Netherlands.

Ferrari, J. A. & K. S. Rai. 1989. Phenotypic correlates of genome size variation in *Aedes albopictus*. Evolution, 42: 895–899.

Sorensen, J. T. (in press). Three new species of *Essigella* (Homoptera: Aphididae). Pan-Pacif. Entomol.

Illustrations. — Illustrations must be of high quality and large enough to ultimately reduce to 117 × 181 mm while maintaining label letter sizes of at least 1 mm; this reduction must also allow for space below the illustrations for the typeset figure captions. Authors are strongly encouraged to provide illustrations no larger than 8.5 × 11 in for easy handling. Number figures in the order presented. Mount all illustrations. Label illustrations on the back noting: (1) figure number, (2) direction of top, (3) author's name, (4) title of the manuscript, and (5) journal. FIGURE CAPTIONS must be on a separate, numbered page; do not attach captions to the figures.

Tables. — Keep tables to a minimum and do not reduce them. Table must be DOUBLE-SPACED THROUGHOUT and continued on additional sheets of paper as necessary. Designate footnotes within tables by alphabetic letter.

Scientific Notes. — Notes use an abbreviated format and lack: an abstract, key words, footnotes, section headings and a Literature Cited section. Minimal references are listed in the text in the format: (Bohart, R. M. 1989. Pan-Pacific. Entomol., 65: 156–161.). A short acknowledgment is permitted as a minor headed paragraph. Authors and affiliations are listed in the last, left indented paragraph of the note with the affiliation underscored.

Page Charges. — PCES members are charged $35.00 per page, for the first 20 (cumulative) pages per volume and full galley costs for pages thereafter. Nonmembers should contact the Treasurer for current nonmember page charge rates. Page charges do not include reprint costs, or charges for author changes to manuscripts after they are sent to the printer. Contributing authors will be sent a page charge fee notice with acknowledgment of initial receipt of manuscripts.

THE PAN-PACIFIC ENTOMOLOGIST
Volume 73 JULY 1997 Number 3

Contents

SCIENTIFIC NOTES

The
PAN-PACIFIC
ENTOMOLOGIST

Volume 73 October 1997 Number 4

Published by the PACIFIC COAST ENTOMOLOGICAL SOCIETY
in cooperation with THE CALIFORNIA ACADEMY OF SCIENCES
(ISSN 0031-0603)

The Pan-Pacific Entomologist

Published quarterly in January, April, July, and October with Society Proceedings usually appearing in the October issue. All communications regarding nonreceipt of numbers should be addressed to: Vincent F. Lee, Managing Secretary; and financial communications should be addressed to: Julieta F. Parinas, Treasurer; at: Pacific Coast Entomological Society, Dept. of Entomology, California Academy of Sciences, Golden Gate Park, San Francisco, CA 94118-4599.

Application for membership in the Society and changes of address should be addressed to: William Hamersky, Membership Committee chair, Pacific Coast Entomological Society, Dept. of Entomology, California Academy of Sciences, Golden Gate Park, San Francisco, CA 94118-4599.

Manuscripts, proofs, and all correspondence concerning editorial matters (but not aspects of publication charges or costs) should be sent to: Dr. Robert V. Dowell, Editor, Pan-Pacific Entomologist, California Dept. of Food & Agriculture, 1220 N St., Sacramento, CA 95814. See the back cover for Information-to-Contributors, and volume 73(4): 248–255, October 1997, for more detailed information. Information on format for taxonomic manuscripts can be found in volume 69(2): 194–198. Refer inquiries for publication charges and costs to the Treasurer.

The annual dues, paid in advance, are $25.00 for regular members of the Society, $26.00 for family memberships, $12.50 for student members, or $40.00 for institutional subscriptions or sponsoring members. Members of the Society receive *The Pan-Pacific Entomologist.* Single copies of recent numbers or entire volumes are available; see 72(4): 247 for current prices. Make checks payable to the *Pacific Coast Entomological Society.*

Pacific Coast Entomological Society

THE PAN-PACIFIC ENTOMOLOGIST (ISSN 0031-0603) is published quarterly for $40.00 per year by the Pacific Coast Entomological Society, % California Academy of Sciences, Golden Gate Park, San Francisco, CA 94118-4599. Periodicals postage is paid at San Francisco, CA, and additional mailing offices. POSTMASTER: Send address changes to the Pacific Coast Entomological Society, % California Academy of Sciences, Golden Gate Park, San Francisco, CA 94118-4599.

This issue mailed 2 October 1997

The Pan-Pacific Entomologist (ISSN 0031-0603)
PRINTED BY THE ALLEN PRESS, INC., LAWRENCE, KANSAS 66044, U.S.A.

PAN-PACIFIC ENTOMOLOGIST
73(4): 201–203, (1997)

Obituary: Richard F. Wilkey (1925–1995)

Douglass R. Miller[1] and John A. Davidson[2]
[1]Systematic Entomology Lab, ARS, USDA, Beltsville, MD 20705
[2]Department of Entomology, University of Maryland, College Park, MD 20742

Richard F. Wilkey in 1993.

Richard (Dick) F. Wilkey was a talented and innovative preparator of insect and mite specimens on microscope slides. The more than 1,000,000 specimens that he prepared during his career are highly prized by researchers and identifiers alike because they are the best for studying the minute structures that are so important in diagnosing species. Richard also was dedicated to 4-H (a training program for children and young adults) and had a major positive impact on the more than 400 students that he taught about insects over the 40 years that he served as part of the 4-H program.

Richard Wilkey died 29 Oct 1995 in Bluffton, Indiana. He was born 14 Aug 1925 in Providence, Rhode Island, to Frank K. and Laura A. Plummer Wilkey. He made his first insect collection when he was six, creating an interest in things entomological that lasted a lifetime.

He moved to Indianapolis, Indiana, when he was 12 and following high school graduation served three years during World War II with U.S. Armed Forces in the Pacific Campaign. Following the war he married Dorothy Weber and moved to Lafayette, Indiana, where he earned a B.S. degree in entomology at Purdue University in 1950. He received his M.S. degree in entomology at Colorado State University in 1951. During this period he developed a life-long interest in microscopic organisms and their preparation. While at Purdue he did an undergraduate project on Collembolla. His Master's thesis continued in this vein as an analysis of the springtails of Larmier County, Colorado. When in later years his focus changed to groups other than springtails, he turned over his collection, including specimens of nearly 50 undescribed species and a dozen new genera, to Kenneth Christiansen, Grinnell College, Grinnell, Iowa.

Wilkey began his professional career in 1951 with the Mexican Cotton Company in Baja California, Mexico, working on pests of cotton. Later that year he was hired by the Santa Clara County, County Agricultural Commissioner's Office where he worked for a year. He then was promoted and moved to San Diego where he did quarantine identifications for three years for the State of California, Department of Agriculture. In Sacramento he finally obtained the job he wanted most: taxonomist responsible for Homoptera identification (except aphids) also working for the State of California. In this position he became recognized world wide for his knowledge of scale insect systematics.

Wilkey often helped colleagues in other states such as Florida, Washington, and Arizona with difficult identifications. Following the death of Howard McKenzie he served as the point person for visitors working with the "Ferris-McKenzie" scale insect collection at the University of California at Davis. In 1971, after a distinguished career with the California Department of Agriculture, he retired early and returned to Bluffton, Indiana. Here Wilkey began a new career. He started Arthropod Slidemounts, a mail order business that supplied arthropods to clientele needing a diverse array of well prepared specimens. The primary clientele were high schools and colleges, but he frequently provided specimens at a nominal fee for Extension short courses, pest control operator training, the food industry, and 4-H programs. During this period he developed a set of tools for micro-manipulation of specimens under the dissecting microscope, which most users believe are the best of their kind. After another 20 year career, in 1991 he retired and sold his business to BioQuip Products.

Richard F. Wilkey was an energetic, enthusiastic, and caring human being who was most comfortable working behind the scenes. Within entomology it is difficult to pick one area among his many accomplishments as the most important, and when consideration is given to his commitment to entomology in 4-H, and his leadership in other community activities the choice becomes even more difficult.

We suspect that after all is said and done, the nearly 1,000,000 perfect, or nearly perfect, arthropod slide mounts that Richard prepared will be the accomplishment that will have the most permanent and important impact. Certainly in our own research it is the beautifully cleared and stained Wilkey preparations that we seek out whenever available. Studying them, it is easy to correctly ascertain the position and structure of morphological features and make accurate determinations, illustrations, and descriptions.

The largest concentrations of Wilkey slides are in the collections of the California Department of Food and Agriculture in Sacramento and the Bohart Museum at the University of California at Davis. He also took on the task of slide mounting the dry scale insect type material of Gordon Floyd Ferris and distributing it to the major museums of the world. This material is especially useful because it is of better quality than preparations made by Ferris himself and is present in collections such as the Smithsonian's National Museum of Natural

History at Beltsville, Maryland and The Natural History Museum in London, where only limited Ferris material was available previously.

Wilkey also contributed significantly as a teacher. He taught others his slide mounting techniques and was a behind-the-scenes coorganizer and teacher in all seven Coccidology short courses at the University of Maryland. In this role he taught over 100 students from around the world how to properly slide-mount scale insects. He also used his broad entomological knowledge and extraordinary enthusiasm to encourage hundreds of 4-H'ers to learn about insects. He was involved in 4-H for 40 years and during that time taught more than 400 students about insects. Through his teaching and enthusiasm, approximately 10 of these students have pursued careers in entomology. Recently, in recognition of contributions to 4-H and the community, he and wife Dorothy were chosen Grand Marshals of the Wells County 4-H parade, an important annual affair in the Wells County area, and he was the Wells County, Indiana, Citizen of the Year in 1994. He was a past board member of the Wells County Society for Crippled Children and Adults, the Bluffon Park Board, the Rivergreenway Project, Public Library Board, and member of Friends of the Library and Bluffon Lions Club.

He is survived by wife, Dorothy Weber Wilkey of Bluffon, Indiana; three sons, John R. and Frank J. of Hayden Lake, Idaho, and David A. of Washington, D.C.; a sister Nancy Thut of Fairfield, Connecticut, and two grandchildren.

Received 10 Feb 1997; Accepted 1 Apr 1997.

PAN-PACIFIC ENTOMOLOGIST
73(4): 204–212, (1997)

SEASONAL FLIGHT PATTERNS OF BARK AND AMBROSIA BEETLES (COLEOPTERA: SCOLYTIDAE) IN NORTHEASTERN OREGON

Robert W. Peck,[1,2] Armando Equihua-Martinez[3,4] and Darrell W. Ross[5]
[1]Department of Forest Science,
Oregon State University, Corvallis, Oregon 97331
[3]Department of Entomology, Oregon State University, Corvallis, Oregon 97331
[5]Department of Forest Science,
Oregon State University, Corvallis, Oregon 97331

Abstract.—The abundance and phenology of scolytid beetles collected in multiple-funnel traps baited with the Douglas-fir beetle (*Dendroctonus pseudotsugae* Hopkins) pheromones frontalin, seudenol, MCOL, and ethanol in NE Oregon are reported. Other than *D. pseudotsugae*, *Dendroctonus ponderosae* Hopkins, and *Dendroctonus rufipennis* (Kirby), a total of 17,612 beetles from 44 species were collected between 5 May and 21 Sep 1993. *Dendroctonus brevicomis* LeConte and *Hylastes nigrinus* (Mannerheim) were most abundant (comprising 44.5% and 31.7% of the total, respectively), followed by *Pityophthorus confertus* Swaine (8.5%), *Dendroctonus valens* LeConte (4.2%), *Hylastes longicollis* Swaine (3.4%), and *Hylastes ruber* Swaine (2.7%). Most species were rare; the combined number of individuals of the 26 least common species comprised <1% of the total. *Pityophthorus deletus* LeConte and *Pityophthorus grandis* Blackman are reported from Oregon for the first time. Flight activity for most species began after a seasonal increase in temperature in mid-May and subsided by late July. Seasonal flight patterns are shown for the 14 most abundant species. It is unknown how each species was affected by the lure, but ethanol may have been an important attractant for many species.

Key Words.—Insecta; Scolytidae; Oregon; Phenology; Pheromones; Trapping

The Scolytidae are a diverse group of beetles that live primarily within phloem and cambium (bark beetles) or xylem (ambrosia beetles) tissues of freshly dead, dying, physiologically stressed, or sometimes healthy trees (Rudinsky 1962, Furniss & Carolin 1977). Scolytids contribute to forest processes such as providing food for insectivorous birds (Knight 1958, Otvos 1965), facilitating the decomposition of dying trees (Schowalter et al. 1992), vectoring tree pathogens (Graham 1967, Hessburg et al. 1995), and providing fuel for wildfires (Geizler et al. 1980), thus influencing the structure and species composition of forest communities (Schmid & Hinds 1974, Veblan et al. 1991). Although the biology of some economically important species is well known (Stark & Dahlsten 1970, Thatcher et al. 1980, Wood, S. L. 1982, Christiansen & Bakke 1988, Raffa 1988), considerably less is known about the distribution and life-history of other species. Chamberlin (1917) first summarized the scolytids found in Oregon. S. L. Wood (1982) and Furniss et al. (1992) subsequently added a number of species to those identified in the earlier report. However, distribution records for most species are from a small number of localities. Information on the flight behavior and seasonal distribution of some scolytids in western Oregon has been provided by Rudinsky

---

[2] Current Address: USDA Forest Service, Pacific Northwest Research Station, 3200 Jefferson Way, Corvallis, Oregon 97331

[4] Current Address: Programa de Entomologia y Acarologia, Instituto de Fitosanidad, Colegio de Postgraduados, Montecillo, Edo. de Mexico, C.P. 56230 Mexico

& Daterman (1964), Daterman et al. (1965), and Zethner-Møller & Rudinsky (1967).

Pheromones and host-tree derived chemicals are useful for studying the biology and behavior of some scolytid species. For example, pheromones have been used to identify communication patterns regulating host-tree colonization, mate-finding, and reproduction of various species (Furniss et al. 1972, Wood & Bedard 1977, Birch 1978, Wood, D. L. 1982). This understanding has led to the development of pheromone applications to reduce damage caused by pest species (Bakke 1982, McGregor et al. 1984, Ross & Daterman 1994, 1995). However, because individual pheromones, or their combinations, are generally narrow in specificity, most studies have been restricted to only one or a few species. In contrast, chemicals released from stressed or decaying trees, such as ethanol (Kimmerer & Kozlowski 1982, Byers 1992, Lindelow et al. 1992, Kelsey 1994) and terpenes (Vité & Gara 1962), are attractive to a variety of scolytids (Rudinsky 1966, Moeck 1970, 1971, Moeck et al. 1981, Montgomery & Wargo 1983, Klimetzek et al. 1986, Chenier & Philogene 1989, Schroeder & Lindelow 1989, Byers 1992). As a result, studies using traps baited with these chemicals have added significantly to our understanding of scolytid distribution and activity patterns (Roling & Kearby 1975, Turnbow & Franklin 1980, Atkinson et al. 1988).

Life-history information for many scolytid species found in Oregon is lacking, particularly east of the Cascade Mountain Range. This study describes the seasonal flight patterns of scolytids caught in funnel traps baited with Douglas-fir beetle (*Dendroctonus pseudotsugae* Hopkins) pheromones in the Blue Mountains of NE Oregon. Of the pheromones used, frontalin (Pitman & Vité 1970), seudenol (Vité et al. 1972) and MCOL (Libbey et al. 1983) are released by the female beetle during the initial stages of tree colonization, and ethanol can be released by either sex, the host tree, or by associated microorganisms (Pitman et al. 1975). Data presented here were obtained by sorting scolytids from a subset of trap samples from a study designed to test the effectiveness of attractant-baited traps for area-wide management of Douglas-fir beetle populations (Ross & Daterman 1997).

METHODS AND MATERIALS

Traps were placed within the NE portion of the Wallowa Valley Ranger District of the Wallowa-Whitman National Forest in NE Oregon. All traps were located at elevations between 1470 and 1690 m. Forests in the area are mixed conifer, comprised largely of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.), grand fir (*Abies grandis* (Dougl.) Lindl.), western larch (*Larix occidentalis* Nutt.) and lodgepole pine (*Pinus contorta* Dougl.), with scattered Engelmann spruce (*Picea engelmannii* Parry ex Engelm.) and alpine fir (*Abies lasiocarpa* (Hook.) Nutt.). Forest structure in the area is variable reflecting a history of natural and human-caused disturbances. Temperature data for the trapping period were obtained from a weather station located at 1281 m elevation approximately 26 km from the trap sites.

Within the study area, three 259-ha plots were established for trapping (Ross & Daterman 1997). Approximate latitude and longitude for each plot were 45°51′ N/117°07′ W, 45°50′ N/117°03′ W, and 45°44′ N/116°52′ W. Within each plot, 12–14 trap sites were chosen that were a minimum of 0.25 km apart. Three traps, spaced approximately 10 m apart, were located at each site. Traps were placed in clearings or young stands away from potential scolytid breeding material. Due to disturbance from cattle and/or wildlife, some traps had missing samples on at least one occasion during the study. Twenty-one traps without missing samples (seven from each plot) were identified for analysis. No site was represented by more than one trap.

The traps were a 16-unit multiple-funnel type (Lindgren 1983) suspended from an eight-foot metal pole, with a DDVP-impregnated piece of plastic in the collecting cup to kill insects. Each trap was baited with 250 ul of frontalin in an eppendorf vial, 200 mg of MCOL in a bubble capsule, and 15 ml of ethanol in a plastic pouch (Phero Tech Inc., Delta, BC, Canada). Each trap also contained either 400 mg of frontalin and 200 mg of seudenol, or 200 mg of frontalin and 100 mg of seudenol, in 5% PVC formulations (Daterman 1974). All formulations released pheromone or kairomone throughout the trapping period (DWR, unpublished data).

Traps were deployed by 5 May 1993. Samples were collected on or within one day of the following dates: 18 and 25 May; 7, 22 and 29 Jun; 6, 14 and 27 Jul; 10, 18 and 24 Aug; 3 and 21 Sep 1993. Samples were initially sorted only for *Dendroctonus pseudotsugae* and selected predators. However, because *Dendroctonus ponderosae* Hopkins and *Dendroctonus rufipennis* (Kirby) look similar to *D. pseudotsugae*, and were relatively rare in the samples, they were probably combined with *D. pseudotsugae* during the sorting process. Remaining scolytids were removed from the samples at a later date for the present study. Species were identified and compared to reference material within the USDA Forest Service Hopkins Forest Insect Collection. Voucher specimens from this study were deposited in the Oregon State University Systematic Entomology Laboratory Collection.

Results and Discussion

Other than *D. pseudotsugae*, *D. ponderosae* and *D. rufipennis*, a total of 17,612 scolytid beetles within 44 species were identified from the 21 funnel traps (Table 1). *Dendroctonus brevicomis* LeConte and *Hylastes nigrinus* (Mannerheim) dominated the samples numerically, comprising 44.5% and 31.7% of the total, respectively. All other species were much less common, with *Pityophthorus confertus* Swaine (8.5%), *Dendroctonus valens* LeConte (4.2%), *Hylastes longicollis* Swaine (3.1%), and *Hylastes ruber* Swaine (2.7%) being the next most abundant species. Overall, most species were relatively rare; the 26 least common species collectively comprised <1% of the total. Specimens of *Pityophthorus deletus* LeConte and *Pityophthorus grandis* Blackman represent first records of occurrence for Oregon. For *P. deletus*, this record fills a distributional gap, with previous collections in British Columbia, Idaho and California, and the known distribution of *P. grandis* is extended northward from California. All species collected are known to utilize coniferous trees present within the study area (Bright & Stark 1973, Wood, S.L. 1982).

Flight patterns of many species showed a strong seasonal trend, with flight initiation corresponding to the first warm days of spring. Temperatures showed a marked seasonal increase on 10 May, rising from a previous two-week average of 6.7° C, to 24° C by 12 May (Fig. 1). *Hylurgops porosus* (LeConte), *Hylurgops*

Table 1. Number of scolytid beetles collected in funnel traps baited with frontalin, seudenol, MCOL and ethanol between 5 May and 21 Sep 1993 in NE Oregon.

Taxon	Number trapped
Hylastini	
Hylurgops porosus (LeConte)	54
Hylurgops reticulatus Wood	29
Hylurgops subcostulatus (Mannerheim)	90
Hylastes gracilis LeConte	4
Hylastes longicollis Swaine	547
Hylastes macer LeConte	110
Hylastes nigrinus (Mannerheim)	5583
Hylastes ruber Swaine	483
Hylastes tenuis Eichoff	2
Tomicini	
Pseudohylesinus dispar Blackman	8
Pseudohylesinus nebulosus (LeConte)	153
Pseudohylesinus granulatus (LeConte)	3
Dendroctonus brevicomis LeConte	7830
Dendroctonus ponderosae Hopkins	—[a]
Dendroctonus pseudotsugae Hopkins	—[a]
Dendroctonus rufipennis (Kirby)	—[a]
Dendroctonus valens LeConte	745
Phloeotribini	
Carphoborus intermedius Wood	1
Phloeotribus lecontei Schedl	3
Polygraphini	
Polygraphus rufipennis (Kirby)	17
Scolytini	
Scolytus laricis Blackman	5
Scolytus opacus Blackman	28
Scolytus piceae (Swaine)	3
Scolytus tsugae (Swaine)	3
Scolytus unispinosus LeConte	83
Scolytus ventralis LeConte	6
Dryocoetini	
Dryocoetes sechelti Swaine	1
Ipini	
Pityogenes carinulatus (LeConte)	49
Pityogenes fossifrons (LeConte)	2
Pityogenes knechteli Swaine	1
Pityokteines elegans Swaine	5
Pityokteines ornatus (Swaine)	2
Orthotomicus caelatus (Eichhoff)	8
Ips emarginatus (LeConte)	1
Ips latidens (LeConte)	2
Ips pini (Say)	24
Xyloterini	
Trypodendron lineatum (Olivier)	2
Corthylini	
Pityophthorus confertus Swaine	1490
Pityophthorus confinis LeConte	31
Pityophthorus deletus LeConte	1
Pityophthorus grandis Blackman	2
Pityophthorus nitidulus (Mannerheim)	4
Gnathotrichus retuses (LeConte)	192
Gnathotrichus sulcatus (LeConte)	5
Total number of beetles	17,612

[a] *D. ponderosae* and *D. rufipennis* were probably grouped with *D. pseudotsugae* during the sorting process. Data for these three species are presented elsewhere (Ross and Daterman 1997).

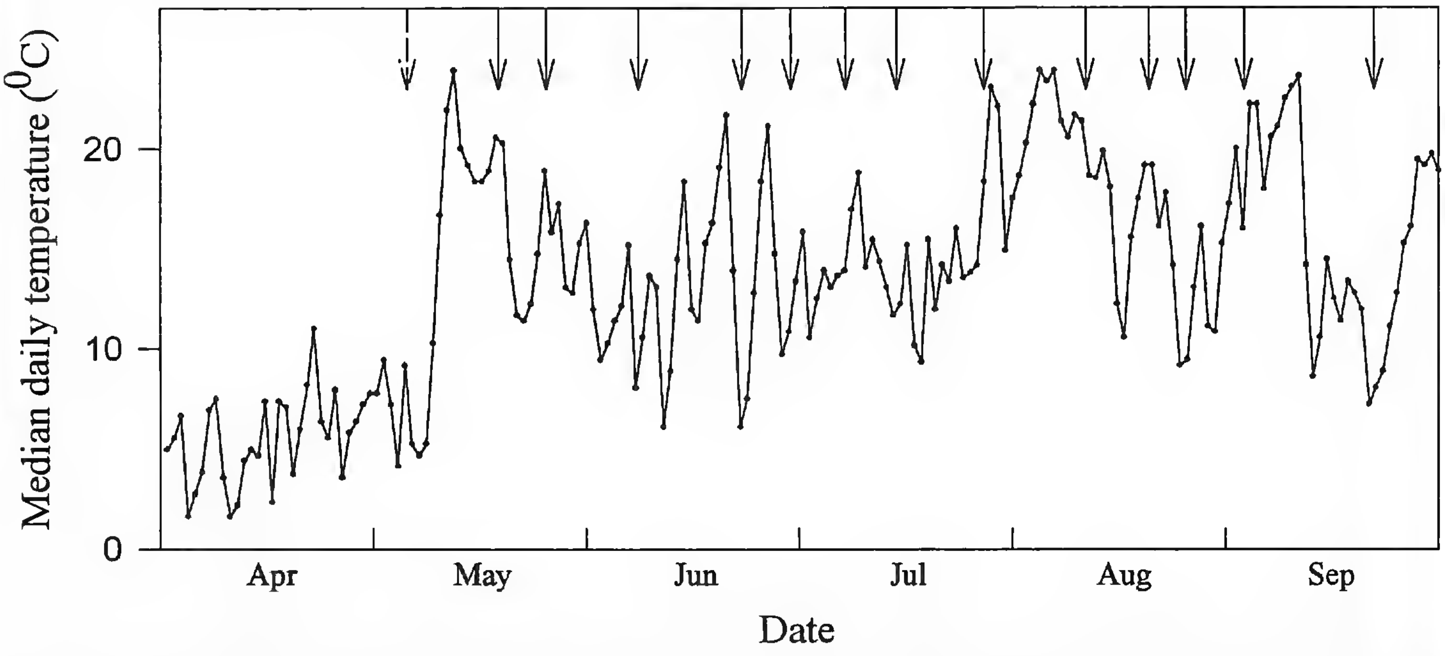


Figure 1. Median daily temperature near the study site. Solid arrows indicate sample collection dates and dashed arrow shows date traps were placed in the field.

subcostulatus (Mannerheim), *Hylastes macer* LeConte, *H. nigrinus*, *Pseudohylesinus nebulosus* (LeConte), *Pityogenes carinulatus* (LeConte), and *Gnathotrichus retusus* (LeConte) were collected at or near their greatest abundance during one of the two sampling periods in May (Fig. 2). Similar early season activity patterns were reported by Daterman et al. (1965), who found a maximum daily temperature of 14° C necessary to initiate flight for most of the scolytid species they collected in western Oregon. Although temperatures were consistently low prior to the time traps were set out, some scolytids may have been flying earlier. For example, *P. nebulosus* was most abundant on the first sample date, with a precipitous drop in activity thereafter (Fig. 2), and was previously found to be one of the earliest species to fly in other regions (Walters & McMullen 1956, Daterman et al. 1965). *Pityophthorus confinus* LeConte was most abundant in the 7 June samples, while five species (*H. longicollis*, *H. ruber*, *D. brevicomis*, *D. valens*, *Scolytus unispinosus* LeConte) were most abundant in the 22 or 29 June samples (Fig. 2). Daterman et al. (1965) also found *H. ruber* and *S. unispinosus* to be most active slightly later than other species, suggesting their need for higher temperatures to initiate flight. Although most species showed a single peak in activity, *P. confertus* was abundant in May, June and July, and *D. brevicomis* and *D. valens* were trapped in relatively large numbers into September. The individuals collected during mid- to late season were likely re-emergent parent adults searching for new breeding substrates or newly emerging early-season brood adults (Miller & Keen 1960, Stark & Dahlsten 1970). For most other species, flight activity had decreased by 14 July. Daterman et al. (1965) also found diminished activity levels by the end of July.

More individuals of many species were collected than expected by chance, suggesting that these species were attracted to the lure rather than being passively intercepted by the traps. However, because lure composition was not experimentally manipulated, it is not possible to determine which components were attractive to each species. Of the attractants used, frontalin is known to be a component of the aggregation pheromone of *D. brevicomis* and may have contributed to its attraction (Bedard et al. 1980). Ethanol has been shown to be a strong attractant

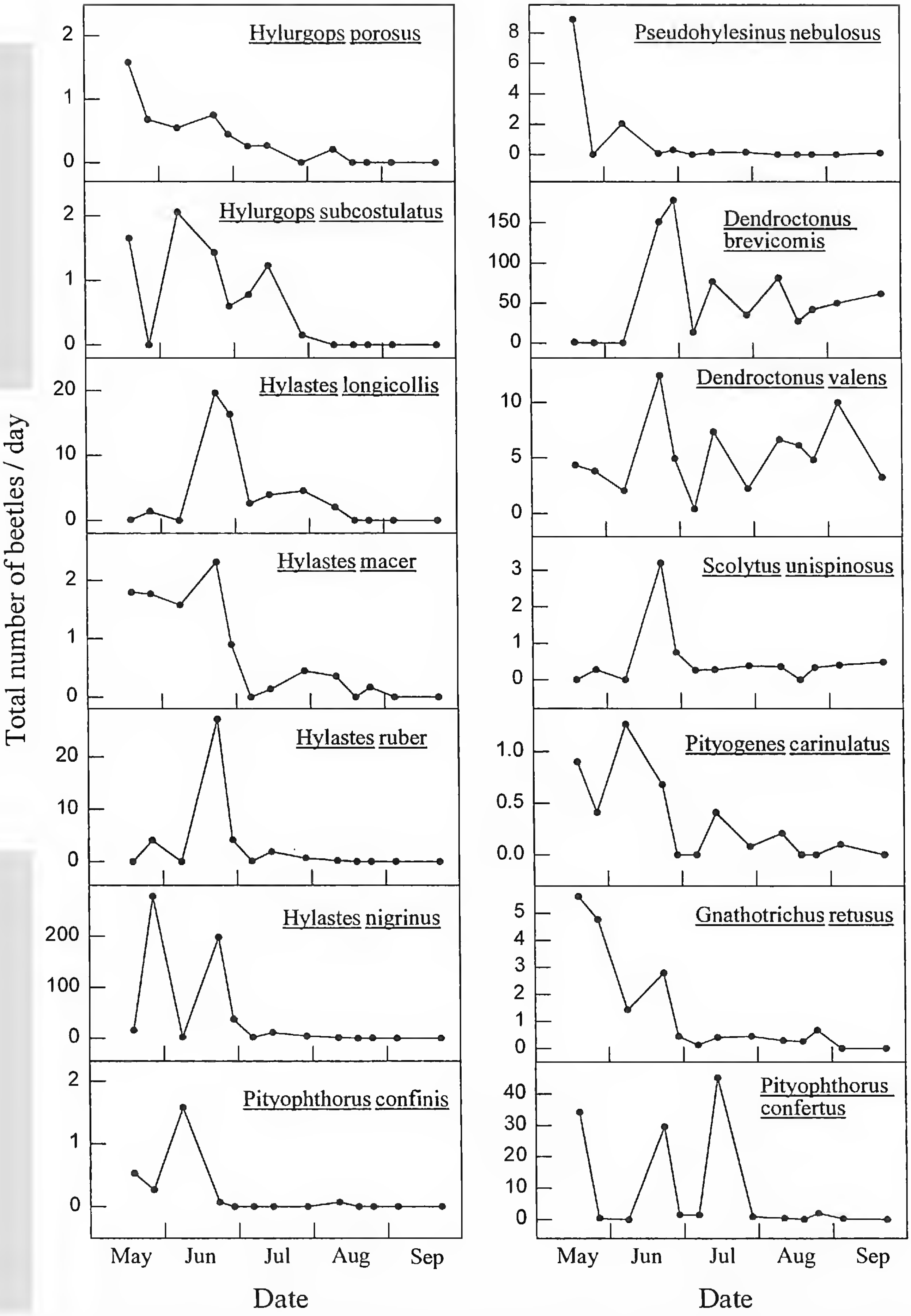


Figure 2. Seasonal flight patterns for the 14 most frequently trapped scolytid species within the study area.

for ambrosia beetles, such as *G. retusus*, (Moeck 1970, 1971, Roling & Kearby 1975, Turnbow & Franklin 1980, Kelsey 1994) as well as for *H. nigrinus* (Witcosky et al. 1987). Ethanol was possibly responsible for the attraction of some of the abundant scolytids, because only *D. brevicomis* is known to be attracted to any of the Douglas-fir beetle pheromones used in the lure. Trapping in the same area in 1994 with frontalin and seudenol lures captured very few scolytids other than *D. pseudotsugae* (DWR, unpublished data), further suggesting the importance of ethanol as an attractant.

The number of scolytids collected in each trap varied greatly even though the surrounding forests were similar in elevation and tree composition. For most species, a relatively small number of traps caught a large proportion of the total number of individuals. For example, 95.0% of *P. confertus* were from one trap, 69.8% of *H. nigrinus* were collected from one trap and 87.3% from two traps, 86.5% of *D. brevicomis* were collected from four traps, 75.4% of *D. valens* were collected from three traps and 81.4% of *H. longicollis* were collected from four traps. Although the numbers collected were concentrated in a few traps for these species, they occurred frequently, being collected in 11, 20, 19, 20, and 12 of the 21 traps, respectively. In contrast, many species were only collected in a few traps. For example, 16 species were caught in only one or two traps and 17 other species were collected in five traps or less.

This study has identified a large number of bark and ambrosia beetles captured in multiple-funnel traps baited with Douglas-fir beetle pheromones from a poorly studied part of Oregon, and has shown seasonal flight patterns for many of these species. It is not known which components of the lure were most attractive to the beetles, but ethanol may have been important because it is a by-product of tree decomposition as well as a pheromone. Because many species are patchily distributed across the landscape, a large number of traps in various forest stand types will be necessary to adequately sample scolytid communities.

ACKNOWLEDGMENT

We thank G.E. Daterman and R.L. Livingston for reviewing an earlier draft of this manuscript. Staff of the Wallowa Valley Ranger Distict of the Wallowa-Whitman National Forest provided maps, records, and permitted access to the research sites. This research was supported, in part, by funds provided by the United States Department of Agriculture, Forest Service, Pacific Northwest Research Station.

LITERATURE CITED

Atkinson, T. H., J. L. Foltz, & M. D. Connor. 1988. Flight patterns of phloem- and wood-boring coleoptera (Scolytidae, Platypodidae, Curculionidae, Buprestidae, Cerambycidae) in a north Florida slash pine plantation. Environ. Entomol., 17: 259–265.

Bakke, A. 1982. The utilization of aggregation pheromone for the control of the spruce bark beetle. pp. 219–229. *In* Leonhardt, B.A & M. Beroza (eds.). Insect pheromone technology: chemistry and applications. Amer. Chem. Soc. Symp. Series 190, Washington, D.C.

Bedard, W. D., Jr., D. L. Wood, P. E. Tilden, K. O. Lindahl, Jr., R. M. Silverstein, & J. O. Rodin. 1980. Field responses of the western pine beetle and one of its predators to host- and beetle-produced compounds. J. Chem. Ecol., 6: 625–641.

Birch, M. C. 1978. Chemical communication in pine bark beetles. Am. Sci., 66: 409–419.

Bright, D. E., Jr., & R. W. Stark. 1973. The bark and ambrosia beetles of California, Coleoptera: Scolytidae and Platypodidae. Bull. Calif. Insect Surv., 16: 1–167.

Byers, J. A. 1992. Attraction of bark beetles, *Tomicus piniperda*, *Hylurgops palliatus*, and *Trypodendron domesticum* and other insects to short-chain alcohols and monoterpenes. J. Chem. Ecol., 18: 2385–2402.

Chamberlin, W. J. 1917. An annotated list of the scolytid beetles of Oregon. Can. Entomol., 49: 321–328.

Chenier, J. V. R. & B. J. R. Philogene. 1989. Field responses of certain forest Coleoptera to conifer monoterpenes and ethanol. J. Chem. Ecol., 15: 1729–1745.

Christiansen, E. & A. Bakke. 1988. The spruce bark beetle of Eurasia. pp. 479–503. *In* Berryman, A.A. (ed.). Dynamics of forest insect populations: patterns, causes, implications. Plenum Press, New York.

Daterman, G. E. 1974. Synthetic sex pheromone for detection survey of European pine shoot moth. U.S. For. Serv. Res. Paper PNW-180.

Daterman, G. E., J. A. Rudinsky, & W. P. Nagel. 1965. Flight patterns of bark and timber beetles associated with coniferous forests of western Oregon. Oregon State Univ. Agric. Exp. Stn. Tech. Bull. No. 87.

Furniss, M. M., L. N. Kline, R. F. Schmitz, & J. A. Rudinsky. 1972. Tests of three pheromones to induce or disrupt aggregation of Douglas-fir beetles (Coleoptera: Scolytidae) on live trees. Ann. Entomol. Soc. Am., 65: 1227–1232.

Furniss, M. M., J. B. Johnson, R. L. Westcott, & T. R. Torgersen. 1992. List of Oregon Scolytidae (Coleoptera) and notes on new records. Great Basin Nat., 52: 373–378.

Furniss, R. L. & V. M. Carolin. 1977. Western forest insects. US Dep. Agric. Misc. Publ. No. 1339.

Geiszler, D. R., R. I. Gara, C. H. Driver, V. F. Gallucci, & R. E. Martin. 1980. Fire, fungi, and beetle influences on a lodgepole pine ecosystem of south-central Oregon. Oecologia, 46: 239–243.

Graham, K. 1967. Fungal-insect mutualism in trees and timber. Annu. Rev. Entomol., 12: 105–126.

Hessburg, P. F., D. J. Goheen, & R. V. Bega. 1995. Black stain root disease of conifers. US For. Serv, For. Insect & Dis. Leafl. No. 145.

Kelsey, R. G. 1994. Ethanol synthesis in Douglas-fir logs felled in November, January, and March and its relationship to ambrosia beetle attack. Can. J. For. Res., 24: 2096–2104.

Kimmerer, T. W. & T. T. Kozlowski. 1982. Ethylene, ethane, acetaldehyde and ethanol production by plants under stress. Plant Physiol., 69: 840–847.

Klimetzek, D. J. Kohler, J. P. Vité, & U. Kohnle. 1986. Dosage response to ethanol mediates host selection by "secondary" bark beetles. Naturwissenschaften, 73: 270–272.

Knight, F. B. 1958. The effects of woodpeckers on populations of the Engelmann spruce beetle. J. Econ. Entomol., 51: 603–607.

Libbey, L. M., A. C. Oehlschlager, & L. C. Ryker. 1983. 1-Methylcyclohex-2-en-1-ol as an aggregation pheromone of *Dendroctonus pseudotsugae.* J. Chem. Ecol., 9: 1533–1541.

Lindelow, A., B. Risberg, & K. Sjodin. 1992. Attraction during flight of scolytids and other bark- and wood-dwelling beetles to volatiles from fresh and stored spruce wood. Can. J. For. Res., 22: 224–228.

Lindgren, B. S. 1983. A multiple funnel trap for scolytid beetles (Coleoptera). Can. Entomol., 115: 299–302.

McGregor, M. D., M. M. Furniss, R. D. Oakes, K. E. Gibson, & H. E. Meyer. 1984. MCH pheromone for preventing Douglas-fir beetle infestation in windthrown trees. J. For., 82: 613–616.

Miller, J. M. & F. P. Keen. 1960. Biology and control of the western pine beetle. US Dep. Agric. Misc. Publ. No. 800.

Moeck, H. A. 1970. Ethanol as the primary attractant for the ambrosia beetle *Trypodendron lineatum* (Coleoptera: Scolytidae). Can. Entomol., 113: 939–942.

Moeck, H. A. 1971. Field test of ethanol as a scolytid attractant. Can. Dep. Fish. For. Bi-Mon. Res. Notes, 27: 11–12.

Moeck, H. A., D. L. Wood, & K. Q. Lindahl, Jr. 1981. Host selection behavior of bark beetles attacking *Pinus ponderosa*, with special emphasis on the western pine beetle, *Dendroctonus brevicomis.* J. Chem. Ecol., 7: 49–83.

Montgomery, M. E. & P. M. Wargo. 1983. Ethanol and other host-derived volatiles as attractants to beetles that bore into hardwoods. J. Chem. Ecol., 9: 181–190.

Otvos, I. S. 1965. Studies on avian predators of *Dendroctonus brevicomis* LeConte (Coleoptera: Scolytidae) with special references to Picidae. Can. Entomol., 97: 1184–1199.

Pitman, G. B. & J. P. Vité. 1970. Field response of *Dendroctonus pseudotsugae* (Coleoptera: Scolytidae) to synthetic frontalin. Ann. Entomol. Soc. Am., 63: 661–664.

Pitman, G. B., R. L. Hedden, & R. I. Gara. 1975. Synergistic effects of ethyl alcohol on the aggregation of *Dendroctonus pseudotsugae* (Coleoptera: Scolytidae) in response to pheromones. Z. Angew. Entomol., 78: 203–208.

Raffa, K. F. 1988. The mountain pine beetle in western North America. pp. 505–530. *In* Berryman, A. A. (ed.). Dynamics of forest insect populations: patterns, causes, implications. Plenum Press, New York.

Roling, M. P. & W. H. Kearby. 1975. Seasonal flight and vertical distribution of scolytidae attracted to ethanol in an oak-hickory forest in Missouri. Can. Entomol., 107: 1315–1320.

Ross, D. W. & G. E. Daterman. 1994. Reduction of Douglas-fir beetle infestation of high risk stands by antiaggregation and aggregation pheromones. Can. J. For. Res., 24: 2184–2190.

Ross, D. W. & G. E. Daterman. 1995. Efficacy of an antiaggregation pheromone for reducing Douglas-fir beetle, *Dendroctonus pseudotsugae* Hopkins (Coleoptera: Scolytidae), infestation in high risk stands. Can. Entomol., 127: 805–811.

Ross, D. W. & G. E. Daterman. 1997. Using pheromone-baited traps to control the amount and distribution of tree mortality during outbreaks of the Douglas-fir beetle. For. Sci., 43: 65–70.

Rudinsky, J. A. 1962. Ecology of Scolytidae. Annu. Rev. Entomol., 7: 327–348.

Rudinsky, J. A. 1966. Scolytid beetles associated with Douglas-fir: response to terpenes. Science, 152: 218–219.

Rudinsky, J. A. & G. E. Daterman. 1964. Field studies of flight patterns and olfactory responses of ambrosia beetles in Douglas-fir forests of western Oregon. Can. Ent., 94: 1339–1352.

Schmid, J. M. & T. E. Hinds. 1974. Development of spruce-fir stands following spruce beetle outbreaks. US For. Serv. Res. Paper RM-131.

Schroeder, L. M. & A. Lindelow. 1989. Attraction of scolytids and associated beetles by different absolute amounts and proportions of alpha-pinene and ethanol. J. Chem. Ecol., 15: 807–817.

Schowalter, T. D., B. A. Caldwell, S. E. Carpenter, R. P. Griffiths, M. E. Harmon, E. R. Ingham, R. G. Kelsey, J. D. Lattin, & A. R. Moldenke. 1992. Decomposition of fallen trees: effects of initial conditions and heterotroph colonization rates. pp. 371–381. *In* Singh, R. P. & J. S. Singh (eds.). Tropical ecosystems: ecology and management. Wiley Eastern, Ltd., New Delhi.

Stark, R. W. & D. L. Dahlsten (eds.). 1970. Studies on the population dynamics of the western pine beetle, *Dendroctonus brevicomis* LeConte (Coleoptera: Scolytidae). Univ. Calif. Div. Agric. Sci., Berkeley, California.

Thatcher, R. C., J. L. Searcy, J. E. Coster, & G. D. Hertel (eds.). 1980. The southern pine beetle. US Dep. Agric. Sci. Educ. Adm. Agric. Res. Tech. Bull. No. 1631.

Turnbow, R. H., Jr. & R. T. Franklin. 1980. Flight activity by Scolytidae in the northeast Georgia Piedmont (Coleoptera). J. Ga. Entomol. Soc., 15: 26–37.

Veblan, T. T., K. S. Hadley, M. S. Reid, & A. J. Rebertus. 1991. The response of subalpine forests to spruce beetle outbreak in Colorado. Ecology, 72: 213–231.

Vité, J. P. & R. I. Gara. 1962. Volatile attractants from ponderosa pine attacked by bark beetles (Coleoptera: Scolytidae). Contrib. Boyce Thompson Inst., 21: 251–273.

Vité, J. P., G. B. Pitman, A. F. Fentiman, Jr. & G. W. Kinzer. 1972. 3-Methyl-2-cyclohexen-1-ol isolated from *Dendroctonus*. Naturwissenschaften, 59: 49.

Walters, J. & L. H. McMullen. 1956. Life history and habits of *Pseudohylesinus nebulosus* (LeConte) (Coleoptera: Scolytidae) in the interior of British Columbia. Can. Entomol., 88: 197–202.

Witcosky, J. J., T. D. Schowalter, & E. M. Hansen. 1987. Host-derived attractants for the beetles *Hylastes nigrinus* (Coleoptera: Scolytidae) and *Steremnius carinatus* (Coleoptera: Curculionidae). Environ. Entomol., 16: 1310–1313.

Wood, D. L. 1982. The role of pheromones, kairomones, and allomones in the host selection and colonization behavior of bark beetles. Annu. Rev. Entomol., 27: 411–446.

Wood, D. L. & W. D. Bedard. 1977. The role of pheromones in the population dynamics of the western pine beetle. Proc. 15th Int. Congr. Entomol., Washington D.C.

Wood, S. L. 1982. The bark and ambrosia beetles of North and Central America (Coleoptera: Scolytidae), a taxonomic monograph. Great Basin Nat. Mem., No. 6.

Zethner-Møller, O. & J. A. Rudinsky. 1967. On the biology of *Hylastes nigrinus* in western Oregon. Can. Entomol., 99: 897–911.

Received 19 Dec 1996; Accepted 1 Apr 1997.

PAN-PACIFIC ENTOMOLOGIST
73(4): 213–224, (1997)

NATURE OF GALLERIES, DURABILITY OF BORING SCARS, AND DENSITY OF *XYLOTRECHUS VILLIONI* (VILLARD) LARVAE (COLEOPTERA: CERAMBYCIDAE), ON CONIFEROUS TREE TRUNKS[1]

Ryûtarô Iwata[2], Fusao Yamada[2], Hirofumi Katô[2], Hiroshi Makihara[3], Kunio Araya[4], Hisashi Ashida[5] and Masashi Takeda[6]

[2]Department of Forest Science and Resources,
College of Bioresource Sciences, Nihon University,
Kameino, Fujisawa 252, Japan
[3]Forestry and Forest Products Research Institute (MAFF),
Matsunosato, Kukizaki 305, Japan
[4]Graduate School of Human and Environmental Studies,
Kyoto University, Sakyo-ku, Kyoto 606-01, Japan
[5]KDK Corporation, Higashi-Kujô-Nishi-Aketachô,
Minami-ku, Kyoto 601, Japan
[6]Ryokusei Kenkyûsho Co., Inc., Muromachi 1-chôme, Ikeda 563, Japan

Abstract.—Spatial distributions and shapes of "whirl-like" scars on the trunks, made by gallery formation of mature larvae of *Xylotrechus villioni* (Villard) (Coleoptera: Cerambycidae), a primary borer of *Abies* and *Picea* coniferous trees in Japan, were investigated at an *Abies firma* Sieb. et Zucc. plantation in Hachiôji, Tokyo Pref., an *A. firma* natural stand in Miyama, Kyoto Pref. and an *A. sachalinensis* (Fr. Schm.) Mast. plantation in Imakane, Hokkaidô. Although all the forests investigated showed cumulative "whirl-like" scars on the tree trunks, a low density of existing larvae was inferred from the analyses of the locations and shapes of these scars. Mortality throughout the larval stages, as well as between the final phase of larva and the adult emergence, was suggested. Trunk analysis of a damaged *A. firma* tree showed that a "whirl-like" scar can remain on the trunk surface for as long as 27 years after the formation of the larval gallery. The most susceptible class of *Abies* trees had a diameter at the breast height of 35–45cm. "Whirl-like" scars were distributed more densely in the lower part of the trunks.

Key Words.—Insecta, Cerambycidae, *Xylotrechus villioni*, larval gallery, spatial distribution, conifers, *Abies*

Xylotrechus villioni (Villard), a cerambycid beetle endemic to Japan (Fig. 1), is a primary borer of coniferous tree species, mostly of the genera *Abies* and *Picea* (Iwata et al. 1990). This species is probably the largest member of the tribe Clytini (subfamily Cerambycinae), with its adult body length being 20–26 mm in males and 25–30 mm in females. Although this species, insofar as historically recorded, once had an outbreak and its larvae caused serious damage on *Abies sachalinensis* (Fr. Schm.) Mast. plantations in Hokkaidô (Kamijo et al. 1970, Kamijo & Suzuki 1973), adult beetles, as well as larvae, are found only rarely. This low density makes direct observations difficult, and little is known about the bionomics and ecology of this species (Iwata et al. 1990).

Larvae bore under the bark of the trunk and branches, and larval galleries cause cicatricial scars, which become more evident on the trunk as the tree cures the

---

[1] Presented at the 102nd Annual Meeting of Japanese Forestry Society at Nagoya (April, 1991), the 105th Ann. Mtg. of Jpn. For. Soc. at Fuchû (April, 1994), the 106th Ann. Mtg. of Jpn. For. Soc. at Sapporo (April, 1995) and 20th International Congress of Entomology at Firenze (August, 1996).

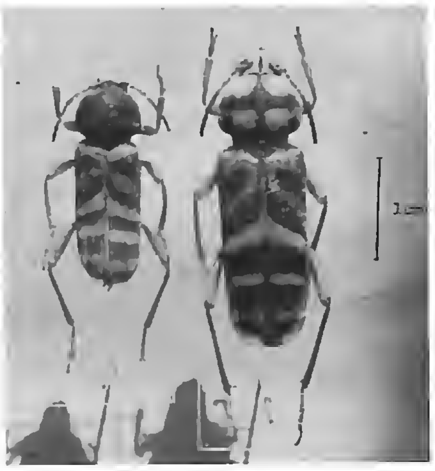


Figure 1. *Xylotrechus villioni* adults from Mt. Kasuga, Nara. Reproduced from Iwata (1991). left, male; right, female.

damage through cicatrization with phloem recovery. These scars remain recognizable for a long period of time because the complete recovery of outer phloem takes many years after the appearance of a scar.

The larval boring consists of 5 phases (Kamijo & Suzuki 1973, Iwata et al. 1990), of which Phase 4, attributed to mature larva, is characterized by the "whirl-like" gallery (Fig. 2), which is peculiar to this species and presumably made as a guard against resin exudation (Iwata et al. 1990, Iwata 1991).

Every scar with a straight, sinuate or "whirl-like" appearance found on *Abies* and *Picea* trunks in Japan is almost always accompanied by a gallery with tightly packed fine frass, which characterizes boring by a clytine cerambycid. As no other clytine species that attacks living conifers is known from Japan, the presence of such scars on coniferous trunks in Japan always indicates attacks by *X. villioni.*

Formation of a "whirl-like" scar (Fig. 3) on the trunk surface is caused through "whirl-like" gallery formation, and their distribution reflects the historical spatial distribution of the insect. Studying the "whirl-like" scars caused by *X. villioni* larvae may contribute to its enigmatic biology.

This paper reports the nature and the spatial distribution of *X. villioni* larval galleries on coniferous tree trunks.

Figure 2. "Whirl-like" gallery (arrowed) made by a *X. villioni* mature larva on a dead *Abies mariesii* tree-trunk, Hinoemata, Fukushima Pref.

Figure 3. "Whirl-like" scar (arrowed) made through gallery formation of a *X. villioni* mature larva on a living *Abies firma* tree-trunk, Mt. Kasuga, Nara. Reproduced from Iwata (1991).

MATERIALS AND METHODS

Study sites.—Investigations were carried out at three sites, (A): an *Abies firma* Sieb. et Zucc. plantation in Tama Forest Science Garden, FFPRI (MAFF), Hachiôji, Tokyo Pref. (about 0.5 ha in extent, northeast-inclined, alt. 220 m) in Sep–Nov 1990; (B): an *A. firma* natural stand in Ashiu Kyoto University Forest (Section 33), Miyama, Kyoto Pref. (about 0.6 ha in extent, southwest-inclined, alt. 450m) in Aug 1990; and (C): an *A. sachalinensis* plantation in Kanahara, Imakane, Hokkaidô (about 0.3 ha in extent, flatland, alt. 80 m) in Aug 1991. The large-scale damage in the *A. sachalinensis* plantations in Imakane (C) and the damage in the *A. firma* plantation in Hachiôji (A), caused by *X. villioni*, have previously been documented (Ganda et al. 1986, Makihara et al. 1995, respectively).

Spatial distributions and morphology of "whirl-like" scars.—The following were recorded for each tree at all sites: (1) diameter at the breast height (DBH), (2) presence of resin exudations (a possible index of larval existence), (3) presence of straight and sinuate scars, and (4) presence of "whirl-like" scars on the trunk. These give the spatial distribution of "whirl-like" scars in relationship to tree's DBH, as well as the density of the existing insects.

In sites (A) and (B), (5) number of "whirl-like" scars in each tree was also recorded, and additional parameters were measured for each of the "whirl-like" scars: (6) rotation (either clock- or counterclock-wise), (7) up-and-down direction of the straight (or sinuate) scar connected with "whirl-like" one, (8) height above the ground, (9) size (as expressed by that divided by ($\pi/4$)), (10) compass direction and (11) exposure of xylem and the gallery through peeling-off of the phloem above it. Then, the trees were categorized with regard to parameters 2–5, and the "whirl-like" scars were categorized with regard to parameters 6–11.

Spatial distribution of "whirl-like" scars is quantitatively expressed with Lloyd's (1967) "mean crowding" and "patchiness".

Whole larval gallery observation.—In Hinoemata, Fukushima Pref., a blighted *A. mariesii* Mast. tree was felled on 24 Jun 1990 to expose the whole gallery made by a single larva. Also, at the *A. firma* plantation in Tama Forest Science Garden, FFPRI (MAFF), Hachiôji, one living tree (DBH 19 cm, 12 m high) was felled and cross-cut on 23 Aug 1993 to record the appearances, dimensions and

Table 1. Categorizations of *Abies* trees with regard to the parameters concerning the damage by *X. villioni* larvae in three forest sites, Tama Forest Science Garden, Hachiôji (A), Ashiu Kyoto University Forest (Section 33), Miyama (B), and a plantation in Kanahara, Imakane (C).

Locality Tree species	(a) Hachiôji *A. firma*		(B) Miyama *A. firma*		(C) Imakane *A. sachalinensis*
Resin exuded	19 (50%)[a]		12 (43%)[a]		16 (17%)[a]
Resin little or not exuded	19 (50%)		16 (57%)		77 (83%)
Straight and/or sinuate scar(s) present	31 (82%)[a]	31 (82%)	17 (61%)[a]	25 (89%)	
Straight and/or sinuate scar(s) indistinctly present	0 (0%)		8 (29%)		
Straight or sinuate scar absent	7 (18%)		3 (11%)		scars present: 25 (27%)[a]
With no "whirl-like" scars	14 (37%)[a]		14 (50%)[a]		scars absent:
With 1 "whirl-like" scar	15 (39%)		5 (18%)		68 (73%)
With 2 "whirl-like" scars	6 (16%)		8 (29%)		
With 3 "whirl-like" scars	2 (5%)		1 (4%)		
With 4 "whirl-like" scars	0 (0%)		0 (0%)		
With 5 "whirl-like" scars	1 (3%)		0 (0%)		
Total	38		28		93

[a] Percent of trees examined.

shapes of all the "whirl-like" scars, as well as all the larval galleries within the trunk. The ages of the "whirl-like galleries" were estimated by counting the numbers of annual rings between each gallery and the cambium.

RESULTS

Spatial distributions of "whirl-like" galleries.—For the three forest sites investigated, the trees were categorized with regard to the presence of resin exudation, the presence of straight and sinuate scars, and the presence or the number of "whirl-like" scars on their trunks (Table 1, Fig. 4).

The spatial distributions of "whirl-like" scars in these forest sites in relationship to trees' DBH are shown in Tables 2 to 4.

We found that 17–50% of the trees investigated showed resin exudation, 82–89% of the trees possessed straight and/or sinuate scar(s) and 50–63% possessed "whirl-like" scar(s) (Tables 1–3).

Although the ages of the investigated forest stands vary considerably, in all the highest ratio of the trees with "whirl-like" scars was found in trees with 35–55 cm DBH (Tables 2–4), suggesting a definite tree diameter preference by *X. villioni* ovipositing females independent of forest age. The mean crowding value of the "whirls-like" scars in each DBH-class is low (Tables 2–3), except for the 2.31 value in the trees with 25–35 cm DBH in Hachiôji. Trees with 35–45 cm DBH had the highest value of mean crowding in Miyama. Lloyd's patchiness values ranged from 0.40 to 2.48 (Tables 2–3). The mean crowding value, and the ratio of trees with "whirl-like" scars suggest that the most susceptible trees have 35–45 cm DBH although there is a time lag of a few years between beetle oviposition and the appearance of scars.

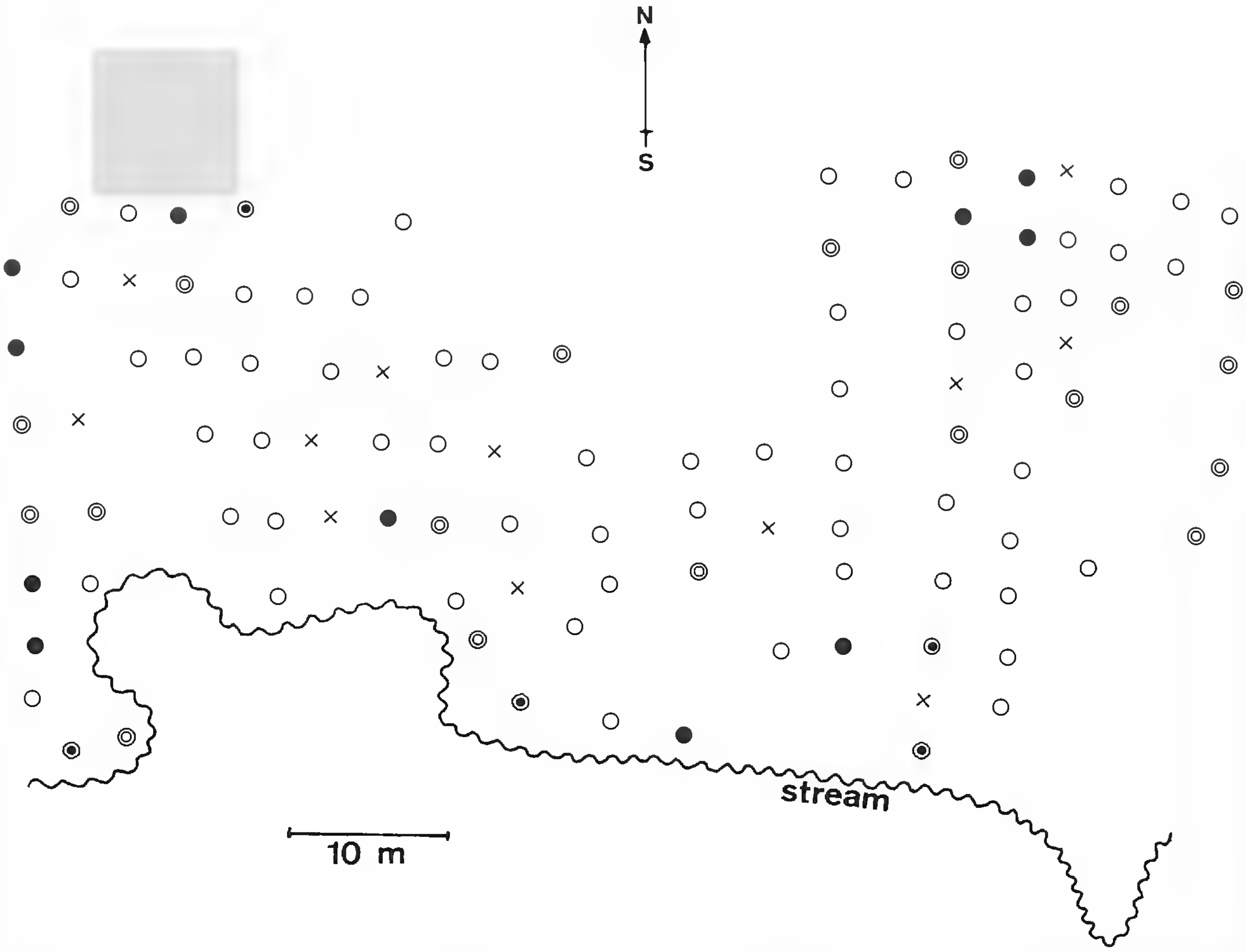


Figure 4. Overview of the distribution of *Abies sachalinensis* trees damaged by *X. villioni* larvae in a plantation, Kanahara, Imakane, Hokkaidô (C). The sign ○ represents a tree without scars or resin exudation, ● with resin exudation and without scars, ◎ without resin exudation and with scars, ⊙ with both resin exudation and scars, and × represents a dead tree.

The "whirl-like" scars were almost evenly observed to have either clock- or counterclock-wise rotation and to be either upward- or downward-connected. The size and the manner of presence of the "whirl-like" scars were shown to be highly variable (Table 5). The mean "whirl" size was larger in Hachiôji ($(251 \times \pi/4)$ cm^2) than in Miyama ($(179 \times \pi/4)$ cm^2), although the mean DBH of the trees (31 cm and 49 cm, respectively) shows the opposite trend.

The correlation between the presence of straight and/or sinuate scars and "whirl-like" scars on the trunk surface is shown in Table 6. The data show a positive significant correlation (Fisher's exact probability test, $P < 0.0005$): "whirl-like" scars are always accompanied by straight and/or sinuate scar(s), suggesting that a straight and/or sinuate scar without a "whirl-like" scar is indicative of larval mortality.

Statistical analyses found that most of the parameters measured are independent of each other at Hachiôji and Miyama, although the presence of straight and/or sinuate scar(s) are correlated to the presence and the abundance of "whirl-like" scar(s) (Fisher's exact probability test, $P < 0.01$ for all), and the presence of resin exudation to the presence of "whirl-like" scar(s) (χ^2-test, $P < 0.01$ for two sites). Also, there were no correlations among the presence of scars, presence of resin exudation, and trees' DBH at Imakane.

Whole larval gallery observation.—The gallery made by a single larva, found in the trunk of a blighted *A. mariesii* at Hinoemata (Fig. 5), had a length of

Table 2. Spatial distribution of "whirl-like" scars made by *X. villioni* larvae on *Abies firma* tree trunks in relationship to trees' diameter at breast height (DBH) in Tama Forest Science Garden, Hachiôji (A).

DBH range (cm)	5–15	15–25	25–35	35–45	45–55	55–65	Total
Number of trees (N)	0	11	14	10	3	0	38
Number of trees with "whirl-like" scars (N′)	0	8	5	8	3	0	24
Ratio of trees with "whirl-like" scars (N′/N)	—	0.73	0.36	0.80	1.00	—	0.63
Total number of "whirl-like" scars ($\Sigma w_i = W$)[a]	0	10	13	10	5	0	38
Median value of the DBH range as expressed in meter (δ)	0.10	0.20	0.30	0.40	0.50	0.60	—
Total surface area of all trees as expressed in arbitrary area unit ($N\delta^2$)[b]	0	0.44	1.26	1.60	0.75	0	4.05
Number of "whirl-like" scars per arbitrary area unit ($W/N\delta^2$)	—	22.7	10.3	6.3	6.7	—	9.38
Number of "whirl-like" scars per a tree ($W/N = \bar{w}$)	—	0.91	0.93	1.00	1.67	—	1.00
Mean crowding of "whirl-like" scars ($\Sigma w_i^2/\Sigma w_i - 1 = \overset{*}{W}$)[a]	—	0.40	2.31	0.40	1.20	—	1.16
Lloyd's "patchiness" ($\overset{*}{W}/\bar{w}$)	—	0.44	2.48	0.40	0.72	—	1.16

[a] Let w_i be the number of "whirl-like" scars on each tree.

[b] Here, the real total area must be $\alpha N\delta^2$ in square meter, with the non-dimensional constant α representing a factor related to the taperness of the trees, supposing all the trees have the same α value.

112 cm, including 25 cm after the entrance into the xylem for pupation. The boring initiation point of the 1st instar larva and the top of the "whirl-like" gallery were situated 205 cm and 295 cm high above the ground, respectively.

A living *A. firma*, felled at Hachiôji, had seven independent larval galleries, of which four had "whirl-like" scars followed by pupal chambers. The appearances, dimensions, shapes and estimated ages of these larval galleries are summarized in Table 7. The formation of the "whirl-like" gallery, preceding pupation, can considerably damage the meristem, and a "whirl-like" scar can remain on the trunk surface for as long as 27 years after the formation of the larval gallery. The bark discs over some of the "whirl-like" galleries were peeled off, exposing the xylem surface.

DISCUSSION

Lloyd's "patchiness" values (0.40–2.48; Tables 2–3) indicate that the "whirl-like" scars are distributed randomly and sparsely with the tree regarded as the sample-unit. Because the "whirl-like" scars represent a cumulative spatial distribution of mature larvae for as long as 27 years, the present distribution of existing larvae within the trees must be even sparser: the existing individuals of this species are distributed in an extraordinarily low density. This is not incompatible with the ratio of trees with "whirl-like" scars of 63% at Hachiôji or 50% at Miyama (Tables 2 and 3). The low density of existing beetles is supported by the

Table 3. Spatial distribution of "whirl-like" scars made by *X. villioni* larvae on *Abies firma* trees in relationship to trees' diameter at breast height (DBH) in Ashiu Kyoto University Forest (Section 33), Miyama (B). (For footnotes a and b, see Table 2.)

DBH range (cm)	15–25	25–35	35–45	45–55	55–65	65–75	Total
Number of trees (N)	1	4	6	2	10	5	28
Number of trees with "whirl-like" scars (N′)	0	1	4	1	5	3	14
Ratio of trees with "whirl-like" scars (N′/N)	0.00	0.25	0.67	0.50	0.50	0.60	0.50
Total number of "whirl-like" scars ($\Sigma w_i = W$)[a]	0	2	8	2	7	5	24
Median value of the DBH range as expressed in meter (δ)	0.20	0.30	0.40	0.50	0.60	0.70	—
Total surface area of all trees as expressed in arbitrary area unit ($N\delta^2$)[b]	0.04	0.36	0.96	0.50	3.60	2.45	7.91
Number of "whirl-like" scars per arbitrary area unit ($W/N\delta^2$)	0	5.56	8.33	4.00	1.94	2.04	21.87
Number of "whirl-like" scars per a tree ($W/N = \bar{w}$)	0	0.50	1.33	1.00	0.70	1.00	0.86
Mean crowding of "whirl-like" scars ($\Sigma w_i^2/\Sigma w_i - 1 = \overset{*}{W}$)[a]	—	1.00	1.25	1.00	0.57	1.00	0.96
Lloyd's "patchiness" ($\overset{*}{W}/\bar{w}$)	—	2.00	0.94	1.00	0.81	1.00	1.12

failure to capture any adult beetles during the field surveys conducted during the adult emergence season using either traps baited with kairomones and genus-specific sex pheromones (Iwata et al. 1991, 1992, 1993) or by visual searching. Because resin exudation indicates that the coniferous tree is inhabited by boring larvae, as has been demonstrated by Kobayashi (1982) for *Semanotus japonicus* (Lacordaire) infesting *Cryptomeria japonica* D. Don, just half of the trees in the forest site and 17-43% of the trees in other sites seemed to contain beetle larvae (Table 1).

The plantation site included open gaps, as well as many stumps made by cutting, suggesting that many young trees had been removed by felling due to lethal damage inflicted by *X. villioni* (Ganda et al. 1986). The damage by *X. villioni* took place on the edge of the plantation, reconfirming the observation of Kamijo & Suzuki (1973). This is not incompatible with the random and sparse distribution of "whirl-like" scars on trees because tree damage is viewed not within a single tree but over a forest section.

Table 4. Scars made on *Abies sachalinensis* trunks through boring activity of *X. villioni* larvae in relationship to trees' diameter at breast height (DBH) in Kanahara, Imakane (C).

DBH range (cm)	5–15	15–25	25–35	35–45	Total
Number of trees (N)	16	51	24	2	93
Number of trees with "whirl-like, straight and/or sinuate scars (N′)	4	12	8	1	25
Ratio of trees with scars (N′/N)	0.25	0.24	0.33	0.50	0.27

Table 5. Categorizations of "whirl-like" scars made by *X. villioni* larvae with regard to geometrical parameters in two *Abies firma* forest sites, Tama Forest Science Garden, Hachiôji (A), and Ashiu Kyoto University Forest (Section 33), Miyama (B). The numbers in some categories, when summed up, are inconsistent to the total number due to lack of data.

		(A) Hachiôji	(B) Miyama
Connected straight or sinuate scar[a]:	downward	19	5
	upward	19	17
(Height above the ground) = h:	$800 \text{ cm} \leqq h < 900 \text{ cm}$	1	0
	$700 \text{ cm} \leqq h < 800 \text{ cm}$	0	0
	$600 \text{ cm} \leqq h < 700 \text{ cm}$	5	0
	$500 \text{ cm} \leqq h < 600 \text{ cm}$	5	0
	$400 \text{ cm} \leqq h < 500 \text{ cm}$	1	2
	$300 \text{ cm} \leqq h < 400 \text{ cm}$	6	0
	$200 \text{ cm} \leqq h < 300 \text{ cm}$	7	5
	$100 \text{ cm} \leqq h < 200 \text{ cm}$	11	9
	$0 \text{ cm} \leqq h < 100 \text{ cm}$	1	8
(Size)/(π/4) = S:	$50 \text{ cm}^2 \leqq S < 100 \text{ cm}^2$	4	4
	$100 \text{ cm}^2 \leqq S < 150 \text{ cm}^2$	6	3
	$150 \text{ cm}^2 \leqq S < 200 \text{ cm}^2$	5	8
	$200 \text{ cm}^2 \leqq S < 250 \text{ cm}^2$	4	1
	$250 \text{ cm}^2 \leqq S < 300 \text{ cm}^2$	4	2
	$300 \text{ cm}^2 \leqq S < 350 \text{ cm}^2$	6	2
	$350 \text{ cm}^2 \leqq S < 400 \text{ cm}^2$	1	0
	$400 \text{ cm}^2 \leqq S < 450 \text{ cm}^2$	3	0
	$450 \text{ cm}^2 \leqq S < 500 \text{ cm}^2$	2	0
	$500 \text{ cm}^2 \leqq S < 550 \text{ cm}^2$	1	0
	$550 \text{ cm}^2 \leqq S < 600 \text{ cm}^2$	1	0
Compass direction:	North	3	1
	Northeast	6[b]	11[c]
	East	2	1
	Southeast	5	1
	South	6	2
	Southwest	9[c]	3[b]
	West	4	1
	Northwest	2	4
Phloem disc above the "whirl-like" gallery:			
Wholly peeled off ("whirl-like" gallery exposed)		8	—[d]
Partly peeled off ("whirl-like" gallery half exposed)		3	—
Recovered ("whirl-like" gallery covered)		26	—
Total		38	24

[a] Not significantly biased (Binomial test, $P > 0.05$) in (A), but biased to "upward" (Binomial test, $P < 0.05$) in (B).

[b] The study area is inclined to this direction.

[c] Not significantly biased to this (Kolmogorov-Smirnov's test, $P > 0.05$).

[d] Not checked.

Table 6. Correlation between the presence of straight and/or sinuate scar(s) and the presence of "whirl-like" scar(s) made by *X. villioni* larvae on each of the tree trunks at two *Abies firma* forest sites, Tama Forest Science Garden, Hachiôji (A) and Ashiu Kyoto University Forest (Section 33), Miyama (B).

Straight and/or sinuate scar(s)	(A) Hachiôji "whirl-like" scar(s)		(B) Miyama "whirl-like" scar(s)	
	Present	Absent	Present	Absent
Present	24 (63%)	7 (18%)	13 (46%)	4 (14%)
Absent	0 (0%)	7 (18%)	0 (0%)	11 (39%)[a]

[a] Including 8 trees only with very indistinct straight and/or sinuate scars.

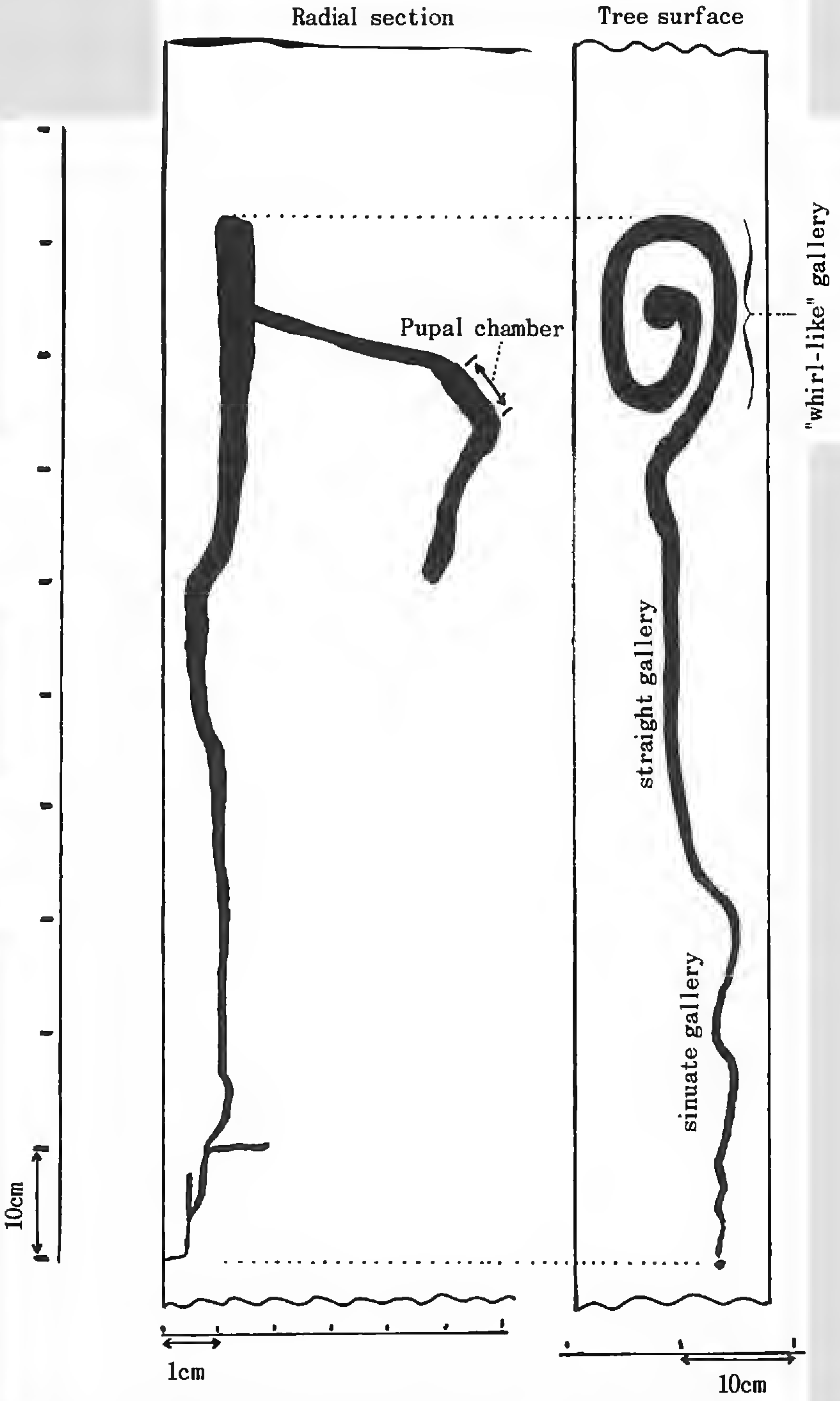


Figure 5. Whole gallery made by a single larva of *X. villioni* on a dead *Abies mariesii* tree-trunk. The tree, of 18cm DBH, was found in 1985, harvested on 24 Jun 1990 at the end of Toyasu Tributary Trail, Funamata Valley, Hinoemata, Fukushima Pref. and presumed to have been blighted in 1982.

Table 7. Four "whirl-like" scars made by *X. villioni* larvae on a living *Abies firma* tree sampled for the whole gallery observation, at Tama Forest Science Garden, Hachiôji (A).

Scar	A	C	D	G
Height above the ground (m)	2.1	3.5	3.7	11.6
Horizontal diameter × vertical diameter of the "whirl-like" scar (cm)	7 × 12	6 × 6	9 × 9	6 × 6
Appearance of the "whirl-like" scar	obscure	evident	evident	evident
Phloem disc over the "whirl-like" scar	wholly peeled off	recovered	partly peeled off	recovered
Total length of the connected straight and sinuate gallery (cm)	85	57	45	68
Presumed site of the initial larval gallery	branch (lost)	branch (lost)	branch (lost)	branch (lost)
Depth of the pupal chamber (cm)	9	6	8	5
Presence of the adult emergence exit hole[a]	−	−	+	−
Time elapsed since the formation of the gallery (years)	27–28	14–15	5	11

[a] +, present; −, absent.

The "whirl-like" scars tend to be distributed more densely in the lower part of the trunks although some in very high positions might have been overlooked to some degree (Table 5). This tendency in *X. villioni* infesting *A. sachalinensis* (Kamijo & Suzuki 1973) is known also in *S. japonicus* infesting *C. japonica*. In the latter species, this tendency has been ascribed to the change of bark roughness (Kobayashi & Yamada 1982). However, in *Abies firma*, by our visual inspection, the roughness of bark does not seem to be related to tree height.

The predominance of upward gallery connections to the "whirl-like" scars in Miyama (Table 5) is ascribed to the concentration of the "whirl-like" scars toward the bottom portion of the trunk. Although not significant, the compass direction of "whirl-like" scars on the tree-trunk is biased to the direction opposite to that toward which the study area is inclined, suggesting a possible strategy to avoid direct attack by natural enemies, such as picid woodpeckers (Iwata et al., in prep.).

The condition of phloem disc above the "whirl-like" gallery (Table 5) suggests that *Abies* trees are partly successful in protecting the severe wounds by cicatrization with phloem recovery. However, in some cases they fail in curing the "whirl-like" wound exposing the xylem, which presumably allows insects and fungi to invade the trunk.

Kamijo & Suzuki (1973) inferred a high mortality of *X. villioni* larvae boring within sound coniferous trees. The data on the presences of straight and/or sinuate scars and "whirl-like" scars on the tree trunk surface (Table 6) suggest that immature larvae, which are responsible for straight and sinuate scars, are not always successful in developing into mature larvae, which are responsible for "whirl-like" scars. At most only 77% of immature larvae formed "whirl-like" galleries. Further, of the four "whirl-like" scars within the tree sampled at Hachiôji (Table 7), only one possessed an adult emergence exit hole, suggesting a rather low probability of successful pupation to adult emergence. Further investigations are needed to clarify mortality factors acting during the immature stages of this species.

The low density of larvae and adults, and the low Lloyd's patchiness value suggest that little interference occurs among beetle adults or larvae.

Although *X. villioni* larvae cause damage to branches of host trees by boring (Iwata et al. 1990, Adachi 1995), the lack of branches and the presence of a complete gallery of one individual in the sampled dead tree in Hinoemata indicates that this species can complete its development only in the tree trunk.

Herein we have described the gross nature and spatial distribution of *X. villioni* larvae within tree trunks. Further investigations on the use of branches versus trunks by ovipositing females, movement of immature larvae from the branches into the trunk and a sensus of adult beetles are needed.

ACKNOWLEDGMENT

We thank Dr. Kazuaki Kamijo (formally, Hokkaido Forest Experiment Station) for his kind advice during our field work in Hokkaidô, Dr. Ko-ichi Soné, Tama Forest Science Garden, FFPRI (MAFF), Hachiôji (presently, Faculty of Agriculture, Kagoshima University), for his help in felling the sample tree at Hachiôji, Messrs. Takahisa Maro, Itaru Suda, Yasuyuki Koma, Seiji Fujii and the other students of Nihon University, and Dr. Aleš Smetana, Biosystematics Research Centre, Ottawa, for their help during the surveys in Hachiôji, Hinoemata and Imakane. This work is supported by a Grant-in-Aid for Scientific Research (No.02660163) from the Ministry of Education, Science and Culture of Japan.

LITERATURE CITED

Adachi, K. 1995. Discovery of *Xylotrechus villioni* (Villard) (Coleoptera, Cerambycidae) from the mainland of Kyushu, Southwest Japan. Gekkan-Mushi, Tokyo, (293): 3–8 (in Japanese).

Ganda, K., S. Shida & H. Konno. 1986. Forest damage caused by *Xylotrechus villioni* (Villard) in Imakane, Hokkaidô. Shinrin-Hogo (Forest Protection), Sapporo, (193): 19–21 (in Japanese).

Iwata, R. 1991. Biononics of a primary borer of coniferous trees, *Xylotrechus villioni*, a review. The Insectarium, Tokyo, 28: 108–113 (in Japanese).

Iwata, R., I. Suda, F. Yamada & K. Nagata. 1993. Capture surveys of beetles by attracting chemicals at coniferous forests. (IV) Further survey at *Abies firma* grove in Tama Forest Science Garden (FFPRI, MAFF), Hachiôji, Tokyo, by using kairomones. Trans. 44th Mtg. Kanto Branch, Jpn. For. Soc.: 119–122 (in Japanese).

Iwata, R., F. Yamada, H. Ashida, K. Araya & A. Kawabata. 1992. Capture surveys of beetles by attracting chemicals at coniferous forests. (II) Survey at *Abies firma* grove in Kyoto University Forest, Ashiu, Kyoto, by using kairomones and pheromones. Trans. 103rd Mtg. Jpn. For. Soc.: 537–538 (in Japanese).

Iwata, R., F. Yamada, I. Suda, H. Makihara, K. Iwabuchi, & K. Nagata. 1991. Capture surveys of beetles by attracting chemicals at coniferous forests. (I) Survey at *Abies firma* grove in Tama Forest Science Garden (FFPRI, MAFF), Hachiôji, Tokyo, by using kairomones and pheromones. Trans. 102nd Mtg. Jpn. For. Soc.: 261–264 (in Japanese).

Iwata, R., F. Yamada, M. Yagi, A. Kitayama, T. Kinoshita, K. Hosokawa, K. Kitayama, K. Iwabuchi & H. Makihara. 1990. Studies on *Xylotrechus villioni* (Villard) (Coleoptera: Cerambycidae), a primary borer of coniferous trees in Japan. (I) General bionomics. Trans. 101st Mtg. Jpn. For. Soc.: 525–528 (in Japanese).

Kamijo, K., O. Ishizaka & S. Hôjô. 1970. Damage on plantations of *Abies sachalinensis* by *Xylotrechus villioni* (Villard) (Cerambycidae). Hokkaidô Ringyô Kenkyû Happyô-kai Ronbunshû (Proc. Forestry Res. Symp. Hokkaidô), Sapporo, (fiscal 1969): 302–314 (in Japanese).

Kamijo, K. & S. Suzuki. 1973. Damage to *Abies sachalinensis* Masters by *Xylotrechus villioni* Villard

(Cerambycidae). Hokkaidô Ringyô Shiken-jô Hôkoku (Bull. Hokkaido Forest Exp. Sta.), Bibai, (11): 113–119, plts. 1–4 (in Japanese).

Kobayashi, K. 1982. Resin exudation of *Cryptomeria japonica* in relation to the attacks of *Semanotus japonicus* (Coleoptera: Cerambycidae). Trans. 33rd Mtg. Kansai Branch, Jpn. For. Soc.: 272–275 (in Japanese).

Kobayashi, K. & E. Yamada. 1982. *Semanotus japonicus. In* F. Kobayashi (ed.). Boring insects of Japanese cedar and cypress. Introduction to their ecology and control. Sôbun Co. Ltd., Tokyo: 11–57 (in Japanese).

Lloyd, M. 1967. 'Mean crowding'. J. Anim. Ecol., 36: 1–30.

Makihara, H., Y. Buyo & Y. Oka. 1995. Host trees and distribution of large tiger longicorn beetle, *Xylotrechus villioni* (Villard) in Tama Forest Science Garden. Trans. 46th Mtg. Kanto Branch, Jpn. For. Soc.: 107–110 (in Japanese).

Received 17 Sep 1996; Accepted 6 Jan 1997.

PAN-PACIFIC ENTOMOLOGIST
73(4): 225–230, (1997)

A NEW *JAPONICA* (LEPIDOPTERA: LYCAENIDAE: THECLINAE) FROM SOUTHWESTERN CHINA

Yu-Feng Hsu
Department of Biology, Taiwan Normal University,
Taipei 117, Taiwan, Republic of China

Abstract.—*Japonica bella* Hsu, NEW SPECIES, is described and illustrated based on material from Guizhou Province, southwestern China. The new species has an unusual brachium and papilla analis, both are unique to the genus *Japonica* and the rest of Theclini species and considered autopomorphies of *J. bella*. The discovery of the new species brings the number of species in genus *Japonica* to five.

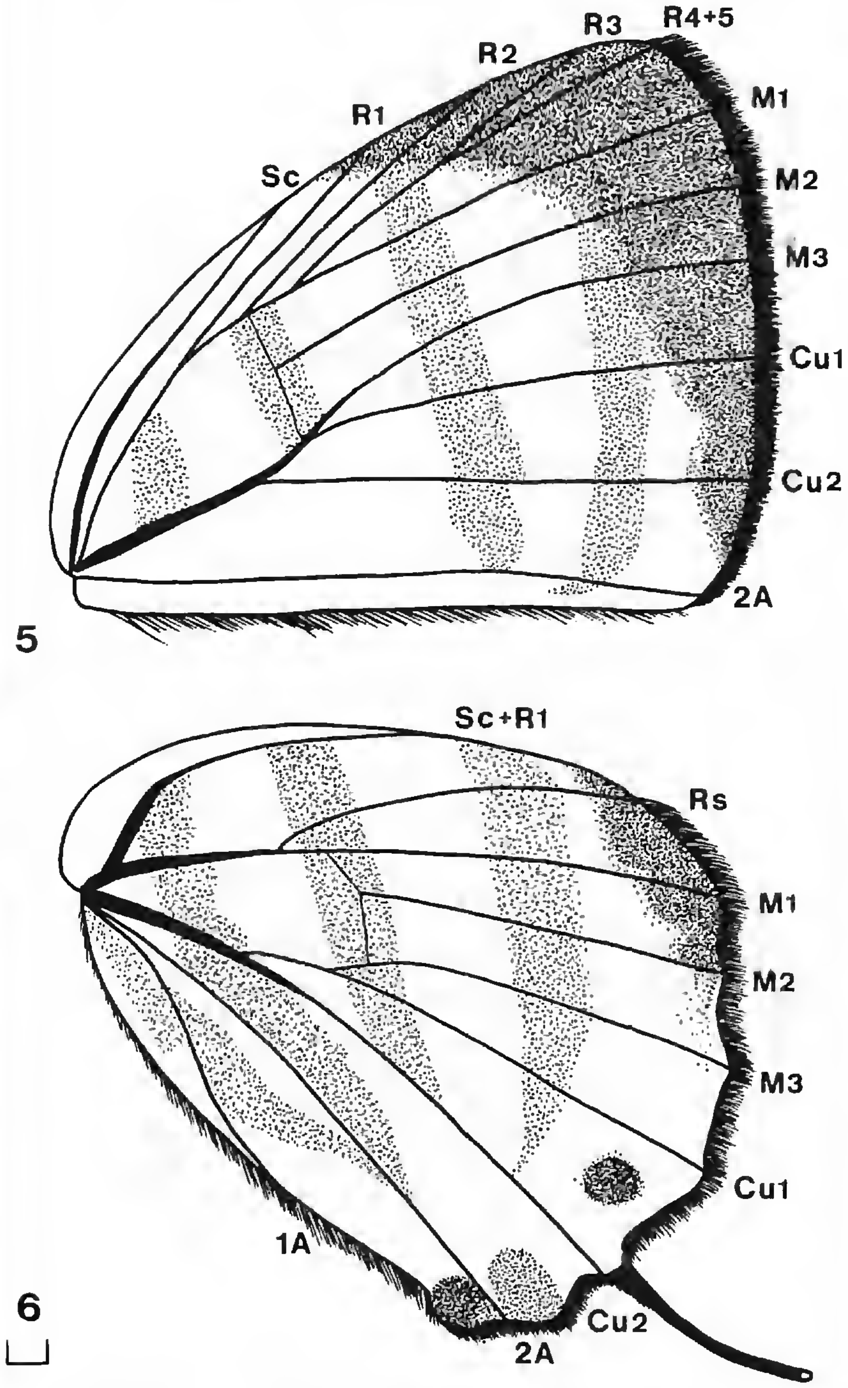
Key Words.—Insecta, Lepidoptera, Lycaenidae, Theclini, China, *Japonica*

Theclini lycaenid butterflies of the genus *Japonica* generally inhabit oak forests in Old World temperate regions. The butterflies are active at twilight or during cloudy conditions (Fukuda et al. 1984). The members of *Japonica* have extensive orange scaling on the wings and possess many primitive characters (Shirôzu & Yamamoto 1956, Hsu & Lin 1994).

Fujioka (1993) recently reviewed the genus *Japonica* and recognized four species. He also reported the presence of a characteristic "vaginal membrane", which is torn during copulation, on the ductus bursae in the female genitalia.

Life histories and host associations of all four *Japonica* species have been docu-

Figures 1–4. *Japonica bella* Hsu, NEW SPECIES. Fig. 1. Holotype male upperside. Fig. 2. Holotype male underside. Fig. 3. Paratype female upperside. Fig. 4. Paratype female underside.



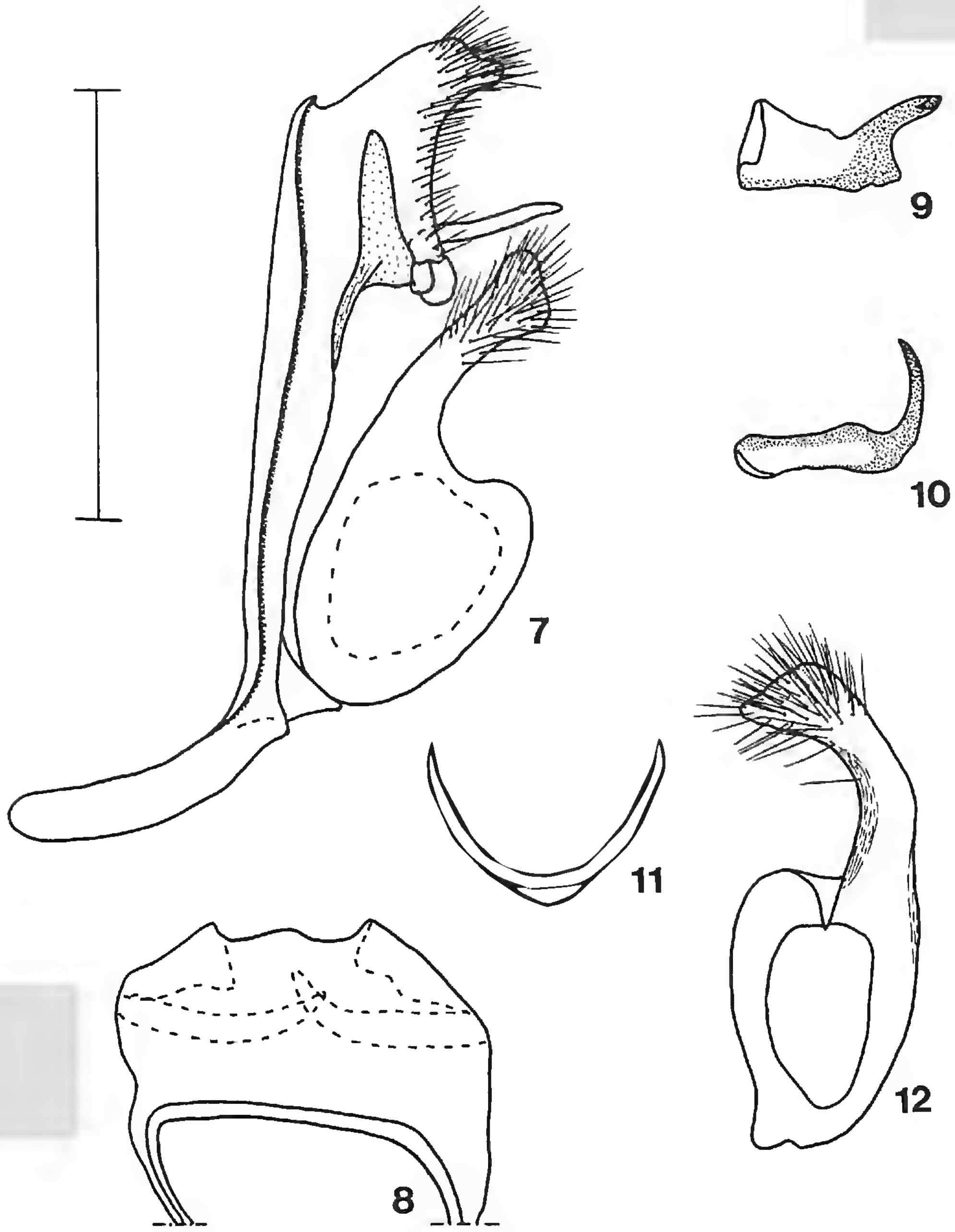
Figures 5–6. Venation of *Japonica bella*. Fig. 5. Forewing. Fig. 6. Hindwing (scale = 1 mm).

mented: larvae of *J. lutea* (Hewitson) utilize both deciduous and evergreen *Quercus* (Fagaceae) species in Japan (Shirôzu 1961) and deciduous *Q. mongolica* Fischeri in Far East Russia (Fujioka 1993); larvae of the closely related *J. adusta* (Riley) feed only on deciduous *Q. dentata* Thunberg in Japan (Inomata 1990) and Far East Russia (Fujioka 1993); larvae of *J. saepestriata* (Hewitson) are associated with deciduous *Quercus* species in most parts of Japan (Fukuda et al. 1984), except for a population in southern Ki-i Peninsula where evergreen *Q. phillyraeoides* Gray is utilized (Saigusa 1993); *J. patungkoanui* Murayama of Taiwan is known to use evergreen *Quercus stenophylloides* Hayata as the larval host (Uchida 1991).

According to Fujioka (1993), three of the four known *Japonica* species have been found in southwestern China. An undescribed species was recognized from the above region and is described here. This new species is distinct from the previously described species in wing pattern and genitalia of both sexes.

Material and Methods

Genitalic dissections were made by removing the entire abdomen, which was placed in 10% KOH at room temperature for 24 hours, then transfered to cellu-



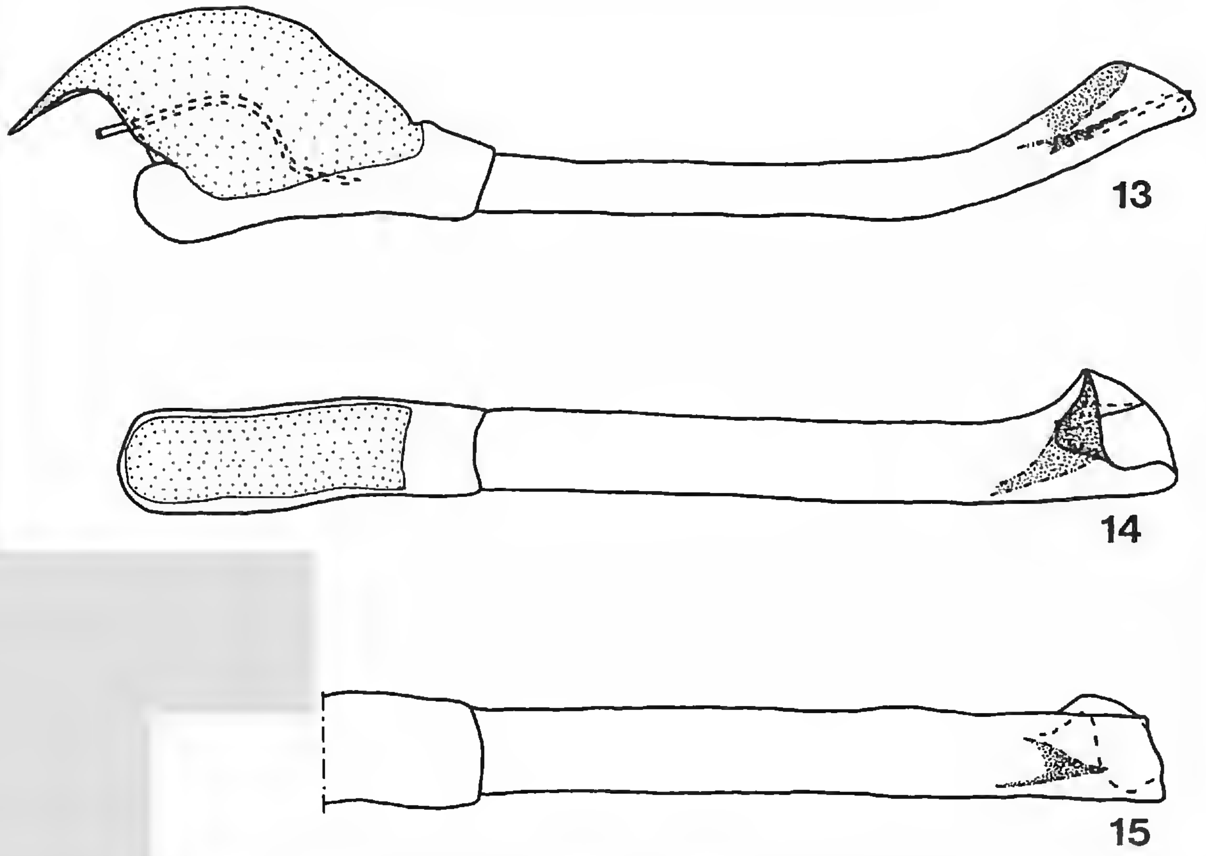
Figures 7–12. Male genitalia of *Japonica bella* excluding phallus. Fig. 7. Lateral view of sclerites of 9 + 10 genitalic segments with left brachium and valva attached. Fig. 8. Dorsum of sclerites of 9 + 10 genitalic segments. Fig. 9. Posterior view of left brachium. Fig. 10. Ventral view of left brachium. Fig. 11. Posterior view of juxta. Fig. 12. Dorsal view of left valva.

solve for another 24 hours for descaling, and finally placed in 70% ethyl alcohol for dissections. During examination, a few drops of xylene were placed on the wings to improve the contrast between veins and the covering scales.

Japonica bella Hsu, NEW SPECIES
(Figs. 1–17)

Types.—Holotype, male; data: CHINA. *GUIZHOU PROVINCE*: Tongren Prefecture, Mt. Fanjing. 1000-1350 m, 18/19 Jun 1995; deposited: Zoological Institute, Academia Sinica, Beijing. Paratypes: same data as holotype, 4 males; deposited: Insect Museum, National Taiwan University, Taipei; California Academy of Sciences, San Francisco; 1 female; same locality as holotype, 23/24 Jun 1996; deposited: Zoological Institute, Academia Sinica, Beijing.

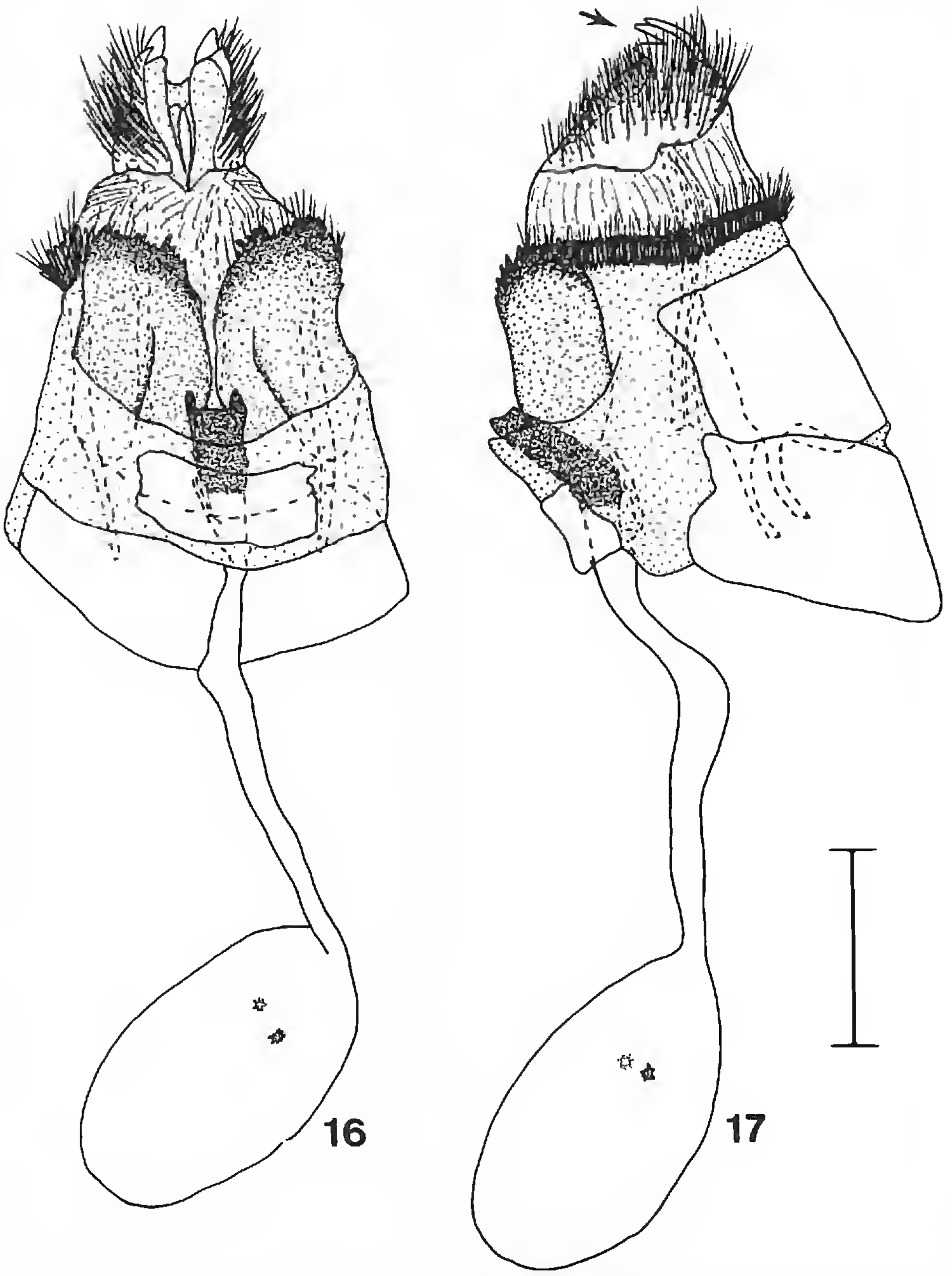
Description.—Male (Figs. 1–2). Length of forewing 17.0-19.2 mm (mean = 17.96 ± 0.84 mm, n = 5); Length of antenna 6.0–6.7 mm (mean = 6.38 ± 0.28mm, n = 5). *Head.* Hairy, clothed with erect, dark brown hairs on vertex and frons, a white, narrow rim surrounding eye; eye semi-oval, sparsely hairy; labial palpus hairy, porrect, pointed, projecting ahead of plane of front; maxillary



Figures 13–15. Phallus of *Japonica bella*. Fig. 13. Lateral view of phallus. Fig. 14. Dorsal view of phallus. Fig. 15. Anterior portion of venter of phallus (scale = 1 mm).

reduced, invisible; proboscis unscaled; antenna smooth-scaled, with projecting setae at nudum. *Thorax.* Pale brown clothed with chrome orange scaling dorsally; white ventrally, legs white, banded with dark brown on tarsi. *Forewing.* Eleven veins, R4+5, M1 forked with R3 (Fig. 5); termen, costa curved; dorsum straight; ground color of upperside chrome-orange with underside markings visible by transparency, margin, apex black; underside ground color pale chrome-orange with dark brown markings. Submarginal band parallel to termen, outlined by white scaling proximally and distally, intersected by orange scaling along veins. Discal band straight, slightly tilted inwards, marking in Cu2 indented. Two bars present in discoidal cell: distal one rectangular, basal one triangular. Fringe dark brown. *Hindwing.* Nine separate veins (Fig. 6). Termen produced at distal ends of veins, forming zig-zag outline. Ground color of upperside chrome-orange with dark brown outline. A patch of black scaling present at anterior corner along termen. A small, black dot present near distal end of Cu1. Anal area slightly lobed, covered with metallic blue and black. Underside ground color chrome-orange with distal half darkened. Four transverse bands outlined with narrow, white lines; submarginal band sharply narrowed posteriorly, forming a slender "W"-shaped marking around tornal area. Tornal area bright orange, a distinct, black dot present in cell Cu1, a patch of black scaling mixed with metallic blue present at tornal lobe. Slender tail-like projection extending from Cu2, black with a white distal tip, approximately 6.5 mm in length. *Abdomen.* Chrome orange dorsally, white ventrally. *Male genitalia* (Figs. 7–15). Sclerites of 9th and 10th segments fused, forming a complete ring, width 0.60 × height. Tegumen 9 + 10 with dorsum fairly flat, slightly concave posteriorly with medial bump; uncus absent; socii folded deeply inwards; brachium double-articulated with tegumen, smooth, flattened, enlarged at base, abruptly narrowed, tapering to a posteriorly directed, hooklike process; saccus produced, approximately 0.48 × height of tegumen; phallus elongate, upcurved posteriorly, slightly asymmetrical with caudal end produced along right side; aedeagus 1.95 × phallobase; cornutus present, forming an elongate, triangular plate with sharp end near caudal end of aedeagus; valva semicircular with inward-curved, digitate posterior process ending with a terminal club; juxta narrow, U-shaped.

Female (Figs. 3–4).—Forewing length 16.0 mm (n = 1); antennal length 6.0 mm (n = 1). *Head.* and *Thorax.* Structure, color pattern as described for male. *Wings.* Shape similar to male, but with straight termen; color pattern as described for male. *Abdomen.* Color as described for male. *Female genitalia* (Figs. 16–17). Apophyses posteriores elongate, slender, down-curved, ending with club-shaped anterior ends. Papillae anales with terminal, heavily sclerotized, bifid processes. Apophyses anteriores short, with blunt terminal ends, approximately one-third x length of apophyses posteriores. Sternite 8 divided, forming oval sclerites with postrior edges straight, serrate. Ductus bursae elongate,



Figures 16–17. Female genitalia of *Japonica bella*. Fig. 16. Ventral view. Fig. 17. Lateral view; arrow indicates the caudal processes at papilla analis (scale = 1 mm).

forming heavily sclerotized tube at the posterior end, with point of origin of ductus seminalis just anterior to the sclerotized tube. Corpus bursae oval, bearing a pair of small, flattened, amoeboid-shaped signa.

Diagnosis.—The pattern of four prominent bands or bars on the underside of the wings is unique among the species of *Japonica*. The enlarged brachium has a form not found in any members of the Theclini species. The caudal end of the valva is curved and clubed (Fig. 12) in *J. bella*, whereas it is straight and bifid in *J. saepestriata* and not clubed in *J. lutea*, *J. adusta*, and *J. patungkoanui*. The signa of *J. bella* are shallow and amoeboid-shaped, whereas those of the other *Japonica* species are invaginated and oval-shaped. The posterior edge of the sternite 8 is serrate, bearing numerous prominent teeth in *J. bella*, but smooth, without teeth in the other *Japonica* species. The terminal processes (Fig. 17) on papillae anales of *J. bella* are absent in the other *Japonica* members.

Geographical Distribution.—Currently only known from Guizhou Province, southwestern China.

Etymology.—An adjective of latin, from *bella* = beautiful.

Discussion.—The most unusual character found in *J. bella* is the enormously basally enlarged brachium, which is not present in the other members of *Japonica*. Hsu & Lin (1994) considered "smooth and simple" as the most plesiomorphic state for the shape of the brachium in the Theclini and assigned this state to the genus *Japonica* in their phylogenetic analysis of a subgroup of Theclini. The discovery of *J. bella* could put such an assignment in jeopardy, but probably will not affect their overall decision on the polarity of character states in the shape of brachium in Theclini. The enlarged part of the brachium in *J. bella* is flattened along a plane perpendicular to the axis of the terminal narrow portion (Figs. 9–10). Such a form of enlargement is unique among members of Theclini and is clearly an autopomorphy of *J. bella*. The sole possession of bifid caudal processes in female genitalia of *J. bella* is evidently also an autopomorphy of *J. bella*.

ACKNOWLEDGMENT

I thank James E. Baxter and Douglas E. Kain, Division of Insect Biology, University of California, Berkeley and C. Don MacNeill, Department of Entomology, California Academy of Sciences, San Francisco for critically reading the manuscript.

LITERATURE CITED

Fujioka, T. 1993. Zephyrus (Theclini butterflies) in the world (4). -Genus *Japonica*-. Butterflies, 5: 13–31.

Fukuda, H., E. Hama, T. Kuzuya, A. Takahashi, M. Takahashi, B. Tanaka, H. Tanaka, M. Wakabayashi, & Y. Watanabe. 1984. The life histories of butterflies in Japan. Vol. III. Hoikusha, Osaka.

Hsu, Y. F. & M. Y. Lin. 1994. Systematic position of *Sibataniozephyrus* and description of a new species from Taiwan (Lycaenidae: Theclini). J. Lepid. Soc., 48: 128–147.

Inomata, T. 1990. Keys to the Japanese butterflies in natural color. Hokuryukan, Tokyo.

Saigusa, T. 1993. A study on new subspecies of Tribe Theclini from eastern Asia. Zephyrus Research, 1: 12–21.

Shirôzu, T. 1961. Evolution of the food-habits of larvae of the Thecline butterflies. Tyô to Ga, 12: 144–162.

Shirôzu, T. & H. Yamamoto. 1956. A generic revision and the phylogeny of tribe Theclini (Lepidoptera; Lycaenidae). Sieboldia, 1: 329–421.

Uchida, H. 1991. Charms of Formosa, Island of Everlasting Summer. Self-published, Numazu City.

PAN-PACIFIC ENTOMOLOGIST
73(4): 231–235, (1997)

XYELA (PINICOLITES) LATA SMITH (VESPIDA: XYELIDAE), A LIVING FOSSIL SAWFLY FROM WESTERN NORTH AMERICA

ALEXANDR P. RASNITSYN
Paleontological Institute, Russian Academy of Sciences,
Moscow, 117647 Russia

Abstract.—*Xyela lata* Smith is an extant member of *Pinicolites* Meunier, 1920, a subgenus previously known from a single fossil species from Tertiary deposits of Germany. The species, known from the highlands of Colorado, Nevada, and Oregon, is first recorded from California (Sierra Nevada Mountains, altitude 2,560–2,800 m).

Key Words.—Insecta, Xyelidae, Tertiary relict, living fossil

Xyelidae is one of the oldest insect families, whose fossil record starts as early as at the Middle or Late Triassic. The genus *Xyela* Dalman is also an ancient as it first appeared in the Lower Cretaceous (Rasnitsyn 1969).

The fossil history of *Xyela* was recently reviewed by Rasnitsyn (1995) who recognized three subgenera: *Mesoxyela* Rasnitsyn (1965) (with one Early Cretaceous species from Zaza lake sediments in Transbaikalia), *Pinicolites* Meunier (1920) (one species from the mid-Tertiary (Aquitanian) of Germany near Bonn), and *Xyela* s.s. (five mid-Tertiary and 31 extant species). *Pinicolites* is found now to persist since mid-Tertiary until the present.

Recently I have examined two specimens of *X. lata* in the collection of the California Academy of Sciences, San Francisco, and found the species to be a member of *Pinicolites*. The species was not recognized as a member in the original description of this subgenus, so it is redescribed here to include important characters not visible on the fossil specimens.

Discovery of the living fossil was presented to the general public in the Sep 1995 edition of the San Francisco Chronicle. The reporter contacted Donald J. Burdick, the collector, who provided details about the habitat.

GENUS *XYELA* DALMAN

SUBGENUS *PINICOLITES* MEUNIER

Finding of an extant species made my previous diagnosis of *Pinicolites* obsolete. A new diagnosis follows.

Diagnosis.—*Pinicolites* differs from *Xyela* s.str. and *Mesoxyela* in having an ovipositor that is both flat (saw-like) and upcurved. In addition, RS either touches M in a point, or is connected to it by short 1r-m crossvein (fused with M for a distance in *Mesoxyela* and a majority of *Xyela* s.str.). Within *Xyela* s.l., *Pinicolites* has a unique combination of a lightly colored mesoscutum (with black spots that indicate muscle attachments) a short antennal flagellum (shorter than or subequal to the article III and about 0.7 as long as the head width). In *Mesoxyela,* the mesoscutum is black and the antennal flagellum short, and in *Xyela* s.str. the antennal flagellum is longer and the mesoscutum is usually lightly colored. *Pinicolites* is similar to *Mesoxyela* and differs from *Xyela* s.str. in having free stalk of SC. Judging from the extant species only, *Pinicolites* differs from *Xyela* s.str.

Figure 1. *Xyela lata* Smith, specimen from Kaiser Pass.

and *Mesoxyela* also in having antennal flagellum 11-segmented, mesonotum surface smooth, unsculptured (except for minute, sparse punctures), and, for the ovipositor blades, in the dorsal valve lacking visible structures, and the ventral valve having a narrow, acute apical projection that is abruptly separated from the main valve portion.

Xyela (*Pinicolites*) *lata* Smith
(Figs. 1–4)

Xyela lata Smith, 1990: 9.

Description.—Female: Length of forewing 4.4 mm, of sawsheath 2.3–2.5 mm. Integument shiny, asetose, unsculptured (except for scattered, minute punctures and pubescent abdominal apex). Body yellow with usual dark pattern (evanescent in part in one specimen); brown (sometimes with red tint) on head: antennomere III and flagellomeres, mandibular apex, lines along and spot between ocellar-antennal furrows, interocellar and postocellar area, spots laterad of postocellar sutures, posterior ocular orbits, and posterior head surface above; on thorax: pronotum, propleuron (except yellow caudally along thoracic midline), mesopleuron anterad of pseudosternal suture, pseudosternum except rostrally, laterally, mesonotum narrowly along notauli, medial, and scutellar furrows and along posterior scutellar margin, lateral and sublateral spots of mesonotum; additionally brown are dorsal body surface posterior of mesonotum disc (except for whitish cenchri, and yellowish metascutellum and abdominal tergal margins), and sawsheath apex. Pterostigma and veins pale yellow, membrane hyaline. Maxillary palp with article III as wide as and almost as long as antennal article III, with article V bearing 4 curved setae submedially, and membranous flap adaxially, subapically. Wing venation (Fig. 2), with several irregularities, viz., one specimen has an extra A_1 stub on left hindwing, another a supernumerary rs_1-rs_2 crossvein in right forewing, its rudiment in left forewing, and r-rs crossvein in left hindwing. Sawsheath slightly upcurved in basal half, almost straight distally, widest subbasally, tapering slightly both basally and distally, tapering abruptly toward apex that is narrowly rounded, almost symmetrical. Basal plate of ovipositor (2nd valvifer) short: externally scarcely longer than maximum height of sheath. Ventral valve (V_1) high, membranous except for simple dorsal longitudinal thickening, abruptly

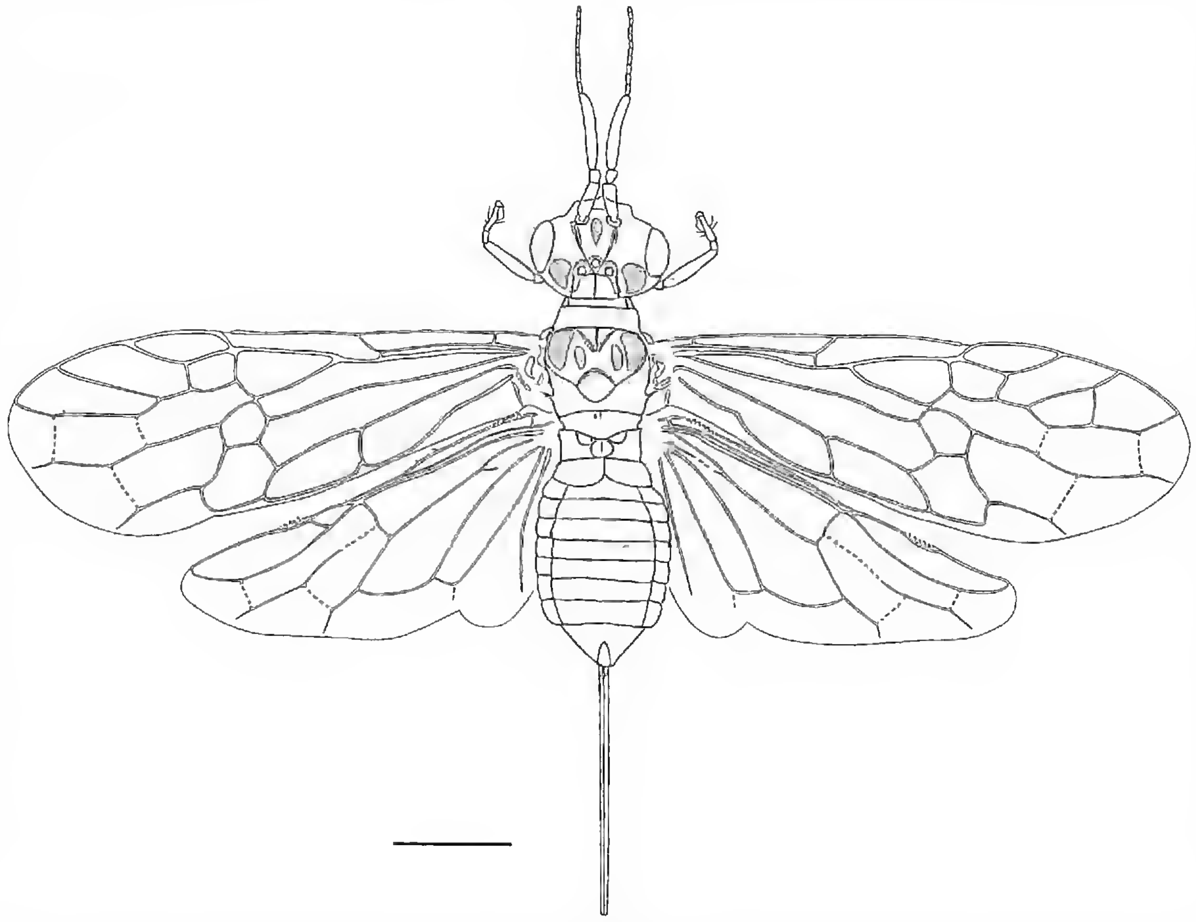


Figure 2. *Xyela lata* Smith, line drawing of Kaiser Pass specimen (legs omitted). Scale line = 1 mm.

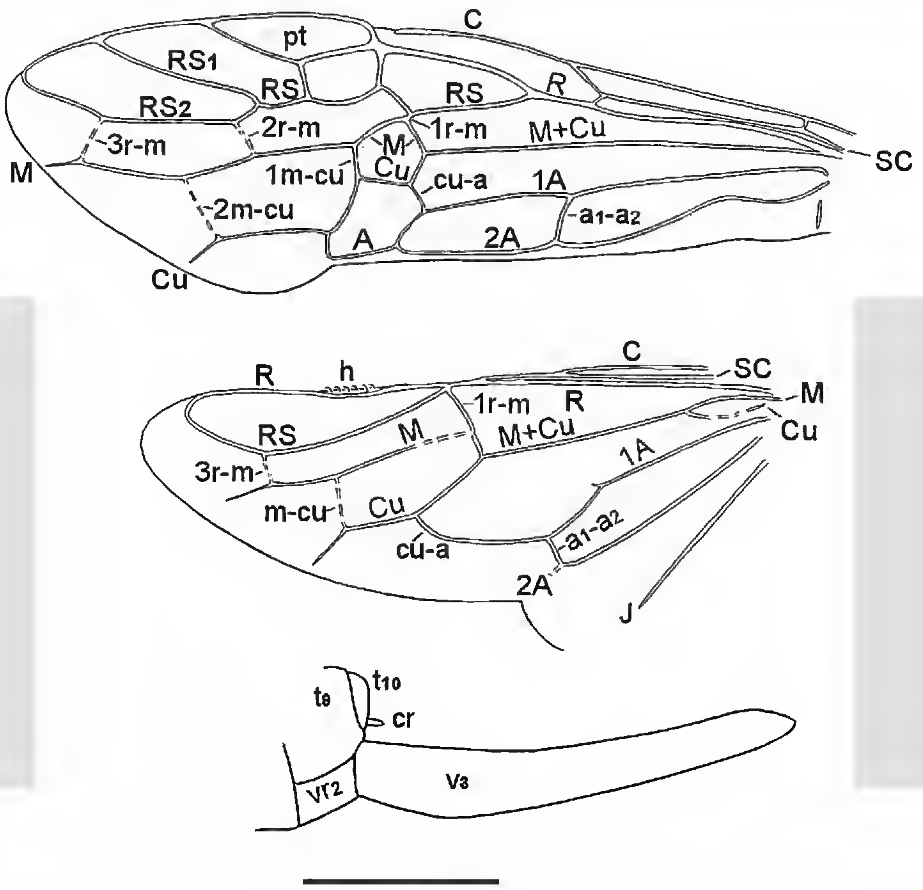


Figure 3. *Xyela lata* Smith, wings and external view of the ovipositor of Bodie specimen. Longitudinal veins are capitalized, crossveins are hyphenated; cr—cercus, h—hamuli, pt—pterostigma, t_9, t_{10}—abdominal terga, v_3—sawsheath, vr_2—second valvifer (basal plate of ovipositor). Scale line = 1 mm.

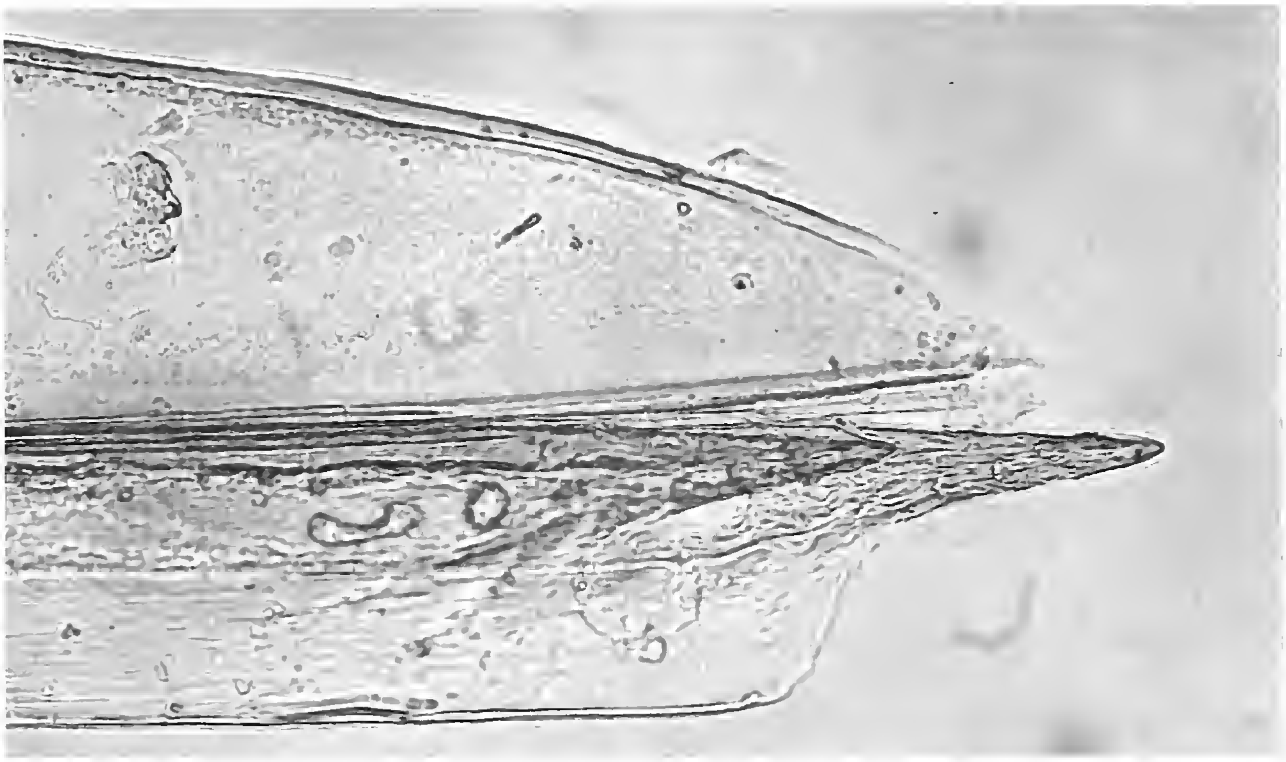


Figure 4. *Xyela lata* Smith, ovipositor blades of Kaiser Pass specimen (v_1 bottom, v_2 top).

narrowed toward needle-like apex armed with 4 oblique, toothed ribs, which are facing cephalad. Dorsal valve (V_2) also high, membranous and lacking visible structure (except for narrow ventral longitudinal rib not reaching apex of valve); narrowing gradually toward simple, hardly visible apex.

Male.—Unknown.

Diagnosis.—*Xyela lata* differs from *X. graciosa* Meunier 1920, in being slightly larger (forewing length 4.0–4.4 mm) and in having the following: antennal flagellum somewhat longer than article III, forewing with SC not reaching the level of RS base, sawsheath more upcurved, widest subbasally, and shorter (equal to distance from forewing R base to 1r-rs). In *X. graciosa* the forewing length is 3.5 mm, antennal flagellum shorter than article III, forewing with SC reaching the level of RS base, sawsheath less curved, widest basally, and as long as the forewing from R base to 2r-rs.

Biology.—One of females was collected "flying around the [male] cone of a white bark pine tree [*Pinus albicaulis* Engelm.] at an elevation of 9,500 feet [= 2,900 m]" (observation by Donald J. Burdick, cited in the San Francisco Chronicle, Sept. 4, 1995, p. 16).

Material Examined.—CALIFORNIA. *FRESNO Co.*: Kaiser Pass, 2900 m, 13 Jun 1966, D. J. Burdick, 1 female. *MONO Co.*: Bodie [2560 m], 12 Jun 1937, W. C. Bush.

ACKNOWLEDGMENT

My visit to California was made possible through a grant from the International Society of Hymenopterists, and also through friendly hospitality by Wojciech J. Pulawski and Veronica Pulawski, San Francisco, California. Wojciech J. Pulawski, Curator, California Academy of Sciences, San Francisco, California, also offered research facilities in the Department of Entomology, California Academy of Sciences. The photograph of the ovipositor blades is through the courtesy of Charles E. Griswold and Darrel Ubick of the same Department. The photograph of the whole specimen was provided by Susan Middleton, formerly of California Academy of Sciences. I sincerely thank David R. Smith of the Systematic Entomology

Laboratory, USDA, who helped identify the species. An anonymous reviewer pointed out several important deficiences in the early version of the article.

LITERATURE CITED

Meunier, F. 1920. Quelque insectes de l'Aquitanien de Rott, Sept.-Monts (Prusse rhénane). Koninklijke Akademie van Wettenschappen te Amsterdam, Proceedings, Section of Science, 22: 891–898.

Rasnitsyn, A. P. 1969. Origin and evolution of Lower Hymenoptera. Trans. Paleontological Institute, Acad. Sci. U.S.S.R., 123 (in Russian; translated into English in 1979 by Amerind Co., New Delhi).

Rasnitsyn, A. P. 1971. Evolution of Xyelidae (Hymenoptera). *In* Current problems in paleontology. Trans. Paleontological Institute, Acad. Sci. U.S.S.R., 130: 187–196 (in Russian).

Rasnitsyn, A. P. 1995. Tertiary sawflies of the Tribe Xyelini (Insecta: Vespida = Hymenoptera: Xyelidae) and their relationship to the Mesozoic and modern faunas. Contributions in Science, Natural History Museum of Los Angeles County, 450: 1–14.

Smith, D. R. 1990. A new *Xyela* (Hymenoptera, Xyelidae) from the Western United States. Entomol. News, 101: 9–12.

Sphon, G. G. 1973. Additional type specimens of fossil Invertebrata in the collections of the Natural History Museum of Los Angeles County. Contributions in Science, Natural History Museum of Los Angeles County, 250: 1–75.

Statz, G. 1936. Über alte und neue fossile Hymenopterenfunde aus den tertiären Ablagerungen von Rott am Siebengebirge. Decheniana, 93: 256–312.

Received 26 Apr 1996; Accepted 30 Dec 1996.

PAN-PACIFIC ENTOMOLOGIST
73(4): 236–242, (1997)

Scientific Note

INTRODUCTION OF WESTERN ASIAN EGG PARASITOIDS INTO CALIFORNIA FOR BIOLOGICAL CONTROL OF BEET LEAFHOPPER, *CIRCULIFER TENELLUS*

In North America, beet leafhopper, *Circulifer tenellus* (Baker), is the only known vector of curly top virus which affects a wide variety of crop species, including tomatoes, sugar beets, peppers, melons, spinach, and beans. Curly top virus has been a major economic problem in sugar beet and vegetable production in the western United States for almost 100 years (Bennett, C. W. 1971. The Curly Top Disease of Sugarbeet and Other Plants. Amer. Phytopath. Soc. Monogr. 7). To reduce losses caused by curly top virus, the California Department of Food and Agriculture (CDFA) has been conducting a control program since 1943 to reduce regional populations of the beet leafhopper vector in California. In addition to beet leafhopper's importance as the sole vector of curly top virus in North America, it is also a vector of citrus stubborn disease, a serious plant pathogen affecting citrus (Oldfield, G. N., Kaloostian, G. H., Pierce, H. D., Calavan, E. C., Granett, A. L., & Blue, R. L. 1976. Calif. Agric. 30[6]: 15).

Beet leafhopper has a strong migratory habit and is polyphagous with over 30 plant species from several plant families serving as reproductive hosts, and perhaps 60 or more additional species on which the leafhopper can feed (Severin, H. H. P. 1933. Hilgardia 7: 281–360, Cook, W. C. 1967. U.S.D.A. Agr. Res. Service Tech. Bull. 1365, Bennett 1971, and personnel in CDFA's Curly Top Virus Control Program). Beet leafhopper is believed to be native to the arid and semi-arid areas of central Asia. Both its migratory and polyphagous habits are adaptations to arid and semi-arid regions, where its success as an herbivore is largely a result of its ability to abandon areas undergoing seasonal drying and to move to locations where the vegetation is still green. Location of green vegetation at different times of the year is a daunting challenge in these arid and semi-arid habitats even without having to locate specific plant species; thus, the leafhopper's polyphagous habits complement its migratory habits to make this species a successful nomad in areas characterized by ephemeral host plant patches that occur in different locations throughout the year. In North America, beet leafhopper is a serious pest only in the western part of the United States where the leafhopper's migratory and polyphagous habits make it well suited for the generally arid and semi-arid climate of this region (Cook 1967, Johnson, C. G. 1969. Migration and Dispersal of Insects by Flight. Methuen & Co. pub.).

In California's San Joaquin Valley, beet leafhopper's annual migratory cycle is summarized as follows (Cook 1967, Johnson 1969, and personnel in CDFA's Curly Top Virus Control Program). Adults in reproductive diapause congregate for overwintering in the foothills of the coastal range on the west side of the valley. Here they subsist on a wide variety of perennial plants that are still green after the long hot dry summer, but they do not reproduce on these perennial "holdover hosts." When winter rains stimulate germination of annual plants in the foothills, the leafhoppers move to these annuals and begin to oviposit in them, generally in February. The most important of the winter/spring annual host plants for beet leafhopper reproduction are filaree (*Erodium* sp.), plantain (*Plantago* sp.), and peppergrass (*Lepidium* sp.). Winter/spring rains are generally erratic and usually cease by the end of March, causing the winter/spring annual host plants in the foothills to die, and thus forcing the leafhoppers to migrate down into the valley where a new set of host plants are now growing. The uncultivated host plants now include London rocket (*Sisymbrium irio* L.), mustards (*Brassica* spp.), goosefoot, pigweed, and lamb's quarters (*Chenopodium* spp.), Russian thistle (*Salsola tragus* L.), annual saltbushes (*Atriplex* spp.), *Bassia* sp., and *Kochia* sp. These plants are generally concentrated in disturbed habitats along roadsides, in cultivated fields, and along irrigation ditches. Many of these late-spring hosts such as *Sisymbrium, Brassica* and *Chenopodium* die during the dry summer unless they occur in irrigated fields, but some such as Russian thistle, a few annual saltbushes, *Bassia* sp., and *Kochia* sp. survive even in non-irrigated locations throughout the summer and into the early fall. In early summer, beet leafhoppers abandon the dying short-lived uncultivated spring hosts and move to the remaining longer-lived uncultivated host plants or migrate into cultivated host plants, bringing curly top virus with them. In the fall, the uncultivated summer hosts (Russian thistle, annual saltbushes, *Bassia*, and *Kochia*) finally mature and die, and the cultivated hosts (as well as weed hosts in cultivated fields) are removed by harvesting or disking, forcing the leafhoppers to migrate back to the perennial holdover hosts in the foothills where they overwinter and complete the annual cycle. Beet leafhopper has similar types of migratory cycles in other regions of western North America.

Because of the migratory nature of beet leafhopper, control strategies on a field-by-field basis are not effective at reducing the spread of curly top virus. Crops become inoculated with virus from leafhoppers migrating into the fields from surrounding wild vegetation. Thus, a regional control strategy rather than a local field-by-field strategy is the most efficient way to reduce the incidence of curly top virus in the affected agricultural crops. The primary strategy of CDFA's Curly Top Virus Control Program is to reduce regional populations of beet leafhopper by spraying malathion in the leafhopper's overwintering and spring breeding grounds in wild vegetation (mostly rangeland in the San Joaquin Valley and desert in the Imperial Valley). CDFA is currently funding attempts to utilize biological control agents as an alternative regional control strategy in the beet leafhopper's wild vegetation habitats. As a component of the biological control strategy, we have made three foreign exploration trips to Asia in search of natural enemies of beet leafhopper, two in the former Soviet republic of Turkmenistan in May-June 1992 and September 1994, and one to Iran in June-July 1995 (Fig. 1). The focus of the exploration trips was on egg parasitoids. This report documents the importation of at least 11 different species of egg parasitoids of leafhoppers from Asia, the release of seven of these in California, and the establishment of at least one of these species.

The migratory nature and broad host plant range of beet leafhopper make it a particularly difficult target for biological control. Because the leafhopper does not stay in one place, successful natural enemies will have to either 1) remain in the same habitat and aestivate during the times of year when beet leafhopper is not

Figure 1. Map of the Iran–Turkmenistan region where parasitoids of beet leafhopper were collected and shipped to California during foreign exploration in May–June 1992 (Turkmenistan), September 1994 (Turkmenistan), and June–July 1995 (Iran). Collection sites of the species listed in Tables 1 and 2 are marked with asterisks on the map.

present; 2) remain in the same habitat and locate an alternative leafhopper host during the times of year when beet leafhopper is not present; or 3) follow the beet leafhopper on its migratory route. Another difficulty for biological control of beet leafhopper relates to the diversity of host plants that the leafhopper utilizes throughout its migratory cycle. Natural enemies that are effective on one of the host plants are not necessarily effective on a different host plant. For example, the native mymarid parasitoid *Anagrus nigriventris* Girault is an effective parasitoid of beet leafhopper eggs in unsprayed sugar beet fields in California (Meyerdirk, D. E. & Hessein, N. A. 1985. J. Econ. Entomol. 78: 346–353, Meyerdirk, D. E. & Moratorio, M. S. 1987. J. Econ. Entomol. 80: 362–365); however in our studies, this parasitoid was ineffective when it was mass-reared and released in beet leafhopper habitats in the foothills of the west side of the San Joaquin Valley, where the beet leafhopper host plant complex consisted of filaree, plantain, and peppergrass, and in Oildale, California, where the beet leafhopper host plant complex consisted of Russian thistle and an annual saltbush species (Triapitsyn, unpublished data).

Table 1. List of egg parasitoids emerging from the plant samples collected in Turkmenistan (1992), the host plants from which they emerged, and locations from where they were collected.

Parasitoid species	Host plants from which they were collected	Location Nearest point	Location Province
Family Mymaridae			
Anagrus atomus	red beet	Bayram-Ali	Mary
	red beet	Giami	Ashgabat
	red beet	Enev	Ashgabat
Erythmelus margianus	*Atriplex* sp.	Old Nisa	Ashgabat
	Atriplex sp. and *Salsola* sp.	Bayram-Ali	Mary
	Atriplex sp.	Ashgabat	Ashgabat
Gonatocerus sp(p).	*Atriplex* sp. and *Salsola* sp.	Bayram-Ali	Mary
Polynema sp(p).	*Atriplex* sp. and *Salsola* sp.	Bayram-Ali	Mary
	Atriplex sp.	Old Nisa	Ashgabat
Family Trichogrammatidae			
*Aphelinoidea turanica**	*Atriplex* sp.	Ashgabat	Ashgabat
	Atriplex sp.	Old Nisa	Ashgabat
	Atriplex sp.*	Bayram-Ali	Mary
	Salsola sp.	Bayram-Ali	Mary
Ufens sp.	*Atriplex* sp. and *Salsola* sp.	Old Nisa	Ashgabat
	Atriplex sp.	Bayram-Ali	Mary

Multiple lines for a species indicate that the species was collected from a number of different host plants and/or locations.

* Only the *Aphelinoidea turanica* collected from *Atriplex* sp. in Bayram-Ali was successfully propagated in quarantine, released and established in the San Joaquin Valley; all of the other species listed in Table 1 died in quarantine before they could be released.

Our objective is to establish biological control of beet leafhopper in desert and semi-arid rangeland habitats of beet leafhopper, where the host plant complex consists of a broad range of non-cultivated plants. Therefore, we focused our foreign explorations in arid and semi-arid climatic zones, and more on non-cultivated vegetation than on agricultural crops. This strategy was intended to obtain natural enemies adapted to the less succulent wild vegetation rather than to irrigated crop species. Also, we collected egg parasitoids from a diversity of plant species (Tables 1 and 2) in order to obtain a complex of parasitoids that would attack beet leafhopper eggs over a range of host plants.

Leafhoppers lay their eggs embedded in host plant tissue. To obtain parasitized beet leafhopper eggs, host plants or parts of host plants of beet leafhopper were collected from areas where beet leafhoppers were present (determined by sampling nymphs and adults) in various locations in Turkmenistan and Iran (Fig. 1). Collected plant materials were sealed in plastic bags or in boxes within plastic bags, refrigerated, and then shipped to the entomology quarantine facility at the University of California, Riverside (UCR). In the quarantine facility, many insects emerged from the plant samples. Newly emerged adult wasps that were from taxonomic groups likely to be leafhopper egg parasitoids (mostly Mymaridae and Trichogrammatidae) were then collected alive and placed in small cages containing sugar beet plants with large numbers of beet leafhopper eggs embedded in the plant tissue as described by A. K. Al-Wahaibi and G. P. Walker (in press. Bull. Entomol. Res.). There, the parasitoids had an opportunity to oviposit in the

Table 2. List of egg parasitoids emerging from the plant samples collected in Iran (1995), the host plants from which they emerged, and locations from where they were collected.

Parasitoid species	Identification number*	Host plants from which they were collected	Location	
			Nearest city	Province
Family Mymaridae				
*Anagrus atomus***	45-An	sugar beet	Karaj	Tehran
Polynema sp. 1	10-P	sugar beet	Karaj	Tehran
Polynema sp. 2	41,42,43-P	*Chenopodium* sp. & *Salsola* sp.	Karaj	Tehran
	45-P	sugar beet	Karaj	Tehran
Gonatocerus sp. 1A	36-GL	*Kochia* sp.	Atar, Neyshabur	Khorasan
Gonatocerus sp. 1B**	15-GLX	*Atriplex* sp.	Shams-abad, Neyshabur	Khorasan
Gonatocerus sp. 2	11–GD	*Salsola* sp.	Karaj	Tehran
	23–GD	*Artemisia* sp.	between Mashhad and Ghuchan; 35 km from Mashhad	Khorasan
Family Trichogrammatidae				
Aphelinoidea turanica	15,25-Ap	*Atriplex* sp. & *Chenopodium* sp.	Shams-abad, Neyshabur	Khorasan
Aphelinoidea anatolica	3-Ap	*Chenopodium* sp.	Akbar-abad, Kavar	Fars
Oligosita sp.	36-O	*Kochia* sp.	Atar, Neyshabur	Khorasan
	45-O	sugar beet	Karaj	Tehran

* Identification numbers refer to separate cultures of parasitoids and to the voucher specimens (deposited in the Entomology Research Museum at the University of California, Riverside) for those cultures. Three of the parasitoid species (*Polynema* sp. 2, *Gonatocerus* sp. 2, and *Oligosita* sp.) have two cultures each, with each culture originating from a different host plant and/or location.

** Died before they could be released; no longer available.

beet leafhopper eggs and initiate a quarantine culture. Parasitoid cultures then were maintained on beet leafhopper-infested sugar beets kept at approximately 25 ± 2° C and ≈ 60% relative humidity.

The first trip to Turkmenistan in May–June 1992 yielded the egg parasitoids *Anagrus atomus* (L.) (Mymaridae), one or more species of *Gonatocerus* (Mymaridae), one or more species of *Polynema* (Mymaridae), a species of *Ufens* (Trichogrammatidae), and two previously unknown species, *Aphelinoidea turanica* Trjapitzin (Trichogrammatidae) and *Erythmelus margianus* Trjapitzin (Mymaridae). Most of the collecting sites were in oases, the Kara Kum desert, and the foothills of low mountains along the Iranian border (Fig. 1). The collections were focused on Chenopodiaceae, especially *Atriplex* and *Salsola* spp., and additional collections were made from *Plantago* sp. and cultivated red beets (*Beta vulgaris* L.) (Table 1). Voucher specimens for the parasitoids have been deposited in the Entomology Research Museum at the University of California, Riverside. Of the parasitoids listed in Table 1, only *A. turanica* survived through the quarantine process. *Aphelinoidea turanica* was successfully reared on beet leafhopper eggs, and was released between 30 Apr and 11 Jun 1993 in an abandoned gravel quarry alongside Highway 65 near Oildale, California where the beet leafhopper host plant complex consisted of Russian thistle, annual saltbush, filaree, and mustards. The release area was sampled for *A. turanica* from 24 Jul (at least two generation times after the last release date) to 19 Aug 1993 and again from March through May 1994. *Aphelinoidea turanica* were recovered from the 1993 and 1994 samples, indicating that it successfully established and overwintered at this location.

The second trip to Turkmenistan in September 1994 was not as successful. Only a few *A. turanica* emerged from samples collected from drying *Salsola* and *Atriplex* spp. Unfortunately, these were all males, and consequently, this collection of *A. turanica* died in quarantine.

The third trip to Iran in June–July 1995 was very successful, and nine species of leafhopper egg parasitoids emerged from the plant samples and reproduced on beet leafhopper eggs in sugar beet plants in the UCR entomology quarantine facility (Table 2). The host plants that were collected in Iran and shipped to the quarantine facility at UCR were: *Amaranthus* sp., *Artemesia* sp., *Atriplex* sp., *Beta vulgaris* (sugar beet), *Chenopodium* sp., *Kochia* sp., *Plantago* sp., *Polygonum* sp., *Salsola* sp., and *Zantium* sp. Of the listed parasitoid species, *A. atomus* died in quarantine and was never released. It reproduced poorly on beet leafhopper eggs in the sugar beet plants, suggesting that beet leafhopper may not be a good host for *A. atomus*, and that it may have emerged from other species of leafhopper eggs present in the plant samples from Iran. *Gonatocerus* sp. 1B also died in quarantine and, like *A. atomus*, it did not reproduce vigorously on beet leafhopper eggs and also may have emerged from other species of leafhopper eggs present in the plant samples from Iran. The remaining parasitoid species, *Gonatocerus* sp. 1A & 2, *Polynema* sp. 1 & 2, *A. turanica*, *Aphelinoidea anatolica* Nowicki, and *Oligosita* sp. (Trichogrammatidae), all reproduced well on beet leafhopper eggs in quarantine. The two surviving *Gonatocerus* species are thelytokous and all other species are arrhenotokous. The two *Polynema* species originated from different collection locations and were originally thought to represent a single species. However, scanning electron microscopy revealed some subtle morphological differences between the two, and subsequent cross-mating tests revealed an inability to cross-breed, hence establishing the two *Polynema* as separate species. Unfortunately, there are no taxonomists working on *Gonatocerus*, *Polynema*, or *Oligosita*, and thus species identifications are not possible at this time. Voucher specimens have been deposited in the Entomology Research Museum at UCR. Reference numbers for these voucher specimens are given in Table 2.

We have been releasing the seven surviving parasitoid species in beet leafhopper-infested sugar beets grown at UCR's Agricultural Operations in Riverside since December 1995, in wild vegetation breeding areas of beet leafhopper in the San Joaquin Valley since February 1996, in wild vegetation breeding areas of beet leafhopper in Fresno County, California since September 1996, and in wild vegetation breeding areas of beet leafhopper near Hemet, California since October 1996. To date, we have recovered *Oligosita* sp. from sugar beets and *Polynema* sp. from *Chenopodium* in Riverside, but it is premature to determine whether or not they have established a viable population. We have not yet made any recoveries of the introduced species from any of the other release areas. Releases of the introduced species and sampling to determine establishment is planned to continue for at least another year.

Acknowledgment.—The authors thank Bob Peterson and Rod Clark of the California Department of Food and Agriculture for critically reviewing the manuscript and for assistance in choosing release sites for the parasitoids. This project is funded by a grant from the California Department of Food and Agriculture Curly Top Virus Control Program.

G. P. Walker, N. Zareh, I. M. Bayoun & S. V. Triapitsyn, *Department of Entomology, University of California, Riverside, California 92521*

Received 9 Dec 1996; Accepted 26 Feb 1997.

PAN-PACIFIC ENTOMOLOGIST
73(4): 243–244, (1997)

Scientific Note

NOTES ON *BRACHYCAUDONIA* ASHMEAD SPP. (HYMENOPTERA: PTEROMALIDAE)

Two species have been described in the genus *Brachycaudonia* (Hymenoptera: Pteromalidae), *B. californica* Ashmead and *B. cyaniceps* Boucek. In the description of the latter, Boucek (1993. J. Nat. Hist. 27: 1239–1313), noted there were no host records available for either species. I have examined *Brachycaudonia* material from the California Academy of Sciences, San Francisco, California, Bohart Museum of Entomology, University of California, Davis, Essig Museum of Entomology, University of California, Berkeley, California, Oregon State University, Corvallis, Oregon, United States National Museum, Washington, D.C., and my personal collection. Specimens from California exhibit a range of morphological characters and may represent a complex of two or more species (S. Heydon, pers. comm.). However, for the purposes of this paper, I regard them as belonging to a single species, *B. californica*.

Specimens of *B. californica* have been reared from oak galls formed by several species of Cynipidae (Hymenoptera). These include galls of *Dryocosmus dubiosus* (Fullaway) on *Quercus agrifolia* Neé (both leaf galls formed by the unisexual generation, and flower galls formed by the bisexual generation), and galls of *Andricus occultatus* (Weld) on *Q. lobata* Neé. These specimens were collected in every month (except December) from September through May, from the following California counties: Alameda, Contra Costa, Fresno, Los Angeles, Marin, Monterey, Napa, Riverside, San Joaquin, San Mateo, Santa Barbara, Santa Clara, Solano and Tulare. A male *B. californica* was also reared in April from a gall of *Dros pedicellatum* (Kinsey), and a female from an unknown gall, from Benton County, Oregon.

In March 1995 I collected three adult *B. californica* females from the foliage of a *Q. agrifolia*, and exposed them to nine *D. dubiosus* leaf galls (both light and dark galls) on leaves collected from the same tree, 2 days later. The first female antennated both dark and light galls. On five of these, she stood on top of the gall and inserted her ovipositor about midway along the center. The ovipositor did not appear to be deeply inserted into the gall, but the time of insertion varied from a few seconds to 1–2 min. The second female explored the galls with the tip of her ovipositor sheath and antennae, but never drilled. The third female evinced no interest in the galls. One day later I dissected all nine galls. Two of the five galls drilled by the first female each contained a small larva with an egg laying on them. None of the other three drilled galls contained eggs—two each contained a large larva and the other was empty. Of the undrilled galls, one contained a torymid pupa.

I collected additional *D. dubiosus* leaf galls from the same tree during 1996. A male *B. californica* emerged between 14–18 Feb 1997, from a gall collected on 13 Jul 1996.

I also found specimens of *B. cyaniceps* from Kansas, Missouri, Maryland and Pennsylvania (representing a range extension for this species that was formerly reported only from New York and Ontario) but rearing data are not available. The specimen from Maryland is a male, 1.4 mm long, and largely resembles the female, except for the following characteristics: antennae only slightly clavate; propodeal plicae absent; relative length of marginal vein 13, stigmal vein 10, postmarginal vein 13; gaster slightly longer than mesosoma; entire dorsum of gaster non-metallic light brown; head and mesosoma concolorous, maculation of wing lighter. This specimen was taken from a malaise trap, so the true colors may be different from those reported here.

Two *Brachycaudonia* specimens from Minnesota and Michigan resemble *B. cyaniceps*, but are without rearing data.

Thus, in the western United States *Brachycaudonia* is associated with cynipid galls from *Quercus* species, probably as an ectoparasitoid. Interestingly, one specimen each of *B. californica* and *B. cyaniceps* was collected from a peach tree or orchard. However, it is unknown if these species are primary or secondary parasitoids, or if they attack gall-makers or inquilines. I have also reared *Torymus fullawayi* (Huber) (Hymenoptera: Torymidae), a ?*Brasema* sp. (Hymenoptera: Eupelmidae), two *Aprostocetus* spp. (Hymenoptera: Eulophidae), and a *Synergus* sp. (Hymenoptera: Cynipidae) from *D. dubiosus* leaf galls on *Q. agrifolia*.

Of special interest is the rearing of *B. californica* from galls formed by both the unisexual and bisexual generations of *D. dubiosus*. Askew (1961. Trans. Soc. Brit. Entomol. 14: 237–268) noted that the same parasitoid species seldom attacked alternating generations of the same cynipid host, as the gall's structure, placement on tree and the season of growth were the most important factors in determining its parasitoid complement, and these varied between alternating generations. However, Doutt (1959. Ann. Entomol. Soc. Am. 52: 69–74), noted that *D. dubiosus* flower galls are found from February-May in California, and I have noted leaf galls in March and April. Presumably, this seasonal overlap in gall occurrence facilitates the transfer of *B. californica* between the alternating generations of the cynipid.

Acknowledgment.—I thank Eric Grissell of the Systematic Entomology Laboratory, % United States National Museum, Jim Lebonte of Oregon State University and Steve Heydon of the University of California, Davis for their assistance in providing specimens, and Ken Hagen of the University of California, Berkeley for reviewing the manuscript.

Robert L. Zuparko, *Center for Biological Control, 201 Wellman Hall, University of California, Berkeley, California 94720.*

Received 31 Oct 1996; Accepted 5 Feb 1997.

PAN-PACIFIC ENTOMOLOGIST
73(4): 245–247, (1997)

Scientific Note

NATURALLY OCCURRING INFESTATIONS OF DRYWOOD TERMITES IN BOOKS

Drywood termites of the family Kalotermitidae (Isoptera) occur throughout the tropics and subtropics (Snyder, T. E. 1949. Smith. Misc. Coll. 112: 1–490) with a few species occurring in warmer temperate regions of the world. All members of the Kalotermitidae are essentially wood dwellers with the exception of *Paraneotermes simplicicornis* (Banks), which exhibits a semi-subterranean habit (Gulmahamad, H. 1995. Pan-Pacif. Entomol. 71: 105–109). *Incisitermes fruticavus* Rust, which occurs in California, has been reported to infest living plants (Rust, M. K. 1979. Pan-Pacific Entomol. 55: 273–278). Recent evidence suggests that *I. fructicavus* also attacks structures in San Diego County (Michael K. Rust, personal communication).

Incisitermes minor (Hagen) is the most common drywood termite in western North America. Its distribution is mainly confined to California, portions of Arizona and northern Mexico. Isolated infestations of *I. minor* have also been reported from Washington, Utah and many parts of Canada. In many areas where it is endemic, *I. minor* is the most destructive drywood termite species. In southern California, where infestations of *I. minor* are very common in wooden structures, more money is spent controlling this species than subterranean termites.

Natural infestations of *I. minor* largely occur in sound, dry, wood. In California, infestations are commonly found in dead trees and shrubs and in dead portions of living trees and shrubs. Infestations are also found in wooden buildings and other wooden structures.

Over the past 19 years of field work in southern California, I have found infestations of *I. minor* in mobile homes, recreational vehicles, two classic automobiles (a 1932 Ford Huckster and a Woody), trucks, boats, ships, pool tables, pianos, spas, gazebos, wooden water tanks, power poles, fence posts, furniture, wooden pallets, wooden crates, wooden tool handles, decorative wooden statues, wood carvings, totem poles, wooden crosses, picture frames, firewood, scrap lumber, and wooden desks. Many of these infestation records have not been previously reported for this species.

It is common to find infestations and damage of subterranean termites in books and other paper products. These are well documented in the literature. In fact, subterranean termite damage to books, magazines, journals, written and printed records, and other paper documents, has been so great in the tropics that it was once thought that termites were responsible for delaying or at least slowing the progress of intellectual development in tropical areas (Light, S. F., M. Randall & F. G. White. 1930. Univ. Cal. Agric. Exp. Stn. Circ. 318: 1–64).

However, I was unable to locate any reference in the literature pertaining to drywood termite infestations and damage to books.

Here I document naturally occurring infestations of *I. minor* in books.

Case 1.—This incident involved a paperback book which was taken from a bookshelf in a home in Riverside, California. The top of this book had a single

Figure 1. Paperback book showing chamber excavated by a pair of alates of *I. minor*.

entry hole. Figure 1 shows this book when it is opened at about midway through the entry hole. The only termites discovered in the book were two live dealate *I. minor*. It seems that this pair of swarmers excavated a chamber in this book to begin colony initiation.

Case 2.—Figure 2 shows a coloring book which was found on a built-in book-

Figure 2. Coloring book showing a chamber and tunnel excavated by pseudergates of *I. minor*.

shelf in a home in West Covina, California. Note the main chamber at the right side of this book and the gallery extending to the shoulder of the boy carrying a pumpkin. Live pseudergates of *I. minor* were present in the main chamber of this book. Here, a colony of *I. minor* had infested the wall and built-in bookcase and it extended its infestation into this book.

Case 3.—Case 3 involved a hard cover book which was found in a home in Ontario, California. Three small holes and accompanying tunnels were excavated from one cover of the book to the other. Some small chambers were found about midway through the book. Drywood termite pellets, with six concave sides, were present in the holes and chambers within this book but no live termites were found. Apparently alates tunnelled through this book and, not finding it suitable went elsewhere.

Acknowledgement.—I thank Stoy Hedges, John Chapman, Rusty Bracho, Mike Rust, and two anonymous reviewers for manuscript reviews.

Hanif Gulmahamad, *Terminix International, 1501 Harris Court, Anaheim, California. 92806.*

Received 19 Dec 1996; Accepted 26 Feb 1997.

PAN-PACIFIC ENTOMOLOGIST
73(4): 248–255, (1997)

THE PAN-PACIFIC ENTOMOLOGIST: FORMAT INFORMATION FOR CONTRIBUTORS

The Pan-Pacific Entomologist is published quarterly by the Pacific Coast Entomological Society, in cooperation with the California Academy of Sciences. The journal serves as a refereed publication outlet and accepts original manuscripts on all aspects of the biosystematics of insects and closely related arthropods, especially articles dealing with their taxonomy, biology, behavior, ecology, life history, biogeography and distribution. Articles with either a natural, descriptive orientation or a technical and analytical emphasis are welcome. Articles that deal with the strictly economic aspects of insects, however, are inappropriate for submission to the Pan-Pacific Entomologist. Manuscripts must be in English, but foreign language summaries are permitted.

As of 1 January 1990, beginning with volume 66, number 1, the Pan-Pacific Entomologist will employ changes in format which will be consistently applied. The format changes will require contributing authors to closely observe these guidelines. Because of comments by peer reviewers, but more particularly copy-editing, very few manuscripts are ultimately accepted without being redrafted to incorporate changes.

FORMAT

All manuscripts must be typed or printed on one side of 8.5 × 11 in nonerasable, high quality paper. Three (3) copies of each manuscript must be submitted: an editor's copy (original or high quality photocopy), and two high quality review copies each including reductions of any figures to an 8.5 × 11 in page. Manuscripts must either be double or triple spaced in a legible typeface (preferably a serif font) that makes identification of letters and numbers distinct, especially characters such as the number 1, lower case L, and upper case I. All margins should be 1.5 in, all pages must be numbered and the senior author's name should appear in the upper right corner of each page following the title page. Do not break words with hyphenation at the right margin of the text.

The pages must be ordered and numbered separately in sequence 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, original figures (unnumbered).

TITLE PAGE

The upper right corner must include the statement "Send galleys to:" and list the corresponding author's name, address including ZIP code, and phone number. Type the title of the manuscript in all upper case letters in the center of the page. Use a title that is informative and specific, but as brief as possible. Compound titles are permitted and are separated by a colon; do not include a serial number in the title. The title should not include both the common name and scientific binomial of an insect. Titles must list the order and family involved within parentheses and separated by a colon.

The name of each author should be typed in upper case letters several lines below the title. In no case should the professional or academic title of authors be noted. Several lines below the author's name, the institutional affiliation should be typed in upper and lower case letters, as the sequence: department, institution, city, state or province, postal ZIP code or equivalent, and country if different from the United States or Canada. Abbreviations must not occur within affiliations or addresses, spell out all words in the affiliation, but omit building and room numbers (i.e., Department of Entomological Sciences, University of California, Berkeley, California 94720); do not use two letter postal abbreviations for states. In institutional addresses use a street number (i.e., 2258 Howard Avenue) or building (i.e., Wellman Hall) only if mail would not be likely to ultimately reach its destination without that addition. If the address on an article is different from the author's current correspondence address, use a footnote number after the address associated with the title and supply the current correspondence address on a separate footnote page.

If multiple authors are associated with different institutions or addresses, separate these addresses with a semicolon; place a footnote marker after each author's name, and before the respective address.

ABSTRACT PAGE

The second page of the manuscript should contain only the abstract and key words. It is essential that the abstract be concise, not exceeding 250 words. The abstract should be an informative digest of the significant findings or main conclusions of the article and is often the only information made available by the abstracting publications. The abstract must be in a left indented paragraph format and begin with the word Abstract in upper and lower case letters, underlined, and followed by a period and two hyphens (i.e., Abstract.--). Begin the abstract to the right of the hyphens. When a taxonomic binomial is first mentioned in the abstract, the author (unabbreviated) of the name must be stated. Reference citation is not permitted in the abstract.

The key words paragraph (again, left indented) follows several lines below the abstract. Its lead is treated similarly to the abstract (i.e., Key Words.--). This is followed by five to seven key words or concise phrases, the first of which should be "Insecta" (or the class of related arthropod if applicable). The key words are aids to abstracting services that will index the article and as such should be chosen wisely. You may repeat words or phrases from the title.

Text Pages

The text should generally follow the guidelines established in a recent edition of the Council of Biological Editors Style Manual (CBE Style Manual Committee. 1983. CBE style manual: a guide for authors, editors, and publishers in the biological sciences. 5th ed. Council of Biological Editors, Bethesda, Maryland.). In the introduction avoid statements such as "The purpose of this paper is . . ." and use instead simply "This paper . . ." followed by what is accomplished. Throughout the article use simple and concise phrasing.

Major sections are delimited by centered headings using upper and lower case letters, such as: Methods and Materials, Results, Discussion, Results and Discussion, Acknowledgment, Literature Cited. Do not use a heading for the introduction. In taxonomic manuscripts the major headings might include: Taxonomy, Biology, Behavior, etc. Minor headings are delimited as are the abstract and key words paragraphs. Minor headings begin as left indented paragraphs with the word(s) in upper and lower case letters and underlined, followed by a period and two hyphens (i.e., Description of Adult Female.--).

References in the Text.—Cite published works by a single author by using the author's last name and the date of publication, without intervening punctuation (i.e., Burton 1989). For two authors cite both names with an intervening ampersand, but no punctuation, followed by the date (i.e., Burton & Bickham 1989). For multiple authors, cite the senior author's last name followed by "et al." and the date (i.e., Burton et al. 1989); place a period after "al" and do not indicate italics. When citing multiple papers by an author or authors in a single year, follow the year by a lower case letter (i.e., Burton 1979a, b or Hicks 1986c). Lower case letters must follow the dates of the appropriate citations in the Literature Cited section. Sequences of references in the text must be cited chronologically (i.e., Nelson 1978, Nieukoop & Sutasurya 1983, Raff 1987). In cases where sequential citations occur within the text and note multiple papers by the same author, the dates of articles should be separated by commas and the authors separated by semicolons (i.e., Weber 1932, 1936, 1941; Whitcomb 1950, 1952; Henderson 1978, 1979). Citations within the text that include reference to pages, figures or tables should be cited as: (Smith 1983: 149–153, Price 1985: fig. 7a, Nothwith 1987: table 3). Note that citations within the text of illustrations or tables from other works should begin with a lower case letter (i.e., fig. 2, table 2), to distinguish them from the figures and tables of the manuscript which begin with upper case letters. All (and only) articles cited in the text must occur within the Literature Cited section.

Cite as "in press" (i.e., Hawksworth in press), any manuscript which has been formally accepted for publication by a journal (not which is in preparation, or that merely has been submitted, acknowledged, or is in review by a journal!); do not estimate a date of publication in either the text reference or Literature Cited listing for articles that are in press. Data which does not exist in press (in this strict sense) or in publication and read and are not being presented in the manuscript under consideration can be cited as unpublished. If the unpublished data are from the sole author or all authors of the manuscript under consideration, then cite simply as "(unpublished data)" but if the data are from only one of multiple authors of the manuscript under consideration cite by initials (i.e., JAC, unpublished data). Cite as "unpublished data" any manuscript in preparation or which has been submitted for publication but has not yet been formally accepted after review. If the unpublished data are from a source other than the author(s) of the manuscript under consideration, cite the data as a personal communication. Personal communications should be kept to an absolute minimum, but where necessary should be cited without abbreviation as: (D. Hille Ris Lambers, personal communication). Personal communications and unpublished data citations are not listed in the Literature Cited section.

Measurements.—All measurements must be in metric units. Measurements in U.S. equivalents are permissible only within quoted data (as from the label of a holotype), or within parentheses after their metric counterpart if such display has a practical value. All fractions must be in decimal format (i.e., 0.2, 0.33, 0.67, 0.125); if such numbers are less than one, place a zero before the decimal (i.e., 0.05, not .05). When using measurement or count data and citing its range, mean and standard deviation, use the format: low–high (mean ± SD) (i.e., 337–388 [361 ± 16]).

Numbers.—Numerals are expressed as their word equivalents if between one (1) and nine (9), unless part of a sequence including values of 10 or greater; values greater than 10 are expressible as their numbers. Always begin a sentence with the word equivalent of a numeral (i.e., "Four specimens were . . ."). When a large number begins a sentence it is usually preferable to modify the beginning of the sentence to avoid awkwardness (i.e., "We examined 175 taxa . . ." rather than "One hundred and seventy-five taxa were . . ."). Usage can be confusing, and acceptable examples are: "Six genera were examined which contained a total of 26 species . . . ," ". . . 10 males among the seven groups could be classified into three categories . . . ," "The number of synapomorphies associated with each respective internodal segment in the phyletic sequence is: 3, 5, 13, 11, and 8." Values representing counts or distances should use their numerical rather than word equivalents, even if under 10; for example, in the Material Examined section of a taxonomic paper use the data format: ". . . 3 km E of Wilsonville, hwy 17, 6 males, 10 females, ..."

Comparative Ratios.—Use a slash (/) rather than "per" to indicate standard units in relation to other standard units (i.e., mg/liter, not mg per liter). Use "per" to indicate counts in relation to nonstandard units (i.e., 10 insects per leaf). Indicate ratios using a colon (i.e., 10 males : 1 female). Use a lower case "x" to indicate "times" in comparative ratios (i.e., mesothoracic width 0.8 x width).

Dates and Time.—Dates must be expressed in the format: day month year, without punctuation; not as: month day, year. Months are abbreviated as their first three letters in upper and lower case: Jan, Feb, Mar, Apr, May, Jun, Jul, Aug, Sep, Oct, Nov, Dec. Do not shorten the notation for the year, cite in full (i.e., 1989, not 89 or '89). Examples of acceptable dates are: 4 Jul 1990, 17 May 1753. Time is expressed in 24 hour format followed by h. If appropriate, time zones can be noted following the time, as a standard, three letter, upper case abbreviation. An example is 06:30 h (PDT), representing 6:30 AM, Pacific Daylight Time.

Italics.—Italics are indicated by underlining words. It is preferable not to use actual italicized words in a manuscript, even if the capability exists in word processing, but rather to use a single underline to denote words to be italicized; this promotes clarity and reduces the chance of error during the editing and type-setting stages of publication. Italics are used only for taxonomic names, for denoting minor subheading sections in the text, for highlighting categorical descriptors or "flags" within a block of text, and for denoting mathematical variables as in formulae. Italics may be used to denote a word which should stand out in a block of text. Examples are: the word "Thorax" when used within text comprising a taxonomic description; the name of a county (or equivalent) when used in a Material Examined section; the word "In" denoting a contribution to a larger work, as used in a bibliographic citation in the Literature Cited section. Do not use italics to emphasize a word for effect in a sentence (i.e., "Only *some* of the insects were . . ."). Do not indicate italics for Latin abbreviations such as: i.e., e.g., ca., sic., et al., etc.

Abbreviations.—Reference to tables should not be abbreviated in the text, whereas reference to figures should be (i.e., Table 4, Figs. 1–3, Fig. 6A); capitalize such references when they are part of the manuscript but not in citations from other articles (i.e., Hamilton 1983: fig. 2, Rolling 1975: table 2). Abbreviations for conventional units are in lower case letters and not followed by a period. Examples are: h, min, sec, km, m, mm, µm, cc, ml, g, mg, µg, kg. Spell liter completely, do not abbreviate as "l." Symbols for male (♂) and female (♀) may be used.

Avoid the use of ca. by using approximately instead. States should be spelled out in full, do not use their two letter postal abbreviations (except possibly in tables where space is at a premium). Do not abbreviate morphs, castes or life forms as their symbols. Do not include periods after, or spaces between, the letters of abbreviations of institutions (i.e., use USDA, NMNH and BM[NH] for U.S. Department of Agriculture, National Museum of Natural History and British Museum [Natural History], respectively). Abbreviate percent as %. Abbreviate feet as ft, not ('), when necessary in elevations, after altitude in meters. Trademarks and registered brand names are noted as ™ and ®, respectively.

Compass directions are presented entirely in upper case without periods (i.e., N, S, E, W, NW, SE, NEE, SSW). Direction from a source, as in data presented in the Material Examined section of taxonomic papers, should have the word "of" between the direction and source to avoid potential confusion in locality names (i.e., 3 km E of Palo Alto, instead of 3 km E Palo Alto, which should be taken as East Palo Alto rather than East of Palo Alto).

Taxonomic Studies and Citations

Taxonomic works present special editorial problems in maintaining relative consistency within and between articles on systematics within the journal. Because of these inherent problems, there is necessarily less flexibility for style and format in taxonomic works in the journal than for articles on solely biology. For detailed instructions see Pan-Pac. Ent. 69: 194–198.

Taxonomic Citations.—Upon the first mention of a species or lower level taxon in both the abstract and text, the author of an animal taxon must be cited using the International Commission of Zoological Nomenclature convention; botanical names must be so cited using the ICBN. Do not abbreviate the generic name of a taxon upon first mention. The names of authors of taxa must not be abbreviated, except for Linnaeus (as L.) and Fabricius (as Fabr.). If more than a single taxonomic author with the same last name worked in the taxonomic group considered, the author's initials should be used to avoid confusion (i.e., Papilio bairdii W. H. Edwards, to avoid confusion with H. Edwards who was also a lepidopterist). Multiple authorship for taxa should substitute an ampersand (&) for "and" between the names (i.e., Gillette & Palmer).

When citing authors of taxa, citation of the year of description is optional; if used, however, the year must be enclosed within parentheses and the citation must be considered a reference citation within the article and be listed in the Literature Cited section (see below for an exception). Examples are: Chaitophorus populellus Gillette & Palmer (1928) (where populellus was originally described in Chaitophorus), and Chaitophorus populifolii (Essig 1912) (where populifolii was not originally described in *Chaitophorus*). In these cases Gillette & Palmer (1928) and Essig (1912) must be listed in the Literature Cited section. If no year citation is noted for a species when citing its author, a literature citation is not invoked. The only exception to treating the author-year citation as a literature citation is in checklists and synonymies, where year citations may be more appropriate than in the text, and where the numbers of such citations would make literature citation unwieldy. In such cases, cite years as C. populellus Gillette & Palmer, 1928, and C. populifolii (Essig), 1912.

All nomenclature erected in taxonomic studies must follow the rules established in the most recent nomenclatural code by the ICZN. When mentioning the ICZN code, refer to it as such, rather than just "the code." At any mention of a particular article in the ICZN code, cite the publication date of the code version used, to avoid confusion (i.e., ". . . due to ICZN article 49 [ICZN 1985].") and list the code citation in the Literature Cited section (see the Literature Cited examples for citation of the ICZN code).

New taxa or synonymies that are erected should be clearly and appropriately marked, or "flagged," in upper case letters after mention in the text (i.e., NEW GENUS, NEW SYNONYMY, NEW STATUS, etc.), and notation should also occur in the abstract. New taxa must be listed with the name of the describing author(s), even if it is the same as the manuscript author, after the binomial but before any taxonomic "flag" (i.e., Diodontus retiolus Eighme, NEW SPECIES).

Descriptions and Diagnoses.—Taxa being described must have the following: a description (preferably with appropriate illustrations), and a separate diagnosis. The diagnosis must occur as a separate paragraph delimited as "Diagnosis.--" and must be concise but not in telegraphic style. Comment briefly and only on those attributes required to separate the taxon from related taxa in the diagnosis.

The description must be delimited by a minor subheading, as is the diagnosis; it need, however, not be labeled as "description" but rather can be labeled as a sex, life stage or form (i.e., male, egg, larvae, viviparous apterae, etc.). Descriptions must be concise and be in telegraphic style. It is preferable to separate major components with periods (i.e., legs), minor components with semicolons (i.e., tibiae, tarsi) and the details of minor components with commas (i.e., color of tibiae and the forms of setae on them). Avoid conjunctives as much as possible in telegraphic descriptions; also avoid "-ish" adjective suffix forms of colors, such as "head yellow with brownish" using instead "head yellow with slight brown"; avoid latin color descriptors (i.e., testaceous). An example is: ". . . Genitalia (Fig. 5A): valve breadth greatest ventrally, filling entire vinicular area, bilobed and constricted near indentation, caudal extension tapered, blunt terminally; saccus diminutive, lobate with rounded margins; aedeagus robust, ceacum two-fifths aedeagal length."

Types.—Descriptions and revisions also require comments on the types involved. Comments on types are to be in a separate paragraph delimited as "Types.--" that lists the type of type(s) (holotype, paratype, etc.) erected, and their data and deposition. An example is: "Holotype, male (Figs. 2E, 5A) deposited BM(NH), data: PERU. Cajamarca, 2800 m, Simons collection. Paratype, 1 male deposited NMNH, (poor condition with tails broken off), data: same as holotype but 3800 m, O. T. Baron collection, ex Hamilton collection 1919." When citing data from the labels of types it is permissible to quote within quotation marks. If not directly quoting from type labels, use the data format listed below for material examined. The deposition of types must be noted appropriately and be in accord with ICZN requirements. Deposition of types in private collections should be avoided for reasons of "professionalism," but when deposition is so designated, the ultimate intended deposition after the death of the author(s) should be stated; neotypes require institutional deposition (ICZN 1985: article 75-d-6).

Keys.—Keys are not required in taxonomic works, but are highly recommended. When presented, keys must be concise, clear, easy to follow and have reversibility provisions. Keys must also be in adjacent couplet style, and each couplet should contain preferably more than a single, nonoverlapping attribute. It must be clear to which life stage, sex, caste, morph, etc., the key pertains; keys requiring more than a single such life form are discouraged, and it is recommended that separate keys be provided in such cases.

Material Examined.—Data for material studied in taxonomic manuscripts must be listed under a separate paragraph delimited as "Material Examined.--." This taxonomic section should have the countries, as well as major (i.e., state, province) and minor (i.e., county or equivalent) political units spelled out in upper case, with the minor political units also underlined for italics. Use the following format, with modification as appropriate: USA, ARIZONA, *APACHE Co.:* 10 km N of Lupton, hwy 12, 2070 m, 11 Sep 1978, J. T. Sorensen (JTS 78I18), P. ponderosa, 6 females. *COCHISE Co.:* nr Rustler Park, Chiricahua Mts, 2500 m, 16 Sep 1978, J. T. Sorensen (JTS 78I47), P. ponderosa, 12 females. COLORADO. *ARCHULETA Co.:* 25 km W of Pagosa Springs, hwy 160, 2140 m, 8 Aug 1978, J. T. Sorensen (JTS 78H50), P. ponderosa, 1 female. CANADA. BRITISH COLUMBIA. Fairmont Hotsprings, hwy 93, 17 Jul 1978, J. T. Sorensen (JTS 78G91), P. ponderosa, 25 females.

Acknowledgment Page

Begin this section on a separate page and spell the heading as Acknowledgment, not as Acknowledgement, Acknowledgements or Acknowledgments. The acknowledgment should be concise, thanking people first, institutions second where necessary, and grant or contract support third where appropriate. Do not use the professional or academic titles of those being acknowledged. If the affiliations of those acknowledged are included, do not abbreviate institutional names but do include their locations. Do not abbreviate number as "No." or as "#" in citing grant or contracts; rather, for example, cite as "NSF grant BSR-8908456."

Literature Cited Pages

Begin this section on a separate page, titled Literature Cited, not References, References Cited or Bibliography. All paragraphs should be hanging format (left block first line and indented thereafter). Do not list references which are not cited in the text. Do not list unpublished data, personal communications, or works in preparation in the Literature Cited section. Citations listed should be in alphabetical order first and then in chronological order; if multiple citations bearing the same author(s) and year are cited, they should be listed using lower case letters after the year and be in the sequence in which they appear in the text. Do not use Ibid.

Authors cited are listed as last name first followed by initials for sole or senior authors and initials followed by last name for subsequent authors. Omit reference to number (issue) in citations after the volume. Omit the number of total pages in books, separates, pamphlets, etc. Abbreviate journal titles as listed in the International Serials Catalogue: Part I: Catalogue (International Council of Scientific Unions Abstracting Board, 1978). Do not abbreviate single word journal names (i.e., Evolution, Ecology). All citations must fully cite the authors, even when more than one article is present for any author(s). When listing articles or books, all letters in the title should be lower case, except the first letter of the title's first word and any proper nouns. Examples of acceptable citation formats follow:

One author articles:

Arnold, R. A. 1983. Speyeria callippe (Lepidoptera: Nymphalidae): application of information—theoretical and graph-clustering techniques to analyses of geographic variation and evaluation of classifications. Ann. Entomol. Soc. Am., 76: 929–941.

Two author articles:

Ferrari, J. A. & K. S. Rai. 1989. Phenotypic correlates of genome size variation in Aedes albopictus. Evolution, 42: 895–899.

Articles with more than two authors:

Atchley, W. R., E. V. Nordheim, F. C. Gunsett & P. L. Crump. 1982. Geometric and probabilistic aspects of statistical distance functions. Syst. Zool., 31: 445–460.

Manuscripts in press:

Sorensen, J. T. (in press). Three new species of Essigella (Homoptera: Aphididae). Pan-Pacif. Entomol.

Books:

Anderson, T. W. 1984. An introduction to multivariate statistical analysis (2nd ed.). John Wiley & Sons, New York.

Parts of larger works:

Klecka, W. R. 1975. Discriminant analysis. Chapter 23. pp. 434–465. In Nie, N. H., C. H. Hull, J. G. Jenkins, K. Steinbrenner & D. H. Brent. 1975. SPSS: statistical package for the social sciences (2nd ed.). McGraw-Hill, New York.

Blackman, R. L., P. A. Brown & V. F. Eastop. 1987. Problems in pest aphid taxonomy: can chromosomes plus morphometrics provide some answers? pp. 233–238. In Holman, J., J. Pelikan, A. G. F. Dixon & L. Weismann (eds.). Population structure, genetics and taxonomy of aphids and Thysanoptera. Proc. international symposium held at Smolenice Czechoslovakia, Sept. 9–14, 1985. SPB Academic Publishing, The Hague, The Netherlands.

Proceedings of meetings:

Philbrick, R. N. (ed.). 1967. Proceedings of the symposium on the biology of the California islands. Santa Barbara Botanic Garden, Santa Barbara, California.

Wilson, M. R. & L. R. Nault (eds.). 1987. Proceedings of the second international workshop on leafhoppers and planthoppers of economic importance, held In Provo, Utah USA, 28th July–1st August 1986. CAB International Institute of Entomology, London.

Governmental or institutional publications:

Little, E. L. Jr., & W. B. Critchfield. 1969. Subdivisions of the genus Pinus (Pines). U.S. Dept. Agric., Forest Serv. Misc. Publ., 1144.

Hafernik, J. E. Jr. 1982. Phenetics and ecology of hybridization in buckeye butterflies (Lepidoptera: Nymphalidae). Univ. Calif. Publ. Entomol., 96.

Anonymous institutional or organizational publications:

International Code of Zoological Nomenclature. 1985. (3rd ed.) International Trust for Zoological Nomenclature (BM[NH]). University of California Press, Berkeley, California.

California Department of Food & Agriculture. 1987. Environmental assessment of gypsy moth and its eradication in California, 1987 program. California Department of Food & Agriculture, Division of Plant Industry, Sacramento, California.

Theses and dissertations:

Sorensen, J. T. 1983. Cladistic and phenetic analysis of Essigella aphids: systematics and phylogeny in relation to their Pinaceae host plants (Homoptera: Aphididae, Lachninae). Ph.D. Thesis, University of California, Berkeley.

Computer programs:

Felsenstein, J. 1984. PHYLIP—Phylogeny inference package (Version 2.5). (A phylogenetics computer program package distributed by the author). J. Felsenstein, Dept. of Genetics, University of Washington, Seattle, Washington.

Pimentel, R. A. & J. D. Smith. 1985. Biostat II. (A multivariate computer program package distributed by the authors). Sigma Soft, Placentia, California.

Footnote Pages

All title and text footnotes must appear on a separate and numbered footnote page and be indicated by consecutive superscript numbers. Author-line footnotes that denote a change of affiliation or current address must also appear on the separate footnote page. Only multiple author and affiliation address footnotes (as described under the title page section) should not be on the footnote page. Text footnotes provide additional information and are usually discouraged; such information, if short, may preferably be enclosed within parentheses in the text. Footnotes cannot be used for acknowledgments, list these in the Acknowledgment section.

Figure Caption Page

Figure captions should briefly interpret the figures but need not be complete sentences. Captions should not unnecessarily repeat or explain information provided in the text. Be sure, however, to adequately explain any graphics that employ symbols (i.e., graphs, charts, scattergrams) in their figure captions. The caption for each plate or block of illustrations should be represented by a separate left block paragraph. If several figures are illustrated on a single plate, each figure may be cited separately as a sequential Arabic number. Alternatively, each individual figure making up a plate may be cited as a subcomponent and labeled sequentially and alphabetically (preferably as an upper case letter) when the plate itself bears a single Arabic number. In the former case, appropriate citation for a plate containing several figures would be the figure caption paragraph: "Figures 1–3. Thoracic morphology of Rhyacophila chordata (lateral views). Figure 1. Prothorax. Figure 2. Mesothorax. Figure 3. Metathorax." In the latter case, the paragraph would state: "Figure 1. Thoracic morphology of Rhyacophila chordata (lateral views). A. Prothorax. B. Mesothorax. C. Metathorax."

Do not use "multiple nested" explanations when multiple figures of different subjects appear on the same figure plate. For example, the following format is unacceptable: "Figures 1–4. Aphid taxonomic characters. Figures 1–2. Myzus persicae. Figure 1. Siphunculi. Figure 2. Cauda. Figures 3–4. Myzus cerasi. Figure 3. Siphunculi. Figure 4. Cauda." Instead use a format such as: "Figures 1–4. Aphid taxonomic characters. Figure 1. *Myzus persicae,* siphunculi. Figure 2. Myzus persicae, cauda. Figure 3. Myzus cerasi, siphunculi. Figure 4. Myzus cerasi, cauda."

Illustrations

Illustrations must be of high quality and large enough to stand reduction. Authors must plan their illustrations to reduce to a 117 × 181 mm (approximately 4.5 × 7.0 in) galley bed, allowing space for the figure caption below the figure. They are strongly encouraged, however, to provide illustrations which are not larger than 8.5 × 11 in format for easy handling; damage to larger illustration formats is the responsibility of the author(s). Do not attach legends to the illustrations. Figures must be numbered in the order presented. Multiple figures on a plate may be numbered or lettered (preferably upper case). All illustrations must be mounted; the editor will not handle loose illustrations.

Line drawings must be done in black, waterproof ink (i.e., India ink). The original drawings need not necessarily be submitted, but copies submitted must be of equal quality. Photostats (from negatives), the highest quality photocopies, or laser-printer output may be acceptable, provided the black lines are uniformly and absolutely black and the background is absolutely and uniformly white. Multiple figures on a plate must be grouped closely to eliminate unnecessary large spaces between the illustrations. Photographs must be trimmed and mounted, abutting each other; they must not be less than the width of the printed page. Lettering must be consistent throughout, and appropriately sized for the potential reduction so that it does not reduce to less than 1 mm. Lettering must be of quality appearance; hand lettering or typewriter lettering is not acceptable for illustrations.

If return of original illustrations is desired, request it when the manuscript is originally submitted. To avoid confusion and loss at the press, all original illustrations submitted should be labeled with nonreproducible, light blue pencil on the back noting the following: (1) figure number, (2) direction of top as indicated by an arrow, (3) author's name, (4) title of the manuscript, and (5) journal. For guidance in preparing illustrations for optimal presentation, consult the following books:

Hodges, E. R. S. (ed.) 1989. The guide handbook of scientific illustration. Van Nostrand Reinhold, New York.

Papp, C. S. 1976. Manual of scientific illustration, with special chapters on photography, cover design and book manufacturing. American Visual Aid Books, Sacramento, California.

TABLES

Because of the expense involved in reproducing tables, their use should be kept to a minimum. Tables should have a short title and be numbered in Arabic numerals (i.e., Table 1). Each table must be double-spaced and can be continued on additional sheets of paper as necessary. Do not reduce tables. Double-space all segments of the table, including title, heading, body and any footnotes. Use standard abbreviations for column heads. Nonstandard abbreviations may be used sparingly and must be defined in footnotes. Table footnotes are indicated by consecutive use of lower case letters. Tables must be numbered in the order presented.

SCIENTIFIC NOTES

As an alternative format, the Pan-Pacific Entomologist also publishes scientific notes to allow an outlet for contributions which are not judged suitable for full length articles. Scientific notes use an abbreviated format. The title is in full upper case and as a centered paragraph. No abstract, key words, footnotes or major and minor section headings are permitted. Minimal use of figures and tables is permitted.

A Literature Cited section is not allowed. Reference citations are kept to a minimum, but when necessary are cited initially in the format (Bohart, R. M. 1989. Pan-Pacif. Entomol., 65: 156–161.), without title. After being cited initially, if it becomes necessary to cite a reference again, simply cite it as author and year, in this instance: (Bohart 1989) or Bohart (1989). Avoid citing contributions to larger and edited works or those which entail lengthy citations, to maximize reading ease.

An Acknowledgment paragraph is permitted, but is handled as a paragraph with a left indented, minor subheading (i.e., Acknowledgment.--). Authors and affiliations are cited as the last left indented paragraph of the note, with the affiliation underlined for italics as:

John T. Sorensen, Insect Taxonomy Laboratory, California Department of Food & Agriculture. Sacramento, California 95814.

VOUCHER SPECIMENS

Where appropriate, manuscripts must name a public repository where specimens documenting the identity of the studied organisms can be found (see Pan-Pac. Ent. 73: 200). Please put in Materials and Methods section of the manuscript or in the text of scientific notes.

PAN-PACIFIC ENTOMOLOGIST
73(4): 256, (1997)

Pan-Pacific Entomologist Reviewers

Volume 73

Anderson, R.
Andrews, F.
Austin, JG.
Baranowski, R.
Becker, E.
Berenbaum, M.
Berlocher, S.
Bezark, L.
Brower, L.
Brownbridge, M.
Burdick, D.
Byers, G.
Campbell, J.
Chalfant, R.
Clark, D.
Cromartie, W.
Deyrup, M.
Dobson, H.
Ehler, L.
Fisher, E.
Garrison, R.
Gelhaus, J.
Gilbert, A.
Gill, B.
Gill, R.
Gordon, R.
Greenberg, B.
Hamilton, S.
Hardy, A.
Henry, T.
Hoffman, K.
Hovore, F.
Hunter, A.
Johnson, K.
Kimsey, L.
Krafsur, E.
Landolt, P.
Latheef, M.
Lee, V.
Lewis, V.
Luck, R.
Marsh, P.
McMillen, C.
Merickel, F.
Oswald, J.
Pickett, C.
Poole, R.
Price, P.
Ratcliffe, B.
Roubik, D.
Rust, R.
Rust, M.
Savary, W.
Shapiro, A.
Shepard, W.
Siebert, C.
Sikes, D.
Sorensen, J.
Thomas, D.
Waller, D.
Ward, P.
Wasbauer, M.
Wehling, W.
Weller, S.
Westcott, R.
Whaley, W.
Whitfield, J.
Wood, D.
Wood, S.
Yokoyama, V.
Young, C.
Zera, A.

PAN-PACIFIC ENTOMOLOGIST
73(4): 257–259, (1997)

The Pan-Pacific Entomologist

Contents for Volume 73

PAN-PACIFIC ENTOMOLOGIST
73(4): 260–261, (1997)

The Pan-Pacific Entomologist Index to Volume 73 (title and key words)

PAN-PACIFIC ENTOMOLOGIST
73(4): 262, (1997)

Announcement

Publications of the Pacific Coast Entomological Society

PROCEEDINGS OF THE PACIFIC COAST ENTOMOLOGICAL SOCIETY

Vol. 1 (16 numbers, 179 pages) and vol. 2 (9 numbers, 131 pages). 1901–1930. Price $5.00 per volume.

THE PAN-PACIFIC ENTOMOLOGIST

Vol. 1 (1924) to vol. 51 (1975), price $10.00 per volume of 4 numbers, or $2.50 per single issue. Vol. 52 (1976) to vol. 57 (1981), price $15.00 per volume or $3.75 per single issue, except for vol. 57, no. 1, $10.00. Vol. 58 (1982) to vol. 66 (1990), $20.00 per volume or $5.00 per single issue. Vol. 67 (1991) to vol. 69 (1993), $30.00 per volume or $7.50 per single issue. Vol 70 (1994) and subsequent issues, $40.00 per volume or $10.00 per single issue.

MEMOIRS OF THE PACIFIC COAST ENTOMOLOGICAL SOCIETY

Volume 1. *The Sucking Lice* by G. F. Ferris. 320 pages. Published October 1951. *OUT-OF-PRINT.*

Volume 2. *A Revision of the Spider Mite Family Tetranychidae* by A. Earl Prichard and Edward W. Baker. 472 pages. Published July 1955. OUT-OF-PRINT.

Volume 3. *Revisionary Studies in the Nearctic Decticinae* by David C. Rentz and James D. Birchim. 173 pages. Published July 1968. Price $4.00* (plus $0.75 postage and handling).

Volume 4. *Autobiography of an Entomologist* by Robert L. Usinger. 343 pages. Published August 1972. SPECIAL PRICE $5.00 (plus $1.00 tax, postage, and handling for California orders, 0.70 postage and handling for non-California U.S. orders, or $1.70 for foreign orders). No members discount at this special price.

Volume 5. *Revision of the Millipede Family Andrognathidae in the Nearctic Region* by Michael R. Gardner. 61 pages. Published January 21, 1975. Price $3.00* (plus $0.75 postage and handling).

*For California orders only, add appropriate sales tax currently in effect in your country. If requested, members of the Society can receive a 20% discount on the price of the memoirs, except vol. 4.

Send orders to:

Pacific Coast Entomological Society
% California Academy of Sciences
Golden Gate Park
San Francisco, California 94118-4599
U.S.A.

PAN-PACIFIC ENTOMOLOGIST
73(4): 263, (1997)

Editorial Policy Change

Beginning with manuscripts submitted after 1 January 1998, The Pan-Pacific Entomologist will require that voucher specimens for all articles be deposited in a properly maintained collection accessible to other scientists. This policy represents a departure in tradition for non-taxonomic studies that is necessitated by the rapid discovery of numerous cryptic species and species complexes. These situations make it imperative that future scientists be able to confirm exactly what species was studied in past papers. The uncertainty surrounding whether older studies used *Bemisia tabaci* (Gennadius) or *Bemisia argentifolii* (Bellows & Perring) is a good example of a situation that could have been avoided if voucher specimens were available. Similar confusion surrounds older studies of *Bactrocera dorsalis* (Hendel) from numerous locations, several *Rhagoletis* species and numerous aphids. The location at which the voucher specimen(s) have been deposited and the coding necessary to access them shall be noted in the Materials and Methods section of the article or the text of the scientific note.

PAN-PACIFIC ENTOMOLOGIST

Information for Contributors

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.

Data Formats. — All specimen data must be cited in the journal's locality data format. See volume 69(2), pages 196–198 for these format requirements; if you do not have access to that volume, request a copy of the taxonomy/data format from the editor before submitting manuscripts for which these formats are applicable.

Literature Cited. — Format examples are:

Anderson, T. W. 1984. An introduction to multivariate statistical analysis (2nd ed). John Wiley & Sons, New York.

Blackman, R. L., P. A. Brown & V. F. Eastop. 1987. Problems in pest aphid taxonomy: can chromosomes plus morphometrics provide some answers? pp. 233–238. *In* Holman, J., J. Pelikan, A. G. F. Dixon & L. Weismann (eds.). Population structure, genetics and taxonomy of aphids and Thysanoptera. Proc. international symposium held at Smolenice Czechoslovakia, Sept. 9–14, 1985. SPB Academic Publishing, The Hague, The Netherlands.

Ferrari, J. A. & K. S. Rai. 1989. Phenotypic correlates of genome size variation in *Aedes albopictus*. Evolution, 42: 895–899.

Sorensen, J. T. (in press). Three new species of *Essigella* (Homoptera: Aphididae). Pan-Pacif. Entomol.

Illustrations. — Illustrations must be of high quality and large enough to ultimately reduce to 117 × 181 mm while maintaining label letter sizes of at least 1 mm; this reduction must also allow for space below the illustrations for the typeset figure captions. Authors are strongly encouraged to provide illustrations no larger than 8.5 × 11 in for easy handling. Number figures in the order presented. Mount all illustrations. Label illustrations on the back noting: (1) figure number, (2) direction of top, (3) author's name, (4) title of the manuscript, and (5) journal. FIGURE CAPTIONS must be on a separate, numbered page; do not attach captions to the figures.

Tables. — Keep tables to a minimum and do not reduce them. Table must be DOUBLE-SPACED THROUGHOUT and continued on additional sheets of paper as necessary. Designate footnotes within tables by alphabetic letter.

Scientific Notes. — Notes use an abbreviated format and lack: an abstract, key words, footnotes, section headings and a Literature Cited section. Minimal references are listed in the text in the format: (Bohart, R. M. 1989. Pan-Pacific. Entomol., 65: 156–161.). A short acknowledgment is permitted as a minor headed paragraph. Authors and affiliations are listed in the last, left indented paragraph of the note with the affiliation underscored.

Page Charges. — PCES members are charged $35.00 per page, for the first 20 (cumulative) pages per volume and full galley costs for pages thereafter. Nonmembers should contact the Treasurer for current nonmember page charge rates. Page charges do not include reprint costs, or charges for author changes to manuscripts after they are sent to the printer. Contributing authors will be sent a page charge fee notice with acknowledgment of initial receipt of manuscripts.

THE PAN-PACIFIC ENTOMOLOGIST
Volume 73 **October 1997** **Number 4**

Contents

SCIENTIFIC NOTES