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MATERNAL EFFECTS AND EGG HATCHABILITY IN *MELANOPLUS* (ORTHOPTERA: ACRIDIDAE)

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Abstract.—Continuous culturing of nondiapause strains of *Melanoplus* is possible because eggs are able to hatch within a short period of time and without the requirement of cold exposure. Analysis of intercross data involving field and nondiapause strains reveals that the proportion of eggs with this property is under maternal influence and, in some cases, a function of the egg's genotype. The problem of loss of genetic variation that is often associated with laboratory strain maintenance is discussed and a solution that capitalizes on maternal effects is offered.

Key Words.—Insecta, Orthoptera, Acrididae, *Melanoplus,* hatchability, maternal effects

The central and desirable feature of the much used nondiapause strain of *Melanoplus sanguinipes* Fabr., developed by Pickford & Randell (1969), and of the recently established nondiapause strain of *M. differentialis* (Thomas) (Oma et al. 1990), is the ability of eggs to hatch in a relatively short period of time (about 21 days at 30° C for *M. sanguinipes*) without the requirement of cold treatment. In this paper the term "egg hatchability" is restricted to this usage, which in reality is equivalent to the proportion of nondiapausing eggs; indeed, it is this trait that was selected for by the developers of these nondiapause cultures. There is no doubt that egg hatchability has a heritable basis, and although the mode of inheritance is presently unknown, polygenic inheritance is likely involved judging from the slow responses to selection for the trait (Slifer & King 1961). Environmental factors, such as temperature and photoperiod (Oma et al. 1990), can also influence hatchability; these agents probably interact with genotype to account for latitudinal variations in voltinism that are observed in the United States. Maternal effects, genic or nongenic (mediated, for example, through maternal nutrition), result in offspring with phenotypes more similar to those of the female parent than to those of the male parent (Mather & Jinks 1982). Such effects were recently suspected during hybridization experiments (WC, unpublished data) when the species status of distant populations of *M. sanguinipes* and the nondiapause strain noted were examined. To support the claim for maternal effects, an analysis of these data and results collected 27 years ago (PWR, unpublished data) on *M. sanguinipes* and *M. packardii* Scudder is presented.

MATERIALS AND METHODS

Data were gathered separately by the authors. In studies by WC, the following field populations were sampled. Fourth and fifth instars of *M. sanguinipes* were collected near Bethune, Saskatchewan (Bet); Rigaud, Quebec (Que); and Green Mountain Road, British Columbia (BC) during the spring and summer of 1981. Insects were sexed, separated and allowed to mature in laboratory cages until commencement of matings. Adult *M. sanguinipes* were sampled from West Lafayette, Louisiana (Lo); Trinity Texas (Tx1); Oakhurst, Texas (Tx2); and Prescott, Arizona (Az) during the spring and summer of 1980. Insects were allowed to

Table 1. Mean (±SE) hatchability of field strains and of crosses with nondiapause strains of *Melanoplus sanguinipes* (NDwc and NDpr) and *M. packardii* (NDpr-pac).

Strain	Strain values	Crossed with ND ♀♀	Crossed with ND ♂♂
NDwc	78.8 ± 2.4 (111)[a]	—	—
Bet	0.3 ± 0.3 (22)	87.2 ± 3.4 (26)	22.4 ± 5.9 (31)
Que	2.6 ± 1.3 (36)	54.0 ± 5.1 (43)	0.0 ± 0.0 (11)
BC	25.2 ± 4.5 (49)	79.4 ± 6.3 (24)	5.1 ± 2.8 (7)
Lo	30.4 ± 6.4 (38)	55.3 ± 5.9 (42)	42.7 ± 8.6 (24)
Tx1	38.9 ± 6.9 (21)	50.7 ± 8.2 (14)	21.7 ± 13.6 (5)
Tx2	30.6 ± 13.6 (7)	70.5 ± 7.6 (21)	9.7 ± 7.6 (8)
Az	38.7 ± 6.8 (34)	91.8 ± 2.6 (22)	43.1 ± 7.4 (28)
NDpr	81.7 ± 2.7 (100)	—	—
Wyn	NA	83.5 ± 2.7 (61)	23.1 ± 2.3 (168)
NDpr-pac	76.4 ± 1.5 (305)	—	—
Dav	26.2 ± [b] (49)	68.9 ± 4.9 (53)	25.8 ± 3.4 (67)

[a] n = number of pods.
[b]—no standard error because pods hatched in groups.
NA—not available.

deposit eggs in cages available in the laboratories of resident colleagues (see Acknowledgment). Harvested eggs (F_1 of field animals) were sent to the University of Regina and the emergent offspring used for these studies. All strains were crossed reciprocally with the nondiapause strain (NDwc) developed by Pickford & Randell (1969) beginning with material collected near Delisle, Saskatchewan (Pickford 1958). In addition, two of the above field populations, Que and BC, were mated reciprocally. Experimental conditions were essentially the same as those in Chapco (1984). About 10 pairs of virgin adults were introduced into standard Hunter-Jones cages. Dead insects were removed and replaced with virgins, if available. Egg pods were collected daily until most or all egg layers were dead and then individually transferred to shell vials with moistened vermiculite and incubated at 30° C for a maximum of 50 days, a length well beyond the period required for the nondiapause strain. Hatchlings were counted daily and removed. Hatchability for each pod was obtained by dividing hatchling number by the total number of eggs, determined by summing the former figure and the number of unhatched eggs.

In studies by PWR, fifth instars of *M. sanguinipes* and *M. packardii* were sampled from Wynyard (Wyn) and Davidson (Dav), Saskatchewan, respectively and allowed to mature in the laboratory. The former was crossed reciprocally (14 pairs) with Pickford and Randell's nondiapause strain (in its 45th generation of selection at the time of the study) and the latter (10 pairs) with a nondiapause strain (in its seventh generation of selection for nondiapause) initiated by PWR. To avoid confusion with NDwc used by WC, the nondiapause strains of PWR are labelled NDpr and NDpr-pac, respectively. Experimental conditions were the same as those of WC except that egg pods were transferred to petri dishes containing moistened filter paper.

Statistical significance of reciprocal differences and of other linear contrasts (see below) was assessed by a modified t-test that takes into account unequal sample variances (Zar 1984), which is the case here. Nonparametric tests of significance

Table 2. Analysis (*t*-tests) of reciprocal differences (maternal effects) and homogenic vs heterogamic mating differences (egg effects).

Strain	Reciprocal differences	ND strain vs ND ♀♀ × field ♂♂	Field strain vs field ♀♀ × ND ♂♂
Bet	***	*	***
Que	***	***	ns
BC	***	ns	***
Lo	ns	***	**
Tx1	ns	**	ns
Tx2	***	ns	ns
Az	***	***	ns
Wyn	***	ns	—
Dav	***	ns	—

ns—not significant.
*—$P < 0.05$.
**—$P < 0.01$.
***—$P < 0.001$.

(Campbell 1967) essentially yielded the same conclusions as the *t*-tests, attesting to the robustness of the latter.

Results and Discussion

Mean percent hatchabilities along with standard errors are presented in Table 1 for the field strains and reciprocal crosses with nondiapause strains. Hatchabilities for the WC field material ranged from almost 0 (Bet) to 39% (Tx1), far below the value for the nondiapause strain, 79%. A comparison of values for reciprocal crosses suggests a maternal influence on the trait. In general, hatchabilities of eggs laid by nondiapause females mated with field males are consistently greater (significantly so in 5 cases; Table 2) than values for the reciprocal crosses. For example, the hatchability of eggs produced by the cross, NDwc ♀♀ × Bet ♂♂, exceeds the value for Bet ♀♀ × NDwc ♂♂ by about 65%. The phenomenon is apparently not restricted to the nondiapause strain. Que and BC are two field strains that differ in hatchability and exhibit significant reciprocal differences ($P < 0.01$): values for Que ♀♀ × Bet ♂♂ and Bet ♀♀ × Que ♂♂ are 0.7 ± 0.7 (10) and 39.2 ± 9.9 (9), respectively. Analysis of the PWR data on *M. sanguinipes* and *M. packardii* also reveals significant differences between reciprocal crosses (Table 2) adding further support to the claim for maternal effects. It is difficult to assess what these effects really represent. Had all strains been reared under the same conditions, the claim could be made that maternal effects are genotypically mediated on the female parent's side. This conclusion may be valid for the southern populations since insects were uniformly treated (at the University of Regina) and reared from eggs that had been sent although transgenerational effects are not unknown (Sander et al. 1985). In any case, the experimental design precludes a proper separation of genetic and environmental factors that underly the maternal effects.

Despite the ambivalence regarding inheritance and hatchability at the maternal level, a genetic analysis is possible, but at the level of the egg. The availability, on the whole, of two sets of homogamic and heterogamic crosses permits an examination of the possible role of the egg's genotype on hatchability. If maternal effects, genic or nongenic, were entirely responsible for the trait, then it would be expected that values would be the same irrespective of the source of the male. To test this possibility, differences between means for crosses with the same maternal type were examined (Table 2, last two columns). Out of a total of nine contrasts involving nondiapause females, there were five significant differences and out of a total of seven contrasts involving field females, there were three significant differences. The magnitude of these differences varies. To illustrate, in the Quebec study, the hatchability of eggs laid by NDwc females mated to Que males is in the same direction as that for the NDwc strain (i.e., indicating a maternal effect), but the value (54%) is significantly less than the value for NDwc (79%). In a few situations the hatchability of F_1 eggs is greater than the corresponding parental value, a result that suggests heterotic effects. For instance, the hatchability associated with the cross, NDwc ♀♀ × Az ♂♂, is 92%, a value significantly greater than the figure for NDwc. It would appear, therefore, that the genotype of the egg can, in some cases, influence its hatchability.

The findings with respect to maternal effects are germane to those wishing to maintain cultures of nondiapause grasshoppers that serve as model systems for purposes of investigating natural populations. It is not uncommon for laboratory strains to experience a reduction in numbers and a subsequent loss of genetic variation, or experience inadvertent selection as a result of adaptation to laboratory conditions. After a number of generations, a laboratory strain may no longer be representative of its species. The problem can be ameliorated to some extent by mating virgin females from the nondiapause strain with field-caught males thereby increasing the storehouse of genetic variation. By virtue of the maternal influence revealed in this paper, the inconvenience that diapause would otherwise present can be circumvented. Indeed, two such "hybrid strains" had been successfully propagated with the Louisiana and Arizona materials for seven generations, when they were terminated.

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LIFE HISTORY AND DESCRIPTIONS OF IMMATURE STAGES OF *TEPHRITIS BACCHARIS* (COQUILLETT) ON *BACCHARIS SALICIFOLIA* (RUIZ & PAVON) PERSOON IN SOUTHERN CALIFORNIA (DIPTERA: TEPHRITIDAE)

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Abstract.—*Tephritis baccharis* (Coquillett) is bivoltine and monophagous on *Baccharis salicifolia* (Ruiz & Pavon) Persoon in southern California. The egg, second and third instar larvae, and puparium are described and illustrated. Eggs are inserted singly into terminal buds of main and axillary branches in late winter or early spring. First instar larvae hatch and tunnel into the pith just basad to the apical bud where they initiate gall formation. Gall and larval growth continue slowly into the fall, when pupation occurs. Most F_1 flies emerge, mate, and after about one week begin oviposition. Some F_1 flies that emerge in the fall may overwinter as adults; however, a few F_1 individuals may not emerge and instead overwinter as pupae in puparia in mature galls. Second and third instar, F_2 larvae also overwinter in developing galls. Flies were long-lived under laboratory conditions; males and females lived an average of 140 days and 83 days, respectively. This longevity and the long fecundity period of females allow *T. baccharis* to attack the new buds and branch growth produced by *B. salicifolia,* because this phraetophyte is capable of protracted, nearly year-round vegetative growth and flowering in southern California.

Principal natural enemies of *T. baccharis* include three, solitary, primary, parasitoids, *Pnigalo* sp. (Hymenoptera: Eulophidae), *Halticoptera* sp. and *Pteromalus* sp. (Hymenoptera: Pteromalidae), and unidentified birds as important predators on overwintering larvae in galls.

Key Words.—Insecta, biology, gall, parasitoids, bird predation, mating behavior, chemosensilla

Among 18 described species of *Tephritis* indigenous to North America (Foote 1960, Stolzfus 1977, Foote & Blanc 1979, Jenkins & Turner 1989), only the biology of *T. stigmatica* (Coquillett) on *Senecio* spp. heretofore was well known (Tauber & Toschi 1965, Goeden 1988a). This paper details the biology of a second Nearctic species, *T. baccharis* (Coquillett), on *Baccharis salicifolia* (Ruiz & Pavon) Persoon [= *B. glutinosa* Persoon and *B. viminea* deCandolle (McVaugh 1984)], Asteraceae in southern California.

Interest has been expressed in the biological control of *B. salicifolia* (Boldt & Robbins 1990), other *Baccharis* spp. (Boldt & Robbins 1987, Boldt et al. 1988), and other indigenous weeds (Pemberton 1985) in the U.S. with natural enemies obtained from South America. Also, stenophagous *Baccharis,* feeding insects from North America have been imported to Australia for the biological control of *B. halimifolia* L. (Palmer 1987, Julien 1987, Palmer & Bennett 1989).

Materials and Methods

Field observations, laboratory examination, and the rearing of field collected galls from several locations (see below) in southern California during 1983–1990 provided most of the information reported herein. These field data were supplemented by laboratory cagings, in 1989, of single males and females or paired reared adults of opposite sex. The adults were reared in 850 ml, clear plastic cages fitted with screened lids for ventilation and basal water reservoirs in which absorbant cotton wicks and bouquets of excised vegetative branches of *B. salicifolia* were emersed through a hole in each cage bottom. Honey striped with a bulb and syringe on the underside of the lids provided food for the flies. Flies or parasitoids were reared from larvae and puparia dissected from galls held separately in cotton-stoppered, glass, shell vials within humidity chambers at 22–24° C and 76% RH.

Plant names follow Munz (1974) and McVaugh (1984); tephritid names follow Jenkins & Turner (1989). Voucher specimens of *T. baccharis* from each study site are located in the research collection of RDG (Department of Entomology, University of California, Riverside). RDG also has established a separate collection of hymenopterous parasitoids of California Tephritidae; DHH has established a separate collection of immature Tephritidae.

Immature stages were described from two eggs dissected from buds (laboratory cagings), a second and third instar larva, and a puparium dissected from galls. Larvae and eggs were treated for scanning electron microscopy (SEM) as described in Headrick & Goeden (1990a). Specimens were examined and micrographs prepared at 15 kV accelerating voltage, using Polaroid SS P/N film on a JEOL JSM-C35 SEM, located in the Department of Nematology, University of California, Riverside. The third instar larva is described in detail using the nomenclature and format adopted by Headrick & Goeden (1990a); the second instar larva description is limited to observed differences. Means ± SE are provided throughout the paper.

Taxonomy

Coquillett (1894) described *T. baccharis* as a *Trypeta*. Jenkins & Turner (1989) revised the *Baccharis*-infesting tephritids of North America, reviewed the taxonomy, designated the lectotype, illustrated and measured ova, and described and illustrated important characters of adult *T. baccharis*.

Egg.—Five eggs dissected from oviposition punctures (Fig. 1A) were white, fusiform, 0.68 ± 0.02 mm long and 0.26 ± 0.01 mm wide. The chorion is reticulated and the apex bears a 0.04 mm button-like, honey-combed pedicel (Fig. 2A). Polygonal reticulation of the chorion (Fig. 2B) is common to all eggs of Tephritidae examined to date (by DHH), but is highly developed in *Tephritis* species, especially *T. baccharis* (Jenkins & Turner 1989). An unusual feature of the reticulation is its differential complexity. The end embedded in plant tissue has more shallow fenestrations (Fig. 2C), which increase in height and become topped with papillae toward the heavily ridged pedicel (Fig. 2D). The plant itself may provide some measure of protection for the smooth end of the egg, which probably has little gas exchange function for the developing embryo, because it is inside plant tissue. The polygonal reticulation strengthens the exposed chorion, protecting not only the embryo, but also the pedicel through which most gas exchange probably takes place (as seen in a more exaggerated form in the eggs of *Paracantha gentilis* Hering [Headrick & Goeden 1990a]).

Third Instar Larva.—A single third instar larva measured 5.3 mm long and 2.5 mm wide (Fig. 3A). It is creamy white, superficially smooth, elongate, cylindrical, tapered and bluntly rounded anteriorly, and gradually increasing in width to its truncate posterior end.

The gnathocephalon is less conical and more reduced, and the rugose pads are

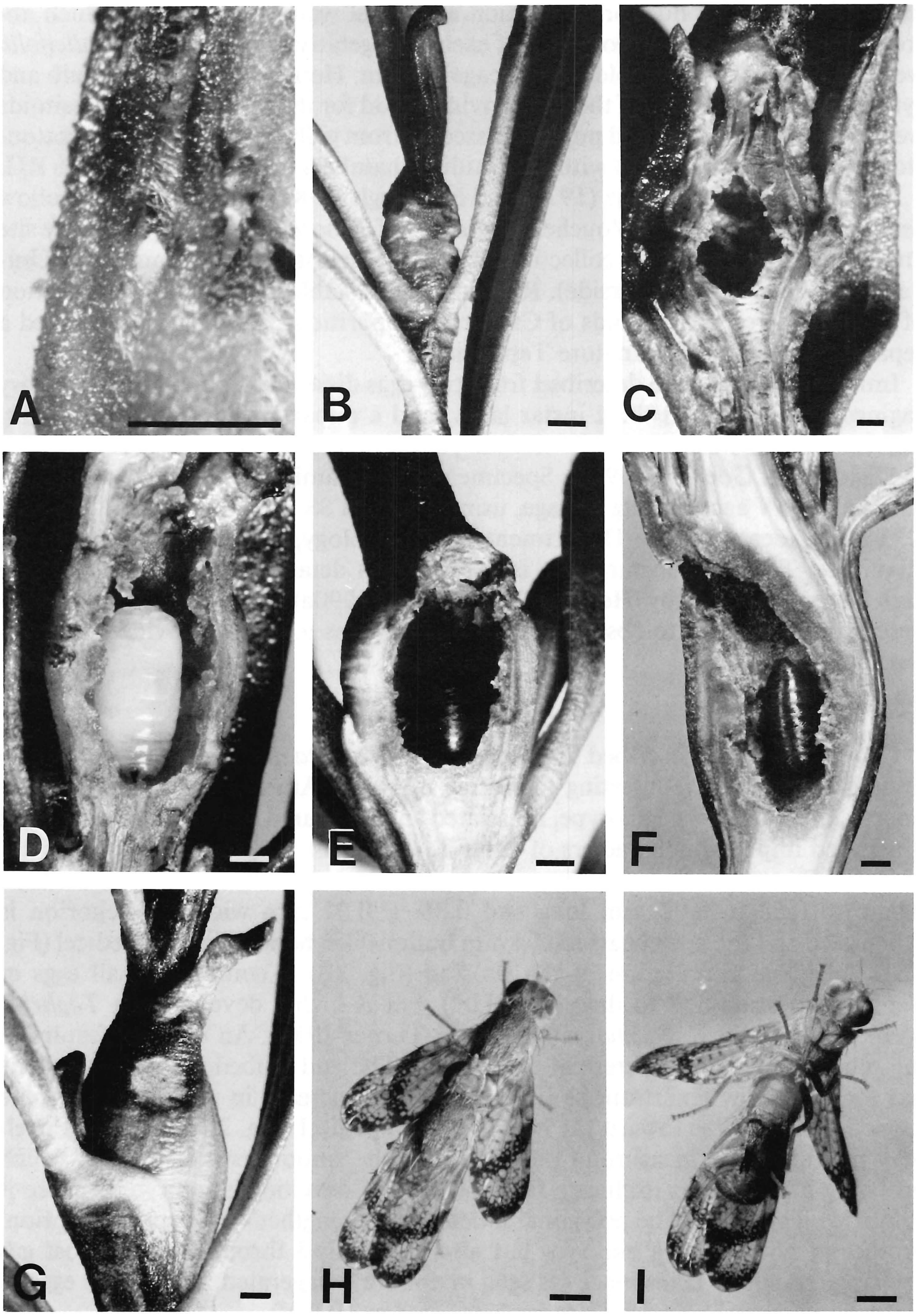


Figure 1. Life stages and galls of *Tephritis baccharis* on *Baccharis salicifolia*: (Bar = 1 mm) (A) egg protruding from ovipositional puncture in bud; (B) lateral view of small, immature gall; (C) sagittal section through small immature gall exposing feeding chamber; (D) third instar larva in feeding chamber in full-size gall; (E) gall with apical meristem killed by larval feeding; (F) puparium in feeding chamber below exit tunnel for adult; (G) lateral view of mature gall with round window through which adult emerges; (H) mating adults, dorsal view; (I) mating adults, ventral view.

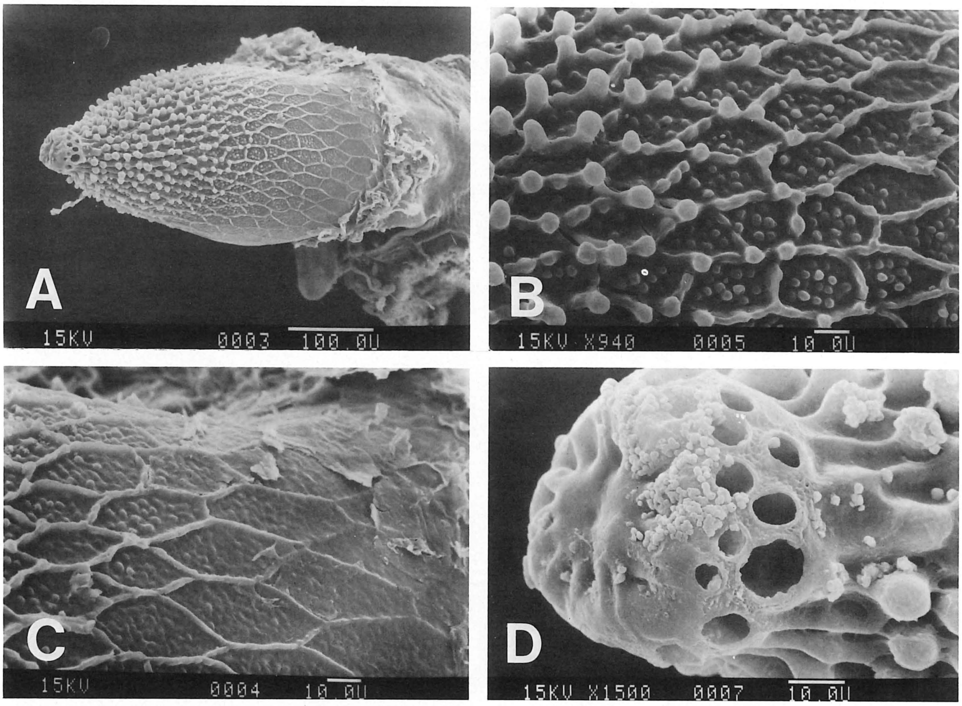
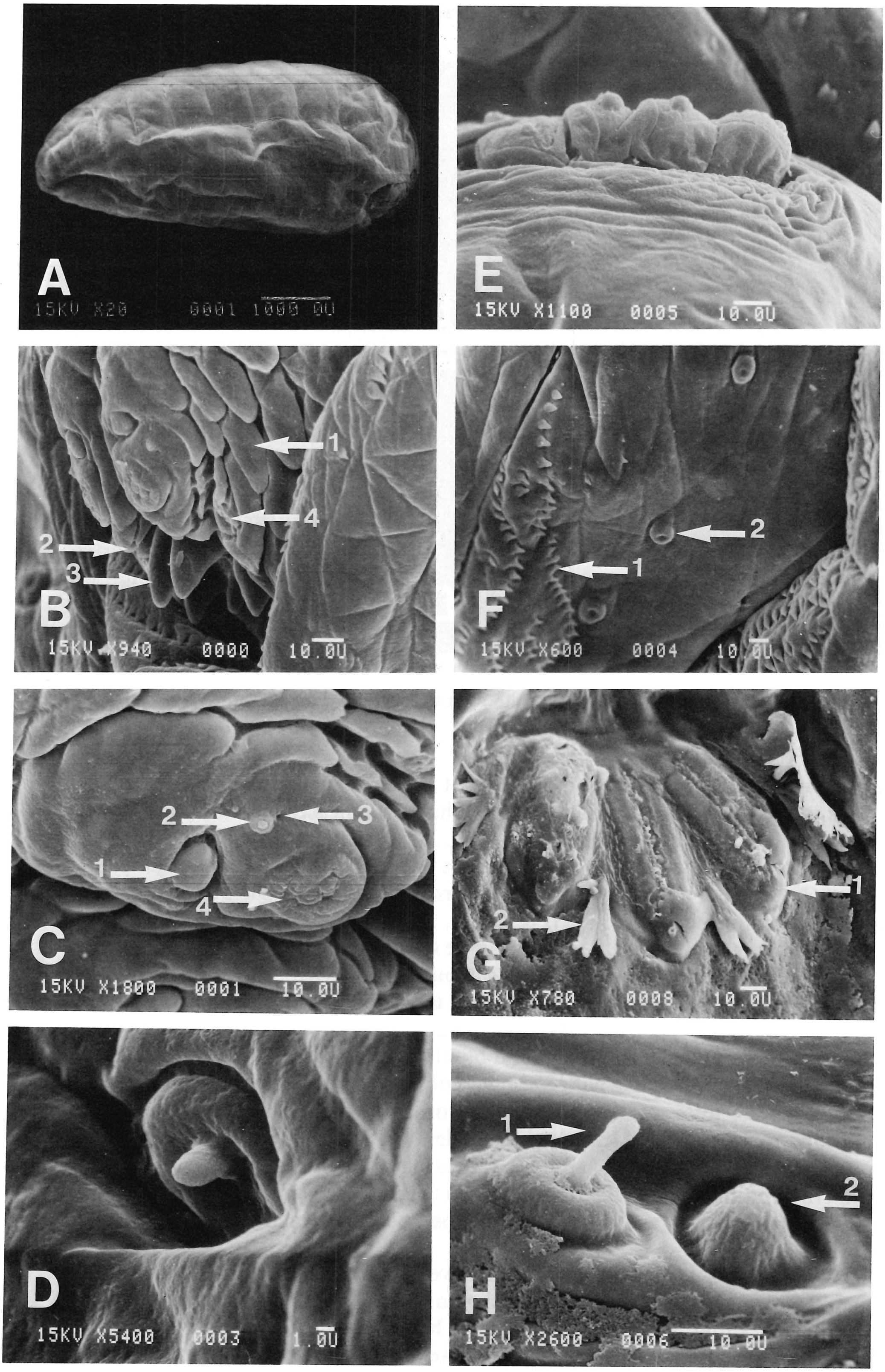


Figure 2. Egg of *T. baccharis*: (A) habitus, dissected from *B. salicifolia*; (B) detail of polygonal reticulation; (C) detail of point of insertion into plant tissue; (D) pedicel at exposed end of egg.

more dorsoventrally elongate than in most species of tephritid larvae examined by us to date (Fig. 3B: 1). The gnathocephalon bears flattened anterior sensory lobes separated by a medial depression (Fig. 3C). The paired dorsal sensory organs lie just dorsad of the anterior sensory lobes and are composed of a single papilla (Fig. 3C: 1). The sensory lobes bear the lateral sensory organ, the pit sensory organ and the terminal sensory organ (Fig. 3C: 2, 3, 4), which share the same structure and placement as with other tephritid larvae examined to date (DHH, unpublished data). The integumental petals which surround the mouth lumen (Fig. 3B: 2) are much reduced in comparison with other tephritid larvae (e.g., *Stenopa affinis* Quisenberry [Goeden & Headrick 1990]). The mouth hooks are heavily sclerotized and tridentate. The teeth are stout and bluntly conical (Fig. 3B: 3). A median oral lobe, which was not visible with SEM, was observed with a dissecting microscope; this brings the total number of nonfrugivorous tephritid larvae with a median oral lobe to 15 species (Headrick & Goeden 1990a; Goeden & Headrick 1990; DHH, unpublished data). Lateral lobes bearing several sensilla were located dorsolaterally on the edge of the mouth lumen (Fig. 3B: 4), are similar in placement, and share similar types of sensilla to those observed in *S. affinis* (Goeden & Headrick 1990).

The prothorax is smooth and bears several flattened sensilla. Larvae of Tephritidae typically have flattened sensilla on the prothorax (Foote 1967, Headrick & Goeden 1990a); however, *T. baccharis* has at least four sensilla, each with a finger-like projection surrounded by a collar. These sensilla may be mechanically


A
15KV X20 0001 1000 0U
E
15KV X1100 0005 10.0U
1
4
2
3
B
15KV X940 0000 10.0U
2
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F
15KV X600 0004 10.0U
2
3
1
4
C
15KV X1800 0001 10.0U
1
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G
15KV X780 0008 10.0U
D
15KV X5400 0003 1.0U
1
2
H
15KV X2600 0006 10.0U

stimulated by deflection (Fig. 3D). The anterior thoracic spiracle is located dorsolaterad on the posterior margin and bears four papillae, each in turn topped with a distinct, smooth, rounded smaller papilla (Fig. 3E).

The succeeding segments are superficially smooth and demarcated by a depression that circumscribes the body. The integument adjacent to the segmental line is reticulated with shallow depressions and has intersegmental bands of minute acanthae (Fig. 3F: 1). Each segment bears a group of three sensilla arranged in a vertical row, posterior to the segmental line on the lateral aspect of the body (Fig. 3F: 2). The sensilla are smooth with a central pore, and are similar in shape and placement to the lateral sensilla described for *S. affinis* (Goeden & Headrick 1990).

The caudal segment bears the posterior spiracular plates composed of three elongate oval rimae about 0.07 mm long (Fig. 3G: 1), and four interspiracular processes with two to five branches; the longest process measured 0.03 mm in length (Fig. 3G: 2). The caudal segment also has the typical arrangement of sensory papillae that includes dorsal, lateral and ventral pairs of finger-like projections in a basal collar located on the posterior margin of the body (Fig. 3H: 1). A tuberculate chemosensillum is associated with each of the two dorsal sensilla in a shallow depression (Fig. 3H: 2). On the apex of the chemosensillum is a raised crown that bears several open pores. This sensillum has not been observed or described for any other tephritid larva to date (DHH, unpubl. data).

Second Instar Larva.—A second instar larva dissected and examined from an overwintering gall measured approximately 3.5 mm long and 1.5 mm wide (Fig. 4A). It is a translucent white, cylindrical, with a cone-shaped gnathocephalon, and rounded posteriorly. Most structures were similar in shape and placement to those of the third instar larva. The gnathocephalon is slightly rugose, with elongate pads as seen in the third instar. The anterior lobe is flattened and bears all three sensory organs as well as the closely associated dorsal sensory organ. The mouth hooks are bidentate and not bluntly rounded at the apex as in the third instar larva. The caudal segment has dorsal, lateral and ventral finger-like sensilla around the posterior margin. The posterior spiracular plates bear three rimae and interspiracular processes with one or two blades about 0.01 mm in length.

Puparium.—Fifty-two of 61 puparia of *T. baccharis* dissected from galls averaged 1.99 ± 0.03 (range, 1.50–2.31) mm in widest width, and 40 of these that were intact averaged 4.37 ± 0.07 (range, 3.34–5.59) mm in length. The puparia are superficially smooth, distinctly segmented, elongate ellipsoidal, anteriorly rounded, and slightly flattened posteriorly and dorsoventrally. The anterior end bears the invagination scar of the mouth and the anterior thoracic spiracles (Fig. 4B: 1, 2). The posterior end is finely wrinkled without protruding spiracular plates (Fig. 4C). One of 61 puparia dissected from galls was mostly unpigmented and black only at both ends; all other puparia were uniformly black. Goeden (1988a)

←

Figure 3. Third instar larva of *T. baccharis*: (A) habitus, anterior end at left; (B) detail of gnathocephalon, 1—rugose pads, 2—integumental petals, 3—mouth hooks, 4—lateral sensory lobes; (C) anterior sensory lobes (dorsal at left), 1—dorsal sensory organ, 2—lateral sensory organ, 3—pit sensory organ, 4—terminal sensory organ; (D) sensillum on anterior of prothorax; (E) anterior thoracic spiracles; (F) lateral aspect of the body, 1—acanthae, 2—lateral sensilla; (G) posterior spiracular plate (dorsal at right), 1—rimae, 2—interspiracular processes; (H) posterior sensilla, 1—finger-like process, 2—dome sensillum.

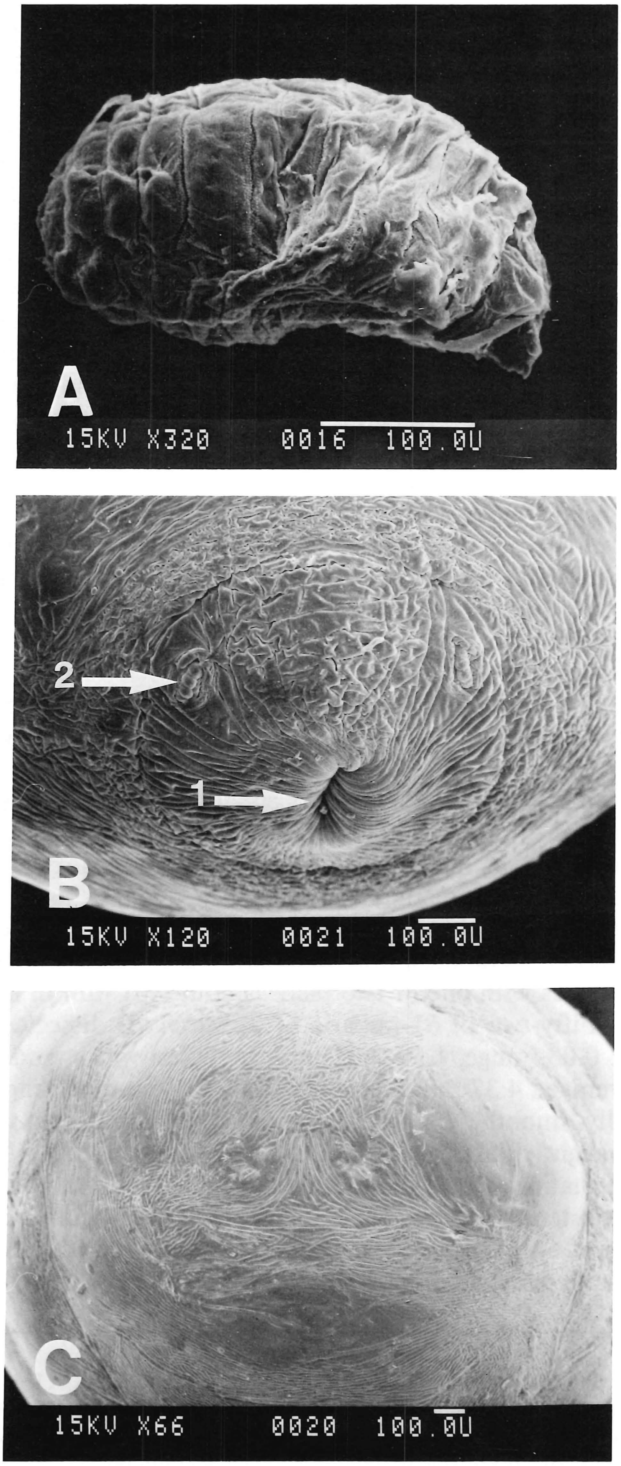

Figure 4. Second instar larva and puparium of *T. baccharis*: (A) habitus, second instar (anterior at right); (B) anterior end of puparium, 1—mouth invagination, 2—anterior thoracic spiracles; (C) posterior end of puparium.

reported incomplete pigmentation of some *T. stigmatica* puparia. This color variation also has been observed among some flower head infesting *Trupanea* (Goeden 1988b), gallicolous *Procecidochares* spp. (RDG, unpublished data), and was reported by Headrick & Goeden (1990a) among puparia of *Paracantha gentilis* Hering.

Distribution, Host, and Study Sites

Jenkins & Turner (1989) described the range of *T. baccharis* as "eastcentral Mexico northwest to westcentral California." The distribution of its only known host plant, *B. salicifolia* (Wasbauer 1972, Jenkins & Turner 1989) was described by Boldt & Robbins (1990) as "common along waterways in the southwestern United States and northern Mexico as well as western and southern South America."

Tephritis baccharis has been reared only from bud galls on *B. salicifolia,* never from capitula of this or any other species of *Baccharis* or Asteraceae widely sampled throughout California since 1980 (RDG, unpublished data). Nearctic species of *Tephritis* are either obligate or facultative gall formers on branches or stems, or ovule feeders in capitula (Foote 1960; Tauber & Toschi 1965; Jenkins & Turner 1989; Goeden 1988a; RDG, unpublished data). *Tephritis baccharis* is a monophagous, obligate gall former.

Our field study locations for flies and galls augment the California and southwestern U.S. distributions plotted by Foote & Blanc (1963) and Jenkins & Turner (1989), respectively: W end of Central Valley, Laguna Canyon, and Cebada Canyons (Goeden 1983), Santa Cruz Island, Santa Barbara Co., 8–13 Oct 1983; Big Morongo Canyon, Riverside Co., 7 Mar 1985, 3 Apr 1986, 23 Jan 1989, 30 Jan 1990; Oriflamme Canyon, NW San Diego Co., 8 Mar 1989. Additional locations where the characteristic galls on *B. salicifolia* were observed or collected included: Canebrake Creek, N of Spring Canyon, NW Kern Co., 3 Mar 1987; Mission Canyon, Riverside Co., 2 Apr 1987; Scissors Crossing, NW San Diego Co., 19 Dec 1989 and 9 Jan 1990. This fly, like *B. salicifolia,* is widely distributed in riparian habitats in southern California; however, its galls were not observed at many other locations where flower heads of this dioecious shrub sampled yielded other Tephritidae (Goeden 1983; RDG, unpublished data).

Biology

Egg.—In laboratory cagings, eggs were inserted for all or most of their lengths, mainly into apical buds, and a few into axillary buds. Only the highly reticulated, pedicellar ends slightly projected beyond or below the edges of the longitudinal egg punctures (Fig. 1A). Three egg punctures measured 0.55 mm long by 0.15 mm wide. The long axes of the egg bodies, buds, and branches were parallel. Bud tissues turned necrotic in areas immediately surrounding the eggs, as reported for *Eutreta diana* (Osten Sacken), another gallicolous tephritid (Goeden 1990). One unhatched egg contained an embryo with its partly pigmented cephalopharyngeal skeleton located at the pedicellar end; however, the first instar larva always ecloses through a slit in the chorion near the end opposite the pedicel, and immediately begins tunneling basipetally. Apparently the embryo of *T. baccharis* turns 180° just before eclosion, like several other species of nonfrugivorous Tephritidae (Varley 1937, Cavender & Goeden 1982, Goeden 1987, Goeden et al. 1987). This behavior apparently evolved to allow instant entry by the delicate, newly eclosed first instar larvae into moist, host plant tissues, and also to accommodate embryo respiration via the exposed pedicel (Headrick & Goeden 1990a).

All galls examined contained only one larva or puparium, indicative of only one egg having been oviposited in each bud in nature; however, in cagings, where ovipositional sites were scarce, as many as 10 eggs were inserted in a single apical bud. Similarly, in the field, most current generation galls were solitary at ends of separate branches; only one branch from Oriflamme Canyon bore two similar aged galls connected by a narrow neck of ungalled internode. Both sexes of *B. salicifolia* bore galls of *T. baccharis*.

Larva.—Two newly hatched larvae averaged 0.49 mm in length. The first instar tunneled until it reached the pith of the branch just basad to the apical meristem. The necrotic tunnel of one first instar was traced for 9 mm from this incipient gall site distally to its empty egg chorion. The young larva settles, molts, and initially excavates a small ellipsoidal cell about 3 mm long and <2 mm wide in the juvenile gall, evidenced externally as only a slight swelling of a branch terminal (Figs. 1B, 1C). Here, it feeds and develops (perhaps sporadically) through the summer or the following fall and winter, depending upon which generation it represents, F_1 or F_2, respectively (see below). The molt to the second instar could be ascertained by the presence of a small, intact, cephalopharyngeal skeleton discarded at one end of the cell. Once plant growth begins in mid-winter to early spring, or is triggered once again later in the year by late summer rainfall as sometimes occurs in southern California, gall and larval growth are accelerated and proceed concurrently.

Twenty (87%) of 23 fully formed F_2 galls of the previous year's overwintering generation sampled at Oriflamme Canyon were fusiform; the remaining galls, subovoidal. The former shape resulted from continued growth of the bud at each gall apex; whereas, the latter shape resulted from death of the terminal bud from larval feeding by *T. baccharis*. Such intragenerational differences in shape also were noted among galls of *T. stigmata* by Goeden (1988a), and the causes for this difference were discussed relative to galls of *E. diana* by Goeden (1990). The galls of *T. baccharis,* like those of *T. stigmatica,* are shortened, thickened, succulent terminal parts of main or axillary branches (Figs. 1D, 1E). The 23 mature galls incorporated an average of 3.8 ± 0.3 (range, 1–6) nodes, and were smooth surfaced, light green and longitudinally striped or unilaterally colored red-purple when occupied. When empty, the galls turned tan, shriveled, and dehisced, or became woody and persisted as branch swellings. Externally, the 23 galls averaged 13.1 ± 0.5 (range, 8–19) mm in length, and 5.6 ± 0.2 (range, 4–7) mm in width. The larva feeds on the expanded pith parenchyma which comprises the bulk of the gall (Figs. 1C, 1D). The feeding larva eventually hollowed out an ellipsoidal, central, longitudinal, basally rounded cavity. This open feeding cavity was irregularly surfaced with yellow-white callose tissue, and averaged 5.5 ± 0.2 (range, 4.4–7.8) mm in length and 2.7 ± 0.1 (n = 23; range, 2.1–3.5) mm in width (Fig. 1D).

Twenty (66%) of 30, F_1 galls collected on Santa Cruz Island were fusiform; the remainder, subovoidal. These 30 galls incorporated 3.8 ± 0.1 (range, 3–5) axils and externally measured 20.4 ± 1.0 (range, 12–33) mm long by 8.3 ± 0.3 (range, 6–13) mm wide.

When fully grown, the larva extends the feeding cavity into an exit tunnel 1.7 ± 0.1 (n = 23; range, 0.8–3.2) mm long, which may end apically (and thus kill the terminal bud, Fig. 1E), or more commonly ends subapically (Fig. 1F) in an oval to round, thin, cuticular window 1.6 ± 0.1 (range, 1.1–2.1) mm in diameter (Fig. 1G).

Puparium.—Pupation occurs in the feeding chamber with the posterior end of the puparium resting on, or up to, about 1 mm above the bottom of the feeding chamber. The anterior end of the puparium normally faces the window to allow egress of the emerging adult (Fig. 1F).

Adult.—Five males and five females (F_1) emerged between 13 Nov and 6 Dec 1985 from galls collected on Santa Cruz Island during the previous October. Six males and three females emerged from 22 Mar to 5 Apr (overwintered F_2) from galls collected in Oriflamme Canyon in Mar 1989. Both sexes emerged throughout the emergence periods. Also, two females emerged from F_1 galls collected at Big Morongo Canyon on 23 Jan 1985. One male and one female emerged on 15 Jan 1990 from F_1 galls apparently containing these individuals as fully developed pupae within puparia collected at Scissors Crossing on 9 Jan 1990. These latter two rearing records demonstrate that some F_1 individuals also overwinter as puparia in galls.

Apparently females are polygamous, males are polyandrous. Females began to mate in laboratory cagings (n = 3) 1 to 2 days after their emergence. Pairs mated repeatedly; one pair mated on at least 17 different days, and for the last time when the female was 121 days old. Another pair caged together at emergence mated on each of the first 7 consecutive days after they emerged. Mating by virginal males and females in laboratory cagings was protracted, involving little courtship behavior and no apparent postmating behavior. The male mounted the female after a short period of mutual recognition evidenced when the flies stood face-to-face and alternately, slowly waved their wings three to seven times. The anal edge of each wing was turned downward as each wing was brought forward until nearly perpendicular to the substrate in supination (Headrick & Goeden 1990b). The male then jumped over and atop the female or mounted her from one side, forcibly spread her wings, and rapidly initiated coitus. The mating posture (Figs. 1H, 1I) was much like that illustrated and described by Tauber & Toschi (1965) for *T. stigmatica.* The hind tarsi of the male rest on the substrate or move back and forth along the oviscape to help position the female's terminalia, his midtarsi grasp the middle of her abdomen laterally, and his foretarsi clasp her abdomen at its juncture with the thorax. The mouthparts of the male are positioned above her scutellum; the mouthparts of both flies pump rapidly during copulation (four to five pumps/sec). The wings are held parallel to the substrate. The wings of the female are spread at about 80° and centered over her abdomen; those of the male are overlapped atop his dorsum or are spread up to about 30° (Figs. 1H, 1I). Except for their mouthparts, both flies generally remain motionless during copulation, although the female may groom her head and mouthparts with her foretarsi, occasionally bring one wing forward, or even walk about while carrying the male with his hind tarsi on or off the substrate. Matings were observed throughout the daylight hours, and in one instance was extended over 2 days and nights under artificial lighting. To avoid mating, a nonreceptive female turned in tight circles, flew at the male, or turned and walked away. Males also mounted, rode, but did not couple with nonreceptive females. For example, one male daily mounted and remained in a mating posture atop a nonreceptive female for up to 6 h on each of 4 consecutive days after they last mated, but without coupling with her.

Females began oviposition in bouquets in cages 1–2 weeks after emergence. Probing did not always result in oviposition. An average of about one egg per day was laid by each of seven females (range, 0.4–2 eggs daily). The oldest female was 65 to 72 days old when she last oviposited. Five males lived an average of 140 (range, 58–196) days; three females, 83 (range, 38–142) days. Tauber & Toschi (1965) reported the laboratory longevity of *T. stigmatica* adults when fed water, sugar, and enzymatic protein hydrolysate of yeast as 6 to 187+ days. Long-lived adults occur more widely among nonfrugivorous Tephritidae than is generally recognized (Christenson & Foote 1960, Freidberg 1984). Whether longevity among nonfrugivorous species correlates with the presence or absence of symbionts in the adult as suggested by Harris (1989) remains to be addressed experimentally.

Seasonal History.—*Tephritis baccharis* usually is bivoltine on *B. salicifolia* in southern California, but may be univoltine at some desert locations during dry years, as reported with *Procecidochares* sp. by Silverman & Goeden (1980). *Tephritis baccharis* does not additionally reproduce in capitula of the same host species or of an alternate host, as do *T. stigmatica* (Coquillett) (Tauber & Toschi 1965, Goeden 1988a), *T. arizonaensis* Quisenberry (Goeden 1983; Jenkins & Turner 1989; RDG, unpublished data), *T. palmeri* Jenkins, and *T. subpura* (Johnson) (Jenkins & Turner 1989). However, the combination of long-lived adults and long-fecund females in *T. baccharis* and a host phraetophyte capable of nearly year-round growth and flowering under southern California conditions (Munz 1974), can lead to localized overlapping and obscuring of fly generations. This reproductive flexibility on the part of *T. baccharis* facilitates utilization of buds and new branch growth on its host plant, which itself shows reproductive flexibility, traits useful for survival in drainages with high water tables and riparian habitats in otherwise harsh, arid environments.

Natural Enemies.—Three species of chalcidoid Hymenoptera were reared from *T. baccharis* during this study. Three females of *Pteromalus* sp. (Pteromalidae) were recovered from puparia as solitary endoparasitoids. Two males of *Halticoptera* sp. (Pteromalidae) were reared as solitary, larval ectoparasitoids. One female of *Pnigalo* sp. (Eulophidae) was recovered from a small gall as a solitary, ectoparasitoid of an early stage larva of *T. baccharis.*

Large holes in the sides of empty galls matched symptoms of predation by birds, probably bush tits, *Psaltriparus* sp., recently documented for galls of *Eutreta diana* (Goeden 1990). Five (14%) of 35 galls sampled from Oriflamme Canyon yielded parasitoids; five more galls suffered bird predation. Fifty-nine (69%) of 86, mainly F_2 galls of all sizes collected in Big Morongo Canyon on 30 Jan 1990 had been opened by birds and the larvae within removed.

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PARASITOIDS OF BLACK SCALE IN CALIFORNIA: ESTABLISHMENT OF *PROCOCCOPHAGUS PROBUS* ANNECKE & MYNHARDT AND *COCCOPHAGUS RUSTI* COMPERE (HYMENOPTERA: APHELINIDAE) IN OLIVE ORCHARDS

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Abstract.—A survey of the parasitoid species of black scale, *Saissetia oleae* (Olivier), in California central valley olive orchards revealed that two recently imported parasitoids, *Prococcophagus probus* Annecke & Mynhardt and *Coccophagus rusti* Compere, have become established. These South African parasitoids were released from 1979 to 1983. During the release period, neither parasitoid was recovered. However, subsequent to the release, surveys of distribution of these species revealed that both had become established. In the first survey (1984–1987), 23 commercial olive orchards located in Tehama, Glenn, Madera, and Tulare Counties, were sampled. A second survey (1988–1990) included seven olive orchards located in Tehama and Madera Counties, and black scale infestations on selected ornamental olive and oleander plants in Tehama, Colusa, Sutter, Glenn, and Butte Counties. *Prococcophagus probus* and *C. rusti* were reared from black scale infested olive and oleander plants in Tehama County. Recovery of these species, over the three years after the last release, provides evidence of their establishment in the Sacramento Valley.

Key Words.—Insecta, Aphelinidae, *Prococcophagus, Coccophagus,* Homoptera, *Saissetia oleae,* olive, biological control

Black scale, *Saissetia oleae* (Olivier), believed native to South Africa (De Lotto 1976), is found throughout the tropical and subtropical regions of the world. It is a very polyphagous species with a host range that includes such common plants to California as oleander (*Nerium oleander* L.), pepper tree (*Schinus molle* L.), coyote brush (*Baccharis pilularis* Wolf), and toyon (*Heteromeles arbutifolia* Lindahl) (Argyriou 1963). In California, *S. oleae* has been a pest of olive (*Olea europaea* L.) and *Citrus* spp. since the 1880s. As a result of its wide host range and high reproductive rate, the scale has spread throughout California and is ubiquitous in the state's central valley olive orchards, resulting in frequent infestations.

Black scale is exotic to most olive growing regions and has been the target of numerous classical biological control programs (Bartlett 1978). Studies of population dynamics in the Mediterranean region have attributed significant scale mortality to natural enemies (Argyriou & Katsoyannos 1976, Monaco 1976, Paraskakis et al. 1980, Roberti 1981). In California, biological control programs against *Saissetia oleae* began in 1891 and natural enemies have been imported since from Asia, Africa, Australia, Central and South America, Europe, and the Middle East (Bartlett 1978, Kennett 1986). Parasitoid importation and establishment in California resulted in relatively successful control of black scale on ornamentals and citrus in coastal regions. However, parasitoid establishment in the central valley has not been as successful. Over 50 natural enemies of black scale have been introduced in California and less than 15 have become permanently established in the central valley (Table 1).

Establishment of black scale parasitoids is best understood in light of the population dynamics of their host. Seven black scale stages can be differentiated from egg to adult (Argyriou 1963), although most black scale parasitoids are specific to only two or three consecutive host stages (Smith & Compere 1928, Compere 1940). Thus, it is difficult for some parasitoids to become established where scale development is univoltine and synchronous because of the long periods in which suitable host stages are not commonly found. Due to harsh climate in the central valley, black scale development there is more synchronous than in coastal California (Daane 1988). For example, *Metaphycus lounsburyi* (Howard) is abundant at coastal locations but is rarely found in the interior valleys (Kennett 1986).

Further, many of the initial attempts to establish imported species of black scale parasitoids failed because of inadequate biological information (Bartlett 1978). For example, until the 1930s many primary parasitoids with obligatory male hyperparasitic habits were discarded as undesirable secondary parasitoids. Differences between parasitoid biotypes may also affect establishment. Panis & Marro (1978) showed that there were sufficient behavioral differences between two biotypes of *Metaphycus lounsburyi* (Howard) for them to be used in the same orchard for biological control.

We report here the establishment of two black scale parasitoid species, *Prococcophagus probus* Annecke & Mynhardt and *Coccophagus rusti* Compere, in olive orchards in the Sacramento Valley, where they were previously thought to have failed to become established. *Prococcophagus probus* was first released in California in 1979. *Coccophagus rusti* was first released in 1937 and was reported as established (Flanders 1952) in coastal locations, but not within the central valley. It was imported from South Africa again in 1978 and released in central valley olive orchards in 1980.

Materials and Methods

Parasitoid Release.—From 1979 to 1982, five parasitoid species were imported to California from South Africa. *Prococcophagus saissetiae* Annecke & Mynhardt, *P. probus, C. rusti, Aloencyrtus saissetiae* (Compere), and *Metaphycus inviscus* Compere were collected by S. Neser (South African Ministry of Agriculture) and sent to the quarantine station at the Division of Biological Control, University of California, in Albany. After release from quarantine, colonies were established in the insectary on black scale reared on oleander. From 1979 to 1983, 1180 *P. probus* (67% female), 3265 *P. saissetiae* (59% female), 535 *C. rusti* (88% female), 265 *A. saissetiae* (98% female), and 1352 *M. inviscus* were released at five olive orchards in the central valley (three orchards near Corning, Tehama County, one near Parlier, Fresno County, and one near Porterville, Tulare County) and on selected ornamental host plants of the black scale in the east bay region of the San Francisco Bay area (Alameda and Contra Costa Counties). Releases were concentrated in the fall of each year when the proper black scale host stages were most common.

Recovery Attempts.—During the parasitoid release period (1979–1983), olive twigs infested with black scale were collected at each release site in the fall and

Table 1. A partial list of introduced primary black scale parasitoids (source: Smith & Compere 1928, Bartlett 1978, Kennett 1986).

Species	Origin	Date introduced	Established
Aphelinidae			
Aneristus ceroplastae Howard	Taiwan	1933, 1952	no
Coccophagus anthracinus Compere	South Africa	1923	no
Coccophagus baldassarii Compere	Eritrea	1953	no
Coccophagus basalis Compere	Brazil	1958	no
Coccophagus capensis Compere	South Africa	1924	yes
Coccophagus caridei (Brethes)	Brazil, Argentina	1934, 1935	no
Coccophagus cowperi Girault	East Africa	1937	yes
Coccophagus eleaphilus Silvestri	Eritrea, Morocco	1953, 1953	no
Coccophagus hawaiiensis Timberlake	Taiwan	1951	no
Coccophagus japonicus Compere	Japan	1951	no
Coccophagus lycimnia (Walker)	Africa	1900s (accidental)	yes
Coccophagus lycimnia (Walker)[a]	Brazil, Argentina	1935, 1935	no
	Australia	1972	no
	Africa, Mexico	?	no
Coccophagus mexicensis Girault	Mexico	1956	no
Coccophagus nigritus Compere	Eritrea	1954	no
Coccophagus ochraceous Howard	Africa	1990s (accidental)	yes
Coccophagus eritreaensis Compere	South Africa	1925, 1937	no
Coccophagus rusti Compere	Kenya, Uganda	1937	yes
	South Africa	1932, 1981	yes
Coccophagus scutellaris (Dalman)	Africa	1900s (accidental)	yes
Lounsburyi trifasciatus (Compere)	South Africa	1924	yes
Prococcophagus saissetia Annecke & Mynhardt	South Africa	1978	no
Prococcophagus probus Annecke & Mynhardt	South Africa	1978	yes
Encyrtidae			
Aloencyrtus saissetia (Compere)	South Africa	1979	no
Anicetus annulatus Timberlake	Australia, Taiwan	1931, 1951	no
Coccidoxenus niloticus Compere	Kenya	1937	no
Diversinervus elegans Silvestri	Eritrea, Lebanon	1953, 1964	yes
Diversinervus smithi Compere	South Africa	1937	no
Encyrtus fuliginosus Compere	South Africa	1937	no
Encyrtus infelix Embelton	Hawaii	1921	yes
Metaphycus angustifrons Compere	Taiwan	1952, 1957	no
Metaphycus bartletti Annecke & Mynhardt	South Africa	1956	yes
Metaphycus citrinus Compere	Eritrea	1953	no
Metaphycus flavus (Howard)	Spain	1954, 1955	no
Metaphycus gilvus Compere	North Africa	1953	no
Metaphycus helvolus (Compere)	South Africa	1937	yes
Metaphycus lichtensiae Compere	South Africa	1958	no
Metaphycus lounsburyi (Howard)	Australia	1916–1918	yes
Metaphycus luteolus (Timberlake)	Mexico	1954, 1955	yes
Metaphycus stanleyi Compere	South Africa	1937	yes
Metaphycus zebratus Mercet[b]	Spain	1986	?
Microterys flavus (Howard)	Pakistan	1957	no
Microterys okitsuensis Compere	China, Japan	1951, 1952	no
Microterys saissetiae Compere	Uganda	1937	no
Microterys tricoloricornis (DeSoto)	Mexico	1956	no
Eupelmidae			
Lecanobius utilis Compere	Brazil, Argentina	?	yes

Table 1. Continued.

Species	Origin	Date introduced	Established
Pteromalidae			
Anysis saissetiae (Ashmead)	China, Pakistan	1924, 1957	no
Lecaniobus cockerelli Ashmead	West Indies	1913, 1915, 1940	no
Mesopelitita atrocyanea (Masi)	East Africa	1937	no
	South Africa	1957	no
	Mexico	1958	no
Scutellista caerulea (Fonscolombe)	South Africa	1901-1902	yes
Scutellista cyanea Motschulsky (red larval race)	Taiwan	1952	no

[a] *Coccophagus lycimnia* has been introduced from a number of countries, however, establishment of this species may be from accidental introductions prior to importation efforts.

[b] *Metaphycus zebratus* has been recovered continually since its release; documentation of permanent establishment is in progress.

spring of each year. Samples were brought into the laboratory and held in glass-topped sleeve cages from four to six weeks. Emerging parasitoids were collected three times a week and stored in 70% ethanol for later identification. These samples were taken as part of a central and northern California survey of black scale parasitoids that included a majority of the counties within the Sacramento and San Joaquin valleys and several coastal counties extending from Napa County to San Luis Obispo County (Kennett 1986). Nearly 70% of the samples were taken from urban and rural landscapes (olive; *Citrus* cultivars of grapefruit, orange; Modesto ash, *Fraxinus velutina* var. *glabra* Rehder; English holly, *Ilex aquifolium* L.), 20% from natural stands of native shrubs (coyote brush and toyon), and 10% from commercial olive orchards. Detailed results from these collections were reported by Kennett (1986).

From 1984 to 1987, a separate parasitoid survey was conducted in conjunction with a black scale population dynamics study on olive. All samples were taken from commercial olive orchards located in the central valley: seven orchards near Corning, Tehama County; one near Orland, Glenn County; one near Madera, Madera County; one near Parlier, Fresno County; and 11 near Lindsay, one near Strathmore, and one near Exeter, Tulare County. Included in this 23 orchard study were four of the five orchards that received the five imported black scale parasitoid species from 1979 to 1983. The release orchard in Porterville was removed in 1984 and is, therefore, not included in the survey. Likewise, the orchard in Parlier was removed in 1986 and data presented for parasitoids collection in 1987 does not include this orchard.

In each orchard sampled, except in Glenn County, collections were made every six to eight weeks. In the Glenn County orchard, samples were taken each fall and spring, when black scale parasitoids were most common. Olive twigs infested with black scale were collected and the scales were counted and recorded by developmental stage (first, second, third, pre-ovipositional, and adult) and condition (alive or parasitized). Infested twigs were placed in parasitoid emergence containers and held between 22 and 24° C for three to four weeks. Emerging parasitoids were collected and later identified.

From 1987 to 1989, seven orchards (five near Corning and two near Madera) were sampled, as described above, in each season of each year. An additional survey for parasitoids on black scale infested olive and oleander plants was carried out in the spring of 1990 at seven sites in the Sacramento Valley: Red Bluff, Tehama County; Willows, Glenn County; Yuba City, Sutter County; Zamora, Yolo County; and Williams and Maxwell, Colusa County. Infested twigs were taken to the laboratory and parasitoids reared from the material as described above.

Results and Discussion

New Parasitoids.—Of the five parasitoid species released, only *P. probus* and *C. rusti* were found to have become established in central valley olive orchards. Establishment is defined here as parasitoid recovery three years after the last insectary release.

Prococcophagus probus was collected in 1985 and 1986 in two of the four original release orchards. Both orchards were located near Corning, Tehama County. *Prococcophagus probus* comprised 0.7% of the total parasitoids collected between 1984 and 1987 (Table 2). It was most commonly found in winter samples. In one orchard, *P. probus* comprised 8.0% (n = 274) and 1.1% (n = 1235), respectively, of parasitoids in November and December collections combined for 1985 and 1986. It was not recovered from any orchards in Glenn, Madera, or Tulare Counties, nor was it recovered from any orchards other than the original release sites. This suggests that *P. probus* did not disperse from the release areas.

Coccophagus rusti was collected from orchards near Corning, Tehama County from 1985 to 1987. The parasite was most commonly reared from third instar and pre-ovipositional stage scale, collected in spring and early summer months. Overall, this parasitoid comprised only 0.4% of the total parasitoids collected between 1984 and 1987 (Table 2). When considering release orchards only, the percent species composition of *C. rusti* was often higher. In one release orchard, *C. rusti* comprised 8.2% (n = 205) of the parasitoids reared from two collections in June and July, 1987. *Coccophagus rusti* was also recovered from two nonrelease sites: 1986, in an olive orchard over 1 km from the nearest release site, and 1990, in Red Bluff on oleander over 64 km from the nearest known release site. At the latter site, *C. rusti* accounted for 58%, the greatest number, of 19 parasitoids reared. This suggests that it either is increasing its geographic distribution or that a population has been present, without detection, in some central valley locations since the releases in 1937. Although *C. rusti* has not previously been found in the central valley, Flanders (1952) reported it to have been established in California at coastal locations, on ornamental plants. Its low numbers in California, contrasts reports that it was the most abundant and widely distributed of black scale parasitoids collected in 1937 in South Africa, Uganda, and Kenya (Compere 1940).

Neither *P. saissetiae* nor *A. saissetiae* were recovered in the 1984 to 1987 or 1988 to 1990 surveys. *Metaphycus inviscus* was not recovered in either the 1984 to 1987 or the 1988 to 1990 surveys. These findings differ somewhat from those of the 1979 to 1983 survey (during the release period) when *M. inviscus* was the only newly released parasitoid to show continued and strong evidence of establishment (Kennett 1986). *Metaphycus inviscus* is morphologically similar to *Metaphycus bartletti* Howard, a commonly collected parasitoid, and can be easily overlooked when large numbers of *M. bartletti* are present.

Abundance.—Relative to the other parasitoid species collected, both *P. probus*

Table 2. Rankings (in parenthesis) and percent total parasitiod abundance of primary and secondary parasitoids reared from black scale samples taken in Tehama, Madera, and Tulare County olive orchards between 1985 and 1987.

Species	Percent Parasitoid Abundance			Total
	Sacramento Valley	San Joaquin Valley		
	Tehama	Madera	Tulare	
Metaphycus bartletti[a]	42.9 (1)	27.1 (2)	51.9 (1)	43.2 (1)
Metaphycus helvolus[a]	25.6 (2)	48.7 (1)	35.4 (2)	29.2 (2)
Scutellista cyanea[a]	13.6 (3)	12.0 (3)	0.2 (10)	11.7 (3)
Coccophagus lycimnia[a,b]	4.1 (4)	5.3 (4)	7.9 (3)	4.8 (4)
Metaphycus zebratus[a]	3.6 (5)	1.1 (7)	0.4 (8)	3.1 (5)
Cheiloneurus inimicus[c]	3.2 (6)	1.5 (6)	0.6 (7)	2.7 (6)
Marietta mexicana[c]	2.2 (7)	3.6 (5)	0.6 (6)	2.2 (7)
Coccophagus ochraceous[a]	2.0 (8)	0.1 (10)	1.5 (5)	1.8 (8)
Coccophagus scutellaris[a,b]	1.7 (9)	0.2 (9)	2.7 (4)	1.7 (9)
Tetrastichus minutum[c]	0.9 (10)	0.6 (8)	0.2 (9)	0.8 (10)
Cheiloneurus noxius[c]	0.7 (11)	–	–	0.5 (11)
Prococcophagus probus[a]	0.7 (12)	–	–	0.5 (12)
Coccophagus rusti[a]	0.5 (13)	–	–	0.4 (13)
Metaphycus luteolus[a]	<0.1 (14)	–	–	<0.1 (14)
Moranila californica[a,c]	<0.1 (15)	–	–	<0.1 (15)
	$n = 8290$	$n = 936$	$n = 2469$	$n = 10{,}593$

[a] Primary parasitoids
[b] Males developed as a secondary parasitoid on some similar species
[c] Secondary parasitoid
[d] Only one specimen found.

and *C. rusti* were not common, ranking 12th and 13th and comprising only 0.5 and 0.4%, respectively, of the total parasitoids collected (Table 2). The most abundant parasitoids in the collections were *Metaphycus bartletti* Annecke & Mynhardt and *Metaphycus helvolus* (Compere). The widespread distribution and abundance of *M. bartletti* reveals its increasingly important economic role since its introduction (Kennett 1980). *Scutellista caerulea* (Fonscolombe) (= *Scutellista cyanea* Motschulsky) ranked third in abundance.

The remaining parasitoid species were found in low numbers, often sporadically in time and space. Together, *P. probus, C. rusti, Metaphycus luteolus* (Timberlake), and *Moranila californica* Howard comprised less than 1% of the total parasitoids recovered. *Metaphycus luteolus* may have been underrepresented because of their small number and close similarity to *M. bartletti.* Because only one specimen of *M. californica* was found, while a colony was kept at the Division of Biological Control insectary, contamination of the field emergence container may have occurred despite housings in separate buildings.

Metaphycus zebratus (Mercet), imported from Spain in 1985 and released from 1986 to 1988 (Daane & Caltagirone 1989), was recovered in Tehama, Madera, and Tulare Counties. It ranked fourth in parasitoid species collected, despite being released in large numbers in orchards being sampled. The parasitoid was recovered in lower numbers each subsequent year after releases were discontinued.

Distribution.—Greater diversity and abundance of parasitoid species were found in the Sacramento Valley than the San Joaquin Valley (Table 2), due, in part, to differences in the synchronization of scale development found in the central valley. Cultural practices typically used in the San Joaquin Valley exacerbate climatic mortality and promote a more synchronous scale population than in the Sacramento Valley (Daane 1988). For *S. caerulea,* there is strong evidence that scale phenology is limiting in the species abundance. Although the third most commonly collected parasitoid in Tehama County, *S. caerulea* was rarely reared from black scale collected on olive in Tulare County. Moreover, it has been found in moderate numbers, in Tulare County, on oleander, where the scale has a less synchronous development pattern (D. Bromberger, personal communication). It is, therefore, not surprising that *P. probus* and *C. rusti,* as well as a number of lesser abundant primary and secondary parasitoids, were found in the Sacramento Valley rather than in the San Joaquin Valley.

Biology.—Documenting black scale parasitoid distribution and establishment in often difficult because of the low number of specimens recovered and the morphological similarity of other parasitoid species. Brief biological descriptions and morphological diagnoses of *P. probus* and *C. rusti* are provided because of the difficulty in identifying these two relatively unknown parasitoid species in California.

Prococcophagus probus was described by Annecke & Mynhardt (1979) as a solitary, primary parasitoid of black scale. Its reproductive biology is probably similar to that of *Prococcophagus varius* Silvestri & *P. saissetiae,* two black scale parasitoids that are morphologically very close to *P. probus.* In those species, both male and female are primary parasitoids, but the diploid female larva develops as an endoparasitoid, while the haploid male larva develops as an ectoparasitoid (Mazzone & Viggiani 1983). The validity of *Prococcophagus,* as a genus separate from *Coccophagus,* has been questioned by Mazzone & Viggiani (1984). Nevertheless, *Prococcophagus* can be distinguished from *Coccophagus* by its ventrally expanded antennal scape, laterally compressed funicle, and usually largely infuscated fore wings. The antennal scape of the female is more than twice as long as wide, with two dark streaks on the outer surface; the first antennal funicle segment is the longest, with rhinaria (Annecke & Mynhardt 1979). Superficially, *P. probus* is similar to *M. bartletti* in color and size. In samples with many parasitoids, misidentification can easily occur.

Coccophagus rusti is a solitary endoparasite of third instar and preovipositional adult black scale (Flanders 1952). The male is hyperparasitic, developing as a direct endoparasite of some primary parasitoids of black scale and other hosts. This species can also develop in soft brown scale, *Coccus hesperidum* L. (Compere 1940). *Coccophagus rusti* is easily distinguished from other black scale parasitoids by the following characters: the scutellum has three pairs of setae, the abdomen is entirely black, the thorax is yellow-brown, the pedicel is shorter than first funicle segment, and the forewing has an infuscation with a pale diagonal streak (Smith & Compere 1928). The male differs from the female, with its whole body black or brown-black (Annecke 1964).

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DESCRIPTION OF A NEW SPECIES OF *EPIBLEMA* (LEPIDOPTERA: TORTRICIDAE: OLETHREUTINAE) FROM COASTAL REDWOOD FORESTS IN CALIFORNIA WITH AN ANALYSIS OF THE FOREWING PATTERN

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Abstract.—*Epiblema deverrae* R. Brown, NEW SPECIES, is described from Monterey and Sonoma Counties, California and is differentiated from the sympatric species, *E. hirsutana* (Walsingham) and *E. radicana* (Walsingham), and from similar allopatric species. A description of its forewing pattern is based on an analysis of fasciae, color fields, and strigulae in the Olethreutinae.

Key Words.—Insecta, Tortricidae, Eucosmini, *Epiblema deverrae,* forewing pattern, strigulae, Asteraceae, *Madia*

An inventory of the Lepidoptera at the Landels-Hill Big Creek Reserve, Monterey County, California, has been conducted during the past decade (JAP, unpublished data). This is the first attempt to census the entire fauna of moths and butterflies at any locality in western North America. The Big Creek Reserve, one of 27 areas maintained by the Natural Reserve System (UCNRS) of the University of California, is situated about 30 km southeast of Big Sur, in the Santa Lucia Mountains, which end abruptly at the Pacific coast. The reserve encompasses 1550 ha, rising from sea level to 1200 m elevation (900 m in the areas surveyed). Rugged coastal mountains rise abruptly from the shoreline and are dominated by narrow ridges separated by deep, V-shaped canyons with walls that rise steeply from narrow streamside terraces. Vegetation types include coastal scrub, California sage scrub, *Ceanothus* and chamise chaparral, redwood forest, mixed hardwood forest, ponderosa pine-manzanita woodland, and sparse chaparral on rocky montane ridges (buckwheat [*Eriogonum*], yerba santa [*Eriodictyon*], and *Yucca whipplei* Torrey).

The reserve has been surveyed on more than 80 dates, using three approaches: diurnal net collecting, larval sampling and rearing, and blacklight attraction at sheets and traps. To date about 650 species have been differentiated, of which 26% are represented by larval collections. Based on comparisons with the numbers of flowering species (326) (Bickford & Rich 1984), as well as butterflies at Big Creek (57), and macro moths known at other stations in coastal California (McFarland 1965; Opler & Buckett 1971; JAP, unpublished data), a census of 800–850 species of Lepidoptera at Big Creek is anticipated.

The survey has yielded several species of moths that were previously unknown in the central coast ranges and at least three undescribed species of microlepidotera in better studied families (Momphidae, Tortricidae), including a distinctive new species of *Epiblema.* The genus *Epiblema* includes more than 100 species in the Holarctic region and southern Asia. Of these, 39 occur in America, north of Mexico (Blanchard 1979, 1985; Powell 1983; Miller 1985). *Epiblema* appears to be related to *Eucosma, Pelochrista, Sonia,* and other eucosmine genera that include species with larvae boring in stems and roots of Asteraceae. The description of this new *Epiblema* is facilitated with selected information from a recent analysis of forewing patters in Tortricidae (RLB, unpublished data).

Methods and Materials

A stereomicroscope with an ocular micrometer was used to examine and measure specimens. Specimens of all species mentioned in the diagnosis were examined except *E. simploniana* (Duponchel), of which figures were examined. The forewing length was measured from base to apex, including the fringe. Cornuti of the aedeagus were counted by examination of their sockets with a compound microscope. Valval length was measured as a straight line from the ventral, proximal corner of the sacculus to the apex of the cucullus. Colors were described with the standards of Kornerup & Wanscher (1983). The forewing description is based on a comparative study of pattern elements in more than 600 tortricid species representing all tribes defined by Horak & Brown (in press). The following abbreviations are used for depositories: Mississippi Entomological Museum, Mississippi State University (MEM); University of California, Berkeley (UCB).

Forewing Pattern Elements in *Epiblema*

Nijhout (1978) provided the following terminology for the five major types of pattern elements on Lepidoptera wings, as described by Süffert (1929): ripple patterns, dependent patterns, crossbands (fasciae), eyespots (ocelli), and color fields. These types, except ripple patterns, are present in *Epiblema,* including the species described here.

Fasciae occur on ontogenetically determined areas of the wing (Nijhout 1978, 1990) and generally are more darkly pigmented than the surrounding ground color. The areas between fasciae here are termed interfascial areas. The distinctiveness of fasciae is dependent on both the number of scales that are darkly pigmented (degree of expression) and the degree to which dark pigment is lacking in the interfascial areas. Based on an analysis of forewing patterns in the Tortricidae, the ancestral pattern is interpreted to include six fasciae: basal, subbasal, medial, postmedial, subterminal, and terminal. These fasciae, except for the terminal, previously have been identified in the tortricine tribe Cochylini (Bradley et al. 1973). In the Olethreutinae, the basal and subbasal fasciae are often confluent to form a basal patch; the median fascia usually is well expressed, although often broken near CuA_2 to form a separate pretornal spot; the postmedian fascia (termed the preapical fascia by some authors) is expressed usually as one or more spots, the largest and most anterior being the postmedian spot (termed the preapical spot by some authors); and the subterminal and terminal fasciae are either not expressed or are represented by narrow umbrae or small spots (Fig. 1).

Color fields have been defined as large areas of the wing surface that contrast in coloration with other areas and are not a fascia or other pattern element (Nijhout 1978). Süffert (1929) and Nijhout (1978) noted that "color fields" represented a lumping of more than one type of pattern element, and that little effort had been

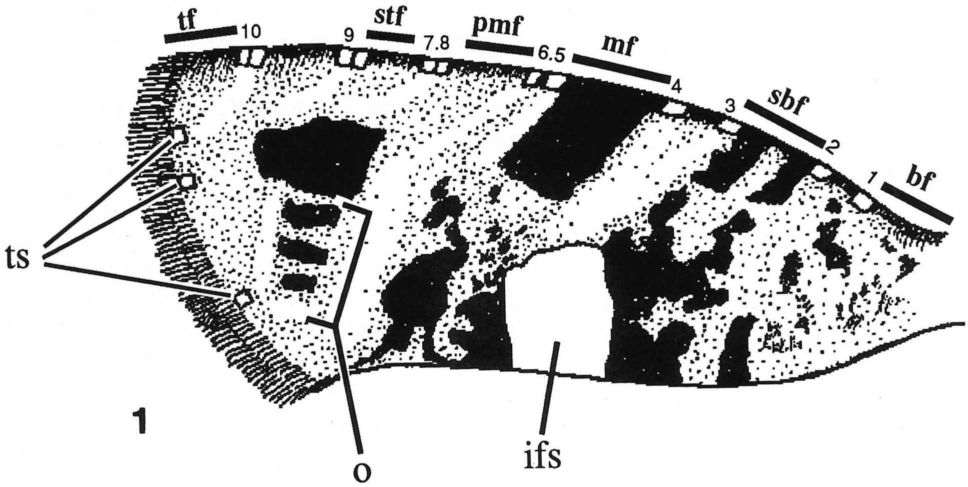

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Figure 1. *Epiblema deverrae,* forewing pattern indicating positions of expressed and nonexpressed fasciae relative to coastal strigulae 1–10. ifs—interfascial spot, mf—median fascia, o—ocellus, pmf—postmedian fascia, sbf—subbasal fascia, stf—subterminal fascia, tf—terminal fascia, ts—terminal strigulae.

made in the analysis of the various types of color fields. Two types of color fields commonly occur in the Tortricidae, and here these are termed "patches" and "spots." The term patch is used to describe a color field that differs from the ground color and that covers at least one fascia and one interfascial area. Although patches include several subgroups, depending on their position and size, patches often involve the expression of fasciae only on the costal or inner margins of the wing and the intervening interfascial area. The term spot is used for contrasting pigmentation that is confined either to a restricted portion of a fascia (i.e., pretornal spot) or to a restricted portion of an interfascial area (i.e., interfascial spot).

Interfascial spots are present on the inner margin (dorsum) between the subbasal and median fasciae in many species of the Olethreutinae, including the *Epiblema* described here (Fig. 1). Patches are common on the inner margin is generalized genera in the Eucosmini, especially in *Ancylis* and *Epinotia* (e.g., *E. solandriana* (L.)) (Bradley et al. 1979: pl. 32, Figs. 5–8) and on the costa in various unrelated genera (e.g. *Ancylis, Pseudexentera* and *Acleris*) (Bradley et al. 1973: pl. 40, Figs. 10–11). Although interfascial spots are present in many species of *Epiblema, Eucosma,* and related genera, patches have not been detected in any representative of this derived group of Eucosmini.

Strigulae, or short transverse marks, are present on the costa of most Olethreutinae, some Chlidanotinae, and some generalized Tortricinae (e.g., Phricanthini) (Horak & Brown in press). These strigulae appear to be dependent patterns, as they occur on the inner and outer margins of fasciae. In addition, strigulae apical to R_2 occur between the veins at the wing margin. Danilevski & Kuznetsov (1968) and Kuznetsov (1978) recognized seven pairs of costal strigulae, and these were numbered one to seven from apex to base. Examinations of species in the tribes Gatesclarkeanini, Phricanthini, and Chlidanotini by RLB indicate that the ancestral condition is the presence of ten costal strigulae between the wing base and R_5; these are numbered here 1–10 from wing base to apex. Strigulae are not limited to the forewing costa; among various Tortricidae, a strigula may be present between each pair of adjacent veins on the termen, and here these are termed terminal strigulae.

Each of the costal strigulae in the Olethreutinae has a narrow stria extending towards the inner or outer margin, and these striae, which often are a shade of gray, appear to be silver when viewed through the microscope at an angle to the light. Each of the ten costal strigulae are paired in representatives of primitive taxa, but some are single in derived taxa. In derived taxa, some strigulae (e.g., numbers five and six in the species described here) are approximate or confluent (Fig. 1). Confluence of two independent strigulae to form what appears to be a single or paired strigula usually can be determined by examinations of related species or the detection of two silver striae arising from one apparent strigula.

Süffert (1929), as translated by Nijhout (1978), recognized four classes of ocelli, or eyespots, on Lepidoptera wings. Of these, band ocelli are present in the Olethreutinae, especially in the Grapholitini and derived Eucosmini. These ocelli are formed from the fragmentation of fasciae, usually the postmedian fascia, and the resulting fascial spots are accentuated by the gray striae, often widened, that originate from costal strigulae (Fig. 1).

Epiblema deverrae R. Brown, New Species

Types.—Holotype, male, data: "CALIF: Monterey Co., Landels-Hill Big Creek Res., 5 mi. N. Lucia, 4–6 June 1982; J. Powell, collector"; deposited at the University of California, Berkeley. The holotype is in excellent condition except for missing meso- and metathoracic legs on the right side. Paratypes, deposited as noted in parentheses: USA. CALIFORNIA. *MONTEREY Co.:* same data as holotype, 2 females, 4 males (genitalia slide JAP 5121) (UCB), 1 female (genitalia slide R. L. Brown 1321) (MEM); Big Creek Reserve, UCNLWR, Brunette Creek, 60–180 m el, redwood-hardwood, 26–28 May 1987, J. Powell, 1 female, 3 males (UCB); Big Creek Reserve, UCNLWR, headquarters, coastal to confluence area, 0–60 m, 26–28 May 1987, J. Powell, 1 female (UCB); Big Creek Reserve, UCNLWRS, Brunette Creek, 60–180 m el, redwood-hardwood, 5–8 Jun 1989, Y-F. Hsu and J. Powell, 1 female, 1 male (UCB), 1 male (MEM); Big Creek Reserve, UCNRS, Devils Creek Flat, 120 m el, 7 Jun 1989, J. Powell, 1 male (UCB). *SONOMA Co.:* Cazadero, 6 Jun 1979, J. Powell, 1 female (UCB).

Description.—*Head:* vertex and upper frons brown, brown-orange, or gray-brown, darker brown between antennae in some specimens; labial palpus with basal one-half orange-white or orange-gray, apical one-half brown or light brown. *Mesonotum:* brown to dark brown; tegulae brown to dark brown basally, brown or brown intermixed with gray-orange apically. *Forewing* (Figs. 1, 2): Forewing length 5.3–7.1 mm in males, 5.5–7.0 in females; male costal fold extending from base to proximal margin of median fascia, length of fold 0.33–0.40 forewing length. Upperside ground color brown to gray-brown intermixed with orange, with orange increasing in apical one-half; pattern elements including indistinct, broken, dark brown fasciae, white to orange-white interfascial spot on inner margin, white to orange-white costal strigulae, and white terminal strigulae. Basal and subbasal fasciae not forming distinct basal patch; basal fascia indistinct, basal area with small spots and broken, narrow umbrae; subbasal fascia reduced to broken umbrae, umbrae broad and confluent near midwing and inner margin, distal margin of fascia angled at midwing, extending to costa at about 0.30× the forewing length; median fascia broken by orange or brown near midwing into large spot on costa and large spot on inner margin, some specimens with inner marginal portion of fascia broken by orange or brown into small proximal spot and larger distal spot; postmedian fascia represented by large postmedian spot (appearing as two or three spots in some rubbed specimens) near apex of discal cell and three

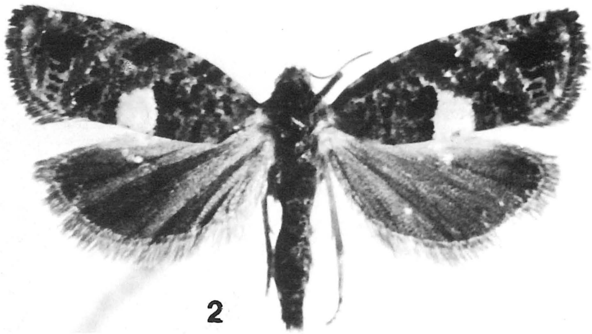

Figure 2. *Epiblema deverrae,* female, Sonoma Co., California.

small bars, three bars bordered by subequal, gray (silver when viewed at an angle to the light) spot on inner margin near tornus and by broad, transverse, gray (silver) lines proximally and distally to form ocellus; subterminal fascia indistinct; terminal fascia represented by small spot at wing apex in some specimens. Interfascial spot present between subbasal fascia and median fascia, extending from inner margin to Cu_2, subquadrate with proximal margin longer than distal margin. Costa with four to six conspicuous strigulae, strigulae one and two confluent with each other or indistinct; strigula three single, marking distal margin of subbasal fascia; strigula four single, marking proximal margin of median fascia, separated from strigula three by small dark brown spot, strigulae three and four indistinct in some specimens, each strigula with a gray (silver) stria extending posteriorly, striae becoming confluent at discal cell and extending to interfascial spot; strigulae five and six approximate at distal margin of median fascia, appearing as a single paired strigula, strigula five with gray (silver) stria extending to midwing, strigula six with gray (silver) stria extending to near tornus, becoming broad at midwing; strigulae seven and eight apparently confluent, appearing as single strigula in some specimens, with single gray (silver) stria extending to proximal margin of postmedian spot; strigula nine single or paired, with gray (silver) stria extending to distal margin of postmedian spot; strigula 10 paired, with strigulae separated by dark brown spot, with gray (silver) stria extending to M_1 at termen; strigulae 5–6, 7–8, 9, and 10 bordered by orange or dark brown, separated from each other by dark brown spots. Termen with small strigulae between R_5 and M_1, M_1 and M_2, and CuA_1 and CuA_2, some specimens with orange-white, attenuate, fringe scales arising from strigulae. Proximal fringe scales attenuate, short, brown with white to orange-white apices; distal fringe scales attenuate, long, gray-brown. Forewing underside brown except white to orange-white costal strigulae and area of hindwing overlap posterior to CuP. *Hindwing:* Upperside uniformly brown except area of forewing overlap anterior to $Sc+R_1$; underside uniformly brown, concolorous with forewing underside. *Male genitalia* (Fig. 3): Uncus reduced to rounded lobe, densely setose dorsally; socii slightly flattened, moderately setose posteriorly; gnathos arising from triangular projections of tegumen; aedeagus with patch of 13 or 14 cornuti on vesica; anellus with pointed anterior ventral corners; valva with sacculus moderately setose, clasper at base near dorsal margin with flat medial surface and beset with group of short, moderately stout setae, a second clasper-like, rounded projection near sacculus with sparse, slender, short to long setae, ventral margin of neck without setae, cucullus large relative to valva, length of cucullus 0.60 × length of valva (one preparation examined). *Female genitalia* (Fig. 4): Sternum VII with moderately dense scales throughout, posterior one-half with sparse, short setae, becoming dense on posterolateral corners; tergum VIII with moderately dense, long setae on posterior fourth and on triangular, lateral extensions, scales absent; papillae anales densely setose, without rugae or papillose projections; lamella postvaginalis with dense microtrichia medially, with sparse, long setae on lateral rims; lamella antevaginalis reduced to lightly sclerotized, smooth rim; ductus bursae weakly spiraled, with moderately sclerotized colliculum posterior to inception of ductus seminalis; signa flat, blade-like, bases with shallow invaginations (one preparation examined).

Diagnosis.—*Epiblema deverrae* is superficially similar to *E. hirsutana* (Walsingham), which was described from Sonoma Co., California. In *E. hirsutana,*

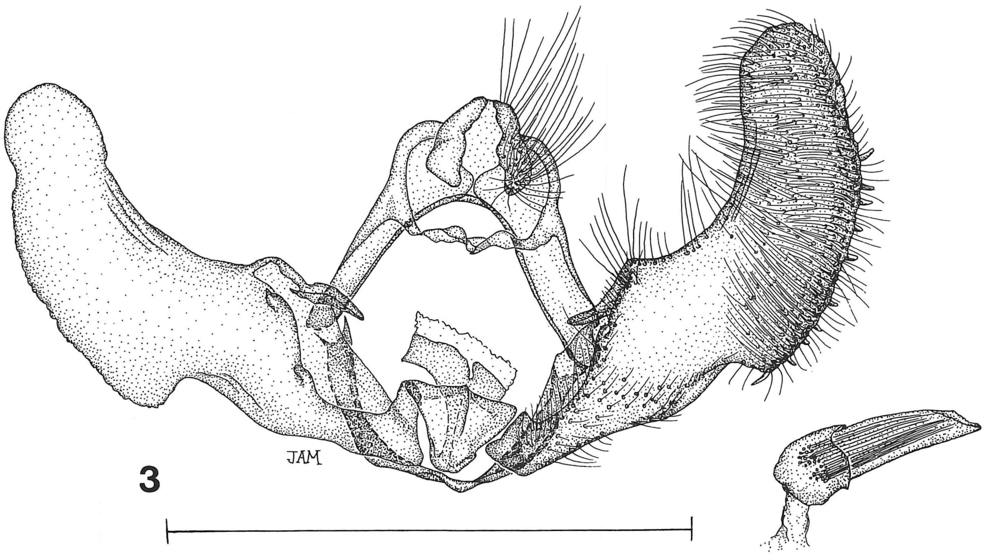

Figure 3. *Epiblema deverrae,* male genitalia with aedeagus detached. Scale line = 0.5 mm.

the head and labial palpi appear bushy due to long, erect, narrow scales, and the forewing lacks a large postmedian spot and a contrasting median fascia. The interfascial white spot is less well defined in *E. hirsutana,* and is not suffused with pale orange. The male genitalia of *E. hirsutana* has a valve with a broader cucullus and a single clasper. The female genitalia of *E. hirsutana* has a longer ductus bursae with a more lightly sclerotized colliculum. *Epiblema radicana* (Walsingham), also occurring in western North America, is a larger species with a forewing lacking an ocellus and having a paler interfascial area between the median fascia and postmedian fascia and with genitalia differing in several characters (Obraztsov 1965: Figs. 1–10). Allopatric species that are superficially similar to *E. deverrae* include *E. walsinghami* (Kearfott) and *E. infelix* (Heinrich), occurring in the eastern United States, *E. arctica* Miller, occurring in Alaska, and *E. graphana* Treitschke, *E. farfarae* Fletcher, *E. simploniana,* and some forms of *E. scutulana* (Denis & Schiffermüller), occurring in the Palaearctic region. None of these latter species has a forewing with a large postmedial spot combined with orange scales in the apical area, and all differ in characters of the male genitalia, as figured by Miller (1985, 1987) and Kuznetsov (1978).

Comments.—The new species was discovered in Big Creek Reserve at two sites, about 2 km apart, in 1982: on the upper Brunette Creek trail at about 180 m elevation in the Big Creek drainage, and along the road above Devil's Creek Flat at 120–130 m. Additional individuals were collected in later years, subsequent to an extensive fire that burned both sites in July, 1985. Adults seem to be univoltine and diurnal; all were flying during afternoons and none have appeared at blacklights deployed in various areas of the reserve. They seem to be associated with *Madia madiodes* (Nuttall) (Asteraceae) growing in loose rocky talus in open areas in forests dominated by redwood (*Sequoia sempervirens* (D. Don.)). No gall formations were found on this herbaceous perennial, and we speculate that larvae of *E. deverrae* feed on underground rootstocks.

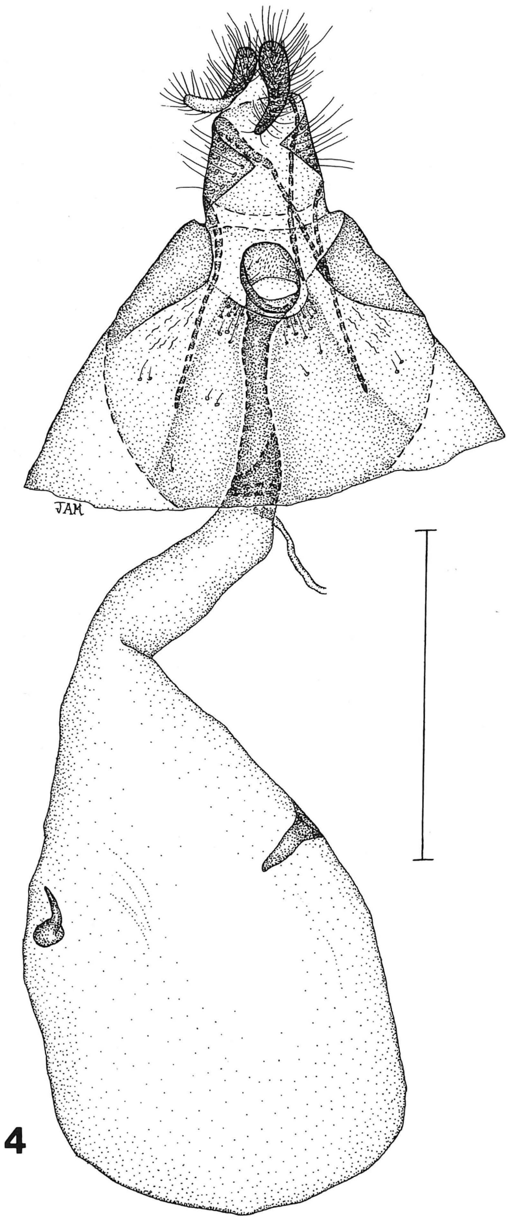

Figure 4. *Epiblema deverrae,* female genitalia. Scale line = 0.5 mm.

Madia madioides ranges from Monterey County, northward, along the Pacific coast, in mixed evergreen and coastal coniferous forests, to Vancouver Island (Munz 1959).

Etymology.—The specific name *deverrae* is formed from Deverra, the Roman goddess of brooms and sweeping.

Material Examined.—See types.

Acknowledgment

We thank K. R. Tuck (British Museum [Natural History]) for comparing *E. deverrae* with the type of *E. hirsutana,* J. A. MacGown for drawing the figures, D. Reed for computer scanning, J. Tisdale for word processing, and S. Cho for photographing the imago. Cooperation by John Smiley (Big Creek Reserve) has facilitated the survey at Big Creek in many ways. The Mississippi Agricultural and Forestry Experiment Station has approved this paper as contribution no. 7607.

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A REVIEW OF THE GENUS *MICROTHURGE* (HYMENOPTERA: MEGACHILIDAE)

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Abstract.—A new South American *Microthurge, M. furcatus* NEW SPECIES, is described. *Microthurge boharti* NEW SYNONYM is synonymized with *M. corumbae.* The male of *M. pharcidontus* is described. New records and keys to the species for males and females are presented.

Key Words.—Insecta, taxonomy, bees, floral records

In a recent revision of the megachilid subfamily Lithurginae (Michener 1983), a new genus *Microthurge* Michener was described to accommodate a small group of heriadiform bees from southern South America. Four species were included: *Microthurge pygmaeus* (Friese), *M. pharcidontus* (Moure), *M. boharti* Michener and *M. corumbae* (Cockerell), the last based only on the description, because Michener was unable to locate the type. Here, I report on the identity of *M. corumbae,* the discovery of a new species, describe the male of *M. pharcidontus* and give new records for the genus. Depositories for specimens (cited by cities) are: University of California (Davis), University of Kansas (Lawrence), American Museum of Natural History (New York), Philadelphia Academy of Sciences (Philadelphia), Carnegie Museum of Natural History (Pittsburgh), USDA Bee Biology and Systematics Laboratory (Logan).

KEYS TO SPECIES

Males

1. Scutal surface roughened medially by transverse rugulae; scutellum rounded in profile; mesopleural surface granular .... *pharcidontus* (Moure)
   Scutal surface not roughened by transverse rugulae; scutellum flat in profile; mesopleural surface shiny 2

2(1). Hind basitarsus with ventral hairs black in part; punctures on medial area of mesopleuron nearly contiguous; basal depression of mandible wide .... *pygmaeus* (Friese)
   Hind basitarsus with ventral hairs light; punctures on medial area of mesopleuron well separated; basal depression of mandible linear ... 3

3(2). Punctures on upper part of clypeus foveolate, larger than those on frons; frons with punctures contiguous; eyes slightly diverging above (ratio of upper interorbital distance at level of lateral ocelli/minimal lower interorbital distance < 1.35) .... *furcatus* NEW SPECIES
   Punctures on upper part of clypeus fine, not foveolate, not larger than those on frons; frons with punctures not contiguous; eyes strongly diverging above (ratio of upper interorbital distance at level of lateral ocelli/minimal lower interorbital distance > 1.4) .... *corumbae* (Cockerell)

Females

1. Upper margin of mandible with basal, dorsoventrally flattened projection; abdominal scopa largely black .... *pygmaeus* (Friese)
   Upper margin of mandible without projection; abdominal scopa white except sometimes on S5 2
2(1). Scutum with broad median zone covered with coarse transverse rugulae; mesopleural surface granular; scutellum rounded in profile; apical hair of T6 dark brown .... *pharcidontus* (Moure)
   Scutum without transverse rugulae; mesopleural surface shiny; scutellum flat in profile; apical hair of T6 black 3
3(2). Facial projection carinate, with deep V-shaped emargination in dorsal view; labrum with conical basomedial projection; clypeus in part with large shiny interspaces between punctures .... *furcatus* NEW SPECIES
   Facial projection not carinate, with shallow rounded emargination in dorsal view; labrum with low, notched basomedial projection; clypeus contiguously punctate or essentially so .... *corumbae* (Cockerell)

Microthurge pygmaeus (Friese)

Material Examined.—(New Records) ARGENTINA. *SALTA:* Rosario de Lerma, 10–14 Nov 1983, malaise trap, M. Wasbauer, 5 males, 17 females (Logan); same except 4–8 Nov 1983, 6 females; Rosario de Lerma, Oct 1984, M. Fritz, 1 male (Logan); same except Oct 1985, 1 male, 4 females (Logan); same except Oct 1986, 2 males (Logan). *CÓRDOBA:* LaCumbre, 1140 m, 21 Nov 1975, R. M. Bohart, 12 males, 7 females (Davis, Logan). *JUJUY:* Perico, S of Jujuy, 21 Oct 1968, L. E. Peña, 1 female (New York). *CATAMARCA:* Alijilan, 3 Nov 1972, *Argemone* sp., G. E. Bohart, 1 female (Logan). *TUCUMÁN:* Tucumán, 19 Oct 1972, *Argemone subfusiformis* G. B. Ownbey, G. E. Bohart, 1 male, 2 females (Logan); Cadillal, 4 Dec 1975, R. M. Bohart, 1 male (Logan).

Microthurge pharcidontus (Moure)

Redescription.—Male. Length, 5–7 mm; forewing length, 4–5 mm. Basal depression of mandible linear; pair of tubercles on supraclypeal area small and close or absent; punctures on upper part of clypeus foveolate, larger than punctures on frons; scutum roughened medially by transverse rugulae; mesopleural surface granular.

Diagnosis.—The transversely rugulose scutum, granular mesopleuron, and rounded rather than flat scutellum are unique to *M. pharcidontus.* Males share these unique characteristics, though the rugulae of the scutum are less well-developed.

Discussion.—Additional material available for this study supports the tentative association by Michener (1983) of males from Guayaramerin, El Beni, Bolivia with *M. pharcidontus.*

Material Examined.—(New Records) ARGENTINA. *SALTA:* Dique Itiyuro, nr Pocitos, 14 Aug 1976, C. Porter, L. Stange (Lawrence). *TUCUMÁN:* Tucumán, 19 Oct 1972, *Argemone subfusiformis* G. B. Ownbey, G. E. Bohart, 1 male (Logan); San José, Rio Marija, 3 Nov 1972, *Opuntia sulphurea* G. Don, G. E. Bohart, 1 male (Logan); Horco Molle, 4 Jan 1976, R. M. Bohart, 1 male, 2 females (Davis, Logan).

Microthurge corumbae (Cockerell)

Lithurgus corumbae Cockerell, 1901. Proc. Acad. Nat. Sci. Phil., 1901: 216. Type deposited in Pittsburgh.

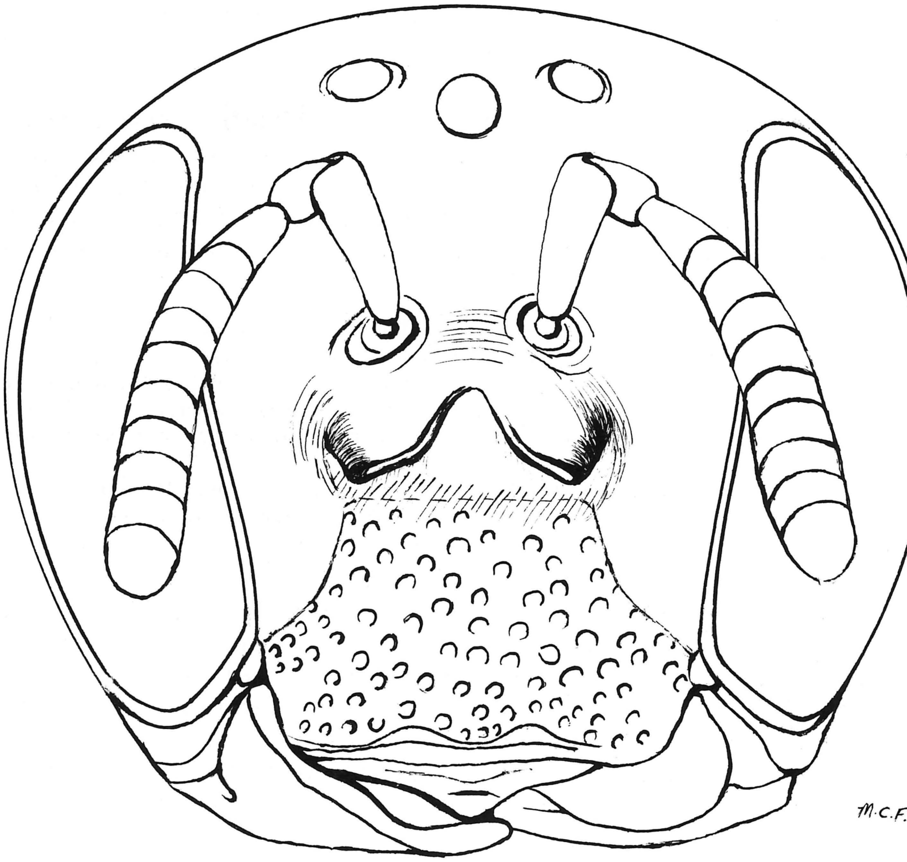

Figure 1. Head of *Microthurge furcatus,* female. Punctation shown only for clypeus.

Microthurge boharti Michener, 1983. Pan-Pacif. Entomol., 59: 186. NEW SYNONYMY. Type deposited in Buenos Aires.

Diagnosis.—Males have eyes more strongly diverging above than in *M. furcatus* (ratio of upper interocular distance at level of lateral ocellus/minimal lower interocular distance 1.41–1.52; $n = 8$, $\bar{x} = 1.46$).

Discussion.—The holotype female of *Lithurgus corumbae* Cockerell from Corumba, Mato Grosso, Brazil, was recently located in the entomological collection of the Carnegie Museum of Natural History. It appears to be the same as *Microthurge boharti* from Córdoba Province, Argentina, despite the geographic separation and apparent ecological differences between the moist tropical region of Corumba and the more xeric environment of Córdoba. The only discernable difference is the slightly better developed frontal prominence in specimens from Argentina. This may be size related, because there appears to be size-dependent variation among the Corumba specimens.

Material Examined.—(New Records) BRAZIL. *MATO GROSSO:* Corumba, Apr, 4 males, 28 females (Philadelphia, Logan); same except Mar, 2 females (Philadelphia).

Microthurge furcatus Griswold, NEW SPECIES (Fig. 1)

Types.—Holotype, female, data: BOLIVIA. *COCHABAMBA:* Peña Colorada, 1800 m, 21 Feb 1976, L. E. Peña. Paratypes; 7 males, data same as holotype; 3 males, 1 female, data: BOLIVIA. *COCHABAMBA:* (no local data), Nov 1976, L. E. Peña. Holotype deposited in American Museum of Natural History, New York; paratypes deposited in the American Museum of Natural History and USDA Bee Biology and Systematics Laboratory, Logan, Utah.

Female.—Length, 7.5–8 mm; forewing length 6 mm. Body black, apical tarsi red; wings heavily infuscated. Pubescence white; scopa off-white except for few dark hairs laterally and apically on S5. Mandible without projection basally on upper margin; labrum with basomedial cone-shaped projection; clypeus with punctures on disk scattered; facial projection carinate, in dorsal view with wide V-shaped notch; scutum without transverse rugulae; scutellum flat in profile; mesopleuron shiny, with punctures separated.

Male.—Length, 6–7 mm; forewing length, 4.5–5 mm. Basal depression of mandible linear; punctures on upper part of clypeus foveolate, larger than those on frons; punctures of frons contiguous; eyes slightly diverging above (ratio of upper interocular distance at level of lateral ocelli/minimal lower interocular distance 1.22–1.33; $n = 10$, $\bar{x} = 1.28$); ventral hairs on hind basitarsus all light.

Diagnosis.—*Microthurge furcatus* seems most closely related to *M. corumbae.* Males of the two species are very difficult to separate, differing as far as I can tell only by slight differences in punctation and by the less divergent inner eye margins. Females are more easily separated. In addition to the characters given in the key, the mandible is covered with a few large punctures, has a very strong dorsal carina, and is abruptly and strongly depressed basally. The mandible of *M. corumbae* has numerous small punctures, a weak dorsal carina, and is only slightly depressed basally.

Material Examined.—See types.

Acknowledgment

I thank John Rawlins and Robert Davidson (Carnegie Museum of Natural History, Pittsburgh) for assistance in locating and studying the type of *Lithurgus corumbae* and the following individuals and institutions for the loan of material: Manfredo Fritz (Instituto de Investigaciones Entomologicas Salta, Rosario de Lerma, Argentina), Jerome Rozen and Eric Quinter (American Museum of Natural History, New York); Robert Schuster (University of California, Davis); Donald Azuma (Academy of Natural Sciences, Philadelphia); Charles Michener (University of Kansas, Lawrence). Marianne Cha Filbert produced the illustration. This is a contribution from Utah Agricultural Experiment Station, Utah State University, Logan, Utah 84322-4810, Journal Paper Number 4074, and USDA–ARS Bee Biology and Systematics Laboratory, Utah State University, Logan, Utah 84322-5310.

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A NEW AND PRIMITIVE GENUS OF CRYPHOCRICINAE (HETEROPTERA: NAUCORIDAE)

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Abstract.—*Procryphocricos perplexus* NEW GENUS, NEW SPECIES is described and compared to *Cryphocricos* Breddin. The predominantly plesiomorphic character states of this new genus are discussed.

Key Words.—Insecta, Heteroptera, Naucoridae, Cryphocricinae

During an expedition to South America Dan A. Polhemus and I collected numerous naucorids among which is a remarkable new cryphocricine genus from Colombia that is superficially similar to *Cryphocricos* Breddin but possessing a number of plesiomorphic and some apomorphic characters that distinguish it.

The subfamily Cryphocricinae was proposed by Montandon (1897) to hold *Cryphocricos* Breddin and *Cataractocoris* Montandon. It was redefined by Usinger (1941) to exclude *Cataractocoris*, which was placed in his new subfamily Ambrysinae. Usinger proposed a family level classification of Naucoridae, based on a number of characters, that was a radical departure from that of Montandon (1897). Since then alternative arrangements the family-group classification of Naucoridae have been proposed by a number of authors (e.g., Popov 1970, De Carlo 1971, Lopez Ruf & Bachmann 1987, Stys & Jansson 1988; the latter overlooked the work by Lopez Ruf & Bachmann). In these proposals the rank and relationships of many family group taxa have been shifted, and a new taxon, Pelocoridae, was proposed by De Carlo (1971), supported by Lopez Ruf & Bachmann (1987), but rejected by others (e.g., Polhemus 1979, Stys & Jansson 1988). The various schemes have been discussed by the latter, who placed *Cryphocricos* in the monotypic tribe Cryphicricini. Both D. A. Polhemus and I consider all of these proposals to be poorly founded, based on too few characters, and none of them have been supported by a convincing phylogenetic analysis; this matter will be treated in detail later, and supported by a cladistic analysis. Although the suprageneric classification of the Naucoridae remains in my view an open question, I have used the classification of Stys & Jansson (1988) in order to establish a framework for this paper.

The addition of *Procryphocricos* NEW GENUS does not require redefinition of the family group taxon that holds *Cryphocricos*, the Cryphocricini, but instead supports Usinger's decision to separate it. In Table 1 these two genera are compared and the polarity of characters shown. Their prosterna, abdominal sense organs, brachyptery and apparent plastron are so similar, but so different from any other closely related naucorid genera (e.g., *Cataractocoris* Montandon) that I consider it unnecessary to include other genera in the comparison. The morphology used here follows Parsons (1966) and Parsons & Hewson (1974).

The CL number following locality data refers to codes used by the author to reference ecological data.

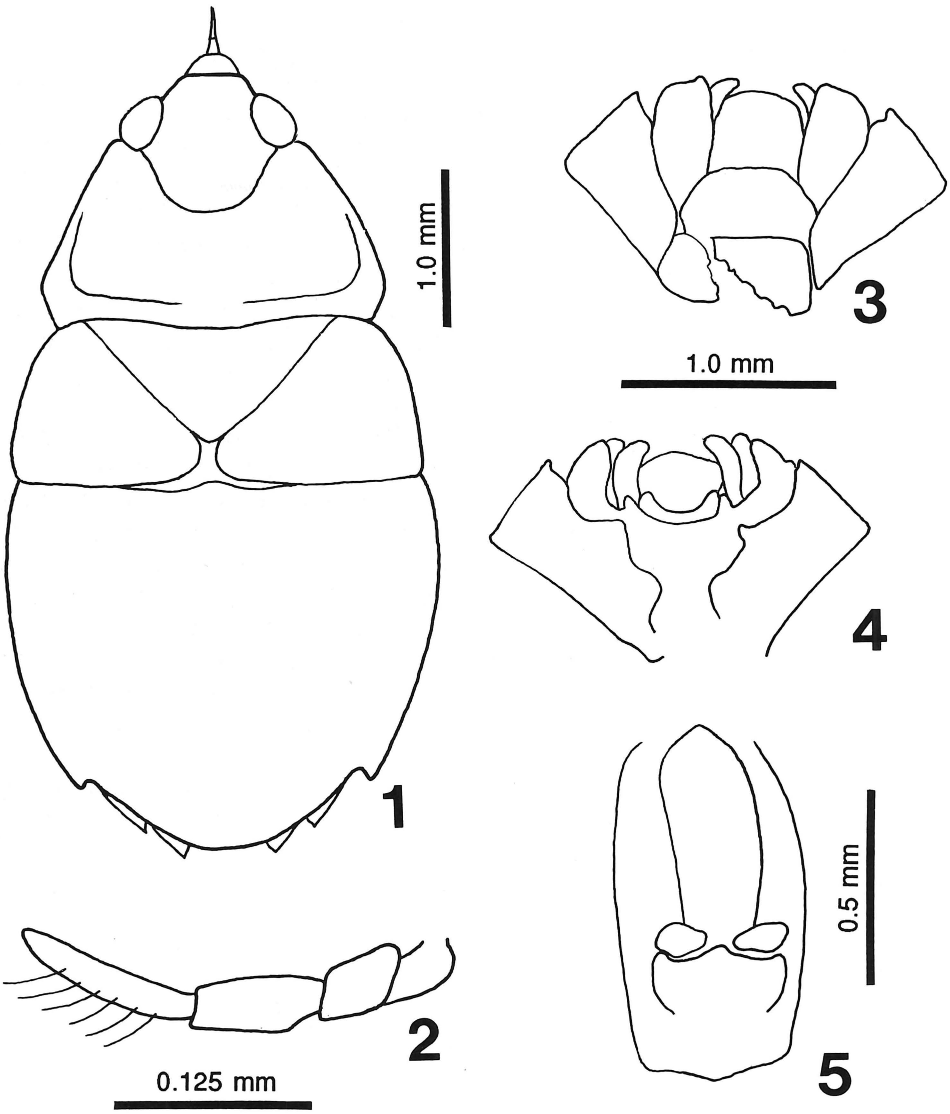
Table 1. Comparison of *Cryphocricos* and *Procryphocricos*. Apomorphic character states are marked with an asterisk.

Character	*Cryphocricos*	*Procryphocricos*
Setae on ventral surface	very short; plastron only*	scattered long silky setae plus plastron
Mid and hind femora armed (knobs, spines)	present*	absent
Distal tibial spines	2 close packed rows*	1 short distal row, ragged subdistal row
Lateral pronotal margins	crenulate, without obvious setae*	smooth, set with short stiff setae
Male abdominal tergite 7	asymmetrical; spur on right side*	symmetrical; no spur
Aedeagus	strongly asymmetrical flagellum very long*	weakly asymmetrical; short flagellum
Antennal segments, length	3 very short; 4 long*	3 and 4 long, subequal
Prosternum, proepimeron	separated by distinct suture	fused, junction faintly demarcated*
Male paratergite 8	large, size equal to 7, exposed; projecting	small, mostly covered by 7; angled medially*
Male abdominal sternite 7	fused with paratergites*	free from paratergites
Loral plates	produced anterad of eyes*	not produced anterad of eyes
Base of rostrum	ahead of eyes*	between and below eyes
Ocular setae	absent	2 kinds present*
Abdominal tergites	distinct	fused*

Procryphocricos J. T. Polhemus, NEW GENUS
Figs. 1–5

Type-species.—Procryphocricos perplexus J. T. Polhemus, NEW SPECIES.

Description.—Small, ovate, brachypterous. Length 5.1 mm, width 2.7 mm, widest across abdomen (Fig. 1). Entire dorsum rugose, set with short appressed scale-like setae. Head narrow, produced anteriorly 0.5× eye length, anteclypeal margin almost straight; vertex slightly domed medially, produced behind eyes 0.75× eye length, with two (1 + 1) trichobothria adjacent to middle of eyes. Eyes 1.5× as long as wide, with narrow posterior flange; raised, rounded, not forming smooth transition to head, but set off by shallow sulcus on head; ocular setae of two kinds, many short mushroom-shaped setae scattered among the ommatidia, and longer slender setae, two of medium length on inner eye margin, one long setae on lateral margin. Labrum small, arising at anterior margin of anteclypeus, rounded; maxillary plates projecting anteriorly, tips pointed, extending to middle of rostral segment three (second visible). Rostrum short, segment two (first visible) very short, recessed into head, segment three much longer and slightly shorter than four. Antennae of moderate length, segments one and two short, three and four subequal (Fig. 2). Pronotum convex, with broad shallow median depression, margins depressed and demarcated posteriorly and posterolaterally (Fig. 1); lateral margins not crenulate, set with short stiff setae. Scutellum triangular, slightly raised above level of adjacent wing pads, declivant anteriorly. Wing pads triangular, not touching medially, reaching posterior margin of abdominal tergite two; embolium poorly defined, set off mesad by a broad weak longitudinal carina not reaching posterior margin. Abdomen moderately convex dorsally, transversely rugose, connexiva evenly rounded, tergites three to five fused, intersegmental sutures weakly indicated only at lateral margins; connexival margin depressed; posterior margin of tergite five broadly rounded posteriorly, obscuring most of remaining tergites. Ventral surface sparsely set with long dark silky appressed setae absent only on head and prosternum; anterior one-third of prosternum carinate medially, anteromedial portions angled forward over base of carinate gula; prosternum completely exposed, very similar in shape to *Cryphocricos* (see Usinger 1941: fig. 1), fused with proepisternum, demarcated by weak



Figures 1–5. *Procryphocricos perplexus.* 1. Habitus. 2. Antennae. 3. Male abdominal terminalia, dorsal view. 4. Male abdominal terminalia, ventral view. 5. Aedeagus.

indication of suture. Mesosternal plate reflexed anteromedially forming tumescence, remainder medially carinate. Metasternal plate not carinate; metaxyphus triangular, posterior margins carinate. Abdominal venter narrowly glabrous laterally; sense organs similar to and in same position as *Cryphocricos* (see Usinger 1941: Fig. 1). Fore legs with femur broad, tibia narrow, tarsi single-segmented; single claw very short, triangular. Middle and hind femora slender, not modified, set with short stiff appressed setae; tibia set with spines except basally, distally with ventral row of closely set spines, subdistal ragged row of four spines, plus dorsal comb of many closely set stiff setae; tarsal segment one short, two long, three longer. Mid and hind pretarsi with long setiform parempodia; claws long, curved, each with large basal spur. Abdominal segments six to eight almost symmetrical (Figs. 3–4); genital capsule similar to *Cryphocricos*, elongate; aedeagus slightly asymmetrical; parameres small (Fig. 5).

Diagnosis.—*Procryphocricos* differs from *Potamocoris* by its smaller antennae, which are not visible in dorsal view, and by its brachyptery; only macropters of the latter are known. It differs from *Cryphocricos* by its vestiture of silky hairs on abdominal ventrites six through eight, and the characters given in Table 1.

Discussion.—As can be seen from Table 1, *Cryphocricos* possesses a number of apomorphies in comparison to *Procryphocricos.* Because both occur in the brachypterous form, both must possess a plastron, or there would be no way to obtain and hold an air store [see Usinger (1941), Parsons & Hewson (1974) and D. Polhemus (1986) for discussion]; this is an apomorphy for the Cryphocricini within the Cryphocricinae but is not unique within the Naucoridae; see Polhemus & Polhemus (1986) for discussion. In addition, all genera of the Cryphocricinae have a dorsal vestiture of silky hairs on abdominal segments six, seven and eight, but only in *Cryphocricos* these are absent ventrally.

To establish the polarity of characters in Table 1, the outgroup chosen for comparison is the genus *Potamocoris* Hungerford, which in my view is close to the ground plan for the Naucoridae [placed in a separate family by some authors; see Stys & Jansson (1988) for discussion]. *Procryphocricos* shares some primitive characters with *Potamocoris,* for instance similar antennal proportions, but in the latter genus the antenna are much longer and visible in dorsal view. In *Procryphocricos* one pair of facial trichobothria are present medially along the eyes, in the same position as in *Potamocoris,* but the latter has three pairs; also the lateral ocular setae are similar in the two genera, but the latter has no medial pair and lacks the mushroom-shaped ocular setae which constitute an autapomorphy for *Procryphocricos.*

Habitat.—The two known specimens of *Procryphocricos* were found among tangles of fine roots along a small section of steep bank bathed by the moderate current of the Rio Claro. A diligent search of other habitats of many kinds failed to yield additional specimens. Midstream riffles of the Rio Claro and a nearby tributary yielded *Ambrysus, Cryphocricos* and *Limnocoris.*

Material Examined.—See species types.

Procryphocricos perplexus J. T. Polhemus, NEW SPECIES
Figs. 1–5

Types.—Holotype, brachypterous male, data: COLOMBIA. *ANTIOQIUA:* Rio Claro, 13 km W of Doradal, 250 m, water temp 25° C, CL 2405, 21 Jul 1989, J. T. and D. A. Polhemus, in J. T. Polhemus Collection (JTPC). Paratype, 1 brachypterous male, same data as holotype (JTPC).

Description, Brachypterous Male.—(See generic description; only additional details given here.) Ground color yellow-brown; pronotum anteromedially and laterally, wing pads, fore legs distally tinged with brown; spines on mid and posterior legs orange-brown; eyes brown. Head deeply set into pronotum; length 0.90 mm, width through eyes 1.10 mm. Eyes with many ommatidia; embraced posteriorly by pronotum; length 0.38 mm, width 0.25 mm, interocular space 0.60 mm. Pronotum broad, maximum length 1.23 mm, length on midline 0.73 mm, width 2.13 mm. Scutellum triangular, roughly 2× as wide as long, length 0.70 mm, width 1.48 mm. Wing pad length 1.03 mm. Abdominal tergites three to seven each set laterally with two (1 + 1) long slender erect tufts of golden setae, on middle of connexival segment three, on posterior one-quarter of four to seven; combined length of fused abdominal tergites three to five, 2.13 mm. Antennal proportions as shown in Fig. 2; distal segment set with a row of stiff evenly spaced setae. Proportions of legs in mm (femur : tibia : tarsus 1:2:3):

anterior, 1.43:1.10:0.30:0:0; middle, 1.18:1.10:0.08:0.18:0.30; posterior, 1.43:1.53:0.10:0.20:0.33. Abdominal terminalia and genitalia as in Figs. 3–5.

Female and Macropterous Forms.—Unknown.

Diagnosis.—*Procryphocricos perplexus* is the only species of the genus.

Material Examined.—See types.

Acknowledgment

I am deeply grateful to D. A. Polhemus for assistance in the field, reviewing the manuscript, and stimulating discussions on naucorid phylogeny. Gabriel Roldán Peréz provided warm hospitality and invaluable assistance in many ways during our stay in Colombia; without his help and that of Luisa Fernanda Alvarez A. and Luis Fernando Roldán, we could not have succeeded in our endeavors there. The field work was supported in part by the National Geographic Society, to whom I am deeply grateful.

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THE MYDIDAE (DIPTERA) OF COSTA RICA

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Abstract.—The species of Mydidae occurring in Costa Rica are reviewed. Four genera and seven species are reported, including *Nemomydas loreni,* NEW SPECIES. Additionally, *Mydas quadrilineatus* Williston, NEW SYNONYM, is synonymized under *M. rufiventris* Macquart.

Key Words.—Insecta, Diptera, Mydidae, Costa Rica, insect fauna

Costa Rica occupies part of the isthmus of Central America and is a complex ecological mosaic (Hall 1985). It has been estimated that upwards of 300,000 species of insects may occur in Costa Rica. This fauna is a complex mixture of Mesoamerican and South American species. One group of flies that attract the attention of even the most specialized collectors are mydas flies. Mydids are a small, but worldwide, family composed of medium to very large, usually sparsely pilose, flies that often resemble wasps (Fig. 1). Adults occupy a wide variety of habitats and can be locally common, especially in arid areas. Many species are restricted to hot, sandy habitats and can be found visiting blossoms or resting on bare ground.

The preparation of a section (JLW, unpublished data) on the Mydidae of Costa Rica for the "Guia para las familias de Insectos de Costa Rica," stimulated this review. There is no single publication available treating all genera and species.

Morphology and terminology follows Wilcox (1981); genitalic structures are labeled in Figs. 4 and 12. Abbreviations for depositions that are used throughout the paper are: British Museum of Natural History, London (BMNH); University of California at Berkeley (UCB); Utah State University, Logan (USU); Museum National d'Histoire Naturelle, Paris (MNHN); Illinois Natural History Survey, Champaign (INHS); Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts (MCZ); and Texas A&M University, Lubbock (TXA&M); collection of J. L. Welch (JLW).

Key to the Genera of Mydidae of Costa Rica
(modified from Wilcox 1981)

1. Laterotergite completely bare; proboscis subequal in length to subcranial cavity; labella broad; apex of female abdomen with setae; length variable 2
– Laterotergite pilose; proboscis 1.0–2.0 × length of subcranial cavity; apex of female abdomen with circlet of spines; length 12–23 mm .... *Nemomydas* Curran

2(1). Prementum of proboscis 0.5 × length of subcranial cavity; labella attached to prementum near its midpoint, and subequal with subcranial cavity in length; anterior margin of subcranial cavity situated at about 0.4 × the distance from lower eye margin to base of antennae; length 15–29 mm .... *Messiasia* d'Andretta

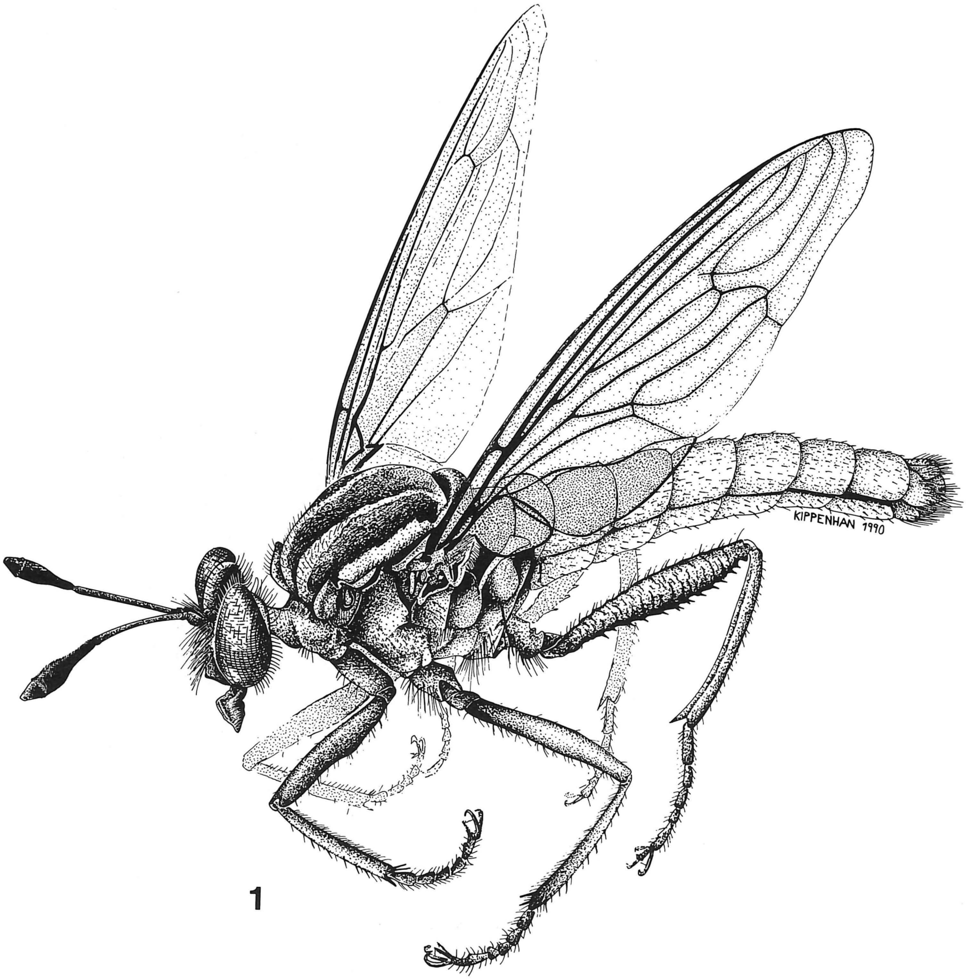

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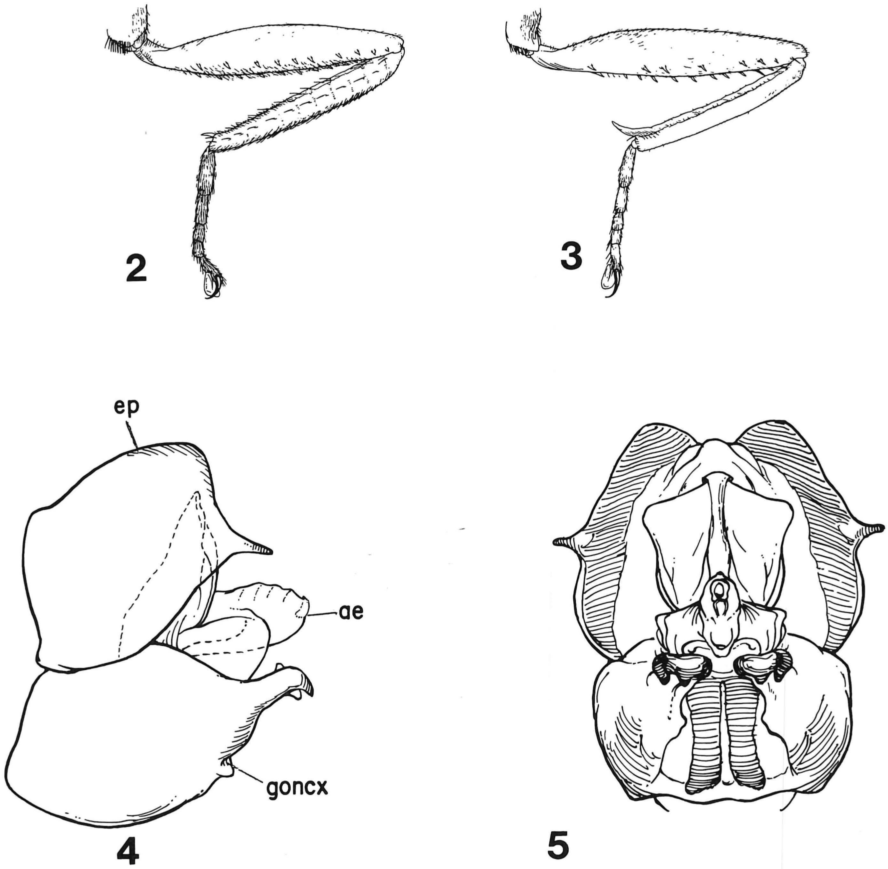
Figure 1. *Mydas rufiventris,* general habitus.

– Prementum of proboscis and subcranial cavity subequal in length; labella attached to mentum near its apical one-half, and extending at about a 90° angle; anterior margin of subcranium level with lower margin of the eye 3

3(2). Carina on hind tibia partially developed (Fig. 2); apical spur of hind tibia reduced or absent (Fig. 2); epandrium strongly arched in lateral view (Fig. 4); process of gonocoxite digitiform (Figs. 4–5); gonostylus saddle-shaped in caudal view (Fig. 5); length 29–45 mm .... *Protomydas* Wilcox, Papavero & Pimentel

– Carina on hind tibia completely developed (Fig. 3); apical spur of hind tibia long and stout (Fig. 3); epandrium rounded in lateral view (Fig. 6); gonocoxite simple or falciform (Figs. 6–7); gonostylus bilobed in caudal view (Fig. 7); length 25–26 mm .... *Mydas* Fabr.



Figures 2–5. 2. *Protomydas rubidapex,* hind leg. 3. *Mydas clavatus,* hind leg. 4. *Protomydas rubidapex,* male terminalia, lateral view. 5. *Protomydas rubidapex,* male terminalia, caudal view.

Messiasia d'Andretta

Messiasia d'Andretta 1951: 52.

Type Species.—*Messiasia carrerai* d'Andretta (by original designation).

Diagnosis.—See key to genera. Species included in this genus closely resemble, in general appearance those of *Mydas,* but they can be readily distinguished from Costa Rican *Mydas* species by their entirely black integument.

Discussion.—*Messiasia* is predominantly South American in distribution but five species are known to range from southwestern United States south to Panama (Wilcox & Papavero 1975).

Key to Costa Rican *Messiasia*

1. Wings pale amber; long white setae present above hind coxa; gonocoxite of male elongate, tapering to hook-like process; gonostylus serrate (Figs. 8–9) . . . . *decor* (Osten Sacken)
– Wings dull black; sparse black setae present above hind coxa; gonocoxite

of male truncate apically, upper process pointed; gonostylus broadly truncate (Figs. 10–11) .... *perpolita* (Johnson)

Messiasia decor (Osten Sacken)

Midas decor Osten Sacken 1886: 71.
Mydas decor; Williston 1898: 55.
Messiasia decor; d'Andretta 1951: 68.
Messiasia decor; Wilcox & Papavero 1975: 21 (includes specimens from La Suiza, Costa Rica).

Types.—Holotype, male; from: PANAMA. Bugaba; deposited in the British Museum (Natural History), London; examined.

Diagnosis.—The white setae above the hind coxae will usually separate both sexes of *M. decor* from *M. perpolita.*

Discussion.—This species is known from Costa Rica and Panama. Wilcox & Papavero (1975) indicate that this species occurs in forested areas. The illustration of the male terminalia of *M. decor* provided by Wilcox & Papavero (1975) is inaccurate.

Material Examined.—COSTA RICA. *MONTEVERDE Prov.:* 20–24 Jan 1986, W. Hanson and G. Bohart, 1 female (USU).

Messiasia perpolita (Johnson)

Mydas perpolita Johnson 1933: 72.
Messiasia polita; d'Andretta 1951: 64.
Messiasia perpolita; Wilcox & Papavero 1975: 31.

Types.—Holotype, male; from: MEXICO. *YUCATAN:* Chichen Itza; deposited in the Museum of Comparative Zoology, Harvard University, Cambridge, Mass.; examined.

Diagnosis.—The dull black wings and no white setae above the hind coxae will distinguish both sexes of this species from *M. decor.*

Discussion.—This species is relatively common in Mexico. Janzen (1986) described the unique tropical dry forest habitat in Costa Rica where this species was collected. Janzen's specimens collected by malaise traps represent the southernmost range extension for this species.

Material Examined.—COSTA RICA. *GUANACASTE Prov.:* Santa Rosa National Park, 14–17 Jun 1977, D. H. Janzen, 1 female (AMNH); same data except, 300 m, May 1983, D. H. Janzen and W. Hallwachs, 2 females (AMNH); same data except 1–15 Jun 1982, 300 m, D. H. Janzen and W. Hallwachs, 1 male (AMNH).

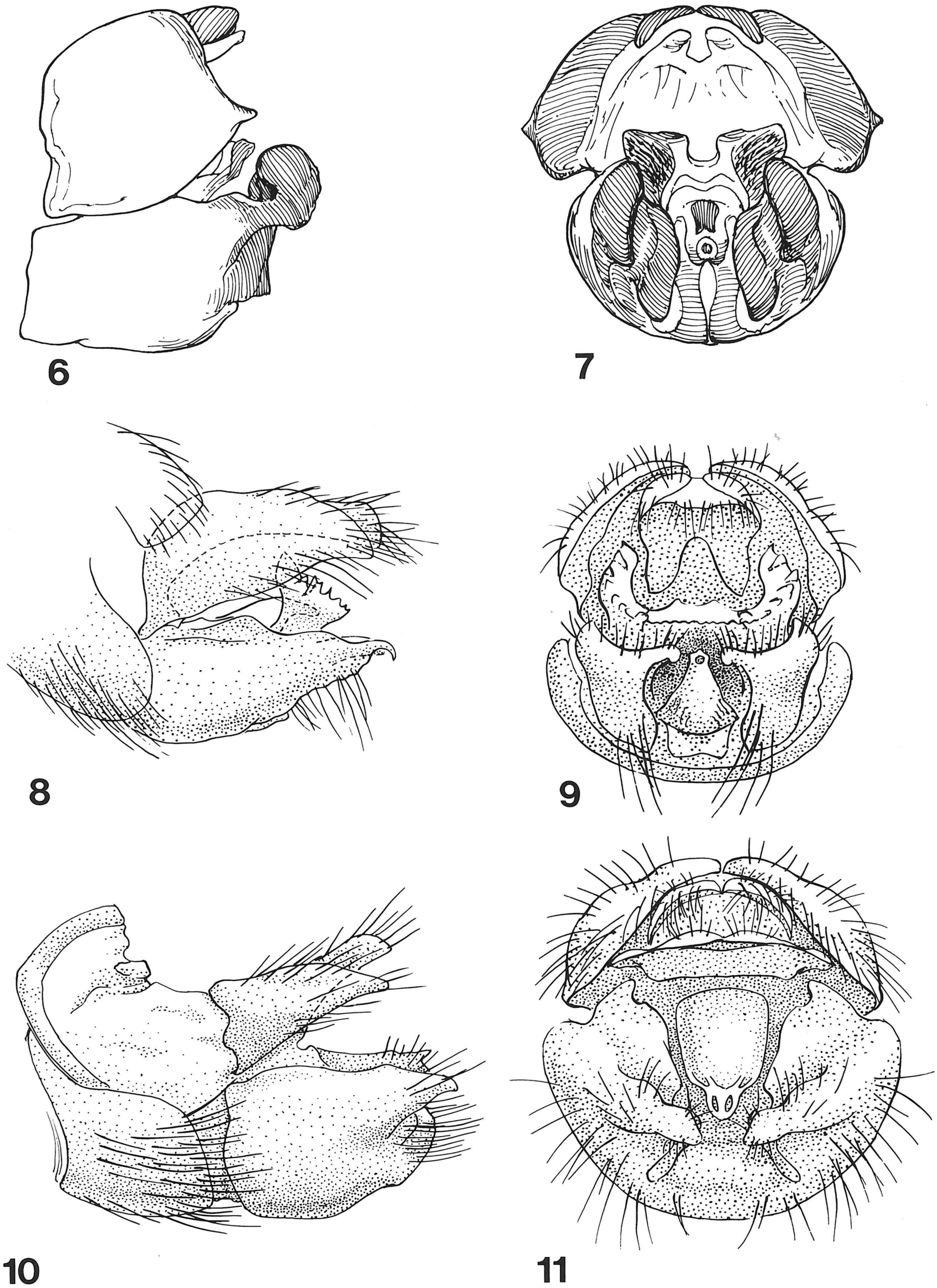
Nemomydas Curran

Nemomydas Curran 1934: 165.

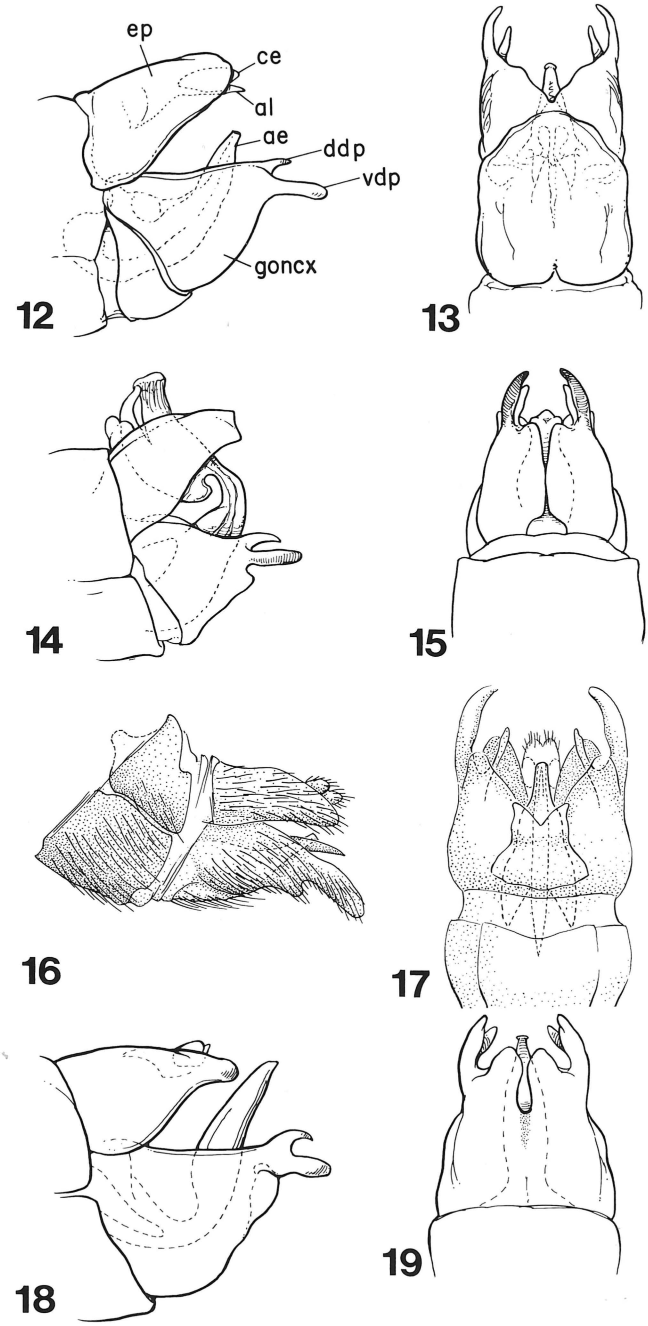
Type Species.—*Leptomydas pantherinus* Gerstaecker (by original designation).

Diagnosis.—See key to genera. Additionally, males are easily distinguished from all other mydids by the digitate processes of the gonocoxite.

Discussion.—*Nemomydas* is restricted to North America and Central America and presently includes 19 species (Steyskal 1956, Kondratieff & Welch 1990,



Figures 6–11. Male terminalia. 6. *Mydas rufiventris,* lateral view. 7. *Mydas rufiventris,* caudal view. 8. *Messiasia decor,* lateral view. 9. *Messiasia decor,* caudal view. 10. *Messiasia perpolita,* lateral view. 11. *Messiasia perpolita,* caudal view. Abbrev.: ae, aedeagus; ep, epandrium; goncx, gonocoxite.



Figures 12–19. Male terminalia. 12. *Nemomydas bequaerti,* lateral view. 13. *Nemomydas bequaerti,* ventral view. 14. *Nemomydas sponsor,* lateral view. 15. *Nemomydas sponsor,* ventral view. 16. *Nemomydas loreni,* lateral view. 17. *Nemomydas loreni,* ventral view. 18. *Nemomydas lamia,* lateral view. 19. *Nemomydas lamis,* ventral view. Abbrev.: ae, aedeagus; al, anal lamellae; ce, cercus; ddp, dorsal digitate process; ep, epandrium; goncx, gonocoxite; vdp, ventral digitate process.

Welch & Kondratieff 1990). Three species occur in Costa Rica including a new species described here: *N. lamia* (Seguy), *N. sponsor* (Osten Sacken), and *N. loreni* NEW SPECIES. These three species are very similar in appearance; females are difficult to separate without associated males.

Key to *Nemomydas* males south of Mexico

1. Abdominal tergites black, posterior margins yellow 2
– Abdominal tergites yellow-brown with middorsal black-brown spots or dashes; terminalia as Figs. 12–13 (Honduras) ..... *bequaerti* (Johnson)
2(1). Distal section of aedeagus in lateral view, abruptly expanded and recurved medially (Figs. 14–15) (Guatemala, Costa Rica) .... *sponsor* (Osten Sacken)
– Distal section of aedeagus in lateral view, tube-like (Figs. 16–17) or tongue-like (Figs. 18–19) 3
3(2). Distal section of aedeagus in lateral view, tube-like (Figs. 16–17) .... *loreni* NEW SPECIES
– Distal section of aedeagus in lateral view, tongue-like (Figs. 18–19) .. .. *lamia* (Séguy)

Nemomydas lamia (Séguy)

Nomoneura lamia Séguy 1928: 146.
Nemomydas lamia; Papavero & Wilcox 1968: 34.11.
Nemomydas lamia; Kondratieff & Welch 1990: 474.

Types.—Lectotype, male; from: COSTA RICA. La Caja; deposited in the Museum National d'Histoire, Paris; examined.

Diagnosis.—See key to *Nemomydas* species.

Discussion.—Kondratieff & Welch (1990) provided descriptions of both sexes of this uncommon species. The specimens examined are apparently the first additional material collected since its original description.

Material Examined.—COSTA RICA. *GUANACASTE Prov.:* S. Cañas, 26–31 Jan 1989, F. D. Parker, 1 male (CSU), 2 males (USU). La Caja, Paul Serre, 1920, 1 male, 6 females (MNHN).

Nemomydas sponsor (Osten Sacken)

Leptomydas sponsor Osten Sacken 1886: 68.
Nemomydas sponsor, Kondratieff & Welch 1990: 475.

Types.—Holotype, female; from: GUATEMALA. San Geronimo; deposited in the British Museum (Natural History), London; examined.

Diagnosis.—See key to *Nemomydas* species.

Discussion.—Kondratieff & Welch (1990) provided the first description of the male of this species.

Material Examined.—COSTA RICA. *SAN JOSE Prov.:* San Jose, 27–29 Dec 1987, F. D. Parker, 4 males, 2 females (USU); Escazu, 14–16 Jan 1989, F. D. Parker, 1 male (USU); 1 male (MNHN).

Nemomydas loreni Welch & Kondratieff, NEW SPECIES

Types.—Holotype male, data: COSTA RICA. *GUANACASTE Prov.:* S. Cañas, 1–3 Feb 1989, F. D. Parker; deposited: Utah State University, Logan. Paratypes deposited in Utah State University, Logan, except as indicated; data: 16 males, 1 female, same data as holotype (1 male deposited CSU), (1 male deposited JLW); same data except 1–5 Mar 1989, 1 male; same data except 21–25 Jan 1989, 4 males; same data except 26–31 Jan 1989, 3 females; same data except 9–14 Feb 1989, 1 male, 9 females (1 female deposited CSU); same data except 22–24 Feb 1989, 1 male (deposited CSU); Tamarindo, 6 Nov 1977, M. E. Irwin, ex. beach sand, 1 male (deposited INHS). *SAN JOSE Prov.:* Escazu, 14–16 Jan 1989, F. D. Parker, 2 females (1 female deposited JLW); Puntarenas, 19 Dec 1989, F. D. Parker, 2 males; Comelco Property, 30 Jan 1976, H. Reed, 1 male (deposited TXA&M).

Description.—Male. Length 12–16 mm. Head shiny black, with white, erect setae; orbital of eye yellow pollinose; antenna 3.6–3.8 mm long, black, flagellomere two white pollinose dorsally, brown pollinose ventrally; proboscis long, 2.6 times as long as subcranial cavity, black. Scutum black, with a pair of submedian yellow pollinose stripes that converge posteriorly, and a pair of lateral yellow pollinose stripes, setae yellow, long, erect, sparse; postpronotal lobe yellow pollinose; scutellum yellow pollinose, black posteriorly; metanotum black, yellow pollinose anteriorly. Wings brown, longitudinal veins brown, costa black with black setae; knob of halter black, stem brown. Foreleg and midleg brown black, setae white dorsally, black ventrally; hind femur white basally, black apically; hind tibia white dorsally, brown-black ventrally; with short, white setae, dorsally, black ventrally; tarsomeres brown-black. Abdominal tergites shiny black, posterior margins yellow to brown; bulla black; tergite one with setae white, long anteriorly, short, sparse posteriorly; tergite two with setae black, short, decumbent, medially; setae white, long, divergent, anteriorly and laterally; tergites three to five with setae black, short, decumbent; tergites six and seven with setae white, long, decumbent; sternites shiny black, sternites two to five with posterior margins yellow to brown; sternites two to four with setae white, long, decumbent; sternites five to seven with setae black, long, decumbent. Terminalia brown-black. Gonocoxite with dorsal digitate process distinctly claw-like, ventral digitate process oblong, rounded, slightly directed inwardly; a smaller rounded protrusion ventrally. Aedeagus tube-like distally, swollen basally (Figs. 16–17).

Female.—Length 12–16 mm. Color and structure similar to male, except setae on abdominal tergites short and sometimes tergites six and seven without yellow posterior margins.

Diagnosis.—The male of *N. loreni* can be distinguished from all other meso-american species by the combination of black abdominal tergites with yellow posterior margins and tube-like distal section of the aedeagus. The female cannot be satisfactorily separated from *N. lamia.*

Etymology.—This species is named in memory of JLW's father, who encouraged her to take an interest in Diptera because of their intriguing life histories.

Material Examined.—Type series.

PROTOMYDAS WILCOX, PAPAVERO & PIMENTEL

Protomydas Wilcox, Papavero & Pimentel 1989: 13.

Type Species.—*Mydas coerulescens* Olivier (by original designation).

Diagnosis.—See key to the genera.

Discussion.—Wilcox et al. (1989) recognized three species in this primarily Neotropical genus; only one is known from Costa Rica and listed here. D'Andretta (1951) provided illustrations of the male terminalia and other characters for these species.

Protomydas rubidapex (Wiedemann)

Mydas rubidapex Wiedemann 1830: 626.

Mydas dives Westwood 1841: 50. (Synonymized by Wilcox, Papavero & Pimentel 1989: 16.)

Protomydas rubidapex; Wilcox, Papavero & Pimental 1989: 16.

Types.—The type of *P. rubidapex* is from MEXICO, and is deposited in Humboldt Universitat, Berlin; it was not examined. The type of *P. dives,* from an unknown locality, is deposited in Hope Museum, Oxford, England, and was not examined.

Diagnosis.—*Protomydas rubidapex* is easily separated from all *Mydas* species by the reduced or absent carina of the hind tibia, the arched epandrium, digitiform process of the gonocoxite, and the saddle-shaped gonostylus.

Redescription.—*Male.* Length 29–45 mm long. Head shiny black, with long, erect, black setae; mystax with long, decumbent, black and yellow setae; orbital margin of eye black; antenna 10–12 mm, orange or black with flagellomere 2 orange; proboscis black. Scutum dull black; setae sparse, decumbent, black; wing opaque orange to brown, wing margin broadly brown to black; veins orange, or sometimes brown apically, costa with black setae basally, and mixed black and orange setae apically; calypter with long dense fringe of black squamose setae; halter black; legs black, setae and bristles black; hind tibia with carina absent or reduced, apical spur weakly developed, shorter than width of first hind tarsal segment. Abdominal tergite one black, with long, decumbent, sparse, golden setae; tergite two black, with short, recumbent, golden setae; bulla black; tergites three to seven with short, recumbent, black, setae; sternites with short, sparse, recumbent setae. Terminalia with epandrium, in lateral view (Fig. 3) arched, concave above spur; gonocoxite with produced, "grasping" digitiform process that is incurved in caudal view; gonostylus saddle shaped; aedeagus tube-like, ribbed dorsally, with lateral rounded ridges (Fig. 4).

Female.—Length 35–40 mm. Antenna length 14.0–15.5 mm. Coloration and structure similar to male.

Discussion.—Wilcox et al. (1989) did not provide a thorough description of this species, and the redescription above is based on Costa Rican specimens. This species ranges from northern Mexico to Venezuela and Brazil.

Material Examined.—COSTA RICA. *GUANACASTE Prov.:* Santa Rosa National Park, 21–24 Dec 1979, D. H. Janzen, ex malaise trap, 1 male (AMNH); same data as above except, 1–15 Jan 1982, 300 m, D. H. Janzen and W. Hallwachs, 1 male (AMNH); Sotobosque, Cerro El Hacha, 12 Sep–2 Jan 1988, Tacotal, ex malaise trap, 1 female (AMNH).

Mydas Fabr.

Mydas Fabr. 1794: 252.

Type Species.—*Musca clavata* Drury (by subsequent designation).

Diagnosis.—See key to the genera.

Discussion.—This genus and its allies were recently revised by Wilcox et al. (1989); we do not agree with several of the taxonomic conclusions reached in that study and will publish our interpretations elsewhere. *Mydas rufiventris* is the only *Mydas* known from Costa Rica.

Mydas rufiventris Macquart

Mydas rufiventris Macquart 1850: 364.
Mydas vittatus Macquart 1850: 364.
Mydas militaris Gerstaecker 1868: 99. (New name for *Mydas vittatus,* preoccupied.)
Stratiomydas rufiventris; Wilcox et al. 1989: 127.
Mydas quadrilineatus Williston 1898: 56. NEW SYNONYM.
Stratiomydas quadrilineatus; Wilcox et al. 1989: 125.

Types.—The holotype male of *M. rufiventris* is labeled "BRAZIL" (in error); it is deposited in the Museum National d'Histoire Naturelle, Paris, and was examined. The holotype female of *M. vittatus* is labeled MEXICO; it is deposited in the Museum National d'Histoire, and was examined. The syntypes of *M. quadrilineatus* are labeled "MEXICO"; they are deposited in the British Museum (Natural History), London, and were examined.

Diagnosis.—The white to yellow mystax and the four pollinose stripes of the mesonotum will easily distinguish this species from all other possible *Mydas* species.

Discussion.—In a recent review of the Mydini by Wilcox et al. (1989), *M. rufiventris* was distinguished from *M. quadrilineatus* by the color of the abdominal tergites which are primarily black in *M. quadrilineatus* and red in *M. rufiventris.* Examination of specimens throughout the range of both species (Arizona, Mexico, El Salvador, and Costa Rica) indicated the presence of only one variable species. The male terminalia of both forms are alike. The key of Wilcox et al. (1989) to this group is unusable, however, especially with females. The series of both sexes, collected by Paul A. Opler near Cañas, contains all color morphs, ranging from specimens with all abdominal tergites completely black to some with tergites two through five or two through seven red. This often extreme polymorphism in abdominal color is common in other species groups of *Mydas* (e.g., *Mydas ventralis* Gerstaecker of the southwestern United States).

Material Examined.—COSTA RICA. *GUANACASTE Prov.:* Cañas, 6.4 km NW of La Pacifica, 14 May 1971, P. A. Opler, ex *Casearia* sp. ("*nitida*"), 1 male, 1 female (UCB); same data except 15 Nov 1971, 1 female; same data except 23–30 May 1972, ex *Forsteronia* sp. ("*spicata*"), 2 males, 2 females (UCB), 1 male (CSU); same data except 6 Jun 1973, ex *Asclepias* sp. ("liana"), 2 males (UCB); same data except 2–4 June 1973, Asclepias vine, 1 male, 2 females (UCB).

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POST-EGESTIVE SURVIVAL OF *SPHENOPHORUS PHOENICIENSIS* CHITTENDEN (COLEOPTERA: CURCULIONIDAE) EGESTED BY WESTERN TOADS

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Abstract.—Billbugs (Coleoptera: Curculionidae) are eaten by toads and egested alive in fecal pellets. This study examines post-egestive weight loss and survivorship of *Sphenophorus phoeniciensis* Chittenden after passing through the digestive tract of the western toad, *Bufo boreas* Baird & Girard. Weight loss (mg/h) in egested billbugs exceeds that found for nonegested billbugs at both low and high RH. Egested billbugs do not live as long as nonegested billbugs at the same relative humidity.

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

Toads (Bufonidae) are known to ingest billbugs (Coleoptera: Curculionidae). Some billbugs (*Sphenophorus* spp.) resist digestion by toads (*Bufo boreas* Baird & Girard) and emerge alive from fecal pellets (Barrentine in press). Egested billbugs have reduced survival at low humidities (Fair 1969). This is putatively due to increased water loss resulting from epicuticular damage. This study compares weight loss and survivorship between egested and nonegested billbugs (*Sphenophorus phoeniciensis* Chittenden) at both low and high relative humidities.

Materials and Methods

Billbugs, *S. phoeniciensis,* in treatment samples were collected from infested turfgrass (2200–2300 h) and immediately fed to captive adult toads (*B. boreas halophilus* Baird & Girard). After two to three days, billbugs were isolated from freshly egested toad fecal pellets, individually weighed (0.1 mg) and then placed in one of two Scheibler desiccators. Both desiccators were kept at room temperature at 23° C, but differed in < 5% versus > 95% RH. Humidity was controlled using Drierite® (anhydrous calcium sulfate) or distilled water. Weight loss and survivorship of individual weevils were recorded at 24 h intervals. Because curculionids are capable of feigning death (DuPorte 1916, Weiss 1940), mortality was confirmed by lack of antennal reflex (flexor response to mechanical stimulation). After death, billbugs were oven dried at 68° C to constant weight. Billbugs in control samples were collected and handled as described above, for treatment samples, except that these were not fed to toads. Billbugs in treatment and control samples were paired by weight (± 0.1 mg, wet) before comparison using Student's *t*-test.

Results and Discussion

At low humidity, there was no difference in weights between paired treatment and control samples at the time of death (Table 1). Although death weights were

Table 1. Weights of *Sphenophorus phoeniciensis* (mg, $\bar{x} \pm$ SE).

	n	Wet weight (mg) $\bar{x} \pm$ SE	Death weight (mg) $\bar{x} \pm$ SE		Dry weight (mg) $\bar{x} \pm$ SE
<5% RH					
Control	50	18.62 ± 0.48	10.90 ± 0.36		7.93 ± 0.19
Treatment	50	18.62 ± 0.48	11.28 ± 0.39		7.89 ± 0.19
>95% RH					
Control	50	18.57 ± 0.54	12.68 ± 0.35	a	6.97 ± 0.18
Treatment	50	18.57 ± 0.54	15.44 ± 0.53		6.90 ± 0.18

[a] $t = 4.29$, $P < 0.01$.

similar for both samples (40%), billbugs in the treatment sample did not, on the average, survive as long as those in the control sample (Table 2). Mean weight loss for egested billbugs was 0.153 mg/h (7.34 mg/48.0 h) at < 5% RH. Mean weight loss in nonegested (normal) billbugs was 0.134 mg/h (7.72 mg/57.6 h). Assuming that weight loss is proportional to water loss, the desiccation rate for egested billbugs is 15% higher than that for normal billbugs at low humidity.

At high humidity, death weights between paired treatment and control samples differed (Table 1). Death occurred at 17% and 32% weight loss in treatment and control groups, respectively. Billbugs in the treatment sample did not, on the average, survive as long as those in the control sample (Table 2). Mean weight loss for egested billbugs was 0.022 mg/h (3.13 mg/144.5 h) at > 95% RH. Mean weight loss in nonegested (normal) billbugs was 0.020 mg/h (5.89 mg/295.7 h). Again, assuming that weight loss is proportional to water loss, the desiccation rate for egested billbugs is 10% higher than that for normal billbugs at high humidity.

These results both corroborate and extend observations made by Fair (1969). Fair observed that lowered humidity (39–43%) induced death in egested billbugs and that reduced survival was probably the result of increased water loss caused by damage to the epicuticle. This study thus documents reduced survivorship for egested billbugs at both low and high humidities and quantifies weight (water) loss for both egested and nonegested billbugs.

Table 2. Time of death for *Sphenophorus phoeniciensis* (hours, $\bar{x} \pm$ SE and range).

	n	Hours $\bar{x} \pm$ SE		Hours (Min–Max)
<5% RH				
Control	50	57.6 ± 1.81	a	(48–96)
Treatment	50	48.0 ± 1.94		(24–72)
>95% RH				
Control	50	295.7 ± 17.07	b	(72–528)
Treatment	50	144.5 ± 20.29		(24–528)

[a] $t = 3.58$, $P < 0.01$.
[b] $t = 5.65$, $P < 0.01$.

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SEASONAL PATTERNS IN A SAN FRANCISCO BAY, CALIFORNIA, SALT MARSH ARTHROPOD COMMUNITY

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Abstract.—Biomass, abundance, and species richness patterns of detritivore, herbivore, and carnivore components of a San Francisco Bay, California, salt marsh arthropod community were examined over an annual cycle. Abundance and species richness patterns for herbivores and detritivores did not track the occurrence of their respective food resources, perhaps because of the influence of salinity levels, and the frequency and duration of tidal inundation. In contrast, abundance and species richness of carnivores corresponded well with occurrence of their herbivore and detritivore prey, perhaps because carnivores are less susceptible to salt marsh environmental extremes. Trophic biomass analysis showed a typical pyramid-shaped relationship among producer, herbivore and detritivore, and carnivore components in spring; during autumn, however, the biomass of carnivores exceeded that of herbivores and detritivores.

Key Words.—salt marsh, wetlands, seasonality, trophic, arthropods, insects, *Salicornia*

Over an annual cycle, salt marshes are subject to relatively large seasonal fluctuations in tidal inundation frequency and duration, and in soil, ground water, and tidal water salinity. Does the composition of the arthropod fauna show similar temporal fluctuations? If all species of salt marsh arthropods are well adapted to the full range of tidal inundation and salinity that occurs over a year, the occurrence of a trophic group and the availability of its food resources should correspond, as has been reported for more seasonally constant environments (e.g., Hurd & Wolf 1974, Brown & Southwood 1983). However, if physical conditions disrupt the ability of a trophic group to track its food resources, poor correspondence may result. In this paper, we describe the seasonal occurrence of arthropods (as measured by biomass, abundance, and number of species), and relate these findings to the above considerations.

MATERIALS AND METHODS

The study was conducted in Petaluma Marsh, Sonoma Co., California (for map of area, see Balling & Resh 1983: Fig. 1), which is the largest of the San Francisco Bay tidal marshes and one of the largest (1145 ha) estuarine marshes along the Pacific Coast of North America. The marsh is dominated by pickleweed (*Salicornia virginica* L.).

Arthropods were collected using a D-vac suction device with a 0.25 mm mesh collection bag, and were separated from plant matter using a Berlese-Tullgren funnel; a complete description of arthropod sampling methods is given in Balling & Resh (1982). Samples for the present analysis were chosen from a series that was taken approximately monthly from January to November 1978 (representing 12 sampling dates). Specimens were separated into three categories: detritivores, herbivores, and carnivores. Primary feeding habits of the species were obtained from taxonomic specialists in these groups and from existing literature (e.g., Cameron 1972). Although some species do not feed restrictively within a single trophic group, we used the predominant feeding mode of a species to describe its trophic status.

Arthropod abundance and species richness (number of species per 0.09 m^2 sample) were based on data from six samples collected each month. Arthropod biomass was determined from two samples each month, which were individually oven dried at 100° C to a constant weight.

Detailed measurements of physical variables (salinity, tidal inundation, and air temperature) were not done in Petaluma Marsh until 1980; however, values during that year matched periodic observations made during 1977–1979. In 1980, salinity of tidal waters was measured weekly (during high tide) with a refractometer; periodic measurements of interstitial water salinity (Balling & Resh 1983) indicated similar seasonal trends observed to those for tidal water salinity. Tidal inundation frequency of the marsh surface was calculated using data from a tide gauge located on a nearby slough. Average air temperature was determined from constant temperature recordings.

Results and Discussion

Biomass.—Arthropod biomass during the year was characterized by three narrow, well-defined peaks; each peak represented a different trophic level: detritivores peaked in March, herbivores in May and June, and carnivores in September and October (Fig. 1a). At least in part, these biomass patterns reflected the phenology of the large sized species in the arthropod community. For example, the peak in detritivores closely followed peak occurrences of the amphipod *Orchestia traskiana* Stimpson and the isopod *Littorophiloscia richardsonae* (Holmes & Gay). Herbivores were not dominated by any single species; instead the peak largely resulted from four species of brine flies [Ephydridae: *Psilopa* (*Ceropsilopa*) *coquilletti* (Cresson), *Scatella* (*Scatella*) *stagnalis* Fallen, *Scatella* (*Neoscatella*) *setosa* Coquillett and *Scatophila* sp.] and two species of leafhoppers [Cicadellidae: *Streptanus confinus* (Reuter) and *Macrosteles* sp. near *fascifrons* (Stål)]. The carnivore peak reflected the maturation of the population of the large wolfspider (Lycosidae) *Pardosa ramulosa* (McCook).

Abundance.—Of all trophic groups, more individuals of carnivores than herbivores or detritivores were collected throughout the year; however, the abundance peaks were less well defined than the biomass peaks (Fig. 1b). Abundance of all groups peaked in spring and then again in autumn. In contrast to the influence of large individuals on biomass, changes in abundance are often biased toward the smaller sized, more numerous species (e.g., Odum 1971). For example, the spring detritivore peak was dominated by the sminthurid collembolan *Sminthurides* (*Sminthurides*) *malmgreni* Tullberg and the autumn peak was dominated by the psocopteran *Lachesilla pacifica* Chapman. The spring peak in herbivores was dominated by the same species of brine flies and leafhoppers as the herbivore biomass peak. However, the earlier rise in abundance seen in March was caused by early instar leafhoppers, whose small size made them proportionately more important in abundance measures than in biomass measures. Carnivore abundance peaks in spring and autumn were dominated by the small predaceous phytosieid mite *Amblyseius scyphus* Schuster & Pritchard, and also included a broad array of other mites and spiders.

Species Richness.—Like abundance, the peaks in species richness were less well

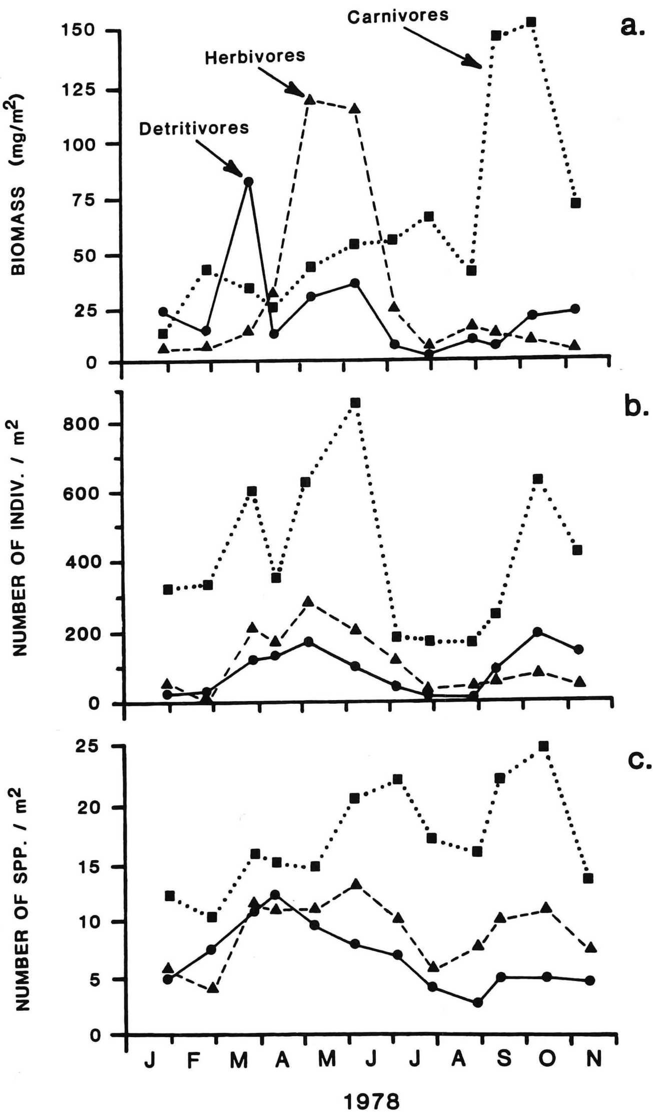

Figure 1. Mean (a) biomass, (b) abundance, and (c) species richness of terrestrial arthropods collected in Petaluma Marsh during 1979; squares represent carnivores, triangles represent herbivores, and circles represent detritivores.

defined than those for biomass. Detritivore species richness was highest in April, with only a small increase in autumn. Herbivore species richness was highest in June (although this was preceded by similarly high levels that began in March), decreased in July and August, and increased again in September and October. Carnivore species richness peaked in May, June and July, and October.

Trophic Pyramids.—Because biomass relationships among different trophic groups changed seasonally (Fig. 1a), the shape of ecological pyramids that are developed from biomass data vary depending on the time of year. For example,

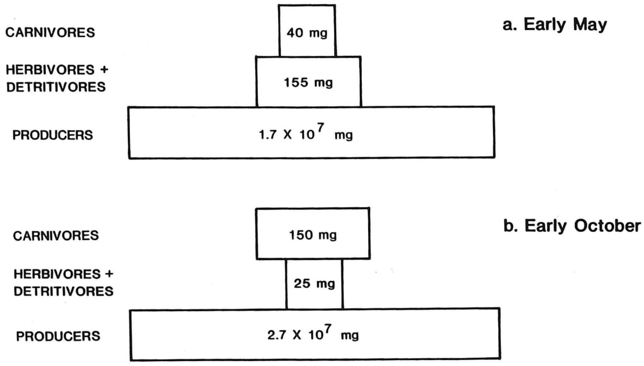

Figure 2. Trophic pyramids of pickleweed and arthropod biomass in (a) early May and (b) early October 1979. Plant biomass data are from Cameron (1972) and Balling & Resh (1983). Pyramid widths are given as the $\log_{10}$ of the biomass (mg/m^2).

during early May the trophic relationships were pyramid shaped; biomass estimates of producers (pickleweed), herbivores/detritivores (combined to estimate potential carnivore prey), and carnivores decreased at successively higher trophic levels (Fig. 2a). In contrast, during early October the carnivore and herbivore/detritivore relationship was inverted (Fig. 2b).

Interaction of Trophic Groups and Abiotic Factors.—Although biomass patterns in this salt marsh arthropod community showed seasonal changes indicating trophic succession, the abundance and species richness patterns showed neither trophic succession nor the typical numerical domination of herbivores. Perhaps this is related to the seasonal patterns of physical features of the salt marsh environment.

In Petaluma Marsh, water salinities were lowest in February, March, and April; they steadily increased through the following summer, and then decreased with the onset of rain at the beginning of the wet season in October (Fig. 3a). Tidal inundation frequency (Fig. 3b) and air temperature (Fig. 3c) showed similar patterns.

Detritivores had their highest biomass, abundance, and species richness during spring, even though their primary food resource (which in a pickleweed monoculture is composed of litter from senescent stems) was most abundant in October and November (Cameron 1972). The early spring flushing of the marsh surface by rainfall and low salinity tides reduces the salt content of surface litter, which may make it more palatable to insect detritivores (Foster & Treherne 1976). In addition, microbial colonization may condition the litter by this time, which also provides bacterial and fungal food sources.

Abundance, richness, and biomass of detritivores declined gradually until August, even though abundant litter still occurred in the marsh; perhaps this decline resulted from high salinities of tidal water (over 20 ppt, Fig. 3a) and frequent tidal inundation of the marsh (Fig. 3b). During July and August, the marsh surface is inundated by tides approximately 10% of the time and for periods of up to 5.5 h. Such inundations are stressful to arthropods that remain under water, and also to those that remain on the water surface or migrate to the tops of emergent

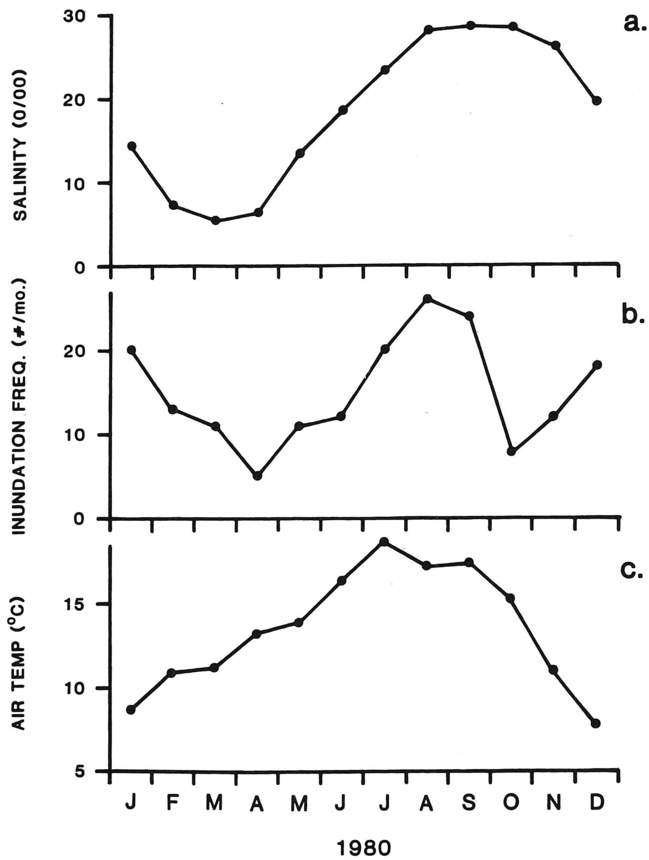

Figure 3. (a) Mean salinity of tidal water, (b) frequency of tidal inundation (per month), and (c) mean maximum air temperature in Petaluma Marsh during 1980.

vegetation because they will be more susceptible to predation or washout by receding tides (Foster & Treherne 1976).

In autumn, the psocid *L. pacifica* was the only detritivore to increase in abundance. The apparent salt tolerance of this species allows it to use this abundant food source at a time when few other detritivore species are present (e.g., Fig. 1c shows an average of only four detritivore species per sample during September and October).

Abundance and biomass of herbivores is highest in late spring even though their food, which consists mostly of surface algae and the annual succulent component of pickleweed, increases in quantity from March through October (Cameron 1972, Mahall & Park 1976, Zedler 1982, Josselyn 1983). The rise in herbivores coincides with the most rapid increase in succulent plant biomass, and with the seasonal increase in air temperature (Fig. 3c). The rather sudden decline coincides with the combination of peak tidal inundation (Fig. 3b) and peak salinities (Fig. 3a).

Tidal salinities, which correlate with groundwater salinities, indirectly affect sap-feeders such as leafhoppers through reductions in their food quality because pickleweed sap salinity increases as groundwater salinity increases (Flowers et al. 1977). For example, Regge (1973) has shown that salt marsh aphids will seek plants with lower sap salinity, and Vince et al. (1981) have shown that a positive relationship between *Spartina* nutritional quality and herbivore abundance occurs in an Atlantic coast salt marsh.

The decline of herbivores at the end of spring also coincided with the rise in carnivore abundance; thus, predation may also be an important regulating factor. Again, as with the detritivores, high tides of mid-summer may drive some insects to the plant tops or water surface, and thus increase the chances of predation. Vince et al. (1981) also indicated that spider predation may limit herbivore abundance.

The seasonal patterns of carnivore abundance and species richness corresponded well with the occurrence of expected food sources (i.e., herbivores and detritivores). Carnivores, represented primarily by mites, reached their peak abundance in spring, which coincided with the herbivore and detritivore abundance peaks. Although carnivore abundance declined through the summer, biomass continued to rise. Most of the autumn predators are spiders that are well adapted to traversing water surfaces and capturing prey that are found there (Roth & Brown 1976). Because most of their prey regulate the salinity of their hemolymph (at least to some extent), predators may be less affected by the rise in salinities during summer and autumn.

In conclusion, salt marsh herbivores and detritivores apparently do not closely track changes in the quantity of their food. In fact, the inefficiency of the detritivores may help promote the rapid accumulation of peat that occurs in many salt marshes. The results of this study suggest that the phenologies of salt marsh herbivores and carnivores are determined less by the quantity of food than by tidal inundation and the quality of food, which in turn is affected by tidal and groundwater salinities (Collins et al. 1986, Collins & Resh 1989). Carnivores, in contrast, appear to respond to food availability rather than to the physical extremes of the salt marsh environment.

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Scientific Note

ATYPICAL SEX ROLE BEHAVIOR IN THE BALL-ROLLING DUNG BEETLE, *CANTHON PILULARIUS* L. (COLEOPTERA: SCARABAEIDAE)

During July, 1990, I observed unusual feeding and reproductive behavior in the ball-rolling dung beetle, *Canthon pilularius* L. On three occasions, females engaged in what have been described as exclusively male behaviors for this species. These observations suggest that the behavioral roles of the sexes of this species may not always be clear-cut.

The feeding and reproductive behavior of this species, and of the Scarabaeinae in general, are described elsewhere (Matthews, E. G. 1963. Psyche, 70: 75–93; Halffter, G. & E. G. Matthews. 1966. Folia Entomol. Mex., 12–14: 1–312; Halffter, G. & W. D. Edmonds. 1982. Publ. Inst. Ecol., Mex. D.F. 10). In all of these accounts, the male is reported to be the active partner in reproducing pairs; only males engaged in combat over possession of dung balls, and only males initiated formation of brood balls. I report females engaging in both of these activities at the Central Plains Experimental Range near Nunn, Colorado.

Groups of four and 12 beetles were maintained in 0.84 m^2 outdoor screen cages. The cages were open to the ground to allow normal ball-rolling and digging behavior, and the beetles were provided with a continuous supply of fresh cow dung. The sides of the cages restricted the distances that beetles could roll their dung balls, but this did not appear to affect their behavior in any other way. All individuals were marked with dots of paint to facilitate field identification without disturbance. I observed the beetles on 31 days at 1–4 day intervals throughout the summer of 1990.

On 11 Jul 1990, I observed a female cut and roll a dung ball that later became a brood ball. The cutting process lasted about 20 min, after which the female beetle continued to shape the ball, with occasional attempts at rolling it. Some difficulty was encountered in rolling due to a small stick and a maggot that protruded from the ball. More than 3 h after initiating ball formation, the female began rolling the ball, and 17 min later she began burying it. Six min later, when the ball was already partially buried, she was joined by a male beetle; the two immediately began rolling the ball as a pair, with the male rolling and the female riding atop the ball. After 32 min of rolling, they began burying the ball together. It is not certain that the female initially intended this ball to be a brood ball rather than a food ball, although the extraordinarily long time taken to create the ball is suggestive.

On two other occasions I observed female beetles engage in combat; in at least one of these the combat was initiated by the female. On 7 Jul 1990, when a pair was in the process of burying a brood ball with the male digging beneath the ball to bury it, and the female on top of the ball, another female approached. The two females grappled together, producing clearly audible scraping, while the male continued digging and standing beside the ball. After approximately 1 min, the intruding female departed and the original pair continued to bury the brood ball. At no time did the male enter the combat, although he emerged from beneath the ball while the combat was still occurring.

The second instance was on 26 Jul 1990. A male was cutting and shaping a dung ball at the dung source when he was approached by a female. A brief fight ensued. Normally this would end quickly with pair-bond formation when the male recognized the sex of the opposing beetle. In this case, however, the fight ended with the female rolling the ball away by herself, the male remaining behind atop the dung pat. The female buried the ball 15 min later, and the male burrowed under the dung pat.

These observations, although anecdotal, indicate that the behavior of *C. pilularius* may be even more complex than has been reported. Previous accounts have shown that males will make a brood ball in the absence of females, apparently choosing the riskier investment in reproduction rather than the more certain feeding opportunity. My observation of a female making a brood ball suggests that females may follow the same strategy. The observations of females engaged in combat suggest that females will fight to defend their reproductive investment if a male is not present, and that females may choose to feed rather than reproduce by stealing a dung ball from a male rather than mating with him.

The unusual behaviors that I observed may be partly due to a more arid environment with shorter summers than those in which previous observations were made (e.g., Miller, A. 1954. Am. J. Trop. Med. Hyg., 3: 372–389; Matthews 1963). The Nunn, Colorado observation site is a semiarid shortgrass prairie near the edge of the geographical range of *C. pilularius*; winters are long and cold, summers are dry and hot, and annual precipitation averages about 325 mm. Different climatic conditions may impose different behavioral strategies upon the beetles. Future observations on these beetles may reveal if the behaviors I observed are repeatable or if they were chance aberrances.

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PROCEEDINGS OF THE PACIFIC COAST ENTOMOLOGICAL SOCIETY

Four Hundred and Fifty Eighth Meeting

The 458th meeting of the Pacific Coast Entomological Society was held on Friday, 15 Jan 1988, at 8:00 PM, in Morrison Auditorium of the California Academy of Sciences, San Francisco, with president Alan I. Kaplan presiding. The minutes of the 457th meeting were read by the recording secretary and accepted. Mr. Daniel Gross, membership chairman, proposed three new regular members and two new student members, who were accepted as members. Several guests were introduced: Laurie Swiadon, who recently received her masters from Hebrew University of Jerusalem, Dr. John E. Lattke of the University of Maracay, Venezuela, Mr. Albert Hom, David Zuckermann of the East Bay Regional Parks and Margaret Kelley of the Tilden Nature Center. Darryl Ubick announced the spider workshop would be postponed until February. Several notes were given. Kirby Brown presented three slides of insect art and artifacts from Hong Kong, China, Singapore and Thailand. The slides depicted stamps, coins, carvings and etchings. Dr. Ferguson presented a note on recovering a tagged monarch butterfly at an overwintering site in Mexico, 80 miles from Mexico City. It is the longest migrant ever recovered. It was tagged on the eastern shore of Georgia Bay in Canada. Contact Dr. Ferguson for detailed direction to the overwintering site. Mr. Kaplan announced that Gail Grodhaus of the State Department of Public Health passed away Christmas eve, 1987. The Gail Grodhaus Memorial Fund will be set up for chironomid study. For tax deductible contributions to the fund in memory of Gail Grodhaus, checks can be sent to the Chironomis Grodhaus Memorial Fund, % Dr. James Sublette, Life Science Building, University of Southern Colorado, 2200 Bonfort Blvd., Pueblo, Colorado 81000.

President Kaplan introduced the speaker for the evening, John Lane, Education Director of the Santa Cruz Museum. Mr. Lane presented an interesting lecture titled "Overwintering Monarch Butterflies in California: Past and Present." The monarch butterfly is the only insect that has a long distance, annual, two way migration. A survey of California overwintering sites of the monarch butterfly was given. Historical documentation was presented along with a summary of the natural history of the monarch and a list of the trees used for overwintering. The Natural Bridges State Park has from 40,000–50,000 butterflies overwintering and sometimes up to 200,000.

President Kaplan announced that the next meeting would be held on 19 Feb 1988 and the speaker would be Leslie Saul. The title of the talk will be "Insect Zoos and their role in Public Education." The meeting was adjourned at 9:30 PM and a social hour was held in the entomology department of the California Academy of Sciences. The following 43 persons were present: (27 members) P. H. Arnaud Jr., A. Balmy, L. G. Bezark, D. S. Brennan, T. S. Briggs, K. W. Brown, H. K. Court, K. Dabney, L. Dong, S. S. Ferguson, W. E. Ferguson, D. F. Gross, A. I. Kaplan, B. Keh, C. Y. Kitayama, V. F. Lee, P. A. Luft, S. S. Mead, J. A. Powell, E. S. Ross, L. S. Saul, W. E. Savary, H. I. Scudder, C. Y. Takahashi, J. E. Tobler I, D. Ubick, and M. L. Utheim; (16 guests) M. M. Arnaud, L. M. Bravo I. Brown, J. E. Court, P. R. Craig, M. Davies, T. W. Davies, L. V. Dubay, D. Hayward, A. Hom, M. Kelley, J. E. Lattke, W. C. Rauscher, L. Swiadon, B. Tobler, and D. Zuckermann.

Four Hundred and Fifty Ninth Meeting

The 459th meeting of the Pacific Coast Entomological Society was held on Friday, 19 Feb 1988, at 8:00 PM, in Morrison Auditorium of the California Academy of Sciences, San Francisco, with president Alan I. Kaplan presiding. The minutes of the 458th meeting were read by the recording secretary and accepted. Mr. Daniel Gross, membership chairman, proposed one new student member, three new regular members, who were accepted as members. Tom Briggs and Darrell Ubick are working to get threatened status for a species of phalangid at Edgewood Park whose habitat is the site of a proposed golf course. Dr. Edward Smith presented a note on new thysanuran drawings by Dr. Kukalova-Peck. Leslie Saul presented a note on several insects that have been used as ornamental jewelry.

President Kaplan introduced the speaker for the evening, Leslie Saul, Director of the Insect Zoo at the San Francisco Zoological Gardens. Ms. Saul presented a slide lecture titled "Insect Zoos and their Role in Public Education." Ms. Saul gave an informative talk on the scope and mission of the Insect Zoo's public education program and detailed the criteria for choosing insects for public exhibit. Methods of collecting, maintaining and transporting live insects for public exhibit were also illustrated.

President Kaplan announced that the next meeting would be held on 18 Mar 1988 and the speaker will be Dr. William Olkowski of the Bio-Integral Resource Center. The title of the talk will be "Recent Developments in Urban Integrated Pest Management." The meeting was adjourned at 9:30 PM in memory of Dr. Donald Denning, a world renowned authority on caddisflies. Dr. Denning died on 7 Feb 1988. A social hour was held in the entomology department of the California Academy of Sciences. The following 50 persons were present: (35 members) P. H. Arnaud Jr., B. T. Berke, L. G. Bezark, F. E. Cave, J. S. Chinn, J. R. Clopton, H. K. Court, T. D. Cuneo, D. K. Dabney, J. G. Edwards, R. Fall, S. V. Fend, N. E. Gershenz, D. F. Gross, J. E. Hafernik Jr., A. Hom, A. I. Kaplan, B. Keh, R. L. Langston, V. F. Lee, J. Leong, P. A. Luft, S. S. Mead, D. P. Pline, R. G. Robertson, L. S. Saul, W. E. Savary, H. I. Scudder, E. L. Smith, G. S. Spicer, R. E. Stecker, C. Y. Takahashi, D. Ubick, M. A. Wolf, and R. L. Zuparko; (15 guests) M. M. Arnaud, L. W. Berke, J. E. Court, P. R. Craig, M. Davies, T. W. Davies, T. Eager, P. Guard da Silva, K. Hobson, S. Kauffman, P. K. Kleintjes, G. Peterson, S. Renkes, J. Robertson, and L. Swiadon.

Four Hundred and Sixtieth Meeting

The 460th meeting of the Pacific Coast Entomological Society was held on Friday, 18 Mar 1988, at 8:00 PM, in Morrison Auditorium of the California Academy of Sciences, San Francisco, with president Alan I. Kaplan presiding. The minutes of the 459th meeting were read by recording secretary Leslie Saul and accepted. Mr. Daniel Gross, membership chairman, proposed one new student member, Mr. John W. Brown and two new regular members: Mr. James C. Milstead and Mr. John D. McCarty, who were accepted as members. Several announcements were made. Ben Keh announced that Dr. Y. Z. Erzinclioglu of the Department of Zoology, University of Cambridge will be giving a U.C. Berkeley departmental seminar titled "Application of Entomology to Forensic Sciences" on 18 Apr, in 101 Moffitt Hall at 4:00 PM. Bill Olkowski will have a poster display with handouts after the meeting. A memorial service was held for Dr. Donald Denning. President Kaplan announced that he was still seeking speakers for April and May and called for any speaker suggestions from the members. It was suggested that one evening could be devoted to member notes and exhibits.

President Kaplan introduced the speaker for the evening, Dr. William Olkowski, Technical Director of the Bio-Integral Resource Center in Berkeley. Dr. Olkowski gave an interesting lecture on "Recent Developments in Urban Integrated Pest Management." The Bio-Integral Resource Center publishes two journals: one for professionals, "The IPM Practitioner," and one for non-professionals, "Common Sense Quarterly." Dr. Olkowski outlined the principles of integrated pest management and the various approaches which can be used on shade trees, home vegetable gardens, structural and medical pest problems. He discussed several programs that BIRC had designed and mentioned several new techniques for monitoring, detection and control.

President Kaplan announced that the next meeting would be held on 15 Apr 1988. The meeting was adjourned at 9:20 PM. A social hour was held in the entomology department of the California Academy of Sciences. The following 36 persons were present: (24 members) P. H. Arnaud Jr., A. M. Balmy, L. G. Bezark, T. S. Briggs, P. Buickerood, R. Buickerood, J. S. Chinn, J. R. Clopton, D. K. Dabney, L. Davis, N. E. Gershenz, A. Hom, A. I. Kaplan, B. Keh, L. P. Kite, V. F. Lee, L. B. Mak, W. W. Pitcher, L. S. Saul, W. E. Savary, H. I. Scudder, M. M. Tierney, D. Ubick, and R. L. Zuparko; (12 guests) M. Anstett, M. M. Arnaud, M. Brennan, N. Brownfield, S. Chinn, M. Furey, S. V. Garity, M. Haines, C. Harvey, D. Mello, W. Olkowski, and W. C. Rauscher.

Four Hundred and Sixty First Meeting

The 461st meeting of the Pacific Coast Entomological Society was held on Friday, 15 Apr 1988, at 8:00 PM, in Morrison Auditorium of the California Academy of Sciences, San Francisco, with president Alan I. Kaplan presiding. The minutes of the 460th meeting were read by recording secretary Leslie Saul and accepted. Mr. Daniel Gross, membership chairman, proposed one new student member, Mr. John K. Jackson and two new regular members: Mr. Don C. Force and Mr. Tony Harris, who were accepted as members. Several announcements were made. Leslie Saul announced that the Insect Zoo's Annual open house would be held on 12 Jun 1988. Alan Kaplan thanked Albert Hom for making arrangements for the speaker for April. He also thanked Pat Kite, Nancy Brownfield and Dr. Harvey Scudder for their suggestions for future speakers for PCES.

President Kaplan introduced the speaker for the evening, Dr. Fernando Agudelo Silva, Senior Researcher at BIOSYS, a Palo Alto firm. Dr. Silva's talk was titled "The Worm's Turn: Developing Nematodes for Insect Pest Management." Dr. Silva gave a very interesting talk on the methods used for mass culturing nematodes for use in biological control programs. These nematodes can be used to control borers in oak and fig trees, in the greenhouse, in cranberry bogs and in apple and almond orchards. In the future it may be possible to control cockroaches, black fly and fire ants. In 1979, the use of nematodes for control took a big leap when an artificial media was developed by Australian researchers. Infective stages are reared. These enter the host through the mouth, spiracles, anus, or through the integument. Once inside, a bacteria is released which quickly kills the insect host. The nematodes are nonpathogenic for people and nontarget organisms.

President Kaplan announced that the next meeting would be held on 20 May 1988. The meeting was adjourned at 9:20 PM. A social hour was held in the entomology department of the California Academy of Sciences. The following 22 persons were present: (17 members) P. H. Arnaud Jr., T. S. Briggs, P. Buickerood, R. Buickerood, L. Davis, W. A. Doolin, J. G. Edwards, A. Hom, A. I. Kaplan, L. P. Kite, V. F. Lee, G. J. Mallick, S. W. Miller, L. S. Saul, C. Y. Takahashi, D. Ubick, and R. L. Zuparko; (5 guests) F. Agudelo Silva, M. M. Arnaud, P. R. Craig, S. Pollitt, and W. C. Rauscher.

Four Hundred and Sixty Second Meeting

The 462nd meeting of the Pacific Coast Entomological Society convened 20 May 1988, at 8:10 PM, in the Morrison Auditorium of the California Academy of Sciences. PCES president Alan Kaplan presided. The minutes of the 461st meeting were read by Mr. Warren Savary and accepted as read. Mr. Daniel Gross, PCES membership chairman, proposed four individuals for student membership: Mr. Gordon C. Snelling, Ms. Danielle Jahnke, Ms. Robin Jean Rathman and Mr. Martin Melia; three individuals for regular membership: Dr. V. R. Vickery, Mr. John Steiner, Mr. Patrick R. Craig; and one individual for sponsoring membership: Ms. Nancy T. Brownfield. The proposal was seconded and these individuals were granted membership. Mr. Warren Savary announced that he had been asked by the San Francisco Beekeepers Association to make available a petition that proposed making the honey bee (*Apis mellifera*) the national insect. Mr. Alan Kaplan introduced the guest speaker of the evening, Mr. Glenn Conner of the Alameda County Mosquito Abatement District, who presented an informative lecture entitled "*Aedes albopictus*: Asian Tiger Mosquito, a New Threat to California's Health." Mr. Conner detailed the spread of this potential disease vector which apparently entered the United States at Memphis, Tennessee in 1983. By 1987, it had been reported from 77 counties in 17 states, and had reached California. This tree-hole breeding mosquito, which feeds aggressively throughout the day, has been shown to serve as vector of dengue fever. Although a lack of summer rains may serve as a barrier to its establishment in California, its potential transport in used tires suggests our need for continued vigilance. The meeting adjourned for refreshments at 9:45 PM. The following 27 persons were present: (23 members) P. H. Arnaud Jr., L. G. Bezark, T. S. Briggs, P. Buickerood, R. Buickerood, R. Fall, D. F. Gross, A. Hom, A. I. Kaplan, B. Keh, W. A. Maffei, G. J. Mallick, S. M. McIlraith, S. S. Mead, M. Melia, W. E. Savary, G. A. Sayre, H. I. Scudder, S. S. Shanks, R. E. Stecker, C. Y. Takahashi, D. Ubick, and T. J. Zavortink; (4 guests) M. M. Arnaud, G. E. Conner, W. C. Rauscher, and S. Renkes.

Four Hundred and Sixty Third Meeting

The 463rd meeting of the Pacific Coast Entomological Society was held on 16 Sep 1988, at 8:10 PM, in Morrison Auditorium of the California Academy of Sciences, San Francisco, with president Alan I. Kaplan presiding. The acting recording secretary read the minutes of the 462nd meeting. The minutes were approved as read. Five persons were proposed by Daniel Gross and elected as new regular members: Dr. Elizabeth A. Bernays, Dr. Ryutaro Iwata, Dr. Penelope F. Kukuk, Ms. Patricia F. Neyman, and Dr. Richard S. Zack. The following guests were introduced: Dr. Janice Edgerly-Rook and her husband, Edward; Dr. C. Riley Nelson, Tilton Fellow in the Department of Entomology, California Academy of Sciences; and Mrs. Heidi E. M. Dobson.

Mr. Warren Savary showed some slides showing the orientation of first instar larvae in several genera of vaejovid scorpions. Mr. Kaplan announced that some members from Chico will host a collecting trip in their local area for the June, 1989, annual meeting of the American Association for the Advancement of Science, Pacific Division, in Chico.

Mr. Kaplan introduced the featured speaker, Dr. Gordon Frankie, who spoke on "Lomas Barbudal: A New Biological Reserve in Costa Rica." Dr. Frankie, president of Friends of Lomas Barbudal, discussed the formation, goals and future plans for the Lomas Barbudal Reserva Biologica, a lowland dry forest. He compared the preserve with the well known wet forests of La Selva and Monteverde and showed that a dry forest can also harbor unique and distinct fauna and flora. He talked about fire as a major problem in Costa Rica, where introduced vegetation gets established after a fire outcompetes the native flora which is not adapted to it. He stressed the importance of educating local people about their native fauna and flora. He also stressed that it is important for them to get involved in conservation projects and decision making regarding the use of their land.

The meeting was adjourned and a social hour was held in the entomology department of the California Academy of Sciences. A total of 52 persons attended the meeting: (30 members) P. H. Arnaud Jr., T. S. Briggs, K. W. Brown, J. S. Chinn, J. S. Cope, K. Dabney, L. H. Davis, H. E. M. Dobson, J. G. Edwards, S. V. Fend, S. S. Ferguson, E. M. Fisher, G. W. Frankie, D. F. Gross, J. E. Hafernik, Jr., A. I. Kaplan, B. Keh, L. P. Kite, R. L. Langston, V. F. Lee, L. B. Mak, G. J. Mallick, M. Melia, N. D. Penny, L. Saul, W. E. Savary, H. I. Scudder, S. S. Shanks, M. M. Tierney, and D. Ubick; (22 guests) M. M. Arnaud, B. Atkinson, D. De Raue, R. W. Douglas, C. W. Fox, J. Edgerly-Rooks, M. Flexer, J. Frankie, J. B. Fraser, M. H. Fraser, M. Furey, J. Hirabayashi, R. Nelson, T. K. Ohsumi, R. A. Raguso, S. Renkes, N. Robinson, E. Rooks, D. Schmidt, P. Sullivan, and A. Zoidis.

Four Hundred and Sixty Fourth Meeting

The 464th meeting of the Pacific Coast Entomological Society was held on Friday, 21 Oct 1988, at 8:10 PM, in Morrison Auditorium of the California Academy of Sciences, San Francisco, with president Alan I. Kaplan presiding. The acting recording secretary read the minutes of the 463rd meeting and they were accepted as read. Two new members were proposed and accepted. Several announcements were made. President Kaplan announced the possibility of having a joint meeting with AAAS and that Vincent Lee has suggested presenting papers; the deadline for the decision on participation is 15 Mar 1988. Mr. Kaplan also announced that a field day will be held in Chico, which will coincide with the June AAAS meeting. Vincent Lee described the Academy's new exhibit "Wild California" and urged all members to make plans to see it. The following guests were introduced: Nora Welk and Derham Giuliani. Mr. Guiliani has been donating specimens to the entomology department at the California Academy for many years. Edward Smith showed a paper wasp nest that he collected near his home. He noted that moths were beginning to emerge in great numbers. Larry Bezark announced that he had brought along some arthropod specimens which had been collected in Papua New Guinea by Larry Orsak. The specimens were available for examination during the social hour. Mr. Kaplan announced that he was preparing to call on members to serve on various committees for the upcoming year.

President Kaplan introduced the speaker for the evening, Mr. Patrick Craig, of Antioch West College in San Francisco, who presented a slide lecture on "Amber and its Inclusions." Mr. Craig began by discussing the different types of amber collected in various parts of the world. His talk focused on the amber mined in the Dominican Republic where amber is an important commodity. Mr. Craig discussed the mining process, how the amber is fashioned and marketed. He pointed out that scientific collectors could not financially compete with merchants that were willing to pay more than twenty thousand dollars for single pieces with large inclusions. He showed photographs of animals preserved in amber which included a fossilized slug, an entire gecko and a variety of arachnids, insects and other arthropods. He noted that animals preserved in amber retained their genetic material which could still be analyzed. He also noted that even though the arthropods in amber are mostly pre-Oligocene, they are for the most part indistinguishable from the species living today in the same type of habitat, indicating the stability of tropical ecosystems over time.

President Kaplan announced that the next speaker would be Dr. Vincent Resh of U. C. Berkeley who would speak on "Geothermal Development and Endangered Species." The meeting was adjourned at 9:20 PM and a social hour was held in the entomology department of the California Academy of Sciences. The following 60 persons were present: (38 members) P. H. Arnaud Jr., L. G. Bezark, T. S. Briggs, K. W. Brown, J. S. Chinn, J. R. Clopton, Patrick R. Craig, T. D. Cuneo, L. Dong, J. T. Doyen, B. Ehreth, S. S. Ferguson, W. E. Ferguson, C. W. Fox, D. F. Gross, D. R. Herlocker, A. Hom, P. S. Johnson, A. I. Kaplan, L. P. Kite, R. L. Langston, V. F. Lee, W. E. Maffei, L. B. Mak, G. J. Mallick, M. Melia, N. D. Penny, D. P. Pline, K. J. Ribardo, R. G. Robertson, W. E. Savary, H. I. Scudder, S.

S. Shanks, E. L. Smith, G. S. Spicer, C. Y. Takahashi, D. Ubick, and T. J. Zavortink; (22 guests) M. M. Arnaud, F. Baker, I. Baker, Y. Black, T. L. Davis IV, E. A. Doyen, D. Giuliani, B. Hall, B. I. Hiler, T. F. Hlavac, D. Maffei, D. L. Mead, C. R. Nelson, B. Ohlanul, J. Ohlanul, W. C. Rauscher, J. Ribardo, J. Robertson, L. S. Saul, M. A. Tenorio, R. Teys, and B. A. Wilson.

Four Hundred and Sixty Fifth Meeting

The 465th meeting of the Pacific Coast Entomological Society was held on Friday, 18 Nov 1988, at 8:00 PM, in Morrison Auditorium of the California Academy of Sciences, San Francisco, with president Alan I. Kaplan presiding. The minutes of the 464th meeting were read and accepted by Leslie Saul, recording secretary. Mr. Daniel Gross proposed two new members, Bernice Demarce and C. Riley Nelson, and they were accepted as members. Several notes were given. Larry Bezark presented a note on rain beetles in the genus *Pleocoma* stating that there were 25 species found throughout California. Another note was presented on insect avoidance behavior in found in caribou where biting flies occur. It was determined that 7–50% of caribou time was spent in insect avoidance behavior depending on biting fly population density. Leslie Saul presented two slides of a species of Amblypigida from the Jimba Caves, Kilifi district of Kenya, Africa collected by Dr. Robert Drewes in May 1988. The first slide was of an adult female with 25–30 young on her back that hatched on 14 Nov 1988. The second slide was a close-up of a one week old juvenile that was 6 mm in length. A third slide was of an artistically decorated cockroach from a nonentomological conference to demonstrate the increasing public interest in entomology. President Kaplan announced that PCES will have a contributed paper session at the AAAS meeting to be held in Chico in June. Detail will be included in the January newsletter and AAAS newsletter. The Society of Vector Ecologists and the American Ecological Society will also be participating. Committee members were announced. Vannoy Davis will be a member of the audit committee; Stanley C. Williams, Larry Bezark, and Curtis Takahashi will be members of the nominating committee. The nominating committee will make their recommendations next meeting. Mr. Kaplan announced that PCES dues are due.

President Kaplan introduced the speaker for the evening, Dr. Vincent Resh of U. C. Berkeley, whose talk was titled "Hot Springs, Geothermal Development, and Rare and Endangered Species: The Search for the Wilbur Spring Shore Bug." Dr. Resh gave a brief history of geothermal energy in the west. Dr. Resh detailed the natural history of the hot springs-inhabiting shore bug, *Saldula usingeri* which was proposed for listing as an endangered species. Dr. Resh studied 119 springs discovering a range for this saldid from Glenn to Contra Costa County. *Saldula usingeri* was discovered to be sluggish, a behavioral advantage in hot spring habitats. It does not drink in highly mineralized springs but instead gets its water by feeding on an ephydrid which is a good osmoregulator. It is thought that spider predation keeps the shore bug from some habitats that it could otherwise occupy. Because of its wide distribution, the Wilbur Springs Shore Bug was not listed as an endangered species.

President Kaplan announced that the next meeting would be held on 16 Dec 1988 and the speaker would be Alan Kaplan. The title of the talk will be "Insects in the News." The meeting was adjourned at 9:35 PM and a social hour was held in the entomology department of the California Academy of Sciences. A total of 46 persons attended the meeting: (35 members) P. H. Arnaud Jr., L. G. Bezark, T. S. Briggs, J. Burberry, J. R. Clopton, S. V. Fend, W. E. Ferguson, S. S. Ferguson, C. W. Fox, N. E. Gershenz, D. F. Gross, D. A. Jensen, P. S. Johnson, A. I. Kaplan, L. P. Kite, R. L. Langston, V. F. Lee, G. J. Mallick, S. S. Mead, M. Melia, C. R. Nelson, N. D. Penny, D. P. Pline, V. H. Resh, K. J. Ribardo, L. S. Saul, W. E. Savary, S. S. Shanks, W. D. Shepard, R. E. Stecker, C. Takahashi, M. M. Tierney, D. Ubick, T. J. Zavortink, R. L. Zuparko, and one unreadable; (11 guests) M. Arnaud, W. Cole, G. T. Coppe, B. I. Hiller, D. Mead, A. M. L. Penny, S. Renkes, J. M. Ribardo, L. Saul, S. M. Villegas, and A. Zoidis.

Four Hundred and Sixty Sixth Meeting

The 466th meeting of the Pacific Coast Entomological Society was held on Friday, 16 Dec 1988, at 8:20 PM, in Morrison Auditorium of the California Academy of Sciences, San Francisco, with president Alan I. Kaplan presiding. The minutes of the 465th meeting were read by recording secretary Leslie Saul and accepted. Membership chairman Mr. Daniel Gross proposed two new student members, Mr. Erik Johanson and Noel Caroline, and two new regular members, Mr. Scott Beckman and Ms.

Irene Terry, who were accepted as members. Several announcements were made. Daniel Gross announced that old schmidt boxes were available in the entomology department for a nominal donation. A request was made for increased support of the refreshment committee. Larry Bezark announced that Cornell press was offering a 20% book discount for a limited time. Two notes were given. Wesley Maffei showed SEM slides of *Morpho* butterfly scales and discussed the possibility of their use taxonomically. Slides of *Morpho cypris, M. aega, M. deidamia, M. achilles, M. godarti, M. menelaus, M. didius* and *M. amathonte* were shown. Larry Bezark made two literary presentations: one covering a robbery by men armed with a cicada; and another about a mouse-eating locust from 1915. President Kaplan called for the annual committee reports. Membership chairman Daniel Gross reported that in 1988, 40 new members were admitted: 25 regular, 14 student and 1 sponsoring, bringing the total number of members to 467. Dr. Paul Arnaud gave the Treasurer's report for Dr. W. Pulawski. He reported that the Society's income was $28,880, expenses were $22,968, resulting in a balance of $5,912. A thank you was extended to H. Vannoy Davis for his services on the auditing committee. The Auditing Committee reported that all was in order and that a statement will be published in the Annual Report. Dr. Paul Arnaud reported for the Historical Committee that the reorganization of the archives has been completed with 161 archive boxes. A special thanks was extended to Madeline Arnaud for her help with the archival material. Vincent Lee announced that the Society receives 63 serials from 51 institutions as exchanges. There have been six new exchanges this year. The Publications Committee reported that the Society will be returning to Allen Press after the 3rd issue which should be ready this week. Dr. Stanley Williams reported nominations for next year for the Nominating Committee: President 1989, Dr. Thomas Zavortink; President-elect 1990, Dr. Robert Dowell; Treasurer, Dr. W. Pulawski; Managing Secretary, Vincent Lee; and Recording Secretary, Leslie Saul.

Dr. Thomas Zavortink took charge of the meeting and introduced the speaker for the evening, current President of the Society Alan Kaplan. Mr. Kaplan, who received his Masters from U. C. Berkeley, is Naturalist at the Tilden Nature Center of the East Bay Regional Parks. President Kaplan gave an entertaining and informative talk titled "Insects and Entomologists in the media." Mr. Kaplan presented a synthesis of entomology through the ages which was well researched. He also summarized public attitude changes through time giving a survey of insect images in films.

The meeting was adjourned at 9:25 PM. A social hour was held in the entomology department of the California Academy of Sciences. The following 42 persons were present: (29 members) P. H. Arnaud Jr., L. G. Bezark, T. S. Briggs, K. W. Brown, P. Buickerood, J. S. Chinn, H. K. Court, J. G. Edwards, S. V. Fend, N. E. Gershenz, D. F. Gross, K. S. Hagen, P. S. Johnson, A. I. Kaplan, B. Keh, V. F. Lee, W. A. Maffei, L. B. Mak, C. R. Nelson, N. D. Penny, K. J. Ribardo, R. G. Robertson, L. S. Saul, W. E. Savary, S. S. Shanks, C. Y. Takahashi, D. Ubick, S. C. Williams, and T. J. Zavortink; (13 guests) M. M. Arnaud, K. Blakwell, R. Buickerood, J. E. Court, D. W. Fletcher, M. Furey, M. Hagen, A. M. L. Penny, W. C. Rauscher, S. Renkes, J. M. Ribardo, J. Robertson, and S. M. Villegas.

Four Hundred and Sixty Seventh Meeting

The 467th meeting of the Pacific Coast Entomological Society was held on 20 Jan 1989, at 8:00 PM, in Morrison Auditorium of the California Academy of Sciences, San Francisco, president Thomas Zavortink presiding. The minutes of the 466th meeting were read by Leslie Saul, recording secretary, and accepted. Membership chairman Daniel Gross proposed four new members which were accepted: Mr. Donald Barwell, Mr. Randall Ridley, Dr. Richard Mason and Mr. Bruce Tilden. Several announcements were made. PCES will participate in a contributed paper session at the AAAS Pacific Division meeting being held in Chico, 11–15 Jun 1989. Rewards for student papers are being offered. A Program Committee was formed. Dr. John Hafernik was appointed as chairman and Dr. Jerry Powell will serve on the committee. Vincent Lee announced that money can be donated and designated specifically to the entomology department of the California Academy of Sciences. Daniel Gross will be retiring from the refreshment committee. Dr. J. W. Tilden passed away 30 Dec 1988, at the age of 83. His specialty was nymphalid butterflies. He was the author of the books "A Field Guide to Western Butterflies" and "California Butterflies." Ben Keh showed slides of the Penang Butterfly House and described its operation.

President Zavortink introduced the speaker for the evening, Dr. Robbin Thorp, professor of Entomology at U. C. Davis. Dr. Thorpe gave an interesting slide lecture titled "Australian Bees and Scenes," on his research trips to Australia covering several visits there to study the impact of the introduced honey bee on native bees and flora there.

Dr. Zavortink announced that the next meeting would be held on 17 Feb 1989 and the speaker would be Dr. C. Riley Nelson speaking on "Winter Stoneflies in California." The meeting was adjourned at 9:45 PM and a social hour was held in the entomology department of the California Academy of Sciences. The following 44 persons were present: (31 members) P. H. Arnaud Jr., F. L. Blanc, T. S. Briggs, K. W. Brown, J. S. Chinn, K. Dabney, J. G. Edwards, E. M. Fisher, D. F. Gross, A. Hom, B. Keh, R. L. Langston, V. F. Lee, M. Melia, N. D. Penny, D. P. Pline, K. J. Ribardo, R. G. Robertson, E. S. Ross, L. S. Saul, W. E. Savary, H. I. Scudder, S. S. Shanks, J. A. Skinner, J. T. Sorensen, R. E. Stecker, C. Y. Takahashi, R. W. Thorp, D. Ubick, S. P. Welles Jr., and T. J. Zavortink; (13 guests) M. M. Arnaud, F. Blanc, L. M. Bravo, L. V. Dubay, A. M. L. Penny, W. C. Rauscher, J. M. Ribardo, J. Robertson, C. Thorp, J. Thorp, P. Thorp, S. M. Villegas, D. Welles, and P. Welles.

Four Hundred and Sixty Eighth Meeting

The 468th meeting of the Pacific Coast Entomological Society was held on 17 Feb 1989, at 8:00 PM, in Morrison Auditorium of the California Academy of Sciences, San Francisco, with president Thomas Zavortink presiding. The minutes of the 467th meeting were read by Leslie Saul, recording secretary, and accepted. Membership chairman Daniel Gross proposed one student member, Mr. Lee H. Simons, and one sponsoring member, Mr. Pat Sullivan, which were accepted. Several announcements were made. Daniel Gross will be retiring from the refreshment committee. A worthy replacement is still being sought. All members are encouraged to volunteer. Dr. Ross introduced guests Gene Hall and Dr. George Ball. Leslie Saul announced that the Insect Zoo's tenth anniversary celebration would be coming up in June. All PCES members are invited to contribute any ideas for this event.

President Zavortink introduced the speaker for the evening, Dr. C. Riley Nelson, current Tilden Fellow in the Department of Entomology at the California Academy of Sciences. Dr. Nelson gave an informative talk titled "Winter Stoneflies in California." Dr. Nelson began with an introduction and overview of early work on Plecoptera with an emphasis on the genus *Capnia.* He noted that there were 55 species found in North America exhibiting a high degree of endemism. Several habitats were discussed including the Feather River, Navarro River, Alder Creek, Long Valley Creek, Lake Tahoe, Dolores River and Lone Pine Creek. *Capnia licustra* from Lake Tahoe was noted to be aquatic in the adult stage and found at depths of 300 ft.

Dr. Zavortink announced that the next meeting would be held on 17 Mar 1989 and the speaker would be Dr. Edward Ross. The meeting was adjourned at 9:30 PM and a social hour was held in the entomology department of the California Academy of Sciences. A total of 47 persons attended the meeting: (26 members) L. G. Bezark, R. L. Bottoroff, P. Buickerood, J. S. Chinn, H. K. Court, T. D. Cuneo, J. G. Edwards, S. V. Fend, W. E. Ferguson, S. S. Ferguson, D. F. Gross, P. Johnson, D. H. Kavanaugh, B. Keh, G. Mallick, C. R. Nelson, N. D. Penny, W. W. Pitcher, K. J. Ribardo, R. G. Robertson, L. S. Saul, S. S. Shanks, W. D. Shepard, G. C. Snelling, C. Takahashi, and T. J. Zavortink; (21 guests) G. E. Ball, R. Buickerood, J. E. Court, M. Duffy, M. Gardner, T. Glenn, C. Greene, W. E. Hall, B. A. Knight, A. W. Knight, M. Monsees, A. M. L. Penny, P. Pitcher, S. Renkes, J. M. Ribardo, J. Robertson, D. Sipes, L. Snelling, J. Snelling, V. Snelling, and S. Wright.

Four Hundred and Sixty Ninth Meeting

The 469th meeting of the Pacific Coast Entomological Society was held on 17 Mar 1989, at 8:00 PM, in Morrison Auditorium of the California Academy of Sciences, San Francisco, with president Thomas Zavortink presiding. The minutes of the 468th meeting were read by Leslie Saul, recording secretary, and accepted. Membership chairman Daniel Gross proposed one student member, Mr. Alvin Glot, and two regular members, Dr. Susan B. Halbert and Dr. Robert S. Martin, which were accepted. Several announcements were made. PCES is still seeking a refreshment committee. Contributing papers for the AAAS meeting in Chico must be received by 31 Mar 1989. Student awards will be presented. Journal Volume 64 number is at A-R Editions and number 1 and 2 of volume 65 have been approved for publication. Daniel Gross gave a short slide presentation on insects of prehistoric nature and their extinction and survival, based upon a new exhibit at the Academy.

President Zavortink introduced the speaker for the evening, Dr. Edward Ross, who gave a slide lecture titled "Recent Entomological Experiences in Mexico." Dr. Ross gave a well illustrated lecture which focused on the embiids and various trips to Baja California spanning from 1931 to a recent adventure along the same route. He also discussed witnessing the monarch butterfly overwintering sites in Mexico and mentioned Dr. Lincoln Brower's conservation efforts there. Unique arthropods, trees and angiosperms encountered were presented.

Dr. Zavortink announced that the next meeting would be held on 21 April and the speaker would be Dr. Robert Dowell. His talk will be titled "Evolution of the Host Range of the Citrus Blackfly." The meeting was adjourned at 10:00 PM and a social hour was held in the entomology department of the California Academy of Sciences. A total of 60 persons attended the meeting: (31 members) P. H. Arnaud Jr., B. T. Berke, F. L. Blanc, T. S. Briggs, K. W. Brown, D. J. Burdick, D. K. Dabney, L. H. Davis, J. Chinn, J. R. Clopton, J. G. Edwards, W. E. Ferguson, S. S. Ferguson, D. F. Gross, L. P. Kite, V. F. Lee, W. Maffei, J. D. McCarty, S. Mead, C. R. Nelson, W. W. Pitcher, K. J. Ribardo, R. G. Robertson, E. S. Ross, W. E. Savary, L. E. Serpa, W. D. Shepard, C. Takahashi, M. M. Tierney, J. E. Tobler I, D. Ubick, and T. J. Zavortink; (29 guests) M. Arnaud, K. Attipaid, F. Blanc, Y. Burgess, L. Disterheft, J. Edwards, T. Glenn, E. A. Goff, K. Haires, D. Holth, K. Hom, J. Johnton, R. Kolesen, D. Maffei, D. Mead, M. Mistry, P. Pitcher, W. Rauscher, J. Ribardo, J. Robertson, N. Solberg, Ca. Tobler, Ch. Tobler, N. Tobler, A. Tung, S. Villegas, and three unreadable.

Four Hundred and Seventieth Meeting

The 470th meeting of the Pacific Coast Entomological Society was held on 21 Apr 1989, at 8:10 PM, in Morrison Auditorium of the California Academy of Sciences, San Francisco, with president Thomas Zavortink presiding. The minutes of the 469th meeting were read, corrected and accepted. One new member was proposed, David C. Taylor, and accepted. Several announcements were made. Five abstracts were submitted for presentation at the AAAS meeting to be held on 11 Jun 1989. A refreshment chairman is needed to provide refreshments for the social hour after the meetings. The program committee would welcome suggestions for speakers for upcoming meetings. Howell Daly would like to step down as publication chairman of *The Pan-Pacific Entomologist.* Leslie Saul announced that the zoo keeper association will be sponsoring a Bowl-A-Thon on 13 May 1989 at Rock and Bowl and the proceeds will go to benefit habitat protection in Guanacaste National Park in Costa Rica.

President Zavortink introduced the speaker for the evening, Dr. Robert Dowell of the California Department of Food and Agriculture and president-elect of PCES, who gave an interesting talk titled "Evolution and Host Range of the Citrus Black Fly." The citrus black fly is a whitefly in the Aleyrodidae family, that is now found in Africa, the Caribbean, Mexico and Florida. It originated in Malaya where citrus was the only host. This whitefly was first found in on Key West, Florida, in 1934 was eradicated using fish oil spray. It reappeared in 1976 in Broward County Florida and eradication with sprays failed. Two parasitic wasps were released reducing populations by over 95%. The pest is polyphagus, feeding on 48 genera of plants and 35 different families. Dr. Dowell presented a detailed description of the citrus black fly's life history, morphology, oviposition behavior, dispersal behavior and foodplant preference. Oviposition preference was studied and it was found that kumquat, mango and pink trumpet were as attractive as citrus. Dr. Dowell also discussed the spread of this insect and its correlation with the spread of different horticultural plants.

The meeting was adjourned at 9:35 PM and a social hour was held in the entomology department of the California Academy of Sciences. The following 22 persons were present: (19 members) P. H. Arnaud Jr., T. S. Briggs, W. A. Doolin, R. V. Dowell, J. G. Edwards, A. Hom, P. S. Johnson, R. L. Langston, V. F. Lee, W. A. Maffei, G. J. Mallick, C. R. Nelson, K. J. Ribardo, L. S. Saul, W. E. Savary, S. S. Shanks, C. Y. Takahashi, S. P. Welles, and T. J. Zavortink; (3 guests) D. Maffei, W. C. Rauscher, and J. M. Ribardo.

Four Hundred and Seventy First Meeting

The 471st meeting of the Pacific Coast Entomological Society was held on 19 May 1989, at 8:00 PM, in Morrison Auditorium of the California Academy of Sciences, San Francisco, with president Thomas Zavortink presiding. The minutes of the 470th meeting were read by recording secretary Leslie Saul, and accepted. Seven new regular members and one new student member were proposed by Daniel Gross and elected: Russell C. Bingham, Dr. Lloyd M. Dosdall, Dr. Boris C. Kondratieff, Dr. Robert E. Page Jr., Dr. Michael Pitcairn, James E. Wappes, Ms. Carrie J. S. Wong, as regular members, and Mr. Dean F. Messer, as a student member.

Several announcements were made. Mr. Warren Savary announced that seven papers were to be presented at the upcoming AAAS meeting. The Western Apiculturist Society will be meeting on the week of 10 Jun 1989 at San Francisco State University and a short course on starting an apiary will be given. Leslie Saul announced that the Insect Zoo's tenth annual open house will be held on 10–11 June 1989. James Toburn of Santa Rosa has back issues of the journal which will be sold individually or as a set for $85.00. There is a new printing of *A Glossary of Entomology* by J. R. de La Torre-Bueno, which will be available at pre-publication price of $35.00; the publication date is 1 Jun 1989; it will include an entomological spelling checker. Copies of the order forms will be available in the entomology department of the Academy. Dr. Thomas Zavortink announced that Volume 65, issue 1 should be arriving soon. Dr. Edward Ross introduced two guests, Dr. P. Jolivet, a chrysomelid expert, and J. Segress. Dr. Zavortink introduced the speaker for the evening, Dr. Kirby Brown of the San Joaquin County Department of Food and Agriculture. His talk was titled "Gold Bugs and other Numismatic Insects." Dr. Brown gave an informative talk on the field of insect coins. There are over 2500–3000 different types of coins that depict insects or bee hives. The first coins date back to 650 BC. Dr. Brown showed a series of slides of various coins depicting insects from his collection and studies from such places as Italy, Papua New Guinea, Panama, Tonga and Utah. Bees were the insect most often represented.

The meeting was adjourned at 9:40 PM and a social hour was held in the entomology department of the California Academy of Sciences. The following 35 persons were present: (23 members) P. H. Arnaud Jr., K. W. Brown, J. S. Chinn, H. K. Court, J. G. Edwards, A. Hom, A. S. Hunter, B. Keh, R. L. Langston, V. F. Lee, W. A. Maffei, G. J. Mallick, M. Melia, N. D. Penny, K. J. Ribardo, R. G. Robertson, L. S. Saul, W. E. Savary, R. E. Stecker, C. Y. Takahashi, J. E. Tobler, C. J. S. Wong, and T. J. Zavortink; (12 guests) M. M. Arnaud, J. E. Court, E. A. Goff, P. Jolivet, D. Maffei, D. S. Mayuoba, A. M. Penny, J. M. Ribardo, J. Robertson, J. Segress, S. Villegas, and one illegible signature.

Four Hundred and Seventy Second Meeting

The 472nd Meeting of the Pacific Coast Entomological Society was held 17 Nov 1989, in the Goethe Room of the California Academy of Sciences with president Dr. Thomas Zavortink presiding. The meeting was called to order at 8:00 PM. Minutes of the 471st meeting were read, corrected and accepted. Four new regular members and one new student member were proposed and accepted.

The October 1989 meeting of the Pacific Coast Entomological Society meeting was cancelled due to the October 17th earthquake in San Francisco.

President Zavortink made several announcements. Dr. Zavortink read a letter from Howell Daly stating that Dr. John Sorensen will assume the duties of Editor of *The Pan-Pacific Entomologist.* A special thanks was extended to Dr. Chemsak for his effort to bring the journal, *The Pan-Pacific Entomologist,* up to date. The publication is now back with Allen Press because of their ability to produce a higher quality product. Thanks were also extended to Ken Cooper, Paul Arnaud and Wojciech Pulawski. The auditing committee members now include Helen Court, Vannoy Davis, chairman of the committee and Dr. Paul Arnaud. The publication committee needs one additional member. The nominating committee includes Ron Stecker. Patty Pratt announced that five of her sculptural works dealing with insects will be on display at the Insect Zoo through 15 Dec 1989. Leslie Saul announced that Dr. Robert Pyle, compiler of the IUCN Invertebrate Red Data Book, will give a lecture on "The Conservation of Monarch Butterflies" on 25 Jan 1990, in Morrison Auditorium at the California Academy of Sciences. Dr. Edward Smith described the exciting development of the new "Life through Time" exhibit at the California Academy of Sciences. The exhibit is scheduled to open in April. Dr. Scudder announced that 50% of the insect paleontology group in the U.S. is retired, but still going strong. Two volumes of "Genera of Fossil Insects" by Frank M. Carpenter from Harvard are being published. Dr. Edward Smith announced that Dr. Alex Rasnitzen, foremost specialist on fossil insects in the world, will be at the Academy in January. Wes Maffei and his wife have generously offered to serve on the refreshments committee for one year. There will be a meeting of the executive board of PCES on 15 Dec 1989. A notice will be sent. A special dedication for the R. L. Usinger Rare Book Collection in the Entomology Library will be held on 15 Dec 1989, at 7:00 PM in the Department of Entomology of the California Academy of Sciences. An invitation will appear in Bits & PCES. Debra Meed, a graduate student at San Francisco State University working on *Hygrotis,* was introduced. Charles Franklin, a graduate student at San Jose State University, was introduced.

Dr. Edward Smith gave a note describing the unusual life history of the primitive sawfly, *Cimbex americana*. It squirts fluid from pores above its spiracles. A large infestation was found on *Zorea americana* (Caprifoliacea). Slides picturing oviposition were shown. Eggs are laid in the leaf margin. After the first feeding, the larvae turn green and retain that color. The first instar have a waxy bloom; late instar larvae do not.

Dr. Zavortink introduced the speaker for the evening, Dr. Philip Ward from the Department of Entomology at U.C. Davis. His talk was titled "Ants in Plants." Dr. Ward discussed the debate about the origin and evolution of the interactions between ants and plants. Different associations between ants and plants were outlined: casual visitation to plants, detrimental to plant, beneficial to plant, and co-evolved mutualism. Plants with domatiums and their ant associates were discussed in detail. Fifty representative taxa were subjected to phylogenetic analysis and a consensus tree was drawn which suggested that these associations evolved a number of different times, perhaps 12 times. The ecology of various relationships was described.

The meeting was adjourned at 9:35 PM. Refreshment were served in the entomology department. A total of 45 persons attended: (32 members) P. H. Arnaud Jr., T. S. Briggs, R. Buickerood, P. Buickerood, J. S. Chinn, D. K. Dabney, S. S. Ferguson, W. E. Ferguson, C. W. Fox, D. F. Gross, P. S. Johnson, D. Kavanaugh, V. F. Lee, W. E. Maffei, L. B. Mak, G. J. Mallick, D. L. Mead, N. D. Penny, W. W. Pitcher, R. G. Robertson, L. S. Saul, W. E. Savary, H. I. Scudder, S. S. Shanks, E. L. Smith, G. S. Spreer, R. E. Stecker, C. Y. Takahashi, P. Welles, S. C. Williams, and T. J. Zavortink; (13 guests) M. M. Arnaud, V. M. Barlow, C. D. Franklin, C. Greene, S. Haughes, L. Hiugich, D. Maffei, M. Marcus, J. Osman, P. Pratt, W. Rauscher, A. A. Roberts, and P. Ward.

Four Hundred and Seventy Third Meeting

The 473rd meeting of the Pacific Coast Entomological Society was held 15 Dec 1989 in the Goethe Room of the California Academy of Sciences at 8:10 PM with president Dr. Thomas Zavortink presiding. The minutes of the 472nd meeting were read, corrected and accepted. Two new candidates were proposed by Daniel Gross, chairman of the membership committee, and elected as new members: Mr. Charles Franklin, graduate student at San Jose State University, was elected as a new student member, and Mr. Gregory S. Sautter of Mishawaka, Indiana, was elected as a new regular member.

Several announcements were made. Vincent Lee turned in his letter of resignation as managing secretary of the Society to be effective 1 Jan 1991. Robin Thorpe will assume the position of chairman of the publications committee effective in January, 1990. Dr. Stanley Williams will join that committee. There were 1400 oral presentations made at the San Antonio meetings of the Entomological Society of America. The 1990 meetings of the ESA will be held in New Orleans, and the 1991 meetings will be held in Reno. Dr. Zavortink extended his thanks to everyone for their support during the year of his presidency. He announced that a PCES Board meeting was held on 15 Dec 1989 at 3:00 and summarized the meeting as follows. There was a discussion of the Society's financial situation. Data will be collected from other organizations on their dues and subscription rates. Dues were raised to \$20.00 for regular members, \$30.00 for subscribing members, \$40.00 for sponsoring members, \$21.00 for family members, \$10.00 for student members, and \$10.00 for retired members. The expenditure of money to defray speakers travel costs to AAAS meeting symposium was discussed. The production and mailing costs of Bits & PCES were also discussed.

Dr. Zavortink called for annual reports from the various committees. Daniel Gross, chair of the membership committee reported that in 1989 the membership remained fairly stable. Twenty-five new members were added (19 regular, 5 student and 1 sponsoring). In the past five years this was the lowest number to apply. There were a total of 448 members in 1989: 352 regular members, 55 student members, and 41 sponsoring members. Under the chairmanship of H. Vannoy Davis, Helen Court reported that the audit committee reports that everything is in order. The full report will be published in the proceedings. Lester Ehler and Ron Stecker asked Zavortink to report that the nominating committee proposed the following slate of candidates for office in 1990: Robert Dowell as president, Leslie Saul as president-elect, Sandra Shanks as treasurer, Leslie Saul as recording secretary, and Vincent Lee as managing secretary.

The gavel was passed to president-elect Dr. Dowell. Dr. Dowell introduced Dr. Tom Zavortink, of the University of San Francisco, who presented the presidential address. Dr. Zavortink presented an excellent and informative talk on "The Biology of Mosquitos." He related that there are 3146 species in the world, 167 species in North America and 47 species in California representing 38 genera.

The classification is conservative. The majority of the species fall into three genera: 379 in *Anopheles,* 946 in *Aedes* and 767 in *Culex.* The morphological differences between the three main genera were described. The largest mosquito in the world is in the genus *Toxerinchides.* This beautiful mosquito is incapable of penetrating the skin and only sucks nectar. The biology of several groups was discussed in detail focusing on oviposition behavior. Dr. Zavortink closed his lecture with a discussion of the difficulties with drawing phylogenetic trees for mosquitos considering all stages. Dr. Dowell announced the upcoming lecture in January "Grape Phylloxera in California: No Sex in the Vineyard" by Dr. Jeffrey Granett. The meeting was adjourned at 9:45 PM. The following 42 persons were present: (35 members) P. H. Arnaud Jr., L. G. Bezark, T. S. Briggs, P. Buickerood, R. Buickerood, J. S. Chinn, H. K. Court, L. Dong, R. V. Dowell, J. G. Edwards, R. Fall, D. W. Gray, D. F. Gross, J. E. Hafernik Jr., A. Hom, B. Keh, R. L. Langston, V. F. Lee, P. A. Luft, W. A. Maffei, L. B. Mak, D. L. Mead, S. S. Mead, N. D. Penny, K. J. Ribardo, R. G. Robertson, L. S. Saul, W. E. Savary, J. T. Sorensen, P. H. Sullivan, C. Y. Takahashi, D. Ubick, S. C. Williams, B. A. Wilson, and T. J. Zavortink; (7 guests) M. M. Arnaud, J. E. Court, C. D. Franklin, D. Maffei, A. M. L. Penny, W. C. Rauscher, and J. M. Ribardo.

ANNOUNCEMENT

Beginning with the July, 1990, issue of the Pan-Pacific Entomologist, the Pacific Coast Entomological Society began sending membership/subscription renewal notices for the following year with its July (number 3) issue. Please check the July issue of the journal for these renewal notices before discarding its shipping wrapper. Only a final subscription notice will be sent, if PCES does not receive a response to the July issue's enclosure.

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) and subsequent issues, $20.00 per volume or $5.00 per single issue.

MEMOIRS OF THE PACIFIC COAST ENTOMOLOGICAL SOCIETY.
Volume 1. *The Sucking Lice* by G. F. Ferris. 320 pages. Published October 1951. Price $10.00 (plus $1.00 postage and handling).*
Volume 2. *A Revision of the Spider Mite Family Tetranychidae* by A. Earl Pritchard 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).*

Send orders to:
Pacific Coast Entomological Society, % California Academy of Sciences, Golden Gate Park, San Francisco, California 94118-9961, U.S.A.

* (Add 6% sales tax on all California orders (residents of Alameda, Contra Costa, San Francisco, Santa Clara, and Santa Cruz counties add 6½%). Members of the Society will receive a 20% discount on the price of the books.)

PAN-PACIFIC ENTOMOLOGIST
Information for Contributors

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

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 66 (1): 1–8, including SEPARATE PARAGRAPHS FOR DIAGNOSES, TYPES AND MATERIAL EXAMINED (INCLUDING A SPECIFIC FORMAT). and a specific order for paragraphs in descriptions. See: Johnson, K. (1990. Pan-Pacif. Entomol., 66[2]: 97–125) for an example of format style and order for taxonomic descriptions, or contact the editor. List the unabbreviated taxonomic author of each species after its first mention.

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.

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