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THE CLEARWING MOTHS OF CALIFORNIA

(LEPIDOPTERA: SESIIDAE)

W. DONALD DUCKWORTH

THOMAS D. EICHLIN

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THE CLEARWING MOTHS OF CALIFORNIA

(LEPIDOPTERA: SESIIDAE)

by

W. DONALD DUCKWORTH

Department of Entomology, National Museum of Natural History,
Smithsonian Institution, Washington, D.C. 20560

and

THOMAS D. EICHLIN

California Department of Food and Agriculture,
1220 N Street, Sacramento, California 95814

INTRODUCTION

Sesiidae are an easily recognizeable family, which has over 1000 species worldwide. In America north of Mexico 19 valid genera contain 113 described species (Duckworth and Eichlin, 1977b and 1977c; Purrington and Nielsen, 1977). The California fauna has 28 species in 11 genera (one species currently not known from California is also treated here).

Adults are diurnal and strongly mimic various aculeate Hymenoptera in both appearance and behavior. Although many structural and behavioral modifications seem obviously to affect hymenopterous mimicry, there have been virtually no investigations conducted on specific mimic-model ecology and behavior. The moths have narrow wings and are usually at least partially devoid of scales. The combination of wing-locking mechanisms is the most intricate in Lepidoptera, insuring synchronous action of both pairs of wings during the rapid flight. The legs are elongate, slender and variously tufted. The abdomen is commonly banded with white, yellow, orange or red (as on many bees and wasps). The form and scale patterns of the thorax and head structures further emphasize the hymenopterous appearance.

With few exceptions sesiid larvae are obligate borers in the limbs, trunks, bark, or roots of trees, shrubs, herbs and vines. Some species are inquiline borers in galls on woody or herbaceous plants. Although biological data are lacking for many species, information is available on most California species and is presented here.

Since the larvae are internal feeders their activities can often

result in considerable damage to the host plants, and when the host involved is of commercial value, the results of heavy or repeated infestations can have significant economic impact. Various species are destructive to strawberries, raspberries and related plants, and to forest, ornamental and fruit trees in California. Certain species, if introduced into the State, are potentially destructive to ornamental trees and shrubs, and to fruit and nut trees, grapes and cucurbits.

This survey of the California clearwing moths is meant to serve as a means for the recognition and identification of the species treated and to supply data currently known to us regarding taxonomic status, distributions, host plants, and other aspects of their bionomics. We have included color plates and keys to genera and species of adults; a survey of the known larval host plants; text figures depicting life stages or host plant damage; and drawings of genitalia, as well as maps showing collection records in California and generalized distribution. When no more than five California records are known for a species, these are listed. The classification followed is that of Duckworth and Eichlin (1977c). Much of the biological data presented here has been extracted from Engelhardt (1946).

Institutional abbreviations used are as follows: National Museum of Natural History, Smithsonian Institution (NMNH); American Museum of Natural History, New York (AMNH); British Museum (Natural History) (BMNH); Academy of Natural Sciences, Philadelphia (ANSP); Michigan State University (MSU); Museum of Comparative Zoology, Harvard University (MCZ); Field Museum of Natural History, Chicago (FMNH).

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BIOLOGY

Adult clearwings are diurnal in their activity periods, possess structural and behavioral modifications apparently associated with mimicry of Hymenoptera, and appear to remain in close proximity to their host plants. A majority of sesiid adults have a well-developed proboscis and occasionally visit flowers to drink nectar; however, a reduced and nonfunctional proboscis is characteristic of four relatively distantly related North American genera, representatives of which occur in California. Adult life is short, generally lasting as much as one week or occasionally a little longer.

Soon after emergence, generally before the warmest part of the same day, the female is ready to mate and begins emitting a

sex attractant. She may not fly at all until mating has been accomplished, while, by contrast, the males are very active at this time.

Oviposition begins immediately after mating, with the eggs deposited singly on or near the host plant. Newly hatched larvae must quickly locate a suitable part of the plant in which to bore, or they will desiccate.

Sesiid larvae, being true borers, lack body color or pattern and generally share characters common to boring larvae of other superfamilies or even other orders, e.g. Coleoptera. Before pupating, the larva constructs the exit gallery and exit hole, but leaves a thin layer of plant tissue to conceal the opening. (to see examples of larval damage, consult Beutenmeuller (1901) and Fibiger and Kristensen (1974)). Pupation occurs in the larval gallery in specially prepared chambers (often in cocoons of frass, wood particles and silk) or in chambers in the soil.

Pupation takes place the following season just prior to adult emergence. Using spines encircling the abdomen, the mobile pupa moves to the previously prepared exit, and breaks through with special protuberances on the pupal head. The opening is tight enough to hold the protruding pupa in place on the external surface of the host. The cast pupal exuviae of emerged adults remains as evidence that the plant had been infested with sesiid borers.

Most North American species are univoltine, but there is evidence indicating that some may require more than one year for development. Certain species (*i.e.* *Melittia* borers in xerophytic cucurbits) may be able to prolong diapause for more than one year, or until the host plant has received the proper stimuli to produce vegetative growth above ground, a prerequisite for oviposition.

Most North American Sesiidae exhibit rather narrow host preferences. Some genera are restricted to certain host plant genera or families. A few species are opportunistic and have been able to exploit a broad range of plants.

Since the initial isolation of two major isomeric components of sesiid pheromone systems (Z, Z and E, Z 3, 13-octadecadien-1-ol-acetate) by Tumlinson *et al.*, (1974) and Yonce *et al.*, (1974), cross attractancy of different species, representing the family's total phylogenetic range, has been demonstrated (Nielsen and Balderston, 1973; Nielsen *et al.*, 1975; Karandinos *et al.*, 1977). New species have been discovered and the status of others clarified as

a result of pheromone field studies (Duckworth and Eichlin, 1977a, 1977b; Purrington and Nielsen, 1977).

For the past three years the pheromones have been used in California during field surveys, which were directed by Eichlin, Laboratory Services/Entomology, and by the Exclusion and Detection unit, Division of Plant Industry, California Department of Food and Agriculture. Much of the actual trapping was done by State Regional Coordinators and personnel from various county Agricultural Commissioners offices. Though they are too numerous to mention, their efforts are much appreciated.

Using pheromones as a basic tool for field sampling of responding males, it is now possible to readily detect sesiids in a given habitat, therefore greatly facilitating the closing of significant gaps in the knowledge of distribution of species, relative abundance, seasonal periodicity, and species richness.

SURVEY OF KNOWN LARVAL HOST PLANTS OF CALIFORNIA SESIIDAE

Betulaceae

<i>Alnus</i> spp. (alders)	<i>Synanthedon culiciformis</i>
<i>Betula</i> spp. (birches)	<i>Synanthedon culiciformis</i> <i>Paranthrene robiniae</i>

Boraginaceae

<i>Lithospermum ruderale</i> Dougl.	<i>Carmenta verecunda</i>
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Cucurbitaceae

* <i>Cucurbita andreana</i> Naud.	<i>Melittia calabaza</i>
<i>C. digitata</i> Gray	<i>Melittia gloriosa</i>
* <i>C. ficifolia</i> Bouche	<i>Melittia calabaza</i>
<i>C. foetidissima</i> HBK	<i>Melittia gloriosa</i> <i>Melittia grandis</i>
<i>C. maxima</i> Duchesne (autumn & winter squashes)	<i>Melittia calabaza</i>
<i>C. moschata</i> Duchesne (cushaw & winter crookneck squashes)	<i>Melittia calabaza</i>
* <i>C. okachobeensis</i> Bailey	<i>Melittia calabaza</i>
<i>C. palmata</i> Wats.	<i>Melittia gloriosa</i>
<i>C. pepo</i> L. (field pumpkin)	<i>Melittia calabaza</i>
* <i>C. texana</i> Gray	<i>Melittia calabaza</i>
<i>Marah fabaceus</i> (Naud.)	<i>Melittia gloriosa</i>
<i>M. oreganus</i> (T. & G.)	<i>Melittia gloriosa</i>

Fagaceae

<i>Quercus agrifolia</i> Nee	<i>Synanthedon resplendens</i>
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Lauraceae

* <i>Persea americana</i> Mill.	<i>Synanthedon resplendens</i>
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*Not native in California (Munz, 1963)

Salicaceae

- Populus* spp. (aspen, cottonwood, poplars) *Paranthrene robiniae*
Sesia tibialis
Salix spp. (willows) *Paranthrene robiniae*
Sesia tibialis
Synanthedon albicornis

Saxifragaceae

- Ribes* spp. (currant, gooseberry) *Synanthedon tipuliformis*

Scrophulariaceae

- Penstemon brevisflorus* Lindl. *Penstemonia dammersi*
P. cordifolius Benth. *Penstemonia dammersi*
P. palmeri Gray *Penstemonia clarkei*
P. parishii Gray *Penstemonia hennei*
**P. richardsonii* Dougl. *Penstemonia clarkei*
P. spectabilis Thurb. *Penstemonia dammersi*
Penstemonia hennei
P. ternatus Torr. *Penstemonia dammersi*

MORPHOLOGY

Because of this study's limited scope, we are using only the more typical and salient features of the Sesiidae. In the species descriptions below, discussion is only of characters not discernable from the plates. Additional morphological details are presented in the recent discussion on classification of North American sesiids (Duckworth and Eichlin, 1977c), and further extensive comparative studies are continuing in our ongoing revisionary work on Western Hemisphere clearwing moths.

Adult.—The general body form and scale patterns of the moths are highly modified, apparently the evolutionary results of positive selective advantages to closely resemble various aculeate Hymenoptera. *Head*: Eyes relatively large compared to vertical width of front (range: 0.8-2.2) ("eye index", Powell, 1973); ocelli prominent; proboscis present on most species, naked, rudimentary on species of some genera; labial palpi upcurved, long, usually approaching or exceeding top of front, either thickened and roughened by slender, projecting scales or slender and smooth with short, broad, appressed scales; antennae variously clavate, though pointed apically, terminated by unique hair-like scale tuft (absent in Tinthiinae), males ciliate ventrally, pecti-

*Not native in California (Munz, 1963)

nate-ciliate in a few groups, females without ciliation ventrally; margin of head with occipital fringe of erect, thin, contrasting colored scales. *Thorax*: Most species with yellow longitudinal stripe above wing bases and a large patch of yellow, orange or white beneath wings. *Legs*: Elongate, slender, variously tufted, normally at tibial spurs, but in some groups more extensively tufted. *Forewing*: Long and narrow, varying from mostly hyaline with prominent discal spot to completely opaque; veins—R generally with five branches, anal veins reduced or lost. *Hindwing*: Slightly shorter and broader than forewing, most often hyaline but opaque on some species; frenulum single in both sexes; veins—M veins widely separated, relative position of bases of M_3 and Cu_1 to crossvein dependent on group, anal veins with 1A degenerate (superficially indicated by line of scales in wing fold), present to varying degrees in primitive species, 2A present, 3A either short, fused to near base of 2A, or absent, 4A present except in primitive groups. Unique wing locking mechanisms, in addition to frenulum/retinaculum system, resulting from down-folded hindmargin of forewing interlocking with up-folded costal margin of hindwing, held firmly together by series of interlocking, recurved spines on both folds. *Abdomen*: Generally long and slender, often narrowed at base, tapering posteriorly to an anal tuft, best developed on males, most often variously banded with either, white, yellow, orange or red, banding may be subject to considerable variation. Genitalia are characteristic for each group but are fairly homogeneous for the species within the individual group (compare the illustrations of male and female genitalia for differences in morphological structures).

Egg.—Usually pale brown to dark chestnut brown, ovate, flat or slightly concave ventrally, with surface sculptured in minute hexagonal designs.

Larva.—Pale, pigmentation usually only on head and bars on prothoracic shield; ocelli I-IV arranged in trapezoid and remote from V and VI; prolegs reduced, with crochets uniordinal in two transverse rows, often reduced in number (MacKay, 1968).

Pupa.—Abdominal segments 3-10 freely movable; with posteriorly projecting spines on segments 2-6 (also on 7 of male), single row on remaining segments; large, broad spines posteroventrally on 10; head often modified with sharp prominences.

TINTHIINAE

This subfamily is characterized by the relatively small head and eyes; filiform antennae, lacking terminal scale tuft; hindwing with vein 1A nearly or entirely developed, 2A present, 3A and 4A absent; male genitalia simple, compact, only simple setae present, without gnathos, scopula androconalis or socii. Both North American tribes are represented in California.

Tribe PENNISETIINI *PENNISETIA* DEHNE

This genus is characterized by: head: eyes small (index 0.77-0.80); male antenna strongly bipectinate in North American species; proboscis short, about one and one-half length of labial palpus. Forewing: veins R_4 and R_5 stalked; two M veins present; Cu_2 nearly as long as Cu_1 . Hindwing: M_3 , Cu_1 long stalked.

PENNISETIA MARGINATA (HARRIS)

Raspberry Crown Borer
(Plate I; Figure 12)

Trochilium marginatum Harris, 1839:309. Type-locality: New Hampshire. (Apparently lost or destroyed).

Description.—Head: vertex dark brown; front dark brown with pale yellow laterally and ventrally; occipital fringe yellow, white laterally; labial palpi roughened, pale yellow; antennae dark brown, perhaps some yellow powdered dorsoapically. Overall female patterns similar to that of male, generally with scaling on forewings more extensive. Form "albicomma" Hulst differs mainly in having yellow replaced by pale yellow to white. Wing length: male, 8-12 mm; female, 12-16 mm. Genitalia as shown.

Distribution.—Throughout America north of Mexico, but only few scattered records in Rocky Mountains and Great Plains. In California recorded only from Central and Northern Coast Range: *Humbolt Co.*, Fieldbrook; *Santa Clara Co.*, Mts. back of Alma; *San Mateo Co.*, Palo Alto.

Biology.—(Raine, 1962; Breakey, 1963). The raspberry crown borer is a serious pest of *Rubus* spp.; including *R. idaeus* L. (red raspberry), *R. occidentalis* L. (black raspberry), *R. procerus* P.J. Muell (Himalaya blackberry), *R. lacineatus* Willd. (cutleaf blackberry), *R. loganobaccus* Bailey (loganberry, boysenberry), *R. odoratus* L. (thimbleberry), *R. spectabilis* Pursh (salmonberry). Adult moths emerge mostly from July through October, appear-

ing in flight much like yellowjacket wasps. Females mate on the same day as emergence and begin ovipositing the following day, producing about 110 eggs on the average. The eggs are placed singly on the underside of leaves near the margin. Hatching is over two to eight week period. The hatchling larvae crawl down or drop from silk threads to the canes, where they form small hibernacula, which appear as small circular bumps or scabs on the sides of the canes at or just beneath soil level. The following spring the small larvae burrow directly into the cambium of the fruiting canes, damaging new buds and shoots arising from the crown. Feeding continues in the summer, girdling new canes just above ground level, often causing the plant to wilt and break off. Some larvae may complete development, but most overwinter a second year in the base of young canes, where they tunnel into the crown during the second summer. Mature larvae burrow upwards a short distance into the fruiting canes, prepare an exit hole with a paper thin bark covering, and pupate. Within a month of pupation, the pupa breaks through the exit hole. The moth then emerges, leaving the pupal case protruding from the cane.

Tribe TINTHIINI
ZENODOXUS GROTE AND ROBINSON

Species of this genus have the following characteristics: Head and eyes small (eye index range, 0.75-0.85); proboscis much reduced in length; labial palpi shortened, usually not exceeding top of front, roughened; male with long cilia ventrally on antennae, not pectinate, female occasionally with short cilia; wings mostly opaque; forewing with veins R_4 and R_5 separate; hindwing with small accessory cell, vein Cu_1 from well basad of crossvein; male genitalia with valves short, quadrangular, with simple setae, uncus reduced to setose knob; female genitalia usually with small circular signum on corpus bursae.

A KEY TO ADULTS OF CALIFORNIA ZENODOXUS

- 1. Abdomen gray, unbanded *Z. canescens*
 Abdomen with at least some segments yellow 2
- 2. Hindwing dorsally brown, some yellow powdering basally.
 *Z. heucherae*
 Hindwing dorsally at least partially powdered pink, orange or red 3

3. Foreleg with coxa yellow-orange, occasionally with pink
 tint *Z. palmii*
 Foreleg with coxa gray-black, occasionally with some deep
 red *Z. sidalceae*

***ZENODOXUS CANESCENS* HENRY EDWARDS**

(Plate I; Figure 14)

Zenodoxus canescens Henry Edwards, 1881:205. Type-locality: Colorado. (Lectotype male, AMNH).

Description.—Head: pale gray mixed with brown-black and pale yellow. Female distinguished from male by red hindwings and by red center of wings. Wing length: 6-11 mm. Genitalia similar to *Z. heucherae* (Fig. 13).

Distribution.—Recorded from Washington, Montana, south to western Texas, southwestern Arizona and southeastern California. In California known only from the eastern Colorado Desert: *Imperial Co.*, El Centro; *Riverside Co.*, Blythe; not known from areas further north in State where its host also occurs.

Biology.—Capture records for adults were mostly in September, October and November, with some taken in California and Texas in February and March. One specimen from Washington was captured in July in a trap coated with a sticky adhesive and baited with pheromone (Z, Z-ODDA). The larvae are apparently borers in the roots of *Sida hederacea* (alkali mallow, Malvaceae). Dammers (unpublished notes) tells of great numbers of the moths flying at Blythe on November 3 and 4, 1936 along the Colorado River Basin. The great majority were males in flight from 11:00 am until 2:00 pm over a large area containing alkali mallow, while the apparently much less numerous females remained on the ground. Dammers collected several pupae embedded in the surface of the soil adjacent to the mallows but did not find larvae in the roots of those plants examined. The late Christopher Henne also notes similar observations at the same locality.

***ZENODOXUS HEUCHERAE* HENRY EDWARDS**

(Plate I; Figure 13)

Zenodoxus heucherae Henry Edwards, 1881:205. Type-locality: Lake Tahoe, California. (Lectotype male, AMNH).

Description.—Head: vertex brown-black, yellow scales at antennal bases; front gray-black or brown-black; occipital fringe

mixed pale yellow and white; labial palpi white with brown-black mixed mostly on apical one-half, pale yellow basally; antennae variously powdered dorsally with pale yellow or yellow-orange. Wings strongly powdered with yellow ventrally. Females may differ from males by slightly more orange powdering on both pairs of wings, yellow on hindtibiae between spurs (this region of the hindtibiae of males being usually pale yellow to white). Wing length: 5-10 mm.

Since *Zenodoxus* genitalia are so similar, only those of *Z. heucherae* have been illustrated (Fig. 13) as being representative of all species.

Distribution.—Sierra Nevada of California from Modoc County to Tuolumne County.

Biology.—The host plant for this species is not known. Engelhardt (1946) made the observation that it commonly visits flowers of *Heuchera rubescens* Torr. (alumroot, Saxifragaceae), a plant found throughout its range, but there is no further indication that this plant is a host for *Z. heucherae*. Adults have been captured from June to August.

ZENODOXUS PALMII (NEUMOEGEN)

(Plate I; Figure 15)

Larunda palmii Neumoegen, 1891:108. Type-locality: South Arizona. (Lectotype male, AMNH).

Description.—The pale color form "incanae" Engelhardt (Blythe, Riverside Co.) is figured on the color plate. Head ("incanae"): vertex pale yellow, brown mixed; front pale yellow to white; occipital fringe pale yellow dorsally, becoming white laterally; labial palpi thickened, slightly roughened, yellow; antennae mostly powdered pale yellow dorsally. Wings powdered red-pink ventrally; hindwing of male with some hyaline regions basally; hindwing of female completely opaque, with more red-pink than on male. Wing length: 7-15 mm. Genitalia of male with valves slightly narrowed and upturned apically, otherwise as shown for *Z. heucherae* (Fig. 13).

The form "sphaeralceae" Engelhardt (New York Mts., San Bernardino Co.) mainly differs from "incanae" by having pale orange replacing the yellow on "incanae" and abdominal segments two and three mostly orange dorsally.

Distribution.—Eastern Washington and Oregon, south into extreme southeastern California, Arizona and Texas. California

records: *Riverside Co.*, Blythe; *San Bernardino Co.*, Keystone Canyon, New York Mountains, 5500 ft. elevation.

Biology.—The various forms have been reared from roots of *Sphaeralcea ambigua*, *S. incana* ("incanae" Yuma, Arizona), *S. munroana*, *Pseudabutilon lozanii* (Malvaceae). Specifics of the life history of this species have not been recorded to our knowledge. Collection data indicate a flight period from July to early October, depending on the portion of the range from which the specimens were obtained (early September in southeastern California). Reared specimens from Brownsville, Texas emerged in April and May.

ZENODOXUS SIDALCEAE ENGELHARDT

(Plate I; Figure 16)

Zenodoxus sidalceae Engelhardt, 1946:196. Type-locality: Pullman, Washington. (Holotype male, NMNH).

Description.—Generally resembling *Z. heucherae* but hindwing pink basally and medially. Head: vertex brown-black; front brown-black, pale yellow or white mixed; occipital fringe pale yellow; labial palpi white with dark brown and some pale yellow; antennae powdered pale yellow dorsally. Forewings ventrally powdered white on costal margin, mixed white and pink in apical area. Hindwings ventrally pink slightly tinted with white. Females more heavily marked red, particularly on occipital fringe, vertex, forecoxae, and other portions of legs; abdominal segments 2, 3, 5 and anal tuft mostly red on black. Wing length: 6-9 mm. Valves of male genitalia broadly rounded apically; otherwise as shown for *Z. heucherae* (Fig. 13).

Distribution.—Recorded from Alberta, south through Idaho, western Washington, Oregon, to Los Angeles, California.

Biology.—Adults have been reared from *Sidalcea oregana* (Malvaceae) in Washington and Oregon, but other details of the life history are lacking. Capture records are from late March to early September.

PARANTHRENINAE

The Paranthreninae have the following combination of characters: Head with antenna clavate, with terminal scale tuft, ciliate, often pectinate on male; labial palpi usually roughened ventrally, upcurved, extending above top of front; eye index range, 1.0-1.4. Forewing with veins R_4 and R_5 long stalked, stalk generally

longer than one-half total length of either vein, Cu_2 nearly as long as Cu_1 . Hindwing with vein 1A degenerate (only line of scales remains on fold), 2A and 3A coincident except near base, 4A present; Cu_1 arising just basad of crossvein (usually hidden by scale covering). Male genitalia with valves elongate, scales multifurcate dorsally, setaceous ventrally and apically, median area with thick dark scales in saccular region or unscaled; tegumen short with small rounded or bifurcate gnathos; uncus elongate, three to five times length of tegumen; saccus relatively short. Female genitalia with ductus bursae elongate narrow, ductus seminalis arising near ostium bursae. The subfamily is represented in California by three species in the nominate tribe.

Tribe PARANTHRENINI
***PARANTHRENE* HÜBNER**

Male head with antenna bipectinateciliate ventrally. Forewing with bases of veins R_3 and $R_4 + R_5$ connate; hindwing with scaling on wing fold not more than two times wider than scaling on 2A distally. Male with subapical spine on aedeagus. Female with corpus bursae having numerous transverse folds and one or more longitudinal pigmented bands.

***PARANTHRENE ROBINIAE* (HENRY EDWARDS)**

(Plates II, VIII; Figures 1, 2, 17)

Sciapteron robiniae Henry Edwards, 1880:72. Type-locality: Virginia City, Nevada. (Lectotype male, AMNH).

Description.—Head: vertex mostly orange or rust; front, occipital fringe yellow or orange; labial palpi roughened, yellow with orange, brown-black laterally, perhaps some orange ventrally; antennae pectinate, orange, perhaps some black apically. Forewings lighter ventrally than dorsally, pale orange, some yellow. Wing length: 11-18 mm. The genitalia as figured are typical for species of *Paranthrene*.

The desert form "palescens" Engelhardt from southern California is nearly entirely pale yellow except for some orange powdering on the thorax, wing bases, forewings, and anteriorly on abdominal segments 2, 3, and perhaps on 4. Another color variant "perlucida" Busck is from the northern Rocky Mountains of the United States and Canada.

Distribution.—From Alaska, Rocky Mountains, to Pacific

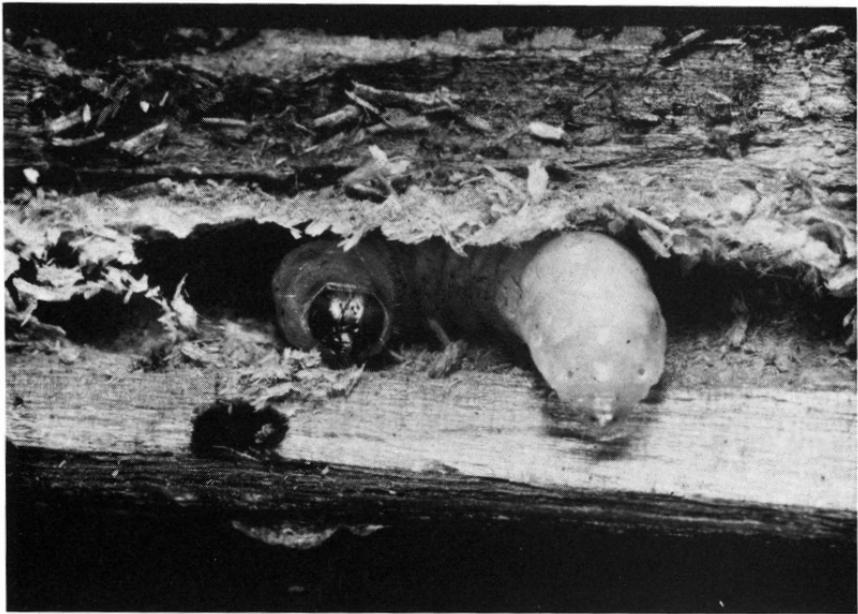


Figure 1. Larva of *Paranthrene robiniae* in willow branch (photo courtesy of Lee Brown).

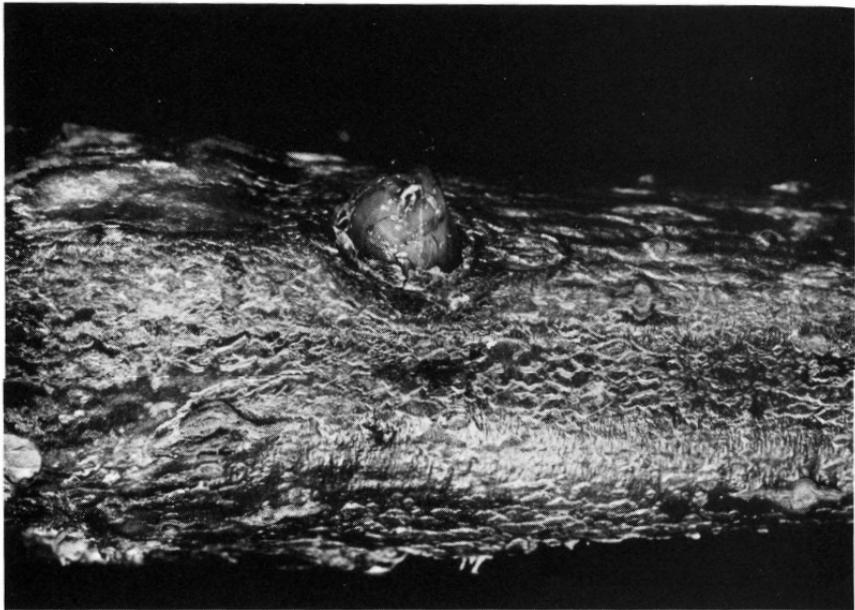


Figure 2. Pupal head of *Paranthrene robiniae* protruding from exit hole in willow branch just prior to emergence (photo courtesy of Lee Brown).

Coast, and south into desert Southwest; from sea level to near timberline.

Biology.—The larvae of *P. robiniae* are wood borers in *Populus* spp. (poplars) and *Salix* spp. (willows) and can be destructive to ornamental plantings of *Betula* spp. (birches) (Plate VIII, top). Trees which are damaged or otherwise weakened are particularly susceptible to heavy infestation by this species, the larvae boring in the trunks and branches. (Fig. 1) Eggs are deposited in bark crevices and around knots and wounds, hatching in about 20 days (Thompson, 1927). The larvae reach maturity normally in the fall of the second year of a two-year cycle. The mature larva over-winters in a pupal chamber prepared at the upper part of the larval burrow, which is capped with silk but without preparing a cocoon. Pupation generally occurs in late May or June, emergence of the adult following two to three weeks later. (Fig. 2) Adults are active usually from May through July; however, in southern California specimens have been taken in November and from February through May. Some specimens of *P. robiniae* have been captured using the Z, Z isomer of ODDA in California.

ALBUNA HENRY EDWARDS

The following characters of *Albuna* will differentiate it from *Paranthrene*: Antennae of male not pectinate; stalk of veins $R_4 + R_5$ of forewing not joined to base of R_3 but are connected by cross-vein; male genitalia with lateral portions of uncus nearly naked, gnathos with spines apically.

ALBUNA PYRAMIDALIS (WALKER)

(Plate II; Figure 18)

Aegeria pyramidalis Walker, 1856:40. Type-locality: St. Martin's Falls, Albany River, Hudson's Bay. (Lectotype male, BMNH).

Description.—Head of typical form: vertex blue-black; front pale yellow to white; occipital fringe pale yellow; labial palpi roughened, pale yellow, black laterally; antennae blue-black, pale orange ventrally. Wing length: 8-14 mm.

Albuna pyramidalis can be readily recognized by the broad oblique discal mark on the forewings, even though there is a wide range of variation in the superficial color patterns as evidenced by the number of names which have been applied to this species by previous workers. Engelhardt (1946) recognized various color forms in addition to the typical form, which range from the nearly

entirely black form "coloradensis" Hy. Edwards to "rubescens" Hulst with much orange-red on the wings, to "beutenmulleri" Skinner with wings opaque, orange-red. The color patterns show all degrees of intergradation throughout the wide range of this species.

Distribution.—Canada, Alaska, northeastern United States, northern Michigan and Wisconsin, Rocky Mountains and Pacific Mountain ranges.

Biology.—The larvae of *A. pyramidalis* are known to bore in the main roots of *Epilobium angustifolium*, *E. latifolium* and *Oenothera biennis* (Onagraceae). They have been found in the roots as far below the soil surface as 30-60 cm. Overwintering by the larvae occurs in specially constructed, oblong cocoons located just beneath the soil at the upper end of vertical silk tunnels which lead down to the main roots. The pupal exuviae can be found protruding from the soil at the base of the host plants following emergence of the adults in the summer. The life cycle apparently requires one year. Specimen records indicate a flight period from late May to mid August, peak emergence occurring in June and July. The moths are attracted to flowers, the rapidly flying males hovering over the blossoms, while the heavier, more sluggish females rest on the foliage or flowers. Males have been attracted to pure E, Z isomer and to a mixture of the Z, Z and E, Z isomers of ODDA.

EUHAGENA HENRY EDWARDS

In *Euhagena* the proboscis is rudimentary; eye index, 1.1-1.2; antenna of male bipectinateciliate, with rami long, somewhat appressed on preserved specimens; genitalia generally of the Paranthrene-type.

EUHAGENA NEBRASKAE HENRY EDWARDS

(Plate II; Figures 3, 19)

Euhagena nebraskae Henry Edwards, 1881:181. Type-locality: Nebraska. (Holotype male, MCZ).

Description.—Head: vertex brown-black and orange mixed, long white silky hairs at posterior margin mesally; front roughened, tufted, white with brown dorsolaterally; occipital fringe setaceous, brown-black; labial palpi white, with long brown-black and white scales mixed ventrally on segments 1, 2; antennae brown-black, powdered white. Wing length: 6-11 mm.

This species has both pairs of wings opaque, deep orange, with the typical color form brown-black broadly on discal spot, wing margins and on some veins. The form "intensa" Engelhardt in California, based on available data, appears to be a subpopulation well isolated from the main population of the species. Superficially, "intensa" differs by having the wings more solidly deep orange, with much less brown-black than typical form, and the abdominal banding is pale yellow instead of white.

Distribution.—Most existing records are from the Rocky Mountains of northern New Mexico and Colorado, with very scattered records from southern California (western Mojave Desert), Nebraska, Utah, South Dakota, Alberta and Saskatchewan near their common border with Montana. California records: *Los Angeles Co.*, 2.5 mi. SSW Valyermo, San Gabriel Mts., 4800 ft. elevation; Upper Santa Ana River; 8.5 mi. SE Phelan; *San Bernardino Co.*, Mojave Riverbed, 1 mi. S Oro Grande, 2700 ft. elevation.

Biology.—The following information applies mainly to the California population of the form "intensa". This information resulted from field observations by Christopher Henne in late October, along the Mojave River, San Bernardino County and visits to the same locality more recently by Eichlin. Henne reported having seen freshly emerged adults in mid to late morning resting on the sand, on the wing, or exhibiting oviposition behavior in the foliage of *Oenothera avita* (Onagraceae). Closer inspection of the low growing plant, which grows alone on open sand, revealed the presence of several long (some were 20-24 cm) tubes made of silk and covered with sand extending vertically from the perennial main root to the soil surface around the crown (Fig. 3). Pupation takes place in a cocoon formed at the base of the sand tube on or just in the root, and at the time of emergence, the pupa comes to the surface through the tube, leaving the exuvium partially wedged in the opening. This species apparently has an annual life cycle, the adults emerging from September through October.

SESIINAE

The Sesiinae have the following combination of characters: Head with eyes proportionately larger than for Paranthreninae and Tinthiinae (eye index range, 1.4-2.2); antennae variously clavate, with terminal scale tuft, ventrally ciliate on male except for Osminiini, pectinate only on certain species of Melittiini and Sesiini. Forewing with stalk of veins $R_4 + R_5$ generally one-half



Figure 3. *Oenothera avita*, host of *Euhagena nebraskae* form "intensa", with sand covered exit tubes leading from root to soil surface.

or less than one-half total length of either vein. Hindwing with M_3 and Cu_1 generally short stalked except in *Melittiini*; 1A degenerate (only line of scales remains on fold), 2A, 3A and 4A present. Male genitalia mostly with tegumen and uncus fused; gnathos usually well developed; scopula androconialis present on most species; vinculum narrow; valves variously modified, most frequently with specialized bifurcate scales. This highly successful group contains the great majority of the world's species.

Tribe MELITTIINI
***MELITTIA* HUBNER**

Melittia species have the following characters which separate the genus from other Sesiinae: Head and eyes proportionately larger (eye index range, 1.9-2.2); plate of broad flat scales projecting horizontally from beneath scape over middle of eye; vertex with pronounced chaetosemae; antennae strongly clavate, male rudimentarily pectinate to unipectinate, depending on species. Hindwing with vein Cu_1 arising well basad of crossvein. Genitalia modified, generally as depicted for *M. calabaza*. Hindleg of most species with tibia and tarsus very strongly tufted, particularly dorsally and mesally.

A KEY TO ADULTS OF INCLUDED *MELITTIA*

1. Abdomen dorsally primarily deep orange with mid-dorsal green-black spot on most segments; forewing with narrow hyaline streak near wing base *M. calabaza*
Abdomen not marked as described above; forewing without narrow hyaline streak near wing base 2
2. Scales of thorax, wings and abdomen tipped with pale yellow or white; abdominal segments dorsally and laterally deep orange, banded brown-black on posterior margins (form "hermosa" with dorsomedial, olive-green to gray, longitudinal band on abdomen). *M. grandis*
Scales of thorax, wings and abdomen not tipped with pale yellow or white; abdomen dorsally with segments 3 and 5 yellow, 1, 2 and 4 gray dorsomedially, 7 and 8 pale blue or steel-blue *M. gloriosa*

***MELITTIA CALABAZA* DUCKWORTH AND EICHLIN**
(Plate II; Figures 4, 20)

Melittia calabaza Duckworth and Eichlin, 1973:151. Type-locality: Teotihuacan, Mexico. (Holotype male, NMNH).

Description.—Head: vertex olive-green; front white, often with gray mesodorsally; occipital fringe setaceous, brown-black mixed with white, eyes margined with white scales; labial palpi roughened, orange, white on basal segment and mixed ventrally on second, line of black setaceous scales subventrally on male; antenna dorsally olive-green, weakly powdered white or pale yellow on apical one-third, on male strongly ciliate, not pectinate, ventrally. Abdomen ventrally orange with some white. Wing length: 12-15 mm.

Although *M. calabaza* has not been recorded from California to date, it is included in this survey because of its presence in the Tucson, Arizona area and its potential economic impact to California's cultivated cucurbits. It is closely related to *M. satyriniformis* (Hübner), the common squash-vine borer of the eastern half of the United States and coastal Veracruz, Mexico. *M. calabaza* is readily distinguishable from the other species in the squash-vine borer complex by having the second abdominal segment mostly orange dorsally, rather than olive-green as on the other species (refer to the original description of *M. calabaza*, Duckworth and Eichlin, 1973 for a comparison of the species in this complex).

Distribution.—Presently known from Tucson, Arizona and southcentral Texas; south into Mexico in the regions adjacent to and surrounding the central cordillera, southeastward into the State of Veracruz.

Biology.—Until very recently no precise data on the biology of *M. calabaza*, including host plant preferences, were available. Most of the following is from field and laboratory studies of Tim Friedlander, University of Texas, Austin, soon to be published in full detail. This species completed development in cultivars of the following species of pumpkins and squashes (Cucurbitaceae): *Cucurbita pepo*, *C. maxima*, *C. moschata*, *C. andreana*, *C. ficifolia*, *C. texana* and *C. okachobeensis*. Hosts for oviposition are selected by the females. Most of the average 100 eggs per female are placed at the bases of the stems near the soil surface but may also be laid on the leaves, petioles, and epidermal hairs of the host plant. The biologies of *M. calabaza* and *M. satyriniformis* are apparently very similar, and some of the following is extrapolated from what is known for the latter species (Friend, 1931; Howe, 1950; Miller, 1955): The average incubation period for the eggs is 9 days. Newly hatched larvae wander over the surface about one hour before entering the stem. The average total duration of the

four larval instars is approximately 30 days. The borers migrate to other stems if the food supply is depleted. Maturing larvae hollow out stems (Fig. 4), which crack open, permitting frass to exude. Mature borers leave the vines to pupate in tough, leathery cocoons in the soil at depths of 2.5 to 15 cm. Overwintering occurs in cocoons as prepupal larvae, pupation occurring in late spring or early summer. Prior to emergence the pupa breaks out of the cocoon and wriggles to the soil surface (Plate VIII, bottom), mating often occurring on the same day as emergence. Friedlander noticed males flying rapidly over tree tops at about 7.5 m, apparently in search of females, while females tended to rest on leaves of the host plants when not ovipositing. Males have shown a limited attraction to the Z,Z isomer of ODDA in the field. There are two generations per year in Austin, Texas, with adults of each generation active from mid May to July and from July to September respectively.

MELITTIA GLORIOSA HENRY EDWARDS

(Plate II; Figures 5, 6, 7, 21)

Melittia gloriosa Henry Edwards, 1880:71. Type-locality: California. (Holotype male, NMNH).

Description.—Head: vertex roughened, greenish-tan; front white, perhaps with some gray dorsally; occipital fringe yellow; labial palpi yellow, venter flattened, white, subventrally with line of long setaceous, black scales; antennae of male unipectinate-ciliate, brown-black on one side, slightly powdered white, yellow on other side. Abdomen ventrally mixed pale yellow and white. Forewing ventrally yellow or yellow-orange. Females average larger in size than males; greenish-tan of males replaced with olive-green; hindwing opaque, orange, though variously hyaline in the more eastern form "lindseyi" Barnes and Benjamin. Wing length: 15-28 mm.

Prized by collectors, this species is one of the largest and most striking of the clear wing moths.

Distribution.—From Kansas south to western Texas, west through New Mexico and Arizona into southern California and coastal islands, and north to central Oregon.

Biology.—The larvae of *M. gloriosa* bore in the large, tuberous, water storage, tap roots of *Cucurbita foetidissima* (Fig. 5), *C. palmata*, *C. digitata*, *Marah fabaceus*, and *M. oreganus* (Cucurbitaceae). The life cycle may take one or two years, depending on local yearly climatic conditions. Eggs are deposited on the soil



Figure 4. Larva of *Melittia calabaza* in squash vine.

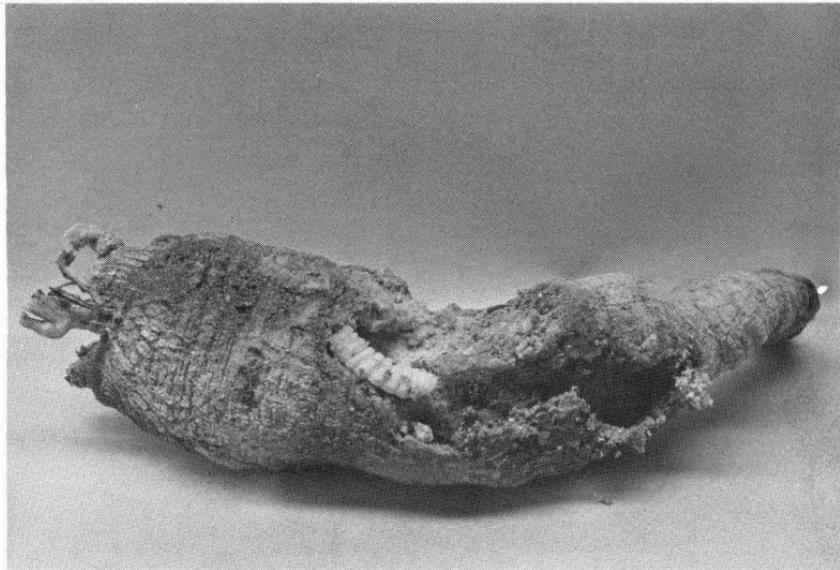


Figure 5. Larva of *Melittia gloriosa* boring in tuber of *Cucurbita foetidissima*.



Figure 6. Larva of *Melittia gloriosa*.



Figure 7. *Melittia gloriosa*: freshly emerged female with pupal exuvium protruding from sand covered cocoon.

surrounding a suitable host plant. Upon hatching the larvae burrow down in the soil to the tuber, where they initially feed externally, entering the tuber later. Apparently, the larvae (Fig. 6) are variously active throughout the winter and when mature leave the tuber, burrow up through the soil to near the surface, construct a tough leathery cocoon, and pupate soon thereafter. Remarkable cutting and drilling structures on the pupal head and large spines on the abdomen enable the pupa to work its way through to the surface at the time of adult emergence (Fig. 7). Moths fly from May through October, depending on the locality. They can be found in the cool morning hours sitting docily on the cucurbit leaves near the bases facing outward and can be collected quite easily. As the ambient temperature increases, the moths, particularly the males, become more active, are easily frightened, and fly off very rapidly. Males have not appeared to respond to any of the stereoisomers of ODDA.

MELITTIA GRANDIS (STRECKER)

(Plate II; Figure 22)

Trochilium grande Strecker, 1881:156. Type-locality: Texas. (Holotype female, FMNH).

Description.—Head: vertex roughened, pale orange medially, smooth olive-green laterally; front pale orange; occipital fringe white mixed with setaceous black scales; labial palpi roughened, pale orange; antennae brown-black powdered yellow, males strongly ciliate ventrally, not pectinate. Abdomen ventrally pale orange, often with some brown-black medially on most segments. Forewing ventrally powdered variously with pale orange. The olive-green scales of the thorax, abdomen and wings are uniquely tipped with white or pale yellow. The color form "hermosa" Engelhardt differs mainly by having a broad, dorsomedial, olive-green, longitudinal band on the abdomen. Wing length: 16-21 mm. Genitalia much like *M. gloriosa* but differs in certain details; compare figures for both species.

Though nearly as large as *M. gloriosa*, *M. grandis* is easily distinguishable by its black segmental rings and pale tipped, olive-green scales on thorax, abdomen and wings, the abdominal pattern of *M. gloriosa* being quite different and with unicolorous scales.

Distribution.—Kansas, Texas, New Mexico, Arizona, south-

eastern California and northern Mexico. One California record: Imperial Co., Palo Verde.

Biology.—As with *M. gloriosa*, larvae of *M. grandis* bore in the tubers of *Cucurbita foetidissima*. The life cycle of the two species is apparently very similar. Adults of *M. grandis* have been collected from April through September, depending on the locality and local climatic variations from year to year, with the frequency and quantity of rainfall being probably the most important single factor in the timing of pupation and adult emergence. California is listed here for the first time as being part of the range of this species on the basis of a single female specimen from ten miles south of Palo Verde, Imperial County, September 8, 1967, collected by M. Cazier. Adults are most easily captured early in the day in or around patches of *Cucurbita foetidissima*, which commonly grows in dry areas along road sides or similar disturbed situations.

Tribe SESIINI *SESIA FABRICIUS*

Sesia has the following combination of characters: Head with proboscis reduced, about two-thirds length of labial palpus; antenna strongly clavate, ventrally ciliate-unipectinate on male; horizontal flat plate of scales projecting somewhat over middle of eye as with *Melittia* but less pronounced. Forewing with vein R_4 terminating at apex, R_5 below. Hindwing with veins M_3 and Cu_1 joined at corner of cell or very short stalked. Genitalia unique, generally as shown for *S. tibialis*.

SESIA TIBIALIS (HARRIS) (Plate II; Figure 23)

Trochilium tibiale Harris, 1839:309. Type-locality: New Hampshire. (lost).

Description.—Head: vertex roughened, blue-black, yellow posteriorly; front yellow laterally, blue-black medially; occipital fringe blue-black dorsally, yellow laterally; labial palpi roughened, pale yellow with setaceous blue-black scales mixed laterally and ventrally, perhaps some pale orange dorsally and apically; antenna blue-black. Abdomen ventrally with anterior one-half of each segment yellow, posterior one-half blue-black. The form "melanoformis" Engelhardt shown on Plate II differs slightly by having somewhat narrower yellow banding on ab-

dominal segments and wings with margins, veins and discal spot darker, brown-black, the typical form being rust-brown. Wing length: 12-19 mm.

Distribution.—Nova Scotia and New England, west to Vancouver, British Columbia; Rocky Mountains of Wyoming, Colorado and New Mexico, west to the Pacific Coast.

Biology.—This species has been associated with several species of Salicaceae; including *Populus alba* L. (silver poplar), *P. candicans* Ait., *P. deltoides* Marsh (cottonwood), *P. fremontii* Wats. (Fremont cottonwood), *P. tremuloides* Michx. (quaking aspen), *P. trichocarpa* T. & G. (black cottonwood), *Salix* spp. (willows). The larvae are borers beneath the bark in the cambium and solid wood of the lower trunk or exposed roots of the host tree. Adults have been taken from May through August, with most records from California in June. The form "melanoformis" is from higher elevations mostly in the Sierras and Rocky Mountains. Males of this species are very responsive to the Z,Z isomer of the sesiid pheromone. In flight they closely resemble wasps, even to the droning sound produced by the rapid beat of their wings.

Tribe SYNANTHEDONINI

This is a large, relatively homogeneous tribe, characterized by the male genitalia with specialized bifurcate scales on valves; fused uncus-tegumen complex; valve most often with some form of crista sacculi; gnathos a broad shield like, often heart shaped plate with medial perpendicular crista gnathi; specialized paired processes from uncus (scopula androconialis), clothed with bifurcate scales.

SYNANTHEDON HÜBNER

Male genitalia: valve with crista sacculi either much expanded, or nearly straight, oblique ridge with variously modified scales, or absent; saccus less than one-third length of valve; bend of tegumen-uncus complex slightly obtuse angle. Female genitalia: ductus bursae elongate, slender, membranous, except for sclerotization confined on most species to posterior one-third or less; ductus seminalis arises from ductus bursae nearer to ostium bursae than to corpus bursae, on posterior one-third on most species.

This genus contains the greatest number of species (12) so far known from California.

**A KEY TO THE ADULTS OF CALIFORNIA *SYNANTHEDON*
AND *CARMENTA***

1. Head with labial palpus with orange or orange-red at least ventrally 2
 Head with labial palpus lacking orange or orange-red 5
2. Head with front orange *S. novoensis*
 Head without orange on front 3
3. Head with front white laterally *S. culiciformis*
 Head with front entirely brown-black 4
4. At least some orange or orange-red on abdomen, perhaps confined to venter, or if solid blue-black then both pairs of wings opaque *S. polygona*
 No orange or orange-red on abdomen and both pairs of wings mostly hyaline *S. saxifragae*
5. Occipital fringe laterally brown-black *S. exitiosa*
 Occipital fringe laterally white or yellow 6
6. Abdomen solid blue-black, perhaps with few pale yellow scales on posterior margin of segment 2 *S. albicornis*
 Abdomen variously banded with white or yellow 7
7. Head with front mostly white or white laterally 8
 Head with front mostly yellow or brown-black 9
8. Head with much white on labial palpus and front; forewing nearly or entirely opaque, strongly powdered white; abdomen with banding white, ventrally mostly white
 *Carmenta verecunda*
 Head with no white on labial palpus, yellow with brown-black laterally and front with white laterally only; forewing mostly hyaline not powdered white, some yellow between veins apically; abdomen with banding yellow, ventrally mostly brown-black with some narrow yellow bands *S. tipuliformis*
9. Forewing ventrally powdered with orange or orange-red . 10
 Forewing ventrally powdered with yellow 11
10. Labial palpus roughened; powdering ventrally on forewing orange-red *S. chrysidipennis*
 Labial palpus thickened but not roughened; powdering ventrally on forewing orange *S. mellinipennis*

11. Labial palpus slender and smooth *S. resplendens*
 Labial palpus thickened and roughened 12
12. Margins and discal spot of forewing very narrow, total
 opaque area less than one-tenth of wing area . . *S. sequoiae*
 Margins and discal spot of forewing broad, total opaque area
 about one-half or more of wing area *S. bibionipennis*

***SYNANTHEDON ALBICORNIS* (HENRY EDWARDS)**

(Plate III; Figure 24)

Aegeria albicornis Henry Edwards, 1881:201. Type-locality: Nevada. (Holotype female, MSU).

Description.—Head: vertex brown-black; front brown-black, often with white scales laterally; occipital fringe brown-black, often with pale yellow; labial palpi relatively smooth, pale yellow and white ventrally and mesally, brown-black laterally, palpi occasionally solid brown-black on females; antenna brown-black, preapical white patch dorsally, male ventrally ciliate. Abdomen with bluish iridescence, laterally pale yellow on segments 1, 2, occasionally forming narrow band on posterior margin of segment 2 dorsally. Wings ventrally powdered with pale yellow on margins. Wing length: 8-11 mm.

Superficially, this species resembles a small male of *S. exitiosa* form "graefi" Hy. Edwards, but *S. albicornis* is recognizable by its preapical white patches on the antennae and smoothly scaled labial palpi.

Distribution.—California and Nevada, north to British Columbia and Northwest Territory.

Biology.—The larvae attack various species of *Salix* (willows, Salicaceae). They bore in the bark of large trees or in exposed roots, limbs or canes of smaller willows. Henne reared adults in Los Angeles County from the upper branches of *Salix lasiandra* Benth. and *S. laevigata* Bebb. Most adults were taken from late June through August. Males respond well to the Z,Z isomer of ODDA.

***SYNANTHEDON BIBIONIPENNIS* (BOISDUVAL)**

Strawberry Crown Moth

(Plate III; Figure 25)

Sesia bibionipennis Boisduval, 1869:64. Type-locality: California. (Holotype male, NMNH).

Description.—Head: vertex brown-black, often mixed with yellow; front brown-black; occipital fringe yellow; labial palpi roughened, yellow with row of elongate brown-black scales sub-ventrally, dark scales absent on females; antenna brown-black, often powdered yellow on posterior margin, scape yellow. Abdominal banding dorsally may vary in width and number from one specimen to another; abdomen ventrally sparsely powdered yellow. Forewings ventrally with opaque areas mostly yellow; dorsally yellow powdering between veins apically may vary considerably, females may have dull orange powdering. Wing length: 8-10 mm.

This species is easily confused with another common California species, *S. resplendens* (Hy. Edwards). The roughened palpi of *S. bibionipennis* will separate it from *S. resplendens* with smooth palpi, a condition sometimes more difficult to ascertain between females of the two species. Examination of the genitalia may be necessary to differentiate between the species when there is doubt.

Distribution.—Rocky Mountains, Montana to Arizona; west to Pacific Coast, British Columbia to California.

Biology.—Adults have been reared from *Fragaria* sp. (strawberries), *Potentilla* sp., *Rosa* sp. (roses), *Rubus* spp. (raspberries, blackberries, boysenberries) (Rosaceae). The larvae bore in the roots near the crown or in the stems near the base of the host plant. Most of the following information is from Wilcox *et al.* (1932) on the strawberry crown borer in Oregon. Adult emergence occurs from April through mid-August. Their flight is fairly straight and swift and usually not higher than 22-25 cm above the host plants. Adults are often seen taking nectar from flowers of various kinds. Female moths spend much time crawling among dead leaves and stems close to the crown, depositing single eggs on the underside of various objects about every four minutes. In the laboratory, 13 females laid an average of 405 eggs per moth during a 6-11 day period. The incubation period for the eggs is 10-17 days. For the first few days following hatching the larvae feed externally and at about three days burrow under and below the leaf scales around the crown. After about 10 days the larvae burrow into the cambium and by 30 days all have burrowed into the pith of the crown. Larvae feed until September or October and then prepare a silken chamber in the burrow, in which they overwinter. Feeding is resumed the following spring. Just prior to pupation the mature larva bores to the outside above ground

level, leaving an exit hole for the pupa and prepares a cocoon a short distance back from the exit hole. Pupation occurs about nine days following the formation of the cocoon, the duration of the pupal stage taking about 23 days. At emergence the pupa pushes the cap off the cocoon and works itself partially out of the exit hole, from which position the adult emerges. Males have been captured in traps baited with the Z,Z isomer of ODDA in several localities throughout California.

***SYNANTHEDON CHRYSIDIPENNIS* (BOISDUVAL)**

(Plate III; Figure 26)

Sesia chrysidipennis Boisduval, 1869:64. Type-locality: Los Angeles, California. (Holotype male, NMNH).

Description.—Head: vertex, front brown-black; occipital fringe yellow; labial palpi roughened, yellow with brown-black mixed subventrally, brown-black absent on females; antenna brown-black, often powdered yellow-orange on posterior edge, ventrally on scape. Abdomen ventrally with yellow band on segment 4, often on 5, 6. Forewings ventrally mostly orange-red, except narrowly at apical margin and on discal spot. Females usually have greater suffusion of orange-red on forewings and more yellow on abdomen than males. Wing length: 9-11 mm.

The color form "wallowa" Engelhardt is characterized by an overall darker appearance resulting from very little orange-red dorsally on the wings and the yellow on the legs confined mostly to the tarsi.

Distribution.—At higher elevations from British Columbia south to Utah and California. The type-locality, Los Angeles, is probably erroneous and may simply represent a locale from which the type specimen was sent.

Biology.—The larvae have been recorded as boring in the roots of *Polygonum davisiae* and *Polygonum* sp. (Polygonaceae). Pupation takes place in cocoons in the larval burrow near the crown of the host plant, or the larvae may construct silk-lined tubes extending from the exit hole in the root to the soil surface to provide a means of escape for the mature pupa. Adults can be seen, often in large numbers, from late June through early August flying about the host plants in alpine meadows. Henne notes that several specimens were observed in Smokey Valley, Tulare County visiting flowers of *Achillea lanulosa* Nutt. (Asteraceae).

***SYNANTHEDON CULICIFORMIS* (LINNAEUS)**

(Figure 27)

Sphinx culiciformis Linnaeus, 1758:493. Type-locality: Europe. (lost).

Description.—Head: vertex brown-black; front brown-black, white laterally; occipital fringe brown-black, perhaps some orange lateroventrally; labial palpi roughened, orange-red, brown-black dorsally; antenna brown-black. Thorax: brown-black dorsally, mostly orange below wings; collar white subventrally. Abdomen: brown-black with slight blue-green iridescence; posterior margin of segment 2 orange-red, solid orange-red dorsally, ventrally on 4, and orange-red laterally from base to 4. Legs: mostly brown-black, pale yellow to orange mesally, on tarsi, apically on hind tibiae. Forewing: mostly hyaline, margins, veins, discal spot brown-black, orange powdered near wing base, on costal margin, ventrally lightly between veins on apical margin. Hindwing: hyaline, with narrow margins, veins and very small discal spot brown-black. Wing length: 9-12 mm. Females may have forewings with broader apical margins and more orange powdering than males.

Distribution.—A Holarctic species; known in North America from Alaska south to Utah, and California. One California record: *El Dorado Co.*, Echo Lake, July 6, 1975.

Biology.—The larvae are bark borers in Betulaceae, recorded from *Betula* sp. (birches) in Europe, and from *Alnus* sp. (alders) in North America. In those areas on the infested tree where larval burrowing is heavy, the damage may be evident externally by the blistered appearance of the dead bark. Preferred trees are those with injuries and those in disturbed or exposed areas. The pupae protrude from the exit holes in the bark at emergence. Adults are most easily obtained by rearing but have been observed visiting flowers. Adults are active in May to July, with some records in Washington dated August.

***SYNANTHEDON EXITIOSA* (SAY)**

Peachtree Borer

(Plate IV; Figures 8, 28)

Aegeria exitiosa Say, 1823:216. Type-locality: Unknown. (lost).

Description.—Head: vertex brown-black, often with pale yellow on typical form; front brown-black; occipital fringe brown-

black laterally, variously pale yellow dorsally, more so on typical form; labial palpi thickened, somewhat roughened on males, smooth on females, brown-black, typical form male mostly pale yellow with brown-black dorsolaterally; antenna brown-black. Abdomen ventrally brown-black; males dorsally variable with narrow pale yellow banding on posterior margin of some or all segments, or banding absent (form "graefi" Hy. Edwards); typical females with segment 4, less commonly also segment 5, ringed solidly orange, "graefi" females completely brown-black. Wing length: 6-15 mm.

The predominant color form in the Pacific Coast states is "graefi." The typical color form "exitiosa" is found throughout eastern temperate North America into the Rocky Mountains, excluding most of the Great Plains. The form "graefi" also occurs commonly in the Rocky Mountains. The Z,Z-ODDA pheromone attracted several examples of both forms in and around Albuquerque, New Mexico, and a few examples of the eastern form in the Sacramento area of California, demonstrating that this form is present in the western population, though evidently in small proportion to "graefi."

Distribution.—United States and southern Canada, excluding most of Great Plains, Great Basin, and desert Southwest.

Biology.—Most of the following information is from Quaintance (1906), Moulton (1911), Gossard and King (1918), and Snapp and Thompson (1943). The peachtree borer is one of the most economically important species in Sesiidae, as a pest on *Prunus persica* Batsch (peach), but has also been recorded from *P. amygdalus* Batsch (almond), *P. armeniaca* L. (apricot), *P. cerasus* L. (sour cherry), *P. domestica* L. (European plum), *P. hortulana* Bailey (Hortulan plum), *P. persica* var. *nectarina* Maxim. (nectarine), *P. serrulata* Lindl. (Japanese flowering cherry), *P. virginiana* var. *demissa* (Nutt.) (chokecherry), and probably occurs in various uncultivated species of Rosaceae.

The larvae bore beneath the bark and cambium just below ground level or above, if infestation is very heavy. Large amounts of gummy frass may be extruded from the base of the infested tree. Trees of all ages are subject to attack by the borers. Young trees are often killed, older trees are weakened and become targets of attack for other insects and diseases. The partially grown larvae diapause in galleries during winter and resume feeding in the spring. At maturity larvae in the trunk below ground exit through the bark and tunnel to near the soil

surface, where they construct cocoons incorporating frass, bits of chewed bark and soil particles (Fig. 8). Larvae in the trunk above ground construct cocoons in the larval chamber just beneath the outer bark surface. The prepupal stage takes about three to seven days and about 17-35 days are required for the pupal stage. The mature pupa works free of the cocoon and wriggles to the soil surface or partially through the exit hole in the bark, when the adult emerges and crawls up the tree trunk or a nearby weed stem. Emergence usually takes place between 7:00 am and 2:00 pm. During this time period most males have been attracted to pheromone baits. Females tend to stay on or near their host tree and usually do not fly far to oviposit. Mating and initial ovipositioning usually occur on the same day as emergency. Eggs may be deposited on any part of the tree or on nearby plants or bare soil, but the majority are placed singly or in small groups on the lower six inches of the host trunk or on the soil adjacent to the tree. On the average one female will lay over 500 eggs. The eggs hatch at night or very early in the morning. Newly hatched larvae travel away from light and downward, either down to the base of the tree trunk, or if on the ground, into cracks in the soil and immediately attempt to find entrance into the bark layers. This is the most critical point in their life cycle, since at this stage they are particularly susceptible to desiccation.

Adult specimens have been taken as early as April and as late as October, with the most during mid-summer.

Holloway *et al.* (1977) presents a complete bibliography of the peachtree borer through 1975.

SYNANTHEDON MELLINIPENNIS (BOISDUVAL)

(Plate III; Figure 29)

Sesia mellinipennis Boisduval, 1836:pl. 14. Type-locality: Amerique septentrionale. (lost).

Description.—Head: vertex, front brown-black; occipital fringe yellow; labial palpi slightly thickened, not roughened, yellow; antenna brown-black, scape yellow. Abdomen dorsally with yellow banding of various widths on all segments except 3, which may have yellow powdering, banding widest on females; ventrally mostly yellow except toward base. Wings ventrally with orange powdering on margins and veins; female forewings more opaque, with orange powdering more extensive than on males. Wing length: 10-12 mm.

Figure 8. *Synanthedon exitiosa*: larva and cocoon exposed in young peach tree (from Quaintance, 1906).

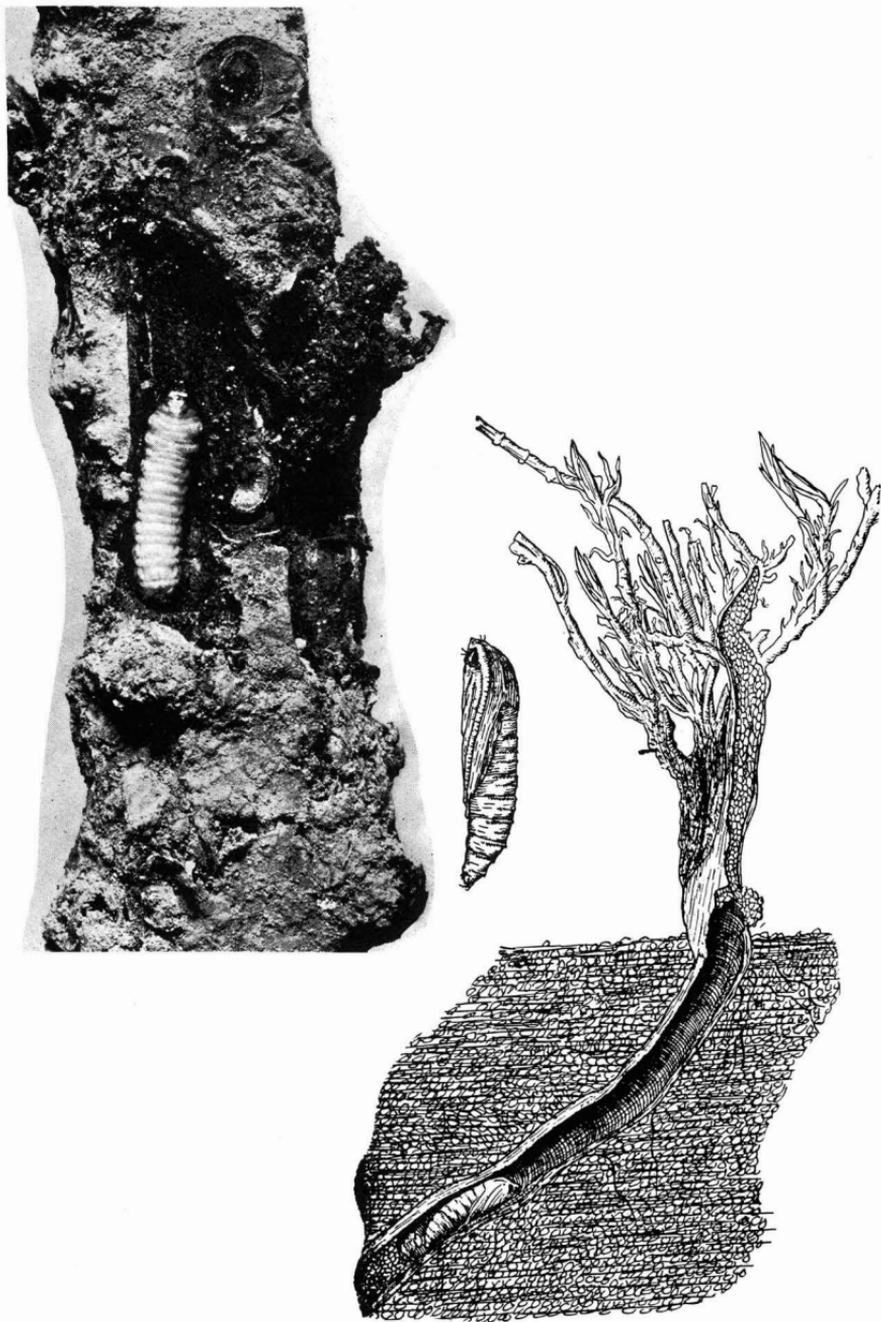


Figure 9. *Synanthedon polygona*: drawings of pupa and host plant, showing larval tunneling and pupal chamber (from Williams, 1909).

This species may be confused with *S. chrysidipennis*, which it somewhat resembles, but *S. mellinipennis* does not have the labial palpi roughened; wings with orange powdering, not orange-red; and male genitalia lacking bifurcate scales apically on crista sacculi.

Distribution.—Mountainous regions of California; one record from Robson, British Columbia, indicating a much broader range than is currently known.

Biology.—F. X. Williams (1909) reported having reared out a few specimens of *S. mellinipennis* from a large decumbent trunk of *Ceanothus thrysiflorus* (Rhamnaceae) in a canyon a few miles south of Carmel, Monterey County. He observed the larvae boring in the solid wood and found pupae in cocoons under the bark. The larvae are apparently likely to be found in the trunks of mature, weakened *Ceanothus* spp. Collection data indicate flight from mid-June through August. Though scattered records imply the species is widely distributed in California and probably northward to British Columbia, *S. mellinipennis* has not been frequently encountered.

***SYNANTHEDON NOVAROENSIS* (HENRY EDWARDS)**

Douglas Fir Pitch Moth

(Plate IV; Figure 30)

Aegeria novaroensis Henry Edwards, 1881:199. Type-locality: Navarro, Mendocino County, California. (Lectotype female, AMNH).

Description.—Head: vertex brown-black with orange anteriorly and at antennal base; front orange, some brown-black laterally; occipital fringe orange; labial palpi thickened, slightly roughened, orange, often with some brown-black lateroapically; antenna brown-black. Abdomen orange ventrally. Wing length: 10-12 mm.

Distribution.—Northern California to Alaska; west to Montana. California records: *Alpine Co.*, Bear Valley; *Mendocino Co.*, Navarro; *Placer Co.*, 2 mi. S. Tahoe City, Ward Creek, 6050 ft. elevation; *Shasta Co.* (no specific locality).

Biology.—The larvae bore in cambium and solid wood, primarily of spruces, but are also known to attack pines, particularly when associated with spruce. Recorded hosts include: *Picea engelmannii* (Engelmann spruce), *P. sitchensis* (Sitka spruce), *Pinus contorta* (shore pine), *P. monticola* (western white pine), *P. ponderosa* (western yellow pine), and *Pseudotsuga menziesii*

(Douglas fir). Engelhardt (1946) states that the life cycle is most likely two years, while Brunner (1915) maintains that three years are required. Thompson (1927) believed the life cycle to be much shorter than three years. The presence of larvae is indicated externally by resinous nodules or pitch tubes, which are small and soft initially, becoming larger and harder later. The nodules result from efforts of the host tree to seal off the tunneling larvae. Pupation occurs in silk-lined chambers in the pitch nodules, requiring about 30 days for maturation. The pupae work through the thin layer of pitch at the end of their burrows, and adults emerge from pupae which partially protrude from the nodules. Emergence takes place over a period from March to September, but mainly in June and July. Most adults have been obtained by rearing, since they have been very seldom observed in the field. Brunner writes that a female lays about 50 eggs, based upon his laboratory studies. Females fly up and down the trunk, depositing eggs singly in cracks and crevices or wounded areas of the tree. Trees 10 to 50 years old and those trees or portions of trees in shaded situations are apparently favored for attack.

***SYNANTHEDON POLYGONI* (HENRY EDWARDS)**

(Plate V; Figures 9, 31)

Pyrrhotaenia polygoni Henry Edwards, 1881:202. Type-locality: San Miguel, California. (Holotype female, AMNH).

Description.—Head: vertex blue-black, orange-red on “*praestans*” Hy. Edwards; front brown-black; occipital fringe blue-black, or with orange-red mixed, or orange-red; labial palpi roughened, orange-red, blue-black apically, often ventrally; antenna blue-black. Wing length: 7-12 mm, with “*praestans*” the largest of the forms.

This is one of the most polymorphic species of Sesiidae known. Some of the more extreme color forms are shown on Plate V. They vary greatly in the degree of opaqueness of the fore- and hindwings and in the amount of orange-red on the wings, abdomen and legs. Generally the form “*fragariae*” Hy. Edwards, with clear areas on the forewings, is found at higher elevations in the Sierras and Rockies, northward to Alaska. In the mountainous regions of Oregon and Washington, the form “*praestans*” predominates, a form which looks like a larger version of “*fragariae*.” The form “*animosa*” Hy. Edwards is mostly from south-

ern California, Arizona and northern Mexico. The other color forms and all gradations inbetween are found mostly at lower elevations in California and Arizona, including the coastal sand dunes. The typical form is much like "helianthi" Hy. Edwards shown on Plate V, but with less orange-red on the abdomen and more blue-black on the hindwings of the female of the former.

Distribution.—Chihuahua and northern Baja California, Mexico; north to Alaska.

Biology.—The habits of this species were first recorded by Williams (1909); one of his illustrations is reproduced here (Fig. 9). His observations near San Francisco were of *S. polygona* larvae boring in the roots of *Polygonum paronychia*. Most subsequent host records are of *Eriogonum* (wild buckwheat, Polygonaceae), including: *E. compositum*, *E. fasciculatum*, *E. gracile*, *E. inflatum*, *E. latifolia*, *sulphureum*, *E. parvifolium*, and *E. wrightii*. In addition, J.A. Powell, University of California, Berkeley reared two specimens from *Leptodactylon pungens halkii* (Polemoniaceae), collected by P. Opler. The larvae tunnel into the root and somewhat into the stem, the galleries often more than 75 mm long. Reddish fecal pellets are extruded at the base of the plant and fill the abandoned galleries. The last portion of the larval burrow, about 25-50 mm, serves as the pupal chamber, which is silk-lined and leads to a thinly covered exit above ground level. Adults are present as early as April and May in the coastal and southern portions of the range and June to August in the mountains and northern portions. They frequently visit flowers, not necessarily those of their host plants. Males have been attracted to the E,Z-ODDA pheromone isomer.

SYNANTHEDON RESPLENDENS (HENRY EDWARDS)

(Plate IV; Figures 10, 11, 32)

Albuna resplendens Henry Edwards, 1881:186. Type-locality: Soda Springs, Siskiyou County, California. (Lectotype female, AMNH).

Description.—Head: vertex brown-black, or mixed yellow anteriorly; front brown-black, or mixed yellow ventrally; occipital fringe yellow; labial palpi smooth, yellow; antenna brown-black. Abdomen ventrally yellow except segment 3 and medially on 2. Forewing ventrally yellow except discal spot and apical veins. Fringe toward base of hindwings yellow. Wing length: 8-12 mm.

This species resembles *S. bibionipennis* with which it is

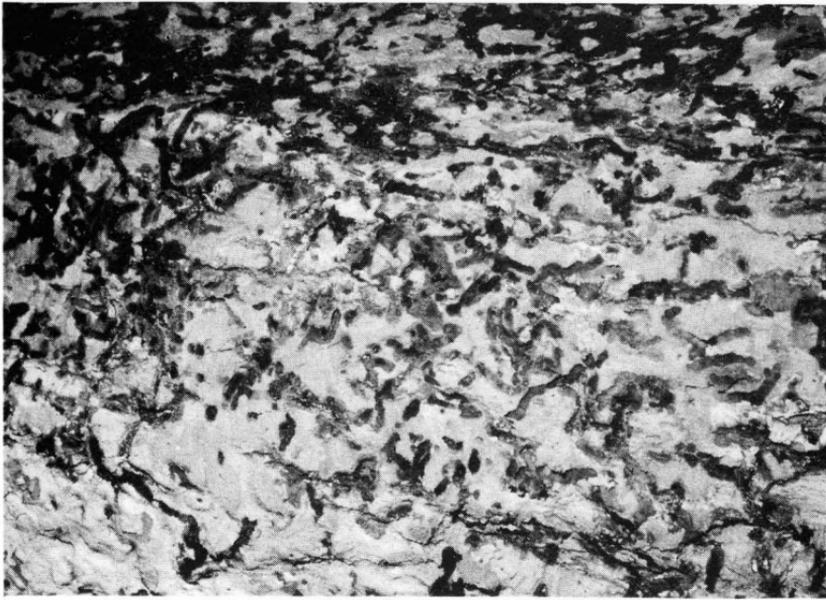


Figure 10. Meandering tunnels of larvae of *Synanthedon resplendens* under bark of sycamore (from Brown and Eads, 1965a & b).



Figure 11. Egg of *Synanthedon resplendens* on bark of host (from Brown and Eads, 1965a & b).

sympatric in California. As mentioned in the description of the latter, *S. resplendens* differs morphologically mainly in the genitalia and by the smooth labial palpi. The habits of each species are quite different.

Distribution.—California to Washington and western Idaho.

Biology.—Though not on the list of approved common names of the Entomological Society of America, *S. resplendens* is often referred to in literature as the Sycamore Borer, because *Platanus racemosa* (California sycamore, Platanaceae) is one of its preferred hosts. This moth also feeds on *Quercus agrifolia* (coast live oak, Fagaceae) and was reported by Ryan (1928) as attacking *Persea americana* (avocado, Lauraceae). Brown and Eads (1965a, 1965b) gave a good account of the biology of *S. resplendens*, and much of the information given below is from their publications. Larvae are bark borers, usually found in older and larger trees. Borer activity can be detected externally by the roughened appearance of the bark and buildup of frass around the base of the tree, but this is often not noticed until after several years of repeated infestation. The somewhat serpentine tunneling (Fig. 10) of any one larva covers an area of about 100 mm². Pupation occurs in the larval gallery in a cocoon, which incorporates frass and bits of chewed bark. The exit is covered by a thin layer of bark, which is broken through by the mature pupa at the time of emergence. The pupa partially protrudes from the surface of the bark, and the adult then emerges. Adults can be reared with comparative ease from sections of infested bark. The moths are found mostly in June and July, but some have been collected as early as April in southern California and as late as August in the mountains. Males have been attracted to a commercial preparation of the Z,Z isomer of ODDA, which contains trace amounts of other isomers. The adults confine most of their activities to the crown of the trees except for emergence and oviposition. The eggs are laid singly in crevices in the bark (Fig. 11). There is one generation per year.

SYNANTHEDON SAXIFRAGAE (HENRY EDWARDS)

(Plate V; Figure 33)

Aegeria saxifragae Henry Edwards, 1881:190. Type-locality: Colorado. (Holotype male, AMNH).

Description.—Head: vertex, front, antenna brown-black; occipital fringe brown-black, often with yellow laterally; labial

palpi roughened, orange with brown-black apically. Large patch of orange on thorax beneath wings. Abdomen ventrally blue-black. Forewings ventrally orange on costal margin, apical margin, veins and somewhat on discal spot. Both pairs of wings with orange basally. Wing length: 10-11 mm. Legs mostly orange.

Distribution.—Arctic-boreal, spotty records from Laborador to Alaska, south in the higher elevations of the Rocky Mountains to Colorado and in the Sierra Nevada of California.

Smith (1950) reported the first record of this species from California captured in flight by C.D. MacNeill (Oakland Museum) at China Flat, El Dorado County. J. Chemsak and J. Doyen (University of California, Berkeley) recorded another specimen (photograph on Plate V) at McBride Springs, Mt. Shasta, Siskiyou County. No other records came to our attention from California, and Thompson (1929) reported the only record from Oregon known to us.

Biology.—Even though *S. saxifragae* has a fairly broad distribution, records are scattered and nothing is known of its habits. All captures were made in June and July. According to Engelhardt (1946) saxifrage is definitely not the host plant.

***SYNANTHEDON SEQUOIAE* (HENRY EDWARDS)**

Sequoia Pitch Moth
(Plate V; Figure 34)

Bembecia sequoiae Henry Edwards, 1881:181. Type-locality: Mendocino County, California. (Lectotype male, AMNH).

Description.—Head: vertex brown-black mixed with yellow; front brown-black, pale yellow laterally; occipital fringe yellow; labial palpi roughened, yellow with brown-black laterally. Abdomen ventrally broadly banded yellow on all segments. Wing length: 10-14 mm.

This species superficially resembles *Sesia tibialis*, but *S. sequoiae* differs by having a well developed proboscis; genitalia typical of the Synanthedonini; males with antennae ciliate but not pectinate.

Distribution.—Coastal California from Monterey County, north to British Columbia; one record from Colorado.

Biology.—The life history is similar to that presented for *S. novaroensis*, but *S. sequoiae* is primarily a borer in pines and the former primarily in spruces. However, hosts are shared by both

species, and Engelhardt indicated that the two may occur together in the same tree. The known host species for *S. sequoiae* include: *Pinus contorta* (shore pine), *P. lambertiana* (sugar pine), *P. ponderosa* (western yellow pine), *P. muricata* (Bishop pine), and *P. radiata* (Monterey pine). Interestingly, to our knowledge, *Sequoia sempervirens* (D. Don) (redwood) has never been proven to be a host. Larval activity is mostly confined to the base of the tree, from which large amounts of pitch can exude. According to Brunner (1914) larvae in the cambium always tunnel nearly perpendicular to the grain of the wood. The life cycle requires two years for completion. Adults are found from May to August, with peak emergence occurring in June and July. Large numbers of *S. sequoiae* (around 900) were captured in traps baited with Z,Z-ODDA in Washington by R. L. Cambell, Washington State University, Puyallup. Also, some were attracted to the E,Z isomer and its alcohol; while Nielsen *et al.* (1975) reported a few specimens as having been attracted to two mixtures (100:1 and 1:1) of both Z,Z and E,Z isomers. Refer to the description of *S. novaroensis* for more details on the biology.

***SYNANTHEDON TIPULIFORMIS* (CLERCK)**

Currant Borer

(Plate VI; Figure 35)

Sphinx tipuliformis Clerck, 1759: Pl. 9. Type-locality: Unknown. (unknown).

Description.—Head: vertex brown-black; front brown-black, white laterally; occipital fringe yellow, some brown-black mixed dorsally; labial palpi smooth, yellow with broad brown-black band laterally; antenna brown-black. Abdomen ventrally brown-black. Forewings with yellow powdering on margins, between veins in apical area. Wing length: 7-9mm.

Distribution.—In Temperate regions of Europe, Asia, Australia, New Zealand and North America. California records: *Alameda Co.*, (no specific locality); *Sacramento Co.*, Sacramento; *Santa Cruz Co.*, (no specific locality).

Biology.—This species has been dispersed throughout the world wherever its host plants have been introduced, the original source being Europe. The recorded host plants include species of *Ribes* (currants and gooseberries, Saxifragaceae) and to a lesser extent certain species of *Rubus* (blackberries, Rosaceae). The larvae bore in the canes and branches, feeding in the pith. They

overwinter as nearly mature larvae in the canes a short distance above ground level. After feeding in the spring the mature larva cuts a small circular exit hole nearly through the bark and pupates in the larval chamber. At the time of emergence the mobile pupa works its way partially out of the exit hole. The female moth deposits 20 to 60 eggs on young wood near the buds (Duckworth and Eichlin, 1974). Adults are active from late April to July in North America.

CARMENTA HENRY EDWARDS

Male genitalia: with posterior end of crista sacculi sharply downcurved to ventral margin of valva; saccus more than one-third length of valva; bend of tegumen-uncus complex at approximately right angle. Female genitalia: with ductus bursae sclerotized on at least posterior one-half of its length; ductus seminalis arises midway between ostium bursae and corpus bursae or nearer the latter for most species.

CARMENTA VERECUNDA (HENRY EDWARDS)

(Plate VI; Figure 36)

Aegeria verecunda Henry Edwards, 1881:190. Type-locality: Colorado. (Lectotype female, MSU).

Description.—Head: vertex roughened, brown-black, often mixed with elongate, straw colored or white setaceous scales especially posteriorly; front white, often straw colored medially; occipital fringe straw colored dorsally, white laterally; labial palpi roughened, white with brown-black laterally, apically; antenna brown-black, often with pale yellow apically. Abdomen ventrally mostly white. Forewings ventrally mostly white. Wing length: 5-9 mm.

Some fresh specimens may have thorax and basal segments of abdomen overlaid with long, silky, blue-white scales. The color form "nigra" Beutenmuller has the wings opaque and brown-black, lacking most or all of typical white scaling. The females generally have less white on wings and legs, wings more opaque, and labial palpi thickened but not as roughened as on the males.

Distribution.—Manitoba to Washington; south to Oklahoma, western Texas; in Rocky Mountains to Arizona; in high elevations to Sierra Nevada of California.

Biology.—Several specimens of this species have been reared in Washington from roots of *Lithospermum ruderale* (Boraginaceae). Munz (1963) notes about this plant, "Dry slopes and plains, 4500-6000 ft.; Sagebrush Scrub, Northern Juniper Woodland; Placer Co. to Modoc Co.; to B.C., Rocky Mts. May-June." No California species of *Lithospermum* are listed as occurring above 1850 m elevation, yet most records of *C. verecunda* in the State are from above 2750 m. Preferred hosts in California are probably some other boraginaceous species from high elevations and another host species in the eastern portions of the range. The life history specifics are as yet undocumented. It is probably similar in habits to other synanthedonine root borers in perennial root stock of herbaceous plants. Adults have been taken from June to mid-August. One male was captured by Powell in Utah, 1030 MDT, attracted to Z,Z-ODDA, July 28, 1977.

PENSTEMONIA ENGELHARDT

Penstemonia is similar to *Carmenta* but differs mainly by the rudimentary proboscis condition of *Penstemonia*. The genitalia are too similar to be useful in differentiating the species; therefore, differences in color patterns must be used, and positive identification can sometimes be difficult.

A KEY TO ADULTS OF CALIFORNIA *PENSTEMONIA* SPECIES

1. Male — antenna ciliate ventrally 2
 Female — antenna not ciliate ventrally 4
2. Anal tuft with lateral portion elongate, extending well beyond tip of abdomen *P. dammersi*
 Anal tuft without elongate lateral portions 3
3. Abdominal segment 6 dorsally brown-black *P. hennei*
 Abdominal segment 6 dorsally banded yellow to nearly white *P. clarkei*
4. Abdominal segment 5 dorsally brown-black *P. clarkei*
 Abdominal segment 5 dorsally banded yellow 5
5. Head with front gray or gray-black, occasionally with some yellow ventrally; forewing powdered orange medially and apically *P. dammersi*
 Head with front yellow; forewing powdered yellow medially and apically *P. hennei*

PENSTEMONIA CLARKEI ENGELHARDT

(Plate VII; Figure 37)

Penstemonia clarkei Engelhardt, 1946:18. Type-locality: The Dalles, Oregon. (Holotype male, NMNH).

Description.—Head: vertex brown-black; front brown-black, some pale yellow mixed, occipital fringe yellow; labial palpi roughened, mostly yellow, some white basally, some brown-black apically; antenna brown-black. Abdomen ventrally with all but segment 3 mostly or entirely yellow, occasionally some yellow on 3. Forewing ventrally yellow except discal spot, anal margin. Wing length: 5-10 mm. Females have forewings generally more completely opaque than males; front entirely pale yellow, and vertex mixed with yellow-orange.

Specimens from high elevations in the Sierras typically have more extensive hyaline areas on the forewings, and the yellow scaling is much more pale to nearly white (see male, Plate VII). Henne reared a series from the New York Mountains, about 1677 m elevation in the eastern Mojave Desert, which is apparently a form of *P. clarkei*. This form has males like those from high elevations in the Sierras, but the females differ from the typical form by having nearly or entirely opaque fore- and hindwings with no lighter powdering. The absence of yellow banding on abdominal segment 5 will separate females of *P. clarkei* from females of the other two known species of California *Penstemonia*.

Distribution.—Montana and Idaho to California.

Biology.—All known species of *Penstemonia* are root borers in various *Penstemon* (beard-tongue, Scrophulariaceae). To date, *P. clarkei* has been reared only from *Penstemon richardsonii* in Oregon and *P. palmeri* from Keystone Canyon, New York Mountains, San Bernardino County. Recently, near Lewiston, Trinity County a three-fourths acre of the noxious introduced weed *Linaria dalmatica* (dalmatian toad flax) was found to be heavily infested with *P. clarkei*. This scrophulariaceous plant is native to the eastern Mediterranean region.

The larvae bore in the roots, tunneling into the stems prior to pupation. A thinly covered circular exit hole is prepared in the stem at the top of the burrow. Before pupating the larvae construct firm, oval, silk-lined cocoons of frass and wood chips. According to Engelhardt (1946) cocoon construction is unique to this species in *Penstemonia*. Adults have been captured from May through August, the earlier records from lower elevations

and the southern portions of the range, and the later records from higher elevations and northern portions of the range. Several males have been captured coming to Z,Z-ODDA, and several others were taken in traps baited with E,Z-ODDA. Evidently, both isomers of the pheromone are part of the overall pheromonal system of this species.

PENSTEMONIA DAMMERSI ENGELHARDT

(Plate VII; Figure 38)

Penstemonia dammersi Engelhardt, 1946:19. Type-locality: Mt. Wilson, California. (Holotype male, NMNH).

Description.—Head: vertex brown-black; front brown-black, some pale yellow lateroventrally; occipital fringe yellow; labial palpi thickened, relatively smooth, yellow; antenna brown, strongly overlaid with tan on form "brevifolia" Engelhardt. The typical form differs by having all but segment 3 of the abdomen with at least some yellow banding, and the forewings have more extensive hyaline areas, particularly on the males.

The elongate lateral extensions of the anal tuft readily distinguish male *P. dammersi* from males of other species of *Penstemonia*. On the male genitalia the crista gnathi is comparatively larger than on other *Penstemonia*. The female genitalia are unique for the genus by the presence of a signum on the corpus bursae, an irregularly shaped, granulose, pigmented spot.

Distribution.—Southern California in foothills and mountains.

Biology.—This species is a borer in the roots and lower stems of various *Penstemon* growing on dry slopes and canyons below 1850 m elevation. Adults have been reared mostly by Henne, Dammers or Engelhardt from the following species: *P. breviflorus*, *P. cordifolius*, *P. spectabilis*, and *P. ternatus*. Unlike *Penstemonia clarkei*, *P. dammersi* larvae do not pupate in a cocoon but are free to move up and down in the burrow, which may extend several centimeters up into the stem. The adults emerge in August and September. Engelhardt (1946) states that the life cycle probably requires two years to complete, but he was unable to verify this. Typically, adults of *Penstemonia* species are very rarely encountered in the field, since they are apparently unable to take nectar from flowers because of the reduced condition of the proboscis; therefore, they are not found visiting flowers.

Many of the numerous other *Penstemon* occurring in California

and elsewhere need to be investigated as possible hosts, more rearing attempted, and the biologies studied for all *Penstemonia* before a clear understanding of the taxonomy of this group can be obtained. The use of isomeric combinations of the sex pheromones as a survey tool should prove helpful in pinpointing local populations, in providing more data on distributions of species, and perhaps shed some light on pheromone systems as a species isolating mechanism.

***PENSTEMONIA HENNEI* ENGELHARDT**

(Plate VII; Figure 39)

Penstemonia hennei Engelhardt, 1946:16. Type-locality: Mill Creek, San Bernardino County, California. (Holotype male, NMNH).

Description.—Head: vertex brown-black; front brown-black on males, yellow on females; occipital fringe yellow mixed with brown-black dorsally, white laterally; labial palpi somewhat roughened, white with brown-black apically on males, smooth, yellow on females; antenna brown-black. Abdomen ventrally mostly white except for segments 3, 7 on males, yellow except for segment 3 on females. Forewing of females nearly or entirely opaque, yellow in areas normally hyaline on males. Wing length: 7-12 mm.

Males of *P. hennei* can be separated from males of other *Penstemonia* species by the white on the labial palpi, forecoxae and certain portions of other leg segments, and the pale banding on abdominal segments 4 and 7 only, or occasionally narrowly banded also on posterior edge of 2. The females resemble females of *P. dammersi*, but the head of *P. hennei* has the front yellow, not brown.

Distribution.—Southern Coastal California generally, to western Riverside and San Bernardino Counties.

Biology.—Adults have been reared from *Penstemon parishii* and *P. spectabilis*. The larvae bore in the crown roots and lower stems. Plants infested with the borers can be detected by an accumulation of pale frass at the base of the plants. Pupation takes place in the larval gallery without the formation of a cocoon. The pupa can move freely to the thinly covered, circular, exit hole in the stem at the time of emergence. There is apparently one generation per year. Most adults specimens have been obtained through rearing from *Penstemon spectabilis*, but several specimens were captured in traps baited with Z,Z-ODDA.

ALCATHOE HENRY EDWARDS

Alcathoe is unique in that the males of the various species have a long, slender, flexible, scaled process, which extends posteriorly from the dorsomedial posterior end of the eighth abdominal segment.

ALCATHOE VERRUGO (DRUCE)

(Plate VI; Figure 40)

Sannina verruga Druce, 1884:34. Type-locality: Esperanza (Sonora), Mexico. (Holotype female, BMNH).

Description.—Head: vertex, front, occipital fringe, labial palpi, antenna brown-black to blue-black. Wings totally opaque. Wing length: 8-15 mm.

The color form "corvinus" Engelhardt applies to those individuals which are entirely brown-black to blue-black. From any one rearing lot, one can expect to get adults of both color forms and a few specimens showing intermediate color patterns.

Distribution.—Sonora, Mexico, north to southern coastal California.

Biology.—The larvae bore in the roots and main stems of *Clematis ligusticifolia* mostly near the ground. The host's range is much more extensive than the borer's distribution, according to present records. Pupation takes place in the swollen portions of the stems. Adults emerge in July, but we have records in June and September.

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ILLUSTRATIONS

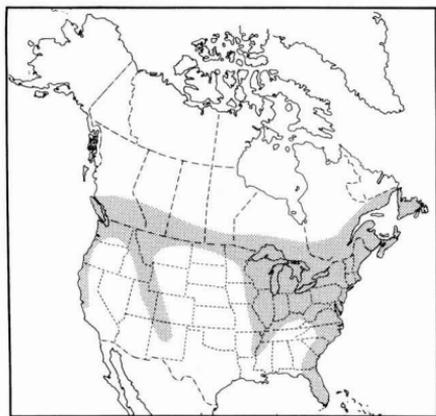
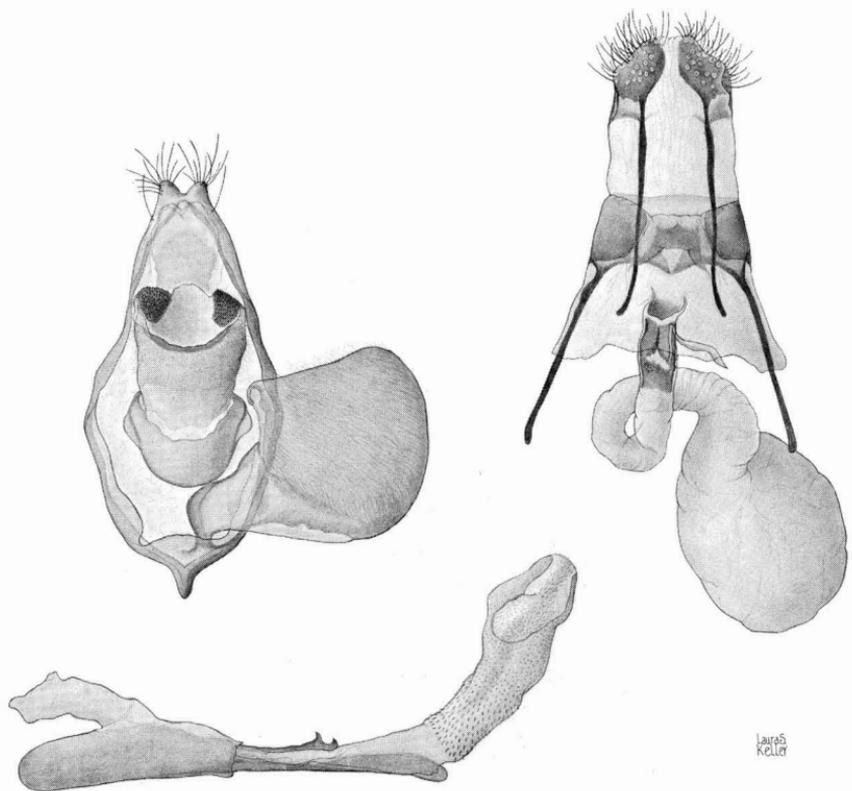


Figure 12. *Pennisetia marginata*.

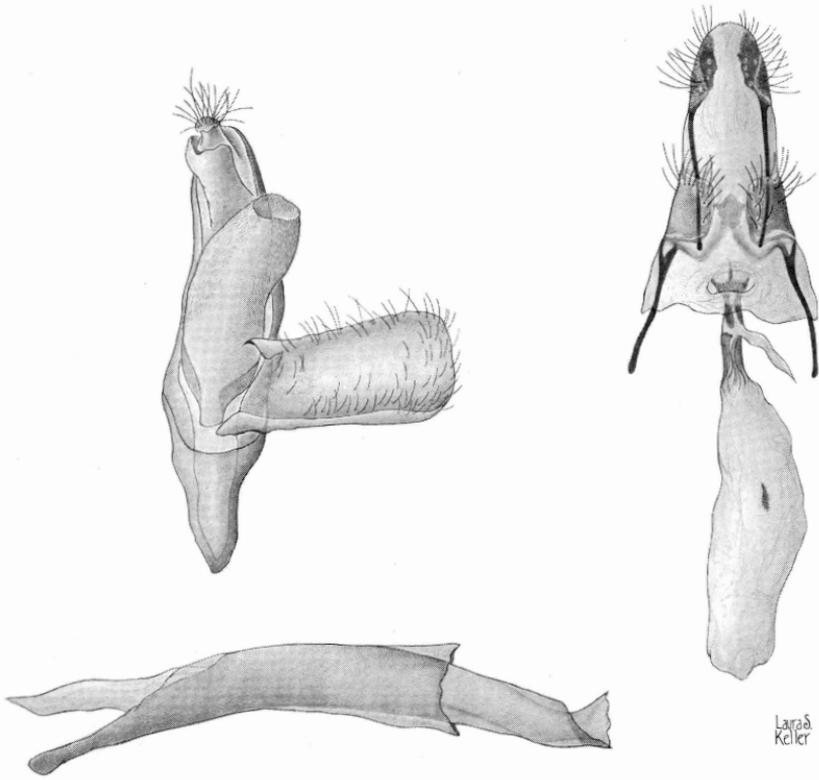


Figure 13. *Zenodoxus heucherae*.

Figure 14. *Zenodoxus canescens*.

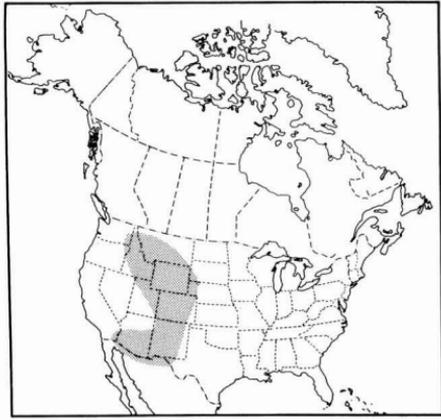


Figure 15. *Zenodoxus palmii*.

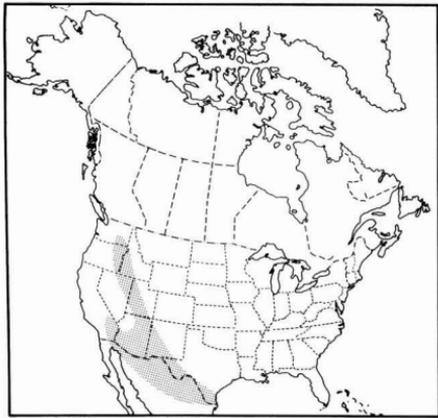
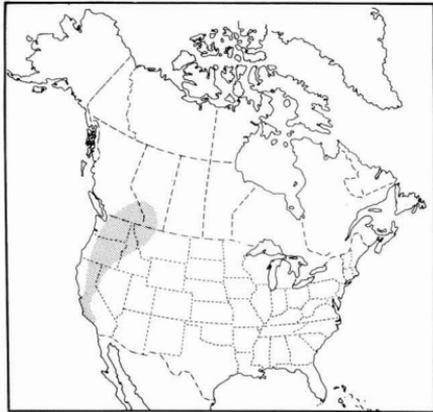


Figure 16. *Zenodoxus sidalceae*.



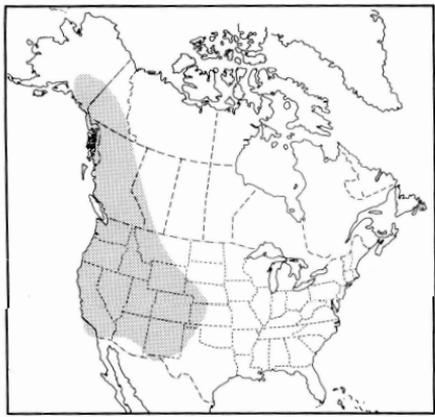
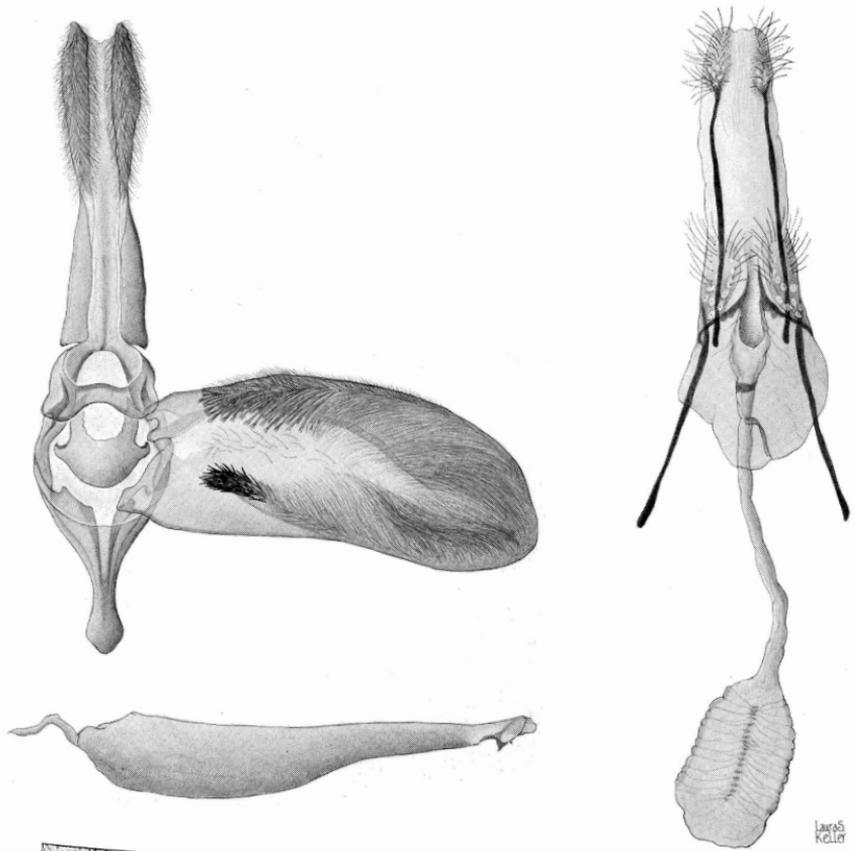


Figure 17. *Paranthrene robiniae*.

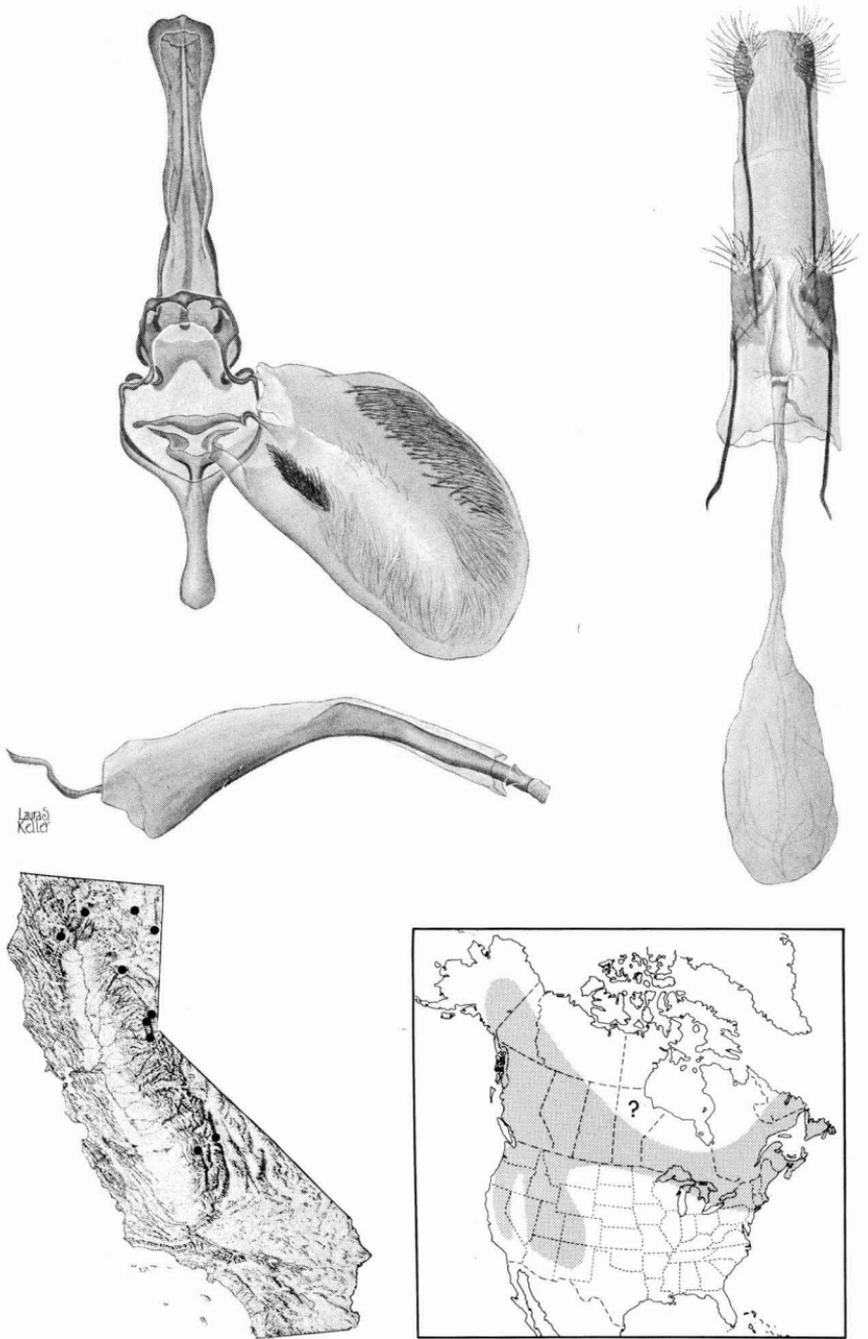


Figure 18. *Albuna pyramidalis*.

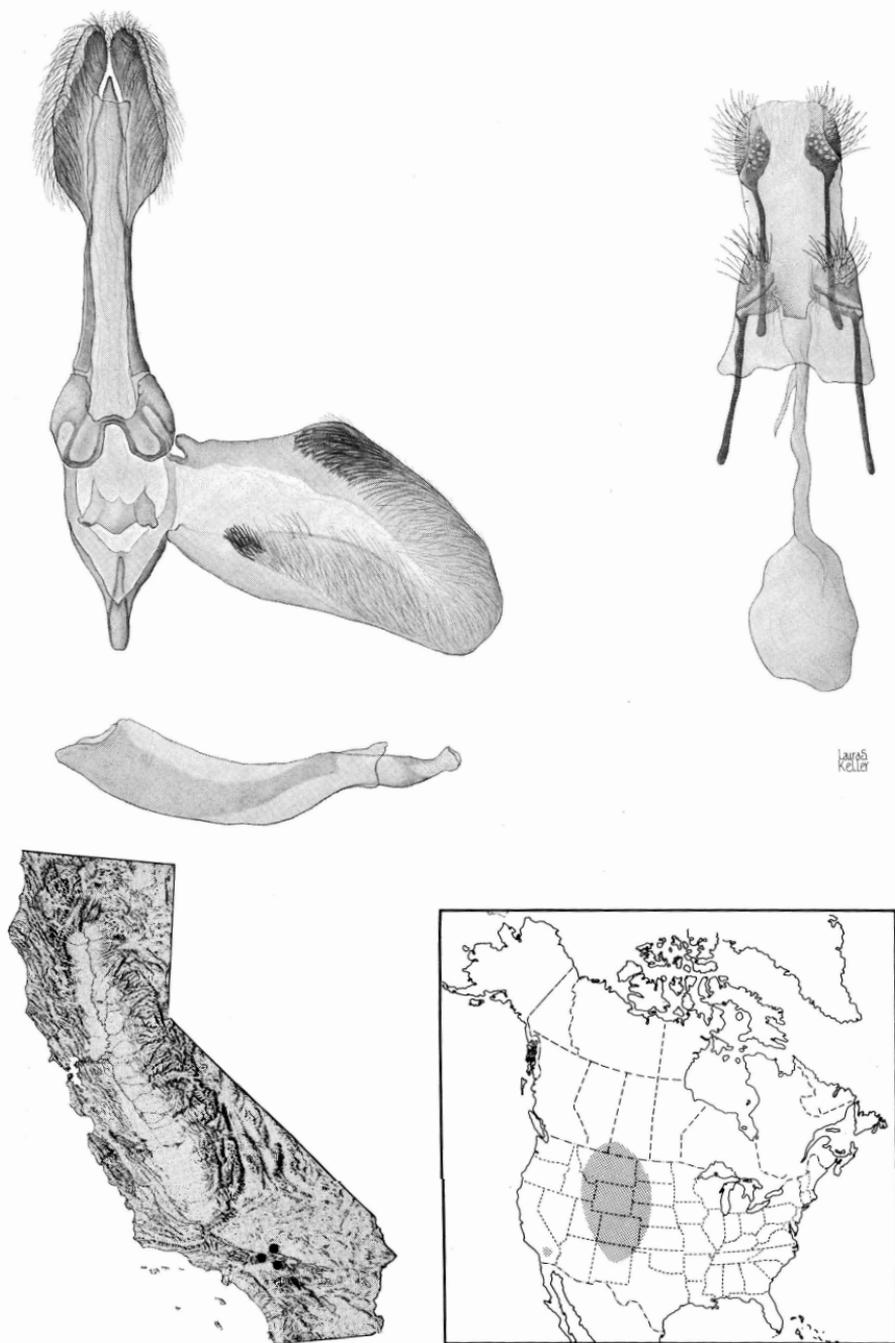


Figure 19. *Euhagena nebraskae*.

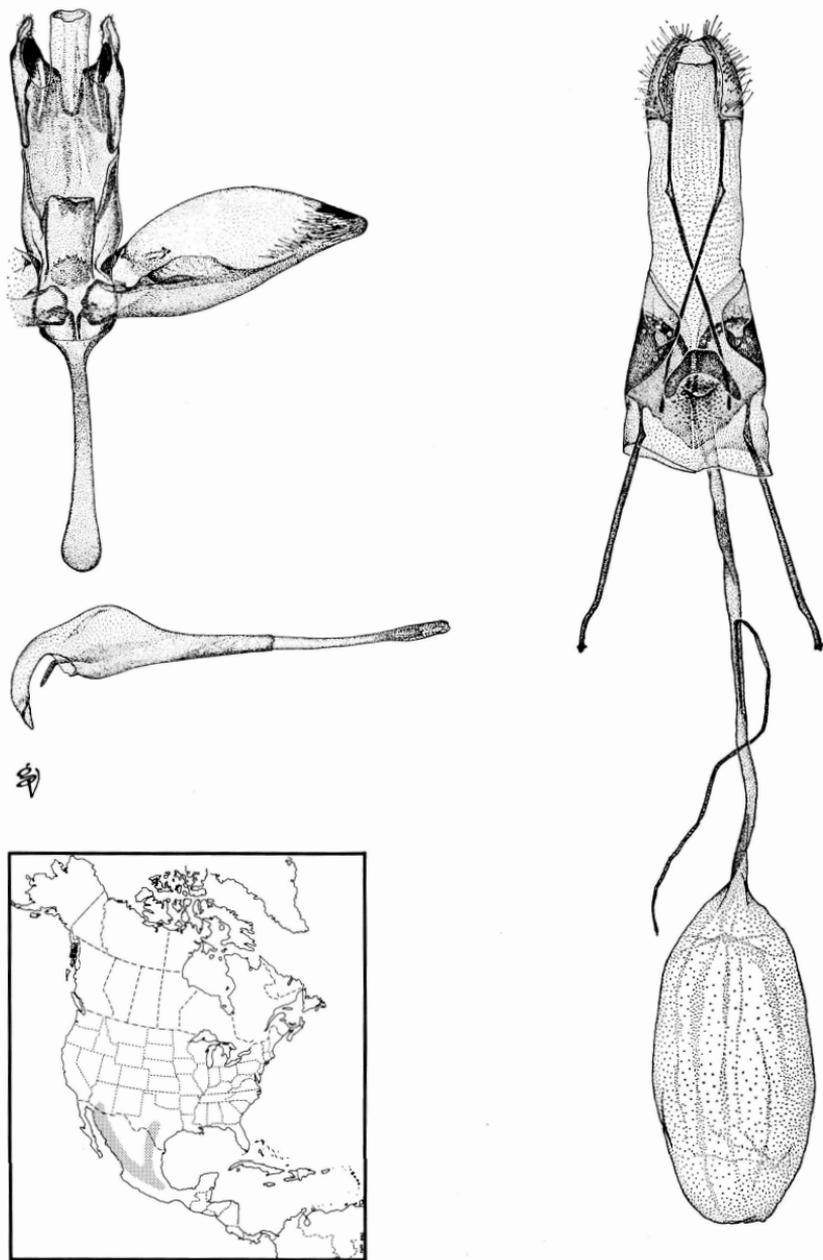
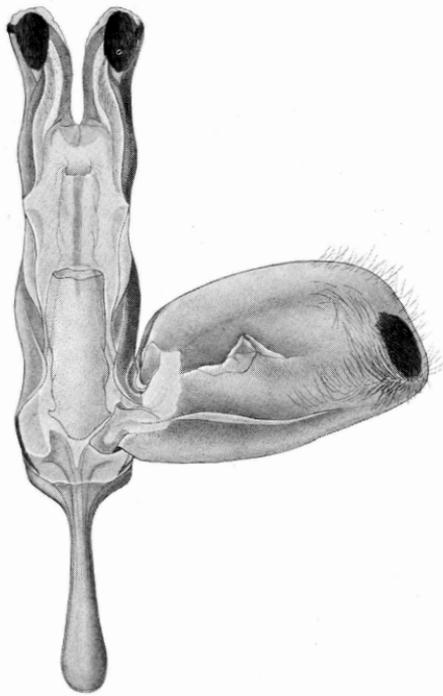


Figure 20. *Melittia calabaza* (from Duckworth and Eichlin, 1973).



Larva
Keller

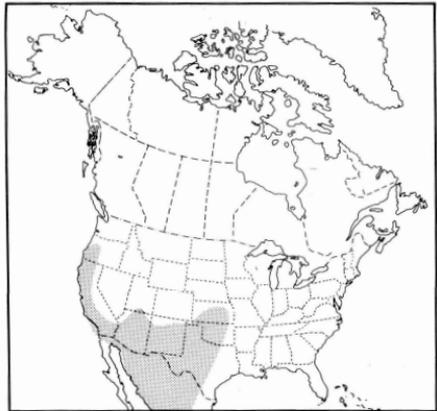
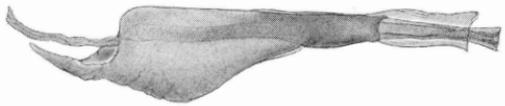


Figure 21. *Melittia gloriosa*.

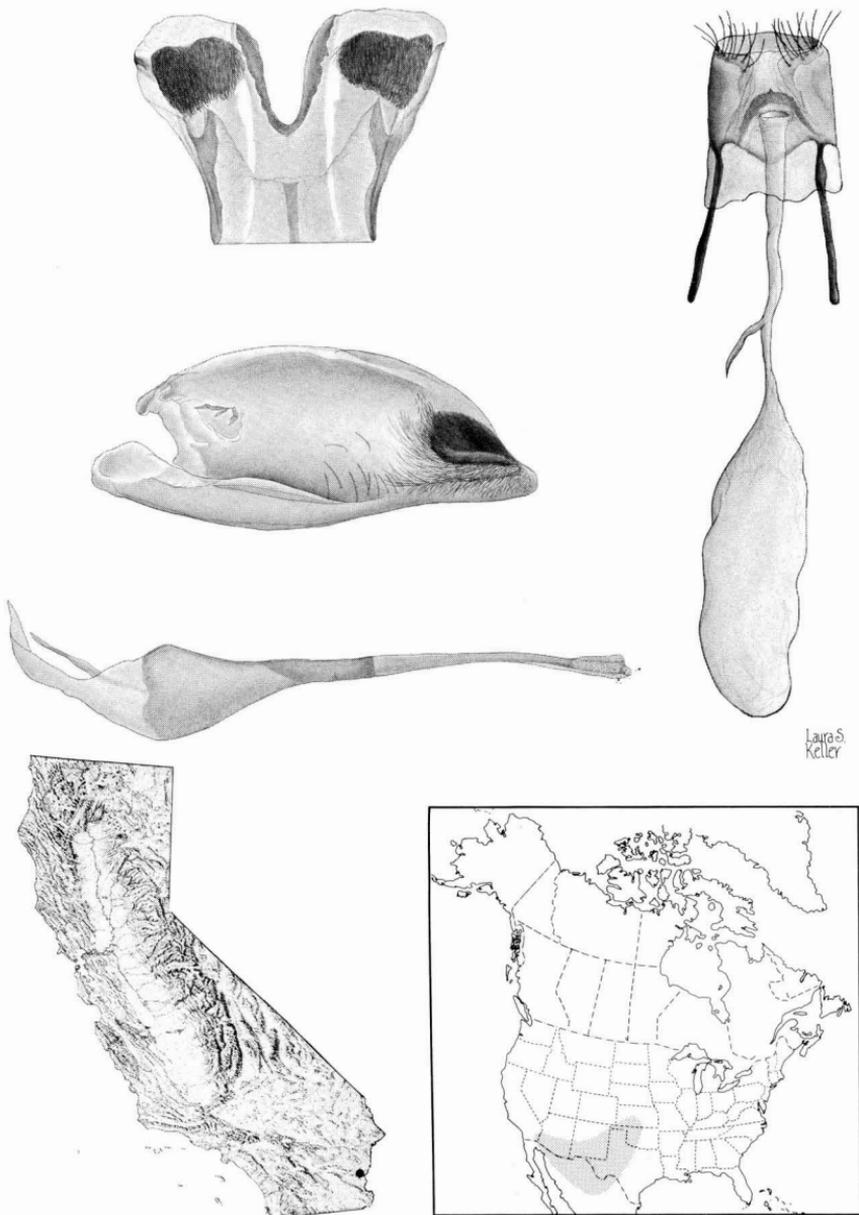
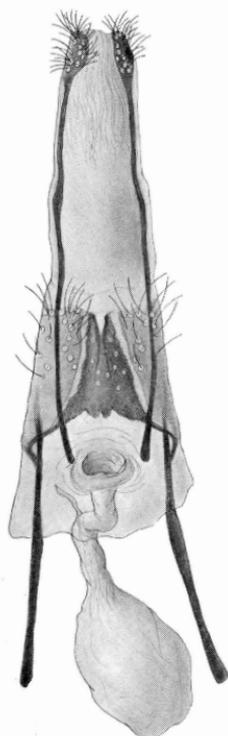
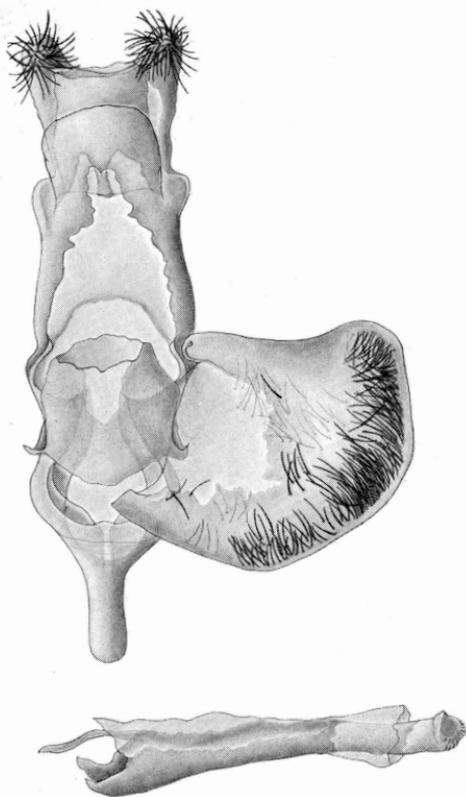


Figure 22. *Melittia grandis*.



Larva &
Pupa
Keller

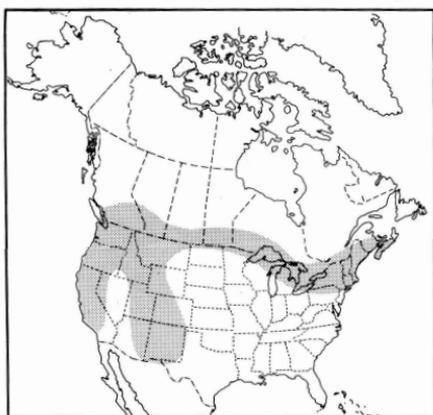
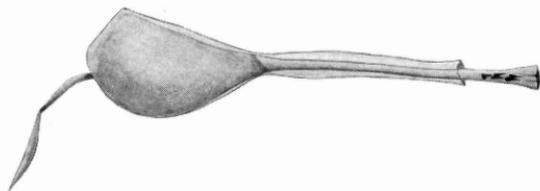
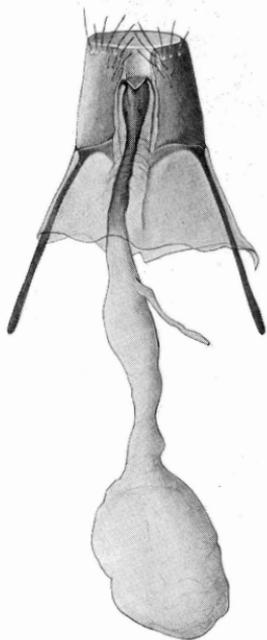
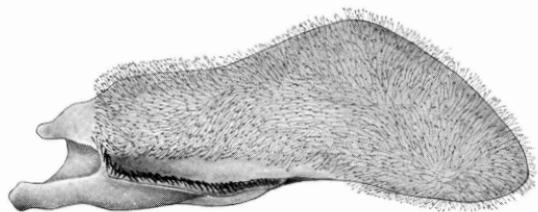


Figure 23. *Sesia tibialis*.



Laura S.
Keller

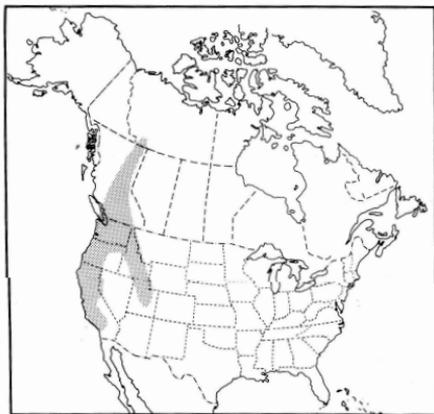


Figure 24. *Synanthedon albicornis*.

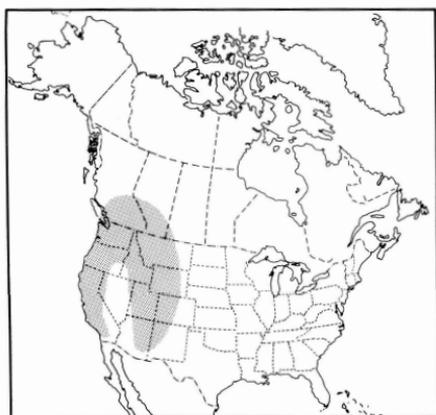
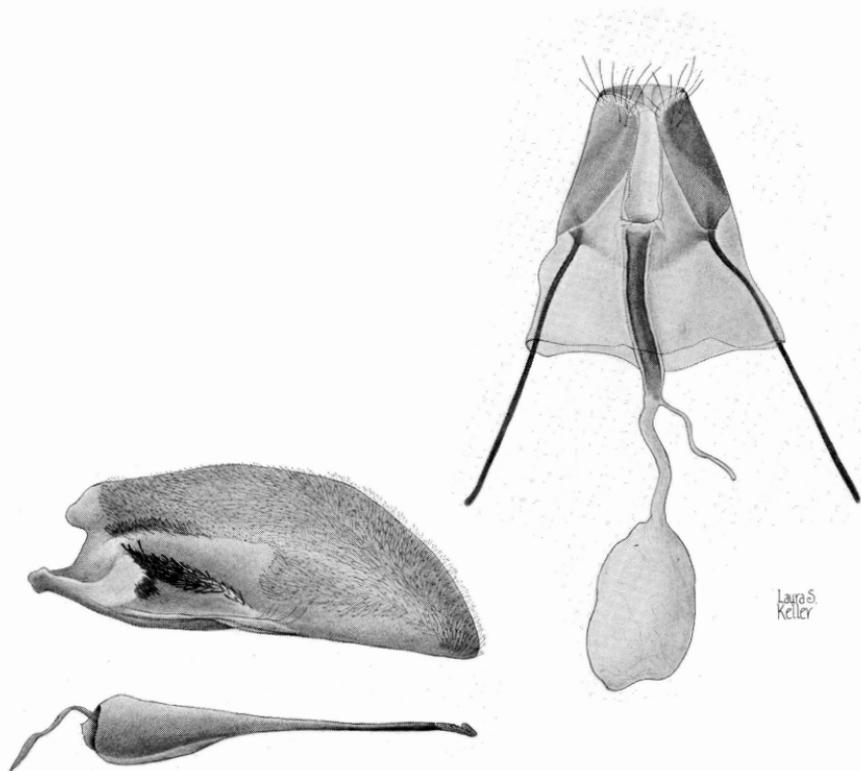


Figure 25. *Synanthedon bibionipennis*.

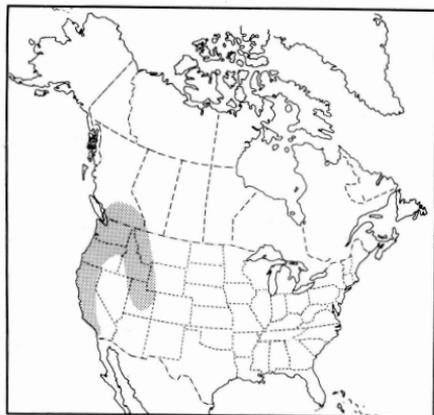
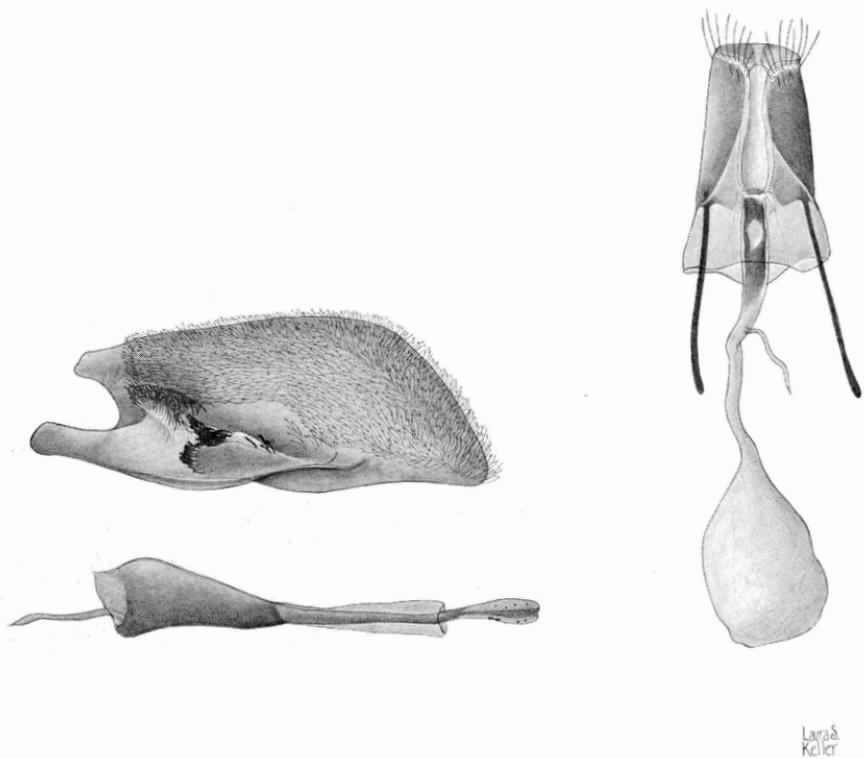


Figure 26. *Synanthedon chrysidipennis*.

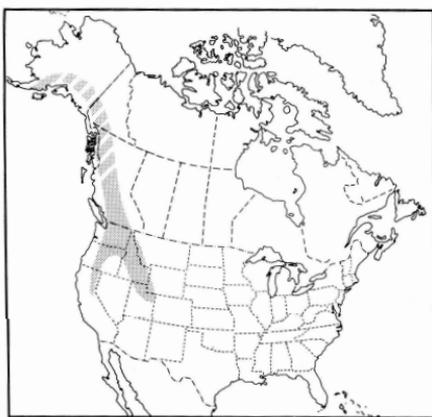
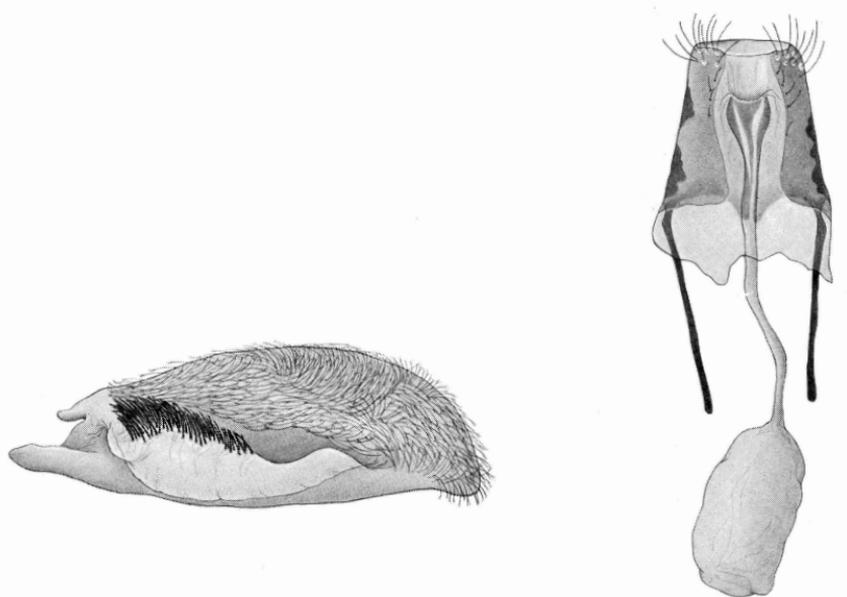


Figure 27. *Synanthedon culiciformis*.

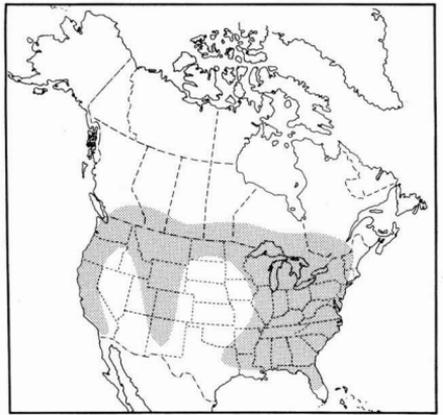
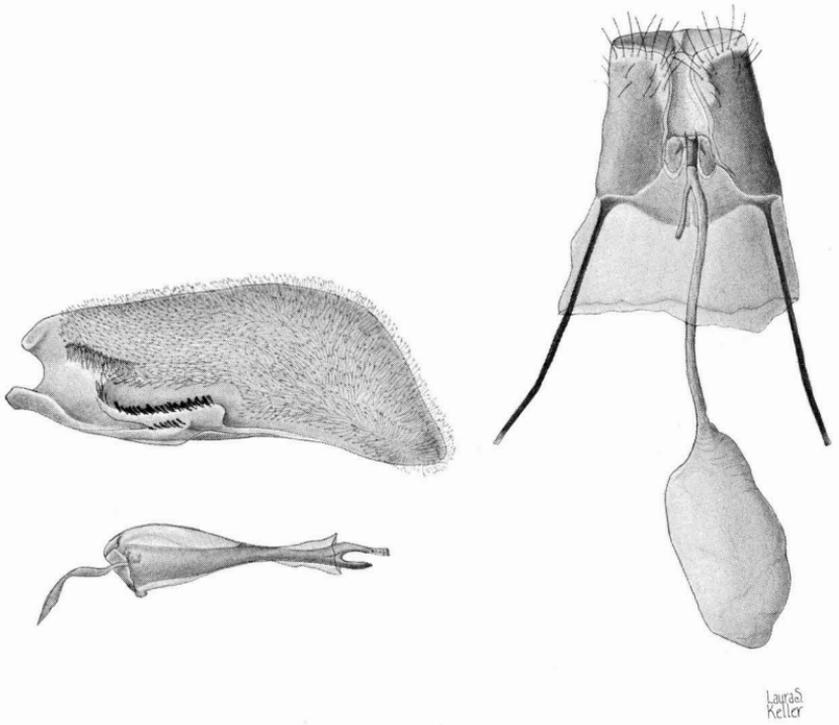


Figure 28. *Synanthedon exitiosa*.

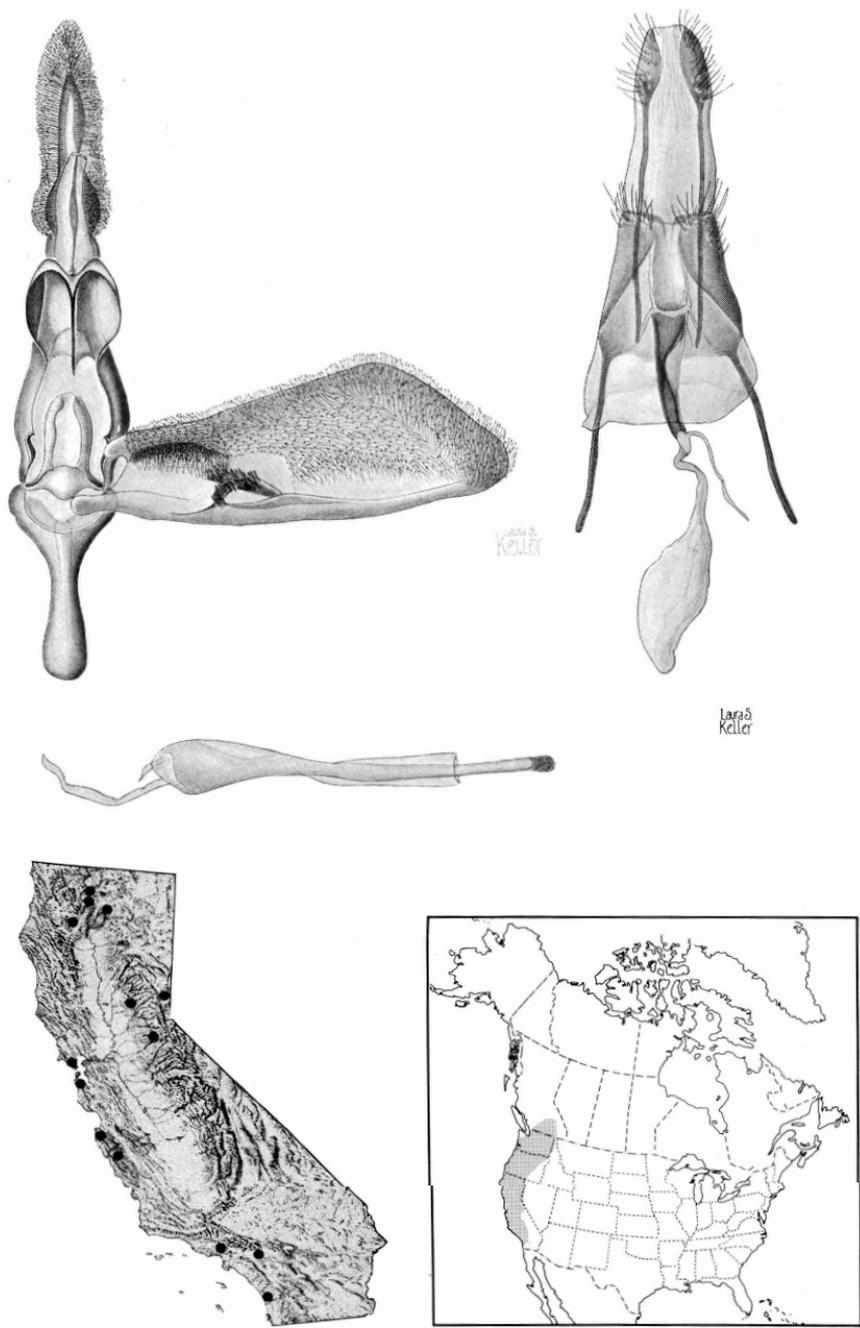
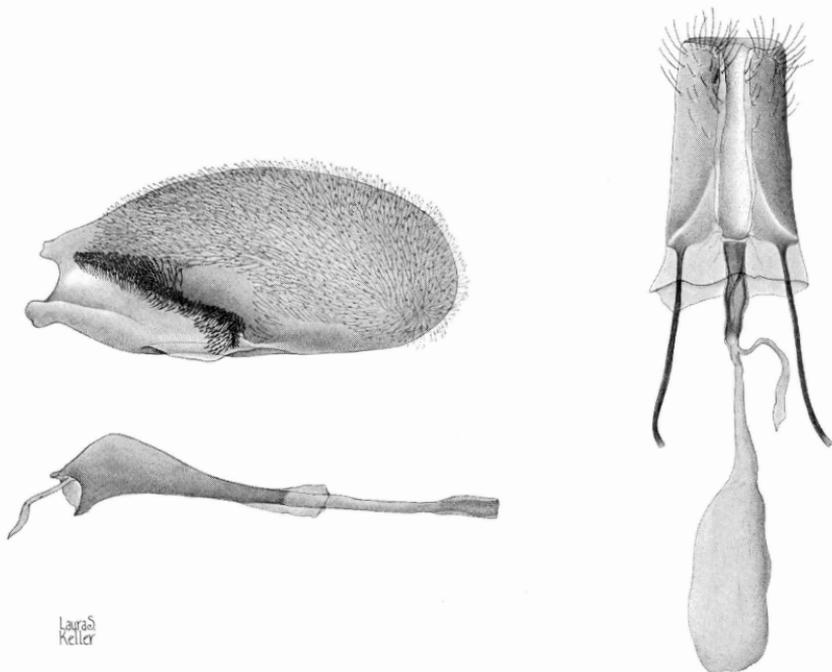


Figure 29. *Synanthedon mellinipennis*.



Laura S.
Keller

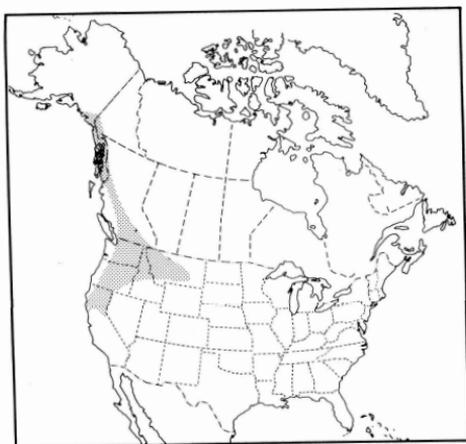
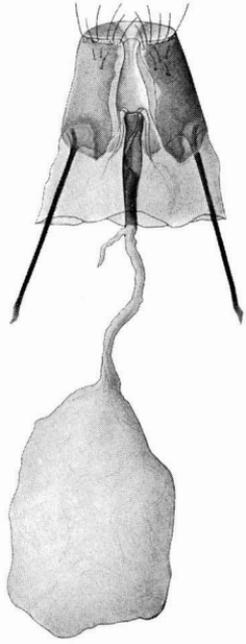
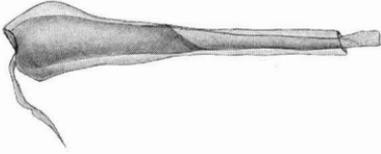
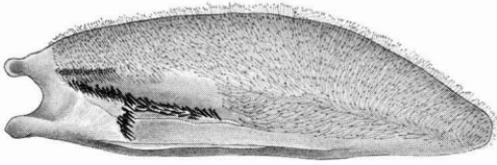


Figure 30. *Synanthedon novoensis*.



Laura S.
Keller

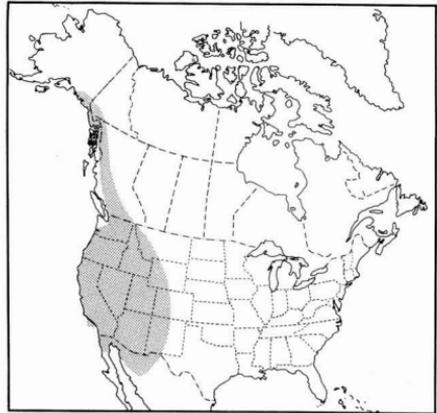
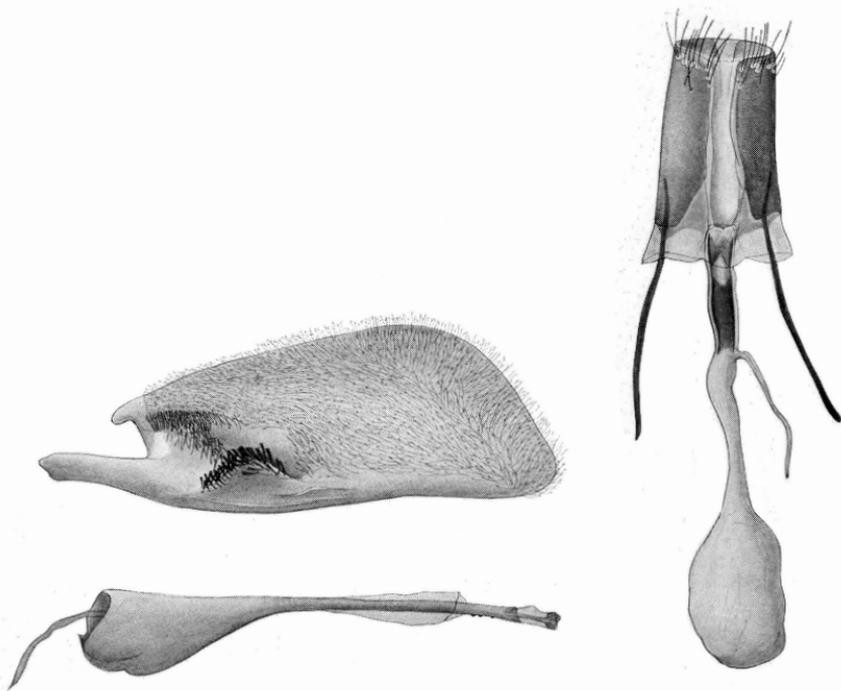


Figure 31. *Synanthedon polygoni*.



Larva
Kollar



Figure 32. *Synanthedon resplendens*.

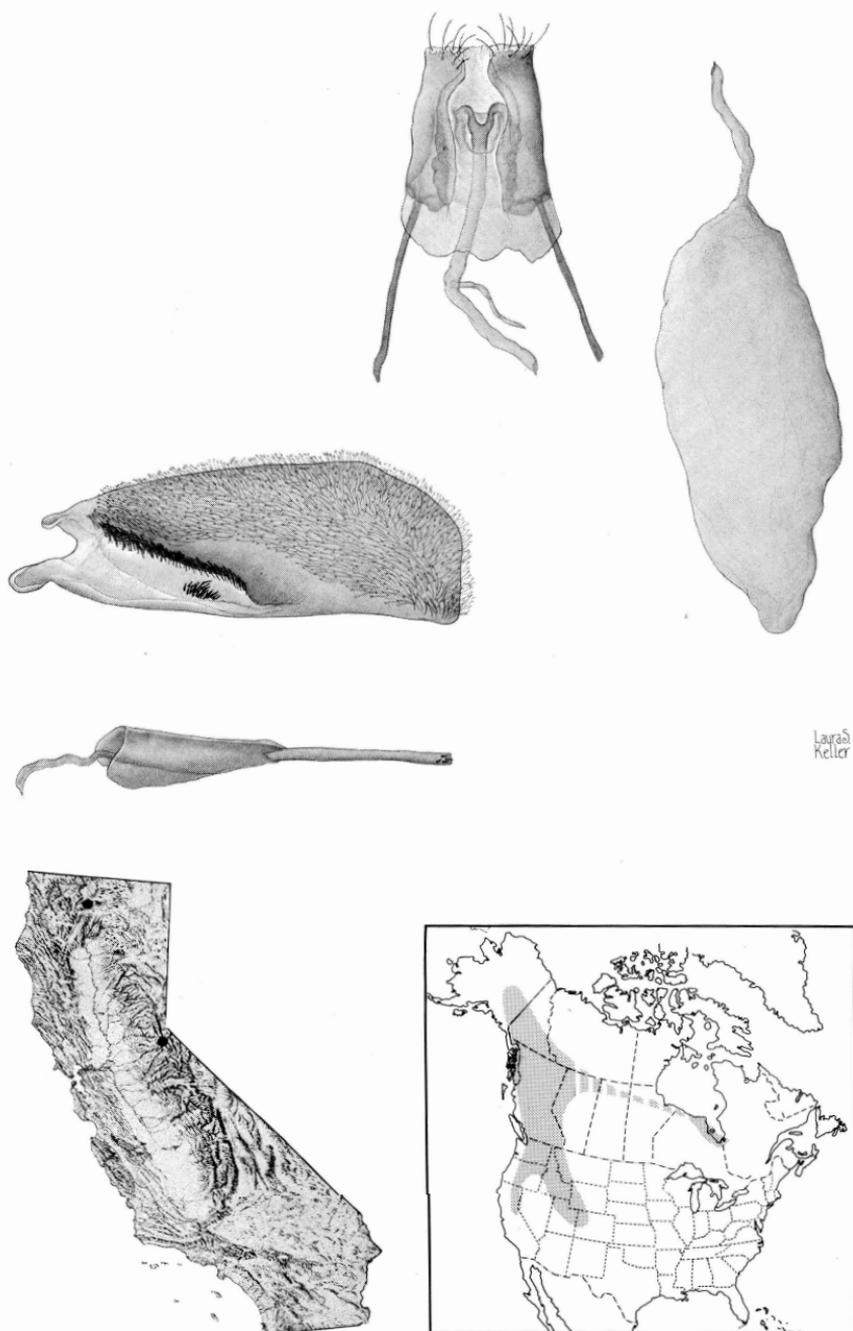


Figure 33. *Synanthedon saxifragae*.

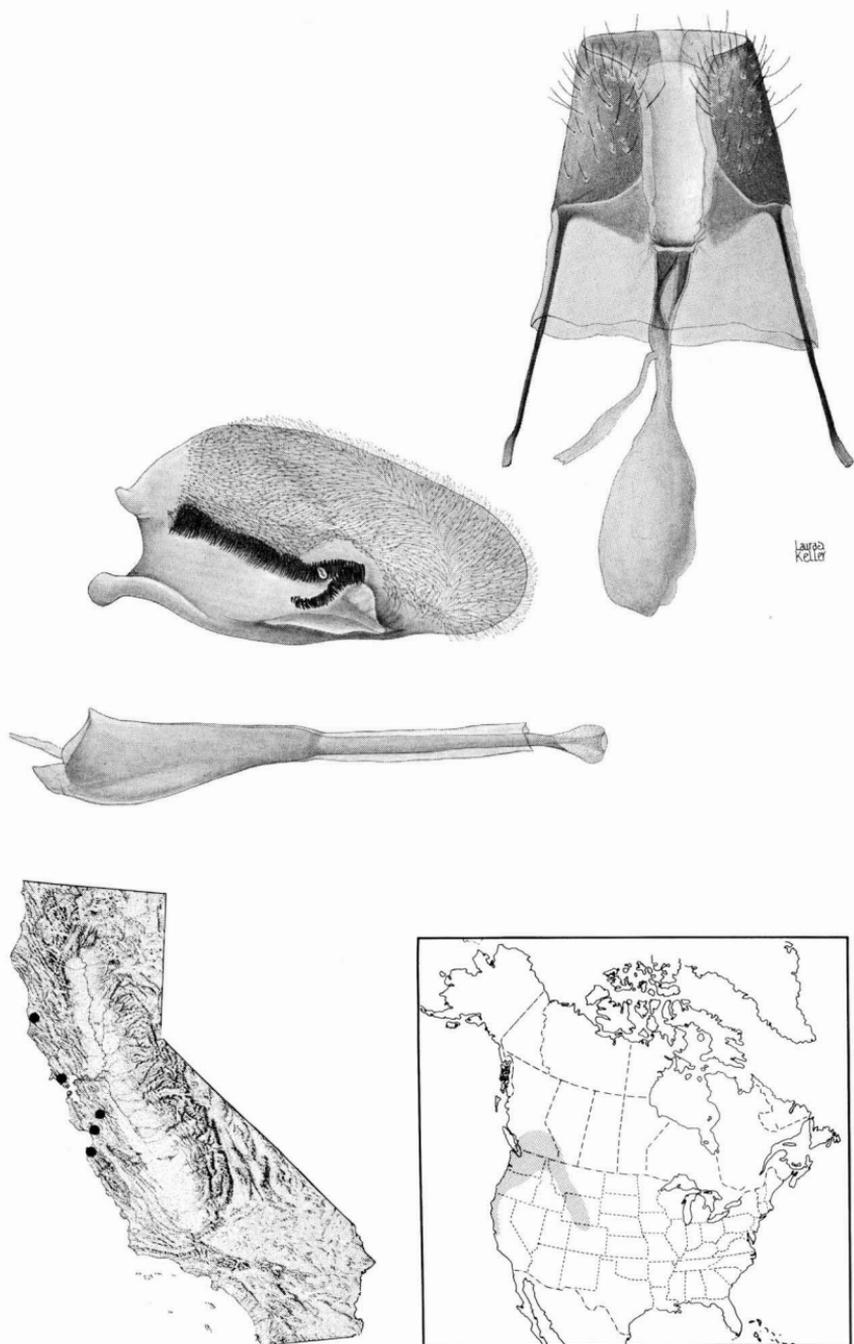


Figure 34. *Synanthedon sequoiae*.

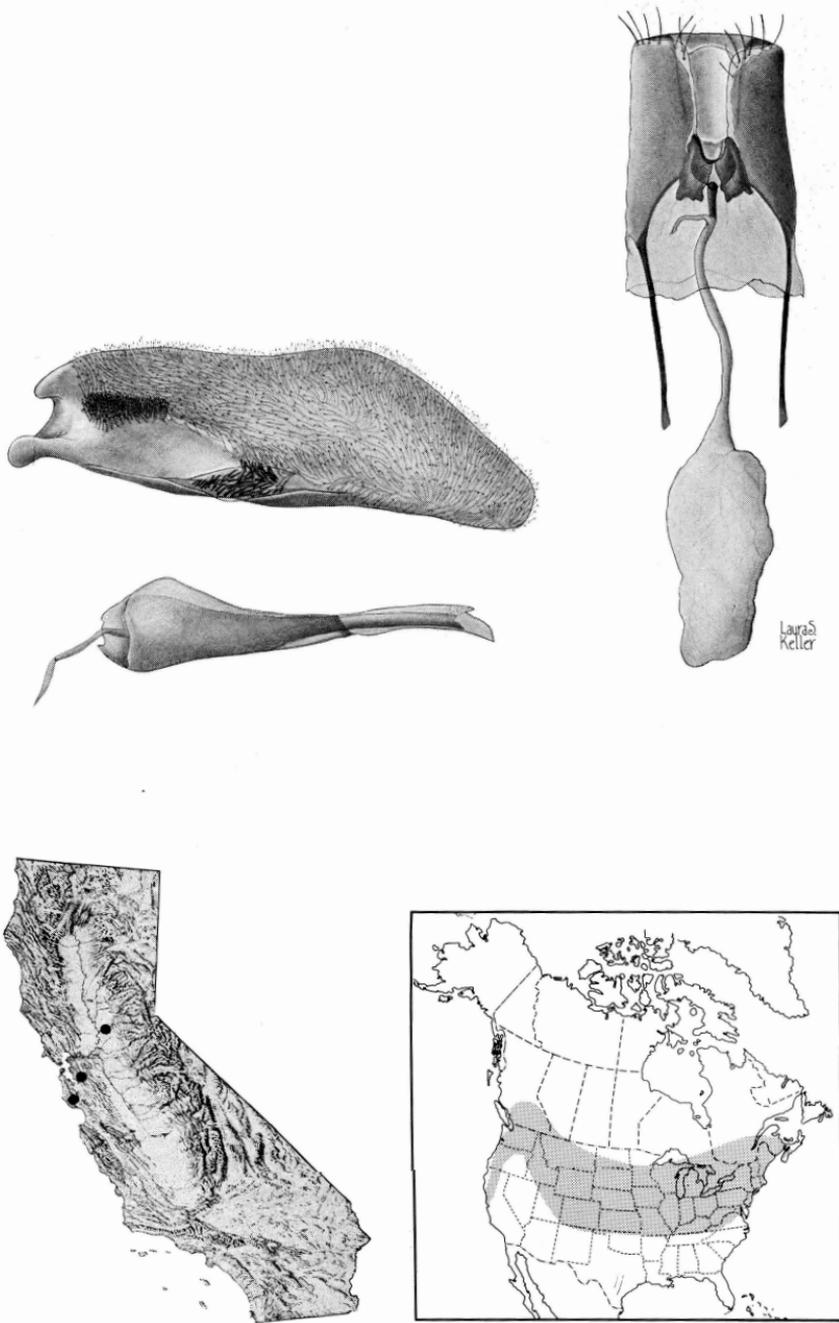


Figure 35. *Synanthedon tipuliformis*.

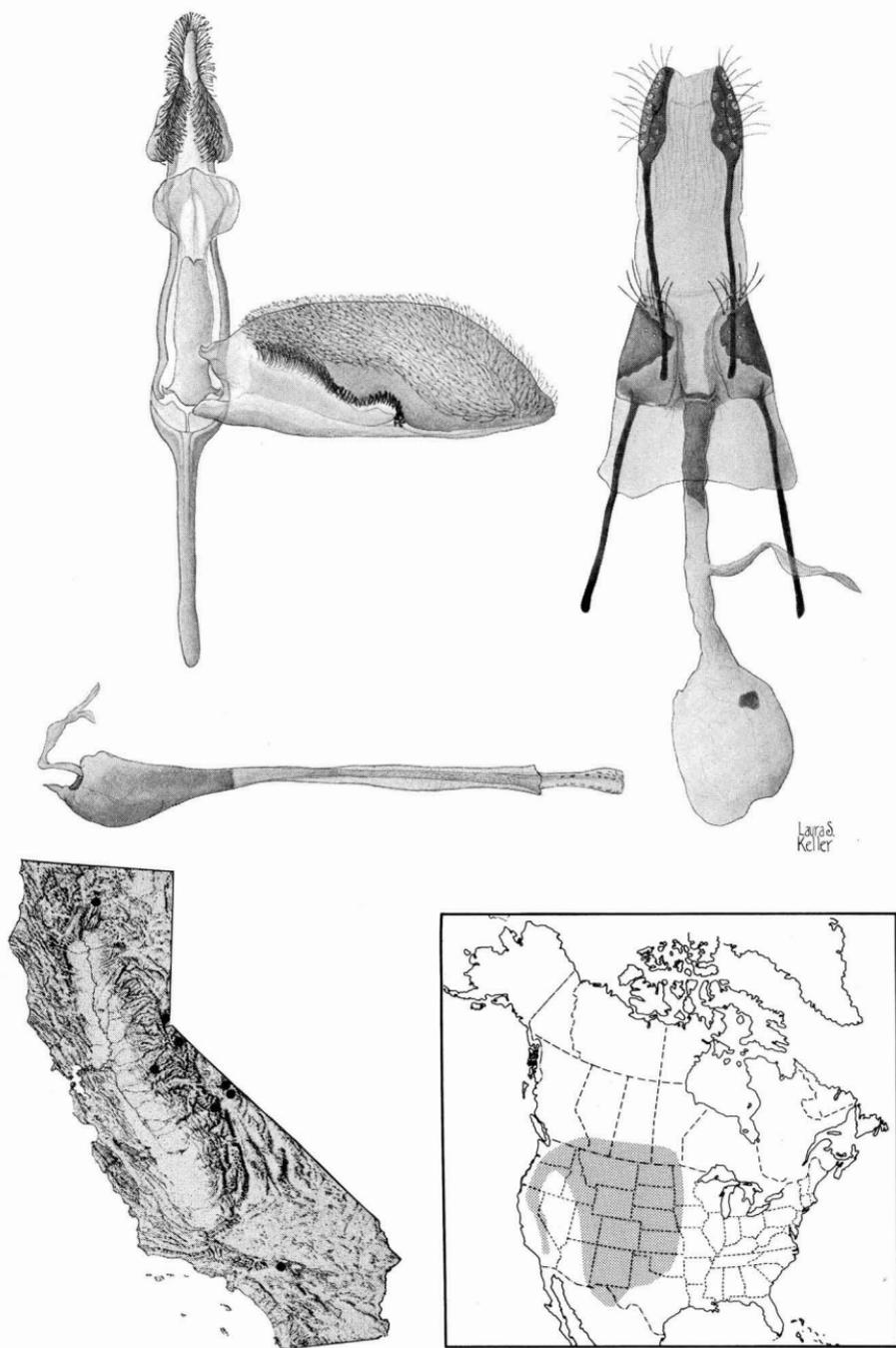


Figure 36. *Carmenta verecunda*.

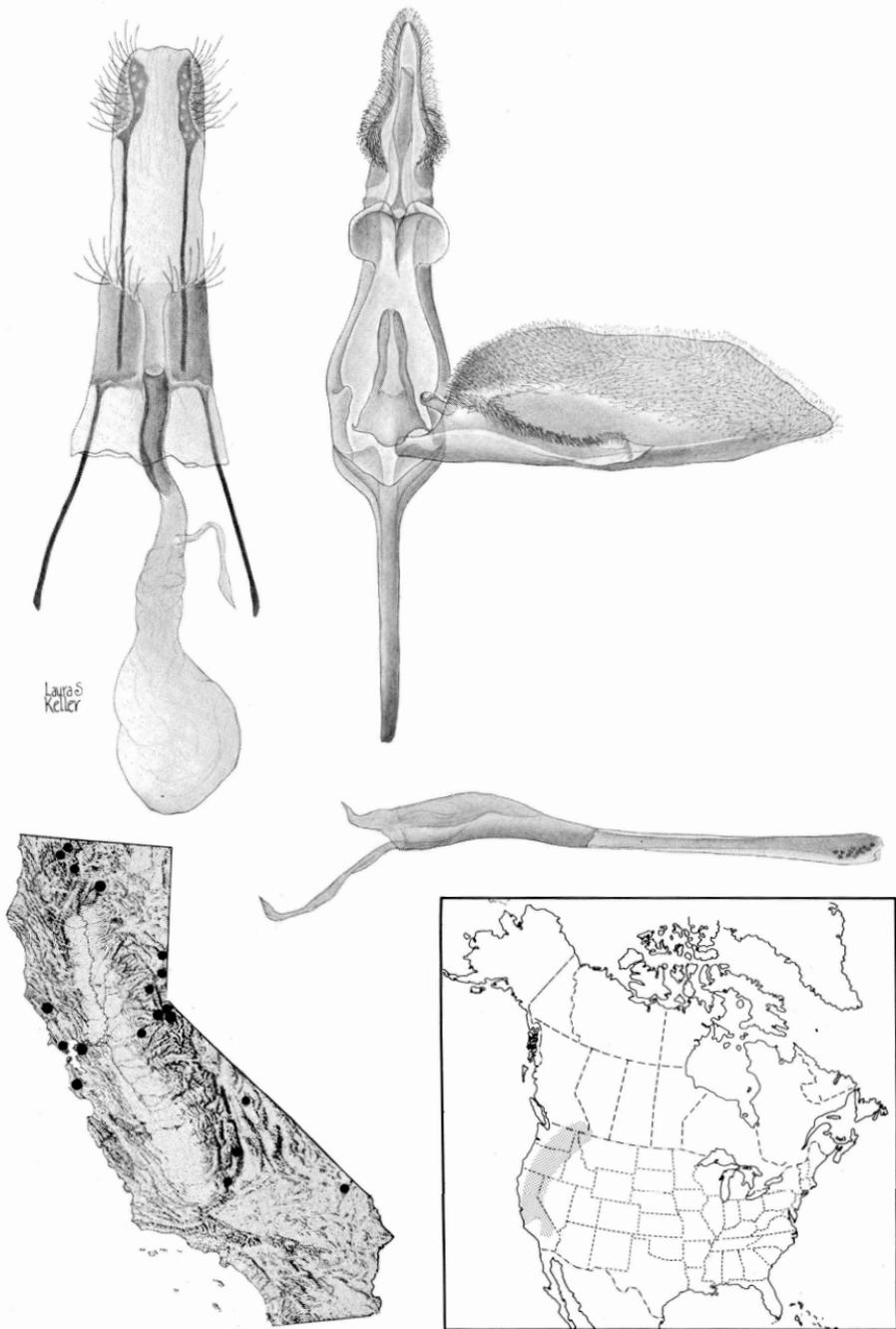


Figure 37. *Penstemonia clarkei*.



Figure 38. *Penstemonia dammersi*.

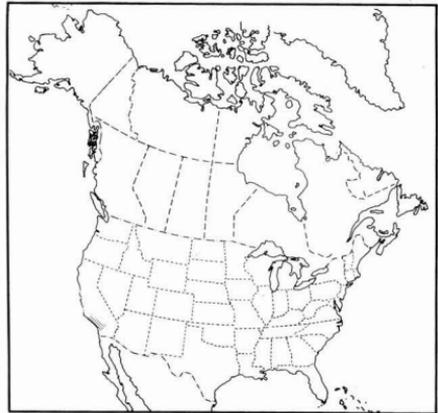


Figure 39. *Penstemonia hennei*.

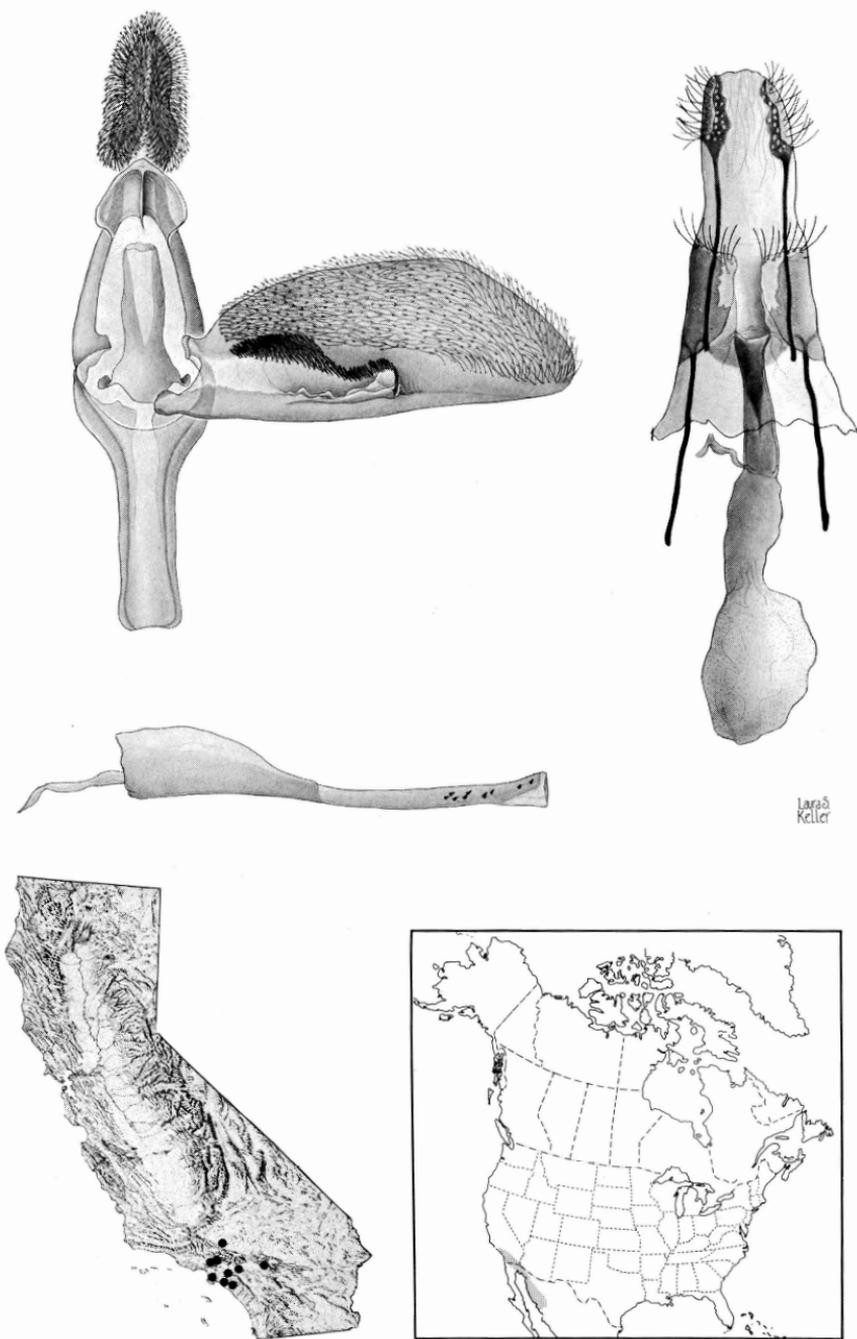


Figure 40. *Alcatloe verrugo*.



Pennisetia marginata ♂



Zenodoxus huecherae ♂



Zenodoxus canescens ♂



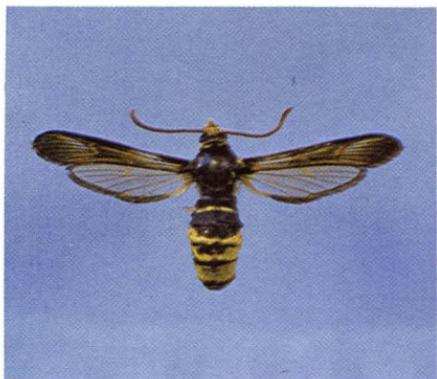
Zenodoxus canescens ♀



Zenodoxus sidalceae ♀



Zenodoxus palmii "incanae" ♀



Paranthrene robiniae "robiniae" ♀



Paranthrene robiniae "palescens" ♀



Albuna pyramidalis ♀



Euhagena nebraskae "intensa" ♀



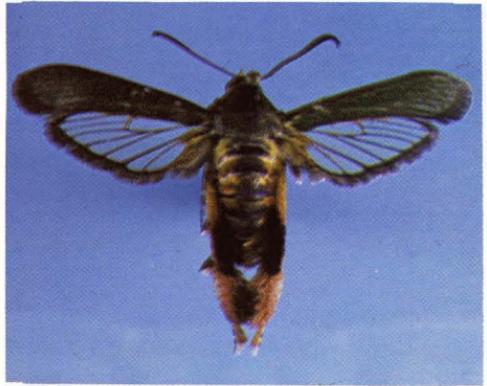
Sesia tibialis ♂



Melittia calabaza ♀



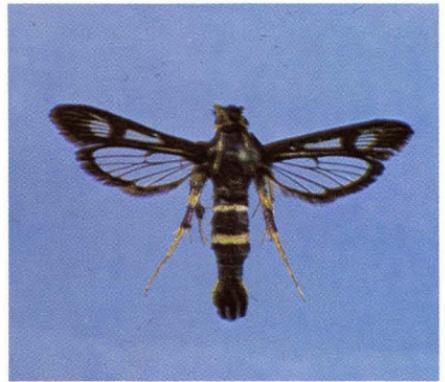
Melittia gloriosa ♂



Melittia grandis ♀



Synanthedon albicornis ♂



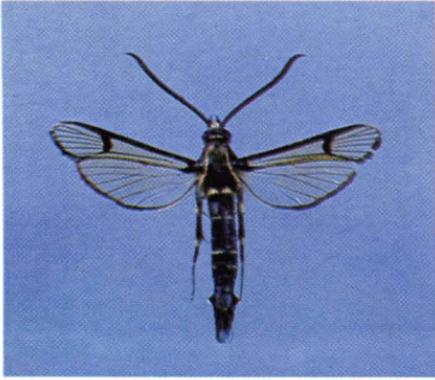
Synanthedon bibionipennis ♂



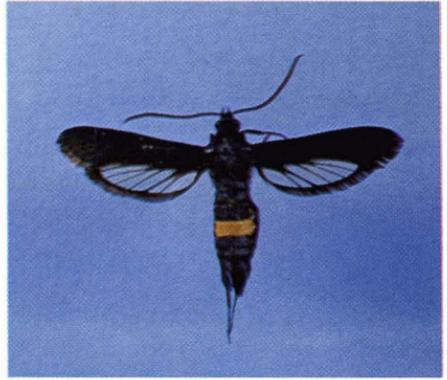
Synanthedon chrysidipennis ♀



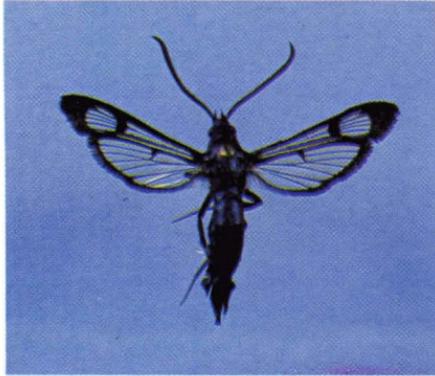
Synanthedon mellinipennis ♂



Synanthedon exitiosa "exitiosa" ♂



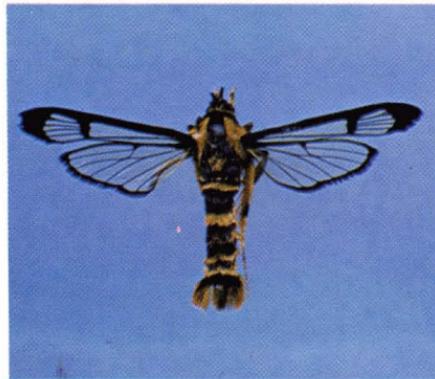
Synanthedon exitiosa "exitiosa" ♀



Synanthedon exitiosa "graefi" ♂



Synanthedon exitiosa "graefi" ♀



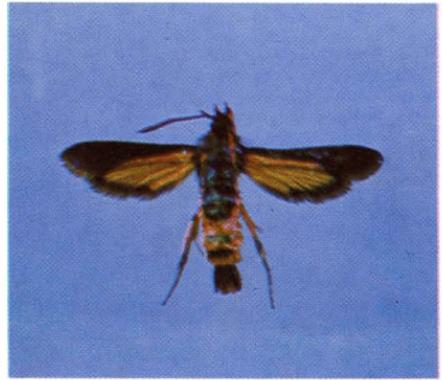
Synanthedon novaroensis ♂



Synanthedon resplendens ♀



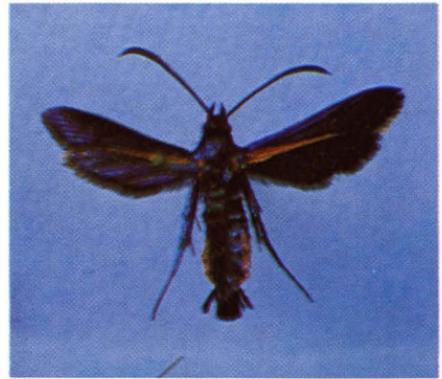
Synanthedon polygona "helianthi" ♂



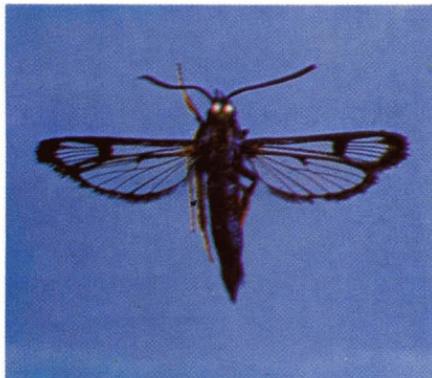
Synanthedon polygona "helianthi" ♀



Synanthedon polygona "fragariae" ♂



Synanthedon polygona "animosa" ♀



Synanthedon saxifragae ♂



Synanthedon sequoiae ♀



Synanthedon tipuliformis ♀



Carmenta verecunda ♂



Alcathoe verrugo "verrugo" ♂



Alcathoe verrugo "verrugo" ♀



Alcathoe verrugo "corvinus" ♂



Alcathoe verrugo "corvinus" ♀



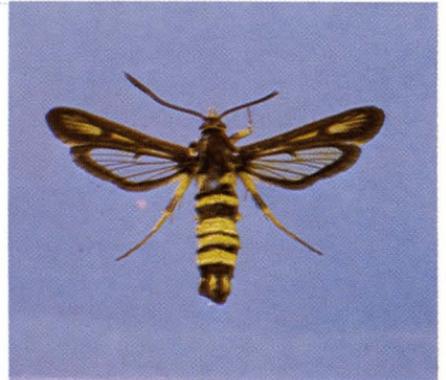
Penstemonia clarkei ♂



Penstemonia clarkei ♀



Penstemonia hennei ♂



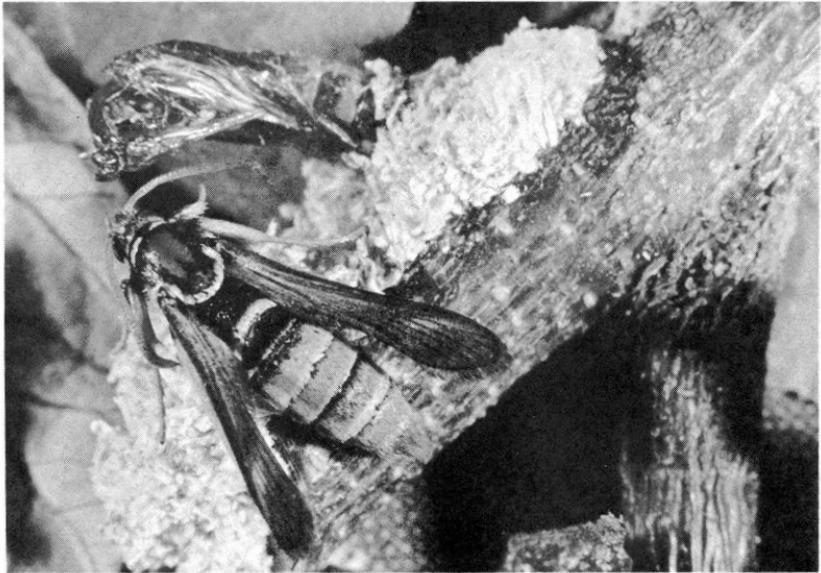
Penstemonia hennei ♀



Penstemonia dammersi ♂



Penstemonia dammersi ♀



Paranthrene robiniae, freshly emerged female, with pupal exuvium protruding from birch twig.



Melittia calabaza, freshly emerged female, with pupal exuvium protruding from sand covered cocoon.

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Dr. W. Donald Duckworth has been a research entomologist with the National Museum of Natural History, Smithsonian Institution for the past 16 years. As a Lepidopterist, his primary responsibility is in the Yponomeutoidea and Sesioidea. Don is currently on a three year leave of absence from the Department of Entomology, serving as Special Assistant to the Assistant Secretary for Museum Programs. Dr. Duckworth takes a very active role in professional societies and participates on various national committees. He has conducted field studies throughout Central and South America and serves as Executive Director for the Association for Tropical Biology. Don, married and with three children, was born in Athens, Tennessee. He received his B.Sc. from Middle Tennessee State University and the M.Sc. and Ph.D. from North Carolina State University.

Dr. Thomas D. Eichlin has been employed by the California Department of Food and Agriculture for the last five years as a Systematic Entomologist. His area of specialization and responsibility is the Lepidoptera, with particular interest in the systematics of larval and adult Microlepidoptera. Tom was a secondary-school teacher before entering graduate school, with a three year tour in the Army Security Agency thrown in. He was born in Easton, Pennsylvania, is married, and has two sons. Tom received his B.Sc. from Indiana State University, Indiana, Pennsylvania and the M.Sc. and Ph.D. from Auburn University, Alabama. He did postgraduate work as a Research Fellow and Presidential Intern at the Smithsonian Institution, and before coming to Sacramento was temporarily employed with the Environmental Protection Agency as a Special Assistant.