

Biology and Systematics of the Leafmining Gracillariidae of Brazilian Pepper Tree, *Schinus terebinthifolius raddi*, with Descriptions of a New Genus and Four New Species)

Authors: Davis, Donald R., Mc Kay, Fernando, Oleiro, Marina, Vitorino, Marcelo Diniz, and Wheeler, Gregory S.

Source: The Journal of the Lepidopterists' Society, 65(2) : 61-93

Published By: The Lepidopterists' Society

URL: <https://doi.org/10.18473/lepi.v65i2.a1>

BioOne Complete (complete.BioOne.org) is a full-text database of 200 subscribed and open-access titles in the biological, ecological, and environmental sciences published by nonprofit societies, associations, museums, institutions, and presses.

Your use of this PDF, the BioOne Complete website, and all posted and associated content indicates your acceptance of BioOne's Terms of Use, available at www.bioone.org/terms-of-use.

Usage of BioOne Complete content is strictly limited to personal, educational, and non - commercial use. Commercial inquiries or rights and permissions requests should be directed to the individual publisher as copyright holder.

BioOne sees sustainable scholarly publishing as an inherently collaborative enterprise connecting authors, nonprofit publishers, academic institutions, research libraries, and research funders in the common goal of maximizing access to critical research.

JOURNAL OF THE LEPIDOPTERISTS' SOCIETY

Volume 65

2011

Number 2

Journal of the Lepidopterists' Society
65(2), 2011, 61–93

BIOLOGY AND SYSTEMATICS OF THE LEAFMINING GRACILLARIIDAE OF BRAZILIAN PEPPER TREE, *SCHINUS TEREBINTHIFOLIUS RADDI*, WITH DESCRIPTIONS OF A NEW GENUS AND FOUR NEW SPECIES)

DONALD R. DAVIS

Department of Entomology, National Museum of Natural History, Smithsonian Institution, Washington, D.C. 20013-7012;
email: davisd@si.edu

FERNANDO MC KAY

USDA, ARS, South American Biological Control Laboratory, Bolívar 1559 (1686), Hurlingham, Buenos Aires, Argentina

MARINA OLEIRO

USDA, ARS, South American Biological Control Laboratory, Bolívar 1559 (1686), Hurlingham, Buenos Aires, Argentina

MARCELO DINIZ VITORINO

Universidade Regional de Blumenau-FURB, Rua Antonio da Veiga, 140, Programa de Pós-graduação em Engenharia Florestal – PPGEF,
Blumenau – SC, Brazil, 89012-900, diniz@furb.br

AND

GREGORY S. WHEELER

USDA/ARS/Invasive Plant Research Lab, 3225 College Ave. Ft Lauderdale, FL 33314; greg.wheeler@ars.usda.gov

ABSTRACT. Recent surveys in southern Florida, USA, Brazil and Argentina, for biological control agents to assist in the control of the invasive Brazilian peppertree, have discovered several previously unknown species of plant mining Lepidoptera of the family Gracillariidae. Morphological descriptions with summaries of their biology for the following four new species and one new genus are presented: *Caloptilia schinusifolia* Davis and Wheeler, from Brazil and possibly Argentina; *Eucosmophora schinusivora* Davis and Wheeler, from Argentina and Brazil; *Leurocephala schinusae* Davis and Mc Kay, new genus and species, from Argentina and Brazil; and *Marmara habecki* Davis, new species, from Florida, USA. The larvae of all four species exhibit a hypermetamorphic development consisting of early instar sapfeeding and later instar tissue feeding stages typical for members of Gracillariidae. Larvae of *M. habecki* were also observed to possess an additional nonfeeding, transitional instar prior to the final instar as is typical for the genus (Wagner *et al.* 2000). Larvae of the new genus *Leurocephala* were discovered to undergo an intermediate, nearly apodal tissue feeding stage between the sapfeeding and final tissue feeding instars. Unique specimens representing an additional three species of Gracillariidae also have been reared from this tree in Argentina or Brazil, but these could not be identified because of inadequate material. COI barcodes were obtained for *Marmara habecki*, *M. smilacisella*, and an undescribed *Marmara* from Brazil. Each species was separated by a minimum barcode divergence of > 4.5% (Fig. 111).

Additional key words: Adult and larval morphology; larval biology; Anacardiaceae, biological control, *Astronium balansae*, *Caloptilia coruscans*, leaf mining, hypermetamorphosis, *Lithrea molleoides*, *Morella faya*, parasitoid, *Schinus fasciculatus*, *Schinus lentiscifolius*, *Schinus weinmannifolius*, Smilacaceae, *Smilax*, stem mining.

Brazilian peppertree (*Schinus terebinthifolius* Raddi, Anacardiaceae) is a Neotropical species whose native range extends along the Atlantic coast of Brazil and Uruguay, west to northeastern Argentina and

adjacent Paraguay (Barkley 1944, 1957; Mc Kay unpublished data; Fig. 1). This species has been introduced to many countries around the world as an ornamental (Morton 1978; Panetta & McKee 1997). In

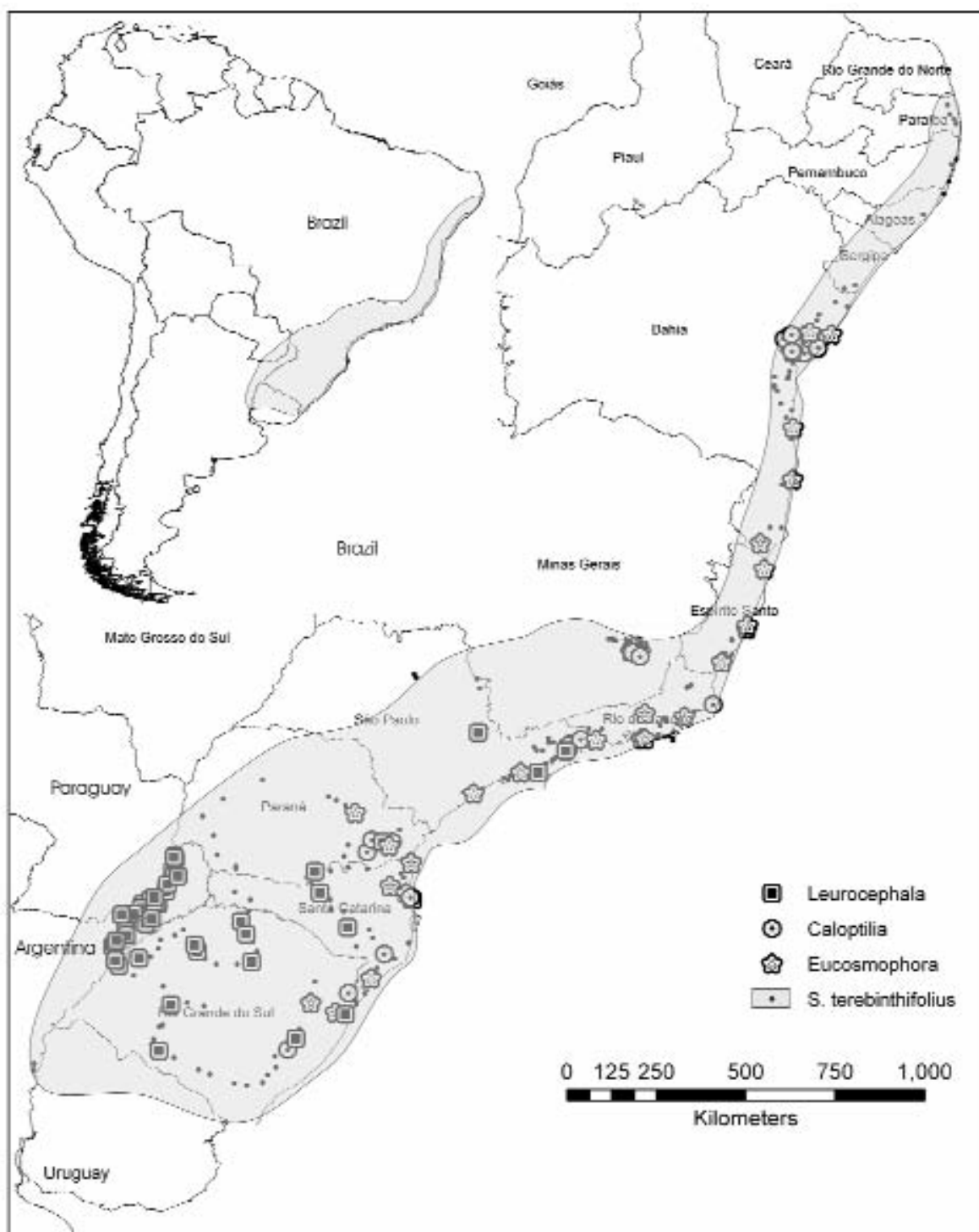


FIG. 1. Distribution of the host *Schinus terebinthifolius* in South America and its gracillariid leafminers: *Caloptilia schinusifolia*, *Eucosmophora schinusivora*, and *Leurocephala schinusae*.

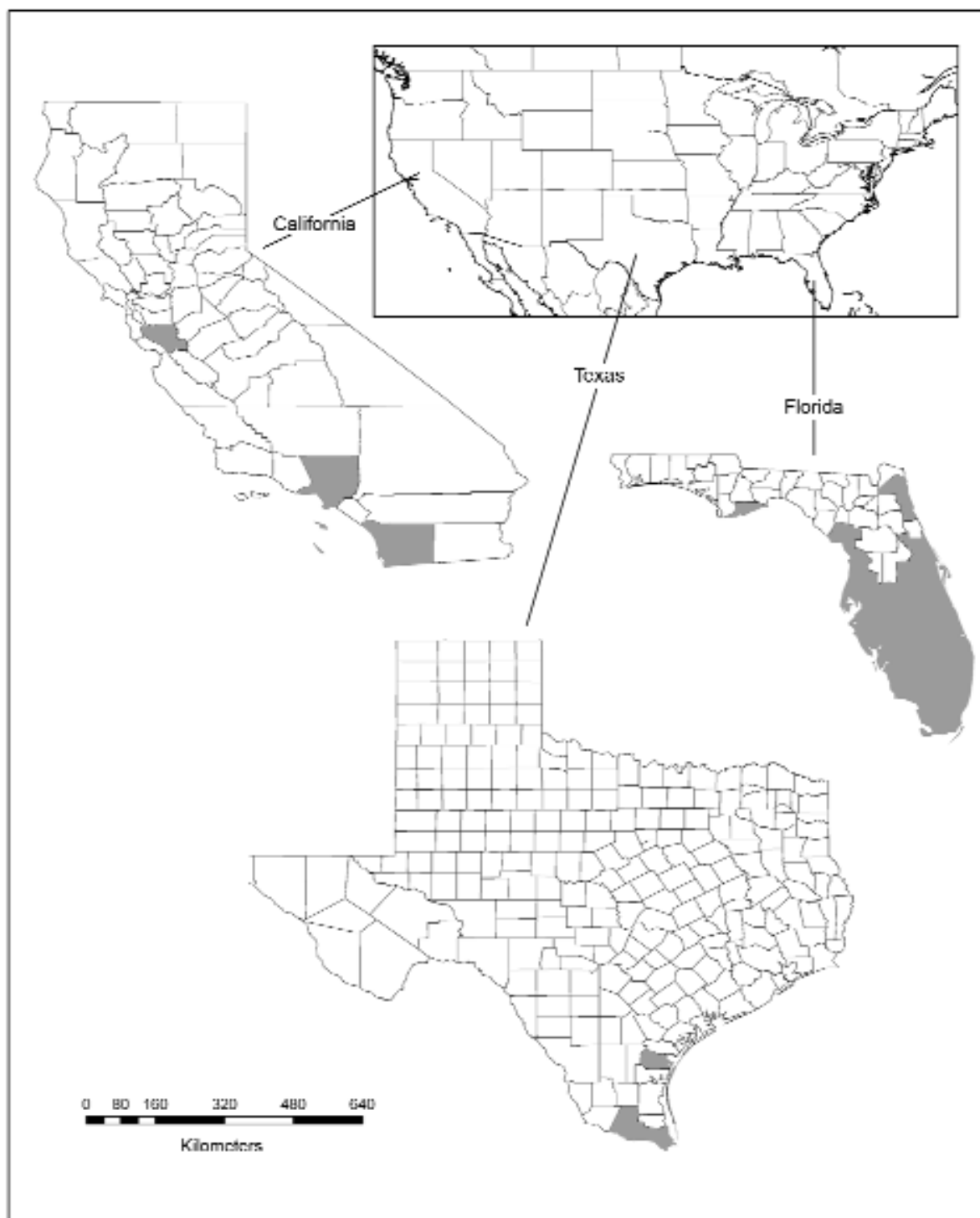


FIG. 2. Distribution of *Schinus terebinthifolius* in the United States showing counties (shaded) where it has been collected (from Wunderlin & Hansen 2008).

its exotic range, especially in Florida, the tree decreases the biodiversity of infested natural areas by aggressively invading a variety of coastal and upland habitats (Mytinger & Williamson 1987; Gann et al. 2001). Currently, in the USA, *S. terebinthifolius* is considered an invasive species in Florida, California, Texas, Hawaii, Puerto Rico and the Virgin Islands (Randall 2000; HSASC 2001; FLEPPC 2009; USDA-NRCS 2009). In Florida, where infestations of *S. terebinthifolius* are estimated to occupy over 283,400 ha (Wunderlin & Hansen 2008; Fig. 2), the species is a prohibited plant and a noxious weed. *Schinus terebinthifolius* constitutes not only a threat to natural areas but also to agriculture and cattle production (Morton 1978; Ewel 1986; Yoshioka & Markin 1991). Allelopathic compounds are known to be produced that suppress the growth of neighboring plant species (Gogue et al. 1974; Morgan & Overholt 2005). *Schinus terebinthifolius* is also suspected of causing allergic reactions and respiratory illnesses in sensitive humans from volatiles released by the leaves, flowers, and fruit (Morton 1978). Conservation organizations consider *S. terebinthifolius* a high-priority target due to its already widespread occurrence and great potential to expand its range (Randall 1993).

Biological control of *S. terebinthifolius* began in the 1950s and resulted in the release in Hawaii of three insect species: a gall-forming caterpillar, *Crasimorpha infusca* Hodges (Lepidoptera: Gelechiidae), a defoliating caterpillar, *Episimus utilis* Zimmerman (Lepidoptera: Tortricidae), and a seed-feeding beetle, *Lithraeus atronotatus* (Pic) (Coleoptera: Bruchidae) (Davis & Krauss 1962; Krauss 1962, 1963; Hight et al. 2002). Only the last two species established in Hawaii, but are exerting negligible control of the weed population (Hight et al. 2002). A previously unidentified species of *Caloptilia*, herein confirmed to be *C. coruscans* Wlsm., was introduced into the island of Hawaii in 1991 (Markin 2001) to control the invasive Firetree, *Morella* (= *Myrica*) *faya* (Aiton). By 1994 the moth had become established in Hawaii Volcanoes National Park and adjacent areas. It is not known if this *Caloptilia* is also feeding on *Schinus* in Hawaii.

In Florida, exploration for biological control agents of *S. terebinthifolius* occurred in the 1980s and 1990s. These studies, mostly literature reviews of Brazilian work, listed at least 200 species of insects associated with the plant in its native range (d'Arújo et al. 1968; Bennett et al. 1990; Bennett & Habeck 1991). Included in these studies were the reports by Krauss (1962, 1963) wherein he listed a species of "*Gracillaria*" (= *Caloptilia*) mining leaves of *S. terebinthifolius* in Salvador and Bahia and a species of

Parornix mining leaves in Sao Paulo. Three insects were selected for further studies in Florida: the leaf-feeding sawfly *Heteroperreyia hubrichi* Malaise (Hymenoptera: Pergidae), the sap-feeding thrips *Pseudophilothrips ichini* Hood (Thysanoptera: Phlaeothripidae), and the defoliating caterpillar *E. unguiculus* (= *utilis*) (Medal et al. 1999; Hight et al. 2002; Martin et al. 2004).

To date, none of these biological control candidates has been released in Florida. However, the continuous spread of *S. terebinthifolius* motivated the search for additional natural enemies against this weed in northern Argentina, an area that had not been surveyed and the most likely center of origin of the genus *Schinus* (Barkley 1944; Muñoz 2000). The results of these surveys indicate that Argentine *S. terebinthifolius* populations harbored natural enemies not previously reported (Mc Kay et al. 2009). Among these, several blotch leaf miners (Lepidoptera: Gracillariidae) were selected for further studies.

Four species of Gracillariidae belonging to four separate genera, all reared from *S. terebinthifolius*, are described in this report: *Caloptilia schinusifolia* Davis and Wheeler, new species, from Brazil; *Eucosmophora schinusivora* Davis and Wheeler, new species, from Argentina and Brazil; *Leurocephala schinusae* Davis and Mc Kay, new genus and species, from Argentina and Brazil; and *Marmara habecki* Davis, new species, from Florida, USA. Unique specimens representing an additional three species of Gracillariinae have also been collected from *S. terebinthifolius* in Brazil, but these could not be identified because of their poor physical condition. Interestingly, one of these is a stem mining *Marmara* closely related to *Marmara habecki*, currently known only from southern Florida, USA. As discussed under the latter species in this report, sequence divergence of their CO1 barcode region of nearly 12% indicates that these two *Marmara* represent distinct species.

METHODS AND MATERIALS

Genitalic dissections were cleared by heating in hot 10% KOH for ~ 30 minutes, and subsequently cleaned and stained with either 2% chlorazol black E or mercurochrome solutions. All genitalic illustrations were drawn from dissections temporarily stored in glycerin, which were later permanently embedded in Canada balsam. Genitalic terminology follows Klots (1970). Samples of alcohol-preserved larvae and pupae were gently washed in 409[®] detergent, then dried in a critical point drier, sputter coated with 20–25 gold palladium 60:40 alloy, and photographed with an Amray 1810 scanning electron microscope.

Field Collections. Argentina. Field collections of these leaf mining insects were part of larger biological control surveys searching for arthropods and diseases associated with *S. terebinthifolius* in its native range. Collections began in 2004 and continued through 2009 and were conducted throughout the Argentina range of the host in Misiones, Corrientes, and Entre Rios provinces (Fig. 1). These surveys were conducted 4–6 times per year.

Field Collections. Brazil. In Brazil surveys began in 2005 and continued through February 2010. The host plant is reported to occur (JBRJ 2009; NYBG 2009; Tropicos 2009) mostly along the Atlantic coast from Recife, Pernambuco (S 8.05°) south to Bagé, Rio Grande do Sul (S 31.33°), then west to northeastern Argentina and eastern Paraguay. Our surveys ranged from Natal, Rio Grande do Norte (S 5.79°), to Pelotas, Rio Grande do Sul (S 31.76°) at the northern and the southern extremes of the host plant range, respectively (Fig. 1). Additionally, these surveys extended west from the coast until the host plants disappeared. In Bahia this occurred near Feira de Santana and in Minas Gerais this species ranged west to Belo Horizonte then south to western Rio Grande do Sul. These surveys were conducted 2–3 times each year, generally lasted 14 days, and usually included three collectors (e.g., GSW, FM, and MDV). All three leaf blotch miner species *L. schinusae*, *E. schinusivora*, and *C. schinusifolia* were common, and were discovered in this Brazilian range during the first year of the project (2005). Insect collections during all trips were conducted under the IBAMA export licenses: 07BR001027/DF; 08BR002120/DF; 09BR003939/DF; 10BR004731/DF.

RESULTS

Field Collections. Field surveys conducted in Argentina (Mc Kay et al. 2009) and Brazil indicate that *L. schinusae*, *E. schinusivora* and *C. schinusifolia* were almost always collected on *S. terebinthifolius*. Larvae of *Leurocephala schinusae* (on leaves of *S. terebinthifolius*) and *Eucosmophora schinusivora* (on leaves of *Lithrea molleoides*) were first discovered in Argentina in 2004 and 2008, respectively. Leaf mines similar to those of *L. schinusae* also have been found on *S. weinmannifolius*, *S. lentiscifolius*, *S. fasciculatus*, and *Astronium balansae*, but adults have not been reared. Likewise, mines similar to *E. schinusivora* were found on *S. weinmannifolius* and *Astronium balansae*, but no adults were reared. *Caloptilia schinusifolia* has not been reared in Argentina, although leaves with folded tips have been observed there, as also noted below.

Although data were not collected on insect densities, the species *L. schinusae* was seasonally abundant in northeastern Argentina and southern Brazil during the austral winter and spring from June to November; this species was difficult to find during the remainder of the year. No seasonality was noticed for *E. schinusivora* or *C. schinusifolia*.

Distribution. Leaflets of *S. terebinthifolius* infested with blotch mines of *L. schinusae* were found at several sites in the northeastern provinces of Argentina (Corrientes and Misiones; Fig. 1). In Brazil this species was collected from sites as far north as near Salvador, BA (S 12.33°) south to Santana Do Livramento, Rio Grande do Sul (S 30.85°). *Eucosmophora schinusivora* generally had a more northern distribution and was collected near Salvador, Bahia (S 12.32°) south to near Porto Alegre, Rio Grande do Sul (S 29.88°). In Argentina this species was only found near Santa Ana, Misiones Province on *L. molleoides*, its other known natural host. *Caloptilia schinusifolia* had a similar broad range from near Salvador, Bahia (S 12.35°) south to near Porto Alegre, Rio Grande do Sul (S 30.83°). *Caloptilia* mine damage with folded leaf tips were also found on *Lithrea molleoides*, *Schinus weinmannifolius*, and *S. lentiscifolius* in Argentina, but no adults were reared for species confirmation.

Natural enemies. Several parasitoids emerged from *Leurocephala schinusae* blotch mines in Argentina from species assigned to Orgilinae (Braconidae) and Brachycyrtinae (Ichneumonidae) and *Isdromas* spp. (Cryptinae: Phygadeuontini). In Brazil parasitism of *L. schinusae* occurred from *Lyneon* sp. (Ichneumonidae: Cryptinae), *Acrolyta* n. sp., *Isdromas* (3 species), and *Pimpla croceiventris* (Cresson) (Ichneumonidae: Pimplinae). Parasitoids belonging to Braconidae included three species of *Orgilus* (Orgilinae), *Pholeteser* sp. (Microgastrinae) and several Chalcidoidea (undetermined species). Parasitism by these Ichneumonidae and Braconidae species reached its highest level (40%) during a collection in July 2008.

DNA Sequencing. Unidentified species of Braconidae and Ichneumonidae and Chalcidoidea have been recovered in Brazil from larval rearings of *Caloptilia schinusifolia* and *Eucosmophora schinusivora* respectively. In Florida a single parasitoid of Chalcidoidea emerged from the pupa of *Marmara habecki*. Sequences were produced at the Biodiversity Institute of Ontario, University of Guelph, Canada. DNA was extracted from legs, entire bodies of adult moths, or entire larvae using a QIAGEN DNeasy Tissue Kit. Primers LepF1 and LepR1 (Herbert et al. 2004) were used to obtain a 658 base pair fragment of

COI with a standard thermocycling regime (Hajibabaei et al. 2006). Sequences are available at the National Center for Biotechnology Information GenBank database and at the Barcode of Life Database (BOLD). Neighbor-joining (NJ) trees were generated from nucleotide sequences as implemented in BOLD (Ratnasingham & Hebert 2007). Phylogenetic and molecular evolutionary analyses were conducted using Molecular Evolutionary Genetics Analysis (MEGA) version 4 (Tamura et al. 2007).

The acronyms used in this study for institutions in which specimens are deposited are as follows:

BMNH The Natural History Museum (formerly the British Museum (Natural History)), London, United Kingdom.

HAD Hawaii Department of Agriculture, Honolulu, HI, USA

MACN Museo Argentino de Ciencias Naturales "Bernardino Rivadavia", Buenos Aires, Argentina.

MGCL McGuire Center for Lepidoptera and Biodiversity, Florida Museum of Natural History, Gainesville, FL., USA.

UPZB Federal University of Paraná, Department of Zoology, Curitiba, Paraná, Brazil

USNM Collections of the former United States National Museum, now deposited in the National Museum of Natural History, Smithsonian Institution, Washington, D.C., USA.

Species summaries

Caloptilia schinusifolia Davis and Wheeler, new species

Figs. 1, 3, 9–10, 22–25.

Diagnosis. *Caloptilia schinusifolia* differs from the only other two congeneric species known to feed on *Schinus* in distribution, wing pattern and male genitalic characters. The forewing of *Caloptilia schinusifolia* is predominantly medium brown with small patches of fuscous scales sparsely scattered over most of the forewing and along the costa, and generally possesses a less iridescent wing color than that of *C. coruscans* (Wlsm.). The forewing of *C. rhoifoliella* (Cham.) is a much darker brown to fuscous, with usually a slender suffusion of white along the costal margin which is lacking in the other two species. The basal half of the male valva of *schinusifolia* is more slender (< half the maximum width across the cucullus) than in either *rhoifoliella* or *coruscans* (~ equal in width), and the vinculum of *schinusifolia* is proportionately longer and

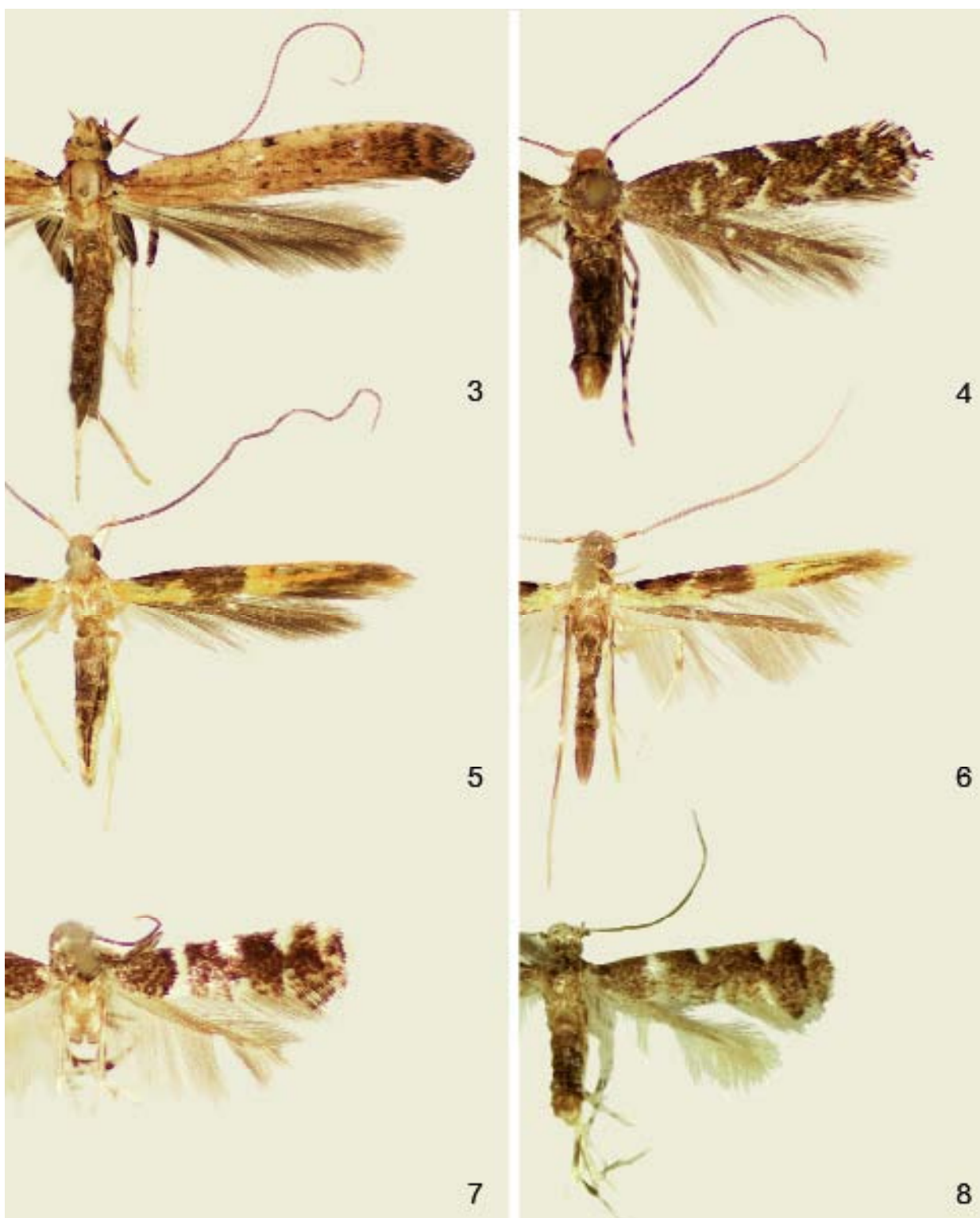
more slender (< 0.7 the length of valve in the other two species). *Caloptilia coruscans* occurs widely through the southern Palearctic region (De Prins & De Prins, 2010) and Hawaii. *Caloptilia rhoifoliella* is known only from North America and Bermuda.

Description. Adult (Fig.3). *Head*: Frons smooth, shiny light brown to bronze, with a lateral pair of partially raised tufts of dark brown to fuscous scales arising from rim of eye below antenna and directed medially; scales of tufts sometimes tipped with paler brown; vertex smooth, light brown to nearly white; occipital tufts prominent, light brown. Antenna with a single row of slender scales encircling each flagellomere; scales mostly dark brown, with bases lighter brown; scape dark brown, usually paler ventrally. Maxillary palpus mostly fuscous laterally, cream to light brown mesally and dorsally on segment II. Labial palpus smooth, mostly whitish cream to light brown over segments I and II, becoming fuscous near apex of II and most of III; extreme apex and a portion of mesal surface of III cream to light brown. *Thorax*: Mostly dark brown dorsally, sharply light cream ventrally; tegula dark brown becoming fuscous anteriorly. Forewing: length 5.0–5.5mm; mostly brown with a small basal patch of fuscous to black of costal scales adjoining tegula; small patches of fuscous scales sparsely scattered over most of forewing and along costa, becoming more concentrated near apex where they form a pair of fuscous transverse bands narrowly separated by brown; a moderately large, fuscous scale patch midway along costa; fringe around apex and along hind margin uniformly dark gray. Hindwing uniformly dark gray. Foreleg with coxa mostly whitish cream with suffusion of brown laterally and fuscous at apex; femora and tibiae of all legs fuscous faintly banded with cream to light brown; tarsomeres white on fore and midlegs, more cream on hindleg, and faintly tipped with fuscous on all legs. *Abdomen*: Sharply demarcated from dark fuscous dorsally to mostly cream ventrally with a few fuscous scales scattered ventrally. Male with 2 pairs of coremata of ~ equal lengths present on segments VII and VIII; caudal margin of tergum VII with a slender, rounded lobe; tergum VIII T-shaped, very slender, abruptly expanded caudally.

Male genitalia (Figs. 22, 23). Tegumen weakly sclerotized; attenuate caudally. Vinculum-saccus relatively long and slender, equaling tegumen in length. Valva simple, lacking ridges or processes, with costal and hind margins evenly curved, gradually widening to smoothly rounded cucullus; maximum width of cucullus nearly 2× that of base of valve. Aedeagus a slender tube ~ 1.3× length of vinculum-saccus, with a slender spinose process projecting from one edge of apex; cornuti consisting of an elongate, tightly and obliquely compressed row of ~ 9–11 slender spines in distal half of aedeagus; phallobase narrowly inflated, ~ 1.25× length of aedeagus.

Female genitalia (Figs. 24, 25). Anterior and posterior apophyses ~ equal in length, with similar broad bases. Ostium broad, width ~ 2/3 the length of anterior apophysis; antrum moderately enlarged, narrowing to junction with ductus seminalis; length of antrum to junction ~ equal to length of anterior apophysis. Ductus bursae extremely long, ~ 10× the length of anterior apophysis, narrow, membranous, and abruptly enlarging at termination with corpus bursae. Corpus bursae oblong-elliptical, with finely wrinkled, membranous walls; length ~ 3.25× length of anterior apophysis; signa a symmetrical pair of slender spines ~ equal to anterior apophysis in length, each with a truncate, spatulate, basal end which projects exteriorly beyond wall of corpus bursae.

Larval biology (Figs. 9–10). Early instars of *Caloptilia schinusifolia* form a serpentine mine that begins along the mid-vein and continues along the leaflet margin. Mid-sized larvae emerge from this mine and feed under a narrow fold of the leaflet edge. Late instars roll the tips of the leaflet and feed externally skeletonizing the lower surface of the leaflets. When



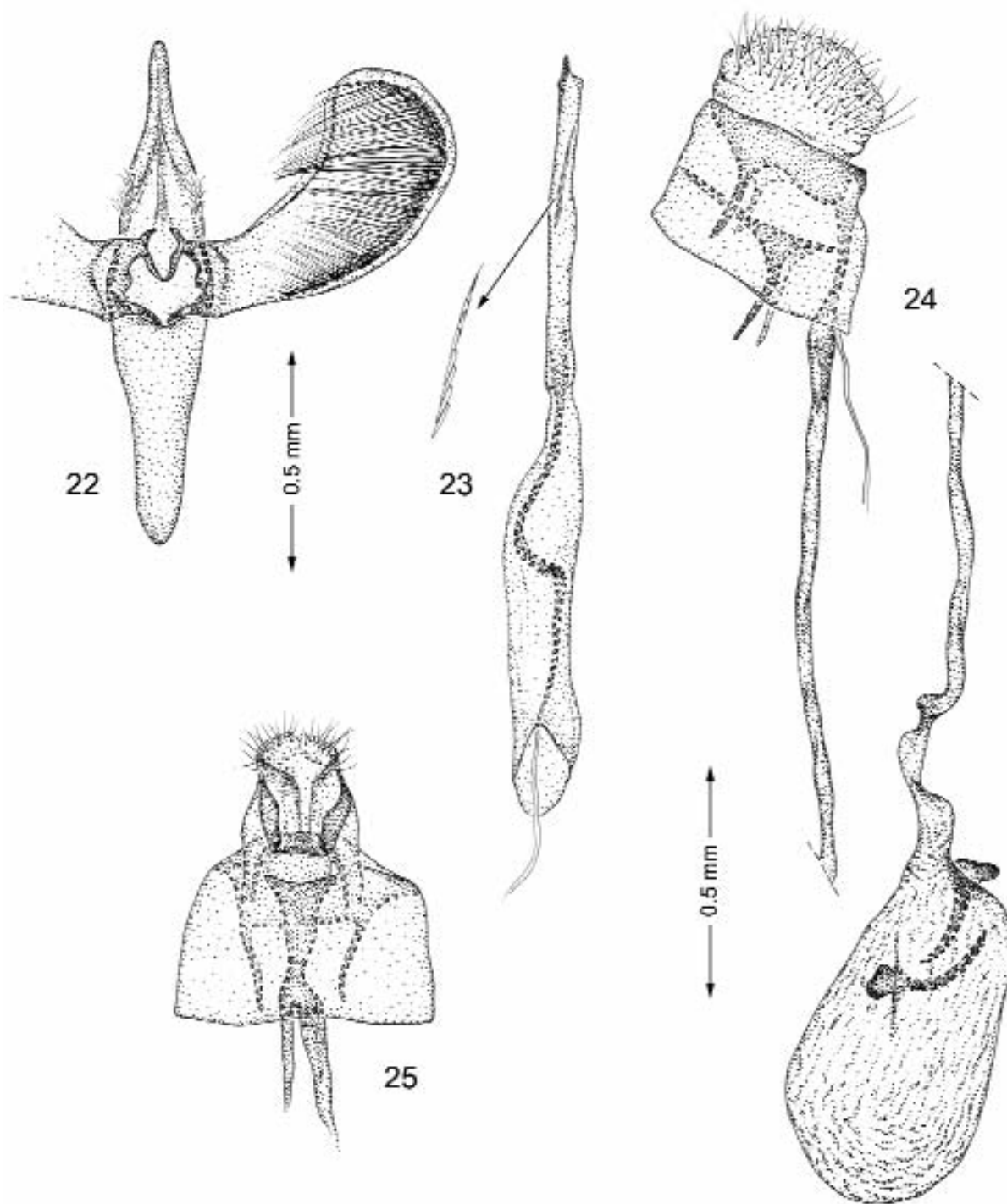
Figs. 3–8. Adults. **3.** *Caloptilia schinusifolia* (5.3 mm), paratype ♀, 10 km NE Capão da Canoa, Brazil. **4.** *Leurocephala schinusae* (3.4 mm), holotype ♂, 2 km. N. Libertad, Argentina. **5.** *Eucosmophora schinusivora* (4.0 mm), paratype ♀, Santa Ana, Argentina, reared from *Lithrea molleoides*. **6.** *E. schinusivora* (3.8 mm), holotype ♂, (left wing reversed), Paranagua, Brazil, reared from *Schinus terebinthifolius*. **7.** *Marmara habecki* (2.0 mm), paratype ♀, Tenoroc, FL, USA, reared from *S. terebinthifolius*. **8.** *Marmara habecki* (2.4 mm), paratype ♂, Monroe Station, FL, USA, reared from *Schinus* sp. (Forewing length in parentheses).



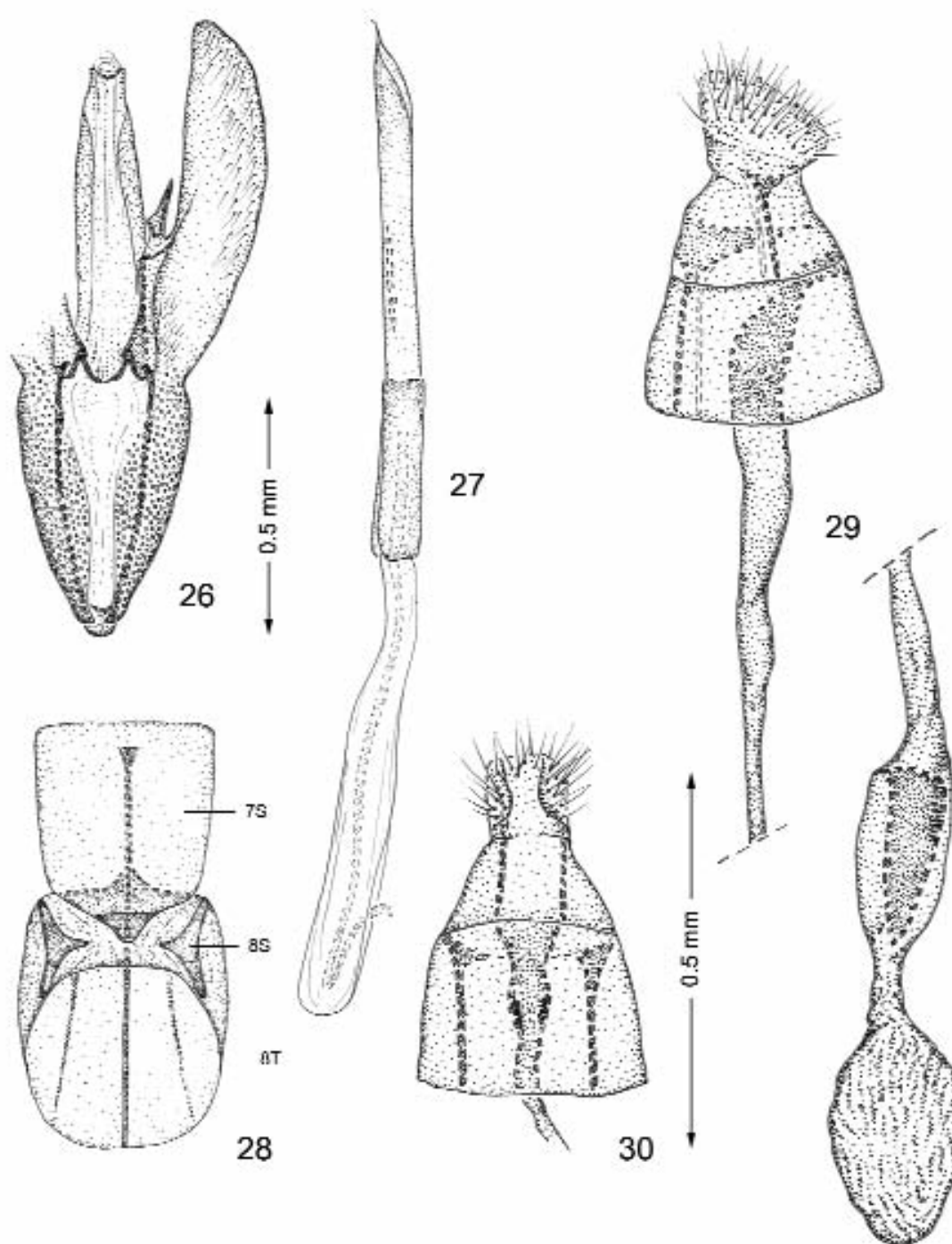
FIGS. 9–13. Larval host damage and cocoons. **9.** Leaf curling by late instar larvae of *Caloptilia schinusifolia* on *Lithrea brasiliensis*; Lapa, Paraná, Brazil. **10.** Leaf curling and cocoons (arrow) of *C. schinusifolia* on *Schinus terebinthifolius*; 1.6 km S of Caraguatatuba, São Paulo State, Brazil, Nov 6, 2009. **11.** Leaf mines of *Eucosmophora schinusivora* on *S. terebinthifolius*; Macaé, RJ, Brazil, July 2008. **12.** Leaf mines of *E. schinusivora* on *S. terebinthifolius*; Macaé, RJ, Brazil. **13.** Detail of leaf mine of *E. schinusivora* on *S. terebinthifolius*; Macaé, RJ, Brazil.



FIGS. 14–21. Larval damage and cocoons. **14.** Leaf mine of *Eucosmophora schinusivora* on *Lithrea molleoides*; Argentina. **15.** Cocoon of *E. schinusivora* with 7 exterior bubbles on *L. molleoides*; Argentina. **16.** Larval damage on *Schinus terebinthifolius* by *Leurocephala schinusae*; near Libertad, Argentina, July 17, 2007. **17.** Leaf mine of *L. schinusae* on *S. terebinthifolius*; near Libertad, Argentina. **18.** Leaf mine of *L. schinusae* on *S. terebinthifolius* showing approximate location of sequential immature stages and collected head capsules; near Libertad, Argentina. **19.** Cocoon with last (5th) instar larva inside; note linear arrangement of bubbles. **20.** Stem mine of *Marmara habecki* on *S. terebinthifolius*; Ft Lauderdale, FL, USA. **21.** Cocoon of *M. habecki* on *S. terebinthifolius* with 4 groups of bubbles; Ft Lauderdale, FL, USA.



FIGS. 22–25. *Caloptilia schinusifolia*, genitalia. **22.** Male, ventral view. **23.** Aedeagus. **24.** Female, lateral view. **25.** Female, ventral view. (Scale lengths indicated).



FIGS. 26–30. *Eucosmophora schinusivora*, genitalia and postabdomen. 26. Male, ventral view. 27. Aedeagus. 28. Male postabdominal segments 7–8, ventral view. 29. Female, lateral view. 30. Female, ventral view. (Scale lengths as indicated).

development is complete, larvae emerge from the rolled leaflet and pupate on the lower side of the leaf in a prepared short crevice covered with silk. No bubbles were attached to the pupal cocoon.

Hosts. Anacardiaceae: *Schinus terebinthifolius* Raddi and *Lithrea molleoides* (Vell.) Engl. Mines similar to *C. schinusifolia* were also found on *Schinus lentiscifolius* March. and *Schinus weinmannifolius* Engl., but no adults were reared.

Parasitoids. Unidentified species of Braconidae (Cheloninae possibly *Phanerotoma* sp.) and Chalcidoidea have been recovered from larval rearings of *C. schinusifolia*.

Types. Holotype - ♂; BRAZIL: Rio de Janeiro: Maricá, S22.90270, W42.82358, 7 m: 15 Jul 2008, S22.90270, W42.82358 RJ 44, Wheeler & Mc Kay, emerged from [leaf tip fold] on leaves of *S. terebinthifolius*, (UPZB). Paratypes (7 ♂, 5 ♀) - BRAZIL: Bahia: 11 km NE Salvador, S12.96176, W38.40338, 2 m: 1 ♂, 1 ♀, 2 Apr 2008, Wheeler, perimeter leaf miner, BAH37, ♀ slide USNM 34031. Paraná: Paranagua, Rio Guaraguacu: Sambaqui: 19 Oct 1992, 1 ♂, adult 30 Oct 1992, slide USNM 34152; 2 ♂, adult 31 Oct 1992; 1 ♀, pupa 27 Oct 1992, adult 2 Nov 1992; Host: *Schinus terebinthifolius*, F.D. Bennett, J.H. Pedrosa Macedo, C. Wickler, M.D. Vitorino, ♀ slide USNM 33920. Paraná: 36 mi W. Curitiba, S25.47520; W49.60064; 1 ♂, 3 Feb 2009, ARO5, Wheeler & Mc Kay, tip folding leaves *S. terebinthifolius*. Rio Grande do Sul: 10 km NE Capão da Canoa, S29.68000, W49.99180; 1 ♂, 2 ♀, 11 Feb 2009, RS52, Wheeler & Mc Kay. Santa Catarina: 20 mi. E. Canomhas, S26.18269, W50.20403; 1 ♂, 13 Feb 2009, SC33, Wheeler & McKay, tip folding leaves *S. terebinthifolius*, slide USNM 34097. (Paratypes deposited in MGCL, UPZB, USNM.)

Flight period. Adults have been collected in February, April, July, and October.

Distribution (Fig. 1). This species has been collected from mostly coastal areas from Bahia Province, Brazil south to Rio Grande do Sul. It has also been observed in Misiones Province (northeastern Argentina).

Etymology. The species name is derived from the generic name of the plant host (*Schinus*) and the Latin *folium* (leaf).

Discussion. At least two species of *Caloptilia* have been reported previously as mining the leaves of *Schinus*: *Caloptilia coruscans* Wlsm. (= *C. schinella* Wlsm.) and *C. rhoifoliella* (Cham.) (Robinson, et al. 2007; De Prins & De Prins 2010). *Caloptilia coruscans* occurs from southern Europe to North Africa and on several associated Atlantic islands (e.g., Azores, Canary Islands), where it has been reared from three genera of Anacardiaceae (including *Schinus molle* L.) and *Morella faya* (Aiton) of the Myricaceae. Several names are now considered synonyms of *C. coruscans*, including *C. schinella* (Wlsm.), *C. terebinthiella* Chrétien, *C. instincta* Meyr., and *C. ferruginipennis* Turati, (Triberti 1985; De Prins & De Prins 2010). *Caloptilia rhoifoliella* occurs across much of the United States where it mines the leaves of *Rhus* and *Toxicodendron*, and in Bermuda where it has been reported feeding on *Schinus*

terebinthifolius (Ferguson et al. 1991; Robinson et al. 2007).

Caloptilia schinusifolia differs from both of the foregoing species in wing pattern and male genital characters. The forewing of *schinusifolia* is predominantly medium brown with a less iridescent color than that of *coruscans*, as described and figured by Walsingham (1908). The forewing of *rhoifoliella* is generally much darker brown to fuscous, with usually a slender suffusion of white along the costal margin which is lacking in the other two species. The basal half of the male valvae of *schinusifolia* is more slender (< half the maximum width across the cucullus) than in either *rhoifoliella* or *coruscans* (~ equal in width), and the vinculum of *schinusifolia* is proportionately longer and more slender (< 0.7 the length of valve in latter two species). The male genitalia from the type series of *C. coruscans* has not been figured, but that of the junior synonym, *C. schinella*, was illustrated by Klimesch (1970).

Only one other species of *Caloptilia*, *C. pastranai* Bourquin, has been reported from southern South America within the maximum range of either *Schinus terebinthifolius* or *Lithrea molleoides*. *Caloptilia aeolastis* (Meyrick), *C. hexameris* (Meyrick), *C. pneumatica* (Meyrick), and *C. semiclausa* (Meyrick) were described from Brazil, but are known to occur only along the Amazon River well north of the range of *Caloptilia schinusifolia*, and none of the foregoing *Caloptilia* are similar to *C. schinusifolia* in forewing pattern. *Caloptilia pastranai* is known to feed only on *Scutia buxifolia* Reiss (Rhamnaceae) in Buenos Aires Province, Argentina. The body and forewings of this species are considerably darker than that of *C. schinusifolia*.

A previously unidentified species of *Caloptilia*, “*Caloptilia* species, near *schinella* Walsingham”, was introduced into the island of Hawaii in 1991 (Markin 2001) to control the invasive Firetree, *Morella* (= *Myrica*) *faya* (Aiton). By 1994 the moth had become established in Hawaii Volcanoes National Park and adjacent areas. Specimens of this introduced species originating from a laboratory colony imported from the Azores Islands, Portugal were borrowed for examination by DRD from the Hawaii Department of Agriculture. This examination confirmed that the Hawaiian species (originating from the Azores) agreed with *C. coruscans* and was distinct from *C. schinusifolia*. The Azores specimens also agreed in wing pattern and male genitalia with specimens in the collections of the USNM, which had been collected in the Canary and Madeira Islands and reared from *Schinus molle* L. and *Myrica faya*. Currently no rearings of *Caloptilia* have been reported from *Schinus terebinthifolius* in Hawaii.

***Eucosmophora schinusivora* Davis and Wheeler,
new species**

Figs. 1, 5–6, 11–15, 26–30.

Diagnosis. *Eucosmophora schinusivora* is the only species of *Eucosmophora* known to feed on a member of the Anacardiaceae. The male genitalia of *Eucosmophora schinusivora* agree with those of the *sideroxytonella* species group (Davis & Wagner 2005) in possessing a costal lobe on the male valve, and with the *dives* species group in the absence of scale tufts on the seventh sternite. The female genitalia of *E. schinusivora* differ from those of both groups in lacking signa and in possessing an enlarged, pocket-like sclerotization within the ductus bursae (Fig. 29). The forewing pattern of *schinusivora* is also unique in possessing a pair of dark fuscous, longitudinal fascia that converge before the apex of the wing (Figs. 5–6).

Description. Adult (Figs. 5–6). *Head*: Frons smooth, pale gold, gradually becoming gray to shiny black over vertex to occiput; collar a narrow band of pale golden white. Antenna slightly exceeding length of forewing; scape smooth, elongate, ~ equal to width of frons, pale gold to light orange; apex of scape with a distinct dorsal tuft of pale golden scales, slightly suffused with fuscous at apex along posterior margin; base of antenna bent slightly ventrad at pedicel; pedicel and basal 2–3 flagellomeres sometimes with light orange luster; remainder or usually all of flagellum lustrous dark gray; each flagellomere completely encircled by a single, dense row of slender scales. Maxillary palpus smooth, pale gold, sometimes with a slight orange luster. Labial palpus smooth, similar to frons and maxillary palpi in color. *Thorax*: Dorsum light orange; light orange beneath wing and tegula but mostly silver to gold ventrally; tegula shiny black. Forewing: length 3.5–4.2mm; ~ equally covered by light orange and dark fuscous to black scales as follow: basal half of forewing dark fuscous along costa, extending completely across wing just before middle; basal third of hind margin light orange with a sinuate medial edge separated from dark fuscous costal margin by an oblique patch of silvery scales; apical half of wing mostly orange except for a pair of elongate, shiny, dark fuscous fascia along the subcostal area and hind margin that converge before entirely fuscous apex; fringe around apex pale gray becoming fuscous toward hind margin. Hindwing uniformly dark fuscous. Fore and midlegs mostly pale golden cream with fuscous banding on dorsum of tibia; hindleg mostly pale golden cream; fuscous laterally on femur, tibia and first tarsomere. Abdomen (Fig. 28): Fuscous to black dorsally and laterally on A3–5; golden cream ventrally. Sternum 7 of male abruptly narrowing caudally to broadly triangular, rounded apex without setal brush. Eighth sternites consisting of a small pair of widely divided, triangular sclerites ~ 0.4 × the length of main body of tergum 8. Tergum 8 with slender median rod extending nearly to anterior margin of sternum 7; anterior apex of rod slightly enlarged.

Male genitalia (Figs. 26–27). Valva slender with mostly straight costal margin and evenly curved saccular margin, gradually narrowing to a rounded apex; a small, acute process arising from basal third of costa. Aedeagus a slender, nearly smooth, elongate cylinder; a series of ~ 20 minute spines arranged subdorsally near middle in 2 irregular rows; apex of aedeagus asymmetrical, with a relatively large, acute, terminal process from dorsal side.

Female genitalia (Figs. 29–30). Antrum mostly membranous. Ductus bursae elongate; walls covered internally with minute, circular spicules, gradually becoming larger and more dense around sclerotized, U-shaped internal pocket just before enlargement of corpus bursae; walls of corpus bursae membranous; signum absent.

Larval biology (Figs. 11–15). The eggs are oval shaped, nearly transparent, milky-white. Eggs are

deposited generally on the upper leaf surface adjacent to a secondary vein. After hatching, the first instar forms a broad leaf blotch. In high densities 3–5 larvae may form blotches on the same leaflet that merge to form a single large blotch which covers most of the leaflet. Leaf damage seems to induce premature leaf drop in the field.

Cocoon (Fig. 15). Pupae are covered with silk, located on leaves on the ground, and are usually on the lower leaf surface. The silk is covered with frothy bubbles, generally six in number, bright white, and arranged around the perimeter of the cocoon. Pupation occurs usually in a constructed leaf groove or occasionally under a folded leaf edge.

Hosts. Anacardiaceae: *Schinus terebinthifolius* Raddi and *Lithrea molleoides* (Vell.) Engl. Mines similar to that of *Eucosmophora schinusivora* were also found on *Schinus longifolius* (Lindl.) Speg., *Schinus weinmannifolius* Engl. and *Astronium balansae* Engl., but no adults were reared.

Parasitoids. Unidentified parasitoids of Ichneumonidae and Chalcidoidea have been reared from this species collected in Brazil.

Types. *Holotype*: ♂- BRAZIL: Paraná: Paranaguá, Rio Guaraguacu, Sambaqui, 19 Oct 1992, adult 13 Nov 1992, Host: *Schinus terebinthifolius*, F.D. Bennett, J.H. Pedrosa Macedo, C. Wickler, M.D. Vitorino, digital image captured USNM, (MACN). Paratypes (21 ♂, 15 ♀): ARGENTINA: Misiones Prov: Santa Ana: 4 ♂, 3 ♀, 4 Apr 2008, leaf mining larva feeding on *Lithrea molleoides*, Mc Kay & Oleiro, slides USNM 33966♂, 33967, 34032♀. BRAZIL: Paraná: Same data as holotype: 1 ♂, 19 Oct 1992; 1 ♂, adult 29 Oct 1992; 1 ♂, adult 29 Oct 1992; 1 ♂, adult 7 Nov 1992; 1 ♂, adult 8 Nov 1992; 2 ♂, 9 Nov 1992; 1 ♀, pupa 27 Oct 1992, adult 10 Nov 1992, slide USNM 33917; 1 ♂, adult 12 Nov 1992, slide USNM 33918. Rio de Janeiro: 41 km SE Campos: 1 ♂, 1 ♀, 9 Apr 2008, Wheeler coll. As larvae, globules random on silk. Rio Grande do Sul: 5 km N N. Hamburgo: 1 ♀, 9 Apr 2008, Wheeler & Mc Kay, RS1, emerged from leafmines on *Schinus terebinthifolius*; Lagoa Itapeva: 1 ♂, 9 Jul 2008, Wheeler & Mc Kay, RS5, emerged from leafmines on *Schinus terebinthifolius*, slide USNM 34025♂. Santa Catarina: 5 km S. Itajaí, S26.92026 W48.64137: 3 ♂, 2 ♀, 8 Feb 2010, Wheeler & Mc Kay, SC40, reared from leaves of *Schinus terebinthifolius*. 11 km N Sombrio: 2 ♀, 10 Jul 2008, Wheeler & Mc Kay, SC4, reared from leafmines on *Schinus terebinthifolius*, 2 ♂, 4 ♀, 11 Feb 2009, Wheeler & Mc Kay, SC4, reared from leafmines on *Schinus terebinthifolius* (Paratypes deposited in MACN, MGCL, UPZB, and USNM).

Flight period. Adult emergences have been reported in February, April, July, October, and November.

Distribution (Fig. 1). This species has been collected in Misiones Province (northeastern Argentina). In Brazil, this species has been commonly collected from Salvador, Bahia, south to Porto Alegre, Rio Grande do Sul.

Etymology. The species name is derived from the generic name of the plant host (*Schinus*) and the Latin *voro* (eat, devour).

Discussion. The Neotropical genus *Eucosmophora*

was revised recently by Davis & Wagner (2005), and generic diagnoses of the larval, pupal, and adult stages are provided in that study. *Eucosmophora* was found to consist of two morphologically distinct groups, each possibly restricted to feeding on a single plant family. The Fabaceae-mining *dives* group containing possibly 5 species, was partially characterized by males lacking a costal lobe on the valva, seventh abdominal sternite without caudal scale tufts, and females bearing a pair of spinulose signa in the corpus bursae. The *sideroxylonella* group included 11 species, 3 of which are known to be leafminers on Sapotaceae. The males of this group possess a small costal lobe on the valva similar to *E. schinusivora* (Fig. 26), as well as a caudal scale tuft on the seventh abdominal sternite; the paired signa of the females are long, often lacinate, and prominently serrate to spinose. Males of *Eucosmophora schinusivora* agree with those of the *sideroxylonella* group in possessing the costal lobe on the male valve, and with the *dives* group in the absence of scale tufts on the seventh sternite. The female genitalia of *E. schinusivora* differ from those of both groups in lacking signa and in possessing an enlarged, pocket-like sclerotization within the ductus bursae (Fig. 29). The forewing pattern of *schinusivora* is also unique in possessing a pair of dark fuscous, longitudinal fascia that converge before the apex of the wing (Figs. 5–6). It is also notable that no *Eucosmophora* had been reared previously from Anacardiaceae.

***Leurocephala* Davis and Mc Kay, new genus**

Figs. 1, 4, 31–43.

Type species. *Leurocephala schinusae* Davis and Mc Kay, new species

Description. Adult (Fig. 4). Small moths with forewing length 3.1–3.5 mm. **Head** (Figs. 31–32): Vestiture entirely smooth; scales tightly appressed, slender, with apices broader, slightly rounded. Eye relatively large, round; vertical diameter equal to minimum interocular distance across frons. Antenna filiform, long, ~ equal to forewing in length, smoothly scaled; a single annulus of long, slender scales completely encircling each flagellomere; scape elongate, ~ 4.8x length of pedicel. Labrum trilobed, pilifers well developed, triangular. Mandible absent. Haustellum naked, elongate, ~ 2.2x length of labial palpus. Maxillary palpus short, smoothly scaled, 4-segmented; ratio of segments from base: ~1.0: 2.1:1.0:2.7. Labial palpus smoothly scaled, moderately long and drooping; ratio of segments from base: ~1.0:2.4:0.8. **Thorax:** Smoothly scaled. Forewing (Fig. 33) lanceolate, L/W index ~ 5.0; R 5-branched; all veins arising separate from cell except with Rs3, Rs4, and M1 either connate at their bases or with Rs4 and M1 stalked; discal cell ~ 0.4x length of forewing; 1A + 2A completely fused, well developed, extending more than half the length of hind margin. Hindwing extremely slender, L/W index ~ 7.0; M1 shortly stalked to M2+3; cell open between M and Cu; CuP present but weak; male frenulum a single stout bristle; female with frenulum divided at extreme base, then fused for nearly its entire length and appearing as a single stout bristle. Legs with tibial spur pattern 0-2-4;

epiphysis absent. Abdomen (Figs. 40–41): Male with segments VII–VIII complex and greatly reduced except for enlarged tergum VIII; VII reduced to a very narrow, nearly complete, sclerotized ring, with lateral juncture of VII tergum and sternum barely discernible; segment VIII with a weakly sclerotized, elongate, hoodlike tergum (Fig. 41) overlapping tegumen (tergum IX); sternum VIII greatly reduced, extending as a narrow ventral ring from indistinct lateral junction with anteriolateral angle of tergum VIII; lateral portions of sternum VIII slightly broaden and bearing a pair of elongate hair pencils (coremata); a second, immediately anterior pair of hair pencils arising from distal apex of an elongate, mostly membranous, everted, tubular lobe arising in membrane between sternum VII and VIII, with a slender, supporting rodlike sclerite extending the length of lobe. Female postabdominal segments unmodified; corethrogynae absent.

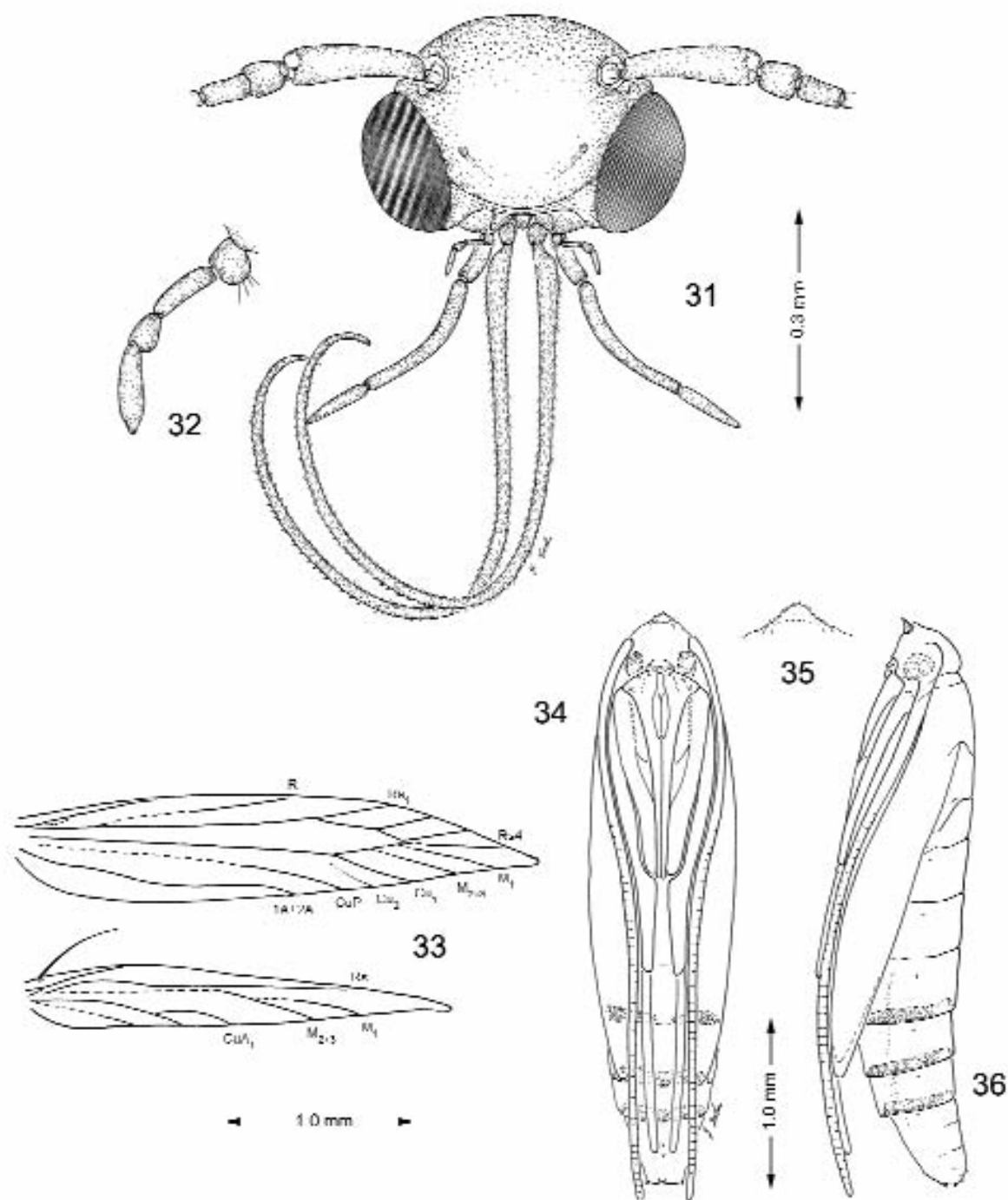
Male genitalia (Figs. 37–39). Uncus absent. Tegumen relatively broad, hood-shaped, partially membranous, with a shallow apical notch. A pair of short, rounded, membranous lobes arising ventrally from mostly membranous area beneath tegumen, possibly representing rudimentary gnathos. Vinculum short, broadly V-shaped, extending laterally along base of valva; sacculus only slightly developed, length equal to less than half the length of vinculum. Valva broad at base, with sharply defined sacculus lobe, abruptly narrowing to truncate, slightly flared apex; costal margin relatively straight. Base of valvae joined by a strongly arched, moderately sclerotized transtilla. Juxta a small, dorsally concave, lightly sclerotized plate firmly attached to middle of aedeagus. Aedeagus (Fig. 39) sinuate, relatively short; length ~ equal to length of valva; basal half of aedeagus tapering cephalad beyond entry point of ductus ejaculatorius.

Female genitalia (Figs. 42–43). Anterior and posterior apophyses short, of similar lengths; posterior apophysis broader at base. Ostium forming a broad chamber with lateral extensions, opening on caudal margin of sternum VII. Ductus bursae short, slightly thickened, abruptly expanding to elongate, elliptical corpus bursae. Ductus seminalis connected immediately anterior to junction of ductus bursae and corpus bursae. Walls of corpus bursae membranous, appearing externally wrinkled, with a single ovoid lenticular signum near middle, possessing a relatively long slender spine projecting anteriorly into corpus bursae.

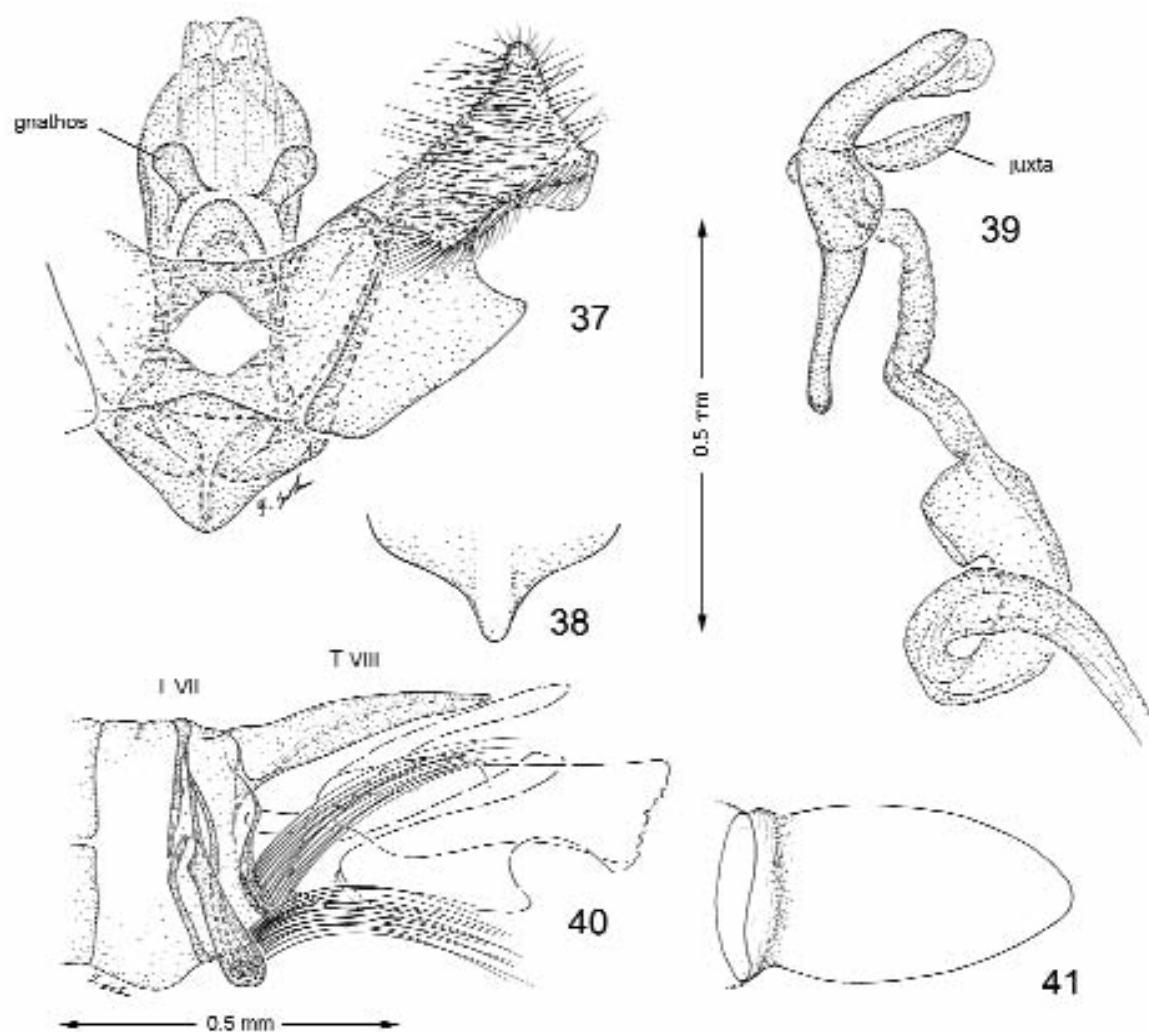
Etymology. The generic name is derived from the Greek *leuros* (smooth, polished) and *kephale* (head), in reference to the entirely smooth-scaled head of the adult.

Discussion. Several morphological characteristics place this genus within the subfamily Gracillariinae, including a smoothly scaled head, 4-segmented maxillary palpus, hindwing with base of Rs arched toward Sc, 2 pairs of coremata in male, pupation outside of mine, and resting posture of the adult with the anterior portion of body raised at ~ 45° angle. *Leurocephala* differs from all known genera in several features, particularly by the presence of paired gnathal lobes in the male genitalia and the anterior extension of aedeagus beyond entry point of the ductus ejaculatorius. In addition, the development of three distinct larval forms similar to that in *Leurocephala* has been observed in only a few other genera of Gracillariidae. The three distinct developmental stages include an apodal, first instar sapfeeding form, a mostly apodal tissue feeding form, and a last instar tissue feeding form with relatively well developed legs and prolegs.

Leurocephala shows some similarity to the American genus *Neurostrota* in fore- and hindwing venation, in



FIGS. 31–36. *Leurocephala schinusae*, adult and pupal morphology. **31.** Head, anterior view. **32.** Maxillary palpus. **33.** Wing venation. **34.** Pupa, ventral view. **35.** Detail of frontal ridge (cocoon cutter). **36.** Pupa, lateral view. (Scale lengths as indicated).



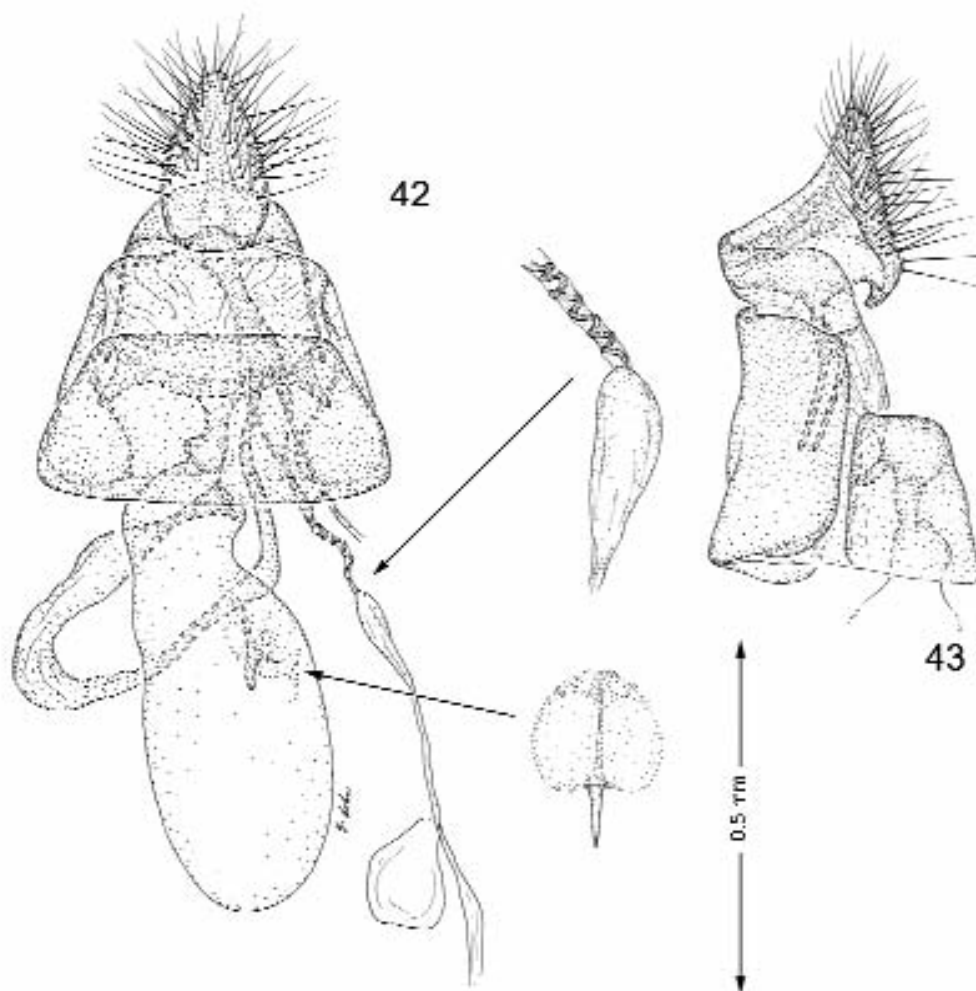
FIGS. 37–41. *Leurocephala schinusae*, male genitalia and postabdomen. 37. Genitalia, ventral view. 38. Variation of anterior margin of vinculum. 39. Aedeagus; J = juxta. 40. Postabdominal segments 7–8 with coremata, lateral view. 41. Tergum 8, ventral view. (Scale lengths as indicated).

the development of a broad saccular lobe on the male valva, a greatly enlarged tergum 8 in the male abdomen, and in the larval excretion of numerous bubbles over the surface of the cocoon. Larval bubble excretion also occurs in several other gracillariid genera, including *Eucosmophora* and *Marmara*, as noted herein. Molecular analysis now nearing completion on the genera of Gracillariidae by Akito Kawahara (2010) place *Leurocephala* within the *Parectopa* group of Gracillariinae near the genera *Liocrobyla*, *Micrurapteryx*, and *Parectopa*.

***Leurocephala schinusae* Davis and Mc Kay,
new species**

Figs. 1, 4, 16–19, 31–106.

Diagnosis. As discussed under the genus, *Leurocephala schinusae* differs from all known genera and species of Gracillariidae in several features, particularly by the presence of paired gnathal lobes in the male genitalia and the anterior extension of the aedeagus beyond the entry point of the ductus ejaculatorius, and, in part, by the development of three distinct larval forms. The intermediate (transitional) form differs from all other known Gracillariidae in



FIGS. 42–43. *Leurocephala schinusae*, female genitalia. **42.** Ventral view, with enlargements of spermatheca and signum. **43.** Lateral view. (Scale lengths as indicated).

possessing three instars with a unique, enlarged spinneret and well developed mandibles of the tissue-feeding type.

Description. Adult (Fig. 4). *Head*: Frons mostly white, becoming slightly more bronzy brown caudally from vertex. Antenna dark bronzy fuscous; scape with a slender white, longitudinal streak dorsally which gradually fade to flagellomeres 1–2; venter of scape and basal flagellomeres white, gradually becoming more light brown distally. Maxillary palpus white. Labial palpus mostly silvery white, dark fuscous laterally and at apex of segment 2. *Thorax*: Mostly fuscous dorsally with scales brown basally gradually becoming more fuscous over distal half; white ventrally; tegula dark fuscous. Forewing: length 3.1–3.5mm; mostly fuscous, scale bases slightly paler; usually with 4 oblique white striae of variable width equally spaced along costa and a similar number of nearly opposite white striae along hind margin; fringe around apex fuscous banded with lighter gray; a small apical tuft

of 3–6 fuscous scales projecting beyond fringe; fringe along hind margin uniformly fuscous. Hindwing uniformly fuscous. Legs mostly fuscous dorsally, white ventrally; tibiae and tarsi strongly banded with white and fuscous. Abdomen (Figs. 40–41): Fuscous dorsally, mostly white ventrally with oblique segmental bands of fuscous laterally. Coremata from segment VIII of male white. Postabdominal segments as described for genus.

Male genitalia (Figs. 37–39). As described for genus.

Female genitalia (Figs. 42–43). As described for genus.

Egg (Figs. 44–45, Table 1). Glued to upperside (adaxial) leaf surface of host, often adjacent to either main or secondary vein. Generally oval to nearly round in outline, relatively depressed, with center slightly raised; length ~ 0.40 – 0.48 mm; width 0.33 to 0.44 mm. Chorion of dorsal surface finely reticulated.

Larva (Figs. 46–98, Table 1). Hypermetamorphic, with three distinct larval forms: 1) First instar, apodal, sapfeeding stage with flattened (depressed) mandibles and rudimentary spinneret. 2) Instars

TABLE 1. Egg and larval head capsule widths of *Leurocephala schinusae* on *Schinus terebinthifolius*.

Egg and head capsule widths (mm)			
Life stage	N	Mean ± SD	Range
Egg	10	0.39 ± 0.04	0.33-0.44
L I	10	0.14 ± 0.01	0.13-0.14
L II	10	0.14 ± 0.01	0.13-0.14
L III	10	0.21 ± 0.01	0.2-0.22
L IV	10	0.35 ± 0.02	0.32-0.39
L V	10	0.43 ± 0.02	0.4-0.46

2–4 more cylindrical, nearly apodal, tissue feeding, with stouter, more opposable mandibles; broad, stout spinneret with a greatly enlarged, flared aperture. 3) Last (5th) tissue feeding instar with a more cylindrical body, stout, opposable mandibles; spinneret fully developed “normal”, more slender; fully developed thoracic legs, and 3 + 1 pairs of abdominal prolegs. Head capsule widths of each instar are provided in Table 1. Among the 10 larvae sampled each for instars 1 and 2, no significant differences were observed between the width of their heads. The morphology of their mouthparts, particularly the spinneret, was distinctly different as described below.

Sap-feeding Instar (Figs. 46–55). First instar ~ 0.85 – 1.0mm in length, with relatively depressed head and body modified for sap-feeding in subepidermal tissue of leaves. *Head*: Most setae reduced to absent. Stemmata absent. Antenna with 3rd segment relatively shorter but with similar sensillae compared with that of later instars. Labrum (Figs. 46–47) generally similar to later instars in outline, moderately bilobed with a median, apical depression; setae greatly reduced, indistinct. Mandibles depressed (Fig. 49), with 3 acute and 1 blunt teeth. Labium (Figs. 50–51) relatively broad and flat, projecting slightly beyond labrum, with anterior margin broadly rounded; spinneret greatly reduced, with only a minute, flush opening at apical-ventral margin of labium; labial palpi vestigial, reduced to a pair of closely appressed, slender setae (Fig. 51). *Body*: Relatively depressed; white except for brownish tergal and dorsal plates, with pronotal plate and abdominal tergal plates 1–7 the largest in size; tergal plates of meso- and metathorax reduced. Legs, prolegs, and crochets absent. Paired dorsal and ventral ambulatory callosities present on all thoracic segments and abdominal segments 1–8.

Apodal tissue feeding Instars (Figs. 56–71). Instars 2–4 with more cylindrical body and head, and larva feeding deeper into mesophyll tissue than first instar and beginning blotch mine; maximum length of 4th instar larva ~ 4 mm. *Head*: Moderately depressed. Chaetotaxy similar to 5th instar. Labrum identical to that of last instar, with 4 pairs of setae. Stemmata relatively flat, poorly defined, with only stemmata 4 (near S1) and 1 (near S2, Figs. 63–64) evident. Antenna and maxilla similar to that of last instar, with segments proportionally equal in length. Mandible similar to last instar, with 5 teeth. Labium with 2-segmented labial palpus; length of basal segment ~ 2x its width; with 2 elongate setae, longest ~ twice the length of shorter seta. Spinneret (Figs. 60, 67) extremely broad and stout, triangular shape, terminating in a flared, fimbriate rim that encloses the aperture of the spinneret in a shallow depression. *Body*: white except for brownish tergal and dorsal plates. Pronotum a large, brown, rectangular plate; plates reduced in size and nearly colorless on meso- and metanotum; only subventral pinaculum of prothorax brown. Prosternum similar to pronotum; meso- and metasterna with small, dark brown plates. Dorsum of abdominal segments 1–9 with brownish plates slightly smaller than corresponding ventral plates; plates slightly decreasing in size caudally, except A9 tergal plate larger, broader; dark brown,

oval plates present on sterna of A1–10; plate of sterna 9 broader. Most setae reduced, with L1 the longest. Thoracic legs (Figs. 69, 71) vestigial, unsegmented, bearing 2–3 short setae and a terminal, rudimentary pretarsal unguis. Prolegs, and crochets absent. Paired dorsal and ventral ambulatory callosities present on all thoracic segments and abdominal segments 1–8.

Tissue-feeding Last Instar (Figs. 72–98). Fifth instar more typical caterpillar form with cylindrical body, feeding on mesophyll tissue of leaf and enlarging full depth blotch mine; maximum length to 5.5 mm; width to 0.8 mm. Body color light green. Head brown; maximum width 0.46 mm; relatively dorsoventrally flattened Fig. 77) with mouthparts fully developed; dorsal area around seta P1 minutely spinose, broadly triangular in outline (Figs. 72, 93); epicranial notch deeply formed as in previous instars and generally similar to that of *Parectopa* except more broadly separated at junction, U-shaped. Frons elongate, extending to epicranial notch and about half the length of head capsule; ecdysial line terminating at lateral margins of epicranial notch. Chaetotaxy relatively well developed; all three MD setae present. P1 well separated from ecdysial line. P2 reduced, widely separated from P1, arising nearer to A3. Six stemmata, arranged in 3 groups: stemmata 1 and 2 together anterior to A3; stemmata 3–5 in an oblique line between A1 and SS2; stemma 6 situated immediately ventrad to S2. Antenna 3-segmented, with sensilla as shown (Figs. 74–75). Labrum with 4 pairs of setae; M2 and L1 lost; epipharyngeal spines and epipharyngeal sclerite not observed. Mandible (Fig. 98) with 5 moderately large cusps; median 3 cusps the longest; both lateral seta present. Maxilla as shown in Fig. 79. Spinneret (Figs. 80–81) relatively short, slender; apex rounded, densely covered with minute, blunt papillae ventral to minute aperture. Labial palpi (Fig. 80) with basal segment ~ 4x length of smaller apical segment and bearing short subapical sensillum; apical segment bearing elongate apical sensillum, exceeding length of basal segment. *Body*: Pale green at maturity. Pronotum relatively large, pale brown, smooth. XD1 and 2 short, arising near ventral margin of pronotum. Ambulatory callosities present dorsolaterally on T1–3. L group bisetose on T1–3. SV bisetose on T1, unisetose on T2–3 (Fig. 92). Sternal plate large, wrinkled. Legs moderately well developed; claw with large axial spine (Fig. 86); coxae widely separated. *Abdomen*: Dorsal plates indistinct, smooth. Paired dorsal and ventral ambulatory callosities present on A1–7. Both D setae present on A9. L unisetose on A1–10. SV group trisetose on A1–10. Prolegs present on A3–5 and A10; crochets arranged in a staggered caudal row of ~ 12 hooks on A3–5 (Fig. 85); A10 with crochets reduced to 2 hooks (Figs. 88, 89). Chaetotaxy of A10 as shown in Figs. 88, 90–91, 95; SD1 and SD2 bisetose.

Pupa (Figs. 34–36, 99–106). Length to 4 mm and width 0.9 mm; brown to fuscous ventrally, white to light brown dorsally with dark brown intersegmental rings over abdomen. Frontal process (cocoon cutter) a low, broad, triangular, mostly transverse ridge bearing numerous minute teeth in scattered rows, with medial 3 teeth the largest; (Fig. 100). Antenna long, extending slightly beyond end of abdomen. Labial palpi extending about 1/3 the length of proleg. Proboscis as long as proleg. Forewings narrow, well separated, extending to abdominal segment A6. Prolegs to A2; midlegs to A4; and hindlegs to A8 or 9+10. D1, SD1, and L1 present on A1–6; only D1 present on A7–8. Dorsum of abdomen minutely and densely spinose, without prominent rows of spines (Fig. 102). Sternum of A7 relatively smooth, without accessory cremaster. Cremaster consisting of a ring of four pairs of small slightly curved spines, with those on dorsum closely set and slightly enlarged (Figs. 103–106).

Cocoon (Fig. 19). Oval in general outline; ~ 6–6.5 mm long, 2.5–3.5 mm wide. Surface flat, adorned with average of 16 (± 2.8; n=22; range 9–20), pearly-white, minute, compartmentalized bubbles, arranged either in an approximate line along longitudinal axis or peripherally around edge of cocoon. These bubbles were discharged from the anus at intervals of approximately 10 minutes by the mature larvae and attached through a slit in the cocoon.

Larval Biology (Figs. 16–19). The first instar larva bores into the plant epidermis and makes a short mine

(length = 0.93 ± 0.08 mm; mean \pm SD; $n=21$) parallel to the leaf vein. After this initial slender mine, the mine of later instars turns 90° and continues forming an increasingly broader blotch mine in the leaf blade. The initial two thirds of a fully developed blotch mine are dark brown and the most distal third is light green. One fully developed mine may remove up to 40% of the leaflet photosynthetic tissue. Occasionally two, but generally one blotch is found per leaflet. Mature larvae leave the blotch through a slit in the light colored part and spin a silk cocoon on the adaxial surface of the leaves.

Hosts. Anacardiaceae: *Schinus terebinthifolius* Raddi and *Schinus longifolius* (Lind.) Spag. Mines similar to that of *Leurocephala schinusae* were also found on *Astronium balansae* Engl.; *Schinus fasciculatus* (Griseb.) *Schinus lentiscifolius* March., *S. longifolius* (Lindl.) Spag. and *Schinus weinmannifolius* Engl., but no adults were reared.

Parasitoids. In Argentina the following parasitoids emerged from *L. schinusae* blotch mines: Braconidae (Orgilinae); Ichneumonidae (Brachycyrtinae) and *Isdromas* sp. (Cryptinae: Phygadeuontini). In Brazil parasitism occurred from Braconidae *Orgilus* sp. (Orgilinae), *Pholeteser* sp. (Microgastrinae) and several Chalcidoidea (undetermined species), Ichneumonidae *Lymeon* sp. (Cryptinae), *Acrolyta* n.sp., 2 species of *Isdromas* (including the same as those from Argentina, as well as a third species), and *Pimpla croceiventris* (Cresson) (Pimplinae).

Types. *Holotype*: ♂; ARGENTINA: Misiones Province; Road 12; 2 km N Libertad, 2 Aug 2006, Mc Kay & Oleiro, leaf blotch miner collected as larva on *Schinus terebinthifolius*, GPS: 394; Digital image captured USNM, (MACN). *Paratypes* (27 ♂, 19 ♀): ARGENTINA: Buenos Aires Province: Hurlingham: July 2007, 3 larvae, [23 larvae], host: *Schinus terebinthifolius*, DRD SEM, slide 33913; Corrientes Prov: Santo Tomé: 1 ♀, 16 Jul 2007, Mc Kay & Oleiro, *Schinus terebinthifolius*, slide 33909; Road 14, km 728: 2 pupae, 16 Jul 2007, Mc Kay & Oleiro, collected as leaf miner larva on *Schinus terebinthifolius*; Road 94, 13 km NE Santo Tomé: 4 larva, 21 Sep 2007, Mc Kay & Oleiro, host: *Schinus terebinthifolius*, SEM slides 33912, 34092. Misiones Prov: 26 km N Capióvi: 1 ♂, 26 Mar 2006, Mc Kay & Wheeler, leaf blotcher collected as larva on *Schinus terebinthifolius*, GPS: 016; Road 12: 24 km N Capióvi: 2 ♂, 2 June 2005, Mc Kay & Oleiro, emerged from mines on leaves of *Schinus terebinthifolius*, GPS: 6; Road 12: 26 km N Capióvi: 5 larvae, 6 Jun 2007, Mc Kay & Oleiro, leaf miner on *Schinus terebinthifolius*, SEM slide USNM 34100; Road 12, 2 km N. Libertad: 3 pupae, 20 Jul 2007, SEM slide 33911; 1 ♂, 1 ♀, 2 Aug 2006, reared ex larva blotch miner on *Schinus terebinthifolius*, Mc Kay & Oleiro; Road 14, km 909: 2 ♂, 3 Aug 2006, Mc Kay & Oleiro, slide USNM 33910; Road 14, near Cerro Azul: 3 larvae, 5 Jun 2007, Mc Kay & Oleiro, leaf miner on *Schinus terebinthifolius*, slide USNM 33931; Road 17, 4 km W 9 de Julio: 8 ♂, 5 ♀, 3 Aug 2006, Mc Kay & Oleiro, slides USNM 33655, 33696, 33908; Road 17, 14 km W 9 de Julio: 2 ♂, 3 Aug 2006, Mc Kay & Oleiro, slide USNM 33699; Road 103, 14 km W Oberá: 1 ♂, 15 Oct 2005, Gandolfo & Mc Kay, leaf blotcher collected as larva on *Schinus terebinthifolius*, GPS: 58. Road 103, 16 km W Oberá: 1 larva, 5 Jun 2007, Mc Kay & Oleiro, leaf miner on *Schinus*

terebinthifolius. BRAZIL: Parana: Curitiba Zoo: 1 ♂, 2–7 May 1991, *Schinus terebinthifolius*, D. Habeck; 1 ♂, 9 Oct 1992, pupa 17 Oct 1992, adult 31 Oct 1992, host: *Schinus terebinthifolius*, F.D. Bennett, J.H. Pedrosa Macedo, C. Wikler, M.D. Vitorino. Rio de Janeiro: 41 km SE Campos, S22.07491, W41.15992, RJ 28, 11 m: 3 ♂, 6 ♀, 9 Apr 2008, Wheeler, slides USNM 34022, 34026, collected as pupae, globules on silk perimeter. 13 km NW Cabo Frio, S22.82407 / W42.12493, RJ 51, 4 m, 11 Jul 2008, Wheeler; 2 ♀, 3 Feb 2010, RJ51, host: *Schinus terebinthifolius*, globules on silk perimeter, Wheeler & Mc Kay, slide USNM 34217. Santa Catarina Province: 14 km N Imbituba, S28.10610 / W48.66161, 7 m, 3 , 10 Jul 2008, Wheeler & Mc Kay. Santa Catarina: 14 km N. Imbituba, S28.10610, W48.66161, 7 m: 1 ♂, 2 ♀, 10 Jul 2008, SC7, reared from leafminer on *Schinus terebinthifolius*, Wheeler and Mc Kay, slide USNM 34087; Itapoa, S26.08309, W 48.61151, 12 m: 2 ♂, 12 Jul 2008, SC14, Wheeler and Mc Kay, reared from leafminer on *Schinus terebinthifolius*. Sao Paulo: Alombari [probably Alambari]: 2 ♀, No. 48, 52, 17 Sep 1987, pupa 21 Sep 1987, adult 2 Oct 1987; No 50, 1 ♂, 17 Sep 1987, pupa, 29 Sep 1987, adult 9 Oct 1987, Host: *Schinus terebinthifolius*, L. Crestana, USNM slide 33916. PARAGUAY: Coronel: 7 km W Coronel: 1 ♂, 17 Sep 2004, reared from leaf mines on *Schinus terebinthifolius*, Gandolfo and Mc Kay, slide USNM 33195. (Paratypes deposited in MACN, UPZB, and USNM).

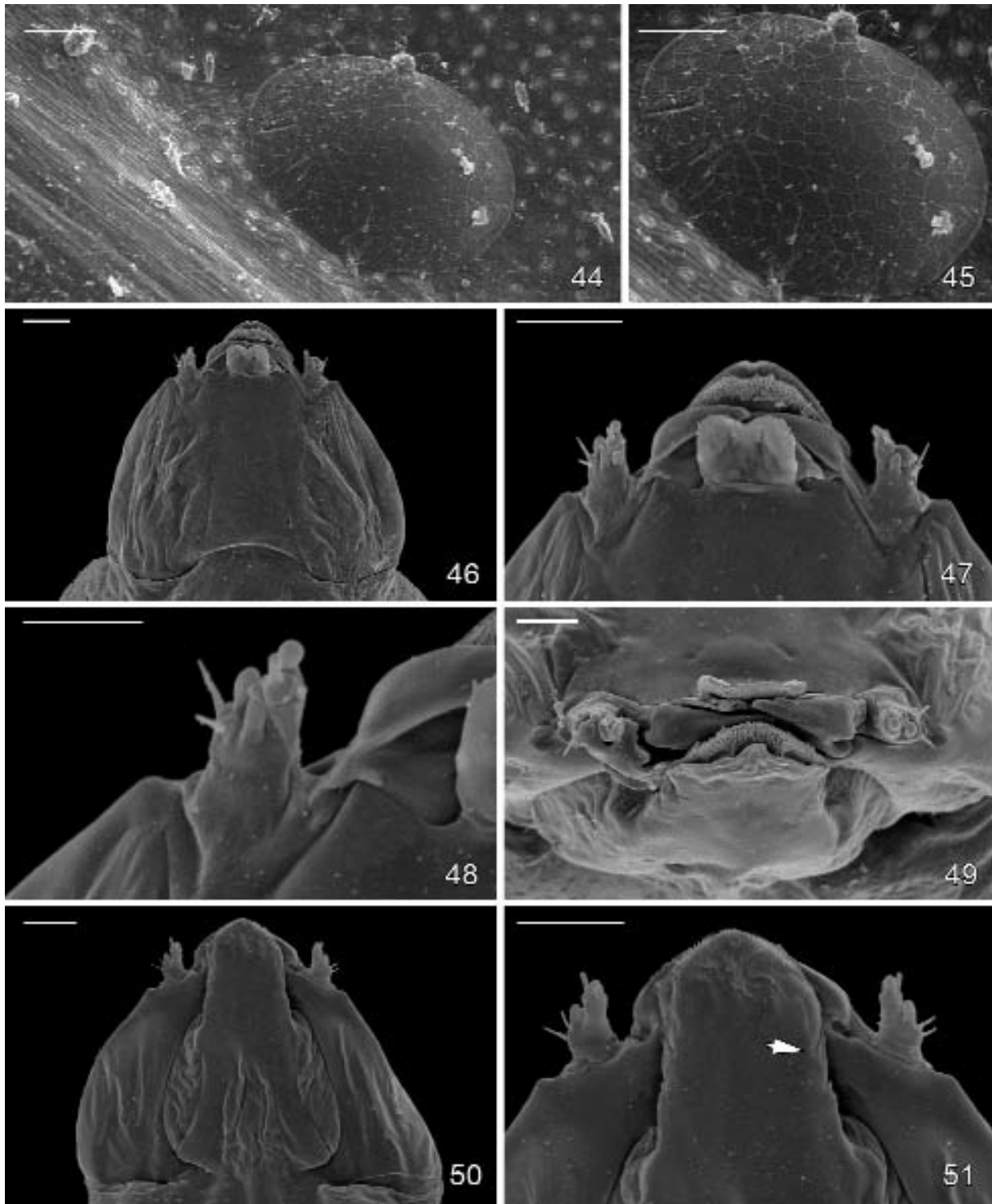
Flight period. Active mines were present year-round, the highest numbers were found during the Austral winter (June–August).

Distribution (Fig. 1). Leaflets of *S. terebinthifolius* infested with blotch mines of *L. schinusae* were found at several localities in northeastern Argentina (Corrientes and Misiones Provinces) and at one site in Paraguay. In Brazil this species was collected near Macae, Rio de Janeiro south to Porto Alegre, Rio Grande do Sul.

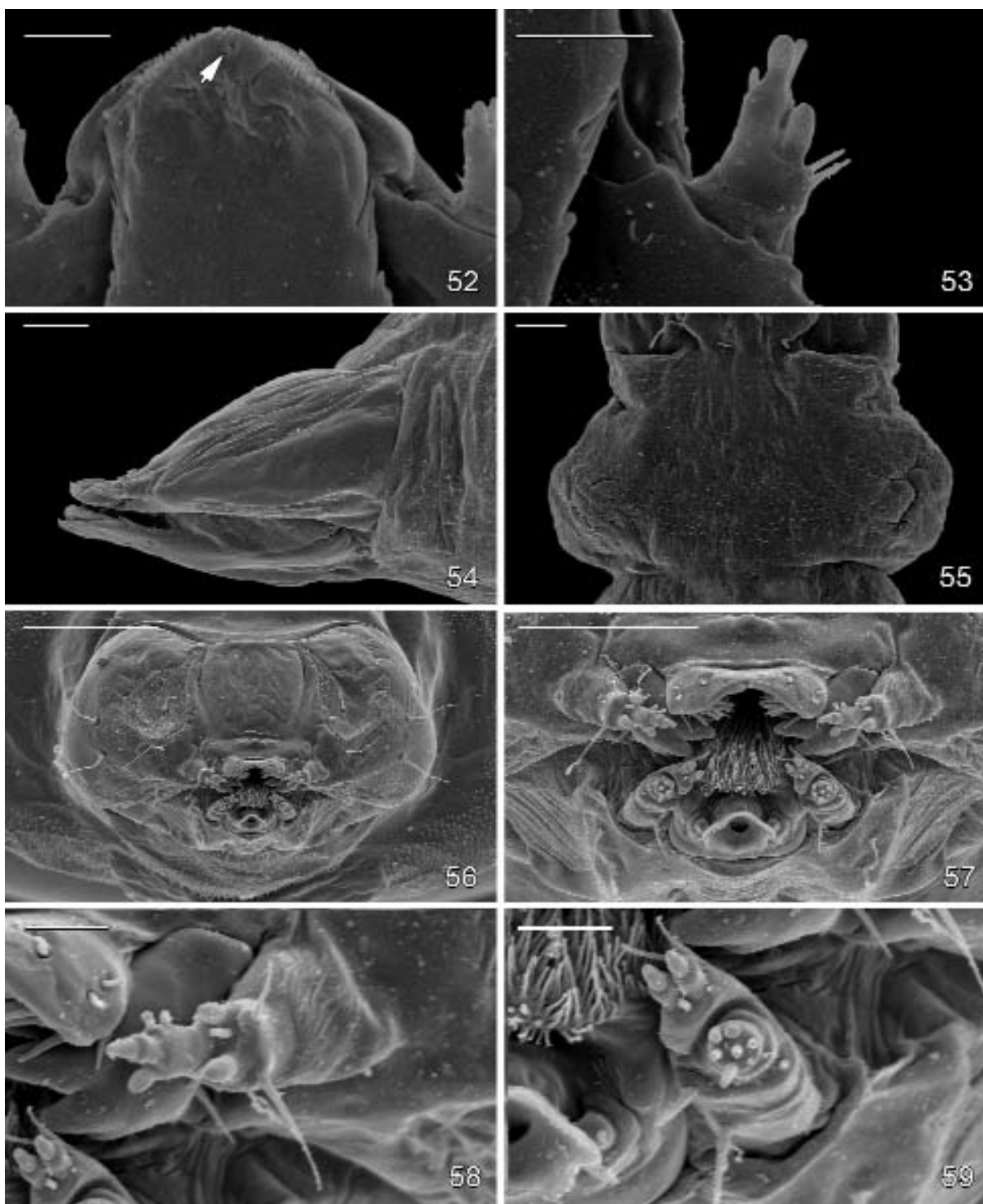
Etymology. The species name is derived from the generic name of the host plant (*Schinus*), with the addition of the genitive suffix (-ae).

Discussion. Other than *Leurocephala*, only a few gracillariid genera have been reported undergoing an additional intermediate larval stage between the sap-feeding and tissue-feeding forms. Intermediate larval forms have been observed in *Chrysaster* and *Dendrorhycter* (Kumata 1978), *Marmara* (DeGryse 1916; Fitzgerald & Simeone 1971; Wagner et al. 2000); and *Neurobathra strigifinitella* (Clemens), (Heinrich & DeGryse 1915). In *Chrysaster*, *Dendrorhycter*, and *Marmara* the transitional instar is a nonfeeding, penultimate instar, and in *N. strigifinitella* it appears as a tissue-feeding, third instar. The intermediate larval form in *L. schinusae* is believed to comprise the second to fourth, tissue-feeding instars (Table 1).

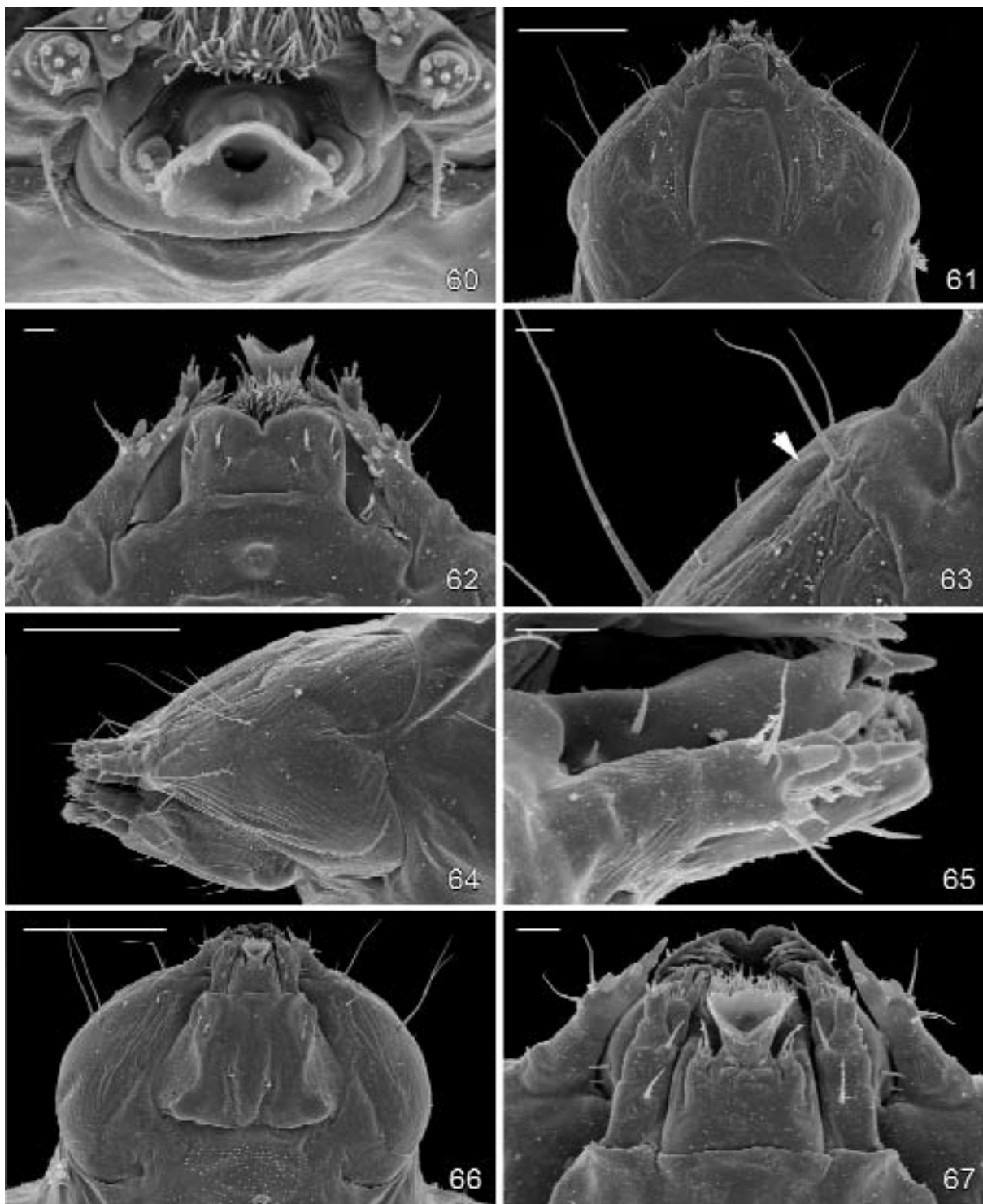
Biological studies were conducted on *Leurocephala schinusae* at the USDA-ARS South American Biological Control Laboratory (SABCL), Hurlingham, Buenos Aires, Argentina between 2006 and 2008. Cultures of *L. schinusae* were established at the laboratory from leaf mines collected on *Schinus*



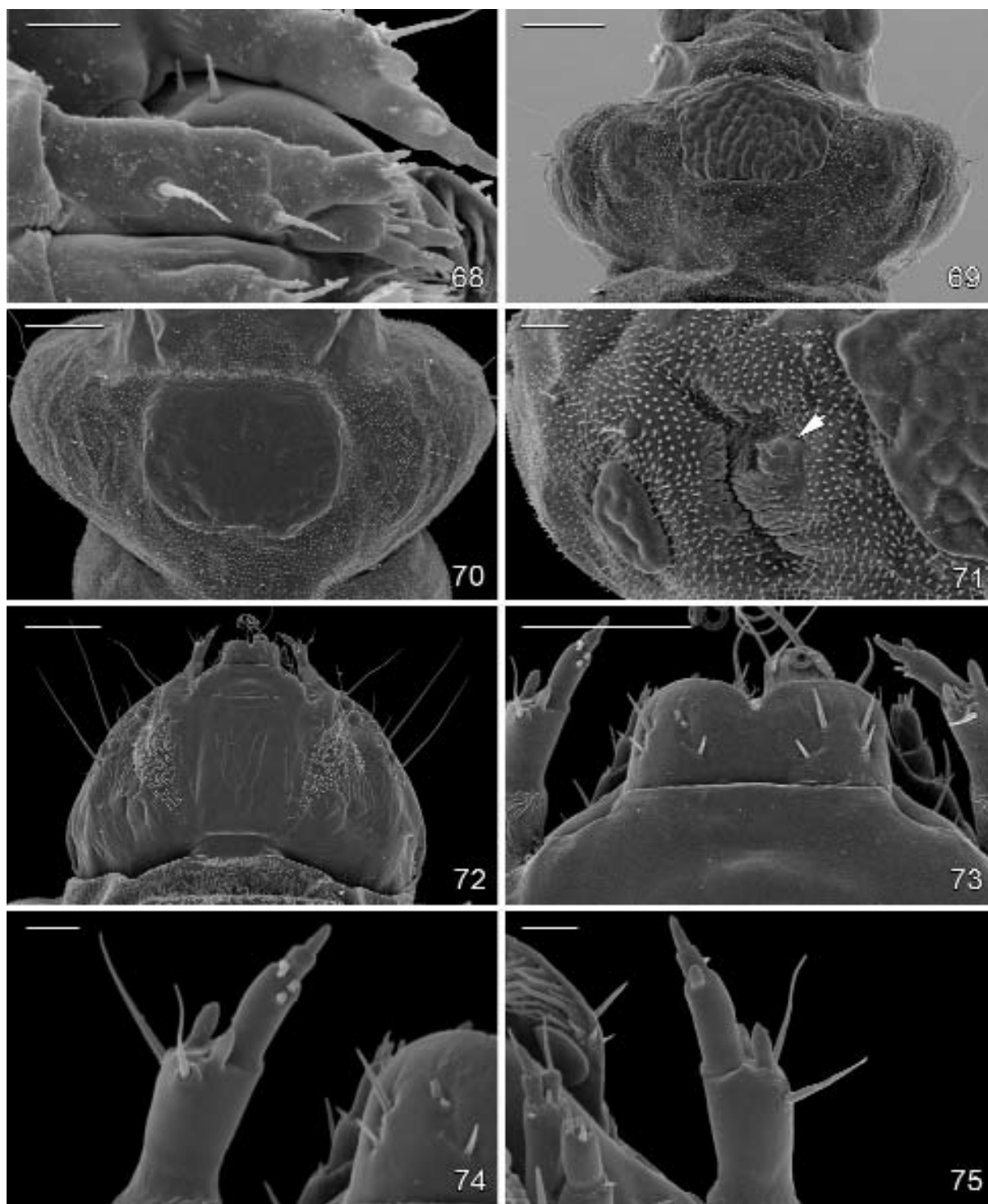
FIGS. 44–51. *Leurocephala schinusae*, Egg and sapfeeding larva. **44.** Egg adjacent to midvein (100 μ). **45.** Detail of egg (100 μ). **46.** Head, dorsal view (20 μ). **47.** Dorsal view of antennae and mouthparts (20 μ). **48.** Dorsal view of antennae (10 μ). **49.** Anterior view of mouthparts (20 μ). **50.** Head, ventral view (20 μ). **51.** Ventral view of antenna and labium; vestigial labial palpus shown by arrow (20 μ). (Length of scale bar in parentheses).



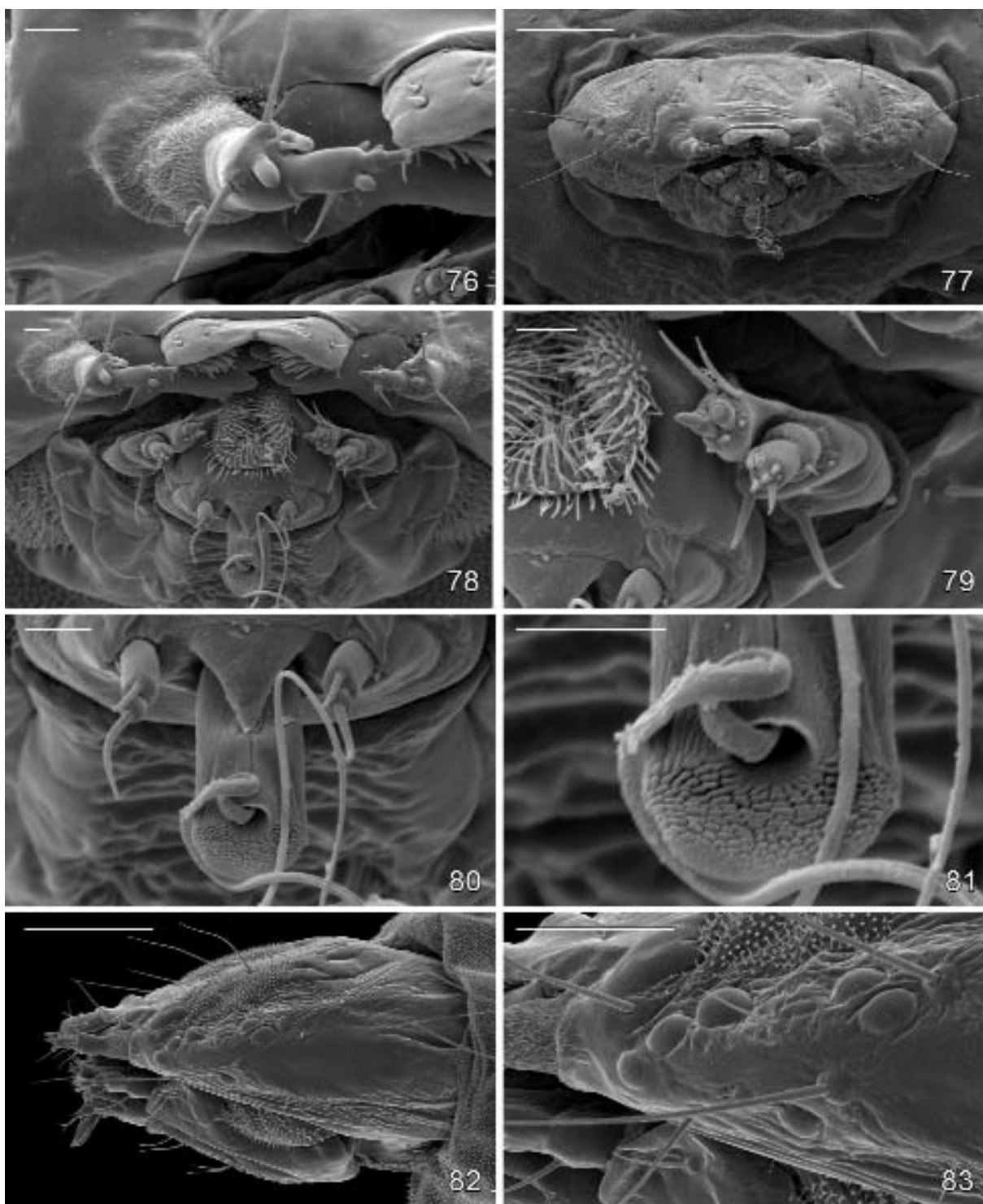
FIGS. 52–59. *Leurocephala schinusae*, sapfeeding larva (Figs. 52–55) and penultimate instar, apodal tissue feeding larva (Figs. 56–59). **52.** Ventral view of labium, spinneret (arrow), and labial palpi (10 μ). **53.** Ventral view of antennae (10 μ). **54.** Head, lateral view (20 μ). **55.** Ventral view of prothorax with paired callosities (20 μ). **56.** Dorsal-anterior view of head (100 μ). **57.** Detail of mouthparts in Fig. 54 (50 μ). **58.** Antenna, lateral view (10 μ). **59.** Maxilla, anterior view (10 μ). (Length of scale bar in parentheses).



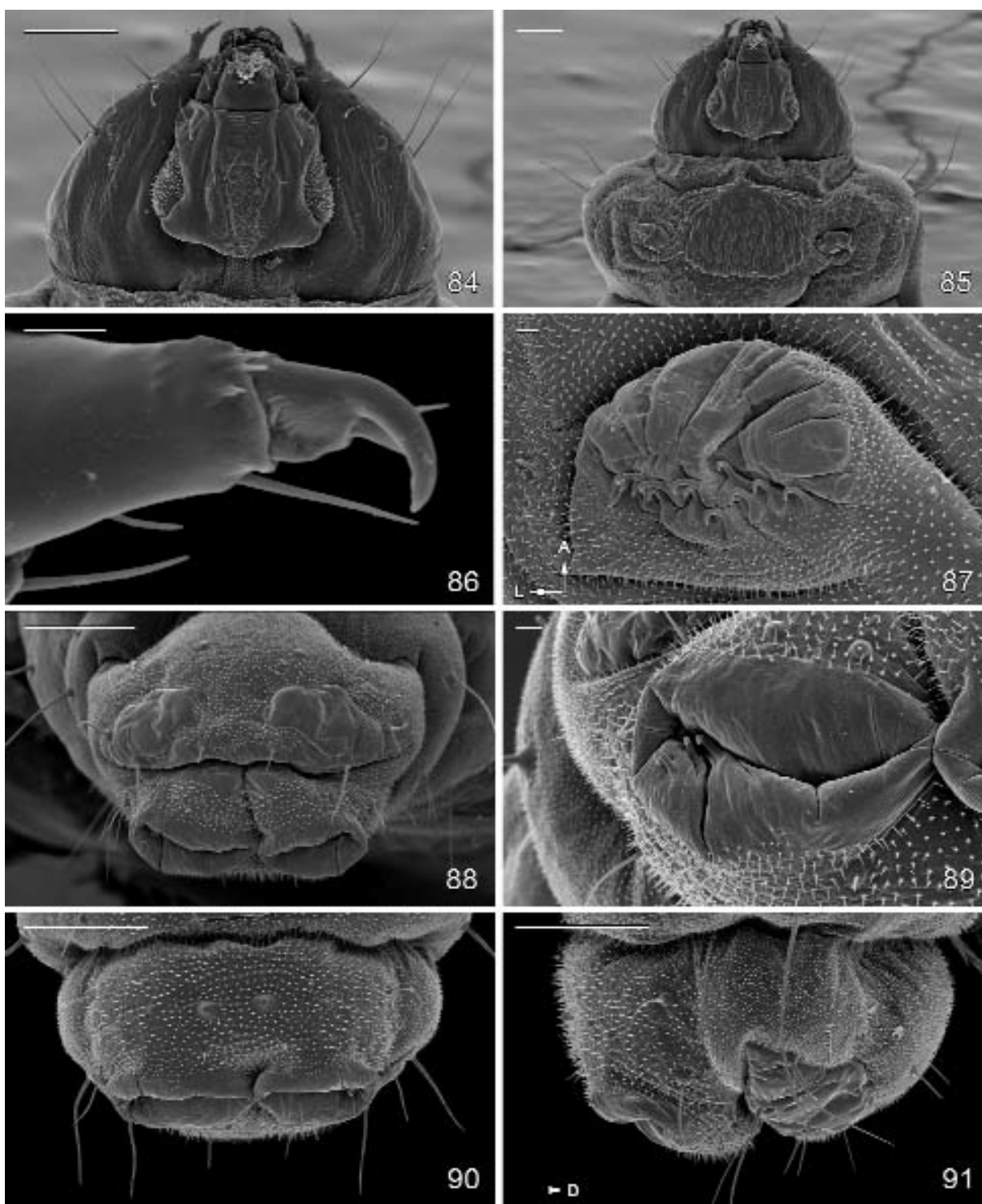
FIGS. 60–67. *Leurocephala schinusae*, penultimate instar, apodal tissue feeding larva. **60.** Spinneret, anterior view (10µ). **61.** Head, dorsal view (100µ). **62.** Dorsal view of antennae and mouthparts (10µ). **63.** Stemmata (arrow), dorsal view (10µ). **64.** Head, lateral view (100µ). **65.** Antenna, lateral view (10µ). **66.** Head, ventral view (100µ). **67.** Detail of mouthparts in Fig. 66 (10µ). (Length of scale bar in parentheses).



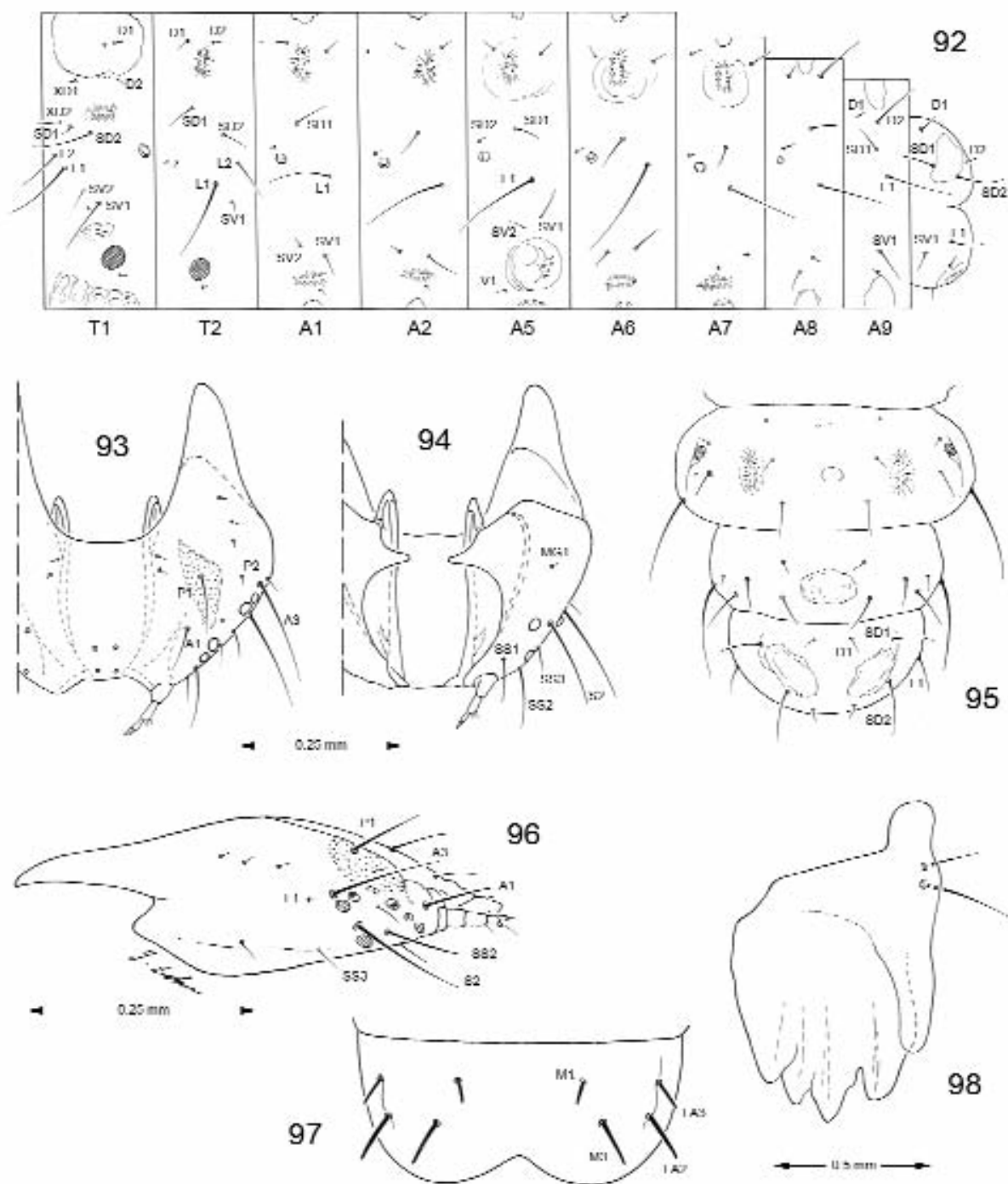
FIGS. 68–75. *Leurocephala schinusae*, penultimate instar, apodal tissue feeding larva (Figs. 68–71) and last instar, tissue feeding larvae (Figs. 72–75). **68.** Maxilla, ventral view (10 μ). **69.** Prothorax, ventral view (100 μ). **70.** Prothorax, dorsal view (100 μ). **71.** Detail of prothorax (Fig. 69) showing rudimentary leg (arrow, 10 μ). **72.** Head of last instar larva, dorsal view (100 μ). **73.** Dorsal view of antennae and mouthparts (50 μ). **74.** Antenna, dorsal view (10 μ). **75.** Antenna, ventral view (10 μ). (Length of scale bar in parentheses).



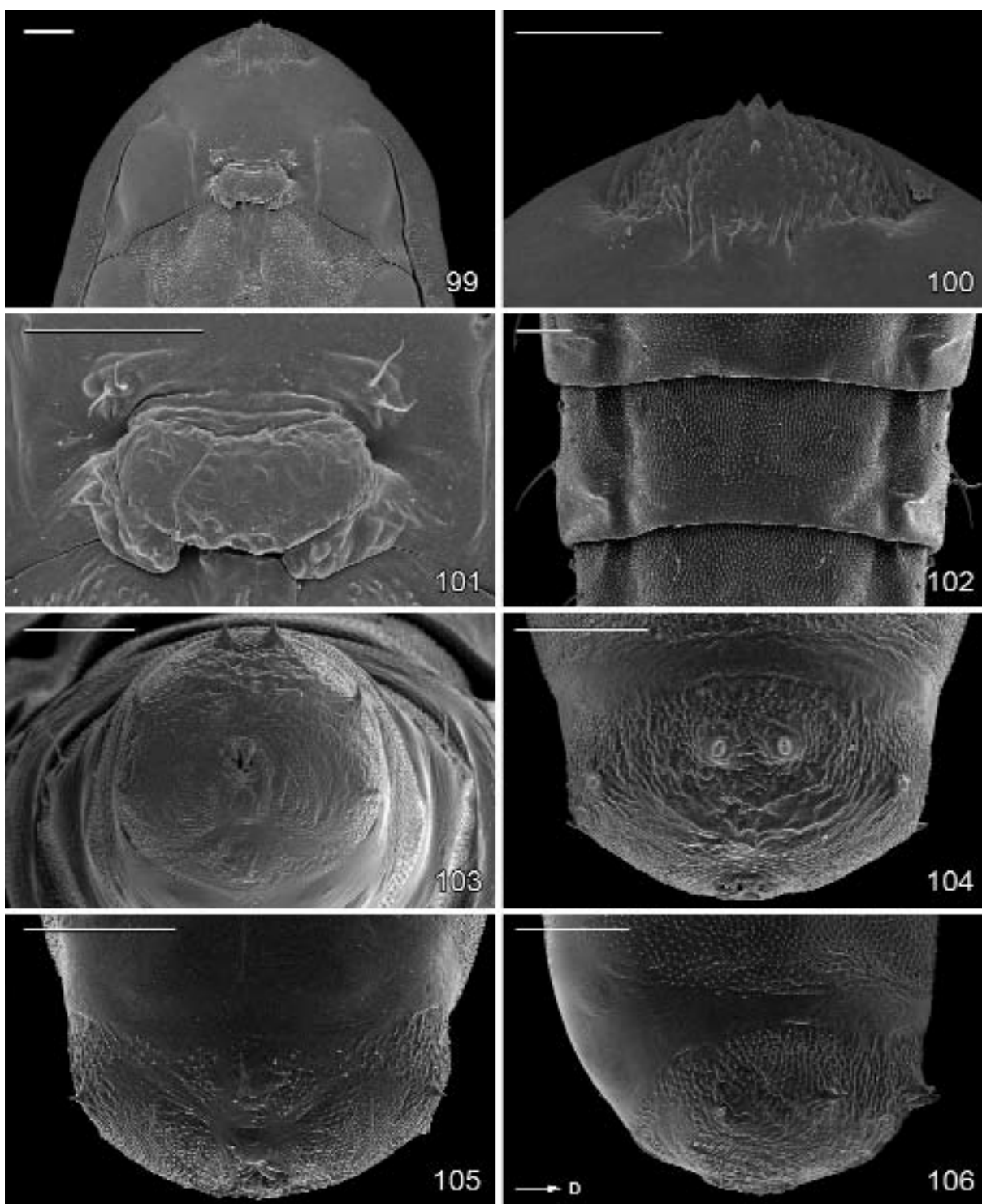
FIGS. 76–83. *Leurocephala schinusae*, last instar tissue feeding larva. **76.** Antenna, anterior view (10µ). **77.** Head, anterior view (100µ). **78.** Mouthparts, anterior view (10 µ). **79.** Detail of left maxilla in Fig. 78 (10µ). **80.** Detail of spinneret (with silk) and labial palpi in Fig. 78 (10µ). **81.** Apex of spinneret (10µ). **82.** Head, lateral view (100µ). **83.** Detail of stemmata in Fig. 82 (50µ). (Length of scale bar in parentheses).



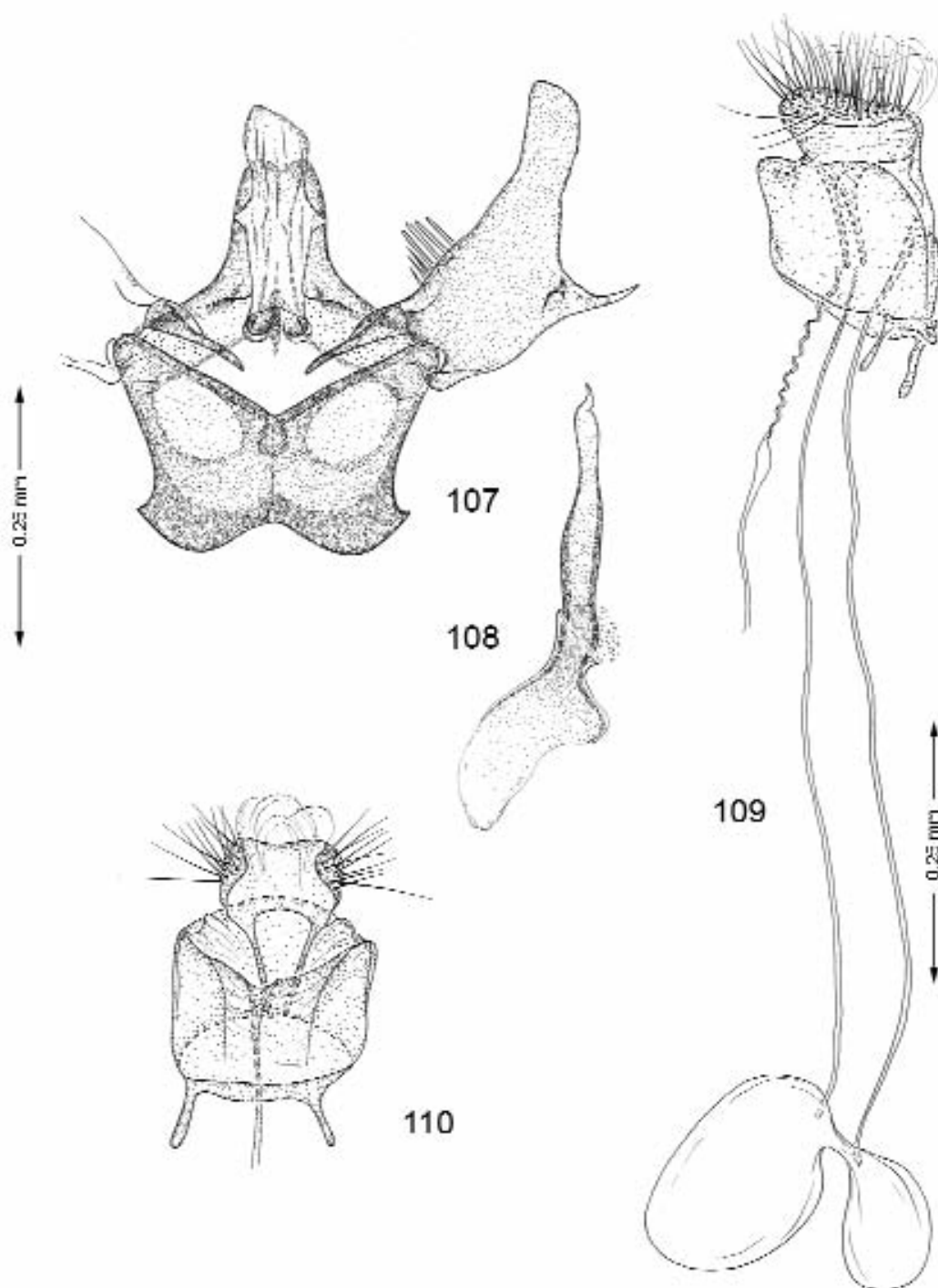
FIGS. 84–91. *Leurocephala schinusae*, last instar tissue feeding larva. **84.** Head, ventral view (100µ). **85.** Head and prothorax, ventral view (100µ). **86.** Thoracic leg (10µ). **87.** Abdominal proleg, A5, A=anterior, L=lateral (10µ). **88.** Abdominal segment 10, dorsocaudal view (100µ). **89.** Anal proleg A10 (10µ). **90.** Abdominal segment 10, ventral view (100µ). **91.** Abdominal segment 10, lateral view, D=dorsal (100µ). (Length of scale bar in parentheses).



FIGS. 92–98. *Leurocephala schinusae*, chaetotaxy of last instar tissue feeding larva. **92.** Lateral schematic of prothorax, mesothorax, and abdominal segments 1, 2, 5–10. **93.** Head, dorsal view. **94.** Head, ventral view. **95.** Dorsal view of abdominal segments 8–10. **96.** Head, lateral view. **97.** Labrum, dorsal view. **98.** Mandible. (Scale lengths indicated).



FIGS. 99–106. *Leurocephala schinusae*, pupa. **99.** Head, ventral view (100 μ). **100.** Head, apex of Fig. 99. **101.** Detail of labrum of Fig. 99 (100 μ). **102.** Abdominal terga A6–7 (100 μ). **103.** Caudal end of abdomen, dorsal side up (100 μ). **104.** Dorsal view of Fig. 101, A10 (100 μ). **105.** Ventral view of Fig. 104 (100 μ). **106.** Lateral view of Fig. 104 (100 μ), D=dorsal. (Length of scale bar in parentheses).



FIGS. 107–110. *Marmara habecki*, genitalia. **107.** Male, ventral view. **108.** Aedeagus. **109.** Female, lateral view. **110.** Ventral view of Fig. 109. (Scale lengths indicated).

terebinthifolius plants growing on the shoulders of secondary roads of north-eastern Argentina. Rearing experiments were conducted in a walk-in chamber under controlled environmental conditions ($25 \pm 1^\circ\text{C}$; $60 \pm 5\%$ RH; 14-10 L:D). Twenty newly emerged adults were confined inside insect rearing sleeves (20 cm in diameter by 60 cm in length) wrapped around branches of potted *S. terebinthifolius* plants. A piece of cotton soaked in water-sucrose solution tied with a wire and hung from the upper access hole of the sleeve constituted the adults' food source. Adults were held for 24h to synchronize oviposition. Measurements were collected on egg incubation time, larval and pupal stage duration. The duration of the different life stages was: 5 days for eggs (mean \pm SD = 5 ± 0 ; $n = 5$), 11–14 days for larvae (mean \pm SD = 12 ± 1.1 ; $n = 19$), and 9–11 days for pupae (mean \pm SD = 10 ± 1.5 ; $n = 19$).

Results of field surveys conducted in Argentina (Mc Kay unpublished data) and Brazil indicate a preference for *Schinus* species. However, host specificity tests currently underway at the quarantine facility of the USDA/ARS/IPRL in Ft Lauderdale, reveal that *L. schinusae* lays eggs and the larvae complete development on native North American Anacardiaceae (*Rhus* species). Consequently, the host range has been determined too broad to be considered as a biocontrol agent against Brazilian peppertree in the United States. (Wheeler unpublished data).

***Marmara habecki* Davis, new species**

Figs. 7–8, 20–21, 107–111.

Diagnosis. The forewing patterns of *Marmara habecki* and *M. smilacisella* (Chambers) are essentially identical, with both subject to slight variation. The morphology of their male valvae is also similar in possessing a large, slightly curved saccular spine and a prominent comb of 4–5 spines arising near the base of the costal margin. The genitalia of the two species differ slightly with the curvature of the lateral margin of the vinculum more concave and the laterocaudal angle slightly flared in *habecki*, compared to being more convex and the angle more rounded in *M. smilacisella*. The larva of *M. habecki* is a stem miner on *Schinus terebinthifolius*, whereas that of *M. smilacisella* has been reared only from the leaves of *Smilax* (Smilacaceae). The most significant difference between the two species is indicated by their different CO1 barcode sequences (Fig. 111) which show a divergence of over 5.6 %.

Adult (Figs. 7–8). *Head*: Frons and vertex smooth, silvery white, irrorated with brown-tipped scales; collar grayish fuscous. Antenna $\sim 0.8\times$ length of forewing; scape fuscous, with pecten consisting of ~ 10 –13 slender, fuscous, piliform scales; pedicel mostly white, with fuscous apical margin; flagellum smoothly scaled, uniformly fuscous, each flagellomere encircled by a single row of slender scales. Maxillary palpus dark fuscous. Labial palpus mostly white, dark fuscous laterally and at apices of segments 2 and 3. *Thorax*: Fuscous dorsally; paler, mostly white ventrally; tegula dark fuscous. Forewing: length 1.8–2.5mm; mostly dark fuscous to black with slight bluish luster, usually with 3 short, triangular, white striae of variable size equally spaced along costa and 3 similar, nearly opposite, white striae along hind margin; basal most striae sometimes fused to form a transverse band; a slender, white costal stria present near subapex at base of fuscous fringe; apex of wing white; terminal fringe with grayish bases to dark-tipped scales. Hindwing uniformly gray. Legs mostly white, strongly banded with dark fuscous at joints. *Abdomen*. Dark fuscous dorsally, except for white scales around T7; partially white ventrally with oblique segmental bands of fuscous laterally at anterior margins of each segment. Male with a pair of coremata consisting of a loose cluster of long, white piliform scales arising ventral-laterally from elongate pockets of eighth segment.

Male genitalia (Figs. 107–108). Uncus absent. Tegumen abruptly constricted to narrow apical half; apex slightly bilobed, with a shallow apical depression. Vinculum broad, with lateral margins curved inwards then flaring slightly outwards at broad, shallowly bilobed anterior margin. Valva with a prominent row of ~ 4 –5 large spines arising near basal third of costal margin and 3–4 smaller spines basal to larger spines; apical half (cucullus) relatively narrow, basally expanding slightly to prominent, elongate saccular lobe bearing a single apical spine; a moderately long, slender triangular lobe projecting mesally from base of saccular lobe. Aedeagus slender, slightly sinuate, with acute apex; total length $\sim 1.3\times$ length of valva; phallobase well developed, usually directed more toward right side of genital capsule, \sim half the aedeagus in length, with hood evenly curved dorsad and with a distinct swelling near junction with of aedeagus.

Female genitalia (Figs. 109–110). Anterior and posterior apophyses short, with posterior apophyses $\sim 1.5\times$ length of anterior pair. Ostium a simple opening on caudal margin of sternum VII. Ductus bursae a very long and slender tube $\sim 10\times$ length of posterior apophyses, terminating on smaller chamber of bilobed corpus bursae. Corpus bursae consisting of two oval chambers connected by a constricted, short passage of variable length. Ductus seminalis similar to ductus bursae in length and diameter, terminating on larger chamber of corpus bursae. Walls of corpus bursae membranous; signum absent.

Hosts. Anacardiaceae: *Schinus terebinthifolius* Raddi.

Parasitoids. In Florida a single parasitoid emerged from the pupa of *M. habecki*, possibly *Copidosoma* sp. Encyrtidae, (Chalcidoidea).

Larval biology (Fig. 20). Larva a stem miner on *Schinus terebinthifolius*. Larvae from Florida (Fig. 20) were observed to mine along the stems a total distance of nearly 70 cm. The width of the stem mines varied from 0.26–2.15 mm. Stem mines of another undescribed species, as indicated by divergent CO1 sequences (Fig. 111), were also discovered on *S. terebinthifolius* in Brazil.

Cocoon (Fig. 21). Cocoons were formed in crevices among dried leaves (in rearing culture) indicating that the larva leaves the mine to pupate. The surface of the cocoon is covered by approximately

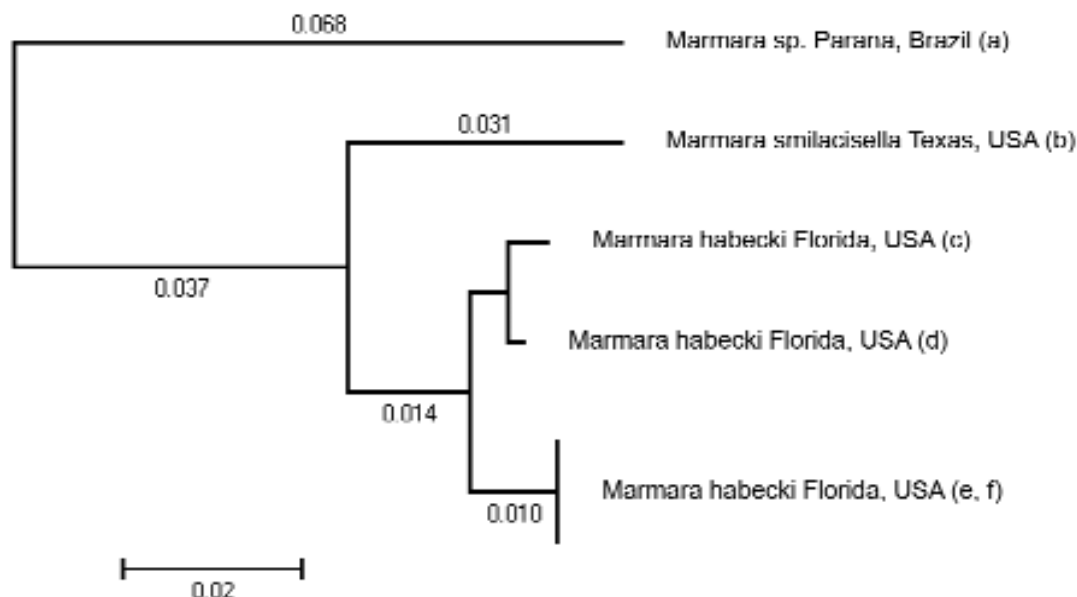


FIG. 111. Sequence distance tree of *Marmara* derived from 6 samples among 3 species based upon neighbor-joining analysis with Kimura 2-parameter model. The analysis shows significant COI divergences among the North American *Marmara smilacisella* reared from *Smilax* (b), the apparently undescribed *Marmara* reared from *Schinus terebinthifolius* in Brazil (a), as well as *Marmara habecki* mostly reared from *Schinus* in Florida, USA (c–f). Sequence lengths are shown on main branches. Pertinent specimen data including source of tissue samples for each specimen are: (a) Brazil: Parana: 13 km W Curitiba, larva, host: *Schinus terebinthifolius*; (b) USA: Texas: Harris Co: Houston, adult legs, host: *Smilax* sp.; (c) USA: Florida: Pinellas Co: Fort Desoto Park, adult legs, host: *Schinus* sp.; (d) USA: Florida: Polk Co: entire moth, Lake Alfred, from *Marmara gulosa* pheromone trap; (e, f) USA: Florida: Broward Co: Fort Lauderdale, larvae, host: *Schinus terebinthifolius*.

30–40 small, silvery, frothy bubbles often arranged in 3–4 smaller clusters of ~ 10–12 bubbles each.

Types. *Holotype*: ♂, USA: FLORIDA: Broward Co: Fort Lauderdale: 13 Aug 2008, Dyer & Wheeler, reared from stem of *Schinus terebinthifolius*, (USNM). *Paratypes* (7 ♂, 7 ♀): USA: FLORIDA: Alachua Co: Edgecliff: 1 ♂, 21 May 1994, adult 5 Jul 1994, DHH rearing, Host: *Schinus* sp., D. Habeck. Collier Co: 1 ♂, em. 2009, Host: *Schinus terebinthifolius*, stem miner, slide USNM 34188. Monroe Station, HWY. 41: 1 ♂, 13 Dec 1989, pupa 16 Dec 1989, adult 8 Jan 1990, DHH rearing #A-5373, Host: *Schinus* sp., berries, J. Gilmore, J. DeNicole, Digital image captured USNM. Lee Co: Ft. Myers: 2 ♂, 14 Sep 1998, adult 1 Oct, Host *Schinus* sp., DHH rearing #A-4542b, D. Habeck, F. Bennett, DRD slide 3731. Monroe Co: Key West: 22 Jul 1991, adult 9 Aug, 1991, F. Bennett, DHH rearing #A-6008, Host: *Schinus* sp., berries & foliage, DRD slide 4491, Digital image captured USNM; 1 ♂, 22 Jul 1991, adult 12 Aug 1991, 1 ♀, 22 July 1991, pupa 2 Aug 1991, adult 9 Aug, 1991, F. Bennett, DHH rearing #A-6008, Host: *Schinus* sp., berries & foliage. Pinellas Co: Ft. Desoto Park: 24 Jan 1989, 1 ♀, adult 10 Feb 1989; 1 ♀, pupa 30 Jan 1989, adult 9 Feb 1989; 1 ♀, pupa 31 Jan 1989, adult 16 Feb 1989, DHH rearing #A-4702c, slide USNM 33926; 1 ♀, pupa 3 Feb 1989, adult 16 Feb 1989, DHH rearing #A-4702c, slide USNM 33919; 1 ♀, pupa 2 Feb 1989, adult 14 Feb 1989; 1 ♂, 4 Feb 1989, adult 20 Feb 1989, DHH rearing #A-4726a, Host: *Schinus* sp., leaves & berries W. Klerks, F. Bennett. Polk Co: Tenoroc: 1 ♀, 13 Jan 1994, adult 1 Feb 1994, D. Habeck, DHH rearing #A-6818, Host: *Schinus terebinthifolius*, slide USNM 34058. (Paratypes deposited in MGCL and USNM).

Other specimens examined: USA: FLORIDA: Polk Co: Lake Alfred: 2 ♂, 25 Sep 2007, L. Stelinski, N-40 Citrus Peelminer,

USNM slide 34146; 2 ♂, Jun 2008, W. L. Meyer, Citrus sp. Pheromone trap. USNM slides 34123, 34124, 2 adults (sex?), BOLD ID: RDOPO096-09, BOLD ID: RDOPO097-09, (USNM).

Flight period. Adult emergences have been reported in Florida from January to mid October with most emergences occurring in February.

Distribution. In Florida this species has been reared on *Schinus terebinthifolius* from Alachua County in northern Florida south to the Florida Keys. Larval mines of an unidentified *Marmara* have been found on stems of *S. terebinthifolius* in Brazil and Argentina, but only a single adult female from near Macae, RJ, Brazil has been reared.

Etymology. This species is named in honor of Dr. Dale Habeck (deceased 17 May 2010) who first reared many of the specimens studied in this report.

Discussion. The genus *Marmara* is known to occur only in the New World where 23 species have been described, 19 of these from North America north of Mexico (De Prins & De Prins 2010). The Neotropical leafmining fauna, however, is largely unknown (Guillén et al. 2001).

Adults of *M. habecki* are nearly inseparable morphologically from *M. smilacisella*. As noted in the

diagnoses, slight differences have been observed in the shape of the male vinculum, with that of *habecki* possessing more concave lateral margins and more flared anterocaudal angles. Distinct differences in their larval biologies are probably significant, although polyphagy and variation between a leaf mining and stem mining habit have been reported in at least one other *Marmara*, *M. gulosa* (Guillén et al. 2001). Because of these uncertainties, attempts were made to obtain CO1 barcode sequences from the few most recently collected populations available of *M. habecki* and *M. smilacisella*, as well as of an unidentified stem mining *Marmara* discovered on *S. terebinthifolius* in Argentina and Brazil. Of the 10 specimens submitted, 4 could not be sequenced. The 6 specimens that were (for the entire 658 bp segment) revealed three distinct groups, each separated by a minimum divergence of 4.5% or more (Fig. 111). Although only a single female was reared from the Brazilian stem mines, CO1 sequence divergence of nearly 12% between the Brazil and Florida populations strongly suggest that these represent distinct species. Because females often provide inadequate morphological diagnostics in this genus, males need to be reared from the Brazilian populations, and more specimens in general need to be sequenced to verify these conclusions.

During a recent survey for *Marmara* pests of Citrus in southern Florida using sticky traps baited with the sex pheromone of the citrus peelminer, *Marmara gulosa* Guillén and Davis from California (W. Meyer in litt.), numerous adult *M. habecki* were collected. These adults were very similar to the adults of *habecki* reared from *Schinus* stem mines in their CO1 barcode sequences and male genitalia but were not included in the type series because of their poor physical condition.

Although most of Habeck's rearing labels variously state "berries", "berries & foliage", or "leaves & berries", it is apparent from Habeck's rearing records, graciously provided by D. Mathews Lott, that most of the moths were reared from the stems of *Schinus terebinthifolius*. This is particularly evident in records A4542b, A4702c, A4726a, A6008, and A6818.

ACKNOWLEDGEMENTS

We wish to thank Young Sohn of the Department of Entomology, Smithsonian Institution and Diana Marques, Lisbon, Portugal, for the line illustrations, and Patricia Gentili-Poole of the Department of Entomology, Smithsonian Institution, who assisted with graphics and final preparation of plates. SEM images were done by P. Gentili-Poole, assisted by Scott Whittaker of the SEM Laboratory, National Museum of Natural History. Mignon Davis of the Department of Entomology, Smithsonian Institution recorded specimen data and assisted with specimen curation. We wish to thank Akito Kawahara for providing DNA sequence data for specimens

provided of *Leurocephala schinusae*, Deborah Mathews Lott and the late Dale Habeck of the McGuire Center for Lepidoptera and Biodiversity, Florida Museum of Natural History, Gainesville, Florida, for the loan of essential specimens and for rearing data from *Schinus terebinthifolius*. We are indebted to Jason Weintraub, Academy of Natural Sciences, Philadelphia, and David Wagner, University of Connecticut, Storrs, CT., for loans of *Marmara smilacisella*, and to Frank Howarth, B. P. Bishop Museum, Bernarr Kumashiro of the Hawaii Department of Agriculture, Honolulu, and Tracy Johnson of the Institute of Pacific Islands Forestry, USDA Forest Service, Volcano, Hawaii for the loan of *Caloptilia corsucans*. Parasitoid identifications were generously provided by David Wahl of the American Entomological Institute for Ichneumonidae, James Whitfield of the University of Illinois and Robert Kula of the USDA/ARS Systematic Entomology Lab for Braconidae, and Michael Gates of the USDA/ARS Systematic Entomology Lab for Chalcidoidea. The DNA barcode sequences were generated at the Biodiversity Institute of Ontario with funding to Paul D.N. Hebert from Genome Canada through the Ontario Genomics Institute, NSERC, and the Ontario Ministry of Research and Innovation. Stephanie Kirk and Jeremy deWaard of the Biodiversity Institute of Ontario also were helpful in preparing specimens for barcoding.

Lauren Helgen of the Department of Entomology, Smithsonian Institution assisted DRD in preparing the *Marmara* tree, figure 111. Wendy Meyers, Citrus Research and Education Center, University of Florida, Lake Alfred, Florida provided specimens for identification of *Marmara habecki* collected from survey traps. Brazilian insect collections were conducted under the Instituto Brasileiro do Meio Ambiente IBAMA permits. This project was partially funded by Florida Fish and Wildlife Federation and South Florida Water Management District.

LITERATURE CITED

- BARKLEY, F. A. 1944. *Schinus* L. Brittonia 5: 160–198.
 BARKLEY, F. A. 1957. A study of *Schinus* L. Lilloa 28: 5–110.
 BENNETT, F. D., L. CRESTANA, D. H. HABECK, & E. BERTI-FILHO. 1990. Brazilian peppertree - prospects for biological control. Pp. 293–297, in E. S. Delfosse (ed.), Proceedings VII International Symposium on Biological Control of Weeds, 6–11. March 1988, Rome, Italy. Instituto Sperimentale per la Patologia Vegetale Ministero dell' Agricoltura e delle Foreste, Rome/CSIRO, Melbourne, Australia. 701 pp.
 BENNETT, F. D., & D. H. HABECK. 1991. Brazilian peppertree - perspectives for biological control in Florida. Pp. 23–33, in T. D. Center, R. F. Doren, R. L. Hofstetter, R. L. Myers, & L. D. Whiteaker (eds.), Proceedings of the Symposium on Exotic Pest Plants, 2–4. November 1988, Miami, FL. U. S. Dept. Interior, National Park Service, Washington, DC. 387 pp.
 BRAUN, A. F. 1909. Notes on Chambers species of Tineina. Ent. News, 20: 428–434.
 CHAMBERS, V. T. 1875. Tineina of the Central United States. Cincinnati Quart. J. Sci. 2(2): 97–121.
 D' ARAÚJO E SILVA, A. G., C. R. GONÇALVES, D. M. GALVÃO, A. J. L. GONÇALVES, J. GOMES, M. N. SILVA, & L. DE SIMONI. 1968. Quarto catálogo dos insetos que vivem nas plantas do Brasil. Seus parasitos e predadores. Parte II, 1. Ministerio da Agricultura, Rio de Janeiro. 622 pp.
 DAVIS, C. J. & N. L. KRAUSS. 1962. Recent introductions for biological control in Hawaii - VII. Proc. Hawaiian Entomol. Soc. 18: 125–129.
 DAVIS, D. R., R. C. KASSULKE, K. L. HARLEY, & J. D. GILLET. 1991. Systematics, morphology, biology, and host specificity of *Neurostrotta gunniella* (Busck) (Lepidoptera: Gracillariidae), an agent for the biological control of *Mimosa pigra* L. Proc. Ent. Soc. Washington 93(1):16–44.

- DAVIS, D. R. & D. L. WAGNER. 2002 [2005]. Biology and systematics of the Neotropical leafminer genus *Eucosmophora* (Lepidoptera: Gracillariidae). *Trop. Lepid.* 13 (1–2): 1–40, 205 figs, 3 maps.
- DE PRINS, J. & W. DE PRINS. 2005. World catalogue of insects, vol. 6, Gracillariidae (Lepidoptera). Apollo Books, Stenstrup. 502 pp.
- . 2010. Global taxonomic database of Gracillariidae (Lepidoptera). World Wide Web electronic publication (<http://gc.bebif.be>) [accessed 15 April 2010].
- DYAR, H. G. 1902 [1903]. A list of the North American Lepidoptera and key to the literature of this order of insects. *Bull. U. S. Nat. Mus.* 52: i–xix, 1–723.
- EWEL, J. 1986. Invasibility: lessons from South Florida. Pp. 214–230, in H. A. Mooney & J. A. Drake (eds.), *Ecology of Biological Invasions of North America and Hawaii*, Springer-Verlag, NY. 321 pp.
- FERGUSON, D. C., D. J. HILBURN, & B. WRIGHT. 1991. The Lepidoptera of Bermuda: their food plants, biogeography, and means of dispersal. *Mem. Ent. Soc. Canada* 158:1–105.
- FITZGERALD, T. L. & J. B. SIMEONE. 1971. Description of the immature stages of the sap feeder *Marmara fraxinicola* (Lepidoptera: Gracillariidae). *Ann. Ent. Soc. Amer.* 64: 765–770.
- FLEPPC PLANT LIST COMMITTEE. 2009. Florida Exotic Pest Plant Council's 2009 list of invasive species. *Wild. Weeds* 12: 13–16.
- FORBES, W. T. M. 1923. The Lepidoptera of New York and neighboring states, part 1, primitive forms, Microlepidoptera, Pyraloids, Bombyces. Cornell University Agriculture Experiment Station. *Memoir* 68: 1–729. Ithaca, New York.
- GANN, G. D., K. BRADLEY, & S. W. WOODMANSEE. 2001. Floristic inventory of South Florida database. Available at: [<http://www.regionalconservation.org>.] Accessed 1/Oct/2009.
- GOGUE, G. J., C. J. HURST, & L. BANCROFT. 1974. Growth inhibition by *Schinus terebinthifolius*. *HortScience* 9: 301.
- GUILLÉN, M., D. R. DAVIS, & J. M. HERATY. 2001. Systematics and biology of a new, polyphagous species of *Marmara* (Lepidoptera: Gracillariidae) infesting grapefruit in the Southwestern United States. *Proc. Ent. Soc. Washington* 103(3):636–654.
- HABIBABAEI, M., D. H. JANZEN, J. M. BURNS, W. HALLWACHS, & P. D. N. HEBERT. 2006. DNA barcodes distinguish species of tropical Lepidoptera. *Proc. Nat. Acad. Sci. U. S. A.* 103(4): 968–971.
- HEBERT, P. D. N., E. H. PENTON, J. M. BURNS, D. H. JANZEN, & W. HALLWACHS. 2004. Ten species in one: DNA barcoding reveals cryptic species in the Neotropical skipper butterfly *Astraptes fulgerator*. *Proc. Nat. Acad. Sci. U. S. A.* 101 (41): 14, 812–14, 817.
- HEINRICH, C. & J. J. DEGRYSE. 1915. On *Acrocercops strigifinitella* Clemens. *Proc. Ent. Soc. Washington* 17: 6–14, plates 1–8.
- [HSASC] HAWAII STATE ALIEN SPECIES COORDINATOR. 2001. Hawaii's most invasive horticultural plants. Department of Land & Natural Resources and Division of Forestry & Wildlife. Honolulu, HI, USA. Available at [<http://www.state.hi.us/dlnr/dofaw/hortweeds/specieslist.htm>]. Accessed 1/Oct/2009.
- HIGHT, S. D., J. P. CUDA, & J. C. MEDAL. 2002. Brazilian peppertree. Pp. 311–321, in R. G. Van Driesche, S. Lyon, B. Blossey, M. S. Hoddle & R. Reardon (eds.), *Biological Control of Invasive Plants in the Eastern United States*, USDA Forest Service, Morgantown, WV. 413 pp.
- JBRJ. 2009. INSTITUTO DE PESQUISAS JARDIM BOTÂNICO DO RIO DE JANEIRO. Jabot - Banco de Dados da Flora Brasileira. Available at: [<http://www.jbrj.gov.br/jabot>]. Accessed 1/Oct/2009.
- KAWAHARA, A.Y. 2010. Phylogenomics, life-history, evolution and taxonomy of leaf mining moths (Lepidoptera: Gracillarioidea). Ph.D. Dissertation. University of Maryland, College Park. 170 pp.
- KLIMESCH, J. 1970. *Caloptilia schinella* Wlsghm (1907) (= *C. terebinthiella* Chret. 1910) Lep., Lithocolletidae). *Nachrichtenblatt der Bayerischen Entomologen* 19(5): 84–89.
- KRAUSS, N. L. 1962. Biological control investigations on insect, snail and weed pests in tropical America, 1961. *Proc. Hawaiian Ent. Soc.* 18: 131–133.
- . 1963. Biological control investigations on Christmas berry (*Schinus terebinthifolius*) and *Emex* (*Emex* spp.). *Proc. Hawaiian Ent. Soc.* 18: 281–287.
- MARKIN, G. P. 2001. Notes on the biology and release of *Caloptilia* sp. nr. *schinella* (Walsingham) (Lepidoptera: Gracillariidae), a biological control moth for the control of the weed Firetree (*Myrica faya* Aiton) in Hawaii. *Proc. Hawaiian Ent. Soc.* 35:67–76.
- MARTIN, C. G., J. P. CUDA, K. D. AWADZI, J. C. MEDAL, D. H. HABECK, & J. H. PEDROSA-MACEDO. 2004. Biology and laboratory rearing of *Episimus utilis* (Lepidoptera: Tortricidae), a candidate for classical biological control of Brazilian peppertree, *Schinus terebinthifolius* (Anacardiaceae), in Florida. *Environ. Entomol.* 33: 1351–1361.
- MCDUNNOUGH, J. H. 1939. Check list of the Lepidoptera of Canada and the United States of America. Part II. Microlepidoptera. *Memoirs S. California Acad. Sci.* 2 (1): 1–171.
- MC KAY, F., M. OLEIRO, G. CABRERA WALSH, D. GANDOLFO, J. P. CUDA, & G. S. WHEELER. 2009. Natural enemies of Brazilian peppertree (Sapindales: Anacardiaceae) from Argentina: their possible use for biological control in the USA. *Florida Entomol.* 92: 292–303.
- MEDAL, J. C., M. D. VITORINO, D. H. HABECK, J. L. GILLMORE, J. H. PEDROSA, & L. P. DE SOUSA. 1999. Host specificity of *Heteroperreyia hubrichi* Malaise (Hymenoptera: Pergidae), a potential biological control agent of Brazilian peppertree (*Schinus terebinthifolius*). *Biol. Control.* 14: 60–65.
- MEYRICK, E. 1912. Adelidae, Micropterigidae, Gracillariidae. In: Wagner (ed.), *Lepidopterorum Catalogus*, Pars 6, W. Junk, Berlin, pp. 1–68.
- MORGAN, E. C., & W. A. OVERHOLT. 2005. Potential allelopathic effects of Brazilian pepper (*Schinus terebinthifolius* Raddi, Anacardiaceae) aqueous extract on germination and growth of selected Florida native plants. *Torrey Bot. Soc.* 132: 11–15.
- MORTON, J. F. 1978. Brazilian pepper-Its impact on people, animals and the environment. *Econ. Bot.* 32: 353–359.
- MUÑOZ, J. D. 2000. Anacardiaceae. Pp. 1–28. In: A. T. Hunziker (ed.), *Flora Fanerogámica Argentina* 65. Conicet, Córdoba, Argentina.
- MYTINGER, L. & G. B. WILLIAMSON. 1987. The invasion of *Schinus* into saline communities of Everglades National Park. *Florida Sci.* 50: 7–12.
- NYBG. 2009. New York Botanical Garden. Available at: [<http://www.nybg.org>]. Accessed 1/Oct/2009.
- PANETTA, F. D. & J. MCKEE. 1997. Recruitment of the invasive ornamental, *Schinus terebinthifolius* is dependent upon frugivores. *Australian J. Ecol.* 22: 432–438.
- RANDALL, J. M. 1993. Exotic weeds in North American and Hawaiian natural areas: The Nature Conservancy's plan of attack. Pp. 159–172. In: B. N. McKnight (ed.), *Biological Pollution: The Control and Impact of Invasive Exotic Species*. Indiana Academy of Sciences, Indianapolis, IN. 270 pp.
- . 2000. *Schinus terebinthifolius* Raddi. Pp. 282–287. In: C. C. Bossard, J. M. Randall, & M. C. Hoshovsky (eds.), *Invasive Plants of California's Wildlands*. University of California Press, Berkeley, CA. 360 pp.
- RATNASINGHAM, S. & P. D. N. HEBERT. 2007. BOLD: The barcoding of life data system (<http://www.barcodinglife.org>). *Molecular Ecology Notes* 7(3):355–364.
- ROBINSON, G. S., P. R. ACKERY, I. J. KITCHING, G. W. BECCALONI, & L. M. HERNANDEZ. 2007. Hosts—a database of the world's Lepidopteran hostplants. World Wide Web electronic publication. The Natural History Museum. <http://www.nhm.ac.uk>. [accessed 21 July 2009].

- TAMURA, K., J. DUDLEY, M. NEI, & S. KUMAR. 2007. MEGA4: Molecular Evolutionary Genetics Analysis (MEGA) Software Version 4.0. *Molecular Biology and Evolution* 24:1596–1599.
- TRIBERTI, P. 1985. A revision of the genus *Aspilapteryx* Spuler (Lepidoptera, Gracillariidae). *Zeitschrift der Arbeitsgemeinschaft Österr. Entomologen*, 37 (1/2):1–16. Tropicos.org. Missouri Botanical Garden Available at: [http://www.tropicos.org]. Accessed 1/Oct/2009.
- TROPICOS.ORG. 2009. Missouri Botanical Garden. <http://www.tropicos.org>. [Accessed 21/July/2009].
- USDA, NRCS. 2009. The PLANTS database. Available at: [http://plants.usda.gov]. Accessed 19/Feb/2009.
- VARI, L. 1961. Lithocolletidae. South African Lepidoptera. Vol. 1. Mem. 12, xix + 238 p., 112 pls. Pretoria: Transvaal Museum.
- WAGNER, D. L., J. L. LOOSE, T. D. FITZGERALD, J. A. DEBENEDICTUS, & D. R. DAVIS. 2000. A hidden past: the hypermetamorphic development of *Marmara arbutiella* (Lepidoptera: Gracillariidae). *Ann. Ent. Soc. America* 93(1): 59–64.
- WALSINGHAM, LORD. 1907 [1908]. Microlepidoptera of Tenerife. *Proc. Zool. Soc. London*, pp. 911–1034, pls. LI–LIII.
- WUNDERLIN, R. P. & B. F. HANSEN. 2008. Atlas of Florida vascular plants (<http://www.plantatlas.usf.edu/>). [S. M. Landry and K. N. Campbell (application development), Florida Center for Community Design and Research.] Institute for Systematic Botany, University of South Florida, Tampa.
- YOSHIOKA, E. R. & G. P. MARKIN. 1991. Efforts of biological control of Christmas berry *Schinus terebinthifolius* in Hawaii. Pp. 377–385. *In*: T. D. Center, R. F. Doren, R. L. Hofstetter, R. L. Myers, & L. D. Whiteaker (eds.), *Proceedings of the Symposium on Exotic Pest Plants*, 2–4. November 1988, Miami, FL. U. S. Dept. Interior, National Park Service, Washington, DC. 387 pp.

Received for publication 21 July 2010; revised and accepted 11 May 2011.