

# Biology of a New Panamanian Bagworm Moth (Lepidoptera: Psychidae) with Predatory Larvae, and Eggs Individually Wrapped in Setal Cases

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**ABSTRACT** The biology and morphology of all stages of a new species of Psychidae from Panama, *Perisceptis carnivora* Davis (Lepidoptera: Psychidae), are described. The larvae of this bagworm are unusual in being obligatory predators, feeding on a broad range of living arthropods, including Arachnida, Coleoptera, Homoptera, Hymenoptera, Neuroptera, and Orthoptera. Probably because of their relative abundance, ants seem to be the most frequent prey. The eggs of this species are protected in a manner that may be unique for insects. Soon after an egg exits the female ovipore, it is wrapped inside a small cocoon-like case constructed of specialized setae from the seventh abdominal segment. Hypotheses as to how these eggs are wrapped and how the cases may protect the eggs are proposed.

**KEY WORDS** egg case, life history, morphology, predation

Whereas adult Lepidoptera depend upon a variety of food sources, the larvae of >99% of all described species are herbivorous (Strong et al. 1984, Pierce 1995). The larvae of a few species of Lepidoptera are known to prey on Homoptera (especially Cicadelloidea, Coccoidea, and Fulgoroidea), or social Hymenoptera (four different subfamilies of Formicidae in particular; De Vries 1992). Aphytophagy (the habit of feeding on nonvegetable hosts) has been well documented for several members of Lycaenidae (see De Vries 1992, and references therein), Tineidae (Davis and Robinson 1998, Davis and Davis 2007), as well as for a few other ditrysian families (Hinton 1951, Pierce 1995, Chapman et al. 1999, Rubinoff and Haines 2005). Some 200 species ( $\approx 0.13\%$  of all described Lepidoptera species) are known to be obligate predators or ectoparasites (Pierce 1995). Numerous references in the literature have noted briefly that larvae of several “primitive” Psychidae tend to eat dead insects or spiders (Hättenschwiler 1997, Sugimoto and Saigusa 2004), or even may be facultatively carnivorous (Saigusa 1961, Davis 1964, Villanueva and Childers 2005).

The accidental discovery on 25 December 1997 at El Parador de Sierra Llorona, Santa Rita, Colon Province, Panama, of a case-bearing larva, whose case was studied with ant and other arthropod fragments, suggested that this larva could be predaceous. This finding

prompted an intense search for additional specimens of this previously unknown moth. Here, we establish its taxonomic position, describe its morphological stages, report our findings regarding the habitat and the predatory behavior of the larva, and briefly describe a possible new defensive strategy for lepidopteran eggs.

## Materials and Methods

Several psychid larval cases, some containing larvae, were hand collected between 1997 and 2006 in the central region of the Isthmus of Panama, on the Caribbean slopes of the Cordillera Central and associated hills. Larvae were kept in the laboratory inside transparent plastic containers, at temperatures between 23 and 27°C, with a 5- by 1-cm cotton-plugged glass vial filled with water. To test larval food preferences, larvae were offered the following potential foods found in the immediate vicinity of the capture site: live ants (*Camponotus lindigi* Mayr, Formicinae; *Dolichoderus* sp., Dolichoderinae; and *Procrystocerus* sp., Myrmicinae), termites (*Nasutitermes* sp.) and material from termite tunnels. Larval behavior was observed and photographed. Larvae were reared to adults and checked for possible parasitism. Adults, larvae, pupal skins, and egg cases were photographed with a Microptics photographic system and Nikon D1X camera. Samples of eggs, egg cases, and larvae were prepared in a critical point drier, sputter coated with 20–25 gold palladium 60:40 alloy, and photographed with an Amray 1810 scanning electron microscope. Specimens examined are deposited in the collections of Museo de

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Invertebrados G. B. Fairchild, Universidad de Panamá, Estafeta Universitaria, Rep. de Panamá (MIUP) and collections of the former United States National Museum, now deposited in the National Museum of Natural History, Smithsonian Institution, Washington, DC) (USNM).

### Systematics and Morphology

The Family Psychidae includes  $\approx 1,000$  species (Heppner 1991) in  $>300$  genera distributed worldwide. Their larvae construct portable cases, as do genera in at least 10 other families of Lepidoptera (Yen et al. 2004, Rhainds et al. 2008). The adult female has evolved a greater array of morphological specializations within Psychidae, especially involving appendage reductions, than have occurred in any other family of Lepidoptera. Males are always fully winged; the females can be fully winged, brachypterous, apterous, or vermiform (with all body appendages vestigial or lost). The morphological reduction of the wings in the females is a derived state that has occurred secondarily at least three times within Psychidae (Davis 1964, Yen et al. 2004, Rhainds et al. 2009).

The genus *Perisceptis* was known previously from only a single species, *Perisceptis horiarcha* Meyrick, from the Chaco of Paraguay. Meyrick (1931) believed the genus to be a member of the family Yponomeutidae. Becker (1984) later reported a male of *P. horiarcha* from Planaltina, Distrito Federal, Brazil, and recognized its correct affinities within the Psychidae. A study currently in progress on the Neotropical Psychidae by D.R.D. has revealed the existence of an additional undescribed Neotropical genus and three species closely related to *Perisceptis*. All females share the remarkable morphology of an abbreviated ovipositor with three distinct pairs of apophyses, and they are suspected of possessing the unusual egg laying behavior similar to that described herein.

#### *Perisceptis carnivora* Davis, sp. n.

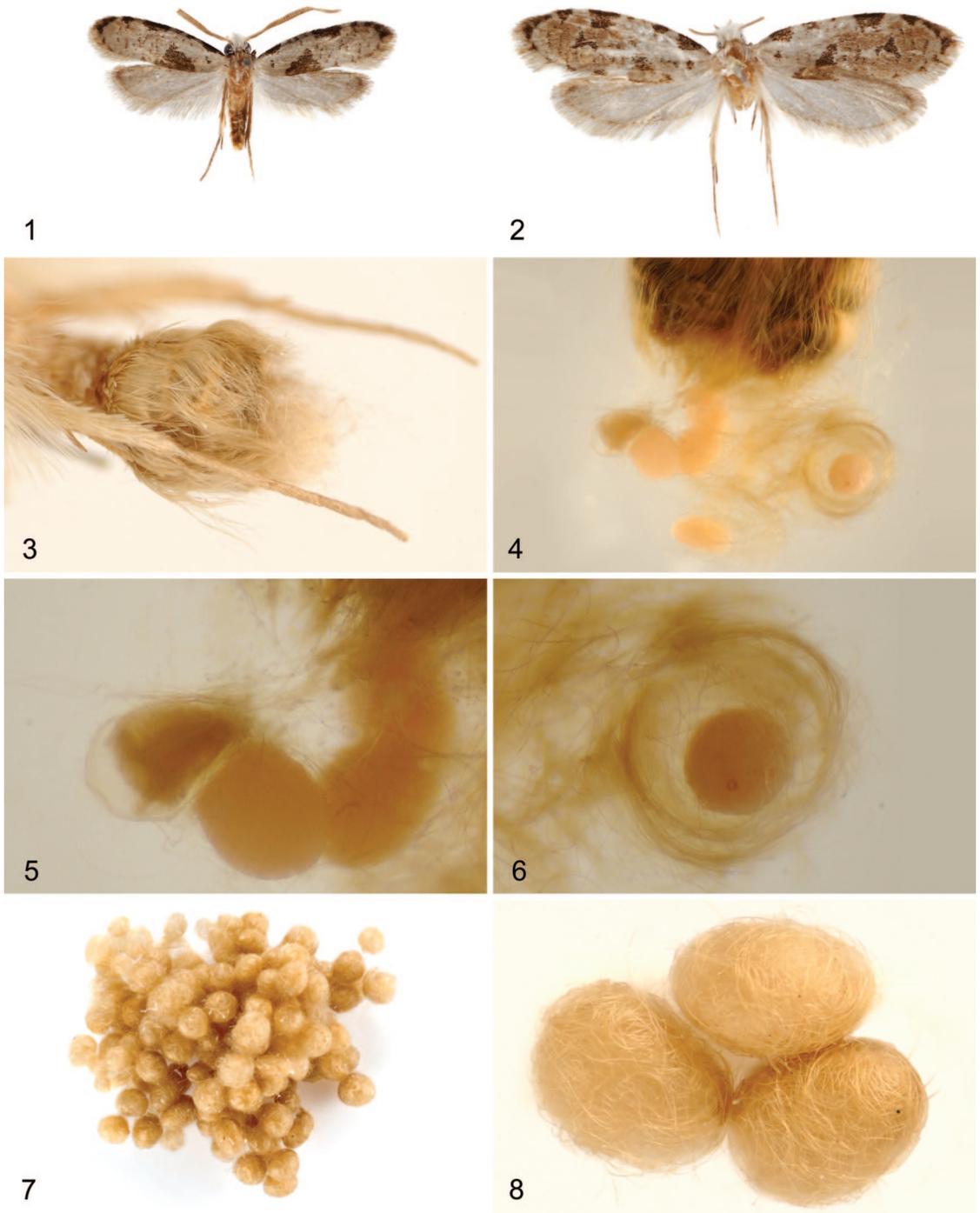
**Adult (Figs. 1 and 2).** Length of forewing: ♂, 6.0–6.5 mm, ♀, 7.5–8.5 mm. **Head:** Scales piliform, erect to suberect; vertex white, scales descending down over upper frons; vestiture of frons dark fuscous laterally around margin of eye and over lower half of frons. Antennae  $\approx 0.7\times$  length of forewing, uniformly cream; flagellomeres broadly flattened, with a single row of small, bidentate scales completely encircling each segment. Eyes round, well developed, interocular index (Davis 1975)  $\approx 1.2$ . Ocelli absent. Maxillae absent. Labial palpi well developed, three-segmented, total length  $\approx 1.5\times$  vertical diameter of eye; length ratio of segments from base  $\approx 1.0:3.3:1.2$ ; vestiture mostly dark fuscous, with distal, mesal one third of segment 2 and all of segment 3 white. **Thorax:** White dorsally, cream to pale brown ventrally; costal edge of tegulae dark fuscous. Forewing (Fig. 41) moderately slender, length/width ratio  $\approx 3.3$ ; venation similar to *P. horiarcha* (Clarke 1965), nearly complete, radial system four-branched with Rs1 fused with Rs2; base of

1A+2A simple, without basal fork; dorsal surface predominantly white with small, irregular streaks or patches of fuscous scales and a series of usually seven variably sized, dark fuscous to black costal spots; largest two spots near base of costa and slightly beyond middle; a large triangular fuscous spot on dorsal margin immediately before middle; fringe mostly white except for dark suffusion near apical spot; ventral surface grayish white. Hind wing similar to forewing in width; M2 and M3 fused; dorsal surface dull white; pale gray ventrally. Fore and midlegs mostly dark fuscous; hindlegs almost entirely cream to light golden brown. Tibial spurs 0–2–4; epiphysis absent (Fig. 42). **Abdomen:** Vestiture uniformly cream to light golden brown. Seventh segment of female with dense corythogyne (Fig. 3) consisting of two major types of setae: a pair of dense elongate tufts of relatively smooth, straight to sinuate setae arising from a pair of large dorsal pockets; and a dense, more or less tangled mass of very long, angulate setae bearing minute barbs along longitudinal ridges (Figs. 17 and 18). Eighth segment of male without coremata.

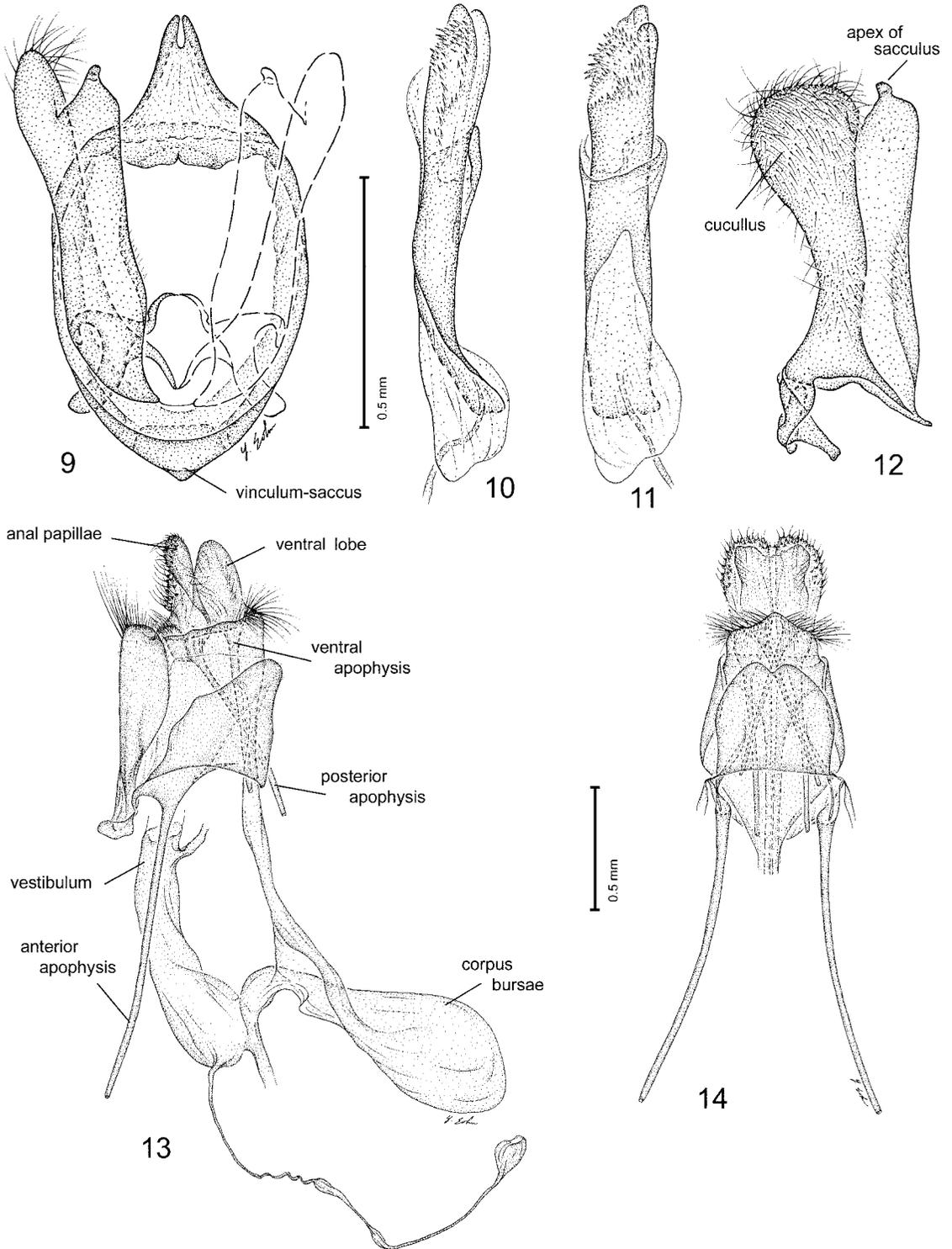
**Male Genitalia (Figs. 9–12).** Genital capsule approximately oval. Uncus weakly sclerotized, narrowly and shortly divided. Vinculum a narrow ventral ring; saccus undeveloped. Valva with cucullus gradually expanding to broadly rounded apex; sacculus extending the length of cucullus, terminating in a minute lobe. Aedoeagus a moderately stout, slightly depressed cylinder, with numerous short, stout, minute cornuti embedded in the membrane at apex.

**Female Genitalia (Figs. 13 and 14).** Ovipositor with three pairs of distinct, fully functional apophyses; anterior apophyses elongate,  $\approx 1.75\times$  the length of posterior apophyses, fused to a broadly curved, sclerotized band (lamella antevaginalis) with a shallow median cleft; posterior apophyses terminating in a pair of broad, mostly fused, flattened papillae anales that are slightly concave dorsally; caudal circumference of papillae covered with rows of stiff hairs directed dorsally; ventral apophyses slightly shorter than posterior apophyses, terminating in a broad, smooth, slightly bilobed ventral lobe (sternum of IX + X) connected laterally to and immediately ventral of papillae anales. Ductus bursae moderately long and slender; length nearly equalling that of anterior apophyses; corpus bursae moderately large,  $\approx 0.7\times$  length of anterior apophyses; signum absent. Ductus seminalis very short; length only slightly greater than width. Vestibulum enlarged; diameter  $\approx 2\text{--}3\times$  that of ductus bursae. Ostium oviductus (ovipore) opening in shallow pocket formed between papillae anales and sternal lobe.

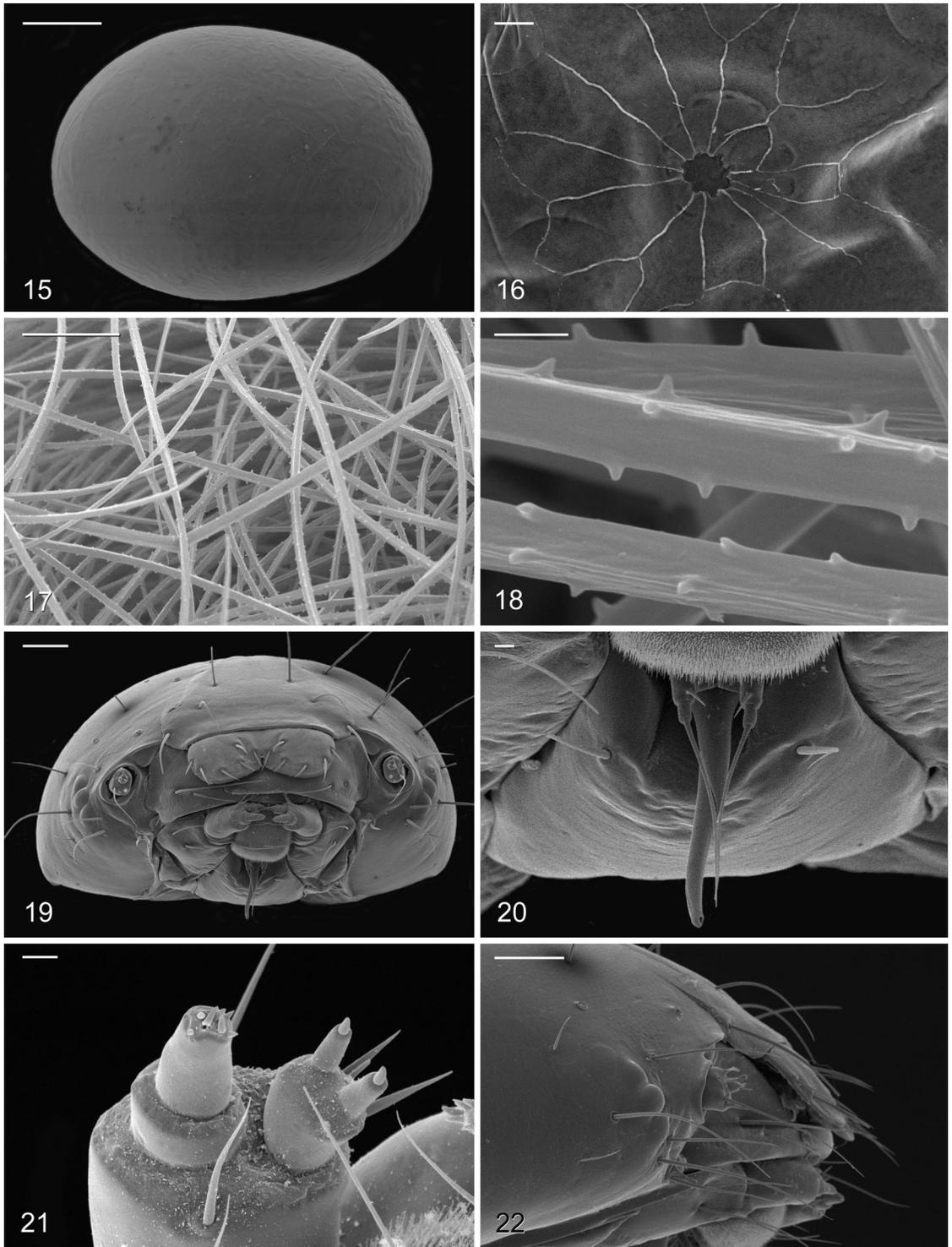
**Egg (Figs. 5 and 6, 15, and 16).** Chorion opaque white, smooth; 0.45–0.5 mm in length, maximum diameter  $\approx 0.35$  mm, superficially similar to that described for *Brachycyttarus griseus* De Joannis (Davis 1990). Micropyle consisting of an irregularly circular central disk  $\approx 8\text{--}13\ \mu\text{m}$  in diameter with 11–13 low, slender ridges radiating outwards; arms occasionally branching, sometimes joining adjacent ridges to form a few closed cells. Each egg enclosed within a firmly



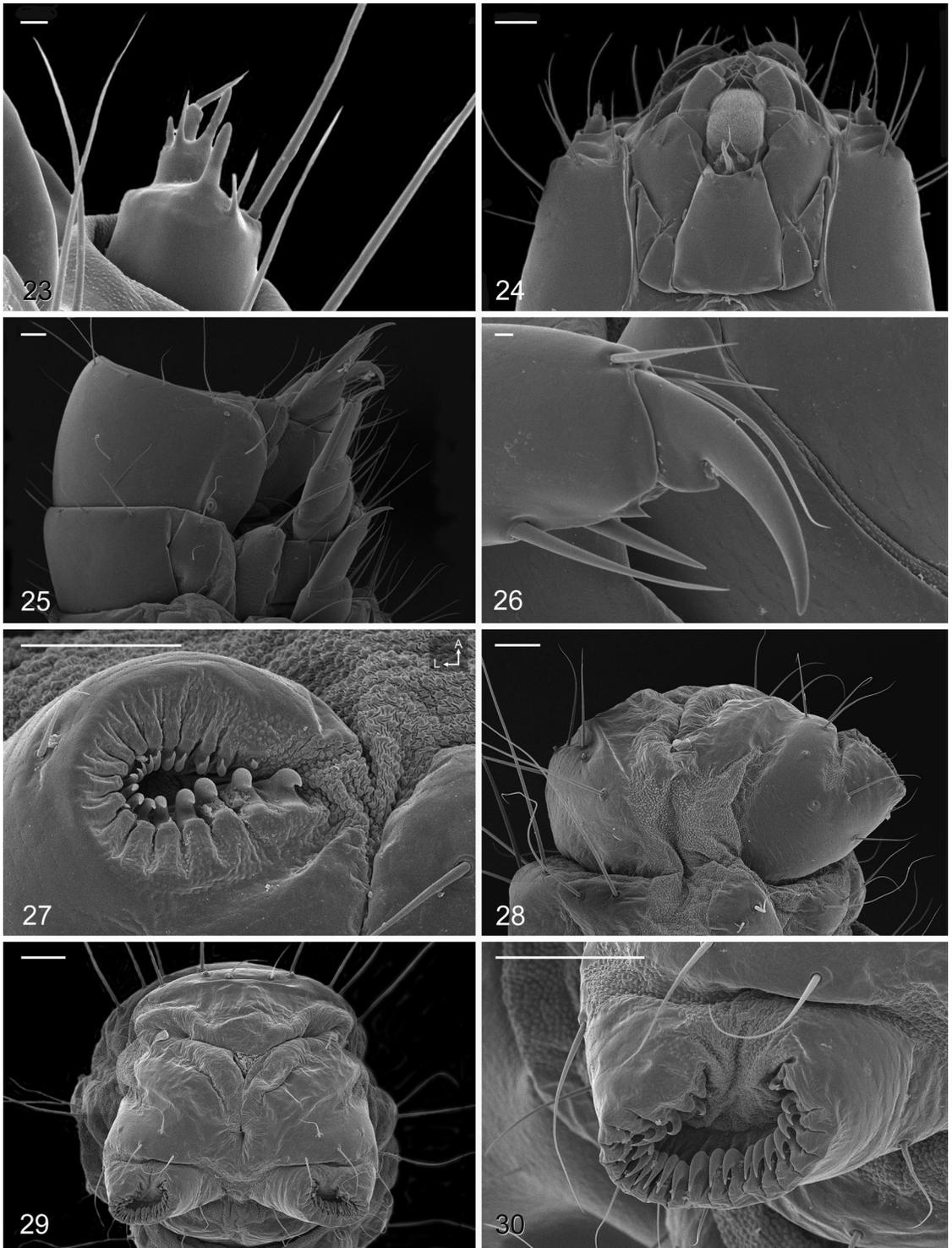
**Figs. 1-8.** Adults, eggs, and egg cases of *P. carnivora*. (1) Adult, holotype ♂, length of forewing 5.8 mm. (2) Adult, paratype ♀, length of forewing 8.7 mm. (3) Female corythogyne on abdominal segment VII. (4) Emergence of eggs from female. (5) Detail of egg strand in D. (6) Detail of D showing single egg at initial wrapping stage. (7) Cluster of egg cases. (8) Detail of egg cases, length of case 1.0 mm.



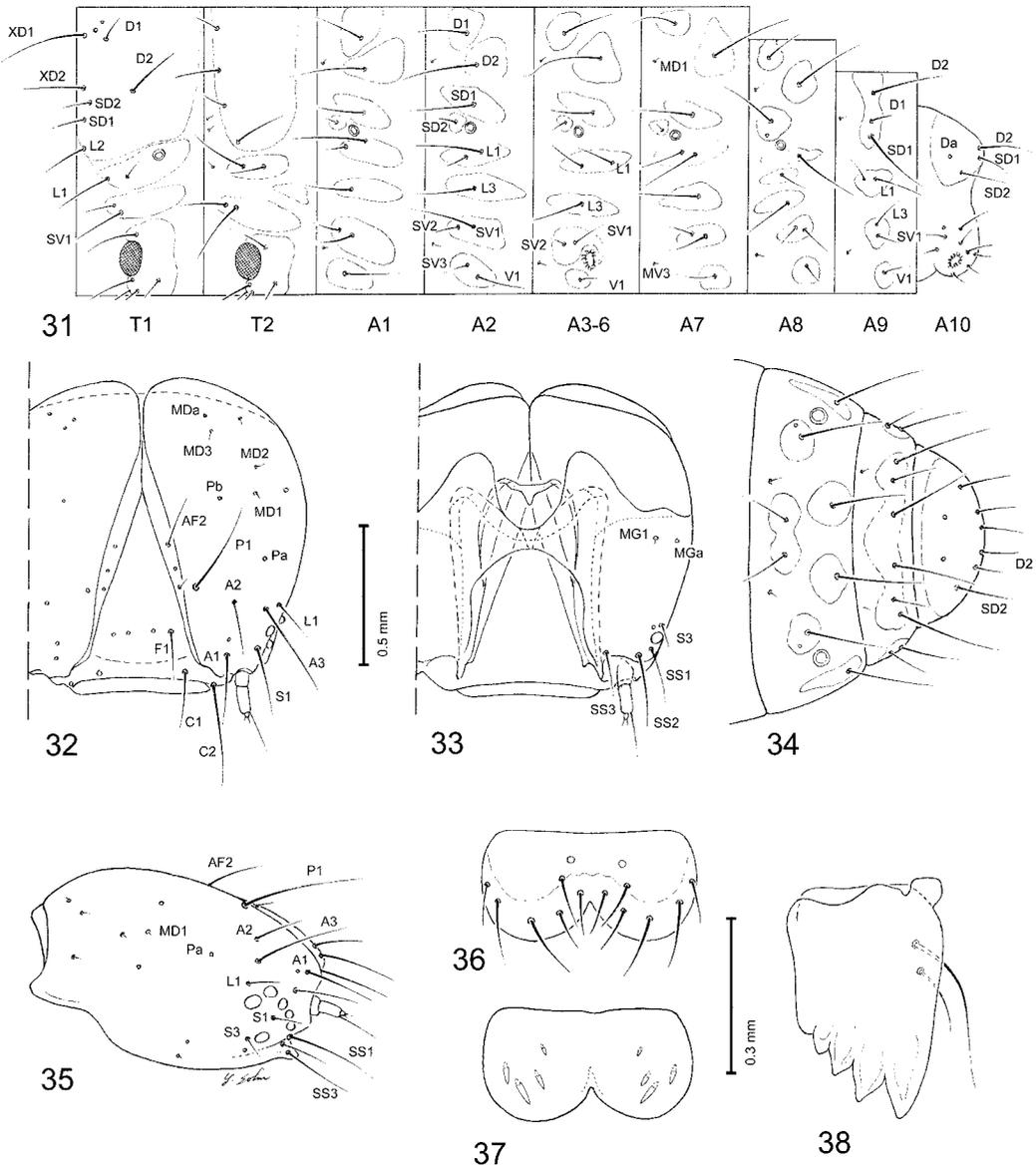
Figs. 9-14. Genital morphology of *P. carnivora*. (9) Male genitalia, ventral view. (10) Aedeagus, lateral view. (11) Aedeagus, ventral view. (12) Valva, right, mesal view. (13) Female genitalia, lateral view. (14) Female genitalia, ventral view.



**Figs. 15–22.** Egg, egg case, and larval morphology of *P. carnivora* (15) Egg (100  $\mu\text{m}$ ). (16) Micropyle of egg (10  $\mu\text{m}$ ). (17) Setae of egg case (20  $\mu\text{m}$ ). (18) Detail of setae in 17 showing barbed ridges (2  $\mu\text{m}$ ). (19) Larval head, anterior view (100  $\mu\text{m}$ ). (20) Larval spinneret and labial palpi (10  $\mu\text{m}$ ). (21) Larval maxilla, left, dorsal view (10  $\mu\text{m}$ ). (22) Larval head, lateral view of stemmatal area (100  $\mu\text{m}$ ). Scale lengths for all figures shown in parentheses.



**Figs. 23–30.** Larval morphology of *P. carnivora*. (23) Antenna, right, dorsal view (10  $\mu\text{m}$ ). (24) Head, ventral view (100  $\mu\text{m}$ ). (25) Pro- and mesothorax, lateral view (100  $\mu\text{m}$ ). (26) Protarsal claw (10  $\mu\text{m}$ ). (27) Crochets of proleg, abdominal segment V (100  $\mu\text{m}$ ). L, lateral; A, anterior). (28) Abdominal segment X, left, lateral view (100  $\mu\text{m}$ ). (29) Abdominal segment X, caudal view (100  $\mu\text{m}$ ). (30) Anal proleg, left, caudal view (100  $\mu\text{m}$ ). Scale lengths for all figures shown in parentheses.

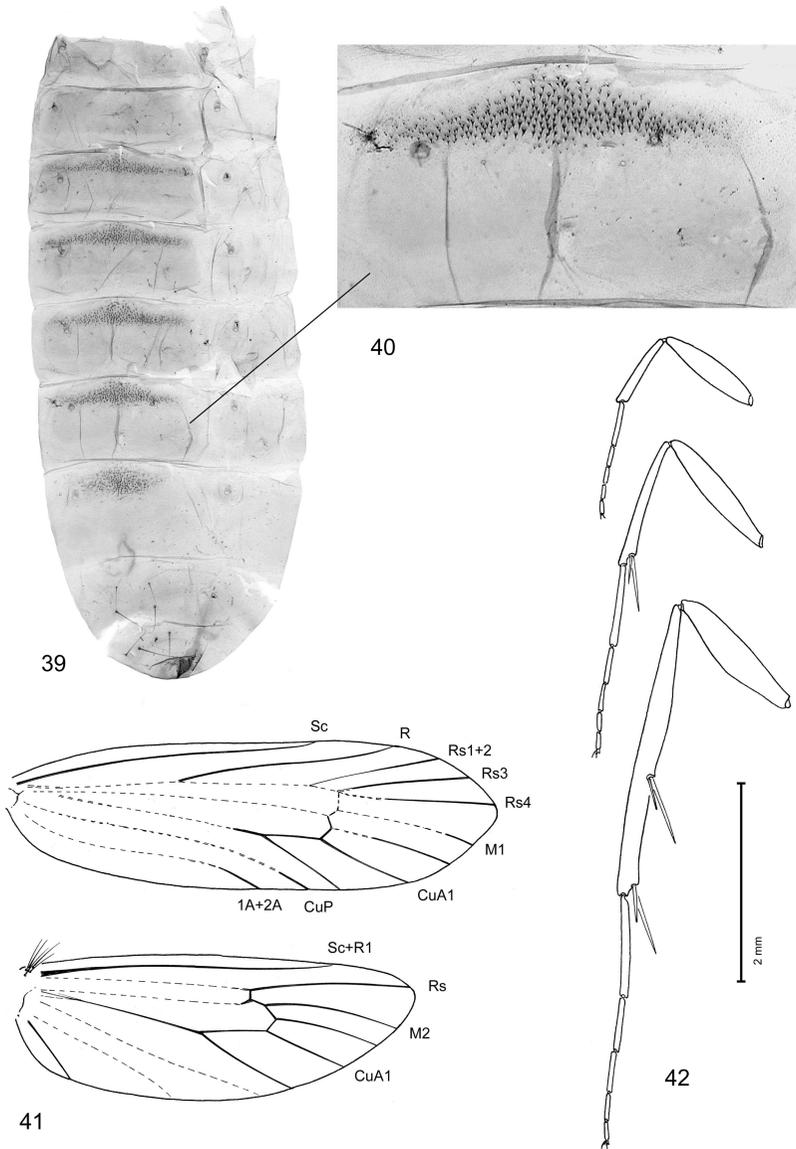


Figs. 31–38. Larval chaetotaxy of *P. carnivora*. (31) Lateral schematic of body segments. T, thorax; A, abdomen. (32) Head, dorsal view. (33) Head, ventral view. (34) Abdominal terga VII–X. (35) Head, lateral view. (36) Labrum, dorsal view. (37) Labrum, ventral view. (38) Mandible, right.

woven, golden, cocoon-like case spun from long, finely barbed setae derived from seventh abdominal segment of female (Figs. 3–8); length of egg case  $\approx$ 1.0 mm, width  $\approx$ 0.7 mm.

**Larva (Figs. 23–38).** Maximum length examined  $\approx$ 8 mm; maximum head width  $\approx$ 1.1 mm. Head and all thoracic plates including sterna well sclerotized, uniformly shiny black. Integument cream with light brown-to-reddish brown pinacula separated by paler, white-to-cream, granular cuticle. **Head:** Epicranial notch reduced, two halves of cranium only slightly separated (Fig. 32). P1 arising anteriorly, opposite AF1. AF2 elongate,  $>3\times$  length of AF1. Six stemmata present. Antenna and maxilla with sensilla as shown

(Figs. 21 and 23). Labrum with six pairs of dorsal setae, all well developed and approximately the same length; venter of labrum with four pairs of epipharyngeal setae; caudal most seta greatly reduced (Fig. 37). Mandible relatively elongate, with four well developed, acute cusps (Fig. 38). Labial palpus with segment II reduced,  $\approx 0.5\times$  length of I; apical seta from segment II extremely long,  $\approx 0.75\times$  length of spinneret (Fig. 20). Spinneret long and slender, gradually tapering to narrow, simple apex. **Thorax:** Pronotum with prespiracular pinaculum bearing L1 and L3 partially separated from pronotum and L2. Dorsal pinacula of meso- and metathorax fused to form single, well sclerotized dark plate over each segment similar to pronotum; lateral



Figs. 39-42. Pupal and adult morphology of *P. carnivora*. (39) Dorsal abdominal spines of pupal shell, female. (40) Detail of dorsal spines of abdominal segment VI in 39. (41) Wing venation. (42) Leg morphology, left side.

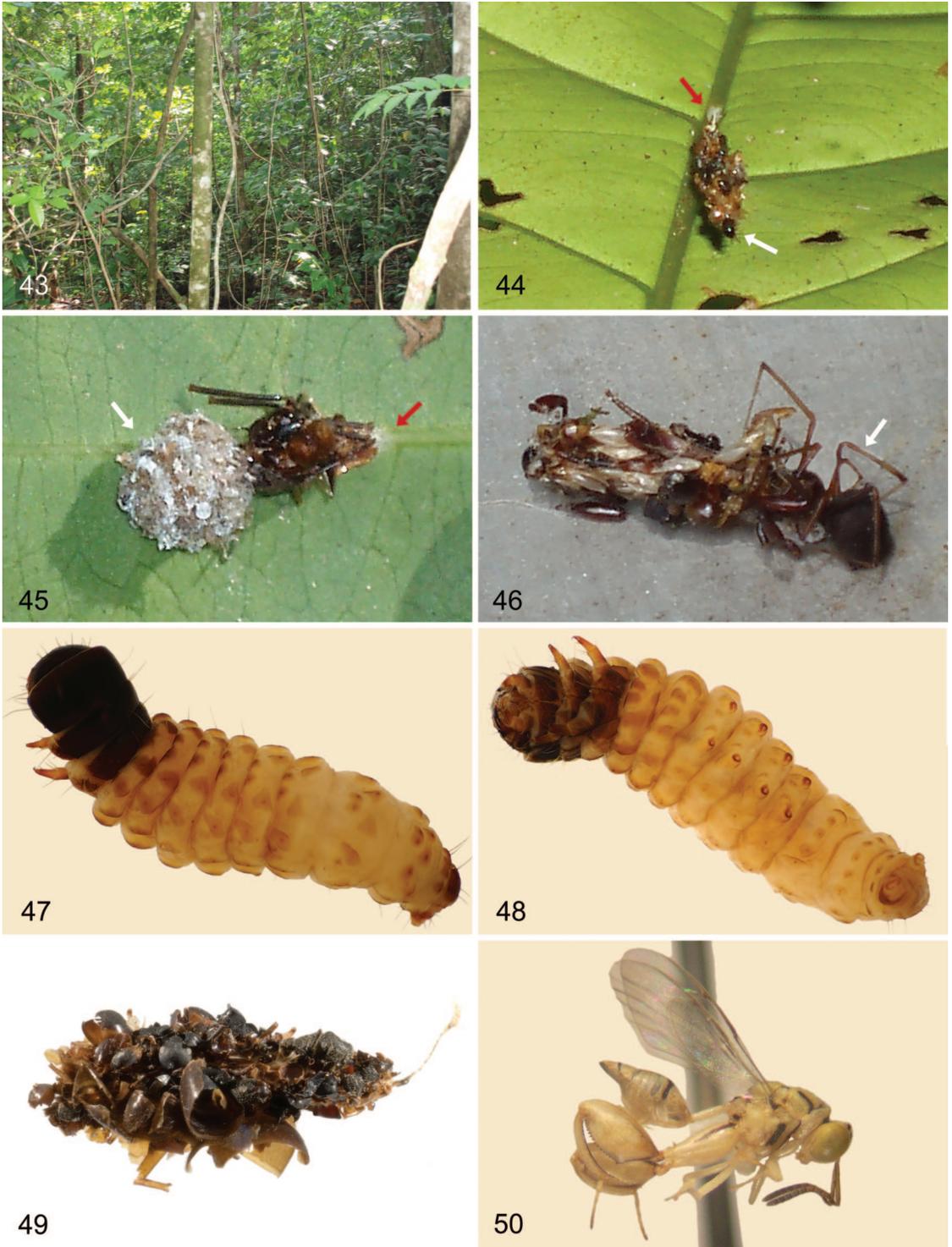
pinacula contiguous but free. SV bisetose on T1-3. *Abdomen*: D1 and D2 arising from separate, triangular to oval pinacula on A1-8, together with SD1 on a narrow transverse pinaculum on A9. SV bisetose on A1, A3-8, trisetose on A2 with SV3 arising on separate pinacula with V1, unisetose with L3 on A9. L series trisetose on A1-9 with L1 and L2 arising together on pinacula separate from L3. Anal plate with D2 absent, represented instead by prominent pore Da. Prolegs 3-6 with 15-19 crochets in a uniordinal, lateral penellipse; crochets decreasing in size anteriorly. Anal crochets 18-20.

**Larval Case (Fig. 49).** Maximum length examined 12 mm; diameter 5 mm. Silken case usually dark colored and spindle-shaped; exterior covered with often

glossy body fragments of various prey (Coleoptera, Homoptera, Hymenoptera, Neuroptera, and Orthoptera) and devoid of plant material.

**Male Pupa.** Length  $\approx$  6-7 mm, light to medium brown. Vertex broadly rounded, smooth. Antennal sheaths extending to middle of A4; wing sheaths to A5. Dorsal spines short, stout, concentrated along anterior margin of A3-8 in dense transverse clusters of numerous irregular rows. A pair of large, nearly contiguous, low tubercles on ninth sternum. Cremaster consisting of two pairs of short, dorsal spines.

**Female Pupa (Figs. 39 and 40).** Length  $\approx$  7-8 mm, medium to dark brown. Vertex smoothly rounded. Antennal sheaths extending to middle of A3, almost to apex of wings. Dorsal spines similar to male, but



**Figs. 43–50.** Biological aspects of Habitat of *P. carnivora*. (43) Type locality, forest along trail to Rio Cascadas, Cerro Azul, Panama. (44) Larval case attached by silk (red arrow) to underside of leaf rachis with larval head protruding from lower end of case (white arrow), along trail to Rio Cascadas. (45) *Perisceptis* larva (right) with case attached (red arrow) and feeding on chrysopid larva (Neuroptera) inside ornamented case of latter (white arrow). (46) *Perisceptis* larva (left) feeding on spitting spider (*Scytoda fusca*, arrow) on balcony of house, Las Nubes, Cerro Azul. (47) Larva, dorsal view, length 5 mm. (48) Ventral view of E. (49) Larval case with insect remains attached, length 14 mm. (50) *Conura* sp., *immaculata* group (Chalcididae), parasitoid of *Perisceptis* pupae.

present only on A3-7. Ninth sternum smooth, without large tubercles. Cremaster consisting of two to three pairs of short dorsal spines.

**Holotype (with larval case).** PANAMA: Panama Prov.: Cerro Azul. Urb. Las Nubes, Camino Rio Cascadas: 21-V-2005, D. Quintero A., No. 17, pupal slide USNM 33466 (USNM).

**Paratypes.** PANAMA: Colon Prov. Parador de Sierra Llorona, 1♀ (with larval case and 14 egg cases), D. Quintero A., larva in "case" hecho de seda & hormigas col. 25. XII-1997, pupa fin de diciembre, adult emerged 17-18-I-1998, huevos 21 I-1998, Aiello lot 1997-52, slide USNM 33321 (USNM). Panama Prov.: Same locality as holotype: 1♀ (with larval case), 11-IX-2005, C. Cortés, No. 8, wing slide USNM 33451, pupa slide USNM 33472 (USNM); 1♀ (with larval case), 2-X-2005, R. Miranda, No. 6, wing slide USNM 33443 (USNM); 1♀ (with larval case and 74 egg cases), 21-X-2005, No. 13 (MIUP); 1♂ (with larval case), 21-X-2005, 500 m, 0.5 m above ground in *Psychotria poeppigiana* eating captured *Ectatomma* ant, pupa c. 5-XI-2005, adult ♂ 21-XII-2005, Quintero No. 15 (MIUP); 1♂ (with larval case), 21-X-2005, No. 18, slide 33349 (USNM); 1♀ (with larval case and 132 egg cases), 21-X-2005, D. Quintero A., No. 14, DRD slide 4431 (MIUP); 1♀ (in alcohol with egg cases, larval case), 21-X-2005, No. 12, wing slide USNM 33448 (USNM); 6 larvae, 14-V-2006, D. Quintero & A. Santos, SEM slide USNM 33831 (MIUP, USNM).

**Flight Period.** December–January. All evidence from larval rearings suggests the species to be univoltine.

**Distribution.** Known only from Colon and Panama Provinces, Panama.

**Etymology.** The specific name is derived from the Latin *carnivorous* (flesh-eating) in reference to the unusual larval feeding biology.

**Diagnoses.** *Perisceptis carnivora* differs from its sister species, *P. horiarcha*, in possessing a more narrow vinculum and in having the apex of the cucullus less round and not extended beyond the apex of the sacular lobe of the male genitalia. The larval prothorax of *P. carnivora* is unusual for Psychidae in having the lateral pinaculum partially separated from the pronotum, a condition most similar to that found in another tineoid family, Acrolophidae (Davis 1987, Davis and Robinson 1998). The lateral pinaculum is completely fused to the pronotum in all previously described larval Psychidae.

## Results and Discussion

**Larval Biology.** *Habitat.* All Psychidae were collected in the Central region of the Isthmus of Panama, at four sites (sites 1 and 2 with canopy cover, Colon Province; sites 3 and 4 without canopy cover, Panama Province). Site 1: El Parador de Sierra Llorona, Santa Rita (located near Chagres National Park). On 25 December 1997, a single case-bearing larva was collected from the underside of a leaf of a "piro" plant, *Aechmea magdalenae* (André) (Bromeliaceae), a terrestrial species, with spine-margined leaves, that forms

dense, impenetrable stands. Active ant colonies were found in the leaf litter that had accumulated in the axils of the thick leaves of most of these plants. Additional cases were searched for in the litter of the ant colonies without success. On 10 March 1998, four additional cases (empty) were collected at this site. Site 2: Pipeline Road, near Rio Macho, Gamboa, Soberanía National Park (9° 12' N, 79° 45' W). A single case (with larva) was collected on 6 October 2005 on a leaf of *Heliconia irrasa* R. R. Sm. (Heliconiaceae), ≈30 cm from the ground. Site 3 (Fig. 43): Trail to Rio Cascadas, Urbanización Las Nubes, Cerro Azul (9° 13' N, 79° 28' W; 600 m). Six field trips were made to this site on 6 September 2003, 11 September 2005, 2 and 21 October 2005, 4 January 2006 (trip to collect parasitoids), and 14 May 2006 (21 cases with larvae preserved in 95% ethanol for DNA analysis). At the trail entrance to this site, a fern, *Dicranopteris pectinata* (Wild.) Underw. (Gleicheniaceae), dominated the vegetation. Most of the larvae were found attached to the undersurfaces of leaves within secondary forest, 2–10 m off the trail. Site 4: Altos de Pacora, Cerro Azul, 11 February 1998. One empty case collected on the undersurface of a leaf. Because the earliest larval collections were on 27 April (and no larvae encountered January through February) and adults were observed only during December and January, the species is thought to be univoltine.

There seemed to be no larval preference for inhabiting any particular plant in the field. No evidence, including the absence of plant material in or on the larval case, indicated that any of the larvae ate or modified any plant. Case-bearing larvae were found on plants belonging to 10 families: *Aechmea magdalenae* (André) André ex Baker (Bromeliaceae), *Terminalia amazonia* (J. F. Gmelin) Exell (Combretaceae), *Erythroxylum citrifolium* A. Saint-Hilaire (Erythroxylaceae), *Dicranopteris pectinata* (Wild.), *Lygodium venustum* Sw. (Schizeaceae), *Heliconia irrasa* Lane ex R. R. Smith (Heliconiaceae), *Lozania pittieri* (S. F. Blake) L. B. Sm. (Lascistemataceae), *Pavonia dasypetala* Turcz. (Malvaceae), *Miconia affinis* DC. (Melastomataceae), *Piper* sp. (Piperaceae), and *Psychotria poeppigiana* J. Müll. Arg. (Rubiaceae).

**Feeding.** Larvae were relative active, moving ≈4.6 mm/min (one observation) inside plastic containers when searching for food or a place to molt. They dragged the case by extending, fixing and contracting the anterior part of the body. A *P. carnivora* larva kept in a plastic container attacked one *Camponotus lindigi* ant ≈1100 hours, eating the thoracic sterna and attaching the ant body to the case aperture; around 1800 hours the same larva captured an additional *C. lindigi*, and attached the body to the opposite aperture of the case. Before prey capture larvae were seen to secrete (apparently from their spinneret) a silk fixation disk on the smooth wall of the plastic container. The silk disk was attached to the case by a short, reinforced silk strand (Figs. 44 and 45); the larva then reversed its direction inside the case. Detailed visual observations using a stereomicroscope served to confirm the reversal capa-

bilities of these larvae within the case. When the larva was active, its heavily sclerotized head and thorax projected from the case (Fig. 44). As is typical of all Psychidae, molting and pupation occurs within the case. At intervals, the larva attached one end of the case to the wall of the rearing container with silk strands, and became motionless for 2 or 3 d, suggesting that molting was occurring.

Other than the somewhat more sclerotized and melanized head and thoracic plates (Figs. 47 and 48), the larval morphology of *P. carnivora* displays little specialization for predation. The mandibular cusps are more pronounced than those developed in some psychid genera examined (Davis 1975, 1990, 2000), but no more so in others (e.g., the lichenivorous West Indian species, *Pterogyne insularis* Davis). Similarly, the thoracic legs seem no more developed and the tarsal claws no more acute than in some Psychidae with herbivorous larvae. Various larval adaptations that have evolved in bagworms associated with bearing relatively large cases (e.g., the forward development of relatively strong legs and tarsal claws, as well as the protective advantages of the case itself) may have preadapted members of this family for predation. Initial adaptations toward obligatory carnivory are evident within various subfamilies of Psychidae whose larvae occasionally feed on dead or live arthropods. The behavioral specialization of first anchoring one end of the larval case and feeding from the opposite end probably was essential in the development of carnivory within this species. Failure to anchor one end could result in the struggling prey dislodging the psychid larva. Because larvae were observed feeding only from the free end of the case (Figs. 44 and 45), it seems apparent that they had reversed their position inside the case. With few exceptions (Davis 2000), psychid larvae normally reverse their direction in the case only before pupation. The behavior of the larva of *P. carnivora* to reverse its position to feed probably represents an uncommon adaptation within Psychidae.

Arthropod remains attached to field-collected cases suggest a variety of prey: Arachnida (*Scytodes fusca* Walckenaer, Scytodidae, Fig. 46), Orthoptera (Gryllidae: Trigonitidae), Homoptera (Membracidae), Coleoptera (Elateridae, Curculionidae: Scolytinae, Carabidae and Chrysomelidae), and Hymenoptera (Vespidae: *Leipomeles dorsata* (F.), Formicidae: *Dolichoderus*, *Pachycondyla*, *Ectatomma*, *Pseudomyrmex*, *Camponotus*, *Gnamptogenys* (?), *Atta*, and *Labidus*). Most previously reported examples of predation by lepidopteran larvae involve ant larvae and pupae (e.g., by Lycaenidae). Scoble (1992) reviewed carnivorous and ectoparasitic larvae that preyed on Homoptera (Coccidae, Fulgoridae), on Lepidoptera (larvae of Hepialidae), and on earthworms. Larvae of Hawaiian *Eupithecia* (Geometridae) capture and devour adult Diptera (Montgomery 1982). We do not know of any previous records of Lepidoptera larvae feeding on Coleoptera, Orthoptera, or larval Neuroptera, the latter of which are themselves predators. As further irony, the chrysid larva captured by the *Perisceptis*

larva (Fig. 45), also camouflages itself with the remains of its prey. Larval cases of moderately large ( $\approx 13$  mm in length), unknown, and possibly un-reared bagworms, heavily adorned with ant body parts have been examined by D.R.D. from Southeast Asia, suggesting that other obligatory predaceous Psychidae probably exist.

The smallest larval case collected in the field (5.5 by 2.3–6.5 by 3 mm) had the remains of five to seven ant species and the elytra of at least two beetle species. This observation suggests that the early larval stages of *Perisceptis carnivora* may attack a variety of prey and do not develop inside ant nests. Feeding habits of the earliest instars of *carnivora* have not been observed, although it is assumed that they may feed on some of the smaller arthropods, including mites. Field-collected cases show that adult ant prey vary in length from 1 to 13 mm and that some have powerful defenses (with strong mandibles and stinging capabilities: e.g., *Pachycondyla*, *Ectatomma*, and *Pseudomyrmex*).

*Observations of Predation in the Field.* At Cerro Azul, on 21 October 2005, 1000 hours, a larva in a case,  $\approx 10$  mm in length  $\approx 1.5$  m from the ground, on the leaf surface of a shrub had subdued and was seen eating a small ant (*Camponotus* sp.), which lacks a sting and relies on the mandibles for its main defense. At the same locality and date, at 1230 hours, we found a larva in a case 9.5 mm in length, on a *Psychotria poeppigiana* (Rubiaceae) leaf. In its mandibles the larva was holding a struggling ant (*Ectatomma* sp.), grasped between the meso and metasoma. This ant species has strong mandibles and a powerful sting. After being captured in a vial, the larva continued holding the ant and over a period of hours, consumed it.

*Observations of Predation in the Lab.* On 17 October 2005 at 1120 hours, a larva, whose case was suspended from the rearing cage lid, was found to have captured a *Dolichoderus* ant. The head and prothorax of the ant had been pulled into the lower (caudal) opening of the larval case, and the only visible parts of the ant were the gaster and the two posterior pairs of legs. The legs occasionally moved slowly, possibly indicating that the ant was being devoured alive. The larva was very young, perhaps in its third stadium, and was slightly smaller than the ant. Within 3 h, only ant fragments were left.

*Perisceptis* larvae in the laboratory were indifferent to dead ants, living termites (*Nasutitermes* sp.), as well as to materials from termite tunnels introduced into their containers. Laboratory observations of larval feeding demonstrated that ants were captured by *Perisceptis* at either of the two case openings, and that captures were preceded by a prolonged period of exploration by the ant, which seemed to find the case openings very attractive. Usually, the ants spent more than an hour exploring one of the case ends with their antennae, licking a glossy droplet there, and then repeatedly licking their antennae. Next day, ant body fragments could be seen stuck on the case surface, near the same opening. Future studies are planned to test larval secretions for possible chemical attractants to lure their prey.

**Parasitism.** No evidence of parasitism was observed among the  $\approx 35$  larvae collected in the field during the rainy season. However, among the 15 psychid cases collected on Cerro Azul on 4 January 2006 (early dry season) four were parasitized by *Conura* sp., *immaculata* group (Hymenoptera: Chalcididae, Fig. 50), a very speciose group of wasps (Delvare and Bouček 1992) whose members are parasitoids of pupae exclusively. The four *Conura* wasps emerged on 13, 19, 23, and 31 January 2006. One of them exited through a hole 0.8 mm in diameter near the middle of the psychid case. The other three wasps did not make holes, and we surmise that they emerged through one of the two case openings. Among the 11 remaining larval cases, none contained larvae and no psychid adults emerged. Two of those cases had pupal exuviae projecting from the posterior end (indicating that adults already had emerged), and nine cases lacked exuviae.

**Adults and Oviposition.** Both male and female *P. carnivora* adults are fully winged, a condition more prevalent among the Neotropical Psychidae than previously reported (Rhains et al. 2008). The adult female is probably capable of flight, but to what extent is unknown. The flight abilities of reared males and females were never tested nor observed within the rearing containers. Females of other species in the *Perisceptis* group have been collected at light in Brazil by V. O. Becker. A female that emerged on the night of 18 January 1998, from a larval case collected at Parador Sierra Llorona, Colón Province, oviposited on 21 January. She deposited two clusters of setal egg cases (23 and 30 each, for a total of 53 egg cases) on the sand in a petri dish. Each egg was individually wrapped in a tiny, elliptical, cocoon-like case of golden setae drawn from the female's corythogyne present on abdominal segment VII. A bare spot was later visible at that portion of the female's abdomen, which otherwise was clothed entirely in long, straight to sinuate, golden setae. The eggs were unfertilized and nonviable. The female died on the day of oviposition.

An adult female emerged on 31 December 2005, and rested on top of her case, with her head directed upward, her wings extended laterally, and her abdomen totally exposed. During the night of 4–5 January 2006, she deposited four clusters of setal egg cases on the inner walls of the plastic container. She was found dead on 6 January. Given that the larva was observed to attach its larval case to the container wall on 7 December 2005 and remained inactive until the adult emerged, the pupation duration for this individual was within 24 d. Another adult female eclosed 2 January 2006, after a pupation that began 12 December 2005. She rested on top of the case in the same position as the moth that emerged 31 December. This third virgin female oviposited the morning of 5 January 2006.

Three male larvae, collected on Cerro Azul, pupated in the lab on 12 November (one individual) and 7 December (two individuals) 2005, with the adults emerging on 27 December 2005, and 5 and 8 January 2006, respectively. One adult male positioned itself on the middle of the case, with his head directed upward and the wings folded over the body, entirely conceal-

ing the abdomen. Another adult male was observed hanging from the end of the case from which it had emerged.

**Egg Cases.** Perhaps the most unusual biological behavior of this highly atypical moth is the manner in which the eggs are deposited and presumably protected. Females in other Lepidoptera families are known to coat their eggs usually in a mass (Epstein 1996) with setae normally from their caudal abdominal segments, without completely enclosing them. In *Perisceptis* each egg is wrapped individually within a firm, neatly woven cocoon-like case soon after the egg emerges from the female (Figs. 4–8). The wrapping of the egg case is derived from the tuft of setal hairs (corythogyne) present on the seventh abdominal segment (Fig. 3). As has been noted previously (Davis 1998), the corythogyne of at least some female moths consists of two structural types of setae—a dense, overlying cover of straight to sinuate setae and a more caudal, tangle mass of very long setae. The egg cases of *P. carnivora* are constructed from the latter, which under high magnification can be observed to be finely barbed and triangular in cross section (Fig. 18). Unfortunately, the precise manner in which the eggs are wrapped has not been observed, but most likely the highly specialized morphology of the female ovipositor plays a major role. Normally the Lepidoptera ovipositor is equipped with two sets of apophyses—a posterior pair arising from abdominal segment 9 (or 9+10) and an anterior pair from segment 8. The females of *Perisceptis* are unique among Lepidoptera in possessing three distinct pairs of mostly “free” apophyses within the ovipositor (Fig. 13), although the ovipositor itself is relatively short (i.e., incapable of unusual extension). Three or more pairs of these sclerotized rods are often present in Tineoidea and a few other superfamilies to support an ovipositor capable of great extension for depositing eggs in more concealed sites (Davis and Robinson 1998). However, in those groups the extra (usually ventral) apophyses are closely associated with the body wall of segment 9+10 and do not project free into the body. In *Perisceptis*, the ventral apophyses are more strongly developed, nearly as long as the somewhat shortened posterior pair, and project into the body cavity where they probably attach to a set of retractor muscles, as do the anterior and posterior apophyses (Kristensen 2003). Furthermore, the anal papillae, which connect with the posterior apophyses, are directed dorsally in *Perisceptis* rather than ventrally as is normally the case in ditrysian Lepidoptera. In this attitude the prominent spines of the anal papillae project dorsally instead of ventrally. It is suspected that female *Perisceptis* are able to extend the papillae, and perhaps with assistance of the legs, to engage the barbed setae from the corythogyne. The ventral apophyses may assist in positioning the strand of eggs emerging from the ovipore so they become separated and eventually entangled within a spiral of setae (Figs. 4 and 6). The barbs are essential in holding the case intact as the setae are rolled around the egg. They also provide a Velcro-like surface to the egg cases as they are packed by the

female to form small clusters. The angular cross section of the setae may cause the seta to curl, thus facilitating the wrapping process.

The setal cases do not seem to attract ant workers, but they may serve to camouflage the egg and first stadium larva, deter parasitoids and predators, including larvae of sibling *P. carnivora*, or both. And to further enhance that protection, the space inside each case is considerably larger than the egg within it, possibly making it more difficult for a parasitoid to reach its quarry. Egg cannibalism is known in several insects groups, including Coleoptera: Coccinellidae (Michaud and Grant 2004), Lepidoptera: Pieridae (Barros-Bellanda and Zucoloto 2005), and Neuroptera. Within the Neuroptera, the stalked eggs of Chrysopidae offer at least some protection from earlier emerging sibling larvae (Smith 1922). Four *Camponotus* ants introduced into a container with several clusters of psychid eggs showed no interest in the cases or their enclosed eggs. Within one cluster of 34 setal cases examined only 15 were found to contain eggs. It is not known whether this is a strategy that has evolved to discourage parasitism or predation, or whether it merely represents mistakes by the female in wrapping eggs. The observation that no setal cases were found that contained more than one egg suggests that this could be normal for the species.

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