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# MORPHOLOGICAL AND MOLECULAR SYSTEMATICS OF PSYCHODIDAE (DIPTERA)

A Dissertation
Presented for the
Doctor of Philosophy
Degree
The University of Tennessee, Knoxville

Gregory R. Curler
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## ABSTRACT

A general overview of family Psychodidae is given. Genus *Eurygarka* Quate is revised to include three species. Genus *Gondwanoscurus* Jezek is revised to include seven species. The status of genus *Stupkaiella* Vaillant is revised. Eight new Nearctic species: *Eurygarka cyphostylus* sp. nov., *E. nelderi* sp. nov., *Stupkaiella lasiostyla* sp. nov., *S. robinsoni* sp. nov., *S. capricorna* sp. nov., *Trichomyia rostrata* sp. nov., *Australopericoma delta* sp. nov., and *Threticus thelyceratus* sp. nov., and two new Oriental species: *Gondwanoscurus cruciferus* sp. nov. and *G. ornithostylus* sp. nov. are described. Two Nearctic species: *Eurygarka helicis* (Dyar) and *Stupkaiella bipunctata* (Kincaid), and four Oriental species: *Gondwanoscurus ejundicus* (Quate), *G. eximius* (Quate), *G. mcclurei* (Quate) and *G. praecipuus* (Quate) are redescribed. A list of species collected during a survey of the Psychodidae of Great Smoky Mountains National Park is given, and a key to the genera of Psychodidae occurring in GSMNP is provided. A classification of psychodid subfamilies based on morphological and molecular evidence is proposed.

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# CHAPTER 1
# INTRODUCTION

Psychodidae (moth flies), with six subfamilies (Trichomyiinae, Phlebotominae, Sycoracinae, Horaiellinae, Bruchomyiinae and Psychodinae) and nearly 2900 described species (Curler & Courtney 2009), is among the most morphologically diverse families of Diptera. Psychodid adults are small, densely haired flies, with short and erratic flight. Wings of most species are characterized by a teardrop shape, and branched, longitudinal veins. Crossveins are absent in nearly all species, and when present, restricted to the basal half of the wing. Many moth flies hold their wings horizontally over the abdomen when at rest, giving the superficial appearance of small moths; hence, the common name.

Pupae of most Psychodidae are uniform in shape making distinctions at the species, or even genus level difficult (Wagner 2000). For a few taxa, however, pupae exhibit sufficient characters for distinguishing species (e.g. rheophilic genera) because they are modified from the typical psychodid pupa to a form more like that of the Blephariceridae. In contrast, psychodid larvae are extremely diverse in morphology.

Larvae are eucephalic with ten or eleven distinct trunk segments (three thoracic, seven or eight abdominal) and an anal division with or without sclerotized plates and posterior processes. Many species exhibit aberrant dorsal sclerites and/or chaetotaxy, providing sufficient characters for identification at the species level. In most subfamilies (excluding Sycoracinae and Trichomyiinae), perhaps the most striking larval character state is the subdivision of thoracic and abdominal segments (annulated trunk). Psychodids are also ecologically diverse.

Species of Psychodidae have invaded a range of niches from restroom drains and sewage treatment filters to torrential montane streams, and are frequently abundant in all life stages in their respective microhabitats. In the subfamilies Phlebotominae, Bruchomyiinae and Trichomyiinae, larvae are fully terrestrial but remain closely associated with moisture. Most Phlebotomine and Bruchomyine larvae are known from specimens obtained from colonized adults, but few species of the former have been collected from animal burrows and both have been found in leaf litter in the tropics. The immature stages of only one species of Trichomyiinae are known, and were collected from moist rotting wood. Larvae of the subfamilies Sycoracinae, Horaiellinae and Psychodinae are aquatic, semi-aquatic or marginal in habitat. They can be found among

mosses and lichens, between decaying leaves, on rocks in fast-flowing streams, in fresh animal dung or nutrient-rich water, as well as in many other microhabitats. Adults are usually found resting on rocks, trees or foliage near the larval habitat.

Most larval psychodids are saprophages, but some aquatic species feed on periphyton and a few species in the subfamily Psychodinae are known to cause myiasis in humans (Riegel & Kniskern 1963). Adults of subfamilies Bruchomyiinae, Trichomyiinae and Psychodinae are not known to feed, but those of subfamilies Phlebotominae, Sycoracinae and perhaps Horaiellinae are adapted to feed on blood. Furthermore, certain species in the subfamily Phlebotominae serve as vectors for agents of various human diseases such as bartonellosis, sandfly fever, and most importantly, visceral and cutaneous leishmaniasis (Young & Perkins 1984).

Psychodidae is cosmopolitan in distribution, and both Psychodinae and Trichomyiinae occur on oceanic islands (Quate & Vockeroth 1981). Although some species of Psychodinae have been recorded as far north as the boreal forest, the other subfamilies are mainly tropical to warm temperate in distribution. Horaiellinae, with only four species, is restricted to the Oriental region and Sycoracinae is not known to occur in the Nearctic region.

Despite its wide distribution and tremendous species diversity, relatively little is known about Psychodidae. Many psychodid genera and species from most regions of the world have yet to be described, revisions of many existing descriptions are necessary, and a classification scheme agreeable to the majority of specialists has yet to be devised. This dissertation includes both revisionary and descriptive work, and a proposed classification of psychodid subfamilies. Descriptions of eight new Nearctic species and two new Oriental species, as well as redescriptions of genera and species from both regions are completed. A list of species collected during a survey of the Psychodidae of Great Smoky Mountains National Park is provided. A classification of psychodid subfamilies based on morphological and molecular evidence is proposed.

As per Article 8.2 of the International Code of Zoological Nomenclature (1999), this document is not issued for the permanent scientific record or for purposes of

zoological nomenclature. Consequently, any species names contained herein should not be considered as published (*sensu* ICZN).

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# CHAPTER 2
# A REVIEW OF THE NEARCTIC SPECIES OF THE GENUS *EURYGARKA* QUATE (DIPTERA: PSYCHODIDAE)

This chapter is essentially the same as an article in Zootaxa published in April 2008 by Gregory R. Curler and John K. Moulton:

Curler, G.R. and J.K. Moulton. (2008) A review of the Nearctic species of the genus *Eurygarka* Quate (Diptera: Psychodidae). *Zootaxa*, 1740, 28–36.

My contributions to this publication include collection and identification of specimens, as well as preparation of illustrations and the manuscript.

## Abstract

The moth-fly genus *Eurygarka* Quate (Diptera: Psychodidae) is revised to include three species. Two new species: *E. cyphostylus*, n. sp. and *E. nelderi*, n. sp. from the southeastern United States are described. The adult male and female of *E. helicis* (Dyar) are redescribed. A key to adult males of the three known species of *Eurygarka* is provided. The generic placement of *Eurygarka* is discussed.

## Introduction

The genus *Eurygarka* was proposed by Quate (1959) to receive a single species of Psychodinae, *Psychoda helicis* Dyar, which was first reared from a dead terrestrial snail in Cuba. At this point, the distribution of the genus was considered "mainly Neotropical", though some specimens of *E. helicis* had been collected from the southeastern United States. Subsequently, Duckhouse (1973) placed *Eurygarka* as a subgenus of *Philosepedon* Eaton, while Quate and Vockeroth (1981) regarded it as a genus in a key to Nearctic genera of Psychodidae. In this study, two new species of *Eurygarka* from the southeastern United States are described, the limits of this genus are expanded, and the monophyly of this taxon is discussed.

## Materials and Methods

*Study area*. This study focused on specimens collected from east Tennessee and central and northwest South Carolina. Several specimens from northern Alabama were also examined.

*Material*. This research is based on an examination of adult males and females of *Eurygarka helicis* and *E. cyphostylus* n. sp., and males of *E. nelderi* n. sp. Most specimens were collected during 2006 and 2007 by CDC trap, except two female specimens of *E. cyphostylus,* which were collected by hand. Association of adult males and females of *E. cyphostylus* is somewhat tenuous, being based on collections from locations where other species of *Eurygarka* have not been collected.

Additional specimens were borrowed from, or are deposited with the following (acronyms used throughout the text): CUAC, Clemson University Arthropod Collection, Clemson, SC.; USNM, National Museum of Natural History, Smithsonian Institution, Washington, D.C.; UTK, Department of Entomology and Plant Pathology, University of Tennessee, Knoxville, TN.

*Specimen preparation*. Specimens were fixed in 70 or 95% EtOH. Morphological studies were based on slide-mounted and pinned specimens. Slides were prepared using sodium hydroxide to clear specimens and Canada balsam as a mounting medium. Specimens were observed by using a Meiji Techno RZ dissecting microscope and a Nikon Optiphot compound microscope, the former fitted with an optical micrometer. Drawings were rendered with the aid of a drawing tube on the Nikon system.

*Terminology*. Descriptions of adult morphology follow mainly Merz and Haenni (2000) as well as papers on Psychodidae (Quate & Brown 2004; Wagner & Hribar 2004). Terminology of the male terminalia is that of Sinclair (2000) and Wagner & Hribar (2004). General female postabdomen terminology follows Kotrba (2000) and Quate & Brown (2004), except the use of "genital complex" which is substituted for "spermathecal complex" and "larviduct" which is substituted for "oviduct".

*Descriptive format*. Diagnoses are provided for all species. Complete descriptions of the adult male and female are provided for new species, where specimens are available. Revised descriptions of known life stages are given for described species, where appropriate. When applicable, sample sizes are provided before each description with measurements in millimeters presented as a mean followed by a range in parentheses. Adult head width was measured at the point of greatest width of the eyes. Adult head length was measured from the vertex to the anterior margin of the clypeus. Palpal ratios were computed as proportions, considering the basal palpomere as 1. Wing length and width were measured at the points of greatest length and width, respectively. Measurements were not taken from shriveled or damaged pinned specimens.

## Key to Males of *Eurygarka*

1. Apices of gonostyli curved approximately 45° medially (Fig. 2-1 D)…*E. cyphostylus*… n.sp.
- Apices of gonostyli tapered, not curved (Fig. 2-2 B, D)…2

2(1). Gonostyli swollen dorsobasally, with a patch of setiform sensilla dorsally (Fig. 2-2 B); eye bridge narrowly divided (Fig. 2-2 A)…*E. helicis* (Dyar)
- Gonostyli not swollen dorsobasally, with few elongate setiform sensilla dorsally (Fig. 2-2 D); eye bridge contiguous (as in Fig. 2-1 A)…*E. nelderi* n.sp.

### ***Eurygarka*** Quate 1959

*Philosepedon (Eurygarka)* (Quate), Duckhouse 1973, 6A: 11 (as subgenus).
*Eurygarka* Quate, Quate & Vockeroth 1981, p. 299 (key to Nearctic genera, as genus)
*Psychoda helicis* Dyar 1929, 31: 64 (type species by monotypy).

DIAGNOSIS. **Larva:** Unknown. **Pupa:** Unknown. **Adult:** Male eye bridge contiguous or slightly separated, with 4 facet rows. Antenna 16-segmented; flagellomeres with nodes strongly bulbous, terminal 3 diminutive. Ascoids paired, with 1 posterior and 2 anterior branches inserted dorsomedially and ventrolaterally on node of flagellomeres 1–11; posterior branch of ascoids spathiform, anterior branches of ascoids leaf-shaped, each with 4–7 longitudinal veins. Mouthparts reduced; labellum bulbous, without blunt apical teeth. Wing without Sc vein ending in $R_1$. Male terminalia: gonocoxites with a posteromedial lobe bearing 5–7 setiform sensilla; aedeagus symmetrical, consisting of a single sclerite, laterally compressed basally, furcate or acuminate apically, with sternal bridge; cercopods cylindrical or tapered, curved slightly dorsad, with a pair of simple retinacula placed side by side, inserted dorsoapically. Female terminalia: cerci semi-

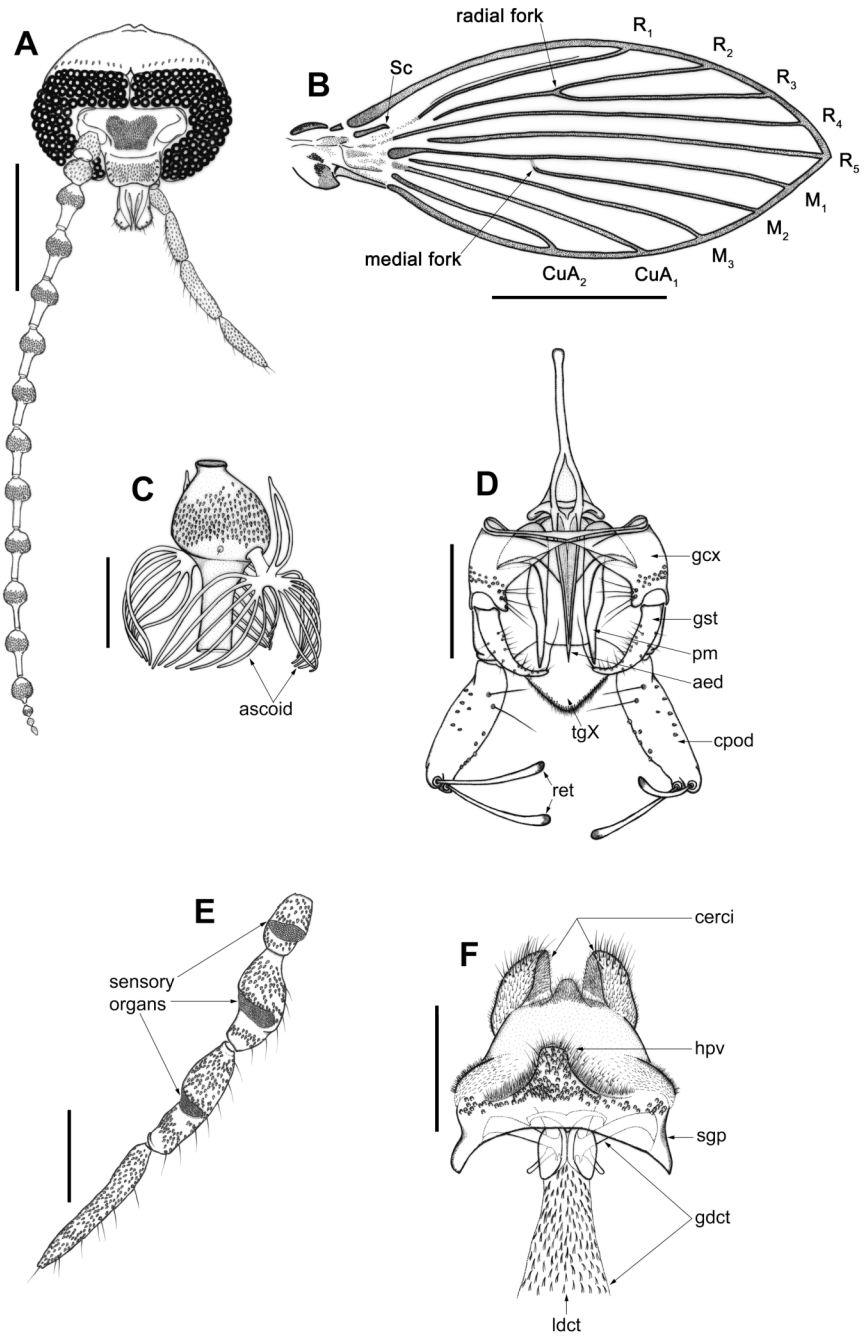



**Figure 2-1.** *Eurygarka cyphostylus* Curler n. sp. **A.** Male head, frontal view. **B.** Wing. **C.** Male antennal flagellomere 8 with ascoids, right antenna, frontal view. **D.** Male terminalia, dorsal view. **E.** Female left palpus, frontal view. **F.** Female terminalia, ventral view. Scale bars = 0.25 mm (A), 0.5 mm (B, E–F), 0.1 mm (D), 0.05 mm (C). (abbreviations: gcx = gonocoxite; gst = gonostyle; pm = paramere; aed = aedeagus; cpod = cercopod; tgX = tergite X; ret = retinacula; hpv = hypovalvae; sgp = subgenital plate; gdct = genital duct; ldct = larviduct).

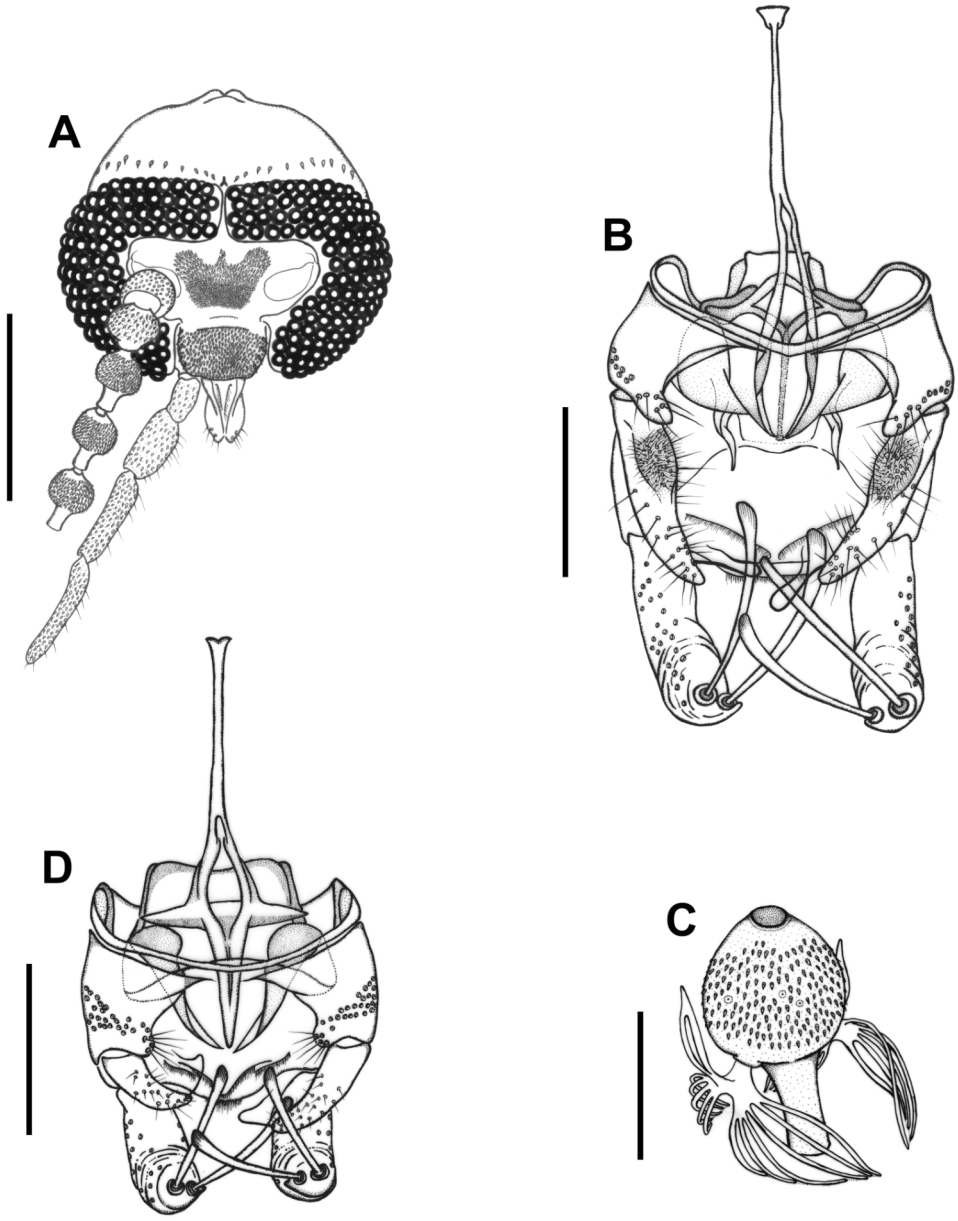



**Figure 2-2.** *Eurygarka helicis* (Dyar). **A.** Male head, frontal view. **B.** Male terminalia, dorsal view. **C.** Male antennal flagellomere 8 with ascoids, left antenna, frontal view. *Eurygarka nelderi* Curler n. sp. **D.** Male terminalia, dorsal view. Scale bars = 0.25 mm (A), 0.1 mm (B, D), 0.05 mm (C).

circular in shape from lateral aspect, slightly longer than tall, their medial surface with dense vestiture of microtrichia; hypovalvae digitiform.

DESCRIPTION. **Larva:** Unknown.

**Pupa:** Unknown.

**Adult Male:** Head strongly rounded from anterior aspect. Vertex rounded. Postocular bristles prominent, numbering 20–22. Eyebridge with 4 rows of facets, narrowly divided or contiguous at median. Frontal scar patch subquadrate anteriorly, bilobed posteriorly, with median spur in some species. Antenna 16-segmented, flagellomeres with nodes strongly bulbous, flagellomeres 1–8 gradually increasing in length, 9–11 decreasing in length, apical 3 diminutive. Ascoids numbering 2, with 1 posterior and 2 anterior branches, inserted dorsomedially and ventrolaterally on node of flagellomeres 1–11; posterior branch of ascoids spathiform, anterior branches of ascoids leaf-shaped, each with 4-7 longitudinal veins. Palpi typical of Psychodinae; first palpomere never more than 1/2 length of second palpomere, distal 3 palpomeres subequal or increasing in length; medial surface of palpomeres with numerous setiform sensilla directed medially, palpomere 4 with pair of setiform sensilla inserted at apex. Mouthparts extending slightly beyond palpomere 1; labellum bulbous or somewhat laterally compressed, bearing numerous setiform sensilla of varying length. Body with vestiture typical of Psychodinae; dense patches of spatulate hairs. Wings ovate, with apex acuminate; distal half of each cell with longitudinal patch of spatulate hairs; base of costa with single break, wings held horizontally over body in life; veins $R_5$ and $CuA_1$ basally wider than adjacent veins, vein Sc subequal in width to costa, parallel to, not ending in vein $R_1$. Legs typical of Psychodinae, with femora and tibia slender, parallel-sided; tibial spurs absent. Terminalia with hypandrium (sternite IX) represented by narrow transverse sclerite; epandrium (tergite IX) short, subequal in length to, or slightly longer than gonocoxites, with suboval depression anterodorsally, directly below distiphallus, bearing numerous erect macrotrichia; aedeagus symmetrical, consisting of single sclerite; basiphallus laterally compressed; distiphallus furcate or acuminate, with ventral transverse bridge; parameres articulated at ventral bridge of aedeagus and gonocoxal

apodeme, bridged dorsally forming sheath around base of distiphallus, with acuminate or sinuate extensions ventrally, flanking aedeagus. Gonocoxites nearly contiguous anterodorsally, with posteromedial lobe bearing 5–7 setiform sensilla. Gonostyli simple, tapered, with single stout setiform sensillum inserted subapically, directed medially. Cercopodia cylindrical or tapered, curved slightly dorsad, with pair of retinacula placed side by side, inserted dorsoapically; retinacula length greater than, or about equal to 1/2 length of cercopod.

**Adult Female:** Head shape as in male. Frontal scar patch shape identical to male. Eyebridge with 4 rows of facets, divided by 1 or more facet diameters. Postocular bristles prominent, numbering 35 or more. Palpomeres 2 and 3 slightly swollen and sinuous. Palpomeres 1–3 each with transverse, ovoid sensory organ placed mid-length on their lateral surface; sensory organs bearing several hundred digitiform papillae. Length of palpi typical of Psychodinae; first palpomere greater than or equal to 1/2 the length of second, distal 3 palpomeres subequal or slightly increasing in length. Antenna 16-segmented, flagellomeres with nodes strongly bulbous, flagellomeres 1–10 subequal in length, flagellomere 11 with little or no distal neck, apical 3 diminutive. Ascoids numbering 2, Y-shaped, with 1 slender, digitiform posterior branch and 2 broad, spathiform anterior branches, inserted dorsomedially and ventrolaterally on the node of flagellomeres 1–11; anterior branches without veins. Mouthparts extending slightly beyond palpomere 1; somewhat laterally compressed, bearing numerous setiform sensilla of varying length. Wings as in male, except for having 2 breaks at base of costa, and held roof-like over body in life. Legs as in male. Terminalia with tergite X lightly sclerotized, uniformly covered in setulae dorsally and laterally. Cerci semi-circular in shape from lateral aspect, slightly longer than broad in some species, not elongate or arched dorsally; with uniform covering of setulae; bearing numerous macrotrichia dorsally and apically. Subgenital plate (hypogynium) short, about 1/2 length of tergite X. Hypovalvae with single median protuberance, not emarginate, rounded or subquadrate. General structure of genital complex typical of Psychodinae; paired ovoid components, with reticulated pattern ventrally; lateral struts simple, transverse bands, about 1/4 width of genital duct; longitudinal struts narrow, less than 1/2 width of lateral struts; larviduct

about as wide as paired ovoid components, some species with larviduct bearing numerous spiniform projections internally; spiniform projections directed posteriorly.

REMARKS. Adult *Eurygarka* are easily distinguished from all other Psychodinae by the shape of the male and female terminalia, specifically by the structure of the gonopods, parameres and aedeagus of males, and the subgenital plate, cerci and larviduct of females. Characteristics of the antenna are also useful for distinguishing *Eurygarka* from related genera. Previous authors have described the ascoids of *Eurygarka* males and females as having 2 anterior branches and no posterior branch, but close examination of ascoids in the males of all known species and the female of *E. cyphostylus* n.sp. confirmed that a posterior branch is indeed present.

### ***Eurygarka helicis*** (Dyar) 1929 (Fig. 2-2 A–C)

*Psychoda helicis* Dyar, 1929, 31: 64 (original description); del Rosario, 1936, 59: 134; Rapp, 1944, 52: 205; 1945, 53: 29; Quate, 1955, 10: 235.
*Philosepedon (Eurygarka) helicis* (Dyar), Duckhouse, 1973, 6A: 11 (new combination).

DIAGNOSIS. **Larva:** Unknown. **Pupa:** Unknown. **Adult:** Male eye bridge divided by less than 1 facet diameter. Female eye bridge divided by nearly 2 facet diameters. Male ascoids: medial anterior branches with 6, and lateral anterior branches with 5 longitudinal veins. Male palpi with palpomere 2 slightly laterally expanded. Male terminalia: gonocoxites with a posteromedial lobe bearing 5 setiform sensilla; gonostyles tapering progressively from base to apex, not curved apically, with a bulge dorsobasally; bulge covered with setiform sensilla; aedeagus furcate apically; sternal bridge quadrate; ventral extensions of parameres sinuous; cercopods cylindrical, retinacula length greater than 1/2 length of cercopod. Female terminalia: hypovalvae digitiform, with apex rounded.

DESCRIPTION. **Larva:** Unknown.

**Pupa:** Unknown.

**Adult Male** (Fig. 2-2 A–C): Measurements, (N = 2) head width 0.43 mm, head length 0.37 mm, wing length 1.67 mm (1.63–1.70), wing width 0.67 mm, palpomere

proportion: 1–1.6–2.4–3.4. Eye bridge divided by less than 1 facet diameter. Frontal scar patch subquadrate anteriorly, bilobed posteriorly, with a median spur. Antennal flagellum typical of *Eurygarka*. Ascoids: medial anterior branches with 6, and lateral anterior branches with 5 longitudinal veins. Palpi with palpomere 2 slightly laterally expanded. Mouthparts slightly laterally compressed. Wing: radial and medial forks at same level, arising basal to apex of $CuA_2$; base of $M_2$ complete. Terminalia: gonocoxites with posteromedial lobe bearing 5 setiform sensilla; gonostyles tapering progressively from base to apex, not curved apically, with dorsobasally bulge covered with setiform sensilla. Aedeagus furcate apically; sternal bridge quadrate, with knob-like projections laterally; ventral extensions of parameres sinuous; cercopods cylindrical, retinacula length greater than 1/2 length of cercopod.

**Adult Female**: Eyebridge divided by 1 facet diameter. Frontal scar patch as in male. Antenna typical of *Eurygarka*. Palpi typical of *Eurygarka*. Mouthparts as in male. Wing venation as in male, but with 2 breaks at base of costa. Terminalia: Cerci as long as broad. Subgenital plate with hypovalvae digitiform, with apex rounded.

TYPE MATERIAL. Holotype [adult male]: CUBA. Jaronú, 26.ix.1927, reared from snails, H. K. Plank. Type deposited at U.S.N.M.

OTHER RECORDS. U.S.A. FLORIDA: Atlantic Beach, 1.v.1945, coll. A.E. Pritchard. ALABAMA: Auburn, 29.viii.1948, coll. J. Robinson.

DISTRIBUTION. Known from two locations in the southeastern United States, and a single location in Cuba.

REMARKS. Adults of *E. helicis* are unique among known species of *Eurygarka*, and can be readily distinguished by the divided eye bridge and shape of the gonostyles in the male and the shape of the subgenital plate in the female.

***Eurygarka cyphostylus*** Curler n. sp. (Fig. 2-1 A–F)

DIAGNOSIS. **Larva:** Unknown. **Pupa:** Unknown. **Adult:** Male eye bridge contiguous. Female eye bridge divided by less than 1 facet diameter. Male ascoids: medial anterior branches with 7, and lateral anterior branches with 6 longitudinal veins.

Male terminalia: gonocoxites with a posteromedial lobe bearing 6 setiform sensilla; gonostyles tapering progressively from base to apex, with apices bent approximately 45° medially, aedeagus acuminate apically; sternal bridge transverse, slightly arcuate; ventral extensions of parameres acuminate, terminating at same point as aedeagus; cercopods tapered from base to apex, retinacula length greater than 1/2 length of cercopod. Female terminalia: hypovalvae digitiform, with apex subquadrate.

DESCRIPTION. **Larva** Unknown.

**Pupa** Unknown.

**Adult Male** (Figs. 2-1 A–D): Measurements, (N = 10) head width 0.38 (0.33–0.40) mm, head length 0.35 (0.30–0.37) mm, wing length 1.55 (1.33–1.70) mm, wing width 0.64 (0.55–0.70) mm, palpomere proportion: 1–1.5–2.1–2.4. Eye bridge contiguous. Frontal scar patch subquadrate anteriorly, bilobed posteriorly, without median spur. Antennal flagellum typical of *Eurygarka*; Ascoids: medial anterior branches with 7, and lateral anterior branches with 6 longitudinal veins. Palpi with palpomeres of subequal width. Mouthparts with labellum bulbous. Wing: medial fork placed slightly basal to radial fork, both arising basal to apex of $CuA_2$; $M_2$ weakened at base. Terminalia: gonocoxites with a posteromedial lobe bearing 6 setiform sensilla; gonostyles tapering progressively from base to apex, with apices curved approximately 45° medially. Aedeagus acuminate apically; sternal bridge transverse, slightly arcuate; ventral extensions of parameres acuminate, terminating at same point as aedeagus; cercopods tapered from base to apex, retinacula length greater than 1/2 length of cercopod.

**Adult Female** (Figs. 2-1 E–F): Eyebridge divided by less than 1 facet diameter. Frontal scar patch as in male. Antenna typical of *Eurygarka*. Palpi typical of *Eurygarka*. Mouthparts as in male. Wing venation as in male, but with 2 breaks at base of costa. Terminalia: Cerci slightly longer than broad. Subgenital plate with hypovalvae digitiform, with apex subquadrate.

TYPE MATERIAL. Holotype [adult male]: U.S.A. TENNESSEE: *Union Co*: property of R.S. Donahoo, 36°10'N 83°52'W, 23.viii.2006, coll. G.R. Curler, CDC trap; deposited USNM. Specimen dissected, mounted on micro-slide. Allotype [adult

female]: TENNESSEE: *Knox Co*: patio at 2705 W. Glenwood Ave., Knoxville, 35°59'N 83°56'W, 10.ix.2005, coll. G.R. Curler, resting on wall; deposited USNM. Specimen dissected, mounted on slide. Paratypes: same locality as holotype, 21.viii.2006 [4 adult male (slides)], coll. G.R. Curler; same data as holotype [6 adult male (slides)] coll. G.R. Curler; TENNESSEE: *Knox Co*: 1137 Winterberry Ln., W. Knoxville, 35º55N 84º08'W, 30.vi.2007 [1 adult female (slide)], coll. J.K. Moulton; 10.vii.2007 [1 adult male (slide)], coll. G.R. Curler and J.K. Moulton; SOUTH CAROLINA: *Richland Co*: Riverbanks Zoo & Botanical Gardens, 34°00'N 81°04'W, 22.viii.2006, coll. M.P. Nelder, Fay-Prince UV trap. Paratypes deposited in USNM and UTK.

OTHER MATERIAL EXAMINED. U.S.A. Same location and collector as holotype, 21.viii.2006 [7 adult male]; 23.viii.2006 [5 adult male]; SOUTH CAROLINA: *Richland Co*: Riverbanks Zoo & Botanical Gardens, 34°00'N 81°04'W, 22.vi.2007, coll. M.P. Nelder, Fay-Prince UV trap.

ETYMOLOGY. From the Greek *cypho*, meaning "bent", in reference to the shape of the gonostyles.

DISTRIBUTION. Collected from several locations in eastern Tennessee, and two locations in South Carolina.

REMARKS. Adults of *E. cyphostylus* can be easily distinguished by the shape of the gonostyles, parameres and aedeagus in the male, and the shape of the subgenital plate in the female.

***Eurygarka nelderi*** Curler n. sp. (Fig. 2-2 D)

DIAGNOSIS. **Larva:** Unknown. **Pupa:** Unknown. **Adult:** Male eye bridge contiguous. Male ascoids: medial anterior branches with 6, and lateral anterior branches with 6 longitudinal veins. Male terminalia: gonocoxites with a posteromedial lobe bearing 6 setiform sensilla; gonostyles tapering progressively from base to apex, with apices curved slightly, not bent 45° medially; aedeagus acuminate apically; sternal bridge transverse, quadrangular, with triangular projections laterally; ventral extensions of

parameres acuminate, arcuate, directed medially, terminating at same point as aedeagus; apices of cercopods tapered, retinacula length about equal to 1/2 length of cercopod.

DESCRIPTION. **Larva** Unknown.

**Pupa** Unknown.

**Adult Male** (Fig. 2-2 D): Measurements, (N = 4) head width 0.38 (0.37–0.40) mm, head length 0.36 (0.35–0.37) mm, wing length 1.64 (1.63–1.67) mm, wing width 0.62 (0.60–0.63) mm, palpomere proportion: 1–1.8–2.6–3.4. Eye bridge contiguous. Frontal scar patch subquadrate anteriorly, bilobed posteriorly, without median spur. Antennal flagellum typical of *Eurygarka*; Ascoids: medial anterior branches with 6, and lateral anterior branches with 6 longitudinal veins. Palpi with palpomeres of subequal width. Mouthparts with labellum slightly laterally compressed. Wing: medial fork placed slightly basal to radial fork, both arising basal to apex of $CuA_2$; $R_3$ and $M_2$ weakened at base. Terminalia: gonocoxites with a posteromedial lobe bearing 6 setiform sensilla; gonostyles tapering progressively from base to apex, with apices curved slightly, not bent 45° medially; aedeagus acuminate apically; sternal bridge transverse, quadrangular, with triangular, lateral projections; ventral extensions of parameres acuminate, arcuate, directed medially, terminating at same point as aedeagus; apices of cercopods tapered, retinacula length about equal to 1/2 length of cercopod.

**Adult Female:** Unknown.

TYPE MATERIAL. Holotype [adult male]: U.S.A. SOUTH CAROLINA: *Richland Co*: Riverbanks Zoo & Botanical Gardens, 34°00'N 81°04'W, 22.vi.2007, coll. M.P. Nelder, Fay-Prince UV trap; deposited USNM. Specimen dissected, mounted on micro slide. Paratypes [3 adult male (slides)]: same location as holotype, 22.viii.2006, coll. M.P. Nelder, Fay-Prince UV trap. Paratypes deposited in USNM, CUAC and UTK.

ETYMOLOGY. Named for Mark P. Nelder, in recognition of his contribution of numerous specimens for this study.

DISTRIBUTION. Known from one location in South Carolina.

REMARKS. Adult males can be easily recognized by the shape of the gonostyli and parameres, and length of the retinacula.

## Discussion

*Taxonomy.* The main objectives of this study were to expand the existing generic diagnosis and description of *Eurygarka* to include previously unknown species, to revise the description of *E. helicis* to clarify its distinction from congeners, and to describe two new species within the genus. Focused collecting efforts, especially with CDC traps, are likely to produce additional new species of *Eurygarka*, in which case the generic diagnosis and description may need to be expanded further.

Previous authors have treated *Eurygarka* as a genus or as a subgenus of *Philosepedon* Eaton, but the generic limits of *Philosepedon* are unclear. Vaillant (1974) divided *Philosepedon* into several genera, but Quate (1996) maintained the use of *Philosepedon s. lat.*, while noting that it is "probably polyphyletic". In recognition of the monophyly of *Eurygarka* and its distinction from *Philosepedon* (*sensu* Vaillant), we follow Quate (1959) and Quate & Vockeroth (1981) by treating it as a genus. The monophyly of *Eurygarka* is supported by the following proposed synapomorphies: (1) anterior branches of male ascoids leaf-shaped, with multiple longitudinal veins; (2) gonocoxites with posteromedial lobe bearing 5 or more setiform sensilla; (3) epandrium with suboval depression anterodorsally, directly below distiphallus, bearing numerous erect macrotrichia; (4) female subgenital plate with unilobate hypovalvae.

*Biology*. Adult females of this genus are not commonly collected in CDC traps, but rather incidentally hand-captured while resting in areas where males are known to be present. Immatures of *Eurygarka* remain unknown, except for the fact that females deposit first instar larvae (larvipary) on dead terrestrial snails (Dyar 1929).

## Acknowledgements

We thank D. G. Furth (USNM) for loans of *Eurygarka*, and M. P. Nelder (Clemson University) for providing specimens of *Eurygarka* from South Carolina. Support for various aspects of this research included grants from the United States Army (Award No. W81XWH-06-1-0471 to JKM) and Discover Life in America.

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# CHAPTER 3
# A REVISION OF THE GENUS *GONDWANOSCURUS* JEZEK (DIPTERA: PSYCHODIDAE)

This chapter is a minimally edited version of an article in Zootaxa published in July 2009 by Gregory R. Curler:

Curler, G.R. (2009) A revision of the genus *Gondwanoscurus* Jezek (Diptera: Psychodidae). *Zootaxa*, 2169, 21–34.

I am the sole contributor to this publication.

## Abstract

*Gondwanoscurus* Jezek (Psychodidae: Psychodinae) is revised to include seven species. *Gondwanoscurus cruciferus* **sp. nov.** and *G. ornithostylus* **sp. nov.** from Thailand are described. Three described species are transferred from *Telmatoscopus* Eaton to *Gondwanoscurus*: *G. ejundicus* (Quate), *G. eximius* (Quate) and *G. praecipuus* (Quate). The adult male and female of *G. ejundicus* and *G. mcclurei* (Quate) and the adult male of *G. eximius* and *G. praecipuus* are redescribed. Keys to adult males of the seven known species and females of the four species for which they are known are provided, and the relationship of *Gondwanoscurus* to other Paramormiine genera is discussed.

## Introduction

Little attention has been given to the Oriental moth fly (Psychodidae: Psychodinae) fauna since the works of Satchell (1958), Quate (1962a, 1962b, 1965) and Jezek (2001, 2004). Duckhouse (1973, 2004) suggested that Psychodidae, in particular subfamily Psychodinae, is represented in the Oriental region by a large number of species, most of which are undescribed. Jezek (2001) underscored this suggestion, pointing out that many undescribed Psychodinae are concentrated in the tropics, and many are "in conflict with existing classifications". Furthermore, many species of Oriental Psychodinae were originally described in the genus *Telmatoscopus* Eaton, and are currently considered "unplaced species of *Telmatoscopus*" (Duckhouse, 1973), indicating that their generic affinities do not lie with *Telmatoscopus s. str.*, but rather, another described or undescribed genus.

Jezek (2001) described the genus *Gondwanoscurus* to include one new species, *G. malaysiensis* Jezek, and one described species, *G. mcclurei* (Quate), from Malaysia (Federation of Malaya). Recent collections of Psychodinae from Thailand contain many undescribed species, including two new species of *Gondwanoscurus*. In this paper, *Gondwanoscurus* is revised to include two new species from Thailand and three described species from North Borneo (Malaysia, Sabah). A revised generic description is

given, keys to adult males of the seven known species and females of the four species for which they are known are provided, and the relationship of *Gondwanoscurus* to other Paramormiine genera is discussed.

## Materials and Methods

*Material*. This research is based on an examination of adult males and females of *Gondwanoscurus cruciferus* **sp. nov.**, *G. ornithostylus* **sp. nov.**, *G. ejundicus* and *G. mcclurei*, and males of *G. eximius* and *G. praecipuus*. Specimens of the former two were collected in Thailand during 2006 and 2007 in Malaise traps operated by the Thailand Inventory Group for Entomological Resources (TIGER) project, headed by M. Sharkey and B. Brown. Association of adult males and females of *G. cruciferus* and *G. ornithostylus* is based on the assumption that specimens with morphological similarities of the head and wing, which were collected from the same locality, are conspecific.

Specimens were borrowed from, or are deposited with the following (acronyms used throughout the text): QSBG, Queen Sirikit Royal Botanical Gardens, Chiang Mai, Thailand; LACM, Natural History Museum of Los Angeles County, Los Angeles, CA; BPBM, Bernice P. Bishop Museum, Honolulu, HI; USNM, National Museum of Natural History, Smithsonian Institution, Washington, DC; BMNH, The Natural History Museum, London, United Kingdom; UTK, Department of Entomology and Plant Pathology, University of Tennessee, Knoxville, TN. All samples taken during the TIGER project were assigned a database number (e.g. T-245, T-203), and these numbers have been included with the appropriated records below. The database is available at **http://sharkeylab.org/tiger/static.php?app=tiger&page=about**.

*Specimen preparation*. Specimens were fixed in 70 or 95% EtOH. Morphological studies were based on slide-mounted specimens. Slides were prepared using sodium hydroxide to clear specimens and Canada balsam as a mounting medium. Specimens were observed by using a Meiji Techno RZ dissecting microscope and a Nikon Optiphot compound microscope, the former fitted with an optical micrometer. Drawings were rendered with the aid of a drawing tube on the Nikon system.

*Terminology*. Descriptions of adult morphology follow mainly Merz and Haenni (2000) as well as recent papers on Psychodidae (Quate & Brown 2004; Curler & Moulton 2008, Curler & Courtney 2009). Terminology of the male terminalia is that of Sinclair (2000) and Curler & Moulton (2008). General female postabdomen terminology follows Kotrba (2000) and Quate & Brown (2004), except "genital duct," which is used in place of "spermathecal complex".

*Descriptive format*. Diagnoses are provided for all taxa. Complete descriptions of all known life stages are provided for new taxa. Revised descriptions of known life stages are given for described species, where appropriate. When applicable, sample sizes are provided before each description with measurements in millimeters presented as a mean followed by a range in parentheses. Adult head width was measured at the point of greatest width of the eyes. Adult head length was measured from the posterior margin of the vertex to the anterior margin of the clypeus. Palpal ratios were computed as proportions, considering the basal palpomere as 1. Wing length and width were measured at the points of greatest length and width, respectively.

**Key to Males of *Gondwanoscurus***

1. Apices of retinacula bifurcate (Figs. 3-1 E; 3-2 H)…2
- Apices of retinacula simple (Figs. 3-2 D; 3-3 D, L)…3

2(1). Gonostyli bifurcate, with rami of subequal length (Fig. 3-2 F); cercopodia about twelve times longer than wide (Fig. 3-2 H); antennal flagellomeres only slightly asymmetrical (Fig. 3-2 E)…*G. ejundicus* (Quate)
- Gonostyli with apical 1/3 constricted, sinuous, not bifurcate (Fig. 3-1 E); cercopodia about nine times longer than wide (Fig. 3-1 E); antennal flagellomeres clearly asymmetrical, with nodes exserted laterally, ascoids two, three or four-branched…*G. cruciferus* sp. nov.

3(1). Gonostyli with apical 1/3 tapered, not bifurcate (Figs. 3-1 E; 3-2 D) …4
- Gonostyli bifurcate, with medial rami of varying shape (Fig. 3-3 C, G, J)…5

4(3). Gonostyli with apical 1/3 constricted, digitiform, sinuous…*G. malaysiensis* Jezek

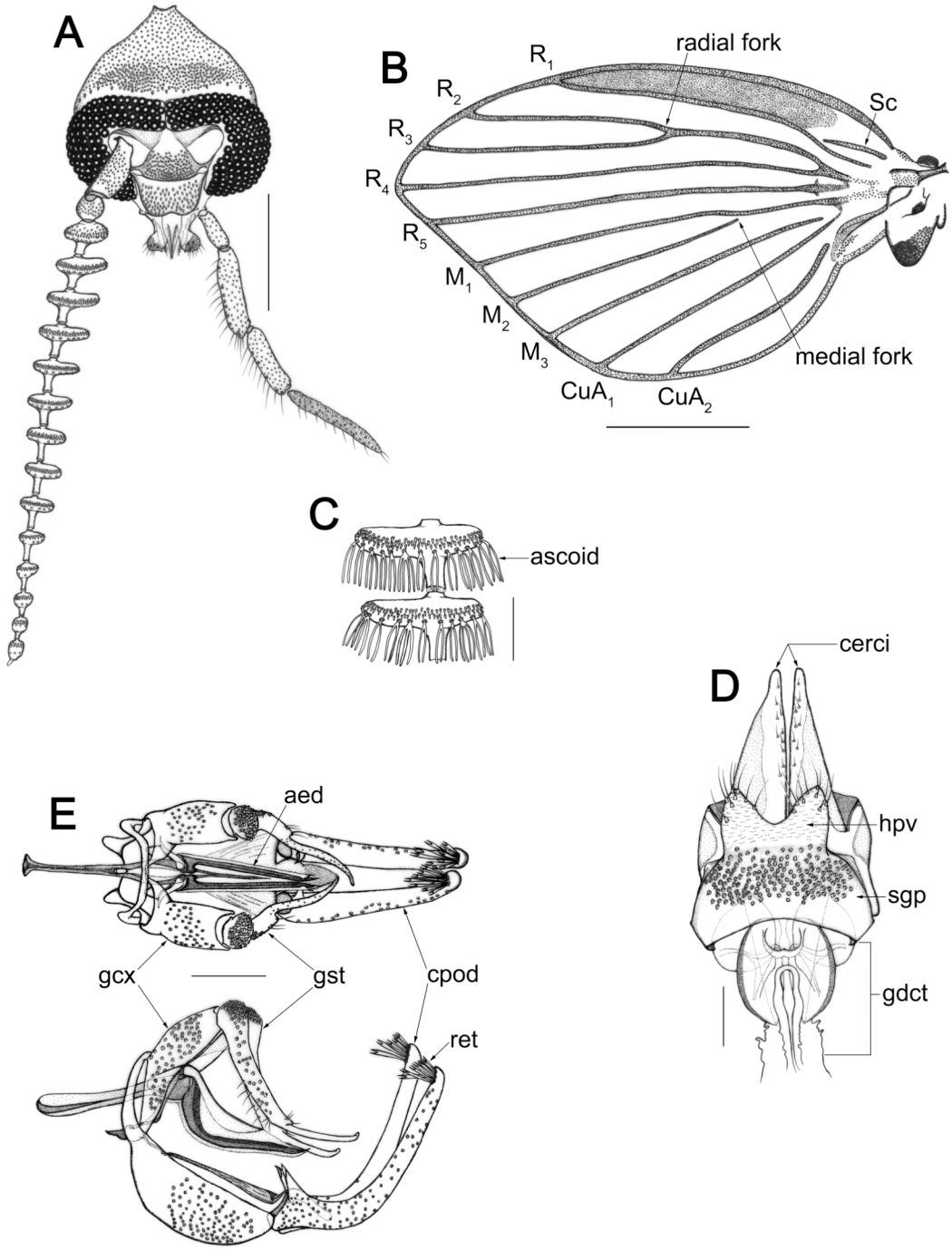



**Figure 3-1.** *Gondwanoscurus cruciferus* Curler sp. nov. **A.** Male head, frontal view. **B.** Wing. **C.** Male antennal flagellomeres 8–9 with ascoids, left antenna, frontal view. **D.** Female terminalia, ventral view. **E.** Male terminalia, dorsal view (above), lateral view (below). Scale bars = 0.25 mm (A), 0.5 mm (B), 0.0625 mm (C–D), 0.125 mm (E). (abbreviations: gcx = gonocoxite; gst = gonostylus aed = aedeagus; cpod = cercopod; ret = retinacula; hpv = hypovalvae; sgp = subgenital plate; gdct = genital duct).

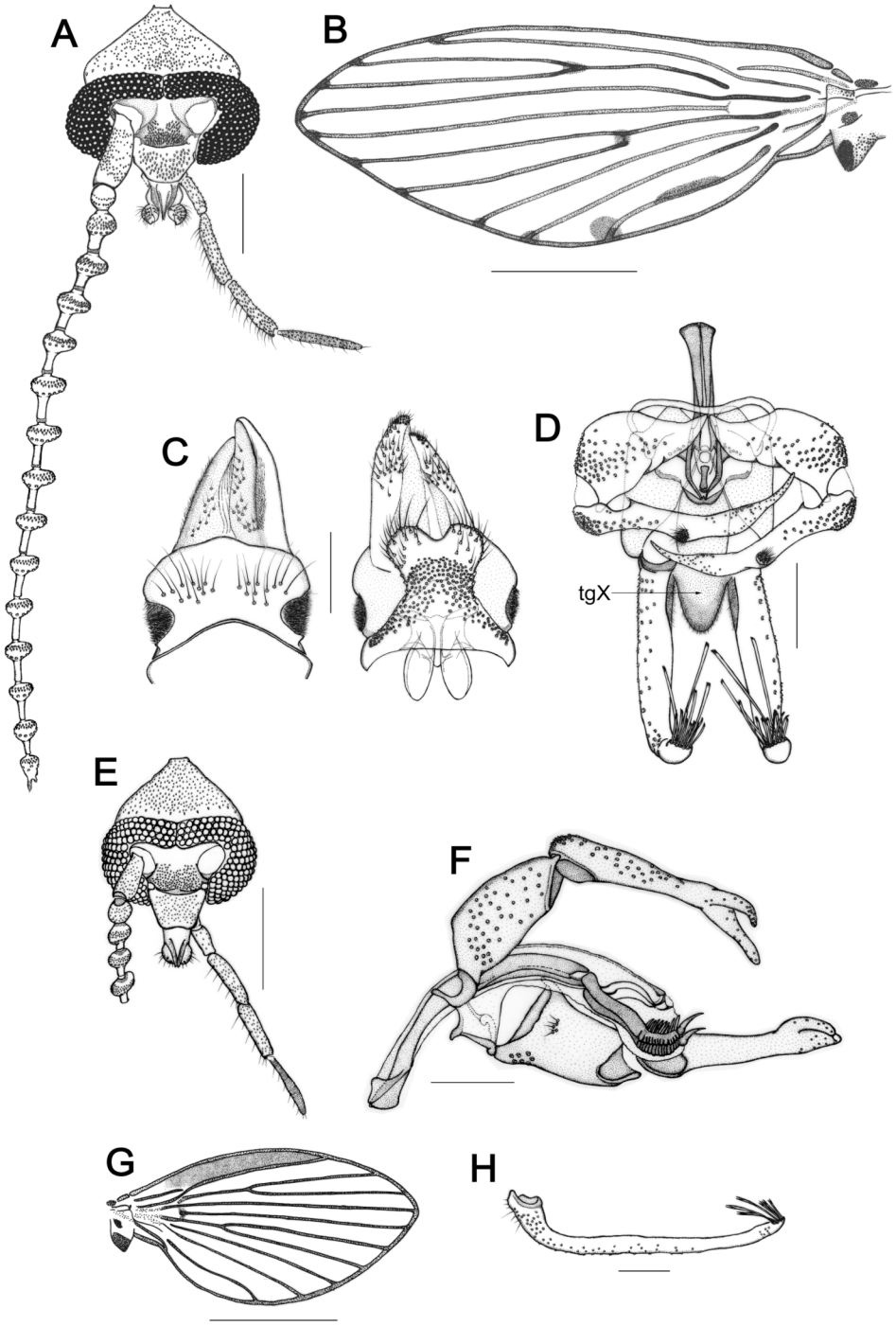



**Figure 3-2.** *Gondwanoscurus ornithostylus* Curler sp. nov. **A.** Male head, frontal view. **B.** Wing. **C.** Female terminalia, dorsal view (left), ventral view (right). **D.** Male terminalia, dorsal view. *Gondwanoscurus ejundicus* (Quate). **E.** Male head, frontal view. **F.** Male gonopods and phallus, ventrolateral view. **G.** Wing. **H.** Male cercopod, lateral view. Scale bars = 0.25 mm (A, E), 0.125 mm (C–D, F, H), 0.5 mm (B, G). (abbreviation: tgX = tergite X).

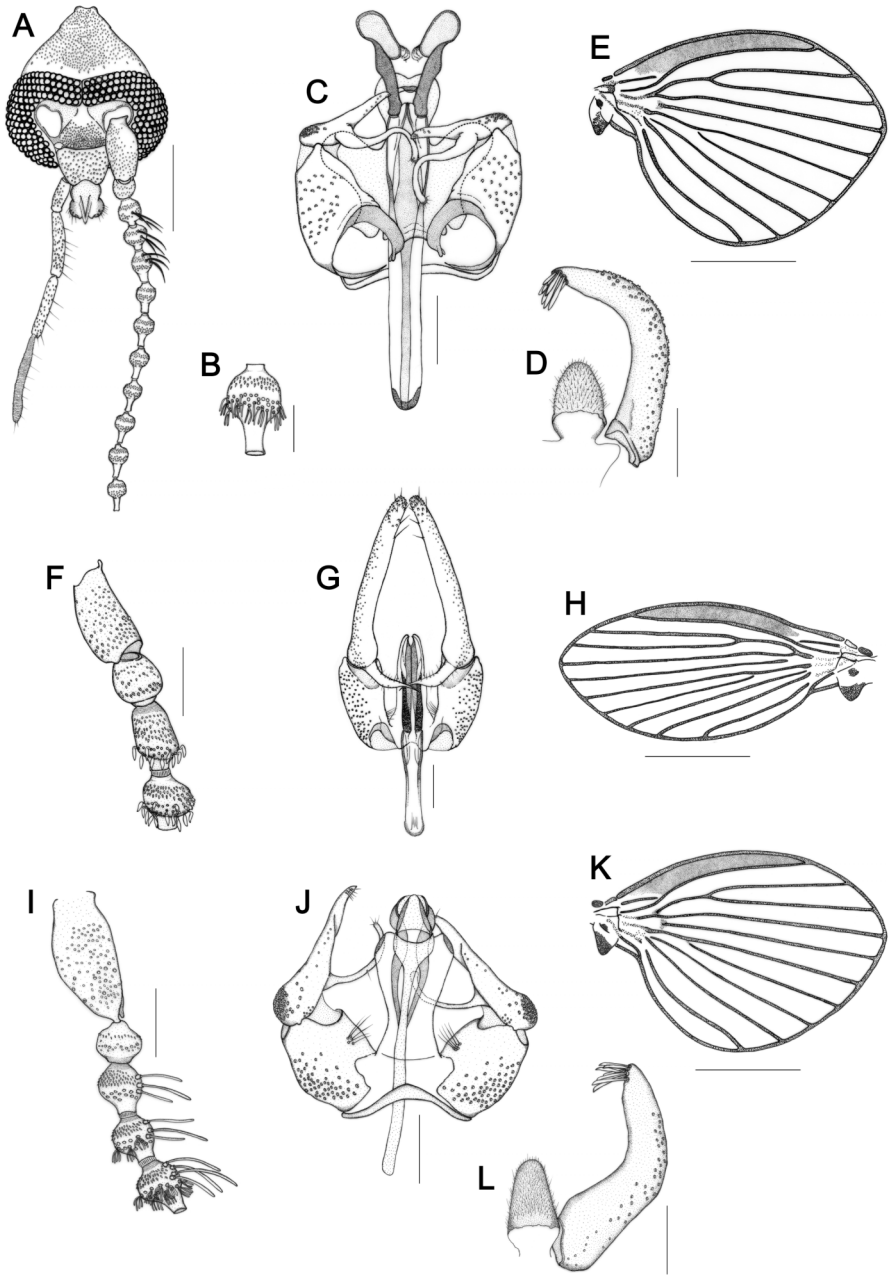



**Figure 3-3.** *Gondwanoscurus eximius* (Quate). **A.** Male head, frontal view. **B.** Male antennal flagellomere 8 with ascoids, left antenna, frontal view. **C.** Male gonopods and phallus, ventral view. **D.** Male cercopod and tenth tergite, dorsal view. **E.** Wing. *Gondwanoscurus mcclurei* (Quate). **F.** Male antennal scape, pedicel and flagellomeres 1–2, left antenna, frontal view. **G.** Male gonopods and phallus, ventral view. **H.** Wing. *Gondwanoscurus praecipuus* (Quate). **I.** Male antennal scape, pedicel and flagellomeres 1–3, left antenna, frontal view. **J.** Male gonopods and phallus, dorsal view. **K.** Wing. **L.** Male cercopod and tenth tergite, dorsal view. Scale bars = 0.05 mm (B), 0.25 mm (A), 0.125 mm (C–D, F–G, I–J, L), 0.5 mm (E, H, K).

- Gonostyli with apical 1/3 acuminate, with setose lobe arising dorsomedially (Fig. 3-2 D)…*G. ornithostylus* sp. nov.

5(3). Medial rami of gonostyli arising at about mid-length on medial surface of gonostylus, more than ten times longer than wide, with apices digitiform (Fig. 3-3 C, J)…6

- Medial rami of gonostyli arising at base of gonostylus directed medially, not more than five times longer than wide, with apices acuminate, not digitiform (Fig. 3-3 G)…*G. mcclurei* (Quate)

6(5). Medial rami of gonostyli sinuous (Fig. 3-3 C); antennal flagellomeres 1– 3 each bearing three lateral spines (Fig. 3-3 A)…*G. eximius* (Quate)

- Medial rami of gonostyli arcuate, not sinuous (Fig. 3-3 A); antennal flagellomeres 1– 2 each bearing three lateral spines, flagellomere 3 bearing four lateral spines (Fig. 3-3 I)…*G. praecipuus* (Quate)

**Key to Females of *Gondwanoscurus***

Females of *G. eximius*, *G. praecipuus* and *G. malaysiensis* are unknown.

1. Tergite IX with prominent semi-circular depressions dorsolaterally, depressions covered with minute setiform sensilla (Fig. 3-2 C)… *G. ornithostylus* sp. nov.

- Depressions absent from tergite IX…2

2(1). Hypovalvae bilobed, apices of lobes angulate, not rounded (Fig. 3-1 D)…*G. cruciferus* sp. nov.

- Hypovalvae bilobed, apices of lobes rounded…3

3(1). Hypovalvae bilobed, lobes broadly rounded, about as long as wide; subgenital plate with digitform projections posterolaterally…*G. ejundicus* (Quate)

- Hypovalvae bilobed, lobes narrow, about twice as long as wide; subgenital plate with prominent bulge medially…*G. mcclurei* (Quate)

***Gondwanoscurus* Jezek 2001**

DIAGNOSIS. **Adult:** Head: eye bridge contiguous, with four facet rows; antenna 16-segmented; scape at least two times longer than wide; pedicel globular; flagellomeres nodiform, gradually decreasing in size from base to apex, terminal three not diminutive. Mouthparts reduced; labellum bulbous, without blunt apical teeth. Wing ovate or broadly rounded, with Sc vein approaching but not ending in $R_1$. Body with vestiture comprised of dense patches of spathulate and spatulate hairs; hairs longer and wider than those of most other Psychodinae. Male terminalia: gonocoxites each with cluster of 5–6 prominent setiform sensilla inserted basally on their medial surface; aedeagus symmetrical, consisting of multiple sclerites, basiphallus comprised of single sclerite, dorsoventrally or laterally compressed basally, bifid apically; distiphallus comprised of paired sclerites of varying shape. Cercopodia tapered, with 7–14 retinacula inserted dorsoapically or with multiple clusters of retinacula dorsally. Female terminalia: cerci membranous or lightly sclerotized, triangular in shape from lateral aspect, about two times longer than broad, with few clusters of minute setiform sensilla laterally; hypovalvae bilobed, lobes digitiform, broadly rounded or acuminate; subgenital plate smooth or with prominent bulge medially.

DESCRIPTION. **Adult Male:** See Jezek (2001). Head longer than wide in most species. Vertex elongated, constricted at cervix. Male eye bridge contiguous, with four facet rows. Frontal scar patch subquadrate anteriorly, bilobed posteriorly, with median spur in some species. Antenna 16-segmented; scape at least two times longer than wide; pedicel globular; flagellomeres nodiform, gradually decreasing in size from base to apex, terminal three not diminutive; nodes exserted laterally in most species; internodes about as long as their preceding node. Shape and number of ascoids variable among species; flagellomeres 1–7 with numerous ascoids encircling each node, flagellomeres 8–14 with fewer ascoids; ascoids lanceolate or with 2–4 digitiform branches. Palpi typical of Psychodinae; medial surface of palpomeres with numerous setiform sensilla directed medially, palpomere 4 with pair of setiform sensilla inserted at apex. Mouthparts extending slightly beyond palpomere 1; labellum bulbous, bearing numerous setiform sensilla of varying length. Body with vestiture comprised of dense patches of spathulate

and spatulate hairs; hairs longer and wider than those of most other Psychodinae. Wings ovate or broadly rounded, with apex rounded; base of costa with single break, wings held horizontally over body in life; most species with costal cell infuscated (except *G. ornithostylus*); vein Sc narrow compared to costa, approaching but not ending in vein $R_1$. Legs typical of Psychodinae, with femora and tibia slender, parallel-sided; tibial spurs or appendages absent. Terminalia with hypandrium (sternite IX) represented by narrow, transverse sclerite; epandrium (tergite IX) about as long as wide or slightly longer than wide; tergite X triangular, rounded apically, about 1.5 times longer than its basal width; aedeagus symmetrical, consisting of multiple sclerites; basiphallus comprised of single sclerite, dorsoventrally or laterally compressed basally, bifid apically; distiphallus comprised of paired sclerites, varying in shape among species; parameres membranous, fused, forming sheath around distiphallus. Gonocoxites widely separated or with medial extensions meeting dorsally, each with cluster of 5–6 prominent setiform sensilla inserted basally on their medial surface. Gonostyli simple or bifurcate, varying in shape among species. Cercopodia tapered, straight or curved dorsad, with retinacula numbering 7–14 or more than 20, inserted dorsoapically or in multiple clusters dorsally; retinacula variable in length, with simple or bifurcate apices.

**Adult Female:** Head shape as in male. Frontal scar patch identical to male. Eyebridge contiguous, with four facet rows. Antenna similar to male, flagellomeres nodiform, nodes not exserted laterally. Ascoids numbering two per flagellomere, shaped as in male. Mouthparts shaped as in male. Wing always ovate, not broadly rounded as in males of some species. Legs as in male. Terminalia with cerci membranous or lightly sclerotized, triangular in shape from lateral aspect, about two times longer than broad with few clusters of minute setiform sensilla laterally; hypovalvae bilobed, lobes digitiform, broadly rounded or with acute apices; subgenital plate (hypogynium) smooth or with prominent bulge medially; genital duct with paired ovoid components, with reticulated pattern laterally or ventrally; struts inconspicuous, less than ¼ width of ovoid component.

REMARKS. Larvae and pupae are unknown for all species of *Gondwanoscurus*. Adult *Gondwanoscurus* are easily distinguished from other Psychodinae by the structure

of the male and female head and terminalia; specifically the contiguous eye bridge with four facet rows, antennal flagellomeres with numerous ascoids and laterally exserted nodes in many species; gonopods with gonocoxites bearing a cluster of setiform sensilla medially, and gonostyli usually bifurcate; unusually elongate cercopodia of the males, as well as the subgenital plate with a medial bulge, and the lightly scleritized, conical cercus of the females. The striking vestiture is characteristic of all species in the genus, but has been lost in most specimens in the process of preservation and mounting.

### ***Gondwanoscurus cruciferus* Curler sp. nov.** (Fig. 3-1 A–E)

DIAGNOSIS. **Adult:** Male antennae: scape approximately 2.5 times longer than wide; flagellomeres cruciform, with nodes exserted laterally. Male terminalia: gonostyli simple, with apical 1/3 constricted, digitiform, sinuous; basiphallus laterally compressed basally, bifid apically, with branches convergent; distiphallus comprised of paired, acuminate sclerites; cercopodia elongate, about 9 times longer than wide, bearing approximately 12 retinacula dorsoapically; retinacula with apices bifurcate. Female terminalia: hypovalvae with lobes tapered, apices acuminate; subgenital plate without prominent bulge medially, with dense patch of alveoli medially.

DESCRIPTION. **Adult Male** (Fig. 3-1 A–C, E): Measurements, (N = 5) head width 0.42 mm (0.41–0.46), head length 0.46 mm (0.45–0.47), wing length 1.97 mm (1.91–2.09), wing width 1.03 mm (0.93–1.20), palpomere proportion: 1–1.8–1.5–2.1. Head: frontal scar patch subquadrate anteriorly, bilobed posteriorly, with median spur; antennae with scape approximately 2.5 times longer than wide; flagellomeres cruciform, with nodes exserted laterally; ascoids with 2–4 digitiform branches, arranged in single row around each node. Wing: ovate, with posterior margin broadly convex; medial fork incomplete, basal to radial fork, both forks arising basal to apex of $CuA_2$. Terminalia: gonocoxites approximately 2.5 times longer than wide, with anterodorsal extensions touching medially; gonostyli simple, with apical 1/3 constricted, digitiform, sinuous, curved dorsally; parameral sheath tapered from base to apex, closely fitting shape of aedeagus; basiphallus laterally compressed basally, bifid apically, with branches

convergent; distiphallus comprised of paired, acuminate sclerites, articulated with basiphallus at apices of branches; sclerites of distiphallus each with lateral notch subapically; cercopodia elongate, about 9 times longer than wide, bearing approximately 12 retinacula dorsoapically; retinacula with apices bifurcate.

**Adult Female** (Fig. 3-1 D): Wing: ovate, anterior and posterior margins equally convex; $M_2$ complete at base. Terminalia: hypovalvae with lobes tapered, apices acute; subgenital plate without prominent bulge medially, with dense patch of alveoli medially.

TYPE MATERIAL. Holotype [adult male]: THAILAND. *Sakon Nakhon Province*: Phu Phan National Park, behind park office, 17°03.521'N 103°58.450'E, 27.vii–2.viii.2006, coll. W. Kongnara, Malaise trap; deposited QSBG [T-207]. Specimen dissected, mounted on micro-slide. Allotype [adult female]: Phu Phan National Park, behind park office, 17°03.488'N 103°58.497'E, 21–27.vii.2006, coll. S. Tongboonchai, Malaise trap; deposited QSBG [T-205]. Specimen dissected, mounted on micro-slide. Paratypes: same locality as holotype, 21–27.vii.2006, Malaise trap [2 adult female (slides)], coll. W. Kongnara [T-203]; same data as holotype [1 adult male, 1 adult female (slides)], coll. W. Kongnara; same data as allotype [2 adult male (slides)], coll. W. Kongnara; same locality as allotype, 8–14.vii.2006, Malaise trap [1 adult male (slide)], coll. S. Tongboonchai, [T-199]; same locality as allotype, 27.vii–2.viii.2006, Malaise trap [3 adult male (slides)], coll. S. Tongboonchai, [T-208]; Phu Phan National Park, Kam Hom waterfall at Haew Sin chai, 17°07.415'N 104°01.179'E, 22–30.i.x2006, Malaise trap [1 adult male, 2 adult female (EtOH)], coll. S. Tongboonchai, [T-619]; *Loei Province*: Phu Kradueng National Park, Forest Protection Unit Loei .5 (Phakbung), 16°50.540'N 101°41.663'E, 7–13.ii.2007, Malaise trap [1 adult male (slide)], coll. S. Khonglasae, [T-1496]. Paratypes deposited in QSBG, LACM, USNM, and UTK.

ETYMOLOGY. From the Latin *crucifer*, meaning "cross bearer", in reference to the cruciform antennal flagellomeres.

DISTRIBUTION. Collected from several locations in northeast Thailand.

REMARKS. Adults of *G. cruciferus* are similar in appearance to *G. malaysiensis*. A suite of characters including the cruciform antennal flagellomeres with two, three, and four-branched ascoids, eye bridge contiguous over four facet diameters, and retinacula

with bifurcate apices in the male, and the subgenital plate with no medial bulge and hypovalvae with acuminate apices in the female will reliably separate *G. cruciferus* from other known species in this group. *G. cruciferus* is currently the best-known species of *Gondwanoscurus* in terms of material examined.

### ***Gondwanoscurus malaysiensis* Jezek**

*Gondwanoscurus malaysiensis* Jezek, 2001: 10 (original description).

DIAGNOSIS. **Adult:** Male antennae: flagellomeres with nodes exserted laterally; ascoids with three branches. Male head: eye bridge contiguous over three facet diameters. Male terminalia: gonostyli simple, with apical 1/3 constricted, digitiform, sinuous; distiphallus comprised of paired, acuminate sclerites; cercopodia elongate, about 9 times longer than wide, bearing 13 retinacula dorsoapically; retinacula with apices simple. Female unknown.

DESCRIPTION. **Adult Male** See Jezek (2001).

**Adult Female** Unknown.

TYPE MATERIAL. Holotype [adult male]: MALAYSIA [FEDERATION OF MALAYA]. *Perak*: Hulu, Belum Expedition, Belum Camp, 5°30'N 101°26'E, iv–vi.1994, coll. light trap; deposited in Slovene Natural History Museum, Ljubljana. Specimen dissected, mounted on micro-slide. Paratypes: same data as holotype, light trap [2 adult male (slides)], deposited in Ljubljana and in the Department of Entomology of the National Museum (Museum of Natural History), Prague [Cat. No. 33859].

OTHER RECORDS. THAILAND. *Sakon Nakhon Province*: Phu Phan National Park, behind forest protection unit at Huay Wien Prai, 17°06.863'N 104°00.327'E, 10–17.ii.2007 Malaise trap [1 adult male (slide)], coll. W. Kongnara, [T-1689]; Phu Phan National Park, north of well, 17°03.543'N 103°58.452'E, 20–30.i.2007, Malaise trap [1 adult male (slide), 1 adult male (EtOH)], coll. S. Tongboonchai, [T-1525].

DISTRIBUTION. Known from the type locality in Malaysia and two localities in Thailand.

REMARKS. Adults of *G. malaysiensis* are similar in appearance to *G. cruciferus*. A suite of characters including the antennal flagellomeres with laterally exserted nodes and three-branched ascoids, eye bridge contiguous over three facet diameters, and retinacula with simple apices in the male will reliably separate *G. malaysiensis* from other known species in this group. The shape of the head (particularly the width of the vertex) in *G. malaysiensis* also appears to differ from that in *G. cruciferus*. The holotype of *G. malaysiensis* was not examined, but several Thai specimens examined matched Jezek's original description.

***Gondwanoscurus ornithostylus* Curler sp. nov.** (Fig. 3-2 A–D)

DIAGNOSIS. **Adult:** Male antennae: scape approximately 3 times longer than wide; flagellomeres nodiform, with nodes exserted slightly laterally. Male terminalia: gonostyli simple, with apical 1/4 tapered, acuminate; basiphallus dorsoventrally compressed basally, bifid apically, with branches nearly parallel; distiphallus comprised of paired, acuminate, convergent sclerites; cercopodia with apical 1/4 curved approximately 90° dorsad, bearing approximately 15 retinacula dorsoapically; retinacula with apices simple. Female terminalia: tergite IX with prominent semi-circular depressions dorsolaterally, depressions covered with minute setiform sensilla; hypovalvae with lobes rounded, cordate; subgenital plate with prominent bulge medially, covered with alveoli medially and posterolaterally.

DESCRIPTION. **Adult Male** (Fig. 3-2 A–B, D): Measurements, (N = 2) head width 0.55 mm, head length 0.57 mm, wing length 3.23 mm (3.16–3.30), wing width 1.28 mm (1.22–1.35), palpomere proportion: 1–1.9–1.8–2.0. Head: frontal scar patch subquadrate anteriorly, bilobed posteriorly, without median spur; antennae with scape approximately 3 times longer than wide; flagellomeres nodiform, with nodes exserted slightly laterally. Wing: ovate; membrane with infuscation patches at forks and apices of longitudinal veins; with posterior margin slightly more convex than anterior; $M_2$ weakened at base; medial fork basal to radial fork, radial fork arising apical to apex of $CuA_2$. Terminalia: gonocoxites approximately 1.5 times longer than wide, with

anterodorsal extensions touching medially; gonostyli simple, with a setose lobe at mid-length dorsally, with apical ¼ tapered, acuminate; parameral sheath broad, wider than long, not extending beyond gonocoxites; basiphallus dorsoventrally compressed basally, bifid apically, with branches nearly parallel; distiphallus comprised of paired, acuminate, convergent sclerites; cercopodia with apical 1/4 curved approximately 90° dorsad, bearing approximately 15 retinacula dorsoapically; retinacula with apices simple.

**Adult Female** (Fig. 3-2 C): Wing: shape as in male; $M_2$ weakened at base; infuscation as in male. Terminalia: tergite IX with prominent semi-circular depressions dorsolaterally, depressions covered with minute setiform sensilla; hypovalvae with lobes rounded, cordate; subgenital plate with prominent bulge medially, covered with alveoli medially and posterolaterally.

TYPE MATERIAL. Holotype [adult male]: THAILAND. *Chiang Mai Province*: Doi Inthanon National Park, Kew Mae Pan, 18°33.163'N 98°28.8'E, 6–13.ix.2006, coll. Y. Areeluck, Malaise trap; deposited QSBG [T-245]. Specimen dissected, mounted on micro-slide. Allotype [adult female]: same data as holotype, coll. Y. Areeluck; deposited QSBG [T-245]. Paratypes: same data as holotype [3 adult female (slides)], coll. Y. Areeluck; Doi Inthanon National Park, summit marsh, 18°35.361'N 98°29.157'E, 27.ix–5.x.2006, Malaise trap [1 adult male (slide)], coll. Y. Areeluck [T-351]. Paratypes deposited in QSBG and USNM.

ETYMOLOGY. From the Greek *ornitho*, meaning "bird", and *stylus*, meaning "pointed instrument" in reference to the gonostyles of this species which resemble the head of a shore bird.

DISTRIBUTION. Collected from two locations in northern Thailand.

REMARKS. Adults of *G. ornithostylus* are distinguished by the elongate, ovate shape, and spotted appearance of the wing, and the structure of the male and female terminalia, specifically the male gonostyli with the medial bulge and acuminate apex, and the female tergite X with setose, circular depressions laterally.

### ***Gondwanoscurus ejundicus* (Quate)** (Fig. 3-2 E–H)

*Telmatoscopus ejundicus* Quate, 1962a, 4: 8 (original description); Duckhouse, 1973, 231 (Oriental catalog).

DIAGNOSIS. **Adult:** Male antennae: scape approximately 2.5 times longer than wide; flagellomeres T-shaped, with nodes exserted laterally. Male terminalia: gonostyli bifurcate; rami digitiform, of subequal length, with apices rounded; basiphallus laterally compressed basally, bifid apically, with branches parallel; distiphallus comprised of paired, spinose sclerites; cercopodia elongate, about 12 times longer than wide, bearing 7 retinacula dorsoapically; retinacula with apices bifurcate. Female terminalia: hypovalvae with lobes broadly rounded, slightly longer than wide; subgenital plate with prominent bulge medially, with digitiform projections posterolaterally; bulge and anterior margin covered with alveoli.

REDESCRIPTION. **Adult Male.** See Quate (1962a). (Fig. 3-2 E–H): Measurements, (N = 1) head width 0.36 mm, head length 0.42 mm, wing length 1.80 mm, wing width 0.93 mm, palpomere proportion: 1–2.2–2.0–2.4. Head: frontal scar patch subquadrate anteriorly, bilobed posteriorly, without median spur; antennae with scape approximately 2.5 times longer than wide; flagellomeres T-shaped, with nodes exserted laterally. Wing: ovate, with posterior margin more convex than anterior; medial fork basal to radial fork, both arising basal to apex of $CuA_2$. Terminalia: gonocoxites approximately 2.5 times longer than wide, widely separated at base; gonostyli bifurcate; rami digitiform, of subequal length, with apices rounded; lateral rami with apices curved medially; parameral sheath parallel-sided, expanded apically, not wider than distance between gonocoxal bases; basiphallus laterally compressed basally, bifid apically, with branches parallel; distiphallus comprised of paired, sinuous sclerites, articulated with basiphallus at apices of branches; sclerites of distiphallus each with longitudinal row of approximately 15 spines on their apical 1/3, arising from medial surface, directed medially, with 1 stout, articulated spine apically; cercopodia elongate, about 12 times longer than wide, bearing 7 retinacula dorsoapically; retinacula with apices bifurcate.

**Adult Female.** See Quate (1962a): Wing: strongly ovate, anterior and posterior margins equally convex, apex broadly rounded; $M_2$ weakened at base. Terminalia:

hypovalvae with lobes broadly rounded, slightly longer than wide; subgenital plate with prominent bulge medially, with digitiform projections posterolaterally; medial bulge and anterior margin covered with alveoli.

TYPE MATERIAL. Holotype [adult male]: NORTH BORNEO [MALAYSIA, SABAH]. Ranau, tree buttress, 6.x.1958, coll. L. W. Quate. Allotype [adult female] Ranau, W. Coast residency, seepage area, 6.x.1958, coll. L. W. Quate. Types deposited at BPBM.

DISTRIBUTION. Known only from two locations in Sabah.

REMARKS. Adult males of *G. ejundicus* are distinguished by the general structure of the terminalia, especially the elongate, bifurcate gonostyli and the spinose distiphallus. Females are separable by the obovate shape of the wings, and the subgenital plate with a median bulge and posterolateral projections. Adults of this species are most similar to those of *G. cruciferus* sp. nov. and *G. malaysiensis*.

### ***Gondwanoscurus eximius* (Quate)** (Fig. 3-3 A–E)

*Telmatoscopus eximius* Quate, 1962a, 4: 8 (original description); Duckhouse, 1973: 31 (Oriental catalog).

DIAGNOSIS. **Adult:** Male antennae: flagellomeres 1– 3 each bearing three lateral spines; ascoids simple or bifurcate, arranged in multiple irregular rows around each node. Male terminalia: gonostyli bifurcate, with medial rami sinuous; parameral sheath broad, wider than distance between gonocoxal bases, trilobed apically, with lateral lobes rounded, extending nearly to apices of gonocoxites, median lobe cordate apically, extending well beyond gonopods; basiphallus dorsoventrally compressed basally; distiphallus comprised of paired, spatulate sclerites; cercopodia curved approximately 90° at mid-length.

REDESCRIPTION. **Adult Male.** See Quate (1962a). (Fig. 3-3 A–E): Measurements, (N = 2) head width 0.45 mm (0.43–0.47), head length 0.51 mm, wing length 2.23 mm, wing width 1.62 mm, palpomere proportion: 1–2.3–2.2–3. Head:

frontal scar patch subquadrate anteriorly, bilobed posteriorly, without median spur; antennae with scape approximately 2.5 times longer than wide; flagellomere nodes bulbous, not exserted laterally; flagellomeres 1– 3 each bearing three lateral spines; spines with apices acuminate; ascoids simple or bifurcate, arranged in multiple irregular rows around each node. Wing: broadly rounded, slightly longer than wide; radial and medial fork at same level, both arising basal to apex of $CuA_2$; base of $M_2$ incomplete. Terminalia: gonocoxites approximately 1.5 times longer than wide, widely separated at base; gonostyli bifurcate; lateral rami stout, tapered, with acute apices; medial rami arising at about mid-length on medial surface of lateral rami, slender, sinuous, with rounded apices; parameral sheath broad, wider than distance between gonocoxal bases, trilobed apically, with lateral lobes rounded, extending nearly to apices of gonocoxites, median lobe cordate apically, extending well beyond gonopods; basiphallus dorsoventrally compressed basally, bifid apically, with branches truncate, not extending beyond gonopods; distiphallus comprised of paired, spatulate sclerites; cercopodia curved approximately 90° at mid-length; retinacula spathulate, numbering 13.

**Adult Female**: Unknown.

TYPE MATERIAL. Holotype [adult male]: NORTH BORNEO [MALAYSIA, SABAH]. Ranau, hillside seepage area, 6.x.1958, coll. L. W. Quate. Type deposited at BPBM. Paratype: same data as holotype [3 adult males]. Paratypes deposited at USNM.

DISTRIBUTION. Known only from the type locality.

REMARKS. Adult males of *G. eximius* can be easily distinguished by the acuminate spines on antennal flagellomeres 1–3, and characters of the terminalia, particularly the gonostyli with sinuous medial rami, and trilobate parameral sheath. Males of *G. eximius* are most similar to those of *G. praecipuus* in the structure of the antenna, and broadly rounded wing.

### ***Gondwanoscurus mcclurei* (Quate)** (Fig. 3-3 F–H)

*Telmatoscopus mcclurei* Quate, 1962b, 4: 227 (original description); Duckhouse, 1973: 232 (Oriental catalog).

*Gondwanoscurus macclurei* (Quate), Jezek, 2001: 8 (*lapsus calami* for *mcclurei*)

DIAGNOSIS. **Adult:** Male antennae: scape approximately 2 times longer than wide; flagellomere 1 with node 1.5 times longer than wide; flagellomeres 2–14 with nodes bulbous, not exserted laterally; ascoids lanceolate, arranged in multiple irregular rows around each node. Male terminalia: gonostyli bifurcate; lateral rami digitiform, elongate, about 6 times longer than wide, with blunt apices bearing numerous setiform sensilla; basiphallus dorsoventrally compressed basally, bifid apically, with branches nearly parallel; distiphallus comprised of paired, spathulate sclerites; cercopodia straight, elongate, about 14 times longer than wide. Female terminalia: hypovalvae with lobes digitiform, slightly longer than wide; subgenital plate with prominent bulge medially; bulge covered with dense patch of alveoli.

REDESCRIPTION. **Adult Male.** See Quate (1962b) and Jezek (2001). (Fig. 3-3 F–H): Measurements, (N = 1) head width 0.42 mm, head length 0.51 mm, wing length 2.25 mm, wing width 1.0 mm, palpomere proportion: 1–2.0–1.8–2.3. Head: frontal scar patch subquadrate anteriorly, bilobed posteriorly, without median spur; antennae with scape approximately 2 times longer than wide; flagellomere 1 with node 1.5 times longer than wide; flagellomeres 2–14 with nodes bulbous, not exserted laterally; ascoids lanceolate, arranged in multiple irregular rows around each node. Wing: ovate; medial fork basal to radial fork, both arising basal to apex of $CuA_2$. Terminalia: gonocoxites approximately 2.5 times longer than wide, widely separated at base; gonostyli bifurcate; lateral rami digitiform, elongate, about 6 times longer than wide, with blunt apices bearing numerous setiform sensilla; medial rami arising at base of gonostylus, not more than five times longer than wide, with apices tapered, acuminate; parameral sheath smoothly tapered, not wider than distance between gonocoxal bases; basiphallus dorsoventrally compressed basally, bifid apically, with branches nearly parallel; distiphallus comprised of paired, spathulate sclerites, articulated with basiphallus at apices of branches; cercopodia straight, elongate, about 14 times longer than wide; retinacula spiniform, numbering more than 20, clustered at mid-length and apically on cercopod.

**Adult Female.** See Quate (1962b). Terminalia: cerci lightly sclerotized, teardrop-shaped from lateral aspect, about two times longer than tall; hypovalvae with lobes digitiform, slightly longer than wide; subgenital plate with prominent bulge medially; bulge covered with dense patch of alveoli.

TYPE MATERIAL. Holotype [adult male]: MALAYA [MALAYSIA, FEDERATION OF MALAYA]. Kuala Lumpur, Batu Caves, Penney Room, Cavern C, light trap, 3.v.1960, coll. K. E. McClure. Allotype: same locality as holotype, 24.iii.1960 [adult female], coll. K. E. McClure. Holotype and allotype deposited at BPBM. Paratypes: same locality as holotype, ix, xii.1959 [6 adult males]; ii, v.1960 [13 adult females] coll. K. E. McClure. Paratypes deposited at USNM and BMNH.

DISTRIBUTION. Known from two localities in Malaysia.

REMARKS. Adult males of *G. mcclurei* are unique among described *Gondwanoscurus* species, and can be distinguished by characters of the antennae such as the fusiform flagellomere 1, and lanceolate ascoids, as well as characters of the terminalia, particularly the elongate, digitiform gonostyli with acuminate medial rami, and the elongate cercopodia. Females of this species can be distinguished by the subgenital plate with a prominent medial bulge and digitiform hypovalvae. The wing of *G. mcclurei* was figured by both Quate and Jezek, and was examined and reillustrated in the current paper. All specimens of *G. mcclurei* examined in this study, including the holotype, had a rounded apex and infuscation of the wing membrane as figured by Quate and myself. The wing figured by Jezek shows a pointed apex and a greater degree of infuscation, suggesting a difference in interpretation, or that *G. mcclurei* may actually be more than one species. Adults of *G. mcclurei* exhibit sufficient characters to support inclusion of the species in *Gondwanoscurus*, but the male is quite unusual and difficult to compare with other known species in the genus. Regardless of its affinities, *G. mcclurei* is the type species of the genus.

***Gondwanoscurus praecipuus* (Quate)** (Fig. 3-3 I–L)

*Telmatoscopus praecipuus* Quate, 1962a, 4: 11 (original description); Duckhouse, 1973, 232 (Oriental catalog).

DIAGNOSIS. **Adult:** Male antennae: flagellomeres 1– 2 each bearing three lateral spines, flagellomere 3 bearing four lateral spines; ascoids each with four digitiform branches, arranged in multiple irregular rows around each node. Male terminalia: gonostyli bifurcate, with medial rami arcuate; parameral sheath constricted medially, expanded apically, not wider than distance between gonocoxal bases; basiphallus laterally compressed basally, bifid apically, with branches of "Y" fused medially, spatulate; distiphallus comprised of paired, sinuous sclerites, articulated with basiphallus basal to "Y"; cercopodia curved approximately 45° at mid-length.

REDESCRIPTION. **Adult Male** (Fig. 3-3 I–L): Measurements, (N = 2) head width 0.5 mm (0.49–0.51), head length 0.5 mm (0.49–0.51), wing length 2.78 mm (2.75–2.80), wing width 1.85 mm, palpomere proportion: 1–1.7–1.6–2.3. Head: frontal scar patch subquadrate anteriorly, bilobed posteriorly, without median spur; antennae with scape approximately 2.5 times longer than wide; flagellomere nodes not exserted laterally; flagellomeres 1– 2 each bearing three lateral spines, flagellomere 3 bearing four lateral spines, spines with apices blunt, rounded; ascoids each with four digitiform branches, arranged in multiple irregular rows around each node. Wing: broadly rounded, slightly longer than wide; medial fork basal to radial fork, both arising basal to apex of $CuA_2$; base of $M_2$ incomplete. Terminalia: gonocoxites approximately 1.25 times longer than wide, widely separated at base; gonostyli bifurcate; lateral rami stout, tapered, with acute apices; medial rami of gonostyli arising at about mid-length on medial surface of lateral rami, slender, arcuate, with rounded apices; parameral sheath constricted medially, expanded apically, not wider than distance between gonocoxal bases; basiphallus laterally compressed basally, bifid apically, with branches of "Y" fused medially, spatulate; distiphallus comprised of paired, sinuous sclerites, articulated with basiphallus basal to "Y"; cercopodia curved approximately 45° at mid-length; retinacula spathulate, numbering 7.

**Adult Female**: Unknown.

TYPE MATERIAL. Holotype [adult male]: NORTH BORNEO [MALAYSIA, SABAH]. Tenompok, approximately 50 km E of Jesselton, 18.x.1958, coll. L. W. Quate. Type deposited at BPBM. Paratype: same locality as holotype, 20.x.1958 [1 adult male, partial specimen], coll. L. W. Quate. Paratype deposited at BPBM.

DISTRIBUTION. Known only from the type locality.

REMARKS. Adult males of *G. praecipuus* are larger than males of all other described *Gondwanoscurus* species, and can be readily distinguished by the blunt spines on antennal flagellomeres 1– 3, and the gonostyli with arcuate medial rami. Males of *G. praecipuus* are most similar to those of *G. eximius* in the structure of the antennae, and broadly rounded wings.

Two female specimens lacking collection data and labeled only as "praecipuus?" were examined with the holotype. It is impossible to positively associate these females with the male of *G. praecipuus*, but the terminalia are similar to females of *G. ejundicus*, confirming that they are *Gondwanoscurus*.

## Discussion

*Taxonomy.* The main objectives of this study were to provide an expanded diagnosis and description of *Gondwanoscurus*, to describe two new species of *Gondwanoscurus*, and to revise the descriptions of *G. ejundicus* (Quate), *G. mcclurei* (Quate), *G. eximius* (Quate) and *G. praecipuus* (Quate). Multiple species groups are apparent in this genus, but analysis of phylogenetic relationships is impossible without fresh specimens of each species for DNA analysis and/or knowledge about the immature stages. Furthermore, focused collecting efforts are likely to produce additional new species of *Gondwanoscurus*, in which case the generic diagnosis and description may need to be expanded further. Adults of *Gondwanoscurus* fit the diagnosis of tribe Paramormiini (Curler & Courtney, 2009) and are morphologically similar to those of some Paramormiine genera including *Paramormia* Enderlein and *Neotelmatoscopus* Tonnoir, but phylogenetic relationships among the Paramormiine genera have not yet been determined.

Jezek (2001) suggested that adults of *Gondwanoscurus* bear resemblance to "*Telmatoscopus" aquilus* Quate from the Ryukyu Islands, as well as "*Telmatoscopus*" *bifidens, digitoides* and *sagittalis* from the Philippines. It should be noted that the former species actually belongs to tribe Mormiini, while the latter three species are now included in *Neotelmatoscopus* (Curler & Courtney, 2009). Few species of the genus *Mormia* Enderlein superficially resemble species of *Gondwanoscurus* (e.g. *Mormia* species exhibit a contiguous eye bridge with three facet rows while all known *Gondwanoscurus* species exhibit a contiguous eye bridge with four facet rows). But the adults of all known species of *Neotelmatoscopus* share some or all of the following character states with species of *Gondwanoscurus*: [males] contiguous eye bridge with four facet rows; palmate ascoids encircling the node of each flagellomere; parameres fused into membranous, conical sheath; apices of retinacula bifurcate; gonostyli bifurcate. [females] cerci shorter than in most Psychodinae, lightly scleritized, triangular in shape from lateral aspect; subgenital plate with prominent posteromedial bulge. It may seem as though some species of *Neotelmatoscopus* are congeneric with *Gondwanoscurus*, but all *Neotelmatoscopus* lack the cluster of setiform sensilla on the medial surface of both gonocoxites, which is present in all known species of *Gondwanoscurus*. A study of the immature stages of *Gondwanoscurus* will likely provide insight into its relationship with *Neotelmatoscopus* and other Paramormiine genera.

*Biology*. With the exception of *G. mcclurei* and *G. malaysiensis*, which were collected with light traps, all known species of *Gondwanoscurus* were collected near seepage and/or stream habitat. This suggests that the immature stages of this genus are aquatic, and could possibly be found feeding on decaying organic matter in or near the seeps or streams where adult *Gondwanoscurus* were collected.

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# CHAPTER 4
# CONTRIBUTIONS TO NEARCTIC *STUPKAIELLA* VAILLANT (DIPTERA: PSYCHODIDAE)

This chapter is a slightly revised version of a manuscript submitted by Gregory R. Curler and John K. Moulton in August 2009 for publication in Zootaxa:

Curler, G.R. and J.K. Moulton. Contributions to Nearctic *Stupkaiella* Vaillant (Diptera: Psychodidae). *Zootaxa*, in press.

My contributions to this publication include collection and identification of specimens, as well as preparation of figures and the manuscript.

## Abstract

The diagnosis of genus *Stupkaiella* Vaillant (Diptera: Psychodidae) is revised. Three new eastern Nearctic species, *Stupkaiella capricornuata* **sp. nov.**, *S. lasiostyla* **sp. nov.**, and *S. robinsoni* **sp. nov.,** and the 4th or final instar larva of *S. bipunctata* Kincaid are described and a key to adult males of the eastern Nearctic species of *Stupkaiella* is provided.

## Introduction

The genus *Stupkaiella* (Psychodidae: Psychodinae: Pericomini) was proposed by Vaillant (1973) to include seven species from the Nearctic region. Vaillant considered the distribution of *Stupkaiella* as "North America and Eastern Asia", but treated only Nearctic species in the original description. Wagner (1984) described an additional species, *S. mastelleri*, from Pennsylvania whereas Duckhouse (1987) placed *Stupkaiella* as a subgenus of *Thornburghiella* Vaillant and included five Himalayan species. Later, Jezek (2001) regarded *Stupkaiella* as a genus in a comparison with other Pericomine genera, but did not mention the work of Duckhouse (1987). In the current study, the status of this genus is corroborated and the diagnosis is revised, three new species of *Stupkaiella* from North Carolina and the larva of *S. bipunctata* Kincaid from Oregon are described, and a key to the adult males of all eastern Nearctic species of *Stupkaiella* is provided.

## Materials and Methods

*Study area*. This study focused on adult specimens collected from multiple locations in western North Carolina as well as larval and adult specimens collected from a single location in western Oregon.

*Material*. This research is based on an examination of adult males and females of *Stupkaiella capricornuata* **sp. nov.**, *S. lasiostyla* **sp. nov.**, and *S. robinsoni* **sp. nov.**, As well as adult males and instar IV larvae of *S. bipunctata*. Adult specimens were collected

during 2007, 2008 and 2009 by Malaise trap or emergence trap and/or sweep netting while larvae were collected from 1993–1995 by benthic sampling. Association of adult males and females is based on morphology, phenology and the location(s) where each species was collected (i.e., *S. capricornuata* begins emerging before, but is sympatric with *S. furcata* Vaillant and *S. recurrens* Vaillant; however, none of these three species was collected in the same location as *S. lasiostyla* or *S. robinsoni*, nor were the latter two collected together). Association of larval and adult *S. bipunctata* was based on a comparison of DNA sequences obtained primarily for use in a higher-level phylogenetic study of the family (Curler and Moulton, unpublished).

Specimens are deposited with the following (acronyms used throughout the text): LACM, Natural History Museum of Los Angeles County, Los Angeles, CA.; USNM, National Museum of Natural History, Smithsonian Institution, Washington, D.C.; GSMNP, Great Smoky Mountains National Park Insect Collection, Gatlinburg, TN.; UTK, Department of Entomology and Plant Pathology, University of Tennessee, Knoxville, TN.

*Specimen preparation*. Specimens were fixed in 70 or 95% EtOH. Morphological studies were based on slide-mounted specimens. Slides were prepared using sodium hydroxide to clear specimens and Canada balsam as a mounting medium. Specimens were observed by using a Meiji Techno RZ dissecting microscope and a Nikon Optiphot compound microscope, the former fitted with an optical micrometer. Drawings were rendered with the aid of a drawing tube on the Nikon system. Photomicrographs are composites of images captured using a Nikon Coolpix® digital camera mounted on a Nikon E600 microscope. Composite images were created using Helicon Focus® 3.10 and edited with Adobe Photoshop® 7.0. Material for SEM examination was critical point dried and sputter-coated with gold. SEM images were captured on a LEO 1525 microscope and edited with Adobe Photoshop® 7.0.

*Terminology*. Descriptions of adult morphology follow mainly Merz and Haenni (2000) as well as recent papers on Psychodidae (Quate & Brown 2004; Curler & Moulton 2008, Curler & Courtney 2009). Terminology of the male terminalia is that of Sinclair (2000) and Curler (2009). Female postabdomen terminology follows Kotrba (2000) and

Curler (2009). General larval terminology follows Courtney *et al.* (2000) and psychodid-specific larval terminology (e.g. segmentation and morphology of tergal plates) follows Vaillant (1971).

*Descriptive format*. Diagnoses are provided for all taxa. Complete descriptions of the adult male and female of each new species and the larva of a described species are provided. When applicable, sample sizes are provided before each description with measurements in millimeters presented as a mean followed by a range in parentheses. All larval characters refer to instar IV. Larval head capsule width was measured at the point of greatest width. Total length of larvae was measured from the anterior-most point of the head capsule to the posterior most point of the anal division, excluding the flabellar processes. Only slide-mounted larvae with extended abdomens were measured for total length. Adult head width was measured at the point of greatest width of the eyes. Adult head length was measured from the vertex to the anterior margin of the clypeus. Palpal ratios were computed as proportions, considering the basal palpomere as 1. Approximate wing length and width were measured at the points of greatest length and width, respectively.

## Key to males of eastern Nearctic *Stupkaiella*

1. Prothorax with a capitate patagium (Fig. 4-1 E) inserted adjacent to prothoracic spiracle on each side…2
- Patagia absent…3

2(1). Gonostyli with ventral ramus approximately 2/3 as long as dorsal ramus…*S. mastelleri* Wagner
- Gonostyli with dorsal rami elbowed basally, with a longitudinal patch of microtrichia apically (Fig. 4-1 F)…*S. lasiostyla* **sp. nov.**

3(1). Gonostyli with rami of subequal length…4
- Gonostyles with rami of unequal length…5

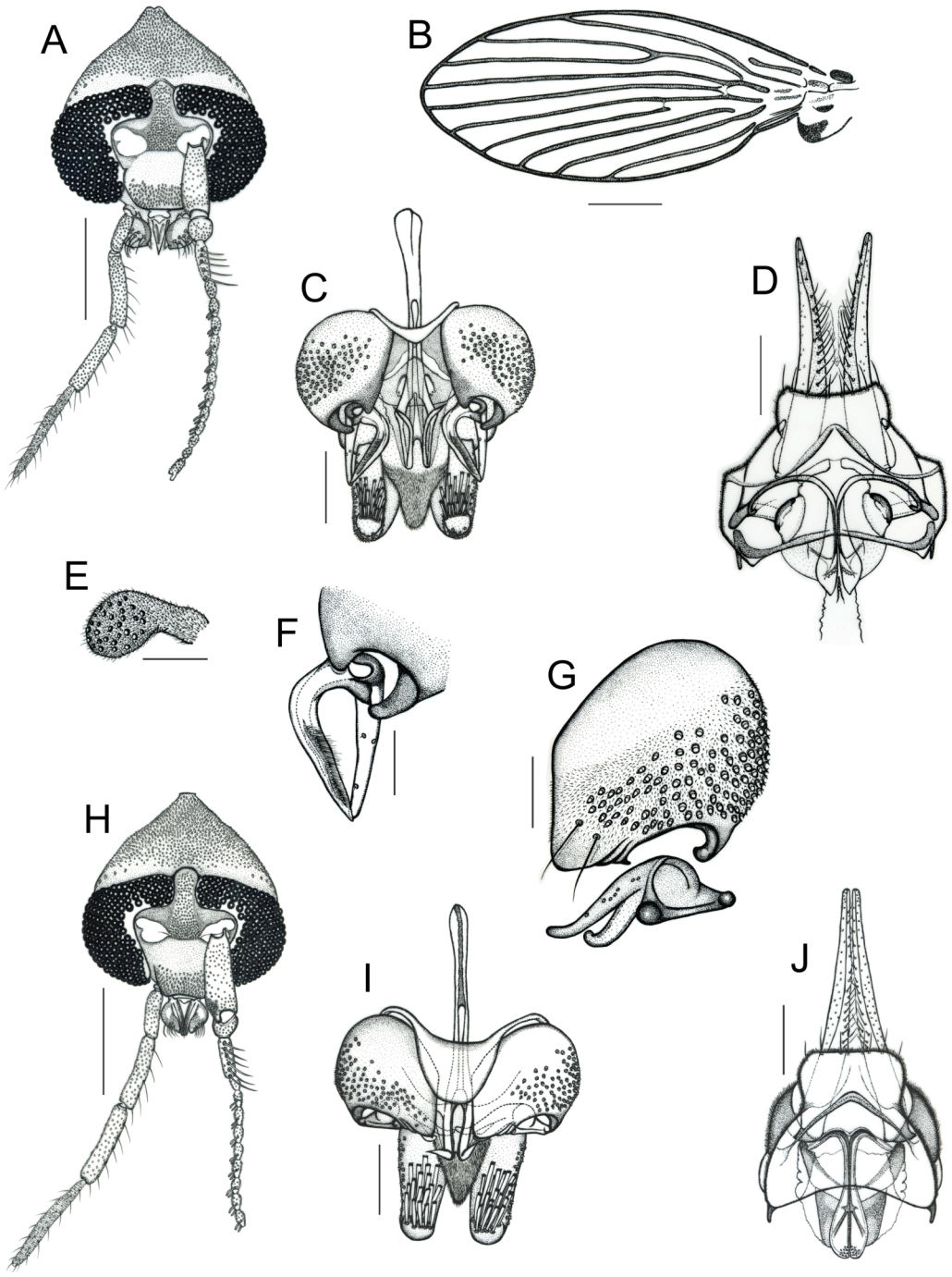



**Figure 4-1.** *Stupkaiella lasiostyla.* **A.** Male head, frontal view. **B.** Wing. **C.** Male terminalia, dorsal view. **D.** Female terminalia, internal structure, ventral view. **E.** Right patagium, frontal view. **F.** Right gonopod, dorsal view. *Stupkaiella robinsoni* Curler n. sp. **G.** Right gonopod, gonostyle separated, dorsal view. **H.** Male head, frontal view. **I.** Male terminalia, dorsal view. **J.** Female terminalia, internal structure, ventral view. Scale bars = 0.05 mm (E–G), 0.1 mm (C, D, I, J), 0.25 mm (A, H), 0.5 mm (B).

4(3). Gonocoxites with conspicuously quadrate margin dorsomedially (Fig. 4-1 G, I), hypandrium extended posteriorly, visor-like (Fig. 4-1 I)…*S. robinsoni* **sp. nov.**

- Gonocoxites with slightly concave margin dorsomedially, hypandrium narrow, U-shaped in dorsal view, not visor-like …*S. furcata* Vaillant

5(3). Gonocoxites with a digitiform posteromedial process about ½ as long as dorsal ramus of gonostyle …*S. carolina* (Banks)

- Gonocoxites without posteromedial processes…6

6(5). Dorsal paramere present, with arcuate, acuminate lateral processes (Fig. 4-2 C)…*S. capricornuata* **sp. nov.**

- Dorsal paramere absent, aedeagus encased by transparent parameral sheath…*S. recurrens* Vaillant

## ***Stupkaiella*** Vaillant 1973

*Stupkaiella* Vaillant, 1973: 367 (original description).
*Stupkaiella* Vaillant, Wagner 1984: 239 (as genus, description of *S. mastelleri*).
*Thornburghiella (Stupkaiella)* (Vaillant), Duckhouse 1987: 87 (as subgenus).
*Stupkaiella* Vaillant, Jezek 2001: 64 (as genus, comparison of Pericomini in part).
*Stupkaiella furcata* Vaillant, 1973: 367 (type species by original designation).

DIAGNOSIS. **Larva:** Postmentum dentate; teeth uniform, conical, arranged in single transverse row. Tergite structure and dorsal chaetotaxy, abdominal segment IV: protergite with paired, simple protuberances medially; medial protuberances flanked by second pair of simple protuberances; each protuberance with setiform macrotrichium inserted apically; mesotergite with paired, bifurcate protuberances medially; medial protuberances flanked by pair of simple protuberances; each bifurcate protuberance with two setiform macrotrichia inserted apically, each simple protuberance with setiform macrotrichium inserted apically; metatergite with paired, simple protuberances medially;

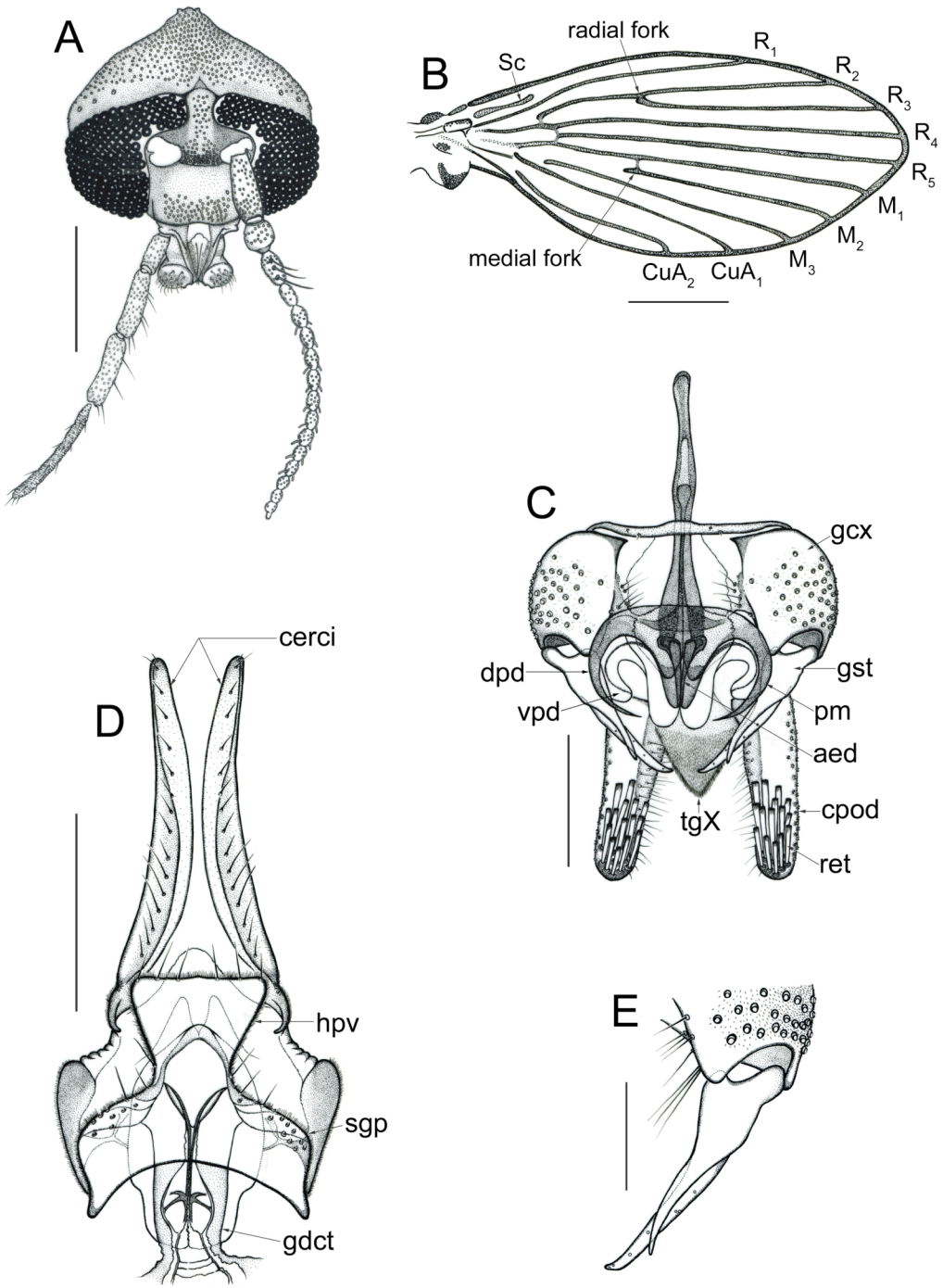



**Figure 4-2.** *Stupkaiella capricornuata* Curler n. sp. **A.** Male head, frontal view. **B.** Wing. **C.** Male terminalia, dorsal view. **D.** Female terminalia, internal structure, ventral view. **E.** Right gonopod, dorsal view. Scale bars = 0.2 mm (D), 0.25 mm (A, C), 0.5 mm (B), 0.125 mm (E). (abbreviations: gcx = gonocoxite; gst = gonostyle; pm = paramere; aed = aedeagus; cpod = cercopod; tgX = tergite X; ret = retinacula; hpv = hypovalvae; sgp = subgenital plate; gdct = genital duct).

medial protuberances flanked by pair of trifurcate protuberances; each simple protuberance with setiform macrotrichium inserted apically, each trifurcate protuberance with three setiform macrotrichia inserted apically. **Pupa:** Unknown. **Adult:** Male eye-bridge with 4–6 facet rows, separated by width of 1–3 (Oriental spp.), 3–4 (eastern Nearctic spp.) or 4–8.5 (western Nearctic spp.) facet diameters. Interocular suture conspicuous, shaped as inverted Y, V, or U. Row of postocular bristles incomplete medially, with 3–6 bristles on each side of head. Antenna 16-segmented; flagellomere I elongate, at least two times longer than broad with 3–7 rigid spines inserted dorsally or dorsolaterally; flagellomeres II–XIII fusiform, flagellomere XIV fusiform or rounded, with digitiform process apically. Ascoids paired, digitiform, approximately half the length of median flagellomeres, inserted dorsomedially and ventrolaterally on anterior half of flagellomeres; number and position of flagellomeres bearing ascoids variable among species. Mouthparts reduced; labellum bulbous, as wide or wider than clypeus, without blunt apical teeth. Prothorax of some species with capitate patagia inserted posterior to vertex, adjacent to prothoracic spiracles. Wing ovate, without Sc vein ending in $R_1$, with base of $M_2$ weakened, prolonged basally. Male terminalia: gonocoxites about as long as wide, rotundate laterally, with margins straight or concave dorsomedially, with posteromedial lobes in some species; gonostyles bifurcate, rami highly variable in shape, of equal or unequal length; aedeagus symmetrical; basiphallus composed of single sclerite, laterally or dorsoventrally compressed basally, bifurcate apically; distiphallus variable in shape, composed of paired acuminate or truncate sclerites articulated with apices of basiphallus, or absent in some species; parameres membranous, fused, forming sheath around distiphallus, or sclerotized, with a conspicuous dorsal component in some species (e.g. *S. bipunctata* and *S. capricorna*); cercopods tapered, curved dorsally, with basal or apical processes in some species, with 10–30 retinacula inserted dorsally; apices of retinacula pectinate. Female terminalia: cerci elongate, more than five times longer than wide, triangular in shape from lateral aspect, their medial surface with irregular rows of macrotrichia; hypovalvae triangular, quadrate or bilobed apically.

SPECIES INCLUDED. *S. bessophila* (Quate), *S. bipunctata* (Kincaid), *S. birama* (Quate), *S. capricornuata* **sp. nov.**, *S. carolina* (Banks), *S. furcata* Vaillant, *S. kincaidi*

(Quate), *S. lasiostyla* **sp. nov.**, *S. mastelleri* Wagner, *S. mixta* (Brunetti), *S. recurrens* Vaillant, *S. robinsoni* **sp. nov.**, *S. spinicornis* (Brunetti).

DISTRIBUTION. Currently known from the Nearctic region (specifically eastern and western United States and Canada, and northwestern Mexico) and the Oriental region (specifically Himalaya).

REMARKS. Larvae and adults of *Stupkaiella* are similar to some closely related genera of Pericomini (e.g. *Bazarella* Vaillant and *Thornburghiella* Vaillant), but can be readily distinguished from these and all other psychodid genera using the following character suites: Larvae: presence of a postmentum with a single row of uniform conical teeth and tergal plates on abdominal segments II-VII with protuberances and chaetotaxy exactly as detailed above. Adults: presence of antennae with spines on flagellomere I as well as rounded gonocoxites and bifurcate gonostyles in the male, or the shape of the hypovalvae and genital duct in the female.

### ***Stupkaiella lasiostyla*** Curler **sp. nov.** (Fig. 4-1 A–F)

DIAGNOSIS. **Adult:** Male eye bridge with 4 facet rows, divided by width of 3.5 facet diameters. Interocular suture inverted V-shaped. Labellum wider than clypeus. Scape three times longer than wide; flagellomere I with 5 spines. Male terminalia: Gonostyles with rami of uneven length, dorsal ramus elbowed basally, with a longitudinal patch of microtrichia dorsally; paramere membranous, forming sheath around aedeagus. Female terminalia: hypovalvae with lateral margins convex, posterior margin concave.

DESCRIPTION. **Adult Male** (Fig. 4-1 A–C, E–F): Measurements, (N = 5) head width 0.5 mm (0.47–0.5), head length 0.48 mm (0.45–0.49), wing length 2.84 mm (2.67–2.95), wing width 1.13 mm (1.03–1.15), palpomere proportion: 1–2.2–2.5–3.3. Eye bridge with 4 facet rows, divided by width of 3.5 facet diameters. Frontal scar patch as wide as frons anteriorly, slightly constricted posteriorly, extending between eyes, interrupted by interocular suture. Interocular suture inverted V-shaped. Antennae: scape three times longer than wide; flagellomere I with 5 spines inserted dorsally; ascoids present on flagellomeres III–XI; flagellomere XIV with node fusiform, apical process

approximately 2/3 as long as node. Mouthparts not extending beyond basal palpomere, labellum wider than clypeus. Wing: medial fork arising slightly basal to medial fork, both arising basal to apex of $CuA_2$. Terminalia: hypandrium narrow, arched, not extended posteriorly; epandrium rectangular, about 2/3 as long as wide; gonocoxites strongly rotundate laterally, with dorsomedial margins straight, void of setiform sensilla; Gonostyles with rami of uneven length, dorsal ramus elbowed basally, flattened, acuminate apically, with a longitudinal patch of microtrichia dorsally; aedeagus with basiphallus dorsoventrally compressed basally, bifurcate apically, distiphallus composed of paired, acuminate, recurved sclerites articulated with basiphallus; paramere membranous, forming sheath around aedeagus; cercopods strongly tapered from base to apex, flattened medially, with 14 retinacula inserted dorsoapically; retinacula with apices pectinate. Tergite X tongue-shaped, about 2/3 as long as cercopod.

**Adult Female** (Fig. 4-1 D): Eyebridge with 4 facet rows, divided by 4 facet diameters. Frontal scar patch as in male. Interocular suture as in male. Antenna nearly identical to male, except without spines on flagellomere I. Mouthparts and palpi as in male. Wing venation as in male. Terminalia: Subgenital plate with hypovalvae widened basally, with lateral margins convex, posterior margin concave; genital duct as figured, about 2/3 as wide as base of hypovalvae.

TYPE MATERIAL. Holotype [adult male]: U.S.A. NORTH CAROLINA: *Buncombe Co*: Blue Ridge Parkway @ milepost 365, exposed rock face with spring flowing from pipe, 35°41'30"N 82°22'15"W, 12.vii.2007, coll. J.L. Robinson, sweep net; deposited LACM. Specimen dissected, mounted on micro-slide. Allotype [adult female]: same data as holotype; deposited LACM. Specimen dissected, mounted on micro-slide. Paratypes: same data as holotype [9 adult male, 3 adult female (slides)]. Paratypes deposited in LACM, GSMNP and UTK.

ETYMOLOGY. From the Greek *lasio*, meaning "hairy", in reference to the distinct fringe of hair on the medial rami of the gonostyles.

BIONOMICS. Due to a paucity of collection records, the phenology of *S. lasiostyla* cannot be accurately determined; however, attempts to collect this species in late July 2009 were unsuccessful, which could mean that *S. lasiostyla* is primarily a

spring species. No other species of Psychodidae were collected with the type series of *S. lasiostyla*, which may be indicative of the conditions at the type locality (bare rock face with standing water at its base).

DISTRIBUTION. Collected from one location on the Blue Ridge Parkway in western North Carolina.

REMARKS. Adults of *S. lasiostyla* are easily distinguished from other *Stupkaiella* by the shape of the gonopods, particularly the gonostyles with hairy, curved dorsal rami in the male, and the shape of the subgenital plate and genital duct in the female. Most specimens of *S. lasiostyla* exhibit a partial 5$^{th}$ row of facets in the eye bridge; however, this partial row is either absent or consists of only one facet in some specimens, and thus is not treated as a true facet row.

***Stupkaiella robinsoni*** Curler **sp. nov.** (Fig. 4-1 G–J)

DIAGNOSIS. **Adult:** Male eye bridge with 5 facet rows, divided by width of 3.5 facet diameters. Interocular suture inverted U-shaped. Labellum as wide as clypeus. Scape three times longer than wide; flagellomere I with 6 spines. Male terminalia: gonocoxites with conspicuously quadrate margin dorsomedially; gonostyles with rami of equal length; hypandrium extended posteriorly, visor-like; paramere membranous, forming sheath around aedeagus. Female terminalia: hypovalvae with lateral margins convex, posterior margin straight.

DESCRIPTION. **Adult Male** (Fig. 4-1 G–I): Measurements, (N = 5) head width 0.49 mm, head length 0.51 mm (0.50–0.51), wing length 3.08 mm, wing width 1.15 mm, palpomere proportion: 1–1.8–1.9–2.6. Eye bridge with 5 facet rows, divided by width of 3.5 facet diameters. Frontal scar patch as wide as frons anteriorly, slightly constricted posteriorly, extending between eyes, interrupted by interocular suture. Interocular suture inverted U-shaped. Antennae: scape three times longer than wide; flagellomere I with 6 spines inserted dorsally; ascoids present on flagellomeres III–X at least (flagellomeres XI–XIV missing). Mouthparts not extending beyond basal palpomere, labellum as wide as clypeus. Wing: medial fork arising slightly basal to medial fork, both arising basal to

apex of $CuA_2$. Terminalia: hypandrium extended posteriorly, visor-like; epandrium rectangular, about ½ as long as wide; gonocoxites strongly rotundate laterally, with conspicuously quadrate margin dorsomedially, with few setiform sensilla inserted posteromedially; gonostyles with rami slightly sinuous, of equal length; aedeagus with basiphallus slightly dorsoventrally compressed basally, bifurcate apically, distiphallus composed of paired, acuminate, recurved sclerites articulated with basiphallus; paramere membranous, forming sheath around aedeagus; cercopods gradually tapered from base to apex, slightly flattened medially, with 18 retinacula inserted dorsoapically; retinacula with apices pectinate. Tergite X triangular, about 2/3 as long as cercopod.

**Adult Female** (Fig. 4-1 J): Eyebridge with 4 facet rows, divided by 4 facet diameters. Frontal scar patch as in male. Interocular suture as in male. Antenna nearly identical to male, except without spines on flagellomere I. Mouthparts and palpi as in male. Wing venation as in male. Terminalia: Subgenital plate with hypovalvae slightly constricted basally, with lateral margins convex, posterior margin straight; genital duct as figured, about as wide as base of hypovalvae.

TYPE MATERIAL. Holotype [adult male]: U.S.A. NORTH CAROLINA: *Buncombe Co*: Blue Ridge Parkway @ milepost 371.6, Shope Creek headwaters, 35°40'40"N 82°25'40"W, 25.v.2007, coll. J.L. Robinson, sweep net; deposited LACM. Specimen dissected, mounted on micro-slide. Allotype [adult female]: same data as holotype; deposited LACM. Specimen dissected, mounted on micro-slide. Paratypes: same data as holotype [5 adult male, 5 adult female (slides)]. Paratypes deposited in LACM, GSMNP and UTK.

ETYMOLOGY. Named for Jason L. Robinson, in recognition of his contribution of numerous specimens for this study.

BIONOMICS. Due to a paucity of collection records, the phenology of *S. robinsoni* cannot be accurately determined; however, attempts to collect this species in late April and late July 2009 were unsuccessful, which could mean that *S. robinsoni* is only present throughout the month of May. Several other species of Psychodidae including *Pericoma signata* (Banks), *Thornburghiella albitarsis* (Banks), *Threticus bicolor* (Banks) and *Psychoda* spp. were collected with the type series of *S. robinsoni*,

which is indicative of the conditions at the type locality (hillside seep with abundant wet mosses and decaying plant material).

DISTRIBUTION. Collected from one location on the Blue Ridge Parkway in western North Carolina.

REMARKS. Adults of *S. robinsoni* are easily distinguished from other *Stupkaiella* by the shape of the genitalia, particularly the gonocoxites with quadrate medial margins and the posteriorly extended hypandrium in the male, and the shape of the subgenital plate and genital duct in the female.

***Stupkaiella capricornuata*** Curler **sp. nov.** (Fig. 4-2)

DIAGNOSIS. **Adult:** Male eye bridge with 4 facet rows, divided by width of 3 facet diameters. Interocular suture inverted Y-shaped. Scape two times longer than wide; flagellomere I with 3 spines. Male terminalia: gonostyles with rami of unequal length, dorsal ramus approximately 2/3 the length of ventral ramus; paramere divided into dorsal and ventral sections, dorsal section with arcuate, acuminate lateral processes. Female terminalia: hypovalvae triangular.

DESCRIPTION. **Adult Male** (Fig. 4-2 A–C, E): Measurements, (N = 5) head width 0.41 mm (0.41–0.42), head length 0.38 mm (0.38–0.39), wing length 2.52 mm (2.34–2.67), wing width 1.03 mm (1.03–1.07), palpomere proportion: 1–1.6–1.8–2.5. Eye bridge with 4 facet rows, divided by width of 3 facet diameters. Frontal scar patch as wide as frons anteriorly, constricted posteriorly, extending between eyes, interrupted by interocular suture. Interocular suture inverted Y-shaped. Antennae: scape two times longer than wide; flagellomere I with 3 spines inserted dorsally; ascoids present on flagellomeres III–XI; flagellomere XIV with node globular, apical process approximately as long as node. Mouthparts extending slightly beyond basal palpomere, labellum about as wide as clypeus. Wing: radial and medial forks at same level, arising basal to apex of $CuA_2$. Terminalia: hypandrium narrow, transverse band, straight, not arched, not extended posteriorly; epandrium rectangular, about 1/2 as long as wide gonocoxites rotundate laterally, with dorsomedial margins nearly membranous, bearing numerous

setiform sensilla; gonostyles with rami of unequal length, dorsal ramus approximately 2/3 the length of ventral ramus; aedeagus with basiphallus laterally compressed basally, bifurcate apically, distiphallus composed of paired, acuminate sclerites articulated with basiphallus; paramere divided into dorsal and ventral sections, dorsal section lightly sclerotized, with arcuate, acuminate lateral processes, ventral section membranous, with arcuate, digitiform lobes laterally, bilobed extension posteriorly; cercopods gradually tapered from base to apex, with 18 retinacula inserted dorsoapically; retinacula with apices pectinate. Tergite X triangular, about ½ as long as cercopod

**Adult Female** (Fig. 4-2 D): Eyebridge with 3 facet rows, divided by 4 facet diameters. Frontal scar patch as in male. Interocular suture inverted V-shaped. Antenna nearly identical to male, except without spines on flagellomere I. Mouthparts and palpi as in male. Wing venation as in male. Terminalia: Subgenital plate with hypovalvae constricted basally, expanded distally, triangular in outline; genital duct as figured, wider than base of hypovalvae.

TYPE MATERIAL. Holotype [adult male]: U.S.A. NORTH CAROLINA: *Macon Co*: Coweeta Hydrologic Laboratory, upper Reynolds Branch, 35°02'N 83°27'W, 5–11.iv.2008, coll. G.W. Courtney, Malaise trap; deposited LACM. Specimen dissected, mounted on micro-slide. Allotype [adult female]: same data as holotype; deposited LACM. Specimen dissected, mounted on micro-slide. Paratypes: NORTH CAROLINA: same data as holotype [10 adult male, 10 adult female (slides)]; *Haywood Co*: GSMNP, Purchase Knob, 35°35'N 83°04'W, 22.iv–10.v.2008, [4 adult male, 4 adult female (slides)] coll. G.R. Curler, Malaise trap. Paratypes deposited in LACM, USNM, GSMNP and UTK.

OTHER MATERIAL EXAMINED. U.S.A. NORTH CAROLINA: same data as holotype, [134 adult male, 29 adult female]; *Macon Co*: Coweeta Hydrologic Laboratory, Grady Branch (WS 18), 35°03'N 83°26'W, 31.iii–5.iv.2008, [2 adult male, 2 adult female], coll. G.W. Courtney, Malaise trap; *Swain Co*: GSMNP, trib of Noland Creek at campsite 62, 35°31'N 83°28'W, 2.v.08, [5 adult male], coll. G.R. Curler, aspirator; *Haywood Co*: GSMNP, Purchase Knob, 35°35'N 83°04'W, 1–22.iv.2008, [3 adult

female]; 22.iv–10.v.2008, [2 adult male, 4 adult female]; 22.iv–7.v.2009, [3 adult male], coll. G.R. Curler, Malaise trap.

ETYMOLOGY. From the Latin *capri* meaning "goat", and *cornuata*, meaning "curved in the shape of a horn", in reference to the shape of the dorsal paramere which resembles a goat's head.

BIONOMICS. Adults of *S. capricornuata* emerge from early April to mid May. The latter half of its emergence period overlaps with the beginning of the emergence period for *S. furcata* and *S. recurrens*—two species with which *S. capricorna* is sympatric. *S. capricornuata* can be locally abundant, as evidenced by the sample from which the type series was selected. All locations where *S. capricornuata* were collected are alongside 1st or 2nd order streams.

DISTRIBUTION. Collected from two locations at Coweeta Hydrologic Laboratory and two locations in Great Smoky Mountains National Park, all in western North Carolina.

REMARKS. Adults of *S. capricornuata* are easily distinguished from other *Stupkaiella* by the shape of the genitalia, particularly the aedeagus and dorsal paramere division in the male, and the shape of the hypovalvae and genital duct in the female.

### ***Stupkaiella bipunctata* (Kincaid)**

*Pericoma bipunctata* Kincaid, 1899: 34 (original description). See Quate 1955: 137 for complete synonymy.
*Stupkaiella bipunctata* (Kincaid), Vaillant, 1973: 371 (key to Nearctic *Stupkaiella*).

DIAGNOSIS. **Larva:** Postmentum dentate; teeth uniform, conical, arranged in single transverse row. Protuberances of tergal plates and dorsal chaetotaxy of abdominal segments II–VII as described below. Protergal plate on abdominal segments II–VII emarginate anteriorly. Anal division: dorsal sclerite with 2 prominent macrotrichia side by side, inserted dorsomedially, with 2 prominent macrotrichia in line, inserted laterally on both sides; ventral flabellar processes elongate, about six times longer than wide.

**Pupa:** Unknown. **Adult:** Male eye bridge with 5 facet rows, divided by width of 8.5 facet diameters. Interocular suture inverted U-shaped. Scape three times longer than wide; flagellomere I with 6 spines. Male terminalia: gonostyles with rami of unequal length, dorsal ramus approximately ½ the length of ventral ramus; paramere with dorsal section, dorsal section with lateral processes resembling bat wings. Female terminalia: hypovalvae triangular, with minute median lobe.

DESCRIPTION. **Larva** (Figs. 4-3–4-5): Measurements, instar IV (N = 5) total length 6.30 mm (5.90–6.31), cranial width 0.43 mm. Head capsule broadly ovate, with genae rounded. Antenna composed of 3 digitiform, 2 pyriform, 2 brush-like sensilla. Labrum with multiple clusters of spathiform, pectinate macrotrichia ventrally and multiple setiform sensilla anteriorly. Mandibles and maxilla typical of Pericomini; prostheca composed of one brush-like and one pectinate macrotrichium. Postmentum dentate; teeth uniform, conical, arranged in single transverse row. Trunk: segmentation and arrangement of tergal plates typical of Psychodinae. Segments I–V parallel-sided, thorax and posterior segments gradually tapered. Integument dark brown to black in color; alveoli moderately numerous, appearing crowded dorsally, smaller, less numerous ventrally; posterior annulus of metathorax, anterior and posterior annuli of abdominal segments II–VII with transverse rows of elongate, brush-like alveoli ventrally; middle annuli of abdominal segments II–VII with patch of elongate, brush-like alveoli between paired, rounded sclerites ventrally. Protuberances of tergal plates and dorsal chaetotaxy of abdominal segments II–VII: protergite with paired, simple protuberances medially; medial protuberances flanked by second pair of simple protuberances; each protuberance with setiform macrotrichium inserted apically; mesotergite with paired, bifurcate protuberances medially; medial protuberances flanked by pair of simple protuberances; each bifurcate protuberance with two setiform macrotrichia inserted apically, each simple protuberance with setiform macrotrichium inserted apically; metatergite with paired, simple protuberances medially; medial protuberances flanked by pair of trifurcate protuberances; each simple protuberance with setiform macrotrichium inserted apically, each trifurcate protuberance with three setiform macrotrichia inserted apically. Protergal

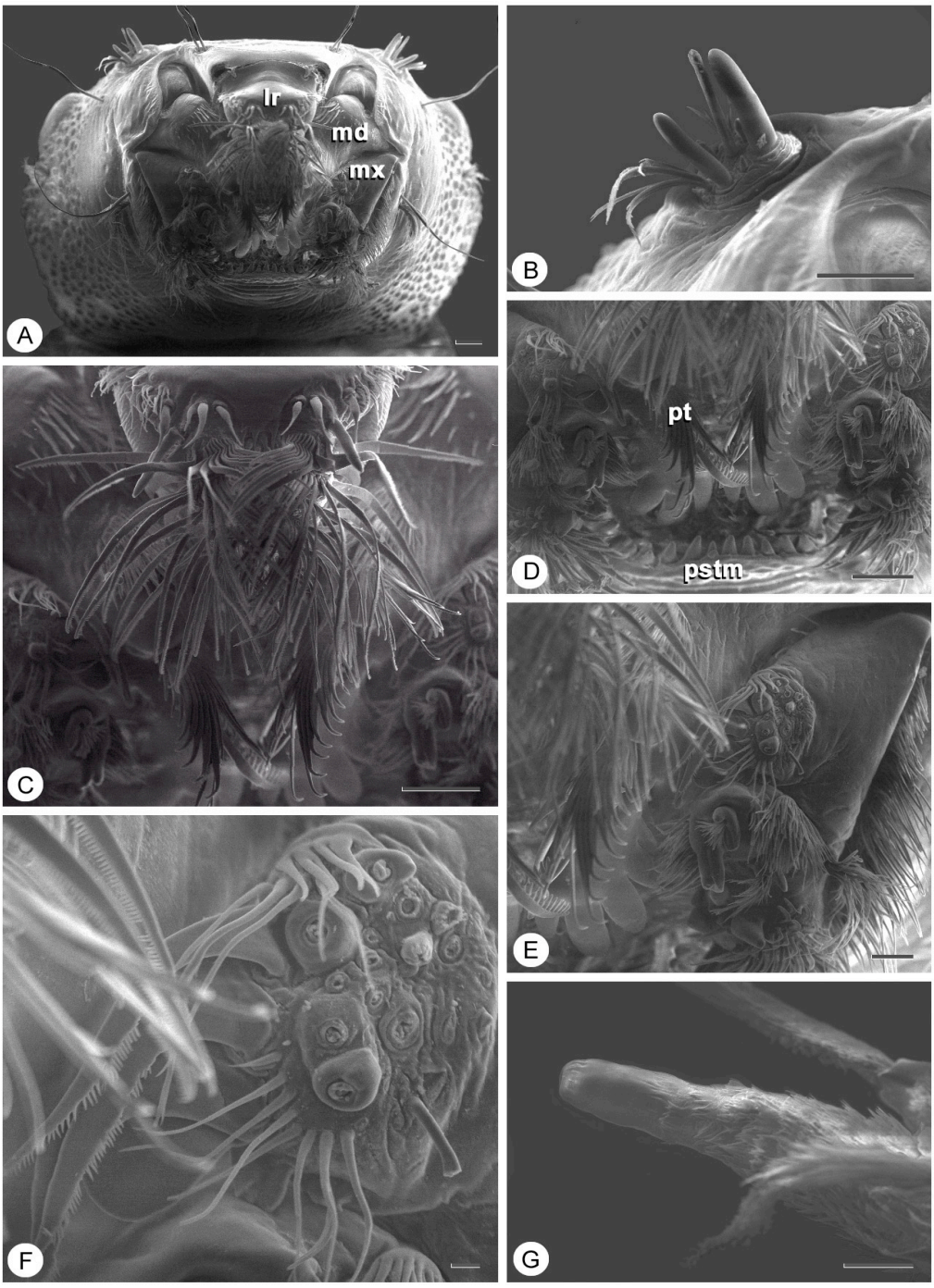



**Figure 4-3.** Scanning electron micrographs of larval *Stupkaiella bipunctata*. **A.** Head capsule, ventral view. **B.** Right antenna, ventral view. **C.** Details of labrum, ventral view. **D.** Details of hypostome and mandibles, ventral view. **E.** Details of left maxilla and mandible, ventral view. **F.** Details of left maxillary palp, ventral view. **G.** Right spiracle, ventral view. Scale bars = 2µ (F), 10µ (E), 20µ (A–D, G). (abbreviations: lr = labrum; md = mandible; mx = maxilla; pt = prostheca; pstm = postmentum).

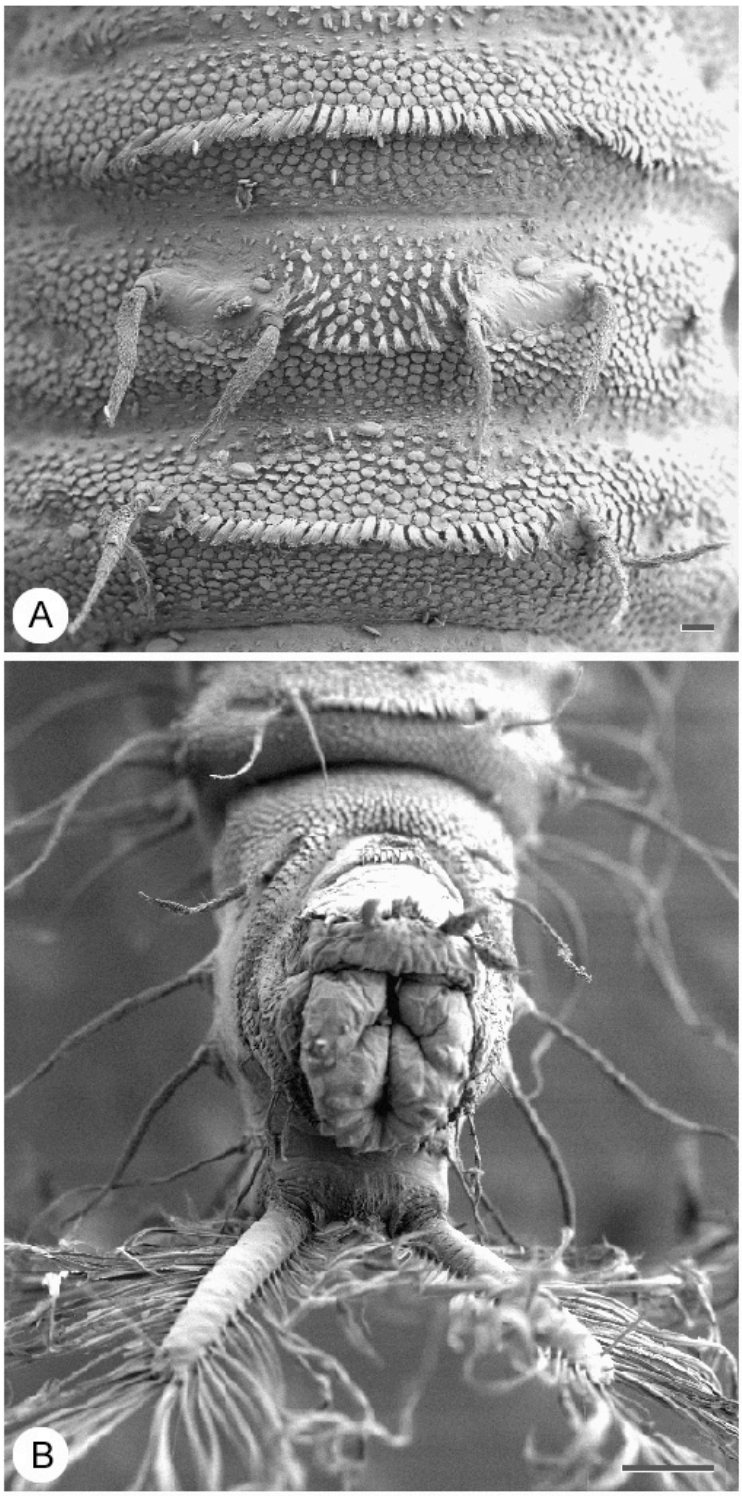



**Figure 4-4.** Scanning electron micrographs of larval *Stupkaiella bipunctata*. **A.** Abdominal segment IV, ventral view. **B.** Anal division, ventral view. Scale bars = 20µ (A), 100µ (B).

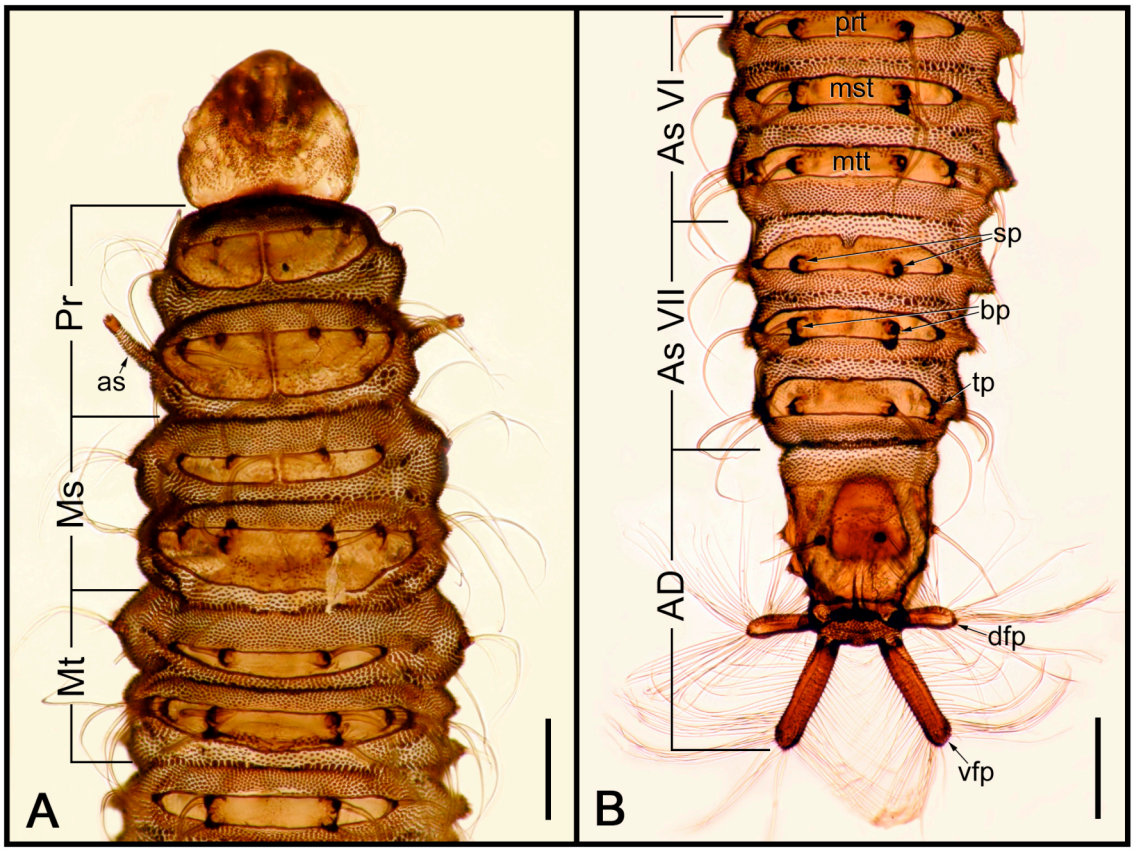



**Figure 4-5.** Photomicrographs of larval *Stupkaiella bipunctata*. **A.** Head, thorax and anterior annulus of abdominal segment I, dorsal view. **B.** Abdominal segments VI, VII and anal division, dorsal view. Scale bars = 0.3 mm (A–B). (abbreviations: pr = prothorax; ms = mesothorax; mt = metathorax; as = anterior spiracle; asVI = abdominal segment six; asVII = abdominal segment seven; ad = anal division; prt = protergite; mst = mesotergite; mtt = metatergite; sp = simple protuberance; bp = bifurcate protuberance; tp = trifurcate protuberance; dfp = dorsal flabellar process; vfp = ventral flabellar process).

plate on abdominal segments II–VII emarginate anteriorly. Anal division: dorsal sclerite with 2 prominent macrotrichia side by side, inserted dorsomedially, with 2 prominent macrotrichia in line, inserted laterally on both sides; ventral flabellar processes elongate, about six times longer than wide.

**Pupa:** Unknown.

**Adult Male:** See Quate (1955: 137).

**Adult Female:** See Quate (1955: 139).

TYPE MATERIAL. Syntype [adult male]: U.S.A. WASHINGTON: *King Co*: Seattle, 11.iv.1898, coll. L.W. Quate; deposited at California Academy of Sciences.

OTHER RECORDS. U.S.A. OREGON: *Benton Co*: Corvallis, NW 60th Street, 44°35'N 123°18'W, 29.viii.1993, [6 instar IV larvae]; 31.i.1995, [1 instar IV larva]; 31.vii.2007, [5 instar IV larvae], coll. N.H. Anderson, benthic sample; 1–14.vi.2004, [1 adult female]; 1–29.iii.2005, [2 adult female]; 15–28.iv.2005, [1 adult male]; 1–15.v.2005, [1 adult male, 2 adult female]; 16–29.vi.2005, [1 adult female]; 1–14.vii.2005, [1 adult female], coll. N.H. Anderson, emergence trap.

BIONOMICS. Adults of *S. bipunctata* apparently begin emerging in early spring (late March?) and continue to emerge throughout the summer, as late as October (one record from British Columbia). Larvae of this species have only been collected in benthic samples taken from one ephemeral stream in western Oregon. It is likely that the larvae were among wet, decaying leaves and mosses.

DISTRIBUTION. Pacific Coast Ranges. Collected from Oregon, Washington, British Columbia and Alaska.

REMARKS. *S. bipunctata* is the only species of *Stupkaiella* for which the instar IV larva is described. Slide-mounted specimens of a congeneric larva from Great Smoky Mountains National Park differ from the larva of *S. bipunctata* only by characters of the anal division. Adults of *S. bipunctata* are most similar to *S. capricorna* as males of both species have a sclerotized, sculpted paramere dorsally. Regardless, both species are quite distinct and separable not only by characters, but also by range.

## Discussion

The main objectives of this study were to reinstate *Stupkaiella* as a genus, revise the existing generic diagnosis and describe three new species and the larva of a described species. Additional new species of *Stupkaiella* exist in the Nearctic region, and undoubtedly in the Oriental region as well. A full revision of the genus is desirable, but will not be possible until more specimens of all life stages become available.

*Taxonomy.* Duckhouse (1987) placed *Stupkaiella*, *Joostiella* and *Tokunagaiella* Vaillant as subgenera of *Thornburghiella* "for reasons to be discussed later", but no supporting characters or diagnoses were provided or discussed. Furthermore, in the absence of a clear diagnosis, Duckhouse included five Himalayan species in *T. (Stupkaiella)*, two of which (*Pericoma spinicornis* Brunetti 1908 and *P. mixta* Brunetti 1911) fit Vaillant's original description of *Stupkaiella* and three of which (*P. alaeoensis*, *hamtensis* and *longipenis* Kaul 1971) do not. Descriptions and figures of the latter three species provide details (i.e., gonostyles simple, not bifurcate) indicating that they are not *Stupkaiella*, but rather *Thornburghiella* s.str., thereby giving the following new combinations: *T. alaeoensis* (Kaul) **comb. nov.**, *T. hamtensis* (Kaul) **comb. nov.** and *T. longipenis* (Kaul) **comb. nov.**

In the current study, larvae and adults of *Stupkaiella* were compared with those of similar Pericomine genera (e.g. *Thornburghiella*, *Bazarella* and *Satchelliella* Vaillant) sensu Vaillant (1981 & 1983), as well as some more distant relatives (e.g. *Pericoma* Walker). Adults of all genera in Pericomini are distinct and readily separable while the larvae are remarkably uniform throughout the tribe and can only be reliably identified to genus by rearing, comparing their DNA, or comparing mouthparts and chaetotaxy. Larvae of *Thornburghiella* provide a compelling example of the utility of chaetotaxy. Nearly all described larvae of *Thornburghiella* (except *T. quezeli* Vaillant) exhibit dorsal setae modified from setiform macrotrichia to conspicuous spathiform or leaf-like sensilla, but the number and position thereof is identical to that of the setiform macrotrichia in *T. quezeli*.

**Acknowledgements**

We are grateful to the National Park Service for granting permission to collect in Great Smoky Mountains National Park and along the Blue Ridge Parkway. We thank J. L. Robinson for collecting the type series of *S. lasiostyla* and *S. robinsoni*, and N. H. Anderson for providing adults and larvae of *S. bipunctata* from Oregon. We also thank G. W. Courtney for providing many specimens of *S. capricorna* from Coweeta Hydrologic Laboratory. E. C. Bernard kindly assisted with photomicrography and A. J. Jacobson was instrumental in completing various lab procedures. Support for various aspects of this research included grants from the United States Army (Award No. W81XWH-06-1-0471 to JKM) and Discover Life in America.

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# CHAPTER 5
# DESCRIPTIONS OF THREE NEW SPECIES OF PSYCHODIDAE (DIPTERA) FROM THE SOUTHEASTERN UNITED STATES

This chapter is a slightly revised version of a manuscript submitted by Gregory R. Curler and John K. Moulton in October 2009 for publication in Zootaxa:

Curler, G.R. and J.K. Moulton. Descriptions of three new species of Psychodidae (Diptera) from the southeastern United States. *Zootaxa*, in review.

My contributions to this publication include collection and identification of specimens, as well as preparation of figures and the manuscript.

## Abstract

Adult males and females of *Trichomyia stylorycha* **sp. nov.** and *Australopericoma delta* **sp. nov.**, and all life stages of *Threticus thelyceratus* **sp. nov.** were collected during various biodiversity surveys in the southeastern United States. Descriptions of these three new species are given.

## Introduction

Quate and Vockeroth (1981) suggested that, although 91 species of Psychodidae were recorded in the Nearctic region, many species await discovery. Since then, 10 species of Nearctic Psychodidae have been described (Wagner 1984, Young & Perkins 1984, Ibanez-Bernal 1992, Quate 2000, Wagner & Hribar 2004, Curler & Moulton 2008) and many undescribed species have been collected (Curler, unpublished). In the current paper, three new species of Psychodidae from the southeastern United States are described.

## Materials and Methods

*Study area*. This study focused on specimens collected from multiple locations in eastern Tennessee, southern Alabama and western North Carolina.

*Material*. This research is based on an examination of adult males and females of *Trichomyia stylorycha* **sp. nov.**, *Australopericoma delta* **sp. nov.**, and *Threticus thelyceratus* **sp. nov.**, as well as fourth instar larvae and a single pupa of *T. thelyceratus*. Adult specimens were collected during 2006, 2007 and 2008 by Malaise trap and sweep netting and/or CDC trap (the latter for *Trichomyia* only) while larvae were collected from 2007–2008 by benthic sampling. Association of adult males and females is based on morphological similarity. Larva-pupa-adult association for *T. thelyceratus* was made using the ontogenetic method (Hogue & Bedoya-Ortiz 1989). A single larva was reared

to pupation, but the pupa died before complete development of the imago. Nonetheless, the imago was developed well enough that its identity could be determined.

Specimens are deposited with the following repositories (acronyms used throughout the text): LACM, Natural History Museum of Los Angeles County, Los Angeles, CA.; USNM, National Museum of Natural History, Smithsonian Institution, Washington, D.C.; GSMNP, Great Smoky Mountains National Park Insect Collection, Gatlinburg, TN.; CUAC, Clemson University Arthropod Collection, Clemson University, Clemson, SC; UTK, Department of Entomology and Plant Pathology, University of Tennessee, Knoxville, TN.

*Specimen preparation*. Specimens were fixed in 70 or 95% EtOH. Morphological studies were based on slide-mounted specimens for the pupa and adults, and scanning electron microscopy (SEM) for larvae. Slides were prepared using cold 10% sodium hydroxide to clear specimens and Canada balsam as a mounting medium. Specimens were observed by using a Meiji Techno RZ dissecting microscope and a Nikon Optiphot compound microscope, the former fitted with an optical micrometer. Drawings were rendered with the aid of a drawing tube on the Nikon system. Material for SEM examination was critical point dried and sputter-coated with gold. SEM images were captured on a LEO 1525 microscope and edited with Adobe Photoshop® 7.0.

*Terminology*. Descriptions of adult morphology follow mainly Merz and Haenni (2000) as well as recent papers on Psychodidae (Quate & Brown 2004; Curler & Moulton 2008, Curler & Courtney 2009). Terminology of the male terminalia is that of Sinclair (2000), Curler (2009) and Duckhouse (1978, 1990). Female postabdomen terminology follows Kotrba (2000), Curler (2009) and Duckhouse (1978). General larval terminology follows Courtney *et al.* (2000) and psychodid-specific larval terminology (e.g. segmentation and morphology of tergal plates) follows Vaillant (1971).

*Descriptive format*. Diagnoses are provided for all new taxa. Complete descriptions of all life stages are provided where specimens are available. When applicable, sample sizes are provided before each description with measurements in millimeters presented as a mean followed by a range in parentheses. All larval characters refer to the fourth instar. Larval head capsule width was measured at the point of greatest

width. Total length of larvae was measured from the anterior-most point of the head capsule to the posterior most point of the anal division, excluding the flabellar processes. Adult head width was measured at the point of greatest width of the eyes. Adult head length was measured from the vertex to the anterior margin of the clypeus. Palpal ratios were computed as proportions, considering the basal palpomere as 1. Approximate wing length and width were measured at the points of greatest length and width, respectively.

## Subfamily Trichomyiinae

### *Trichomyia stylorycha* Curler **sp. nov.** (Fig. 5-1)

DIAGNOSIS. **Adult:** Male eyes divided by width of 6 facet diameters at frons; vertex with a pair of circular sensilla anteriorly, divided by 2 facet diameters; wing with radial fork at same level as tip of $CuA_1$. Male terminalia: gonostyles digitiform, curved approximately 45° at mid length, with rostriform projection apically; aedeagus spatulate, bifurcate posteriorly, with apices recurrent. Female terminalia: subgenital plate entire, rounded posteriorly; cerci elongate, about 2.5 times longer than wide; spermathecae with ducts annulated anteriorly, with pyriform sacs apically; median apodeme with 2 sclerotized projections anteriorly, 3 sclerotized projections posteriorly; median posterior projection 2 times longer than lateral projections.

DESCRIPTION. **Adult Male** (Fig. 5-1 A–E): Measurements, (n = 5) head width 0.39 mm (0.35–0.41), head length 0.27 mm (0.26–0.28), wing length 1.56 mm (1.43–1.60), wing width 0.62 mm (0.53–0.67), palpomere proportion: 1–0.5–0.5. Eyes with medial margins parallel; divided by width of 6 facet diameters at frons. Vertex with paired circular sensilla anteriorly; sensilla divided by 2 facet diameters. Antennae: 15-segmented; scape approximately 1.25 times longer than wide; pedicel globular; all flagellomeres with paired ascoids; ascoids elongate, digitiform, inserted basally on each node, extending to mid-length of following node; apical flagellomere with apical process globular. Mouthparts extending slightly beyond basal palpomere; labellum truncate, about as wide as clypeus; palpi 3-segmented; basal palpomere with circular depression

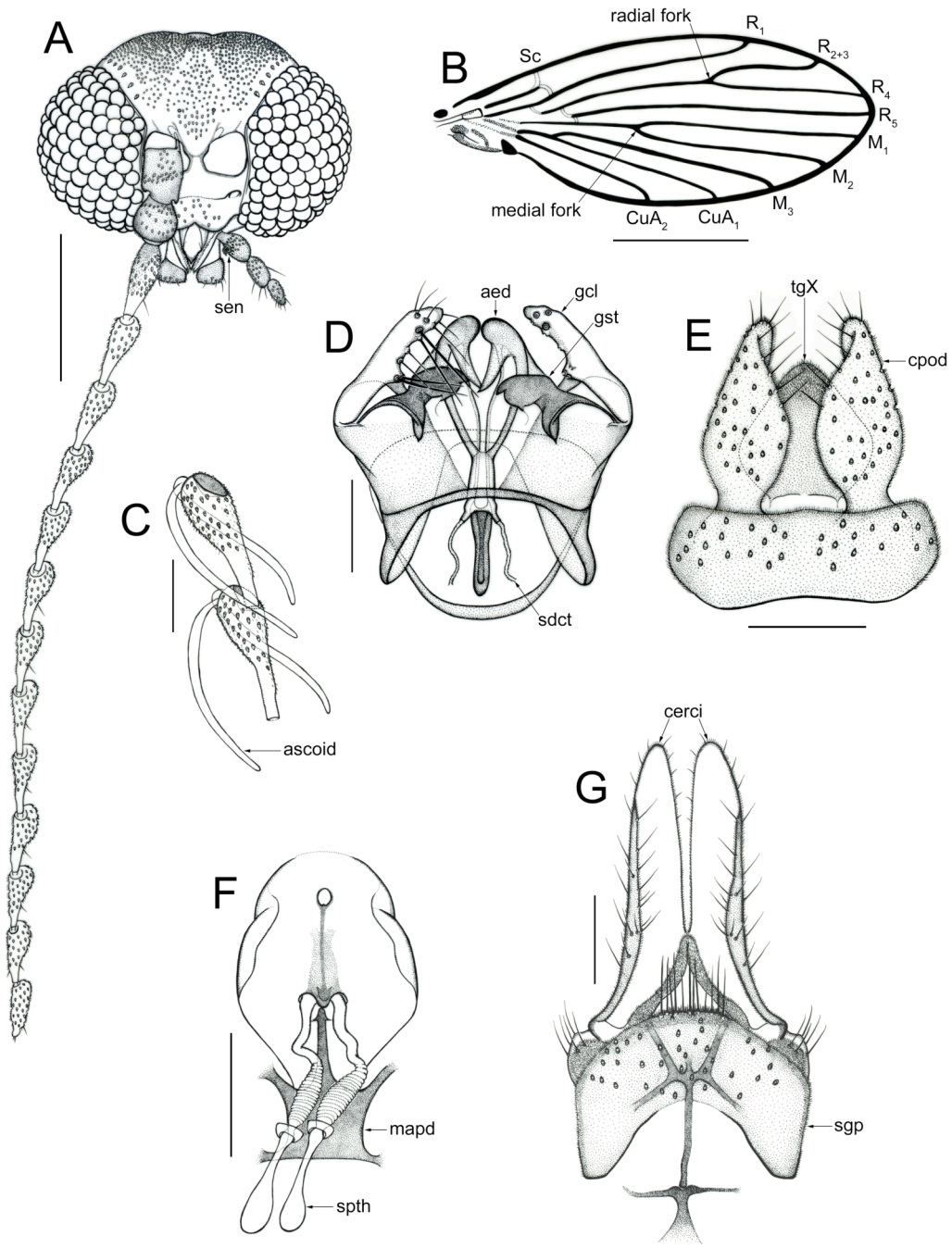



**Figure 5-1.** *Trichomyia stylorycha* Curler sp. nov. **A.** Male head, frontal view. **B.** Wing. **C.** Male antennal flagellomeres 7–8, frontal view. **D.** Male terminalia, dorsal view. **E.** Male epandrium and cercopods, ventral view. **F.** Female terminalia, internal structure, ventral view. **G.** Female terminalia, external structure, ventral view. Scale bars = 0.05 mm (C–G), 0.2 mm (A), 0.5 mm (B). (abbreviations: aed = aedeagus; cpod = cercopod; gcl = lobe of gonocoxite; gst = gonostyle; mapd = median apodeme; sdct = sperm duct; sgp = subgenital plate; spth = spermathecae; sen = sensilla; tgX = tergite X).

medially, bearing 5 or 6 digitiform sensilla. Wing: radial fork at same level as tip of $CuA_1$, medial fork arising basal to apex of $CuA_2$; with $R_5$ ending in apex. Terminalia: hypandrium narrow, transverse band, slightly arched, not extended posteriorly; gonocoxites membranous basally, with conspicuous posterodorsal lobes; lobes bearing numerous setiform sensilla; gonostyles digitiform, curved approximately 45° at mid length, slightly inflated apically, with rostriform projection apically; aedeagus spatulate, bifurcate posteriorly, with apices acuminate, recurrent; sperm ducts lightly sclerotized, annulated, inserted in heavily sclerotized, cylindrical projections of sperm pump; epandrium short, about 1/3 as long as wide; cercopods pyriform, with apices constricted Tergite X quadrate, diamond-shaped, about 3/4 as long as cercopod

**Adult Female** (Fig. 5-1 F–G): Head nearly as in male, with antennal flagellomeres smaller. Mouthparts and palpi as in male. Wing venation as in male. Terminalia: subgenital plate entire, rounded posteriorly; cerci elongate, about 2.5 times longer than wide; sclerotized arch between cerci digitiform, microsetose, about 1/3 as long as cerci; spermathecae with ducts annulated, slightly inflated anteriorly, with pyriform sacs apically; median apodeme with 2 sclerotized projections anteriorly, 3 sclerotized projections posteriorly; median posterior projection 2 times longer than lateral projections.

TYPE MATERIAL. Holotype [adult male]: U.S.A. TENNESSEE: *Sevier Co*: Great Smoky Mountains National Park, Twin Creeks near ATBI headquarters, 35°41'N 83°29'W, 14–28.ix.2006, coll. J. Gulbransen, Malaise trap; deposited LACM. Specimen dissected, mounted on micro-slide. Allotype [adult female]: U.S.A. TENNESSEE: *Cocke Co*: Great Smoky Mountains National Park, Snake Den Ridge, 35°44'30"N 83°11'30"W, 14.viii–10.ix.2001, coll. I.C. Stocks, Malaise trap; deposited LACM. Specimen dissected, mounted on micro-slide. Paratypes: TENNESSEE: same location as holotype, 3–5.vii.2006 [1 adult female (slide)], 15–17.viii.2006 [1 adult female (slide)] coll. J. Gulbransen, Malaise trap; *Cocke Co*: GSMNP, Snake Den Ridge, 35°44'30"N 83°11'30"W, 2.vii–1.viii.2002 [6 adult male (slides)], coll. C.R. Parker, Malaise trap; *Union Co*: Property of R.S. Donahoo, 36°10'N 83°52'W, 2.vi.2007 [1 adult male (slide)], 9.vi.2007 [1 adult female (slide)], coll. G.R. Curler, CDC trap; ALABAMA: *Mobile Co*:

University of Mobile, site 16, 30°47'N 88°7'W, 20.iii.2007 [1 adult male (slide)], coll. E. Benton, Malaise trap; *Baldwin Co*: Fort Morgan Road, site 3, 30°14'N 88°51'W, 19.iii.2007 [3 adult male (slides)], coll. E. Benton, Malaise trap; Raft River, 30°46'N 87°57'W, 4.x.2006 [1 adult male (slide)], coll. J.W. McCreadie, Malaise trap. Paratypes deposited in LACM, USNM, GSMNP, CUAC and UTK.

OTHER MATERIAL EXAMINED. U.S.A. TENNESSEE: *Cocke Co*: GSMNP, Snake Den Ridge, 35°44'30"N 83°11'30"W, 2.vii–1.viii.2002 [1 adult male, 1 adult female], coll. C.R. Parker, Malaise trap; *Cocke Co*: GSMNP, Albright Grove, 35°45'N 83°16'W, 19.vi–6.vii.2001 [1 adult male], coll. M. McCord, Malaise trap, 5–20.vii.2002 [1 adult male], coll. B. Merritt, Malaise trap; *Union Co*: Property of R.S. Donahoo, 36°10'N 83°52'W, 14.viii.2006 [1 adult female], coll. G.R. Curler, CDC trap; ALABAMA: *Baldwin Co*: Fort Morgan Road, site 3, 30°14'N 88°51'W, 3.xi.2006 [1 adult male], coll. E. Benton, Malaise trap; KENTUCKY: *Taylor Co*: Little Angel Spring, 37°26'40"N 85°21'18"W, 27.ix.2005 [1 adult male], coll. J.K. Moulton, black light trap.

ETYMOLOGY. From the Greek *stylo* meaning "pointed instrument" and *rynchos*, meaning "beaked", in reference to the shape of the gonostyle.

BIONOMICS. Adults of *T. stylorynchа* were collected from late March to early November in southern Alabama and from early June to late August in Tennessee. It is presumably multivoltine, but little is known about the developmental period of any *Trichomyia*.

DISTRIBUTION. Collected from several locations in southern Alabama and eastern Tennessee, as well as one location in central Kentucky.

REMARKS. Adults of *T. stylorynchа* are easily distinguished from other Nearctic *Trichomyia* by the shape of the genitalia, particularly the spatulate aedeagus and beaked gonostyles in the male, and the shape of the subgenital plate and spermathecae in the female. *Trichomyia intricata* Quate 1996 is a Neotropical species that is very similar to *T. stylorynchа* according to Quate's description and illustration; however, an examination of the paratype of *T. intricata* revealed the following character states that clearly differ from those of *T. stylorynchа*: aedeagus with median filamentous

projection; gonostyles tapered, not inflated apically, not strongly curved; lobes of gonocoxites tapered from base to apex.

## Subfamily Psychodinae

### *Australopericoma delta* Curler **sp. nov.** (Fig. 5-2)

DIAGNOSIS. **Adult:** Male eye bridge with 3 facet rows, divided by width of less than 1 facet diameter. Interocular suture inverted V-shaped. Frons and clypeus not distinctly divided; frontal scar patch without median posterior projection. Mouthparts extending beyond basal palpomere. Scape about 1.5 times longer than wide; ascoids present on flagellomeres II–VIII. Male terminalia: Gonocoxites about as long as wide, with numerous setiform sensilla medially; gonostyles about as long as gonocoxites, curved, acuminate apically; aedeagus clearly asymmetrical. Female terminalia: hypovalvae bilobed, with lobes rounded, posterior margin concave; genital duct as figured.

DESCRIPTION. **Adult Male** (Fig. 5-2 A–B, D): Measurements, (n = 5) head width 0.33 mm (0.32–0.34), head length 0.31 mm, wing length 1.31 mm (1.27–1.35), wing width 0.46 mm (0.43–0.49), palpomere proportion: 1–1.3–1.4–1.8. Eye bridge with 3 facet rows, divided by width of less than 1 facet diameter. Interocular suture inverted V-shaped. Frons and clypeus not distinctly divided; frontal scar patch bilobed anteriorly, without median posterior projection. Antennae: scape about 1.5 times longer than wide; flagellomeres fusiform; ascoids present on flagellomeres II–VIII; flagellomere XIV with node fusiform, apical process digitiform, approximately as long as node. Mouthparts extending beyond basal palpomere; labellum about as wide as anterior margin of clypeus. Wing: typical of the genus, radial fork arising basal to apex of $CuA_2$, medial fork arising apical to apex of $CuA_2$, $R_5$ ending in apex. Terminalia: hypandrium widened, flat, articulated with gonocoxites laterally, with numerous setiform sensilla inserted ventrally; gonocoxites about as long as wide, not extending beyond aedeagus, with numerous setiform sensilla inserted medially; gonostyles about as long as gonocoxites, curved, acuminate apically; aedeagus clearly asymmetrical; epandrium rectangular, about 1.5

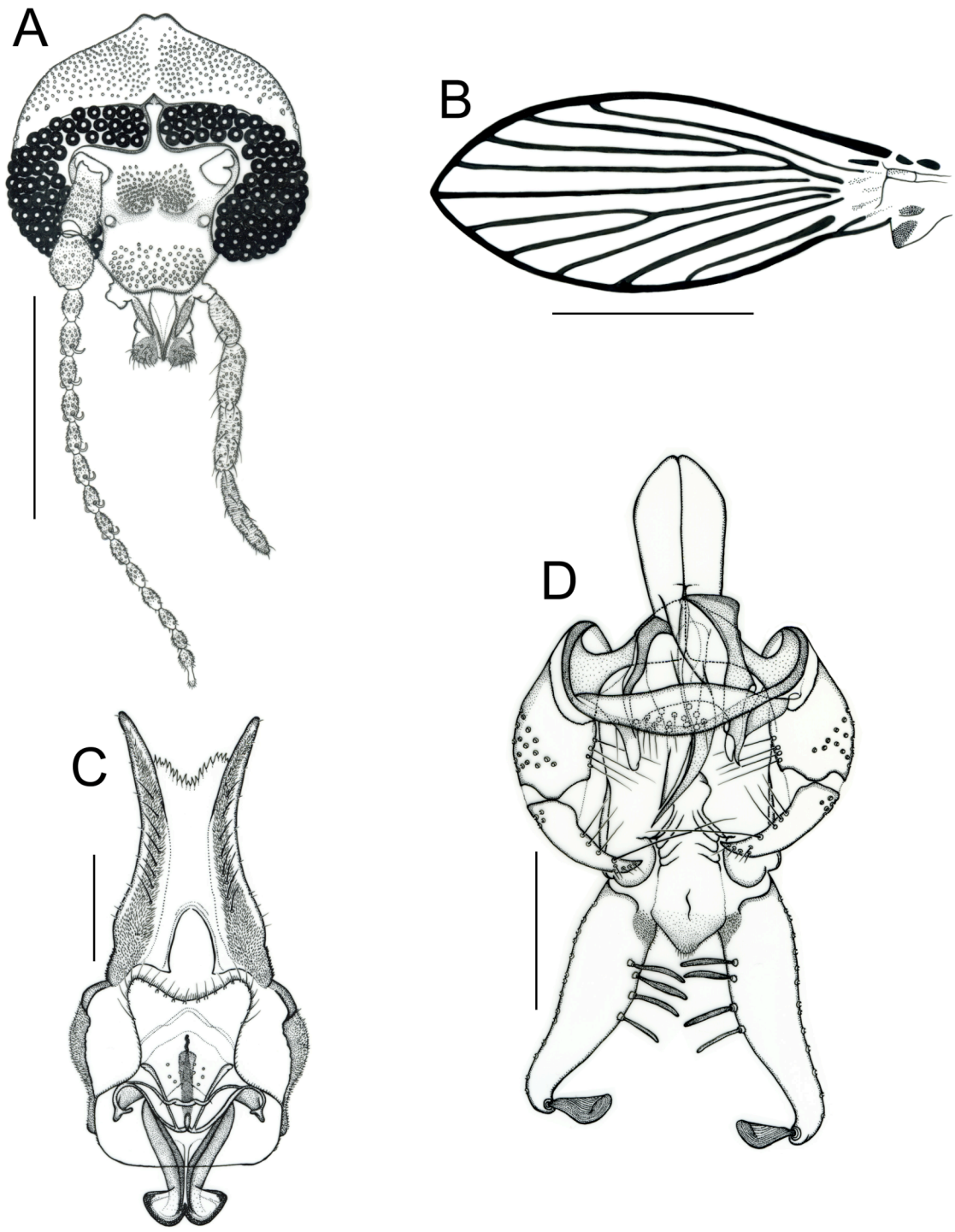



**Figure 5-2.** *Australopericoma delta* Curler sp. nov. **A.** Male head, frontal view. **B.** Wing. **C.** Female terminalia, showing internal structure, ventral view. **D.** Male terminalia, dorsal view. Scale bars = 0.1 mm (C–D), 0.25 mm (A), 0.5 mm (B).

times longer than wide; tergite X triangular, microsetose apically; cercopods strongly tapered from base to apex, flattened medially, with 14 retinacula inserted dorsoapically; retinacula with apices pectinate. Tergite X tongue-shaped, about 2/3 as long as cercopod.

**Adult Female** (Fig. 5-2 C): Eyebridge with 4 facet rows, divided by 4 facet diameters. Frontal scar patch as in male. Interocular suture as in male. Antenna nearly identical to male, except without spines on flagellomere I. Mouthparts and palpi as in male. Wing venation as in male. Terminalia: Subgenital plate with hypovalvae widened basally, with lateral margins convex, posterior margin concave; genital duct as figured, about 2/3 as wide as base of hypovalvae.

TYPE MATERIAL. Holotype [adult male]: U.S.A. ALABAMA: *Baldwin Co*: Raft River, 30°46'N 87°57'W, 9.viii.2006, coll. J.W. McCreadie, Malaise trap; deposited LACM. Specimen dissected, mounted on micro-slide. Allotype [adult female]: same data as holotype; deposited LACM. Specimen dissected, mounted on micro-slide. Paratypes: same data as holotype [10 adult male, 10 adult female (slides)]. Paratypes deposited in LACM, USNM, CUAC and UTK.

OTHER MATERIAL EXAMINED. U.S.A. ALABAMA: *Baldwin Co*: Byrnes Lake, 30°47'N 87°54'W, 9.viii.2006 [1 adult male], 20.iv.2007 [2 adult female], 25.vii.2007 [35 adult male, 18 adult female], coll. J.W. McCreadie, Malaise trap; Bon Secour, 30°18'N 88°44'W, 19.vi.2004 [6 adult male, 11 adult female], 15.vi.2007 [1 adult female], coll. E. Benton, Malaise trap; Gulf State Park, 30°16'N 88°39'W, 19.vi.2004 [3 adult female], coll. J.W. McCreadie, Malaise trap; Big Lizard Creek Malaise, 30°52'N 87°57'W, 23.x.2004 [1 adult male, 2 adult female], coll. J.W. McCreadie, Malaise trap; Big Lizard Creek, 30°46'N 87°57'W, 9.viii.2006 [1 adult female], 4.x.2006 [1 adult male], 11.x.2006 [1 adult female], 20.iv.2007 [1 adult male, 4 adult female], coll. J.W. McCreadie, Malaise trap; Raft River, Malaise #4, 30°31'N 87°34'W, 21.iii.2001 [10 adult male, 7 adult female], coll. J.W. McCreadie, Malaise trap; Raft River, site 17, 30°48'N 87°55'W, 23.x.2004 [10 adult male, 6 adult female], coll. J.W. McCreadie; Raft River, 30°46'N 87°57'W, 9.viii.2006 [176 adult male, 100 adult female], 4.x.2006 [72 adult male, 69 adult female], 20.iv.2007 [79 adult male, 102 adult female], 25.vii.2007 [242 adult male, 122 adult female]; *Mobile Co*: Bellefontaine,

30°27’N 88°6’W, 20.vi.2004 [3 adult male, 4 adult female], coll. J.W. McCreadie, Malaise trap; Grand Bay Sav., 30°23’N 88°18’W, 20.vi.2001 [3 adult male, 6 adult female], 18.viii.2006 [3 adult male, 6 adult female], 10.viii.2007 [2 adult male, 6 adult female], coll. E. Benton, Malaise trap.

ETYMOLOGY. From the Greek *delta*, in reference to the type locality in the Mobile-Tensaw delta.

BIONOMICS. *Australopericoma delta* was collected between late March and late August with a peak emergence in late July or early August. During some years, this species is locally abundant.

DISTRIBUTION. Collected from multiple locations in the Mobile-Tensaw delta of southern Alabama.

REMARKS. Adults of *A. delta* are easily distinguished from other *Australopericoma* by the shape of the gonopods, particularly the widened hypandrium and gonocoxites without stout spines in the male, and the shape of the genital duct in the female. *A. delta* is also much smaller than its congeners.

***Threticus thelyceratus*** Curler & Moulton **sp. nov.** (Figs. 5-3–5-5)

DIAGNOSIS. **Larva:** Antenna composed of 2 bulbous, hemispherical sensilla; postmentum without teeth. Pigment black, alveoli crowded dorsally and ventrally; anterior spiracles capitate; tergal plates nearly void of setae. Anal division with dorsal sclerite robust, encircling entire segment basally, conical apically; flabellar processes minute, respiratory fans inconspicuous. **Pupa:** Anal division with 4 spines apically, dorsoapical spines hooked apically; with 3 spines on each side. **Adult:** Male eye bridge with 4 facet rows, divided by width of 3 facet diameters. Interocular suture inverted Y-shaped. Male terminalia: parameres sclerotized, flanking aedeagus; one paramere filamentous, elongate, extending nearly beyond cercopodia; opposite paramere not extending beyond aedeagus, rostrate apically. Female terminalia: Subgenital plate with triangulate protuberances inserted anterolaterally; protuberances directed posteriorly; hypovalvae bilobed; lobes rounded, with posteromedial margins finely serrate; genital

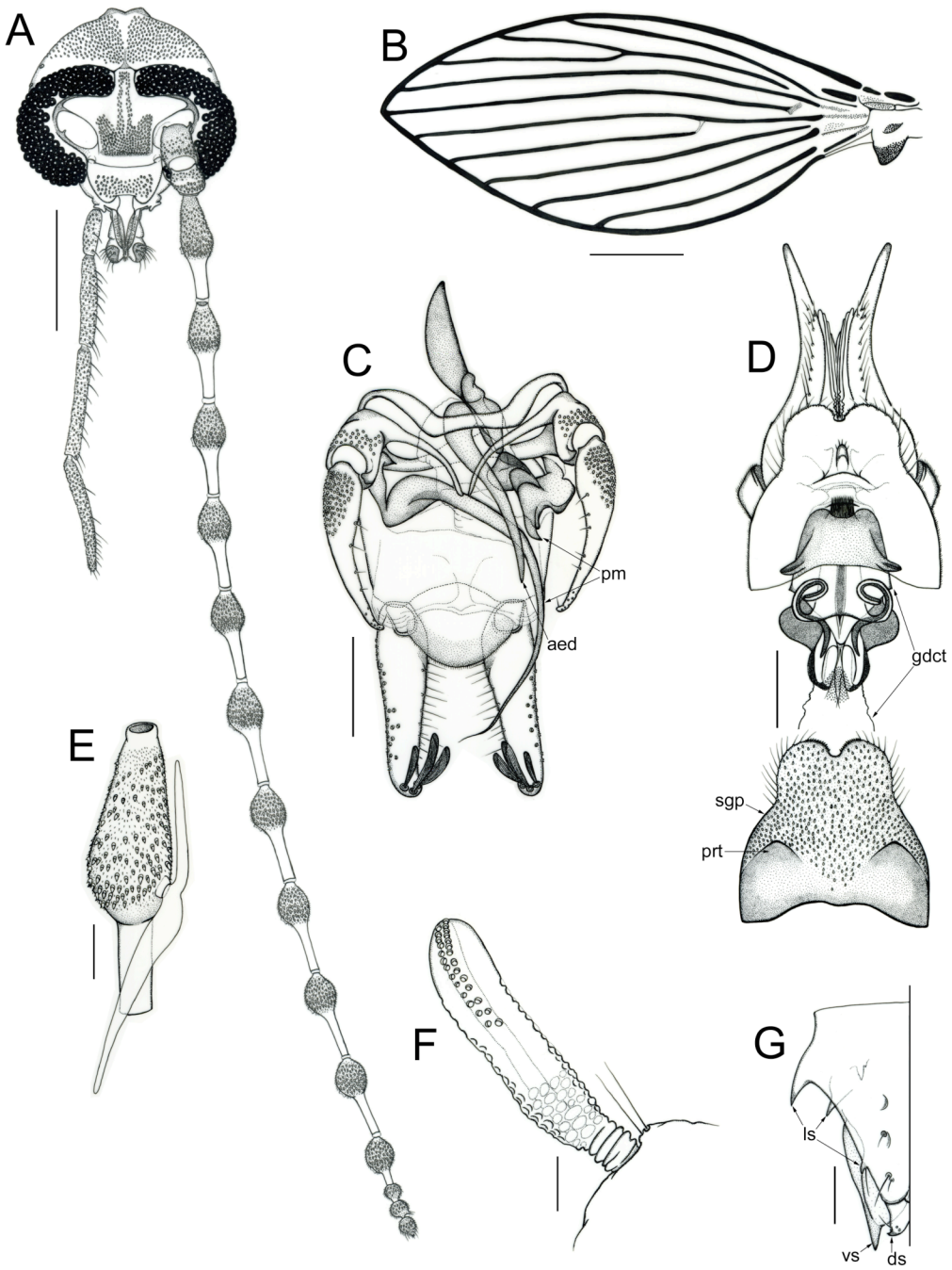



**Figure 5-3.** *Threticus thelyceratus* Curler & Moulton sp. nov. **A.** Male head, frontal view. **B.** Wing. **C.** Male terminalia, dorsal view. **D.** Female terminalia, subgenital plate removed, showing internal structure, ventral view. **E.** Male right antennal flagellomere 1, frontal view. **F.** Right respiratory horn of pupa, dorsal view. **G.** Anal division of pupa, dorsal view. Scale bars = 0.05 mm (E–F), 0.1 mm (G), 0.125 mm (D), 0.25 mm (A, C), 0.5 mm (D). (abbreviations: aed = aedeagus; ds = dorsal spine; gdct = genital duct; ls = lateral spine; pm = paramere; prt = protuberance; sgp = subgenital plate; vs = ventral spine).

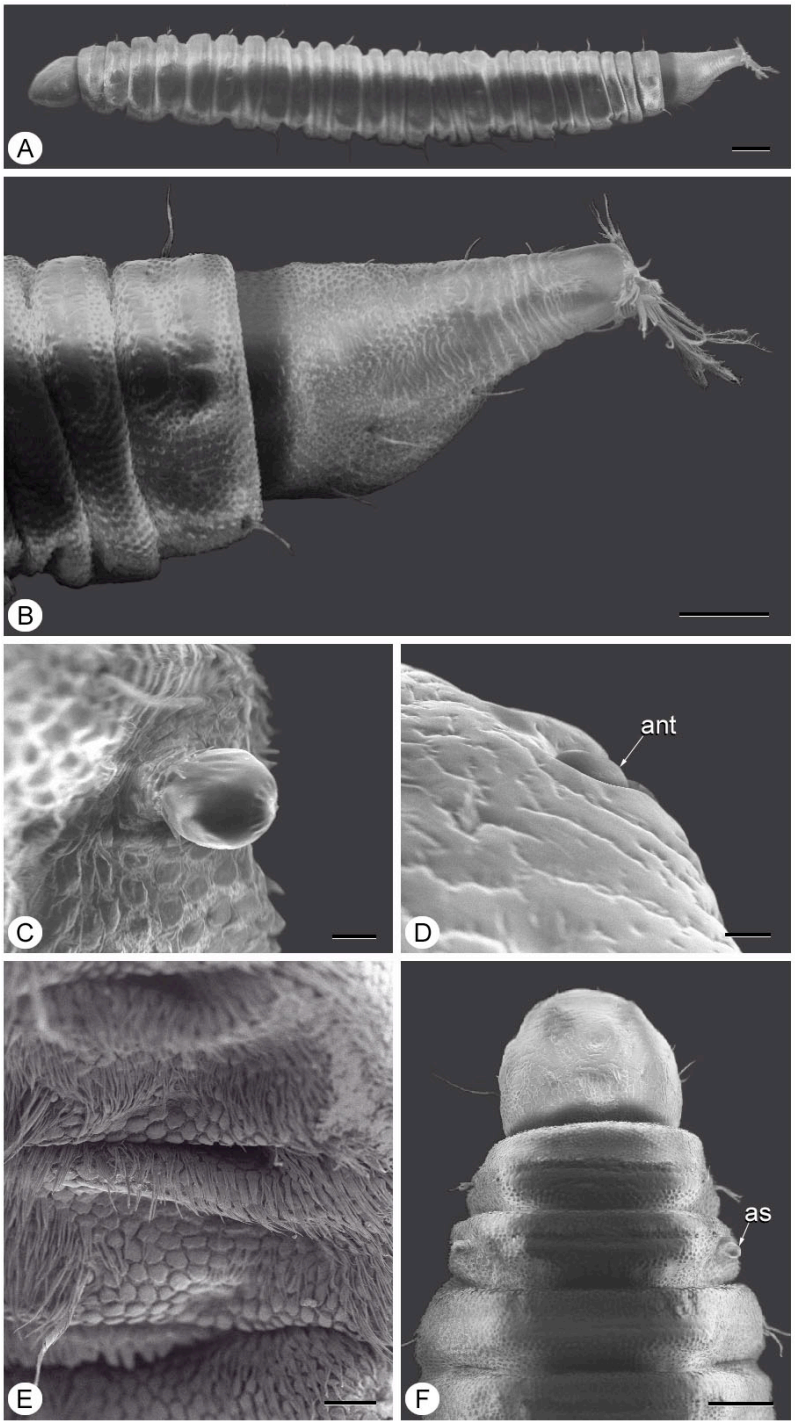



**Figure 5-4.** Scanning electron micrographs of larval *Threticus thelyceratus*. **A.** Habitus, dorsolateral view. **B.** Abdominal segment VII and anal division, lateral view. **C.** Right anterior spiracle, dorsal view. **D.** Right antenna, dorsal view. **E.** Left side of meso and metathorax, detail of alveoli, ventral view. **F.** Head, pro- and mesothorax, dorsal view. Scale bars = 10µ (C–D), 20µ (E), 100µ (B, F), 200µ (A).

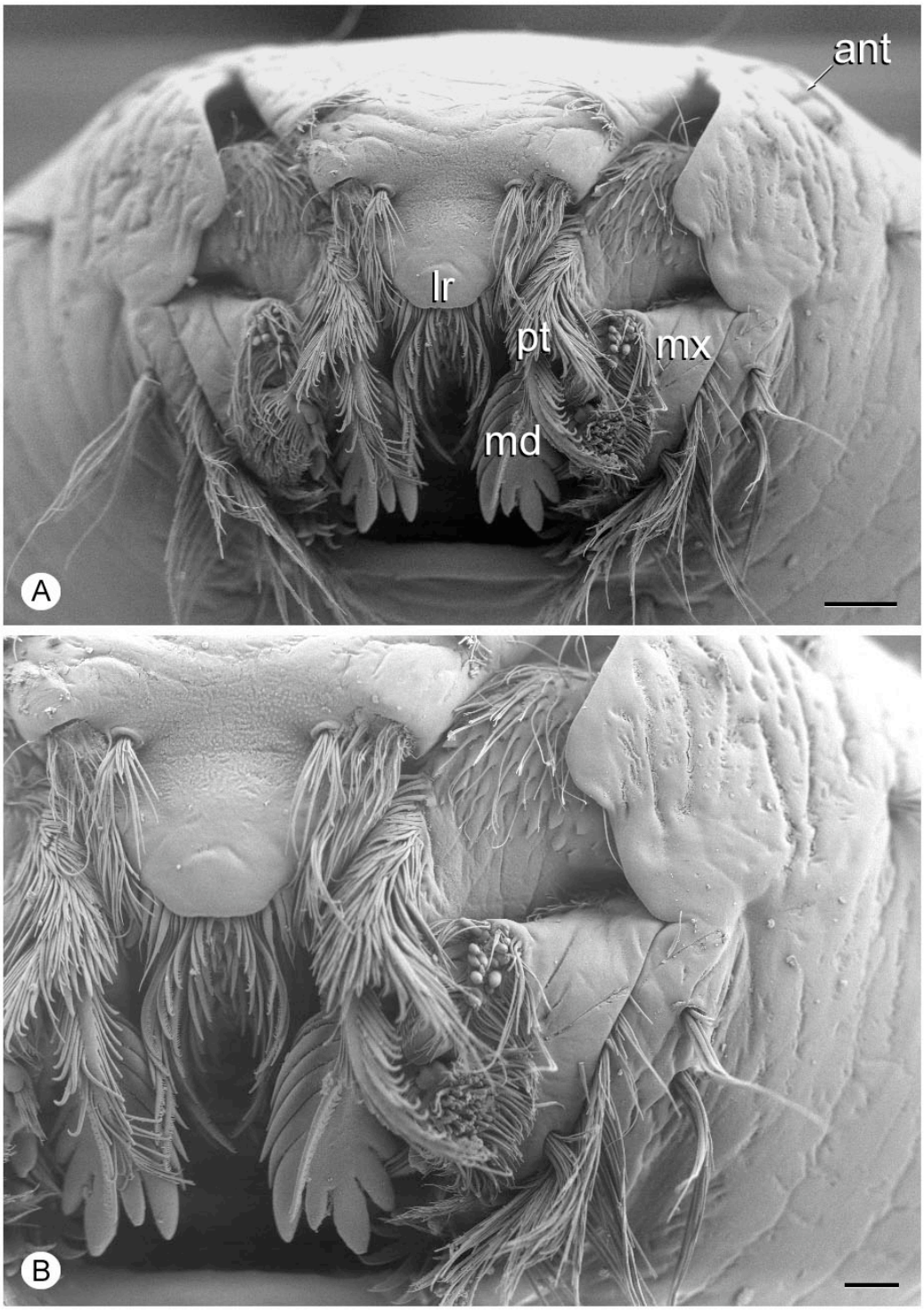



**Figure 5-5.** Scanning electron micrographs of larval *Threticus thelyceratus*. **A.** Mouthparts, ventral view. **B.** Mouthparts, left side enlarged, ventral view. Scale bars = 10µ (24), 20µ (25). (abbreviations: ant = antenna; lr = labrum; md = mandible; mx = maxilla; pt = prostheca).

digit arising near base of hypovalvae, extending to ½ length of hypovalvae; genital duct about as wide as hypovalvae, with curled, horn-like projections ventrally.

DESCRIPTION. **Larva** (Figs. 5-4–5-5): Measurements, instar IV (N = 2) total length 3.94 mm (3.85–4.02), cranial width 0.34 mm. Head capsule ovate, with genae broadly rounded. Antenna composed of 2 bulbous, hemispherical sensilla. Labrum with multiple pectinate microtrichia and macrotrichia inserted ventrally, with paired, brush-like sensilla inserted anteriorly. Mandibles and maxilla typical of *Threticus*; prostheca composed of 1 brush-like macrotrichium and 2 bipectinate macrotrichia. Postmentum straight, without teeth. Trunk: segmentation and arrangement of tergal plates typical of Psychodinae. Segments I–V parallel-sided, thorax and posterior segments gradually tapered. Integument black in color; alveoli numerous, hemispherical or flat, appearing crowded dorsally and ventrally; thoracic and abdominal segments with numerous elongate, brush-like alveoli ventrolaterally. Anterior spiracles capitate, inserted laterally on posterior annulus of prothorax, not extending beyond lateral margin. Tergal plates quadrangular, without protuberances, nearly void of setae. Anal division: dorsal sclerite robust, encircling anal division basally, conical apically, with few macrotrichia inserted dorsomedially, with 3 prominent macrotrichia inserted ventrolaterally on both sides; ventral flabellar processes minute, extending only slightly beyond dorsal sclerite; respiratory fans inconspicuous.

**Pupa** (Fig. 5-3 F–G): Respiratory horn digitiform, constricted basally, with paired, longitudinal row of pores dorsomedially; exterior surface appearing pitted dorsobasally, laterally, ventrally. Anal division with prominent, paired spines posterodorsally, posteroventrally; posterodorsal spines hooked apically; 2 prominent spines inserted dorsolaterally, 1 inserted ventrolaterally on each side; 2 pairs of macrotrichia, 1 pair of microtrichia inserted posterodorsally.

**Adult Male** (Fig. 5-3 A–C, E): Measurements, (N = 5) head width 0.47 mm (0.43–0.49), head length 0.45 mm (0.41–0.49), wing length 2.90 mm (2.50–3.15), wing width 1.12 mm (1–1.20), palpomere proportion: 1–2.2–2.8–2.7. Eye bridge with 4 facet rows, divided by width of 3 facet diameters. Frontal scar patch as wide as frons anteriorly, trilobed posteriorly; lateral lobes divergent, truncate; median lobe divided

medially, extending between eyes, terminating anterior to interocular suture. Interocular suture inverted Y-shaped. Antennae: scape about 1.25 times longer than wide; pedicel globular; flagellomere I with node elongate, fusiform basally; flagellomere XI with distal neck short, about equal in length to the following flagellomere; flagellomeres XII–XIV reduced, globular; ascoids sinuous, with one anterior and one posterior branch, present on flagellomeres I–XI. Mouthparts long for Psychodinae, extending slightly beyond basal palpomere; labellum bulbous, not wider than clypeus, without apical teeth. Wing: base of costa with 2 breaks, wings held horizontally over body in live fly; apex acute, $R_5$ ending in apex; medial fork weakened, arising basal to radial fork, both arising basal to apex of $CuA_2$. Terminalia: hypandrium narrow, quadrate, not extended posteriorly; epandrium trapezoidal, narrowing slightly posteriorly, bilobed posteroventrally, membranous posterodorsally, about as long as wide; gonocoxites about as long as wide, not extending beyond aedeagus or parameres, connected by ventral bridge basally, with elongate digitiform projections dorsobasally; digitiform projections directed medially; gonostyles evenly tapered from base to apex, gradually curved medially, with apices digitifrom; aedeagus with basiphallus laterally compressed basally, connected to ventral gonocoxal bridge apically, articulated with distiphallus and parameres apically; distiphallus composed of single, acuminate sclerite; parameres sclerotized, flanking aedeagus; one paramere elongate, filamentous, extending nearly beyond cercopodia; opposite paramere short, not extending beyond aedeagus, beak-like apically, with apex curved laterally; cercopods about as long as epandrium, gradually tapered from base to apex, with 3 spathiform retinacula inserted dorsoapically. Tergite X semi-circular, about 1/4 as long as cercopodia.

**Adult Female** (Fig. 5-3 D): Head as in male except with antennae and ascoids smaller. Wing as in male. Terminalia: Subgenital plate constricted posteriorly, with triangulate protuberances inserted anterolaterally; protuberances directed posteriorly; hypovalvae bilobed; lobes rounded, with posteromedial margins finely serrate; genital digit short, arising near base of hypovalvae, extending to ½ length of hypovalvae; genital duct as figured, about as wide as hypovalvae, with curled, horn-like projections ventrally.

TYPE MATERIAL. Holotype [adult male]: U.S.A. NORTH CAROLINA: *Haywood Co*: GSMNP, Purchase Knob, 22.iv–10.v.2008, coll. G.R. Curler; deposited LACM. Specimen dissected, mounted on micro-slide. Allotype [adult female]: same data as holotype; deposited LACM. Specimen dissected, mounted on micro-slide. Paratypes: same data as holotype [3 adult male, 6 adult female (slides)]; same location as holotype, 15.v–1.vi.2007 [2 adult male, 3 adult female (slides)], 29.vi–30.vii.2007 [1 adult female (slide)], 28.viii–29.ix.2007 [1 adult male, 2 adult female (slides)], 9–27.v.2008 [2 adult male, 4 adult female (slides)], 27.v–12.vi.2008 [2 adult male, 2 adult female (slides)] coll. G.R. Curler, Malaise trap; same location as holotype, 29.vi.2007 [1 male pupa (slide)], coll. G.R. Curler; Blue Ridge Parkway (BLRI) @ Hornbuckle Valley overlook, 35°28'N 83°08'W, 30.vii.2006 [1 adult female (slide)], coll. G.R. Curler & J.K. Moulton, sweep net. Paratypes deposited in LACM, USNM, and UTK.

OTHER RECORDS. U.S.A. NORTH CAROLINA: *Haywood Co*: BLRI @ Woodfin Cascades, 35°27'20"N 83°5'40"W, 26.vii.2005 [1 adult male], coll. J.K. Moulton, sweep net; same location 22.vii.2006 [3 adult female], coll. G.R. Curler, aspirator; same location 30.vii.2006 [2 adult female] coll. G.R. Curler & J.K. Moulton, mercury vapor light; BLRI @ Hornbuckle Valley overlook, 35°28'N 83°08'W, 30.vii.2006 [2 adult male], coll. G.R. Curler & J.K. Moulton, sweep net; BLRI @ East Fork overlook, 35°19'N 82°50'W, 18.viii.2006 [1 adult male, 1 adult female], coll. G.R. Curler & J.K. Moulton, sweep net; BLRI near Log Hollow overlook, 35°21'20"N 82°48'50"W, 12.vii.2007 [1 adult male, 2 adult female], coll. J.L. Robinson, sweep net.

BIONOMICS. Adult *Threticus thelyceratus* were collected from mid May to late August. Larvae of this species were collected from in between moist decaying leaves, which were lying along the margin of a first order stream.

DISTRIBUTION. Collected from multiple locations in western North Carolina.

REMARKS. *T. thelyceratus* is one of two known Nearctic species of *Threticus*. It is sympatric with but easily separable from *T. bicolor* (Banks) by the shape of the parameres, particularly the elongate, filamentous paramere in the male and the shape of the subgenital plate with protuberances and genital duct with horn-shaped dorsal projections in the female. As illustrated by Wagner (1984), the male terminalia of

*Threticus* species exhibits mirrored symmetry in some specimens, and can appear different in some specimens due to the aedeagus and parameres being retracted into the abdomen. Both of the aforementioned conditions were observed in *T. thelyceratus*, but most specimens died with the aedeagus and parameres fully exerted.

**Acknowledgements**

We are grateful to the National Park Service for granting permission to collect in Great Smoky Mountains National Park and along the Blue Ridge Parkway, and to D. Furth (USNM) for loaning the paratype of *Trichomyia intricata* Quate. We thank J. L. Robinson for collecting specimens of *Threticus*. We also thank J. W. McCreadie & P. H. Adler and for providing many specimens of *Australopericoma* and *Trichomyia* collected during the Total Insect Bio-Inventory Project of the Mobile-Tensaw Delta. A. J. Jacobson kindly assisted with various lab procedures. Support for various aspects of this research included grants from the National Science Foundation (Award No. DEB-0933218 to JKM), the United States Army (Award No. W81XWH-06-1-0471 to JKM) and Discover Life in America.

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# CHAPTER 6
# A SURVEY OF THE PSYCHODIDAE OF GREAT SMOKY MOUNTAINS NATIONAL PARK

## Abstract

As part of the All Taxa Biodiversity Inventory, a survey of Psychodidae was conducted in Great Smoky Mountains National Park (GSMNP). Flies were collected during March-October of 2007-09 by Malaise and CDC traps, sweep netting and aspirating. Three subfamilies, 20 genera and 51 species of Psychodidae were identified from GSMNP and recorded in the ATBI Database. A key to the males of psychodid genera occurring in GSMNP is provided.

## Introduction

Great Smoky Mountains National Park (GSMNP), with its variety of ecosystems, contains a rich diversity of organisms. Unfortunately, our understanding of ecosystem structure and function has been hampered by a lack of taxonomic and ecological data for many components of the ecosystem. This is especially problematic for many major constituents of the insect fauna.

Insects are a critical component of the ecosystems in GSMNP due to their numerical abundance, taxonomic diversity, and trophic significance. Among the most abundant and morphologically diverse groups of insects, the family Psychodidae (Diptera), commonly known as moth flies, is generally involved in the recycling of organic material.

Larval psychodids can be found in high numbers living as saprophages on fallen leaves and other plant and occasionally animal remains (Vaillant 1973). Furthermore, the larvae of some aquatic species feed on algae and diatoms. Adult psychodids are usually short-lived and non-feeding, but are often readily visible in habitats such as roadside mountain seeps and restroom drains, and consequently, the adults have been more frequently collected than their larvae. Despite their major role as decomposers and concomitant abundance in many ecosystems, few workers have studied Psychodidae, especially in the Nearctic region. Furthermore, few species of Psychodidae are known to occur in GSMNP, and most of the psychodid species known to occur in GSMNP are

described only from adult male and/or female specimens. Taxonomic keys for identifying larvae and adults are either outdated or divided among several references (Quate 1955; Quate & Vockeroth 1981; Vaillant 1973). This makes it difficult or impossible for current or future researchers to identify larval or adult specimens to species or even genus and subsequently determine the role of these species in their respective ecosystem.

A survey of the Psychodidae of GSMNP was conducted as part of the All Taxa Biodiversity Inventory in order to complete the following objectives: 1) Sample psychodids in GSMNP using various techniques; 2) Produce a list of psychodid species occurring in GSMNP; 3) Develop a key for identification of the males of psychodid genera occurring in GSMNP.

## Materials and Methods

*Collecting and Preservation*. Flies were collected with Malaise and CDC traps, or by hand. Malaise traps were set following standard GSMNP Malaise trap protocol (i.e. with electric fence). CDC traps were run from dusk to at least one hour after dark. Hand collecting involved sweep-netting and aspirating adult flies from various habitats. Collecting took place in locations with known high diversity of psychodids, ideal habitat, and where new species were known to occur (e.g. Purchase Knob, Cades Cove, Metcalf Bottoms). Immature psychodids were collected by picking through moist decaying leaf litter, washing mosses and lichens and using Tullgren funnels to extract larvae from all of the above habitats.

A subsample of larvae and pupae was kept alive and reared in Petri dishes. All remaining immature and adult specimens were fixed in ethanol. Representatives of each life stage of each species collected were cleared in 10% NaOH and mounted in Canada balsam. All primary type specimens for new species will be deposited in the Natural History Museum of Los Angeles County, Los Angeles, CA. Exemplars of each described species, and paratypes of new species will be deposited in the GSMNP insect collection.

*Identification.* Psychodid specimens were identified to species using the most recent taxonomic keys (Quate 1955; Quate & Vockeroth 1981) as well as recent publications on psychodids from the southeast United States (Curler & Moulton 2008; Quate 2000; Vaillant 1973, 1983; Wagner 1984).

*Use of Data*. After completing the survey, a list of georeferenced psychodid species was generated using the ATBI Database software, verified by Michael Kunze and submitted directly to the ATBI Database. All taxonomic and natural history data collected for all species will be added to a web-based, multi-access taxonomic (i.e. Lucid ®) key, and associated HTML species fact sheets.

## Results

Three subfamilies, 20 genera and 51 species of Psychodidae were identified from GSMNP and recorded in the ATBI Database. Of the 3 subfamilies collected, 2 are new records for GSMNP. Of the 20 genera collected, 11 are new records for GSMNP, 1 is a new record for the Nearctic region and 1 is new to science. Of the 51 species collected, 20 are new records for GSMNP, 1 is a new record for the Nearctic region and 16 are new to science. A list of these species is given in Table 6-1.

### Key to males of the genera of GSMNP Psychodidae

1. Wing with two longitudinal veins between radial and medial forks (Figs. 6-1 I, J)…2
- Wing with one longitudinal vein between radial and medial forks (Fig. 6- 1 H)…***Trichomyia***

2(1). Eyes extended medially, with eye-bridge (Fig. 6-1 B); mouthparts reduced or extending slightly beyond palpomere 1; antennal flagellomeres fusiform (Fig. 6-1 B) or nodiform (Fig. 6-1 A)…3
- Eyes round, without medial extensions; mouthparts elongate, extending nearly beyond palpomere 2 (Fig. 6-2 A); antennal flagellomeres cylindrical…***Lutzomyia***

**Table 6-1.** 51 psychodid species collected from Great Smoky Mountains National Park listed in phyletic sequence, and the status of each record.

| Species | Status |
|---|---|
| *Trichomyia nuda* (Dyar) | new to GSMNP |
| *Trichomyia* sp. nov. | new to science |
| *Lutzomyia (Psathyromyia) shannoni* (Dyar) | new to GSMNP |
| *Setomima nitida* (Banks) | previous record |
| *Pericoma signata* (Banks) | previous record |
| *Thornburghiella clavata* Vaillant | previous record |
| *Thornburghiella albitarsis* (Banks) | previous record |
| *Thornburghiella marginalis* (Banks) | previous record |
| *Thornburghiella slossoni* (Williston) | new to GSMNP |
| *Thornburghiella* sp. nov. #1 | new to science |
| *Thornburghiella* sp. nov. #2 | new to science |
| *Stupkaiella furcata* Vaillant | previous record |
| *Stupkaiella recurrens* Vaillant | previous record |
| *Stupkaiella* sp. nov. | new to science |
| *Clytocerus americana* (Kincaid) | new to GSMNP |
| *Clogmia albipunctata* (Williston) | previous record |
| *Lepiseodina conspicua* (del Rosario) | new to GSMNP |
| *Lepiseodina superba* (Banks) | previous record |
| *Crenopanimerus lucens* (Vaillant) | previous record |
| *Crenopanimerus quadripunctatus* (Banks) | new to GSMNP |
| *Paramormia arnaudi* (Wagner) | new to GSMNP |
| *Mormia* sp. nov. | new to science |
| *Threticus bicolor* (Banks) | previous record |
| *Threticus* sp. nov. | new to science |
| "*Threticus*" *tridactila* (Kincaid)* | new to GSMNP |
| "*Threticus*" sp. nov.* | new to science |
| Gen. nov. sp. nov. | new to science |
| *Perithreticus jonesi* (Quate) | new to GSMNP |
| *Perithreticus bishoppi* (del Rosario) | new to GSMNP |
| *Feuerborniella* sp. nov. | new to science |
| *Quatiella interdicta* (Dyar) | previous record |
| *Eurygarka nelderi* Curler | new to GSMNP |
| *Philosepedon quatei* Vaillant | previous record |
| *Philosepedon opposita* (Banks) | new to GSMNP |
| *Philosepedon* sp. nov. | new to science |

**Table 6-1.** (*continued*)

| | |
|---|---|
| *Psychoda alternata* (Say) | new to GSMNP |
| *Psychoda lativentris* (Berdén) | new to GSMNP |
| *Psychoda phalanoides* L. | new to GSMNP |
| *Psychoda symmetrica* Vaillant | previous record |
| *Psychoda umbracola* Quate | new to GSMNP |
| *Psychoda minuta* Banks | new to GSMNP |
| *Psychoda satchelli* Quate | new to GSMNP |
| *Psychoda reevesi* Quate | new to GSMNP |
| *Psychoda setigera* Tonnoir | new to GSMNP |
| *Psychoda trinodulosa* Tonnoir | new to GSMNP |
| *Psychoda* sp. nov. #1 | new to science |
| *Psychoda* sp. nov. #2 | new to science |
| *Psychoda* sp. nov. #3 | new to science |
| *Psychoda* sp. nov. #4 | new to science |
| *Psychoda* sp. nov. #5 | new to science |
| *Psychoda* sp. nov. #6 | new to science |

*quotation marks indicate tenuous taxonomic placement

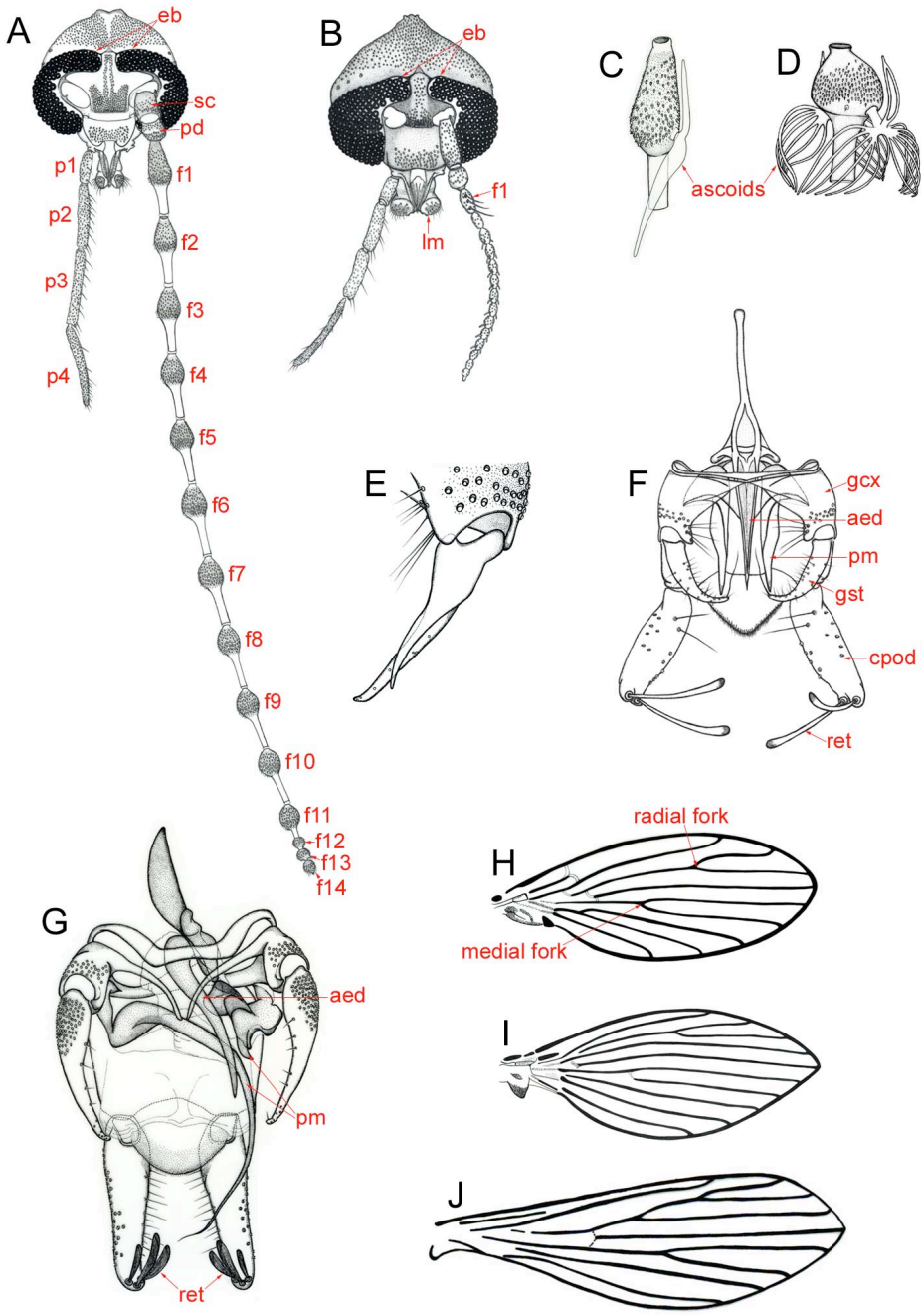



**Figure 6-1.** Adult males of Psychodidae. **A.** *Threticus* sp. head, frontal view. **B.** *Stupkaiella* sp. head, frontal view. **C.** *Threticus* sp. flagellomere 1 with ascoid, frontal view. **D.** *Eurygarka* sp. flagellomere 8 with ascoid, frontal view. **E.** *Stupkaiella* sp. left gonostyle, dorsal view. **F.** *Eurygarka* sp. terminalia, dorsal view. **G.** *Threticus* sp. terminalia, dorsal view. **H.** *Trichomyia* sp. Wing. **I.** *Threticus* sp. Wing. **J.** *Lutzomyia* sp. Wing. (abbreviations: aed = aedeagus; cpod = cercopod; eb = eye-bridge; f1–14 = flagellomeres 1–14; gcx = gonocoxite; gst = gonostyle; lm = labellum; p1–4 = palpomeres 1–4; pd = pedicel; pm = paramere; ret = retinacula; sc = scape).

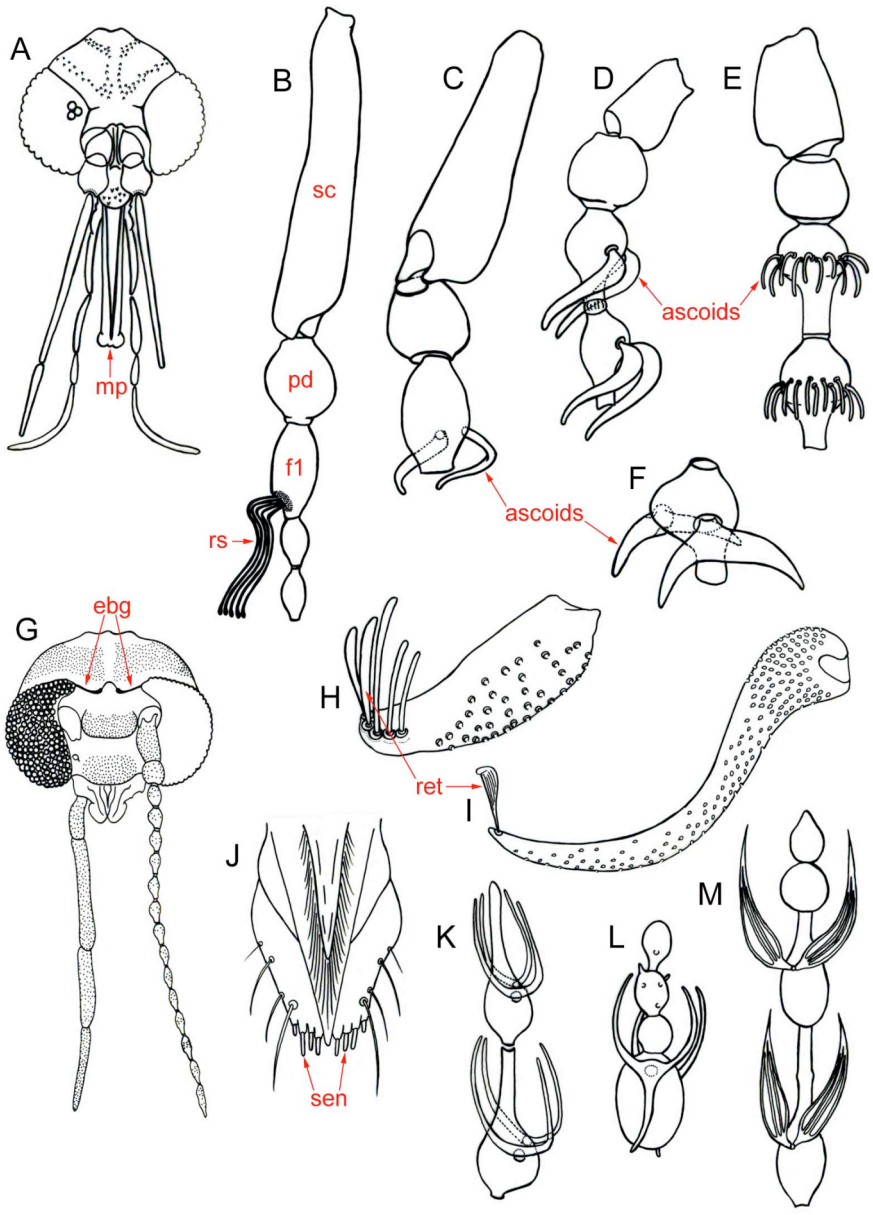



**Figure 6-2.** Adult males of Psychodidae. **A.** *Lutzomyia* sp. Head, frontal view. **B.** *Clytocerus* sp. Basal antennal segments, dorsal view. **C.** *Crenopanimerus* sp. Basal antennal segments, dorsal view. **D.** *Lepiseodina* sp. Basal antennal segments, dorsal view. **E.** *Paramormia* sp. Basal antennal segments, dorsal view. **F.** *Lepiseodina* sp. Flagellomere 4 with ascoids, dorsal view. **G.** *Setomima* sp. Head, frontal view. **H.** *Perithreticus* sp. Cercopod, lateral view. **I.** *Psychoda* sp. Cercopod, lateral view. **J.** *Psychoda* sp. Labellum, frontal view. **K.** *Clogmia* sp. Apical flagellomeres with ascoids, dorsal view. **L.** *Philosepedon* sp. Apical flagellomeres with ascoids, dorsal view. **M.** *Mormia* sp. Apical flagellomeres with ascoids, dorsal view. (abbreviations: ebg = eye-bridge gap; f1 = flagellomere 1; mp = mouthparts; pd = pedicel; ret = retinacula; sc = scape; sen = sensory rods).

3(2). Cercopodia with no more than three retinacula (Fig. 6-1 F, G); antennae with flagellomeres nodiform, symmetrical; apical flagellomeres diminutive (Fig. 6-1 A)…4

- Cercopodia with at least four retinacula; antennae with flagellomeres nodiform or fusiform; apical flagellomeres gradually decreasing in size or diminutive…10

4(3). Retinacula numbering three (Fig. 6-1 G)…5

- Retinacula numbering one (Fig. 6-2 I) or two (Fig. 6-1 F)…6

5(4). Body white with black vestiture; wing with radial fork complete and medial fork complete or weakened (Fig. 6-1 I); wing membrane clear, without vestiture…***Threticus***

- Body gray with black vestiture; wing with radial and medial forks incomplete; wing membrane with vestiture…**Genus novum**

6(4). Retinacula numbering two…7

- Retinacula numbering one…8

7(6). Ascoids with anterior branches leaf-like (Fig. 6-1 D)…***Eurygarka***

- Ascoids with anterior branches spathiform, not leaf-like (Fig. 6-2 L)…***Philosepedon***

8(6). Labellum bulbous (Fig. 6-1 A, B), without apical sensory rods; aedeagus symmetrical…9

- Labellum laterally compressed, with apical sensory rods (Fig. 6-2 J); aedeagus asymmetrical…***Psychoda***

9(8). Retinacula about as long as cercopodia; aedeagus filamentous…***Quatiella***

- Retinacula less than 1/3 length of cercopodia; aedeagus spatulate …***Feuerborniella***

10(3). Eye-bridge gap not wider than ten facet diameters; wing membrane without vestiture…11

- Eye-bridge gap wider than ten facet diameters (Fig. 6-2 G); wing membrane with numerous iridescent scales…***Setomima***

11(10). Antennae with flagellomeres fusiform…12

- Antennae with flagellomeres nodiform…15

12(11). Wing with recurrent spur on medial fork; flagellomere 1 with a row or cluster of rigid spines (Fig. 6-1 B)…13

- Wing without recurrent spur on medial fork; antennae without spines on any flagellomere…14

13(12). Gonostyli simple…***Thornburghiella***

- Gonostyli bifurcate (Fig. 6-1 E)….***Stupkaiella***

14(12). Wing membrane with patches of pigmentation marginally; flagellomere 1 with a tuft of rigid, sinuous setae inserted subapically (Fig. 6-2 B); gonocoxites cylindrical…***Clytocerus***

- Wing membrane without pigment; antenna without rigid setae; gonocoxites bulbous, conspicuous…***Pericoma***

15(11). Cercopodia with more than five retinacula arranged in a cluster; antennae with flagellomeres asymmetrical, ascoids not Y-shaped or sinuous; aedeagus symmetrical…16

- Cercopodia with four or five retinacula inserted subapically, arranged in a transverse row (Fig. 6-2 H); antenna with flagellomeres symmetrical, ascoids Y-shaped or sinuous; aedeagus symmetrical or asymmetrical…***Perithreticus***

16(15). Antennae with two ascoids on each flagellomere; terminalia without parameres…17

- Antennae with numerous digitiform ascoids (Fig. 6-2 E) on each flagellomere; aedeagus flanked by sickle-shaped parameres…***Paramormia***

17(16). Ascoids bifurcate, branches elongate-digitiform or leaf-like, U or V-shaped; aedeagus forming a loop distally…18

- Ascoids simple or bifurcate, branches broad basally, digitiform apically; aedeagus filamentous or looped apically…19

18(17). Eye-bridge with three facet rows; ascoids V-shaped with leaf-like branches (Fig. 6-2 M)…***Mormia***

- Eye-bridge with four facet rows; ascoids U-shaped with elongate-digitiform branches (Fig. 6-2 K)…***Clogmia***

19(17). Antennae with scape at least two times longer than wide (Fig. 6-2 C); ascoids digitiform; aedeagus looped apically…***Crenopanimerus***

- Antennae with scape not more than 1.5 times longer than wide (Fig. 6-2 D); ascoids digitiform (Fig. 6-2 D) or crescent-shaped (Fig. 6-2 F); aedeagus filamentous apically…***Lepiseodina***

## Discussion

The results of this survey have greatly enhanced our knowledge of the GSMNP and regional psychodid faunas. Presumably all genera and most species that occur in the park have been recorded, but it is possible that additional species will be found. Future collecting efforts should focus on the immature stages of described species. Larvae and pupae of several species were collected during this survey, but some rearing attempts were unsuccessful, and additional specimens are needed in order to positively associate them with their adults by rearing or DNA analysis.

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# CHAPTER 7
# PHYLOGENETIC RELATIONSHIPS OF PSYCHODID SUBFAMILIES (DIPTERA: PSYCHODIDAE) INFERRED USING MORPHOLOGICAL AND MOLECULAR DATA

## Abstract

Psychodidae has been the subject of few phylogenetic investigations. Logical classifications of the six psychodid subfamilies and lower taxa such as tribes within subfamily Psychodinae are highly desirable. The current study includes a phylogenetic analysis of all psychodid subfamilies based on morphological data and DNA sequence from two nuclear genes. Hypothesized relationships of all subfamilies and select Psychodine tribes are discussed.

## Introduction

Despite their curious features, wide distribution, and medical importance, psychodids have been the subject of few phylogenetic investigations. As noted by Woodley (2005), Hennig (1972) proposed the most recent hypothesis of subfamilial relationships, which was followed by Ansorge (1994). This hypothesis suggests that Bruchomyiinae + Phlebotominae is the sister group of Trichomyiinae + Psychodinae. Current workers consider the Trichomyiinae of Hennig to be divided into subfamilies Trichomyiinae, Sycoracinae and Horaiellinae. Furthermore, recent fossil evidence (Duckhouse 2000; Azar et al. 2003) suggestes that Hennig's hypothesis may not be entirely accurate. The lack of phylogenetic hypotheses agreeable to all specialists has hindered the development of a logical and stable classification within Psychodidae at the subfamily and lower levels. Classification within the subfamily Psychodinae has been especially problematic, particularly regarding generic and tribal limits and relationships. In this study, morphological and molecular phylogenetic data for representatives of all psychodid subfamilies and select Psychodine tribes are analyzed, and a hypothesis of subfamily relationships is proposed.

## Materials and Methods

*Morphological phylogenetic analysis*. Phylogenetic relationships based on morphology were evaluated according to cladistic principles (*sensu* Hennig (1966), as modified by Wiley (1981), Schuh (1999) and others). Tanyderidae was chosen as the outgroup because it is morphologically similar to Psychodidae. Ingroup and outgroup character states were determined by examining specimens, where available, and from the most recent descriptions of each life stage for all taxa.

The outgroup and each subfamily of Psychodidae were coded for phylogenetically informative characters. Unclear and autapomorphic characters were excluded. Cladistic analyses were performed using PAUP* 4.0 (Swofford 2002) and character transformations viewed in MacClade 4.05 (Maddison & Maddison 2002). PAUP analyses consisted of a branch and bound search with all characters weighted equally. Multistate characters were considered as unordered. Bootstrap values were calculated for 500 replicates.

*Molecular phylogenetic analysis.* At least one representative species of Tanyderidae and each subfamily of Psychodidae were sequenced for two nuclear genes, 18s (ribosomal DNA) and 8-OH (coding gene). Total genomic DNA was extracted from a single ethanol-preserved individual of each taxon. Specimens were homogenized in a sodium dodecyl sulfate (SDS)-based lysis buffer including proteinase K. The homogenates were incubated at 55°C for several hours prior to organic extraction, once with a solution of phenol, chloroform and isoamyl alcohol. DNA salt was created by applying sodium acetate and was precipitated and pelleted by addition of cold (-20°C) absolute isopropanol and centrifugation. DNA was washed with 70% and 95% ethanol, air-dried and resuspended in 100 µL of 1X TE. Purified DNA samples were stored at -20°C.

Amplifications were performed in MasterCycler (Eppendorf North America, Westbury, NY) thermal cyclers using EX Taq Hotstart DNA polymerase (TakaraMirus) per the manufacturer's suggested protocol and 1-2 µL of template DNA. Primer combinations used in this study are listed in Table 7-1. PCR products were electrophoresed in 1% agarose, excised from the gel, and purified using a QiaQuick Gel Extraction Kit (Qiagen, Valencia, California). Both strands of each product were cycle-

**Table 7-1.** List of primers used in this study.

| Gene | Use/Name | F/R | Sequence (5' → 3')* | Length |
|---|---|---|---|---|
| 18s | Old 1F | F | CAWTTACTTGGATAACTGTG | 20-mer |
| | New 1R | R | CCTTCGAACCTCTRACTTTCG | -mer |
| | 2F | F | CGTTTACTTTGAACAAATTAGAG | 23-mer |
| | 2R | R | TTCAATCGGTAGTAGCGAC | 19-mer |
| | | | | |
| 8OH | 344 | F | GTNTGYTGYATHTGYATGGAYGG | 23-mer |
| | 350 | F | GCNGTNCAYCARGAYTGYTAYGG | 23-mer |
| | 750 | R | AYTGYTTRGCNTAYAAYAAYMGRGAYAC | 28-mer |
| | 758 | R | AARGAYACNATGTTYTAYMGNGCNGG | 26-mer |
| | 706 | F | GAYATHGTNAARCAYCCNATGGA | 23-mer |
| | P2,5'#2 | F | GTRAARCATCCRATGGAYTTGAG | 23-mer |
| | P2,5'#5 | F | CCBATGGAYCTAAGYACAATG | 21-mer |
| | P2 bef. intron 1 | R | GGRCTRCAYGGYGGYGTYTG | 20-mer |
| | P2 bef. intron 2 | R | TRAANCCRCTRCARCTRCTRCA | 22-mer |
| | 1389 | R | GGRTANCCNCGRCAYTTRGCCCA | 23-mer |

* W=A/T; Y=C/T; R=A/G

sequenced in 20 μL reactions using 8-fold diluted Big Dye 3.1 (Applied Biosystems, Foster City, CA). Sequencing reactions were cleaned using Centri-sep columns (Princeton Separations, Adelphia, New Jersey), electrophoresed through a 6% polyacrylamide gel using an MJ Research BaseStation Automated DNA Sequencer (Bio-Rad, Hercules, California), and analyzed using Cartographer 1.2.7 software. Sequences from opposing strands were reconciled and verified for accuracy using Sequencher 4.2.2 (Gene Codes, Ann Arbor, Michigan). Parsimony-based phylogenetic analyses were performed using PAUP* 4.0.

## Results

*Morphological analysis.* Twenty characters and 18 taxa were evaluated through a phylogenetic analysis (Table 7-1). Of the characters, eleven were adult characters, one was a pupal character and eight were larval characters (Table 7-2). All characters were considered unordered. Parsimony analysis produced 3 trees of length 36 steps. A majority rule consensus of these trees (Fig. 7-1) had a Consistency Index (CI) of 0.694 and a Rescaled Consistency Index (RC) of 0.362. Bootstrap values did not support any nodes of the consensus tree.

*Molecular analyses.* The final aligned 18s sequences yielded 2,220 characters while the alignments of 8-OH nucleotide and amino acid sequences yielded 2860 and 795 characters, respectively. All sequences will be deposited in GenBank and their accession numbers will be made available at a later date.

Parsimony analysis of 18s sequences resulted in a single most parsimonious tree (Fig. 7-2) of length 1574 with a CI of 0.584 and a RC of 0.214. Parsimony analysis of 8-OH nucleotide sequences resulted in two most parsimonious trees of length 13673 with a CI of 0.309 and a RC of 0.120. A strict consensus of these trees is shown as Figure 7-3. Moreover, parsimony analysis of 8-OH amino acid sequences resulted in six most parsimonious trees of length 3021 with a CI of 0.673 and a RC of 0.445. A majority rule concensus of these trees is shown as Figure 7-4.

**Table 7-2.** Matrix of characters and alternate states used in cladistic analysis of *Neotelmatoscopus* (0, 1, 2 = character states; ? = character state unknown)

| Taxon | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Tanyderidae** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | ? | 0 | 0 |
| **Bruchomyiinae** | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| **Trichomyiinae** | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 2 | 1 | 1 | 0 | 0 | 1 | 0 | 0 |
| **Phlebotominae** | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 |
| **Sycoracinae** | 0 | 0 | 2 | 0 | 0 | 0 | - | - | 1 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 0 | 0 | 1 |
| **Horaiellinae** | 0 | 1 | 2 | 0 | 2 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | ? | 1 | 0 |
| **Psychodinae** | 1 | 1 | 2 | 1 | 2 | 1 | 1 | 0 | 0 | 1 | 1 | 2 | 2 | 0 | 1 | 1 | 0 | 2 | 0 | 0 |

**Table 7-3.** Characters and alternate states used in cladistic analysis of psychodid subfamilies.

## Larva

| | |
|---|---|
| 1. antenna length | 0. elongate<br>1. reduced |
| 2. retractile head | 0. partially retracted<br>1. not retracted |
| 3. annulated abdominal segments | 0. not annulated<br>1. weakly annulated<br>2. strongly annulated |
| 4. dorsal chaetotaxy | 0. undeveloped<br>1. developed |
| 5. tergal plates | 0. absent<br>1. one plate per segment<br>2. one plate per annulus |
| 6. crochets on anal division | 0. present<br>1. absent |
| 7. sclerites on anal division | 0. absent<br>1. present |
| 8. posterior processes | 0. present<br>1. absent |

## Pupa

| | |
|---|---|
| 9. general shape of pupa | 0. typical of lower diptera<br>1. modified from typical form |

## Adult

**Table 7-3.** (*continued*)

| | |
|---|---|
| 10. mouthparts | 0. elongate/developed<br>1. short/undeveloped |
| 11. number of antennal segments | 0. 15-25 segments<br>1. 12-16 segments |
| 12. flagellomere shape | 0. cylindrical<br>1. weakly nodiform<br>2. strongly nodiform |
| 13. ascoid shape | 0. absent<br>1. digitiform<br>2. modified from digitiform |
| 14. longitudinal wing veins | 0. Not reduced/$R_2$ & $R_3$ present<br>1. Reduced/ $R_{2+3}$ present |
| 15. apical wing cross veins | 0. present<br>1. absent |
| 16. basal sperm ducts | 0. present<br>1. absent |
| 17. shape of intromittent organ | 0. simple<br>1. bifurcate |
| 18. spermathecae | 0. single<br>1. paired<br>2. absent |
| 19. spines on gonostyle | 0. absent<br>1. present |
| 20. rotation of male genitalia | 0. rotated 180 degrees<br>1. secondarily unrotated |

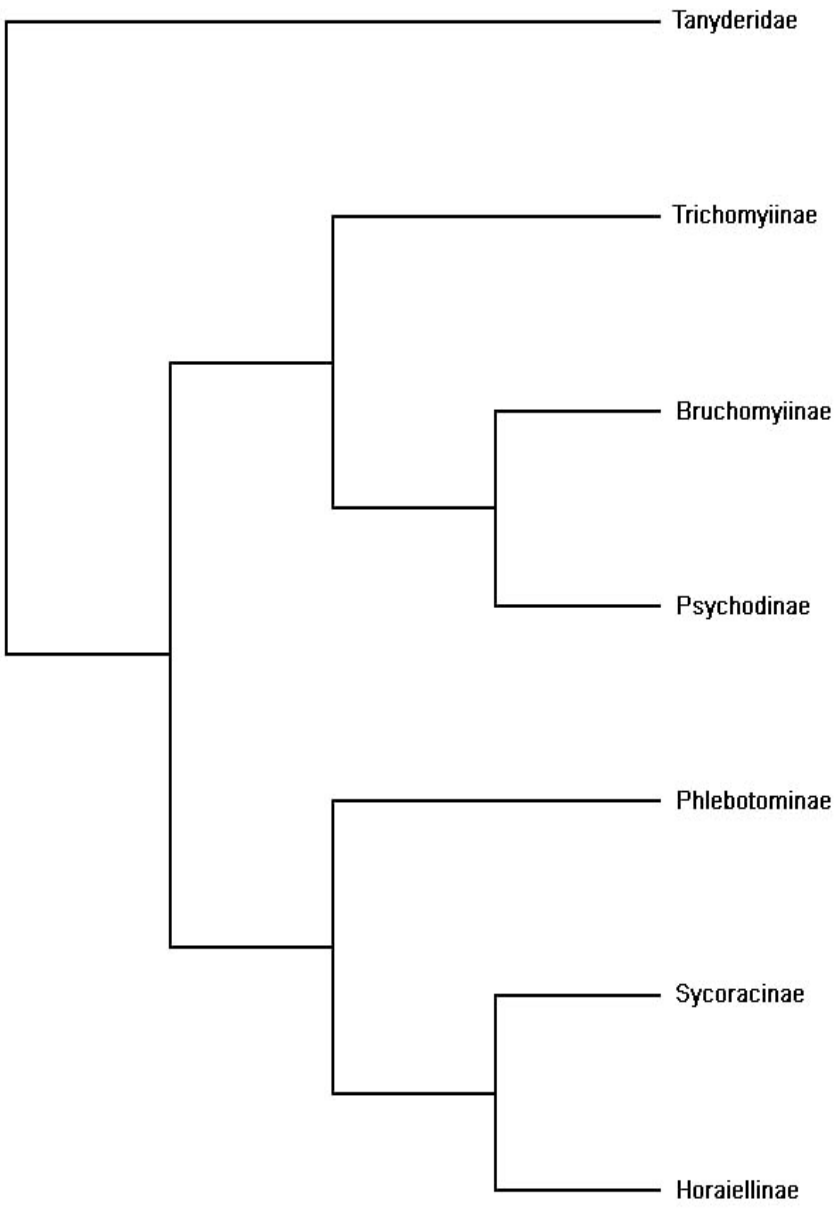



**Figure 7-1.** Majority rule concensus of three most parsimonious trees showing the relationships of psychodid subfamilies inferred from morphological data.

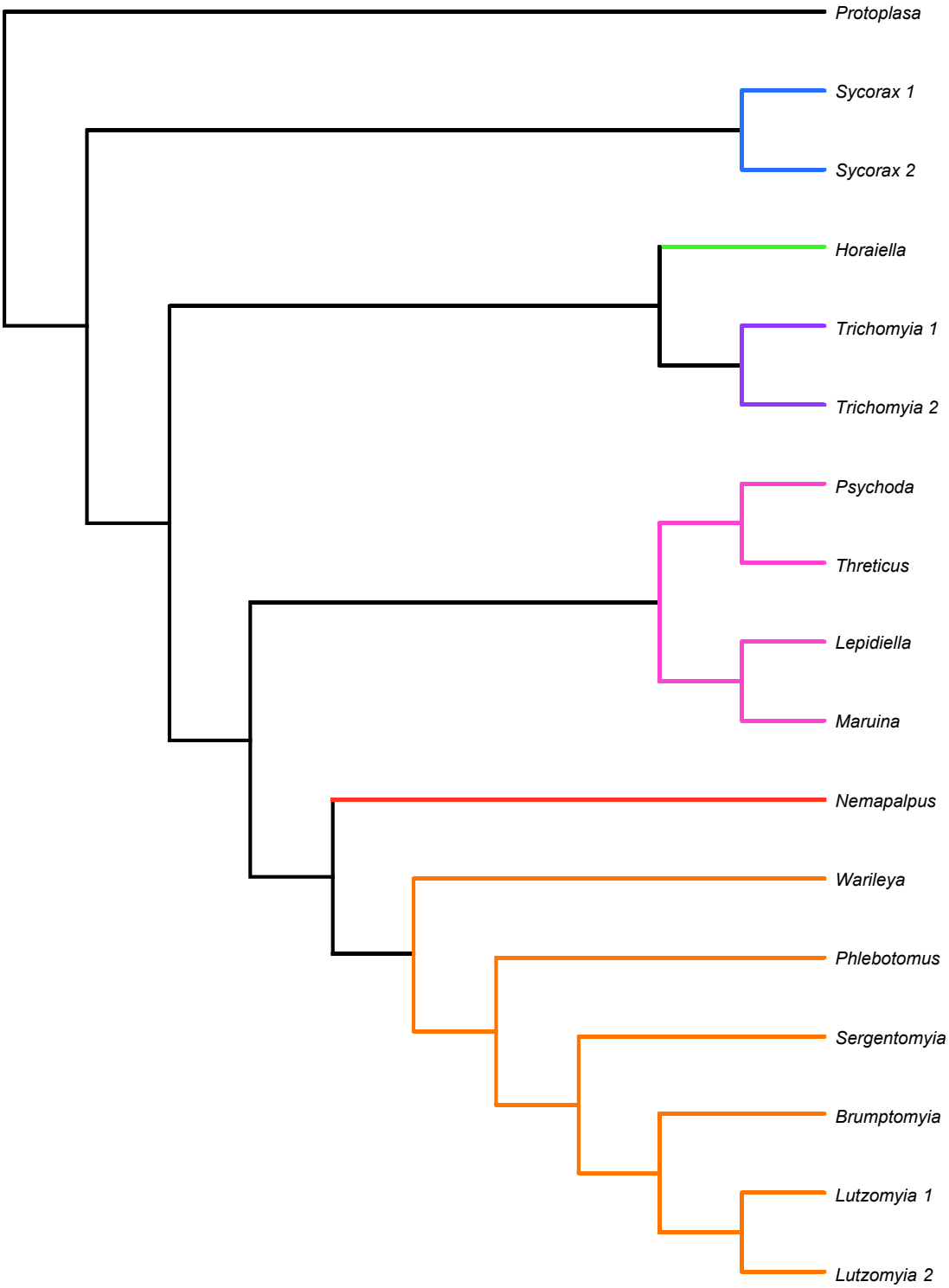



**Figure 7-2.** Single most parsimonious tree showing the relationships of psychodid subfamilies inferred from 18s rDNA sequences. (blue = Sycoracinae; green = Horaiellinae; purple = Trichomyiinae; pink = Psychodinae; red = Bruchomyiinae; orange = Phlebotominae)

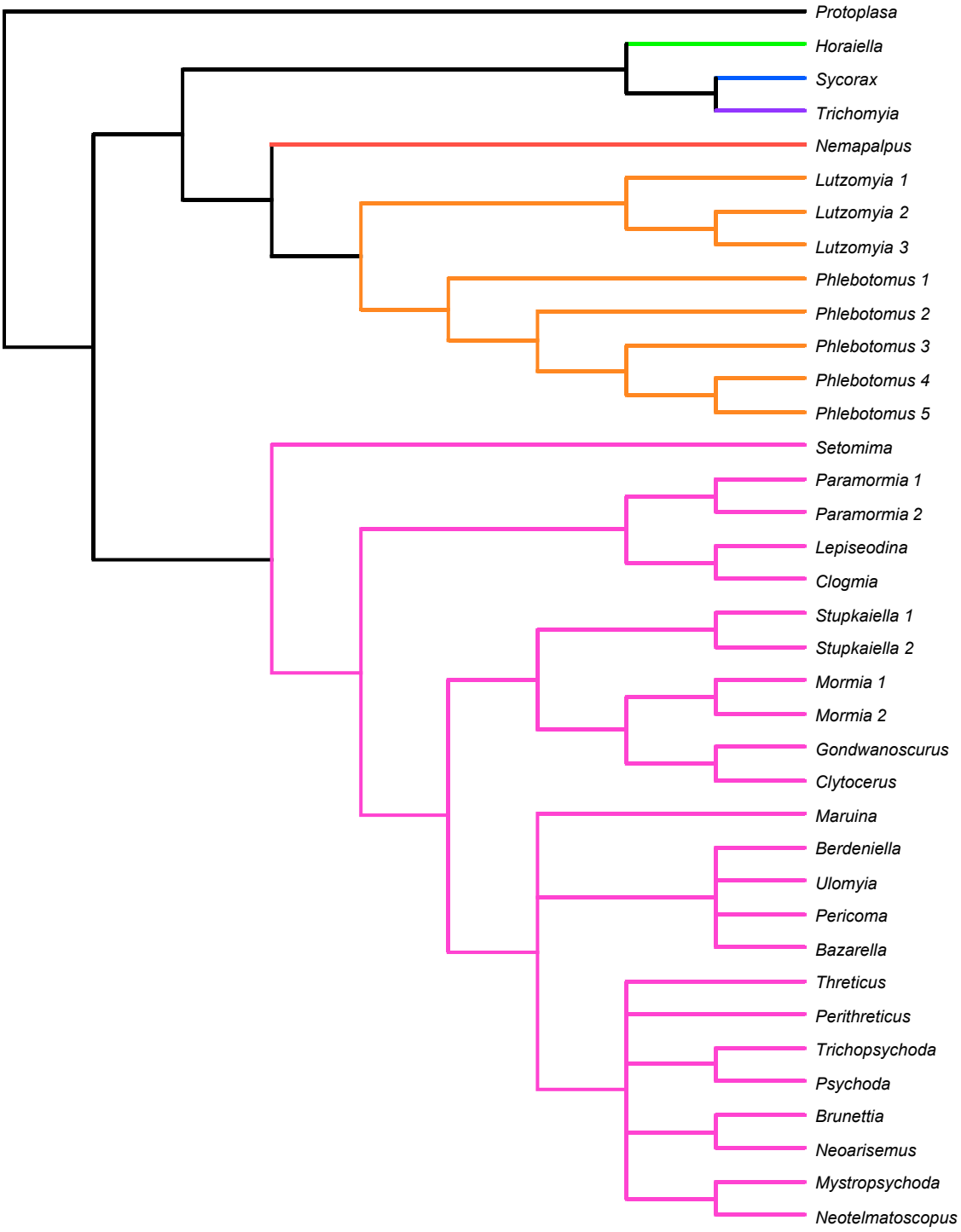



**Figure 7-3.** Strict concensus of two most parsimonious trees showing the relationships of psychodid subfamilies inferred from an alignment of 8-OH nucleotide sequences. (blue = Sycoracinae; green = Horaiellinae; purple = Trichomyiinae; pink = Psychodinae; red = Bruchomyiinae; orange = Phlebotominae)

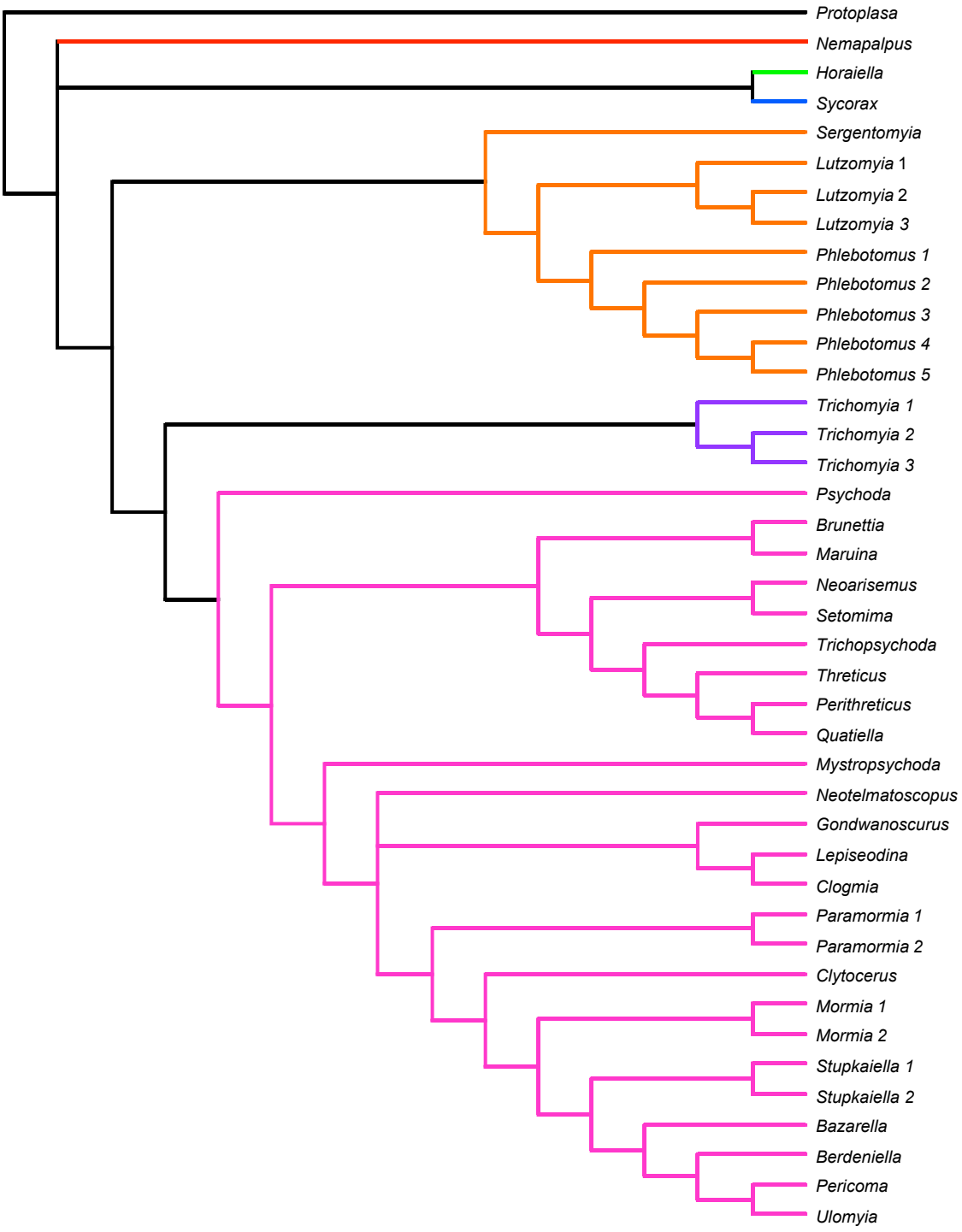



**Figure 7-4.** Majority rule concensus of six most parsimonious trees showing the relationships of psychodid subfamilies inferred from an alignment of 8-OH amino acid sequences. (blue = Sycoracinae; green = Horaiellinae; purple = Trichomyiinae; pink = Psychodinae; red = Bruchomyiinae; orange = Phlebotominae)

## Discussion

*Morphological analysis.* Results from the current analysis of morphological characters differ greatly from the hypothesis of Hennig. Two clades, Trichomyiinae + (Bruchomyiinae + Psychodinae) and Phlebotominae + (Sycoracinae + Horaiellinae) are resolved with the first group basal. This outcome was somewhat expected because most phylogenetically informative characters are found in the adult life stage, and the three taxa in each clade share characters of the head (e.g. reduced or developed mouthparts) and male genitalia (e.g. gonostyles with or without spines). There is also a single character (elongate antenna) in the larvae that is shared by Phlebotominae, Sycoracinae and Horaiellinae, but larvae of Bruchomyiinae, Psychodinae and Trichomyiinae are markedly different. Since the larva is known for only one species of Trichomyiinae, *Trichomyia ubrica* from Europe, it is possible that the larvae of other *Trichomyia* species may exhibit a completely different suite of characters that may help solidify its placement near bruchomyiines and psychodines.

Morphological analyses of psychodids, and other taxa, can be confounded by a lack of phylogenetically informative characters in all life stages. Furthermore, all subfamilies of Psychodidae are polymorphic for most available characters. This makes it nearly impossible to interpret these characters in a phylogenetic framework, thus resulting in fewer characters in the matrix, and reduced or no tree support.

*Molecular analysis.* Both 18s and 8-OH sequence data produced trees with all psychodid subfamilies resolved, but that of 18s raises question about the placement of Psychodinae. Psychodinae is undoubtedly apomorphic, but falls between basal Sycoracinae, Hoariellinae, Trichomyiinae and presumably basal Bruchomyiinae + Phlebotominae. It is worth noting that, aside from the questionable placement of Psychodinae, the results from 18s are similar to the hypothesis of Hennig.

The 8-OH sequence data performed very well. Both an amino acid alignment and a crude nucleotide alignment were analyzed in order to obtain preliminary results, and both resolved all subfamilies as well as multiple psychodine tribes. Psychodinae was derived in both trees, but the placement of other subfamilies varied. Bruchomyiinae was

either basal or the sister group to Phlebotominae. While Horaiellinae and Sycoracinae remained basal, Trichomyiinae was sister group to Psychodinae in the tree resulting from amino acid sequence. Perhaps even more interesting than the placement of subfamilies is the grouping of psychodine genera.

A number of genera were grouped together in their respective tribes in both 8-OH trees. Tribes Pericomini, Psychodini and Paramormiini were at least partially resolved, but none was completely resolved in both trees. Tribes Maruinini and Mormiini are also represented, but only genera of the former were grouped together.

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# CHAPTER 8
# CONCLUSIONS AND RECOMMENDATIONS

Our knowledge of Psychodidae is slowly improving. At least one, and in some cases many new species of each psychodid subfamily have recently been described. Researchers in several countries are analyzing DNA from an unprecedented number of psychodid species, and molecular data has helped clarify taxonomic groupings within Psychodidae. However, many genera and species remain undescribed in most regions of the world, and there is a paucity of specialists capable of addressing this problem. Furthermore, there is a lack of current tools for the identification of psychodids, and as a result, many researchers rely heavily upon the few specialists for accurate identifications. The objectives of the current research were to elucidate the diversity of Psychodidae in two poorly studied regions, describe at least some of the new species from both regions, revise the diagnosis and description of some previously known taxa, and to establish a working classification of higher taxa within Psychodidae.

A dichotomous key to males of all psychodid genera currently known from Great Smoky Mountains National Park, and complete descriptions for all known life stages of eight new Nearctic species have been given. In addition, two new species of Thai Psychodidae were described and a genus of Oriental Psychodidae was revised. In doing so, some poorly understood or unknown aspects of psychodid systematics have now been clarified, and current tools for identification of these flies are now available to future workers in the Nearctic and Oriental region. Moreover, a preliminary phylogenetic analysis of the six subfamilies in Psychodidae has been completed. The results of this analysis indicate which subfamilies are basal, and more importantly, how the basal subfamilies are related to one another.

Future endeavors in the alpha taxonomy of Psychodidae should focus on associating and describing the immature stages of species currently described only from adult specimens. This is especially true in the Oriental and Neotropical regions where the fewest larvae are known with the exception of conspicuous taxa such as *Nedotelmatoscopus* Tonnoir and *Maruina* Müller. Few current keys exist for accurately identifying adult psychodids, but even fewer references are available for identifying larvae. Perhaps the main reason for the latter is that the immature stages of many species have not yet been described.

As mentioned above, many genera and species remain undescribed for any life stage. Many collections of Psychodidae from several regions of the world have been obtained and examined for the purpose of identifying species and/or obtaining taxa for molecular studies. An abundance of new species exists in nearly every sample examined thus far, including those from the Nearctic region. Although it is difficult to focus primarily on describing new species, it is certainly needed.

Future projects concerning the beta taxonomy of Psychodidae might include a thorough analysis of the tribes within subfamily Psychodinae, or examinations of generic relationships within diverse, relatively well-known genera such as *Pericoma* Walker or *Thornburghiella* Vaillant.

# VITA

Gregory Curler was born in Dubuque, Iowa. He attended Dubuque Senior High School and later Iowa State Univeristy where he majored in Animal Ecology, minored in Entomology and earned a Bachelor of Science in 2003. Greg continued at ISU pursuing a Master of Science in Systematic Entomology, which he completed in 2005. His MS research included a revision of *Neotelmatoscopus* Tonnoir, a unique rheophilic genus of Oriental Psychodidae, and a study of Psychodidae collected from Thailand.

Later in 2005 Greg chose to pursue his Ph.D. from the University of Tennessee with Dr. Kevin Moulton as his major advisor. His studies while at UT included revisionary and descriptive work on Psychodidae from the Nearctic and Oriental regions, as well as a phylogenetic analysis of the subfamilies within Psychodidae. During his time in the Department of Entomology and Plant Pathology at the University of Tennessee, Greg authored six publications and co-authored three publications, and gave oral presentations at regional and national meetings. He also made two trips to Thailand for the purpose of research and teaching. Greg completed his Ph.D. in Systematic Entomology in December 2009.

Greg has accepted an offer to continue his research with Dr. Moulton until August of 2010, at which point he hopes to begin a postdoctoral research position at the Natural History Museum of Los Angeles County under the advisement of Dr. Brian Brown.