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NEW SPECIES OF LEPTOHYPHIDAE (EPHEMEROPTERA) FROM COSTA RICA

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Abstract.—Three **new species** of leptohyphid mayflies (Ephemeroptera: Leptohyphidae), ***Leptohyphes mandibulus***, ***Tricorythodes kirki***, and ***Tricorythodes primus***, are described from Costa Rica based upon the larval stages. *Leptohyphes mandibulues* can be distinguished from other species in the genus by its unique mandibular morphology and color patterns of the operaulate gill. *Tricorythodes kirk* larvae are distinctive due to their contrasting abdominal coloration. *Tricorythodes primus* is distinguished from other speices of *Tricorythodes* in Central America due to the presence of a distinctive and well developed frontal shelf and genal projections.

Key Words: Ephemeroptera, Leptohyphidae, *Leptohyphes*, *Tricorythodes*, new species

The mayfly family Leptohyphidae is a diverse assemblage of more than 125 species endemic to the Western Hemisphere. The family is most diverse in South America, with fewer species known from Central and North America. The family has received critical attention recently in both South America (Molineri 1999, 2001a,b, 2002, 2003a,b, 2004; Molineri and Zúñiga 2004), and North and Central America (Baumgardner and McCafferty 2000; Wiersema and McCafferty 2000, 2003, 2005; Wiersema et al. 2001; Baumgardner 2003; Baumgardner et al. 2003, 2006; Baumgardner and Ávila 2006). Additional descriptions and revisions of species are still required before generic boundaries and relationships can be fully analyzed. Examination of collections of mayflies made in 2001 from Costa Rica revealed three distinctive new species of leptohyphid mayflies, as described below.

Materials and Methods

Larvae were collected from streams using forceps and by disturbing the sediment using kick nets, then preserved in 70% ethyl alcohol. Legs, gills, and mouthparts were removed and mounted on slides for detailed study. Figures were drawn using a camera lucida. Collection sites are given in longitude/latitude coordinates as degrees, minutes, seconds, and were determined using a handheld global positioning system unit. Setal descriptive terminology follows Baumgardner and Ávila (2006). Gill formula follows Molineri (2003b), and indicates the number of membranous lamellae on abdominal segments two through seven. Collections (and their acronyms) housing materials used in this study include Florida A&M University, Tallahassee (FAMU) and Texas A & M University, College Station (TAMU).

Descriptions

Leptohyphes mandibulus Baumgardner, new species

(Figs. 1–11)

Adult.—Unknown

Mature larva.—Body length 3.0–3.5 mm; caudal filaments 2.0–2.5 mm. General color black. *Head*: Dark reddish brown to black; small genal projections present; tubercles absent; compound eyes small and widely separated; three ocelli present; antenna light brown, approximately two times length of head capsule. *Mouthparts*: Labrum: dorsally with filiform setae along lateral margin; two rows of acuminate setae recessed from anterior margin; ventrally with one longitudinal row of acuminate setae near midline, with interspersed filiform setae; anterior and lateral margins with dense filiform and acuminate setae. Right mandible (Fig. 1): outer and inner incisors two lobed; prostheca arising at base of inner incisor with highly branched, elongate setae projecting towards molar region; molar region mostly fused. Left mandible (Fig. 2): outer incisor two lobed, teeth fused almost their entire distance; inner incisor two lobed; prostheca arising at base of inner incisor, with highly branched setae projecting towards molar region. Hypopharynx: lingua apically rounded; numerous filiform and acuminate setae present on anterior margin; superlinguae oval, with numerous filiform and acuminate setae along anterior and lateral margins. Maxilla (Fig. 3): palp elongate, three segmented, without apical seta; three subapical setae on inner apical margin; cluster of filiform setae on outer apical surface; galealacinia not fused. Labium: submentum moderately developed (approximately twice as wide as long), with regularly spaced acuminate setae along lateral margins; ventrally with numerous robust setae most abundant near midline; prementum ventrally with numerous filiform setae; labial palp three segmented with numerous filiform setae; glossae and paraglossae subequal, fused except distally, with serrate outer margins; glossae slightly recessed, rounded, and with robust setae; paraglossae with numerous filiform setae. *Thorax*: Dorsally dark reddish brown to black; ventrally pale with diffuse black maculae; hindwing pads present in males, absent in females. Foreleg: femur (Fig. 4) pale yellow to pale brown with dorsal, median black spot; anterior and posterior margins with scattered filiform and acuminate setae; dorsal surface with transverse row of elongate setae (Fig. 5). Tibia and tarsus pale brown; anterior margin of tibia with 14–16 evenly spaced, elongate setae; posterior margin with few, scattered filiform setae; margins of tarsus without setae; ventral surface with row of four to six robust setae; tarsal claw with one submarginal denticle, and a single row of four to six marginal denticles, similar in shape and size with equal spacing. Mid- and hind legs: femora pale yellow with dorsal apical and basal black spots; anterior margins with elongate setae; posterior margins with few robust setae (usually on hind femur) or none; dorsal surface with transverse row of robust setae at base of femur. Tibiae: pale brown, with row of approximately 20 evenly spaced elongate setae along anterior margin; posterior margin with few, scattered elongate setae; dorsal surface with elevated, medio-longitudinal ridge. Tarsi pale brown, margins without setae; four to six acuminate setae along inner margin; claws with one submarginal denticle, and a single row of four to six marginal denticles, similar in shape and size with equal spacing (Fig. 6). *Abdomen*: Dark reddish brown to black; posterior margins of terga 1–10 serrate; terga 5–9 each with a pair of elongate setae located medially on posterior margin; tubercles absent; dorsal lamella of operculate gill elongate oval, basal portion black, apical portion pale; scattered acuminate setae

Figs. 1–11. *Leptohyphes mandibulus*, larva. 1, Right mandible. 2, Left mandible. 3, Maxilla. 4, Foreleg femur (dorsal view). 5, Foreleg femoral seta. 6, Hind leg claw. 7, Operculate gill (dorsal view). 8, Operculate gill (ventral view). 9, gill 5 lamellae (ventral view). 10, Right mandible (pre-emergent larva). 11, Left mandible (pre-emergent larva).

present along inner and apical margins (Fig. 7); ventral lamellae of operculate gill transculent-whitish (Fig. 8); gill 5 lamellae as in Fig. 9; gill formula: 3/6/6/6/2. Cercus with whorls of robust and elongate setae at each annulation.

Etymology.—The specific epithet of this species is a noun from the Latin word *mandibula* (f), meaning jaw or mandible. It alludes to the unusual features of the mandibles for this species.

Discussion and diagnosis.—The reduced number of outer incisor denticles on both the left and right mandibles will distinguish this species from others in the genus *Leptohyphes* Eaton. While the vast majority of species within *Leptohyphes* have four denticles on the outer incisor of the left mandible and three on the right mandible, *L. mandibulus* has only two outer incisor denticles on each mandible. In addition, the coloration of the operculate gills (basal half dark, apical half pale), and the contrasting coloration of the body and legs also is distinct for this species. *Leptohyphes cornutus* Allen, known only from South America, also has reduced outer incisors similar to *L. mandibulus*. It can be distinguished from *L. mandibulus* by the presence of distinct thoracic tubercles, which are absent on *L. mandibulus*.

Also of interest for *L. mandibulus* are the changes associated with the mandibles on mature and pre-emergent larvae. Mandibular description in the above species description is based upon relatively mature larvae, but not pre-emergent larvae. In pre-emergent larvae, the outer incisors of the right mandible are reduced to a single, rounded structure, while the inner incisor is reduced to a single denticle (Fig. 10). For the left mandible, the outer incisors are fused into a single, large incisor, while the inner incisor is reduced to a single denticle (Fig. 11). Reduction and fusion of incisors is very rare among leptohyphid mayflies and is usually a result of wear associated with feeding. However, numerous larval paratypes associated with *L. mandibulus* also displayed this condition, indicating it is probably a naturally occurring condition resulting from maturation, and not necessarily a result of feeding.

There does remain the possability that *Leptohyphes mandibulus* could be the undescribed larval stage of at least one of five species of *Leptohyphes* reported from Mexico and Central America, which were described based upon only the adult stage. These species include *Leptohyphes berneri* Traver (1958) described from central Mexico; *Leptohyphes brevissimus* Eaton (1892) described from southern Guatemala based upon female subimagos; *Leptohyphes nigripunctum* Traver 1943 described from a male subimago from Venezuela and later reported from southern Mexico (McCafferty 1985); *Leptohyphes peterseni* Ulmer (1920) described from South America based upon male and female subimagoes, and later reported from Central America (McCafferty 1985); or *Leptohyphes priapus* Traver (1958), which was described from Costa Rica. Based upon geography alone, *L. priapus* would be the most likely species to be the adult stage of *Leptohyphes mandibulus*. Additional research will be required to resolve this situation.

Distribution and biology.—This species is currently known only from the type locality in northwestern Costa Rica. Other species of leptohyphid mayflies collected with it included *Leptohyphes zalope* Traver and *Tricorythodes sordidus* Allen.

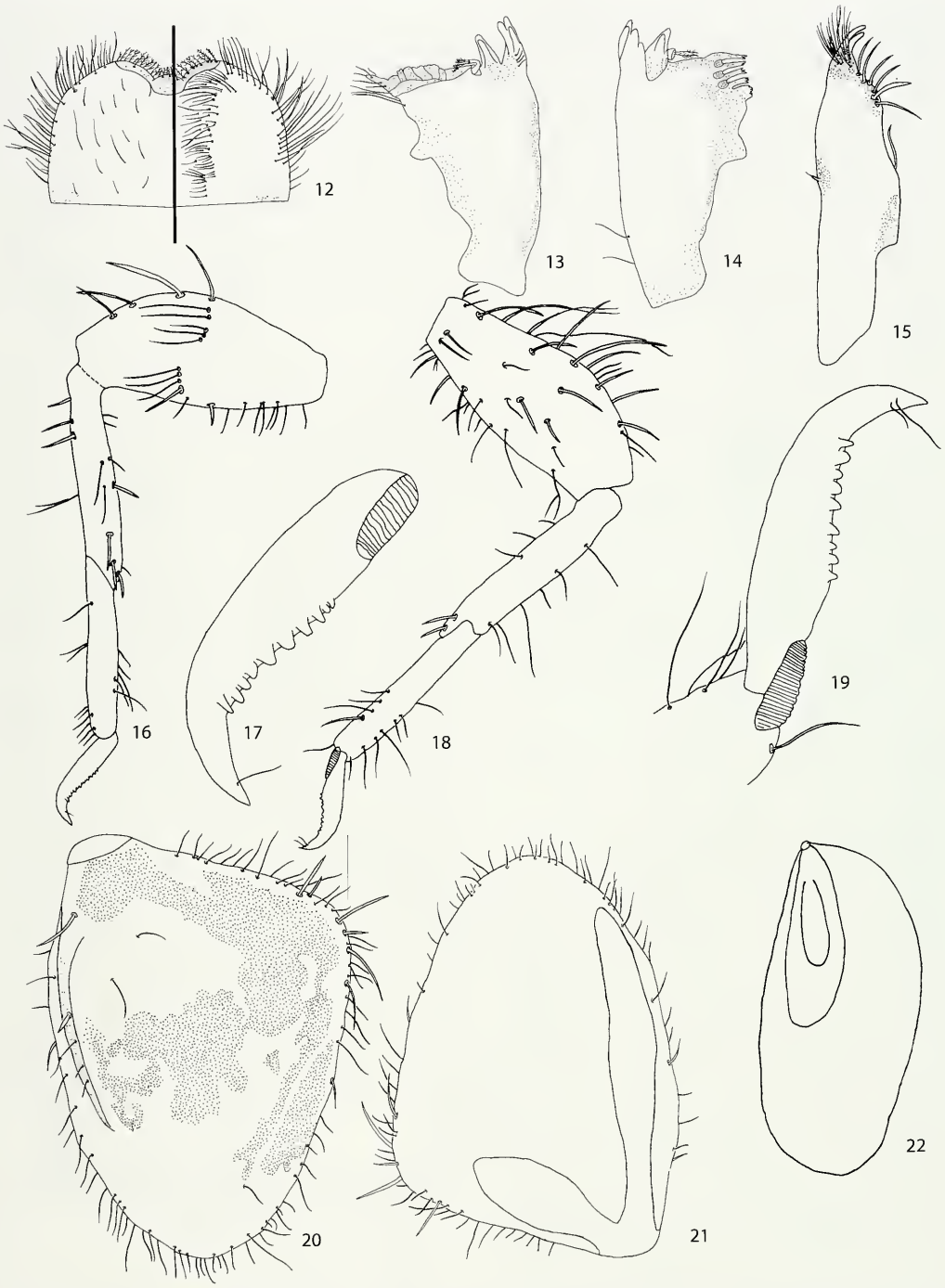
Type material.—Holotype: Mature male larva. COSTA RICA: Alajuela Province; NE of Bijagua, nr. Las Flores, Río Areuo (N10°21′06″, W85°21′05″), 07.vi.2000, WD Shepard (WDS-A-1300). Deposited in TAMU. Paratypes: Same data as holotype, 6 larvae (FAMU), 25 larvae (TAMU).

Tricorythodes kirki Baumgardner, new species

(Figs. 12–22)

Adult.—Unknown

Mature larva.—Body length 2.5–3.0 mm; caudal filaments 1.5 mm. General color reddish brown with extensive black maculae. *Head*: Pale reddish brown with variable black maculae on vertex and posterior to compound eyes; tubercles absent; compound eyes small and widely separated; three ocelli present; antenna pale, approximately two times length of head capsule. *Mouthparts*: Labrum (Fig. 12): dorsal surface with scattered filiform setae; lateral margin with numerous filiform and acuminate setae; highly branched robust setae along anterior margin, projecting from ventral surface; ventrally with longitudinal row of acuminate setae near midline, with interspersed filiform setae; lateral margin with numerous filiform and acuminate setae; anterior margin with robust, highly branched setae. Right mandible (Fig. 13): outer incisor three lobed, with elongate setae at base of teeth; inner incisor two lobed; prostheca arising at base of inner incisor with highly branched, elongate setae projecting towards molar region; molar region mostly fused. Left mandible (Fig. 14): outer incisor four lobed, mostly fused; inner incisor two lobed, mostly fused; prostheca arising at base of inner incisor, with branched, elongate setae projecting towards molar region. Hypopharynx: lingua apically truncate; numerous filiform and acuminate setae present on anterior margin; superlinguae oval, with numerous filiform and acuminate setae along anterior and lateral margins. Maxilla (Fig. 15): palp very short, one segmented, with elongate terminal seta; one or two subapical setae on inner apical margin; cluster of dense filiform setae on outer apical surface. Labium: submentum moderately developed, with regularly spaced acuminate and filiform setae along lateral margins; prementum ventrally with numerous filiform setae; labial palp three segmented with numerous filiform setae; glossae and paraglossae subequal, fused except distally, with slightly serrate outer margins; glossae slightly recessed, rounded, and with robust setae; paraglossae with numerous filiform setae. *Thorax*: Pale reddish brown, with extensive black maculae; pro- and mesonota with extensive black shading medially and along margins; forewing pads of mature larvae pale brown; hind wing pads absent; filiform setae present along lateral margin of thorax. Femora pale with limited black maculation along basal, lateral margin; tibiae pale brown with white band at tibia-tarsus articulation; tarsi pale brown with median white band; claws pale brown. Foreleg (Fig. 16): dorsal surface of femur with median transverse row of filiform and acuminate setae; anterior and posterior margins of femur with diffuse filiform and acuminate setae. Tibia and tarsus: margins with scattered acuminate and filiform setae; tarsal claw (Fig. 17) with single row of 10–12 denticles, similar in shape and size with equal spacing. Mid- and hind legs (Fig. 18): dorsal surfaces of femora with few, scattered filiform and acuminate setae; anterior and posterior margins with numerous filiform and acuminate setae. Tibiae: few, scattered filiform and acuminate setae present along anterior and posterior margins, and dorsal surface. Tarsi: filiform and acuminate setae confined to apical margins. Claws (Fig. 19): with single row of 12–14 denticles, similar in shape and size with equal spacing. *Abdomen*: Without tubercles or elevated carina; terga 1–3 white with black lateral margins; terga 4–6 white with limited black meial maculation and lateral black margins; terga 7–9 black with numerous filiform setae along lateral and posterior margins;



Figs. 12–22. *Tricoryhyphes kirki*, larva. 12, Labrum (left: dorsal; right: ventral). 13, Right mandible. 14, Left mandible. 15, Maxilla. 16, Foreleg. 17, Foreleg claw. 18, Hindleg. 19, Hind leg claw. 20, Operculate gill (dorsal view). 21, Operculate gill (ventral view). 22, Gill 3.

tergum 10 brown. Dorsal lamella of operculate gill (Fig. 20) on abdominal segment 2 triangular with margins rounded; narrow, elongate ridge present near inner margin; basal one-half to two-thirds of gills covered with black maculae; apical margin pale; acuminate and filiform setae present along entire outer margin; ventral lamellae of operculate gill pale translucent (Fig. 21); gill 3 as in figure 22; gill formula: 2/3/3/3/2. Cercus with whorls of elongate and robust setae at each annulation.

Etymology.—This species is named for my son, Kirk, in recognition of his support and assistance.

Discussion and diagnosis.—Only three other species of *Tricorythodes* Ulmer are currently known from Central America, south of Mexico. The common and widely-distributed *T. sordidus* Allen, *T. primus*, n. sp. (see discription below), and *T. costaricanus* (Ulmer), known only from the adult stage. *Tricorythodes kirki* larvae can be differentiated from *T. sordidus* larvae by the lack of elongate filiform setae on the body, which are present on *T. sordidus*. In addition, *T. sordidus* larvae possess abdominal terga which are uniformly pale brown in color, while *T. kirki* larvae have contrasting coloration of the abdominal terga as described above. *Tricorythodes kirki* larvae can be distinguished from larvae of *T. pirmus* by the presence of a distinctive and well-developed frontal shelf and genal projections, which are absent in *T. kirki*. There does remain the possability that *T. kirki* could be the undescribed larval stage of *T. costaricanus*. However, considering the very dark brown coloration of *T. costaricanus* adults, and the very limited dark coloration of mature *T. kirki* larvae, the possability appears remote that the two are indeed the same species.

Distribution and biology.—*Tricorythodes kirki* is known only from Alajuela, Heredia, and San José provinces in north-central Costa Rica. Larvae were collected from a very small, shallow first or second order stream at elevations ranging from 200 to 650 m. Substrate of the steams was composed mostly of rock-rubble with little coarse gravel. Other mayflies collected at these sites included *Tricorythodes sordidus* Allen (Leptohyphidae) and *Camelobaetidius warreni* (Traver and Edmunds) (Baetidae).

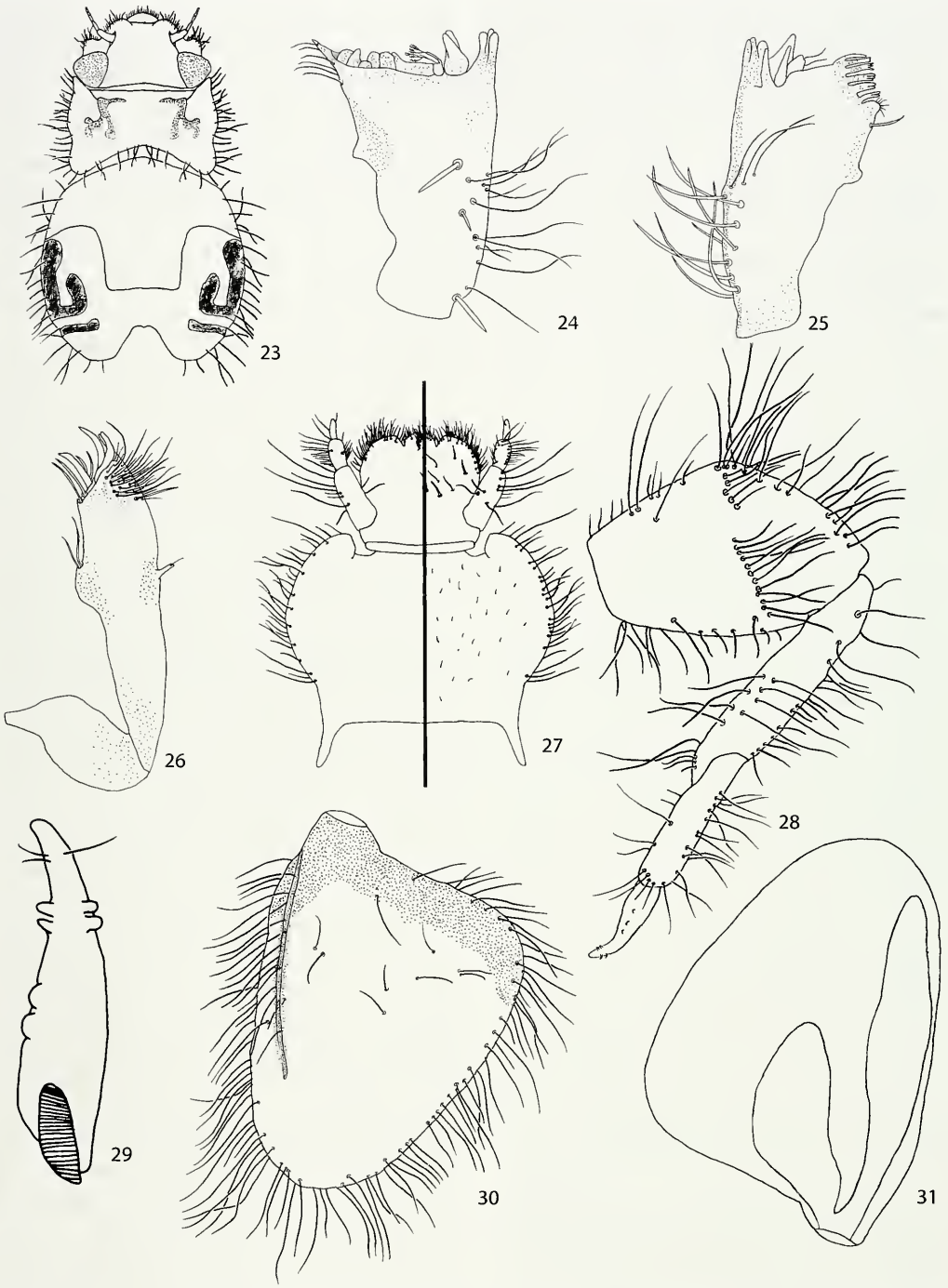
Type material.—Holotype: Mature male larva. COSTA RICA: Alajuela Province, Río Guayabo at Hwy 140, 1.8 km E Venicia (N10°40′45N, W84°15′13″, elev. 460 m), 09.vi.2001, DE Baumgardner (DB 01-25). Deposited at TAMU. Paratypes: Same data as holotype, 5 larvae (3♂, 2♀), 2 slides (DB05012801, DB05xi2208) (4 larvae and slides TAMU, 1 larva FAMU). COSTA RICA: Heredia Province, unnamed creek at Hwy. 4, ca. 3 Km from jct. with Hwy. 32 (N10°15′10″, W83°55′11″; elev. 200 m) 10.vi.2001, DEB (DB 01-28), 2♀ larvae (TAMU); La Selva Biological Station, SW Puerto Viejo, Sura Creek at Rio Puerto Viejo (N10°25′49″; W84°00′06″, elev. 33 m), 09.vi.2001, 8L, DEB (DB 01-26), 8L (5L TAMU, 3L FAMU); Río Isla Grande at Hwy. 4, ca. 5 Km. W. of Rio Frio (N10°23′31″; W 83°58′04″, elev. 65 m), 10.vi.2001, DEB (DB 01-27), 1L (PERC). San José Province; Río Pedregoso at Hwy. 243, ca. 4 Km S. San Isidro de El General (N09° 21′15 W83°43′35″, elev. 660 m), 22.vi. 2001, DEB (DB 01-47), 12L [TAMU].

Tricorythodes primus Baumgardner, new species

(Figs. 23–31)

Adult.—Unknown.

Mature larva.—Body length 3.0–3.5 mm; caudal filaments 3.0 mm. General color yellow with black maculae on thorax and abdomen. *Head*: (Fig. 23) yellow without black maculae; large



Figs. 23–31. *Tricoyrhyphes primus*, larva. Fig. 23, Head and pro- and mesothorax (dorsal view). Fig. 24, Right mandible. Fig. 25, Left mandible. Fig. 26, Maxilla. Fig. 27, Labium (left: dorsal; right: ventral). Fig. 28, Foreleg. Fig. 29, Foreleg claw. Fig. 30, Operculate gill. Fig. 31, Operculate gill (ventral view).

genal and frontoclypeal projections present; tubercles absent; compound eyes small and widely separated; three ocelli present; margins of head with filiform setae; antenna pale, approximately as long as head capsule. *Mouthparts*: Labrum: dorsally with filiform setae along lateral margin; acuminate setae recessed from anterior margin; ventrally with one longitudinal row of acuminate setae near midline, with interspersed filiform setae; anterior margin with filiform setae. Right mandible (Fig. 24): outer incisor three lobed; inner incisor two lobed; prostheca and molar region as in Fig. 17; numerous and very long, thick setae present along outer margin of mandible. Left mandible (Fig. 25): outer incisor four lobed, mostly fused; inner incisor two lobed; prostheca arising at base of inner incisor, with filiform setae projecting towards molar region; numerous and very long, thick setae present along outer margin of mandible. Hypopharynx: lingua apically truncate; numerous filiform and acuminate setae present on anterior margin; superlinguae oval, with numerous filiform and acuminate setae along anterior and lateral margins. Maxilla (Fig. 26): palp one segmented, with terminal seta; two subapical setae on inner apical margin; cluster of filiform setae on outer apical surface. Labium (Fig. 27): submentum moderately developed, with regularly spaced acuminate and filiform setae along lateral margins; ventrally with numerous robust setae; prementum ventrally with numerous acuminate setae; labial palp three segmented with numerous filiform setae; glossae and paraglossae subequal, fused except distally, with slightly serrated margin; glossae serrated with robust setae along margin; paraglossae with numerous filiform and acuminate setae. *Thorax*: (Fig. 23) yellow with extensive black maculae; pronotum with a pair of black inverted "L" shaped markings lateral to midline, and pair of distinctive, sharp projections on anterior lateral margin (Fig. 23); lateral margins with scattered acuminate setae; mesonotum (Fig. 23) yellow with extensive and irregular black maculation, and scattered acuminate setae along lateral margins. Legs: all segments of all legs pale yellow. Foreleg (Fig. 28): dorsal surface of femur with a transverse row of numerous filiform setae; anterior and posterior margins with numerous acuminate and filiform setae. Tibia and tarsus: anterior and posterior margins with numerous acuminate and filiform setae. Claw (Fig. 29): with two or three, minute marginal denticles, and two pair of submarginal denticles. Mid- and hind legs: dorsal surfaces of femora with numerous, irregularly spaced filiform and acuminate setae; anterior and posterior margins with numerous acuminate and filiform setae. Tibiae: filiform setae present along anterior and posterior margins. Tarsi: margins with numerous filiform setae. Claws: with two minute denticles and two pair of submarginal denticles. *Abdomen*: Pale yellow with dorsal and ventral transverse black bands on segments 1–9; posterior margins of terga 1–9 with numerous filiform setae; lateral margins of segments 2–7 expanded outward with filiform setae present along margin. Dorsal lamella of operculate gill (Fig. 30) on abdominal segment two triangular, pale yellow with basal black band at base, and very sparse black maculae over dorsal surface; filiform setae present along entire margin; ventral lamellae of operculate gill pale translucent (Fig. 31); gill formula: 1/3/3/3/2. Cercus with whorls of elongate and robust setae at each annulation.

Etymology.—The specific epithet of this species is a noun from the Latin word *primus* (m), meaning first or original. It refers to the first description of a species of *Tricorythodes* from Central America which possesses a distinctive and well-developed frontal shelf and genal projections.

Discussion and diagnosis.—*Tricorythodes primus* is most similar to *T. condylus* Allen from southwestern United States, and *T. popyanicus* Dominguez from Central America. *Tricorythodes primus* can be distinguished from *T. condylus* by its much smaller size (3.0–3.5 mm for *T. primus* versus 5.0–6.0 mm for *T. condylus*) and more extensive black maculation of the thorax and abdomen. It can be distinguished from *T. popyanicus* by the presence of well-developed antero-lateral projections of the pronotum, which are very weakly developed on *T. popyanicus*. In addition, *T. popyanicus* is known only from southern South America while *T. primus* is known only from Central America.

Tricorythodes popyanicus and *T. condylus* (along with three other species) were recently transferred to the genus *Tricoryhyphes* (Wiersema and McCafferty 2000), which was originally described by Allen and Murvosh (1987) as a subgenus of *Tricorythodes*, and elevated to generic status by Wiersema and McCafferty (2000). Molineri (2002) clearly showed *Tricoryhyphes* to be synonymous with *Tricorythodes*, synonymizing the latter with the former. Unpublished data by D.E. Baumgardner also supports the conclusions of Molineri (2002).

Distribution and biology.—*Tricorythodes primus* was collected from clear flowing streams which were several meters wide, shallow, and with substrate varying from sand to boulders. These low elevation costal streams are located in the extreme southeastern region of the country, near the Panamá border . Other species of mayflies collected with *T. primus* included *Thraulodes brunneus* Koss, *Thraulodes* spp. (Leptophlebiidae), *Leptohyphes zalope* Traver, *Tricorythodes sordidus* Allen, and *Vacupernius packeri* (Allen) (Leptohyphidae).

Type material.—Holotype: Mature larva. COSTA RICA: Puntarenas Province; Río Caracol at CA Hwy. 2, ca. 7.3 Km E. Río Claro (N08°39′47″, W83°00′41″, elev. 80 feet), 23.vi.2001, DE Baumgardner (DB 01-55). Deposited in TAMU. Paratypes: COSTA RICA: Puntarenas: Río Coloradito at CA Hwy. 2, ca. 6.7 Km SE Ciudad Neily (N08°36′09″, W82°52′02″, elev. 180 feet), 23.vi.2001, DE Baumgardner (DB 01-56), 1 larva (legs and mouthparts mounted on slide #05xi2006), slide and specimen deposited in TAMU.

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