Stygifloris, a New Genus of Mayflies (Ephemeroptera: Potamanthidae) from Southeast Asia

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ABSTRACT A new genus and species, *Stygifloris sabahensis* Bae, McCafferty & Edmunds, is described from Sabah, East Malaysia. The description of this unusual potamanthid mayfly is based on well over 100 larval specimens as well as representatives of male and female adults. *Stygifloris* is distinguished in the larval stage by a combination of moderately short tusks, a unique tuft of setae near the apex of the foretibia, generally poorly developed mouthpart setation, and modified labial palpi. It demonstrates relationships with other Southeast Asian genera, particularly *Rhoenanthus* and *Potamanthodes*. Faunal affinities at the type locality are discussed.

KEY WORDS Insecta, taxonomy, new genus and species, *Stygifloris sabahensis*

POTAMANTHIDAE IS ONE of six currently recognized families in the mayfly superfamily Ephemeroidea (McCafferty & Edmunds 1979), the so-called burrowing mayflies. McCafferty (1979) showed it to be the most ancestral of the families with tusked larvae, being characterized by larvae with flattened bodies and plesiomorphic internal anatomy. The family is clearly a distinctive, monophyletic group. Generic and specific limits within the family, however, have not been adequately established; Y.J.B. and W.P.M. are currently revising the family.

The family is distributed in the Holarctic and Oriental Regions and is most diverse in eastern Asia. The mayfly fauna of Southeast Asia still remains relatively poorly known, and only a few works have dealt with the Potamanthidae of the region, specifically those of Eaton (1883–1888, 1892), Ulmer (1920, 1924, 1925, 1939), Navas (1922), and Lestage (1930). Five species of Potamanthidae are currently known from Southeast Asia: *Potamanthindus auratus* Lestage, *Potamanthodes formosus* (Eaton), *Rhoenanthopsis magnificus* (Ulmer), *Rhoenanthus speciosus* Eaton, and *Rhoenanthus vitalisi* Navas.

The validity of some of the genera indicated above has yet to be resolved but is suspect because of weak or doubtful demarcation. A highly distinctive new genus from Southeast Asia, however, is described herein and is based on a large series from Sabah collected by G.F.E., C. H. Edmunds, W. L. Peters, J. G. Peters, and W. M. Beck, Jr. during an expedition in 1972. The new genus and *R. speciosus*, which also was collected at that time, represent the first potamanthids known from East Malaysia, although *R. speciosus* had been previously reported from Borneo by Ulmer (1939).

Depositories of the material examined are as follows: FAMU, Florida A&M University, Tallahassee; NMNH, National Museum of Natural History, Washington, D.C.; PERC, Purdue Entomological Research Collection, West Lafayette, Ind.; UU, University of Utah, Salt Lake City.

Genus *Stygifloris* Bae, McCafferty & Edmunds, new genus (Fig. 1–9)

Mature Larva. *Head.* Clypeus (Fig. 1) with simple-stout and simple-hairlike setae on dorsal surface; anterior margin convex. Mandibular tusks (Fig. 1 and 8) moderately short, 0.3 times length of head, slightly curved inward (8–10°); basal, nonconstricted portion of tusks with 60–80 simple-stout setae evenly distributed on dorsal surface and lateral margin, mixed with 10–15 bipectinate-hairlike setae (setules on bipectinate-hairlike setae poorly developed); apical, narrower portion of tusks 0.9 times length of basal portion, either bare or with only few simple-stout setae. Maxillae (Fig. 8) with bipectinate-hairlike setae on apical ¾ of galealacinial crown (setules on bipectinate-hairlike setae well developed); terminal segment of maxillary palpi 1.3–1.4 times length of segment 2, with bipectinate-hairlike setae on apical half and inner margin. Hypopharynx moderately expanded laterally, with dense bipectinate-hairlike setae on inner margin of superlinguae. Paraglossae (Fig. 8) not greatly expanded laterally, with bipectinate-hairlike setae

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on apical and lateral margins but without setae on ventral surface; glossae with dense bipectinate-hairlike setae over entire surface; terminal segment of labial palpi (Fig. 9) 1.2 times length of segment 2, with poorly developed bipectinate-hairlike setae; inner margin of terminal segment greatly expanded, with 2–3 rows of 10–15 simple-stout setae. *Thorax*. Pronotum (Fig. 1) expanded laterally, anterolateral projection rudimentary to absent. Forefemora (Fig. 2) dorsally with 10–15 simple-stout setae forming transverse row at midlength, with few simple-hairlike or bipectinate-hairlike setae interspersed in row. Foretibiae (Fig. 2) subequal to forefemora in length, 2.2 times length of foretarsi; poorly developed bipectinate-hairlike setae irregularly distributed on inner margin (setules on bipectinate-hairlike setae poorly developed); terminal region without apical spine, with subapical ventral tuft of 30–40 fine, hairlike setae forming short row (Fig. 3). *Abdomen*. Terga 1–10 with slightly darker, broad, longitudinal stripe containing 2 pairs of light spots on each tergum. Gills 1 single, rudimentary, 2-segmented; gills 2–7 well developed, bilobed, and marginally fibrillate. Caudal filaments 0.6 × length of body, without transverse bands or markings.

Adult. *Size*. Male body length 12.0 mm; forewings 11.0 mm long, 4.6 mm wide; hindwings 3.5 mm long, 2.0 mm wide; cerci 21.5 mm; median terminal filament 0.5 mm, 0.02 times length of cerci. Female body length 11.5–13.5 mm; forewings 14.0–14.5 mm long, 5.5–6.0 mm wide; hindwings 4.0–4.5 mm long, 2.5–3.0 mm wide; cerci 16.0–17.0 mm; median terminal filament 13.0–14.0 mm, 0.80–0.85 times length of cerci. *Head*. Compound eyes of male (Fig. 4) large (1.1 mm diameter) and narrowly developed downward as seen in facial view; dorsal distance between compound eyes 0.02 times diameter of compound eye. Compound eyes of female small (0.40–0.45 mm diameter), developed as in male; dorsal distance between compound eyes twice as long as diameter of compound eye. *Thorax*. Pronotum width 3.6 times length. Forewings (Fig. 5) with MA shorter than MA_1 ($MA/MA_1 = 0.85$); MP_2 originating at base of CuA; 2–3 cubital intercalaries present, with at least 1 forked; A_1 symmetrically forked. Hindwings (Fig. 6) with costal projection somewhat rounded and subacute (93° angle as measured between short, nearly vertical base and long horizontal line of costa); base of R_1 moderately arched toward SC (140° as measured between short diagonal base and long horizontal line of R_1); Rs slightly longer than, or subequal to, R_2 ($Rs/R_2 = 1.1–1.0$); MP 0.4 times length of MP_1; MP_2 complete, not broken at base. Foretibiae of male 1.8 times length of forefemora, subequal to foretarsi; tarsal segment 2 subequal to segment 3. Foretibiae of female subequal to forefemora, 2 times length of foretarsi. *Abdomen*. Terga each with U-shaped, dark marking extending across segment. Male genitalia (Fig. 7) with terminal margin of subgenital plate nearly straight; genital forceps with 3 visible segments; segment 3 of genital forceps subequal to segment 2, together 0.5 times length of basal segment; penes elongate, broadly convex laterally, somewhat flattened, with rounded apices as in Fig. 7. Female subgenital plate convex.

Etymology. The genus name *Stygifloris* is Latin, masculine, from Stygis (the River Styx, a river in the nether world), and floris (blossom). The allusion to a "river flower" is analogous to other generic names in Potamanthidae, which also denote river flowers.

Type Species. *Stygifloris sabahensis*, n. sp.

Species Included. *Stygifloris sabahensis*, n. sp.

Distribution. Southeast Asia: East Malaysia (Sabah).

Remarks. The ventral tuft of fine setae near the apices of the foretibiae (Fig. 3) will distinguish the larvae of *Stygifloris* from all other potamanthid larvae. With regard to Asian potamanthids, the mature larvae of *Stygifloris* also can be distinguished from those of *Potamanthodes* by the expanded terminal segment of the labial palp (Fig. 9), the presence of short setae on the clypeal margin (Fig. 1), and its slightly longer mandibular tusks (Fig. 1). They can be distinguished from *Rhoenanthus* and *Rhoenanthopsis* by the much shorter mandibular tusks (Fig. 1); paraglossae that are not expanded (Fig. 8); and only poorly developed, long setae along the inner margin of the foretibiae (Fig. 2).

The adults of *Stygifloris* may be distinguished from those of *Potamanthodes* by their large, nearly contiguous compound eyes (Fig. 4); rudimentary median terminal filament; and weakly arched R_1 in the hindwing (Fig. 6). They may be distinguished from other potamanthids by forewing vein MP_2, which originates from CuA (Fig. 5). Additionally, they may be distinguished from *Rhoenanthus* and *Rhoenanthopsis* by a complete (unbroken) MP_2 in their hindwing (Fig. 6) and their pale yellow bodies (versus the reddish brown bodies of the others). Measurements of the adults of *Stygifloris*, although presented in the generic description, were based on a limited number of individuals and could prove to be more variable if additional species or specimens eventually are found.

The larvae and adults upon which the genus is based were not associated by rearing; however, there can be little if any doubt that they represent the same species. The strong association of the life stages is based on exact similarities in color patterns and, in particular, the fact that developing forewings of the larvae have the same three-spotted pattern found in the adults (Fig. 5). This is a pattern not known among any other potamanthids.

The exact relationships of *Stygifloris* with other genera have yet to be resolved and will be considered more fully in conjunction with the revisionary study of the family. There appears to be a fairly strong relationship with *Rhoenanthus* and somewhat more distant relationship with *Potaman-*

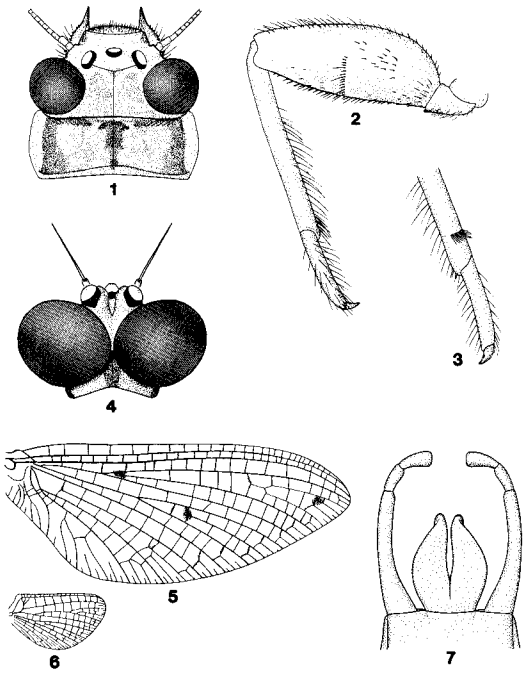

Fig. 1–7. *S. sabahensis.* (1) Dorsal view of larval head and pronotum. (2) Dorsal view of larval foreleg. (3) Ventral view of larval foretibia. (4) Dorsal view of male adult head. (5) Forewing. (6) Hindwing. (7) Ventral view of male genitalia.

thodes. We suggest that the presence of clypeal setae and an expanded terminal segment of the labial palps in the larva, as well as the highly reduced median terminal filament and somewhat rounded penes tips in the male adult, represent synapomorphies in *Stygifloris* and *Rhoenanthus*.

Stygifloris sabahensis Bae, McCafferty & Edmunds, new species (Fig. 1–9)

Mature Larva. *Size.* Body length 11.0–13.0 mm; antennae 4.35–4.40 mm; mandibular tusks 0.35–0.40 mm; caudal filaments 6.0–7.0 mm. *Head.* Vertex (Fig. 1) without consistent or well-defined markings, sometimes central area lighter. Compound eyes black; dorsal diameter of male compound eyes 0.7–0.8 mm; dorsal diameter of female compound eyes 0.4–0.5 mm. Antennae relatively long, 3.3 times length of head, without setae on the surface. *Thorax.* Ground color generally pale brown; markings of nota not consistent or well defined, sometimes with light submedian C-shaped markings in medioposterior region of pronotum. Forewing pads with 3 dark spots arranged in broad triangle (see adult Fig. 4). Legs without clearly defined stripes or markings; coxal projections developed and pointed. Forefemora with simple-stout setae along anterior and posterior margins; relatively short and sparse simple hairlike setae distributed irregularly on dorsal surface (Fig. 2). Hindtibiae with stout-pinnate setae on basal ¾ of inner margin. *Abdomen.* Ground color generally brown or pale brown; markings of terga often not well defined; some individuals with terga 1–10 with slightly darker, broad, longitudinal stripe and each tergum with 2 pairs of small, light spots within stripe; some individuals with terga 2–9 each with dark, narrow, U-shaped marking extending throughout tergum. Gills 2–7 light brown, with lobes somewhat irregularly twisted; fibrillae straight or curved, numbering 10–15 along lateral margins of dorsal lobes and 15–20 along lateral margins of ventral lobes.

Male Adult. *Size.* Body length 12.0 mm; dorsal diameter of compound eyes 1.08 mm; forewing length 10.8 mm, width 4.6 mm; hindwing length 3.5 mm, width 2.0 mm; forelegs 9.8 mm; genital forceps 0.90 mm; cerci 21.5 mm; median terminal filament 0.5 mm. *Head.* Compound eyes (Fig. 4) large, nearly contiguous, gray in alcohol (ventrally darker gray than rest of eyes). Antennae slightly shorter than diameter of compound eye. *Thorax.* Thorax pale yellow with dark brown stripes extending from pronotum to mesopleura and with dark brown median stripe from pronotum to mesonotum. Forewings (Fig. 5) with 3 triangularly arranged, dark spots (one near Rs fork, one near apices of wing, one at base of IMA); crossveins slightly infuscated, numbering 21 between SC and R_1 and 11 between R_1 and R_2 (counts are from 1 male specimen; female forewing is figured). Hindwings (Fig. 6) without maculations or infuscated venation. Forelegs pale yellow, except claws, tarsal segment 5 and apex of tibia dark brown. Midlegs and hindlegs white. *Abdomen.* Terga 1–10 pale yellow with dark, broad, longitudinal, median stripe divided longitudinally by light pinstripe; each tergum with 2 pairs of small light spots arranged within broad median stripe and with narrow U-shaped dark marking encompassing most of tergum. Sterna of abdomen pale yellow, without markings. Genitalia (Fig. 7) white; segment 3 of genital forceps truncated terminally, slightly longer than segment 2 (1.11 times segment 2) and 0.25 times length of basal segment; penes basally fused for ¼ of length visible beyond subgenital plate, subparallel beyond fusion but slightly divergent at tips. Cerci white in basal half, darker in apical half, without bands.

Female Adult. *Size.* Body length 13.0 mm; dorsal diameter of compound eyes 0.43 mm; forewing length 14.3 mm, width 5.7 mm; hindwing length 4.5 mm, width 2.5 mm; forelegs 4.5 mm; cerci 16.3 mm; median terminal filament 13.3 mm. *Head.* Compound eyes small, black or gray in alcohol, widely separated. *Thorax.* Body, wing, and leg color patterns generally similar to male. Forewings (Fig. 5) with 25–27 crossveins between SC and R_1 and 14–16 crossveins between R_1 and R_2. Foretibiae 1.07 times length of forefemora, 2.10 times length

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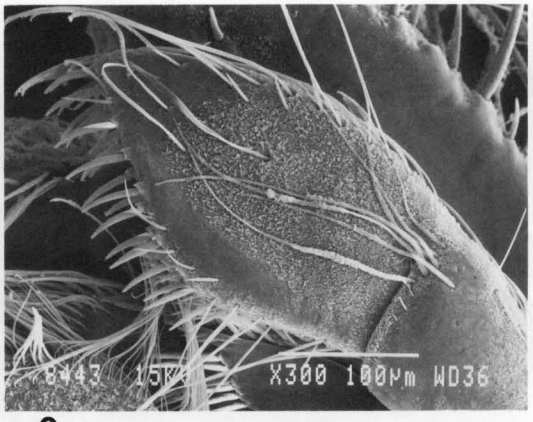

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Fig. 8 and 9. *S. sabahensis* larva (SEM's). (8) Mouthparts, ventral view. (9) Terminal segment of left labial palpus, ventral view.

of foretarsi. *Abdomen*. Color pattern similar to that of male. Caudal filaments white in basal half, darker in apical half, with dark band at every 2–4 joints. Median terminal filament well developed, 0.80–0.85 times length of cerci.

Etymology. The trivial name *sabahensis* is a geographic reference to the type locality.

Type Material. HOLOTYPE: Mature ♂ larva (in alcohol), Liwagu River, Liwagu Cave, SE of Kinabalu National Park Headquarters, Sabah, East Malaysia, 1,525 m, 14–15-VIII-1972, G.F. & C.H. Edmunds (UU). PARATYPES (in alcohol): 11 mature ♂ larvae, 16 mature ♀ larvae, 5 ♀♀, same data as holotype (2 ♂ larvae, 3 ♀ larvae, 1 ♀ [UU]; 2 ♂ larvae, 3 ♀ larvae, 1 ♀♀ [FAMU]; 6 ♂ larvae, 9 ♀ larvae, 2 ♀♀ [PERC]; 1 ♂ larva, 1 ♀ larva, 1 ♀ [NMNH]). 1 ♂ adult, Liwagu River, N of Kundassan, 915 m, 16–17-VIII-1972 [UU].

Other Material Examined. EAST MALAYSIA: 4 ♀♀, 4 ♂ subimagos, 150 larvae, same data as holotype (UU, FAMU, PERC). 1 ♀ subimago, 16 larvae, Liwagu River, N of Kundassan, 915 m, 16–17-VIII-1972 (UU). 1 ♀, Liwagu River at bridge, Ranau, 335 m, 11–16-VIII-1972 (UU). 1 ♀ adult, Paring, Ranau, 8–11-X-1958, T. Maa (UU).

Discussion. The type locality of *S. sabahensis* is the Liwagu River at Liwagu Caves, a clear stream in the lower montane forest on Mt. Kinabalu in Sabah (see Pendlebury & Chasen 1932, Holloway 1970). The river at this point is 5–7 m wide and <1 m deep, with a mixed rocky substrate ranging from sand to boulders more than 2 m in diameter. The microhabitat of larval *S. sabahensis* was not determined at the time it was collected.

Elevation at the type locality is 1,525 m. Mt. Kinabalu is the highest mountain in Southeast Asia (4,101 m) and is of relatively recent origin. With increasing elevation, the diversity of biota declines and is increasingly Himalayan in character, almost certainly as a result of long-distance dispersal during the Pleistocene (Holloway 1970). At the Liwagu Caves area, the biota shows primarily Sunda relationships but has some Himalayan elements.

The mayfly diversity at the type locality is poor. Larvae of only four other mayfly species were taken together with *S. sabahensis*. In addition to *R. speciosus*, they included a large species resembling some members of the genus *Baetis* (Baetidae), as well as a large *Epeorus* species and a species near *Ecdyonurus* (Heptageniidae). Most of these mayflies are apparently of Sunda affinity but are able to tolerate the cooler temperatures at this elevation. The *Epeorus* sp., however, may represent a Himalayan affinity.

The diversity of mayflies in the Liwagu River increases rapidly downstream, with perhaps 30 species at Ranau (1,000 m). Only *Stygifloris* adults were taken at this lower elevation. Other orders of aquatic insects also were more diverse at lower elevations, and at Poring Springs, aquatic cockroaches and aquatic earwigs were encountered.

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