

New species of the family Heptageniidae (Ephemeroptera) from Borneo and the Philippines

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Abstract

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Afronurus webbi sp. n. (♂), *A. sarawakensis* sp. n. (♂) and *Epeorus boonsoongi* sp. n. (larva) are described, and details and new records are provided for *Atopopus tarsalis* (♂, larvae), *Atopopus* sp. A and *Thalerosphyrus* sp. A (♀) from Borneo (East Malaysia). *Afronurus freitagi* sp. n. (♂-La), *A. lantuyanensis* sp. n. (♂), *A. leytenensis* sp. n. (♂), *A. mindanaoensis* sp. n. (♂) and *A. panayensis* sp. n. (♂) are described from the Philippines. *Afronurus philippinensis* Flowers & Pescador, 1984, *A. sibuyanensis* Mol, 1987 are reported from new localities and *Asionurus* sp. A for the first time from the Philippines. The taxonomic position of several controversial species like *Ecdyonurus illotus* Navás, 1933, *Epeorella borneonia* Ulmer, 1939, *Thalerosphyrus torridus* (Walker, 1853), *T. sumatranus* (Ulmer, 1939) and some zoogeographic viewpoints are discussed. *Compsoeuria* (*Palawaneuria*) *cabayuganensis* Braasch & Freitag, 2008 is considered as species incertae sedis.

Introduction

Data on Heptageniidae in Borneo (Kalimantan) are found in the literature only sparsely. Ulmer (1939) recorded the genera *Atopopus* Eaton, 1881, *Compsoeuria* Ulmer, 1939 (= *Compsoeuria* Eaton, 1881), *Epeorella* Ulmer, 1939 and *Heptagenia* Walsh, 1863 in his Great Sunda Islands study. Edmunds & Polhemus (1990) recorded *Epeorus* Eaton, 1881 in Borneo. Recently, Sartori et al. (2003) published on the genera *Asionurus* Braasch & Soldán, 1986, *Cinygmina* Kimmins, 1937, *Notacanthurus* Tshernova, 1974 and *Trichogenia* Braasch & Soldán, 1988 from Eastern Borneo. Wang & McCafferty (2004) mentioned a male specimen belonging to *Thalerosphyrus determinatus* (Walker, 1853).

Publications on Borneonian Heptageniidae (Wang & McCafferty 2004; Braasch 2005; Webb et al. 2006; Webb & McCafferty 2007) include a couple of *Afronurus* Lestage, 1924 from the Sultanate Brunei Darussalam, located between East Malaysian Sarawak and

Sabah in Borneo Island, a new record of *C. thienemanni* from Sabah near Kota Kinabalu, and the new monotypic genus *Darthus* Webb & McCafferty, 2007 from East Kalimantan. Finally, Sartori et al. (2007) described the larva of *Atopopus tarsalis* Eaton, 1881 so far unknown from East Borneo.

The list of Borneonian Heptageniidae species contains *Afronurus bruneiensis* Braasch, 2005, *A. temburongensis* Braasch, 2005, *Atopopus tarsalis*, *A. edmundsi* Wang & McCafferty, 1995, *Compsoeuria thienemanni*, *Darthus vadorus* Webb & McCafferty, 2007, *Epeorella borneonia* Ulmer, 1939, *Thalerosphyrus determinatus*, *Trichogenia nasuta* (Ulmer, 1939), *T. ulmeri* Braasch & Webb, 2006 (in: Webb et al. 2006, possibly = *Trichogenia nasuta*) and *T. hubleyi* Webb & McCafferty, 2006 (in Webb et al. 2006).

Specimens of *Asionurus* sp. from Borneo (Sartori et al. 2003) could belong to *Asionurus ulmeri* Braasch & Soldán, 1986(a). *Cinygmina* sp., described from Sumatra is suggested to be replaced by *Afronurus* in Borneo (Sartori et al. 2003). *Notacanthurus* species is for a

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fact the recently described *Darthus vadorus* Webb & McCafferty, 2007. Wang & McCafferty (2004) affiliated *Epeorella borneonia* to genus *Epeorus*, what seems to be questionable.

A brief survey on the Heptageniidae of the Philippines is given by Hubbard & Pescador (1978), listing *Afronurus lobatus* Ulmer, 1924 from Mindanao, *Atopopus tibialis* Ulmer, 1920 from Luzon, Panaon and Samar (Ulmer 1924), *Ecdyonurus illotus* Navás, 1933 from Luzon (Haightplace) and *Thalerosphyrus torridus* (Walker, 1853) without further details. Ulmer (1924) gave notice of *Thalerosphyrus torridus* from Luzon. Recent descriptions (*Afronurus philippinensis* Flowers & Pescador, 1984 [Luzon], *Afronurus sibuyanensis* Mol, 1987 [Sibuyan], *Afronurus mindoroensis* Braasch, 2005 [Mindoro], *Atopopus meyi* Braasch, 2005 [Leyte, Mindanao], *Afronurus palawanensis* Braasch & Freitag, 2008, *Afronurus zerningi* Braasch & Freitag, 2008, *Compsoeuria (C.) tagbanua* Braasch & Freitag, 2008, *C. (Palawaneuria) cabayuganensis* Braasch & Freitag, 2008 [Palawan]) have raised the number of known Heptageniidae species in the Philippines up to 12. The presence of *Thalerosphyrus* Eaton, 1881 in the Philippines, based on female representatives, is unclear, because confusion with *Afronurus* female is very likely. Wang & McCafferty (1995) delivered a detailed study of imago and larvae of the genus *Atopopus*, recording *Atopopus tibialis* Ulmer, 1920 from the large island of Luzon: Camarines Sur near Mt. Isarog. Later, Wang & McCafferty (2004) recorded one larva each of *Ecdyonurus* Eaton, 1868 and *Thalerosphyrus* from the Philippines, what will be discussed below.

In the past the colonization of the Philippines must have started by Heptageniids from Borneo (Edmunds & Polhemus 1990; Wang & McCafferty 1995). The island is apparently a distribution center of *Afronurus* (Sartori et al. 2003; Braasch 2005). The only *Afronurus* species from Java and Sumatra is *A. javanicus* Ulmer, 1939. Furthermore, Braasch (2005) described *Afronurus malaysianus* from the adjacent peninsular Malaysia, the southernmost mainland of South-East Asia.

The present distribution insight of Heptageniidae in the Philippines can be understood as result of species dispersal and subsequent diversification as observed and interpreted within *Hydropsyche* (Trichoptera) by Mey (2003). Whether some continental taxa were able to reach or not the Philippines in addition to the well-known *Afronurus* and *Atopopus* species is questionable and will be discussed in the following chapter.

Material and methods

Material. The material was collected during several expeditions to Sabah and Sarawak in Borneo by W. Mey and Ebert 2003, 2005 and 2006. Most specimens were caught at light, a few by benthic samples. Larvae of *Atopopus* spp. from Sabah have been provided by H. Freitag.

The Philippine material was collected by W. Mey and Ebert 1995 and 1999, 1997, 1999 and 2000, by Mey and W. Speidel 1997 and

1998, by Mey and V. Samarita 1998 and by Mey, Ebert and M. Nuß 1997. Freitag and M. Zerning completed the material with small collections from Luzon, made in 2005.

J. M. Webb (pers. comm.) has supplied several records of *Epeorus boonsoongi* and an indication of a further unnamed *Epeorus* larva from Borneo.

Terminology. Except for the subgenera within *Epeorus*, the taxonomic terms follow the standard works on genera of Heptageniidae in Webb & McCafferty (2008), Kluge (2004) and Wang & McCafferty (2004). Genus *Cinygmmina* is called here *Cinygmmina (Afronurus)*. *Thalerosphyrus* is regarded as an independent genus excluding *Compsoeuria* Eaton, 1881 (Webb et al. 2006). Nomina of older taxa are found in Hubbard (1990).

Genital and larval preparations. The last male segment resp. tergum was cut off with a fine scalpel for showing the genital segment ventrally and the penis dorsally. The penis was pulled out with care by means of a curved needle and transferred into glycerin, what allows to keep the object in natural condition and save its immobility for drawing.

Wings, legs and caudal filaments were treated likewise for detailed study.

Larvae were prepared by cutting off parts as head (mouthparts), pronotum, abdomen and legs with a scalpel. First, third and seventh gill lamella and their tufts were removed by a fine, curved needle. Microscopic examination of parts of larvae were done by mounting them on slides.

All described material was preserved in 70–80% alcohol and was stored in appropriate vials. Exceptionally, specimens collected and determined by J. M. Webb were fixed in Kahle's Fluid, or in single cases kept in ethanol.

Abbreviations. ♂ – male; ♀ – female; **La** – larva; **La** – Larva, type; **SI** – Subimago; **alt.** – altitude; **asl, a.s.l.** – above sea level; **Brdg** – Bridge; **comm.** – communication; **CPOM** – coarse particulate organic matter; **F.C.** – Field Center; **Gg** – Gunung (mountain or hill); **HR** – Head ratio [head width : head length]; **Isl.** – Island; **Kpg** – kampung = (bahasa “village”); **LR** – Leg ratio in males [Femur : tibia : tarsus (tarsal segments I : II : III : IV : V) in mm]; **Mt.or Mts** – Mountain(s); **NP** – National Park; **pers.** = personal; **S.g. or S.G.** – Sungai (river); **riv.** – river; **trib.** – tributary.

Depositories. **ANIC** – Australian National Insect Collection, Canberra; **DBP** – Collection Dietrich Braasch, Potsdam, Germany; **MFN** – Museum für Naturkunde, formerly Zoological Museum Berlin; **MZB** – Museum Zoologi Bogor, Indonesia; **MZL** – Musée de Zoologie, Lausanne, Switzerland; **ROM** – Royal Ontario Museum, Toronto, Canada; **WPU** – Western Philippines University, Aquatic and Marine Biology Section, Puerto Princesa, City, Philippines.; **ZMKU** – Zoological Museum, Kasetsart University, Bangkok, Thailand.

Results

Afronurus webbi sp. n.

Figures 1–3

Holotype ♂. Malaysia, Borneo, Sabah, Kinabalu Mountains, Liwagu River trail, 10.–13.08.2005, leg. W. Mey and Ebert (MFN).

Paratype 1 ♂. Same data as holotype (MFN).

Etymology. The name is given in honour of Dr. J. M. Webb (USA, presently Australia), who carried out important studies on Borneonian Heptageniidae.

Male. Body length 9.8 mm, length of forewing 10.2 mm; length of hind wing 2.64 mm; length of caudal filaments 25.0 mm.

Head. With compound eyes contiguous, dark blue-grey with darker ring basally.

Thorax. Yellowish, a distinct brown patch above femur attachment. Wings transparent; in forewing C, Sc and R yellow-brown, other veins weakly yellowish shaded; first strong cross vein black-brown, pterostigmatic field milky. Legs tawny; foreleg with femur reddish-brown and tibia darkened proximally; tarsus beige; LR in foreleg 2.76 : 3.34 : 0.81 (0.11 : 0.26 : 0.22 : 0.13 : 0.07); in hind leg 3.45 : 2.42 : 0.85 (0.22 : 0.18 : 0.13 : 0.06 : 0.29).

Abdomen. Terga with pattern as in Fig. 1; last four terga with slightly yellowish tinge; sterna light, without markings.

Genitalia. Penis: length 0.20, basal width 0.22 (Figs 2–3) composed of a plain double pyramidal structure; sockets of forcipes strongly elevated, with finger-like processus inside; length of segments of gonostyles: I = 0.066, II = 0.440, III = 0.110, IV = 0.088 mm.

Caudal filaments in basal half greyish, distal half slightly brown, segments behind articulations darker brown ringed narrowly.

Female, subimagos and larva. Unknown.

Differential diagnosis. The distantly erected, lowly set pyramidal lobes of penis (Fig. 2) is the specific character of *Afronurus webbi* sp. n. It differs further from all other known species from Borneo and the Philippines by its striking pattern of terga (Fig. 1). In *Afronurus mindoroensis* (Braasch 2005: 168, figs 7–8) or *A. malaysianus* (Braasch 2005: 169, figs 11–12), the narrowly standing penis lobes are directed inwards.

Afronurus sarawakensis sp. n.

Figures 4–6

Holotype ♂. Malaysia, Borneo, Sarawak, Gg. Gading NP, 23.–26.X.2003, at light, leg. W. Mey (MFN).

Paratype 1 ♂. Same label as holotype (MFN).

Etymology. The species name is derived from its native country Sarawak in Borneo.

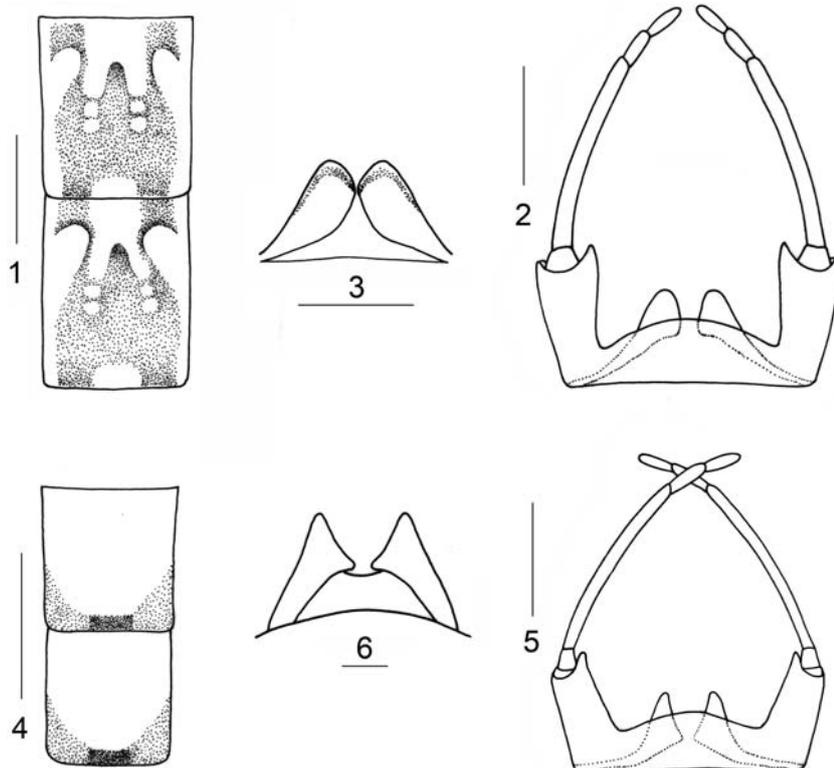
Male. Body length 7.0 mm; length of forewing 6.1 mm, length of hind wing 2.64 mm; length of caudal filaments 16.0 mm.

Head. With compound eyes contiguous, relatively small, grey-blue, with violet shine dorsally.

Thorax. Dark brown. Wings transparent, veins faintly brown, pterostigmatic region milky. Forelegs in proximal third brown, remaining part tawny; LR 1.8 : 1.8 : 2.4 (0.55 : 0.75 : 0.56 : 0.31 : 0.23); in hind legs with 1.98 : 1.54 : 0.77 (0.24 : 0.19 : 0.15 : 0.08 : 0.11).

Abdomen. Terga weakly tinged with reddish-brown; on segments I, VIII, IX and X darker; pattern of terga III–VII much reduced (Fig 4: V, VI); hind margins of terga fringed with dark brown; sterna light without markings.

Genitalia. Penis: length 0.18, width 0.26 mm (Fig. 6); upright, with finger-like lobes; styliger with convex margin and abruptly elevated sockets bearing inside thumb-like projections (Fig. 5); length of segments: I = 0.077, II = 0.330, III = 0.088, IV = 0.077 mm.



Figures 1–6. *Afronurus webbi* sp. n. ♂, Borneo; 1. Terga V–VI (scale 1.0 mm); 2. Genital segment, ventrally (scale 0.1 mm); 3. Penis, dorsally (scale 0.1 mm). *Afronurus sarawakensis* n. sp. ♂, Borneo; 4. Terga IV–V (scale 0.5 mm); 5. Genital segment, ventrally (scale 0.2 mm); 6. Penis dorsally (scale 0.1 mm).

Caudal filaments black-brown basally, lighter distally.

Female, subimagos and larva. Unknown

Differential diagnosis. The penis of *Afronurus sarawakensis* sp. n. is similar to that of *A. webbi*, but the pyramidal lobes are not as massive (Figs 5–6) as in the latter species (Fig. 3) and forceps sockets are narrowed apically, whereas in *A. webbi* forceps sockets are widened apically (Fig. 2). *Afronurus* species from the Philippines, as described below, have much more elevated penes or are with conspicuously spine- or jag-shaped lobal apices. Furthermore, it differs from all other known species of Borneo and the Philippines by its striking pattern of terga (Fig. 4).

***Afronurus freitag* sp. n.**

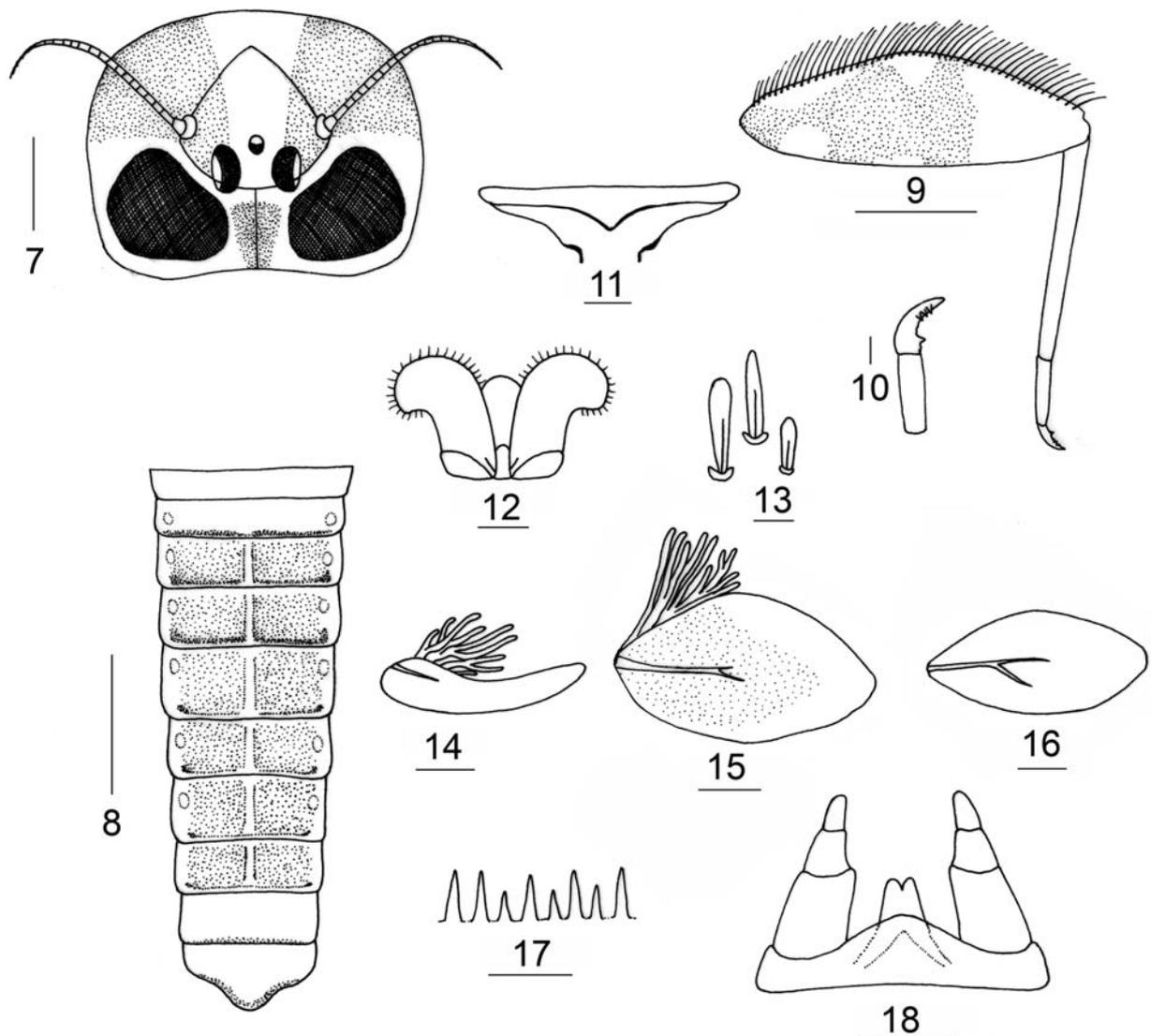
Figures 7–19

Holotype mature ♂-*La.* Philippines, Isl. Luzon, Minalungao National Park, 75 km NE of Manila, Sunmachao River, stony river bed 5–10 m wide, alt. 40–60 m (15°42' N, 121°03' E), 27.04.2006; leg. M. Zerning (DBP for limited time).

Paratypes. 1 small *La.*, same data (WPU); 1 ♀ *La.* Luzon, Ifugao Province, Banaue, Batad, Tapiyah Waterfall, 750 m asl (16°56' N, 121°09' E), 11.03.2000; leg. H. Freitag (WPU).

Etymology. The species is dedicated to Dr. H. Freitag, Germany, the discoverer of the new species.

Male La. Body length 5.3 mm; length of caudal filaments. 6.2 mm; body length of *female La.* 8.1 mm, caudal filaments (broken).



Figures 7–18. *Afronurus freitag* sp. n. ♂-Larva, Luzon, Philippines; 7. Head (scale 1.0 mm); 8. Abdomen, dorsally (scale 1.0 mm); 9. Femur, tibia, tarsus (scale 1.0 mm); 10. Tarsus, claw (scale 0.2 mm); 11. Labrum (scale 0.1 mm); 12. Hypopharynx (scale 0.1 mm); 13. Femur bristles (scale 0.02 mm); 14. Gill I (scale 0.1 mm); 15. Gill III (scale 0.1 mm); 16. Gill VII (scale 0.1 mm); 17. Tergum V, hind margin (scale 0.04 mm); 18. Genital segment, ventrally (scale 0.1 mm).

Head (mouthparts partly lost). Brown with characteristic median light band, subrectangular (Fig. 7), HI = 1.5 (width 1.98 mm, length 1.32 mm); antennae 1.2 mm. Labrum straight (Fig. 11), hypopharynx (Fig. 12) with slightly reversed expansions of superlinguae.

Notum. Pronotum with broad, light rim on posterior 2/3, mesonotum yellow-brown. Legs. Forefemur with stout to slender spatulate bristles (Fig. 13). Supracoxal spurs of middle and hind legs slightly rounded; femur of foreleg (1.4 mm) with brown extended marking in proximal 2/3 (Fig. 9) and long, stiff, swimming setae; length of femur 1.85, width 0.7 mm; length of tibia 1.3 mm, width 0.09 mm; colour pale yellow; length of tarsus 0.33 mm, light brown; claws (Fig. 10) with three denticles.

Abdomen. Terga light brown having inconspicuous pattern as in Fig. 8, sterna pale without markings; hind margin of segments with row of fine pointed bristles (Fig. 17); Gills (Figs 14–16) with tracheation faintly expressed; gills I–VI with tufts of filaments, weakly developed; gill I banana-like, II–VI slightly asymmetrically oval and VII narrower oval without tuft of filaments. Caudal filaments light brown, with whorls of tiny spines.

Genitalia. Preformed genitalia of mature male La as in Figure 18, with penis having contiguous, smoothly convergent lobes, rounded at tips, without titillators.

Imagos and subimagos. Unknown.

Differential diagnosis. The larva of *A. freitagii* sp. n. is unmistakable and can be separated from La of other *Afronurus* spp. from the Philippines by a distinctive pattern of head (Fig. 7). Usually, it has two or more small, light spots on anterior surface of head (Braasch & Freitag 2008: 124–125, figs 34, 45, *A. palawanensis*, *A. zerningi*) or lacks any spots (DBP: La *Afronurus philippinensis* Flowers & Pescador, 1984; La. *Afronurus* sp., leg. M. Zerning 2006). The almost oval form of gills II–VI is not seen in *Afronurus* from South-East Asia, having a more or less triangular shape (Flowers & Pescador 1984; Braasch & Freitag 2008). The triangular gill shape is found in La of *A. philippinensis*, so far the only known *Afronurus*-species from Luzon, and is also present in *A. palawanensis* and *A. zerningi* from Palawan. Recently, Webb & McCafferty (2008: figs 30, 49, 100) keyed out the general characters of genus *Afronurus* as a ‘combination of a slightly thickened anterior margin of the head capsule; simple, scattered setae on the ventral surface of the maxillae; the absence of whorls of long, fine setae on the caudal filaments’. In accordance with these characters and having penis outlines without titillators, the specimen described here may have been correctly placed in *Afronurus*.

Afronurus sp. A

♀. Malaysia, Borneo, Sabah, Danum Valley F.C. 15.–17.VIII.2005, at light; leg. W. Mey and Ebert (MFN).

Female. Body length 5.0 mm, length of forewing 7.0 mm, length of hind wing 2.64 mm; caudal filaments lost.

Head. Compound eyes blue-grey, space between $4.8 \times$ middle ocellus width (0.62 mm).

Thorax. Darker brown. Forewing and hind wing faintly reddish-brown, transparent, deep reddish-brown in costal and subcostal fields. Legs brown.

Abdomen. Terga reddish-brown without visible pattern. Two hind segments lost.

Male, subimagos and larva. Unknown.

Differential diagnosis. Because of the tinged wings, the species resembles *A. philippinensis* and *A. sibuyanensis* from the Philippines with reddish to maroon tinted costal and subcostal fields in forewings. It is presumably an undescribed species from Borneo.

Afronurus lantuyanensis sp. n.

Figures 19–20

Holotype. ♂. Philippines, Mindoro, Baco, Lantuyan, 13.–18.01.1998; leg. W. Mey and V. Samarita.

Paratypes. 1 ♂, 1 ♀. Same label (MFN).

Etymology. *Afronurus lantuyanensis* sp. n. is called after the name of the locality where it was collected.

Male. Body length 9.2 mm, length of forewing 8.1 mm, length of hind wing 1.4 mm; length of caudal filaments 25.0 mm.

Head. With grey compound eyes contiguous, whitish-grey clouded dorsally.

Thorax. Darker brown. Wings transparent; C, SC and R1 dark brown, other veins lighter, pterostigmatic region milky. Legs mostly yellow, only forefemur and -tibia in first third reddish-brown, darkened distally, tarsal segments slightly darker. LR in foreleg 1.7 : 2.3 : 3.0 (0.67 : 0.88 : 0.75 : 0.44 : 0.26); in hind leg 1.67 : 1.76 : 0.79 (0.24 : 0.19 : 0.13 : 0.08 : 0.15).

Abdomen. With reddish-brown terga, without pattern dorsally, with dark brown markings laterally (Fig. 19); sterna light brown.

Genitalia. Penis (Fig. 20) with two upright lobes, towards the smoothly tapered ends somewhat slightly inwards; styliger with elevated sockets and inner thumb-like projections laterally.

Caudal filaments with narrow, blackish rings at articulations.

Female. Body length 7.8 mm, length of forewing 7.7 mm, length of hind wing 1.95 mm, caudal filaments broken.

Head. Eyes grey-blue with black ring basally; distance between them $6 \times$ width of median ocellus.

Thorax. Reddish-brown. Wings tinged with reddish-brown, more conspicuous in costal and subcostal field; pterostigmal region opaque; longitudinal veins dark brown, cross veins brown; LR in foreleg 1.9 : 1.67 :

1.1 (0.25 : 0.22 : 0.18 : 0.11 : 0.25); in hind leg 2.2 : 1.5 : 0.54 (0.17 : 0.09 : 0.07 : 0.04 : 0.17).

Abdomen. All over reddish-brown dorsally; with darker markings laterally; segments light brown ventrally, similar to those in males. Subanal plate broadly tongue-shaped, at tip slightly truncate.

Subimagos and larva. Unknown.

Differential diagnosis. *A. lantuyanensis* sp. n., having distantly positioned penis lobes with a deep incision between (Fig. 20) is distinguished from sympatric *A. mindoroensis* by narrowly converging lobes and a very small incision (Braasch 2005: 168, figs 7–8). With its pointed tips of penis lobes (Fig. 20), it is easy to separate it from *A. philippinensis* which has diverging truncately tube-like lobes (Flowers & Pescador 1984: 364, fig. 7) and all other species from the Philippines having differently shaped lobal apices.

Afronurus leytenensis sp. n.

Figure 21

Holotype. ♂. Philippines, Leyte, Javier, Bito river, altitude about 50 m, 19.04.1997; leg. W. Mey and W. Speidel.

Paratypes. 2 SI ♂. Same label (MFN).

Etymology. The name of the species refers to Leyte.

Male. Body length 6.9 mm, length of forewing 6.3 mm; length of hind wing 0.99 mm, caudal filaments broken.

Head. Compound eyes grey, with reddish tinge dorsally.

Thorax. Dark brown. Wings transparent, in forewings C, Sc and R1 slightly amber-coloured, other veins faintly yellowish to colourless; foreleg brownish; LR in foreleg 1.98 : 2.1 : 2.8 (0.66 : 0.84 : 0.65 : 0.40 : 0.25).

Abdomen. With reddish tinge and without clearly visible pattern.

Genitalia. Penis (Fig. 21) with straight styli, elevated forceps sockets, with inner finger-like projection; penis lobes converging, lobal tips with two small spines. Caudal filaments light, at joints narrowly blackish annulated.

Female, subimagos and larva. Unknown.

Differential diagnosis. *A. leytenensis* sp. n. is closely related to other Philippine species having convergent penis lobes and strong elevated forceps sockets as in *A. mindoroensis* (Braasch 2005: 168, figs 7–8). In contrast to that or other *Afronurus* species, it can be separated from them by two fine spines at the tip of tapered penis lobes (Fig. 21).

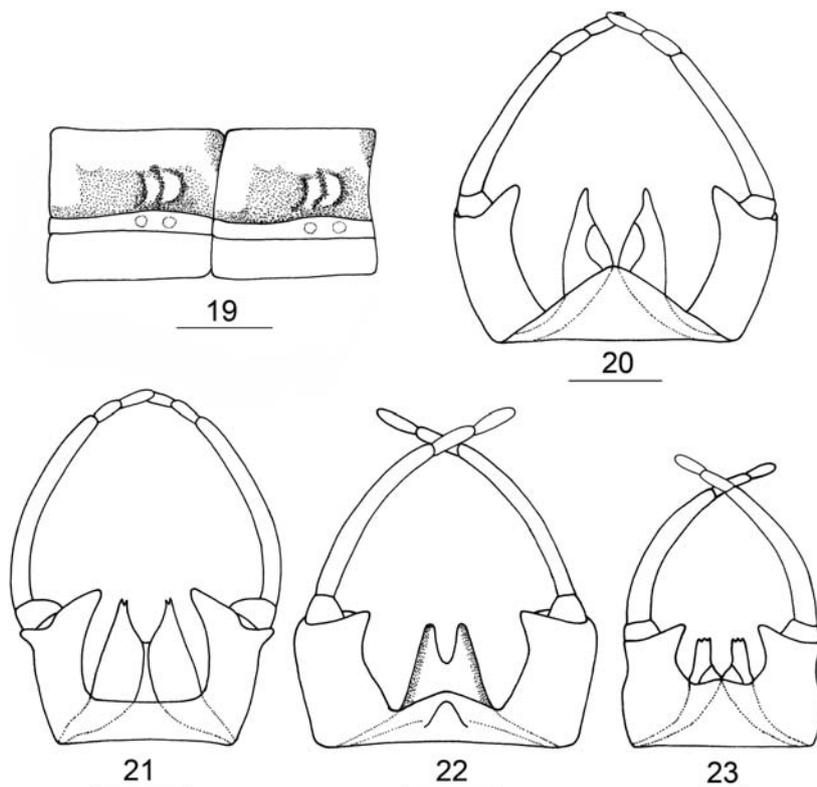
Afronurus mindanaoensis sp. n.

Figure 22

Holotype. ♂. Philippines, Mindanao, Mt. Aktuaganon, altitude 1050 m, 28.05.–07.06.1996; leg. W. Mey.

Paratypes. 2 ♂, 1 ♀. Same label (MFN).

Etymology. The species name refers to Mindanao, where it is resident.



Figures 19–23. *Afronurus lantuyanensis* sp. n. ♂, Mindoro, Philippines; **19.** Terga III, IV, laterally (scale 0.5 mm); **20.** Genital segment, ventrally (scale 0.1 mm). *Afronurus* spp. Male, genital segment, ventrally; **21.** *Afronurus leytenensis* sp. n. ♂, Leyte, Philippines (scale 0.1 mm). **22.** *Afronurus mindanaoensis* sp. n. ♂, Mindanao, Philippines (scale 0.1 mm). **23.** *Afronurus panayensis* sp. n. ♂, Panay, Philippines (scale 0.1 mm).

Male. Body length 8.6 mm, length of forewing 9.2 mm, length of hind wing 0.23 mm, length of caudal filaments 27.0 mm.

Head. Compound eyes dark blue-grey, nearly contiguous.

Thorax. Brownish. Wings transparent, veins colourless; legs yellowish without markings; LR of foreleg 3.9 : 3.9 : 3.1 (1.7 : 0.8 : 0.4 : 0.1 : 0.1). Hind legs lost.

Abdomen. Terga light brown, somewhat darkened posteriorly; sterna lighter brown.

Genitalia. Styliger with strongly elevated sockets, but with inner projection less marked; penis lobes long; separated by a deeply rounded emargination (Fig. 22).

Caudal filaments lightly coloured, not annulated.

Female. Body length 9.5 mm, length of forewing 10.6 mm, length of hind wing 1.36 mm; caudal filaments lost.

Head. Eyes dark blue-grey, separated by $6 \times$ width of median ocellus.

Thorax. Reddish-brown, wings transparent with amber-colored veins. LR of foreleg 2.4 : 2.3 : 1.63 (0.24 : 0.57 : 0.28 : 0.26 : 0.3). Hind legs lost.

Abdomen. Terga reddish tinged without clearly visible pattern, on terga VII–IX more lightened; hind margins of terga with broad darker band; sterna light, without any pattern; subgenital plate with slight convex protrusion; subanal plate broadly tongue-like.

Subimagos and larva. Unknown.

Differential diagnosis. *A. mindanaoensis* n. sp. exhibits a remarkable morphological similarity to *A. lobatus* from Mindanao, but also to *A. sibuyanensis* from nearby Sibuyan. *A. mindanaoensis* sp. n. with insidely less marked projections of forceps sockets has a deeply rounded emargination between penis lobes. Before the slightly domed styliger margin is a bluntly triangular bulge (Fig. 22). *A. lobatus* has forceps sockets with insidely thin, thumb-like projections, a bilobate penis with short, round-angled emargination and a similar looking strange bulge (Ulmer 1924: 84, fig. 51). In contrast, *A. sibuyanensis* has insidely shortly rounded forceps sockets, lacking a bulge and having a low emargination with sharp incision between the penis lobes (Mol 1987: 6, fig. 4).

Afronurus panayensis n. sp.

Figure 23

Holotype. ♂. Philippines, Panay, Culasi, San Vicente, alt. 400 m, 11.04.1995; leg. W. Mey.

Etymology. Species name refers to Panay.

Male. Body length 6.96 mm, length of forewing 6.6 mm, length of hind wing 1.7 mm, caudal filaments broken.

Head. Compound eyes grey with blackish ring basally, contiguous.

Thorax. Yellow; wings transparent except milky in pterostigmatic area; all veins colorless. Legs lost except for hind leg being of light yellow without markings; LR of hind leg 1.7 : 1.3 : 0.77 (0.20 : 0.18 : 0.13 : 0.07 : 0.20).

Abdomen. Terga lightly yellow-brownish, flanks darker brown with indistinct pattern around spiraculum, hind margins of terga slightly bordered with brown; last tergum narrowly fringed with brown; sterna light, without markings.

Genitalia. Copulatory organ (Fig. 23) with forceps sockets strongly elevated and having inwardly thumb-like extensions; middle of styliger slightly convex; penis bilobate, with upright, narrowly parallel, hose-like lobes, tipped with a tiny dentation and a triangular incision above the fused basal lobes.

Female, subimagos and larva. Unknown.

Differential diagnosis. *A. panayensis* sp. n. has jagged penis lobes apically, with long free ends, separated distally; the inside corners of forceps sockets exhibit a thumb-like projection (Fig. 23), and narrowly emarginated styliger is slightly convex. The similar Borneonian *A. bruneiensis*, however, shows contiguous jag-like penis lobes apically, inside forceps sockets with pointed corners, whereas styliger is with wide emargination (Braasch 2005: 170, figs 18–19).

Afronurus philippinensis Flowers & Pescador, 1984

Material. (MFN; leg. W. Mey and Ebert). 1 ♂. Philippines, Luzon, Naga, Mt. Isarog, alt. 1010 m, 22.03.2000, at light; 2 SI ♂, 2 SI ♀, Philippines, Luzon, Mt. Malinao, Amater, alt. 1010 m, 25.–26.03.2000, at light; 6 ♂, 2 ♀, ♂ SI, Philippines, Luzon, Zambales Mts., Coto, alt. 110 m, 05–06.05.1999; 2 SI ♂, 4 SI ♀, Philippines, Luzon, Zambales Mts., Coto, alt. 150 m, 05–07.11.1998; (MFN, leg. Mey and W. Speidel). 1 ♂, 1 ♀ SI, Philippines, Luzon, Zambales Mts., Pili, alt. 50 m, 05.–07.11.1998; 1 SI ♀, 2 La, Philippines, Luzon, Zambales Mts., Pili, alt. 500 m, 06.11.1998; 3 La, Philippines, Luzon, Zambales Mts., Pili, alt. 500 m, 16.11.1998; (MFN, leg. Mey and Ebert and M. Nuß) 1 ♀, Philippines, Luzon, Barlig, alt. 1650 m, 15.11.1997; at light; (MFN, leg. Mey and Ebert) 2 SI ♀, Philippines, Luzon, Santa Fé, Bicol NP, alt. 200 m, 28.03.2000; 1 SI ♀, Luzon, Dinalupihan, Roosevelt National Park, 09.05.1999, at light; (MFN, leg. Mey and Ebert) 2 SI ♂, 2 SI ♀, Luzon, Bataan, Dinalupihan, 11.11.1998, at light; (MFN, leg. Mey and Speidel) 1 ♀, Philippines, Luzon, Bald Mtn., alt. 1150 m, 11.–13.11.1997; (MFN, leg. Mey and Ebert and Nuss) 2 SI ♀, Philippines, Luzon, Santa Fé, alt. 200 m, 28.03.2000; (MFN, leg. Mey and Ebert) ♀, Philippines, Luzon, Mts. Prov., Barlig, 1650 m, 14.–15.11.1997, at light; 3 La, Philippines, Luzon, Barlig, alt. 1650 m, 14.–15.11.1997; 1 ♀, Philippines, Luzon, Barlig, alt. 1650 m, 14.–15.11.1997.

Additional material. ♂, ♀, SI ♂, SI ♀, La (DBP for limited time).

Comments on differential diagnosis. The diverged cylindrical penis lobes are unique among all known species of *Afronurus*. The original discovery site of *A. philippinensis* (♂, La) is the Molavin Creek at lower reaches, about 300 m above sea level in Laguna Province, Luzon (Flowers & Pescador 1984). It is not clear, whether specimens (♂, La) of upper course, more than 1000 m asl, already belong to a different species,

because a female from there has, deviating from species description (Flowers & Pescador 1984), forewings colourless in costal and subcostal fields and a SI female (8.4 mm) with a subanal plate, smoothly rounded apically, whereas forewings in *A. philippinensis* have orange-brown in C- and Sc-fields, and a subanal plate of female weakly emarginated distally (Flowers & Pescador 1984: 362). However, the SI males (8.7 mm, 9.9 mm) from there have a genital segment with two divergent tube-like lobes just as in *A. philippinensis*. The subanal plates of most investigated female specimens of other origin in Luzon are notched apically, whereas their costal and subcostal fields are tinted reddish to reddish-brown. This is in conformity with specimens from the locus typicus of *A. philippinensis*.

The author examined specimens of the species originating from Luzon (Tapiyah Waterfall, Ifugao Prov., Banaue, alt. 759 m) with a female having an anal plate weakly rounded or slightly truncate distally. But males from there are unmistakable *A. philippinensis*, and not being referable to any other Philippine *Afronurus*-sp. The species differentiation in the '*philippinensis*' complex of *Afronurus* on the large island Luzon is still puzzling and depends on better knowledge.

Subimagos. Unknown.

Afronurus sibuyanensis Mol, 1987

Material. 2 ♂. Philippines, Panay, near San Remigio, River Aningalan, alt. c 800 m, 09.–10.04.1995; leg. W. Mey (MFN).

Larva. Unknown.

Comment. Mol (1987) described *A. sibuyanensis* on the base of specimens recorded from Sibuyan at an altitude of 70–80 m. The new record place of the species is the southern Panay, located at a distance of about 70 km from the locus typicus.

Differential diagnosis. It is one of the *Afronurus* species with tinted costal and subcostal fields. Mol (1987: 2) notes to *A. sibuyanensis* that 'the costal- and subcostal fields' were 'dark to dark brown', which may be an effect of dry preservation. A comparable species, in this respect, is *A. malaysianus* (Braasch 2005: 169, fig. 11) from mainland West Malaysia with costal and subcostal fields more reddish tinted and strongly converged penial lobes. In contrast, *A. sibuyanensis* has straight penis lobes, which are separated from each other by a sharp incision (Mol 1987: 6, fig. 4).

Asionurus sp. A

Material. 1 *La*, immature (WPU). Philippines, Palawan, Tay tay, Lake Manguao, SW Bay, Malibongbong, secondary forest, creek, pool: leaves, sand, CPOM, c 20 m asl, 10°44'34" N, 119°31'22" E, 28.08.2008, leg. H. Freitag; 1 ♀ (WPU). Philippines, Palawan, Tay tay, Lake Manguao NE, secondary forest, tributary Palok creek, riffle & pools: gravel, sand, CPOM, c 25 asl, 10°46'42" N, 119°31'55" E, 14.09.2008, leg. H. Freitag.

Larva (damaged). Body length 4.5 mm, caudal filaments broken.

Head. Anterior margin broadly yellowish up to hind margin; between ocelli dark brown; from median ocellus towards middle of anterior margin light wedge-shaped area; its brown fringe including a pair of light spectacle-figures laterally; below antennal bases a large dark brown spot and a further larger one more anteromedially along the light median wedge area forming an equisided trapezoid. Posterior margin of head slightly concave.

Pronotum. With yellowish to light brownish colour and with 4 distantly arranged, comma-like brown blotches along anterior margin; middle ones wide-spaced.

Legs. Femora conspicuously marked with two brown cross bands (at first third and second third each) and black-brown distally as in Braasch & Soldán (1986a: 157, fig. 6, here first cross band not going through) or in Sangpradub et al. (2003: 414, fig. 2.1; here first cross band interrupted).

Abdomen. Terga yellowish, II–III and V–IX medially with brown blotches; on IV blotch lacking; terga II–VIII with submedian, obliquely inwards directed brown streaks (Braasch & Soldán 1986a: 157, fig. 4; Sangpradub et al. 2003: 414, fig. 2.1). Sterna light, without any pattern. Gill I nearly as in Sangpradub et al. (2003: 414, fig. 2.2a) with almost straight dorsal margin; gill III more oval shaped, not as in Sangpradub et al. (2003: 414, fig. 2.2c) with strikingly bulging dorsal margin. Gill VII lost.

Female. Body length 6.0 mm; length of forewing 7.6 mm, length of hind wing 1.9 mm; cerci broken.

Thorax. Reddish-brown. Forewings transparent except with reddish tinge in costal and subcostal fields; veins brown; hind wings transparent, veins faintly brown.

Abdomen. Reddish-brown, without markings. Subanal plate broadly spade-like rounded, subgenital plate obtuse distally.

Males and subimagos. Unknown.

Differential diagnosis. The head markings of *La Asionurus* sp. A are not seen in *La* of *Asionurus primus* Braasch & Soldán (1986a: 157, fig. 1) having only a wedge-shaped lightening in the middle and anterior of head. The markings on terga are quite similar to those found in *A. primus*. Gill I and III show differences in comparison with *A. primus*. However, the immature stage of *Asionurus* sp. A does not allow a clear assignment.

The features of genital and subgenital plates of female suggest that the insular *Asionurus* species could be new for science.

Atopopus tarsalis Eaton, 1881

Figure 24

Material. 1 (MFN) 1 ♂. Malaysia, Borneo, Sabah, Danum Valley F.C., S.G. Palum, Tambun, 15.–17.VIII.2005; at light tower, 2 ♂, Malaysia,

Borneo, Sabah, Danum Valley, F.C., 15.–17.VIII.2005; at light; ? 1 ♀. Borneo, Sabah, Tawau Hills, NP, 18.–21.VIII.2005, at light, leg. W. Mey and Ebert; (MFN) 1 mature ♂-La, 1 La, Borneo, Sabah, Mt. Kinabalu NP, small tributary to Liwagu River, 23.02.2006, leg. W. Mey.

Material 2. (WPU) 4 La, Malaysia, Sabah, round. Kota Kinabalu, Tambunan km 29, Brdg. Kpg. Moyog, Sungai Moyog tributary; rocky, riffle / pool, secondary vegetation / farm, 200 m asl, c 5°53' N, 116°14' E, 09.06.2007; 4 La, Malaysia, Sabah, round. Kota Gard, Kinabalu, Tabunan, km 55, near Gunung Alab, primeval forest, small creek, rock, wood litter, riffle / fall, 1600 m asl, c 5°49'08" N, 116°20'29" E, 09.06.2007; 8 La, 1 mature La. Malaysia, Sabah, round. Kota Kinabalu–Tambunan, km 53, 0.3 km E Gunung Emas Resort; small creek, rocks, stones, CPOM, riffle / fall, secondary vegetation; c 1650 m asl, 5°49'38" N, 116°20'22" E; 08.06.2007 3 La, Malaysia, Sabah, Kota Kinabalu, Inanan Kpg. Sinulihan, tributary Inanan River, Sinulihan Creek, near overland cable; bolder, rocks, secondary forest, c 100 m asl; 5°59'45" N, 116°09'00" E, 04.06.2007; 14 La, Malaysia, Borneo, Sabah, Banggi Isl. Kalangkaman, Kpg. Kapitangan, Bongga Falls, rocky mountain stream, primeval forest, 70 m asl, 7°20' N, 117°11' E, 06.06.2007; leg. H. Freitag.

Additional material 3. Some specimens (DPB for limited time); leg. H. Freitag.

Female and subimagos. Unknown

Comments. In the illustration by Eaton (1883–1888: pl. XXII, fig. 39), the penis of *A. tarsalis* with its apically globular shape closely resembles that of *A. tibialis* (Ulmer 1924: 77, fig. 43) from the Philippines. Presumably, the similar penis figures may have given rise to believe in the past that *A. tibialis* would be resident in the Philippines and in Borneo, likewise (Ulmer 1920, 1924, 1939). However, due to zoogeographical points of view, Wang & McCafferty (1995) have shown that *A. tibialis* is restricted to the Philippines. The authors suggested that the Philippine *Atopopus*-species, being endemic, is derived from a Borneonian species. Figures of *A. tarsalis*, illustrated by Kluge (2004: 179, figs 59B–C), mark a penis of rounded rectangular lobes. Two smaller males (body length 10.0–11.0 mm, forewing length 9.0 mm; caudal filaments 25.0 mm), collected by W. Mey, are not clearly separable from the normal-sized *A. tarsalis* (♂: body length 15.0 mm; s. above) in whole appearance. But the differences in size of penis are considerable, having a ratio of length : width as only 0.39 : 0.35 mm against 0.66 : 0.53 mm, belonging to a large male from the same area.

Differential diagnosis. Male of *Atopopus tarsalis* is recognizable by having moderately convex styliger, provided with slight, lateral tubercles, and weak forceps sockets laterally, penis with approximately rounded rectangular, distantly arranged lobes and moderately long

titillators (Kluge 2004: 179, figs 59B–C); hind wings without acute costal projection. Head of larvae as in Wang & McCafferty (1995: 20, fig. 1, sub nom. *A. edmundsi*): vertex with a pair of narrow, transverse dashes anteromedially to antenna bases and with an additional pair of narrow transverse dashes that are located posteromedially to the antenna bases.

Sartori et al. (2007) found that the larval description of *A. edmundsi* by Wang & McCafferty is wrong and actually refers to the larva of *A. tarsalis*. The female of *A. tarsalis* remains unknown (Sartori et al. 2007). The latter authors found a female larva having a 'Posterior margin of the sternite IX ... slightly concave'. Some female larvae, found in Banggi Isl., Sabah in 2007 by H. Freitag, have a smoothly emarginated subanal plate and seem to belong to *A. tarsalis*. The female from Tawau Hills lacks any emargination of subanal plate (Fig. 24). It remains unclear whether this specimen is *A. tarsalis*.

Male of *A. edmundsi* is characterized by a concave hind margin of the styliger and pronounced forceps sockets, a triangular shape of penis lobes, by titillators extending slightly apices of penis lobes (Wang & McCafferty 1995: 23, fig. 28); hind wings with blunt costal projection. Larva is unknown.

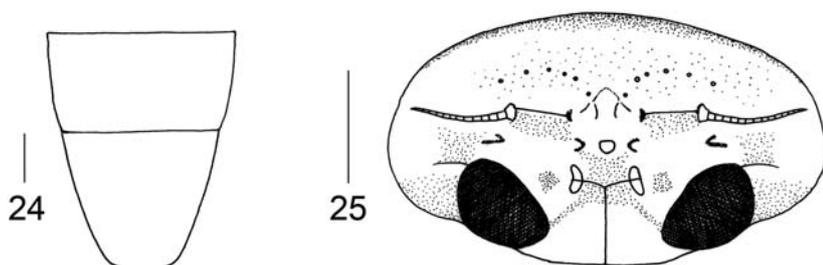
Male of *Atopopus meyi* Braasch, 2005 has a concave hind margin of the styliger and distinctly elevated forceps sockets. The approached, obliquely club-like penis lobes have a fine incision each apically and a very small edge-like extension each laterally; hind wings with acute costal projection. Head of larva having vertex with shorter dashes anteromedially of antenna bases similar as in *A. tarsalis*, with shorter dashes, spindle-like, pointing obliquely upwards to antenna bases posteromedially; further with one transverse dash below median ocellus.

Male of *Atopopus tibialis* has a moderately concave styliger, slightly cornered medially and hardly expressed forceps sockets, narrow standing penis lobes each globular apically and deeply attached, slender titillators (Ulmer 1924: 77, fig. 43); hind wings with acute costal projection. Larva on dorsal head without any dashes (Wang & McCafferty 1995: 'Vertex lacking transverse dashes', confirmed by own material).

Atopopus sp. A

Figure 25

Immature La. (WPU) Malaysia, Sabah, Kota Kinabalu, Inanan, Kpg. Sinulihan, trib. Inanan Riv., Sinulihan



Figures 24–25. 24. *Atopopus tarsalis* Eaton, 1885, ? ♀, Borneo, subanal plate (scale 0.3 mm); 25. *Atopopus* sp. A, La, Borneo, Head dorsally (scale 1.0 mm).

Creek, overland cable; boulder, rocks, secondary forest, 100 m above sea level, c 5°59'45" N, 116°, 09'00" E, 04.06.2007; (DBP for limited time); leg. H. Freitag.

Larva. Body length 6.0 mm. Cerci broken.

Head. HR 27:15 = 1.8. Head capsule with hind margin slightly convex (Fig. 25), laterally emarginated; anterior margin thickened ventrally; forehead grey-brown lightened in posterior half laterally, with small black spots irregularly scattered anteriorly; vertex with long transverse dashes anteromedially, with pair of small hook-shaped dashes below antennal bases posteriorly, medially, at both sides of medium ocellus a pair of very small, angle-formed dashes; head wider than pronotum, ratio 23 : 20 (1.15); antennae slightly protruding from lateral head margin. Hypopharynx with broad lingua basally, apically tapering with a tuft of setae. Superlinguae without folded outer margin, apex pointed and bent backwards.

Notum. Femora brownish without distinct markings, but densely covered with numerous short, oval bristles of 4–5 (6) µm length and up to 3 µm width.

Abdomen. Sternum IX at hind margin conspicuously notched, not faintly emarginated as in *A. tarsalis*.

Differential diagnosis. Larval characters of the single specimen of *Atopopus* sp. A were compared with those of *A. tarsalis* of similar size. In contrast to larvae of all other *Atopopus* spp., the recorded *A. sp. A* has a convex-shaped hind margin of its head (Fig. 25). It could possibly be the larval stage to the apparently rare *A. edmundsi*, described from the near-by Kinabalu Mountains (Wang & McCafferty 1995). Also, the dashes on the head face (Fig. 25) have another arrangement as described for *A. tarsalis* in Wang and McCafferty (1995: 20, fig. 1).

Epeorus boonsoongi sp. n.

Figures 26–35

Holotype. Female *La.* (MFN) Borneo, Sabah, Kinabalu-Mountains, Liwagu-River, 12.11.2006, leg. W. Mey.

Paratypes. 7 *La* (MFN), same label as holotype, leg. W. Mey.

Informal Material (Webb, pers. comm.). 1 *La*, 1 *La* late instar (ZMKU), Indonesia, East Kalimantan, Kayan-mentarang Nature Reserve, Nggeng River. 2.87° N 115.82° E, 378 asl, 30.III.1994, coll. B. Hubley and DC Darling, # JWA1674 [MZB]; 11 *La*, same data, parts of one on slide #JWA1673 [MZB]; 1 *La*, same data # JWA1673 [MZB]; 1 *La*, Indonesia, East Kalimantan, south slope of Lunjut / Menjah, ca 8 km NW Puak, Kayan-Mentarang Nature Reserve, Pujungan, 2.67° N 115.62° E, asl 910 m, 12.06.1993, leg. DC Darling, U. Rosichon, #JWA1677 [ANIC]; 1 *La* Indonesia, East Kalimantan, Bulongan, Apau Ping, stream north of village, flowing through agricultural land into Bahau River, 3.1° N, 115.82° E, asl 438 m, 03.04.1994, leg. B. Hubley, DC Darling #JWA1676 [MZL].

Etymology. The specific name refers to the Thai Ephemeropterist Dr. B. Boonsoong indicating the close affinity between the new species and *Epeorus aculeatus* Braasch, 1990 from Thailand and Vietnam (Nguyen & Bae 2004a).

Premature female La. Body length 15.0 mm, cerci lost (second ♀-*La* 13.0 mm; cerci 15.7 mm).

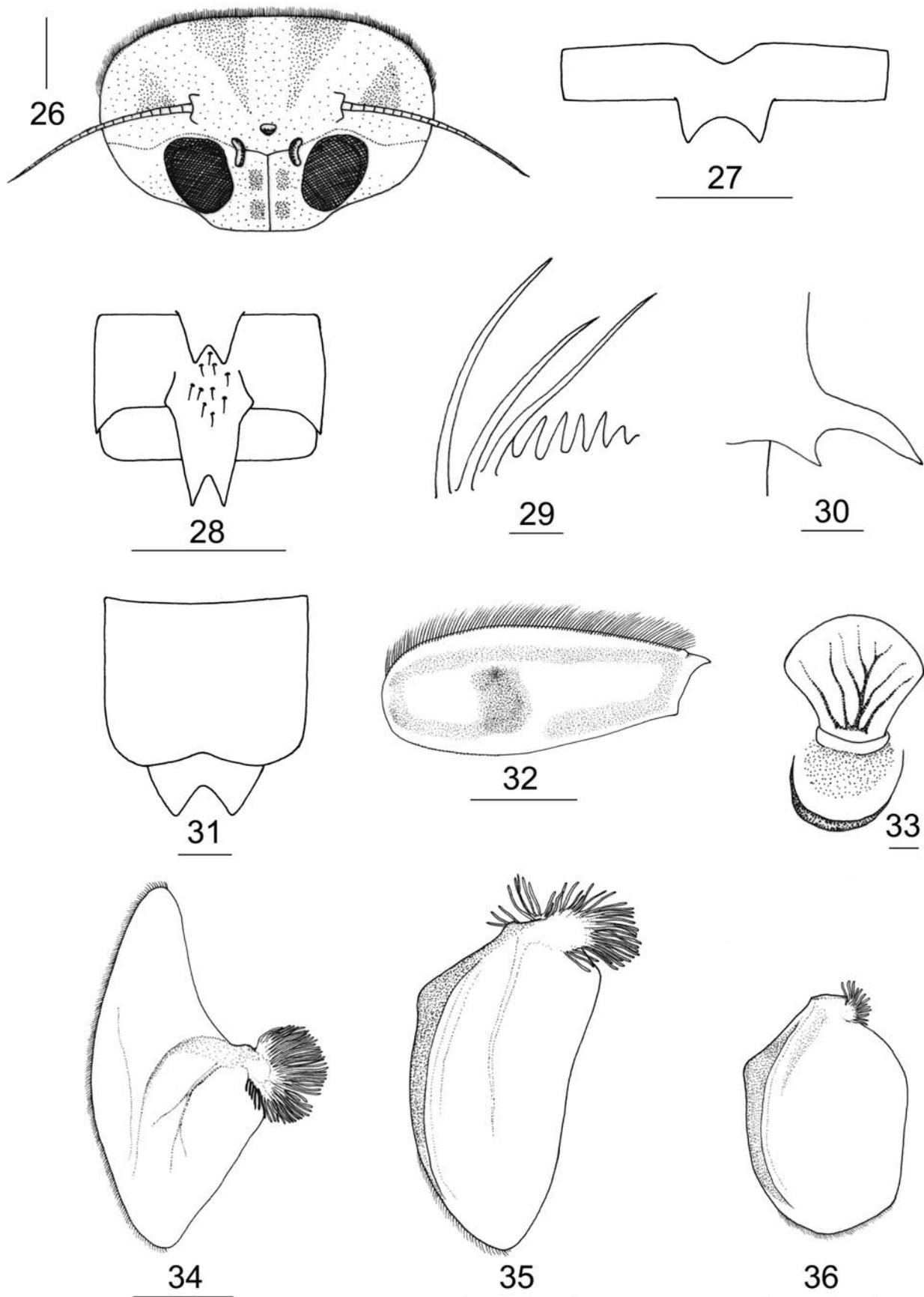
Head. Head capsule (Fig. 26) expanded laterally, posterior margin straight, medio-anteriorly indented; dorsal surface light brown, two dark brown stripes, narrowly extending from anterior margin of compound eyes, broadened to anterior margin; anterior margin with dense fringe of projecting, somewhat upturned setae; antennae brown, subequal to width of head capsule; head width 4.3 mm, head length 2.9 mm, HI = 1.5; antenna length 2.3 mm; labrum slightly wider than long, anterior margin curved ventrally and with longitudinal sclerotized ridges and small median notch, ventral surface with row of simple setae near anterior margin and lateral brush of long fine setae.

Pronotum. Yellowish-brown with dark markings.

Notum. Legs brown. Coxae and supracoxal sclerites sharply pointed; femora (Fig. 32) dorsally with large transverse spot, outer margin with row of long swimming setae of 0.3–0.4 mm length and acutely pointed projections; dorsal surface with numerous spatulate bristles (Fig. 33); length of forefemur 3.35 mm, acute projection 0.26 mm, tibia and tarsus brown; claws towards tip dark brown; length of middle femur 3.56 mm, acute projection 0.5 mm; length of middle tibia 3.63 mm; length of hind femur 4.18 mm, acute projection 0.55; length of hind tibia 3.7 mm; length of fore- and hind tarsal segments 0.77 mm; claws with 3 denticles.

Abdomen. Terga I and X brown, terga II–IX somewhat darker brown along midline ridge and flanks; terga I–IX provided with paired submedian spines directed posteriorly, distinctly curved inward, on terga IV–IX fused basally, and distance between tips of black-brown spines on terga I–IX 0.5, 0.55, 0.48, 0.35, 0.26, 0.24, 0.22, 0.17 and 0.17 mm (Fig. 28); on the median ridge from tergum III–VI scattered, partially slightly curved bristles of about 0.02 mm, on following terga less bristles with transition to rather densely standing setae of up to 0.12 mm. Posterior margin of tergum VIII with bluntly pointed, tooth-like bristles and single longer, hair-like bristles (Fig. 29). The anterior postero-lateral projections of terga II–VII long, curved, extending beyond hind margin of their segments and turned upwards; the posterior one very short (Fig. 30). Flanks of tergum X dark brown. Sterna light without markings; last sternum deeply emarginated with two obtusely pointed tips (Fig. 31), posterior margin with a dense fringe of long setae. Gills. Gill I longest (3.1 mm), anteriorly with narrow curved elongation, rounded apically (Fig. 34); gills II–VII with well visible rounded tubercle on anterior costal rib and with shorter subcostal rib (Fig. 35: gill III, 2.5 mm), gill VII 1.9 mm, shortest (Fig. 36). All gills with moderately developed tufts of filaments. Cerci reddish-brown, basally inside yellow, outside dark brown; with dorsal setae; median caudal filament a minute, single cone.

Differential diagnosis. *E. boonsoongi* sp. n. has paired, pointed, submedian, slightly curved inward spines on



Figures 26–36. *Epeorus boonsoongi* sp. n. La, Borneo; **26.** Head (scale 1.0 mm); **27.** Tergum III (scale 1.0 mm); **28.** Terga VIII–IX (scale 1.0 mm); **29.** Tergum VIII, hind margin (scale 0.03 mm); **30.** Posterolateral projection (scale 0.2 mm); **31.** Anal plate (scale 1.0 mm); **32.** Forefemur (scale 1.0 mm); **33.** Dorsal forefemur, spatulate bristle (scale 0.01 mm); **34.** Gill I (scale 1.0 mm); **35.** Gill III (scale 1.0 mm); **36.** – Gill VII (scale 1.0 mm).

posterior margin of terga I–IX. In contrast, *E. aculeatus* from Thailand and Vietnam has paired, a little longer, pointed, and straight spines on terga II–IX (Nguyen & Bae 2004a: 20, fig. 3). Unlike *E. aculeatus*, gill I of *E. boonsoongi* sp. n. is longer and slenderer, and gills II–VII are characterized by a rounded tubercle on costal rib. Moreover, *E. boonsoongi* sp. n. bears acute projections of femora, which are absent in *E. aculeatus*. The large ‘supra-tergalial projection’ (Kluge 2004) in the new species is much more striking by its rather curved structure extending out of the hind margin of the corresponding segment (Fig. 30), whereas that of *E. aculeatus* is comparatively short, pointed and without extension. In both species, the anal plate is deeply excavated protruding with two triangulated ends (Fig. 31). A single La from the Liwagu River, Sabah, Malaysia is probably conspecific with *E. boonsoongi* sp. n., but lacks the dark stripes on the head capsule according to Figure 26 (J. Peters, coll. Florida A&M University, USA: pers. comm. to J.M.Webb). The change in colour characters may depend on the freshness of material.

Other pair-spined species from South-East Asia are the Vietnamese *Epeorus bifurcatus* Braasch & Soldán,

1979 (266, fig. 15) with paired, smaller spines and *E. carinatus* Braasch & Soldán, 1984 (110, fig. 2) having paired, larger and a row of smaller, stiff spines on posterior margin of terga. Double-spined *Iron martinus* Braasch & Soldán, 1984 (113, figs 37, 40) is well recognizable by its large contiguous first gills. A second Borneonian unnamed *Epeorus* species is without any spines at terga (Webb 2010, pers. comm.).

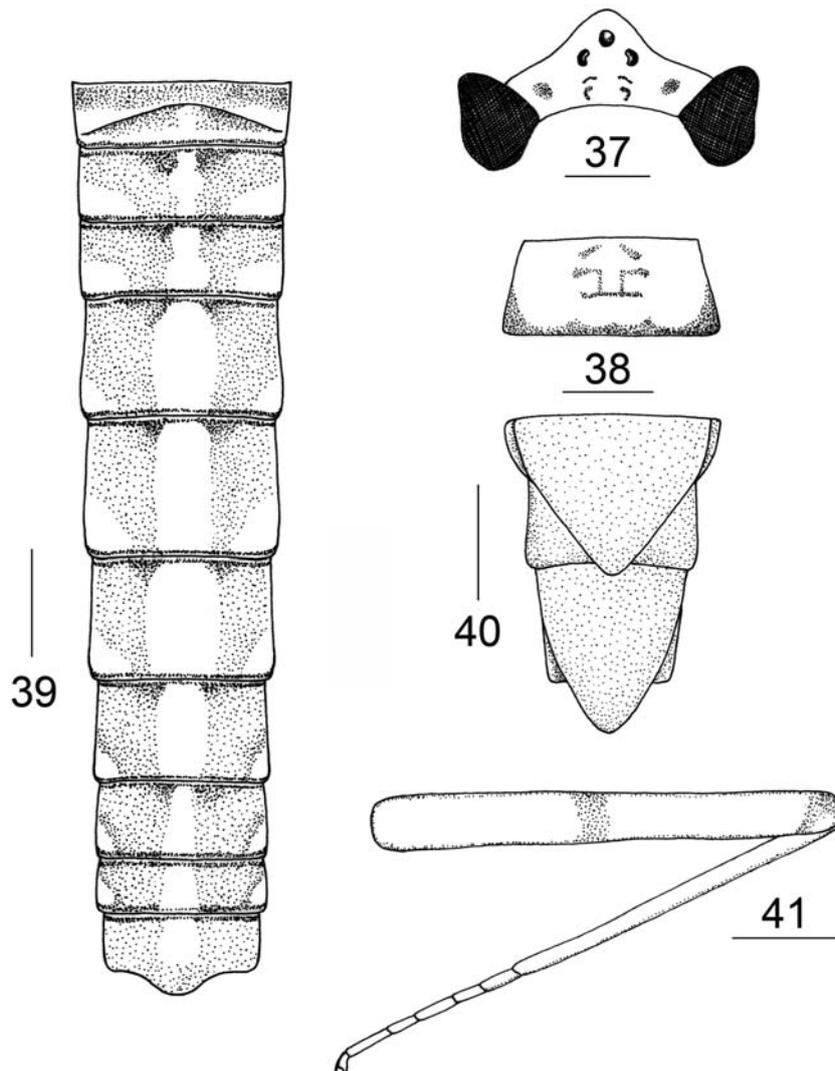
Thalerosphyrus sp. A

Figures 37–41

Material. 1 ♀. (MFN) Malaysia, Borneo, Sabah, Mount Kinabalu, Liwagu river, National Park, 10.–13.VIII.2005; at light, leg. W. Mey and Ebert, 1 ♀. (MFN) Borneo, Sabah, Mount Kinabalu, Silau, 13.11.2006, at light, leg. W. Mey

Female. Body length 14.0 mm; length of forewing 18.0 mm, length of hind wing 5.75 mm; length of caudal filaments 35.0 mm (second female: body length 10.1 mm).

Head. Yellowish; eyes distance $6 \times$ median ocellus width; posterior part of head (Fig. 37) medially with dash-like pattern.



Figures 37–41. *Thalerosphyrus* sp. A, ♀, Borneo; **37.** Head, dorsally (scale 1.0 mm); **38.** Prothorax (scale 1.0 mm); **39.** Abdomen, dorsally (scale 1.0 mm); **40.** Subgenital and subanal plate (scale 1.0 mm); **41.** Hind leg (scale 1.0 mm).

Prothorax. Thorax. Width of prothorax (Fig. 38) 2.3 mm, length 1.0 mm; yellowish, narrow brown margined distally and with brown pattern medially.

Forewings. Transparent with two brownish dots in costal and subcostal fields, C, Sc and R1 black-brown, other veins light brown; hind wing colourless. Forelegs lacking, dorsal face of mid- and hind femur yellowish with two parallel, dark brown streaks (Fig. 41); tibia yellowish, distally darkened; end of tarsal segments narrowly darkened, last segment brownish, claw with blackish line. LR of hind leg 4.7 : 2.8 : 1.9 (0.41 : 0.41 : 0.35: 0.23 : 0.50).

Abdomen. 10.0 mm; yellowish, without any markings dorso-medially, laterally dark brown coloured (Fig. 39); terga VIII and IX with orange tinge, tergum X light yellow; sterna light yellowish, last sterna (Fig. 40) with subgenital plate broadly rounded; subanal plate tongue-shaped, significantly exceeding the abdomen. Caudal filaments in first third light yellow, up to the end black-brown; dark annulated alternately.

Male, subimagos and larva unknown.

Differential diagnosis. Females of *Thalerosphyrus* sp. A have forewings of the ‘sinuosus’ group (Braasch & Soldán 1984b; Ulmer 1939): costal and subcostal fields with two indistinct umbra-brown spots, the first at the beginning of pterostigmatic region, the second directly to the wing tip. Females of *Thalerosphyrus* species from South-East Asia have a pattern of midline figures on terga like *Thalerosphyrus bishopi* Braasch & Soldán, 1986b, *Thalerosphyrus flowersi* Venkataraman & Sivaramakrishnan, 1987 and *Thalerosphyrus vietnamensis* (Dang 1967) (Nguyen & Bae 2004), whereas female of *Thalerosphyru* sp. A is without such markings (Fig. 39). Another species of the genus *Thalerosphyrus* from Borneo is *T. determinatus* having umbra-brown tinged costal and subcostal fields on forewings in both sexes (‘*determinatus*’ group) and abdomen with conspicuously coloured brown pattern (Braasch: own material; Ulmer 1924: 79). Female of *T. torridus* from Luzon, belonging to the ‘*determinatus*’ group, has an abdomen with reddish pitch-brown terga having blackish margins distally, but without any other pattern (Ulmer 1924: 83).

Comments

Afronurus Lestage, 1924; *Ecdyonurus* Eaton, 1868

One species of Heptageniidae, *Ecdyonurus illotus* Navás known only from a female from Haightplace on Luzon, Philippines (Navás 1933; Hubbard & Pescador 1978), is problematic in its taxonomic status. Braasch & Freitag (2008) have pointed out that this female could be an *Afronurus* following a description of coloration of costal and subcostal fields in the forewings of Navás: ‘Ala anterior ... areis costali et subcostali obscurioribus.’ Navás himself mentioned the similarity of his species with *A. lobatus* (sub nom. *Ecdyonurus lo-*

batus) writing ‘*Similis lobato* Ulm.’ Ulmer (1924: 85) gives the following annotation on the female of *A. lobatus* in his description: ‘die Vorderflügel an der Basis des Costalraumes und in der apikalen Region des Costal- und Subcostalraumes etwas kräftiger getönt, etwa umbrabräunlich.’ Accordingly, *Ecdyonurus illotus* from Haightplace, Luzon belongs to the genus *Afronurus* and is most likely identical with *A. philippinensis*. This conclusion is confirmed by checking specimens of different record places on Luzon and by comparison with its description of Flowers & Pescador, 1995 from the locus typicus. Though, *Ecdyonurus* is said to be a component of Philippine current waters by Wang & McCafferty (2004: 28, Philippines-L). Webb & McCafferty (2008: 51, Fig. 225, *Ecdyonurus*) did not list the genus *Ecdyonurus* from South-East Asia, Philippines in their world map of genera distribution.

The close affinity of *Cinygmina* Kimmins, 1937 to *Afronurus* Lestage, 1924 has been repeatedly confirmed (Flowers & Pescador 1984; Belfiore et al. 2003; Braasch 2005). Hubbard (1990) considered *Cinygmina* a synonym of *Ecdyonurus* Eaton, 1968 in accordance with Tshernova et al. (1986), whereas Kluge (2004) and Wang & McCafferty (2004) synonymized it with *Afronurus*. Recently, Webb & McCafferty (2008) have strengthened this position in their study on world-wide heptageniid genera, speaking only of *Afronurus*. Nevertheless, both are taxonomically strictly separated in male adults, whereas differences between larval stages and eggs are said to be vague and not convincing (Belfiore et al. 2003). On a zoogeographic point of view, however, it is convenient to refer to *Afronurus*, confined in its South-East Asian range, to a part of western Malaysia (Braasch 2005), the Sunda Islands (Ulmer 1939; Braasch 2005) and to the Philippines (Flowers & Pescador 1995; Mol 1987; Braasch 2005; Braasch & Freitag 2008). *Afronurus* species are characterized by vertically extended penis lobes, lacking titillators. In contrast, *Cinygmina* (*Afronurus*) is characterized by penes with expanded lateral lobes and reduced titillators or exceptionally sclerotized titillator plate (Zhou & Zheng 2003). It is distributed in mainland South-East Asia, China including Hainan and Taiwan, Japan, Far East of Russia and Indian subcontinent (You et al. 1981; Venkataraman & Sivaramakrishnan 1989; Braasch & Soldán, 1984; Braasch 1990; Kang & Yang 1994; Zhou & Zheng 2003; Kluge 2004). Based on morphology and zoogeography, it seems that two branches of *Afronurus* and *Cinygmina* (*Afronurus*) exist, which are clearly separated. Considering their differences, at least a subgeneric state could correspond to both of them. Meanwhile, until a better knowledge of their genetic relations is provided, it would be better to speak of *Afronurus* and *Afronurus* (*Cinygmina*).

Recent publications on Ephemeroptera from Thailand (Sites et al. 2001) and Vietnam (Nguyen & Bae 2003) did not comment on the taxonomical differences within *Afronurus*. But all morphospecies found there can be expected to belong to *Cinygmina* (*Afronurus*). From the

zoogeographic point of view, it is conceivable that *Afronurus* spp. of Taiwan (Kang & Yang 1994; Soldán & Yang 2003) are also *Cinygmina* (*Afronurus*).

***Asionurus* Braasch & Soldán, 1986**

The few species of the genus *Asionurus* have remarkable similarity. Thus, an extensive material is required to distinguish clearly all the stages from each other. Therefore, the two specimens mentioned in this study (immature La, female) are not sufficient for a description of a new species, although most likely an endemic of Palawan. Until now, the genus is known from Thailand (Braasch 2006), Vietnam (Braasch & Soldán 1986a), Malaysia (Braasch & Soldán 1986b), Sumatra (Ulmer 1939: sub nom. '*Thalerosphyrus sinuosus* Navás, 1931') and Borneo (Sartori et al. 2003). According to experiences of the author in Thailand, specimens of *Asionurus* are apparently adapted to slow running waters, often restricted to meadow creeks with mixed vegetation, but also to pools, filled up with rotten leaves and fed by spring-trickles.

***Compsoneria* (*Palawaneuria*) *cabayuganensis* Braasch, 2008**

Webb and McCafferty (2008) characterized the features of the genus *Compsoneria* Eaton, 1881 by including 'the presence of ventral spines on the penes'. These are absent in *C. (Palawaneuria) cabayuganensis*, although other features (male), such as colour patterns of abdomen, analogous patterns in shaded forewings, reduced and shaded crossveins, C and SC slightly sigmoidal, alternately annulated caudal filaments and spade-like subanal plate in female are shared with *Compsoneria*. Regardless of these affinities, the author put *C. (Palawaneuria) cabayuganensis* in species *incertae sedis* for the time being, until the larval diagnosis can be provided.

***Epeorella* Ulmer, 1939**

Ulmer (1939) described *E. borneonia* (holotype male, 1 female, 1 SI female) from 'Borneo, Nanga Serawai' [= Indonesia, West Kalimantan, Nangaserawai, -0.33° 112.43°], '12.–18. November, 1924, coll. H. Winkler, in Zoologisches Museum Hamburg'. Wang and McCafferty (2004) regarded *Epeorella* to be synonymous with *Epeorus* referring to a male imago from Indonesian West Malaysia located in the Purdue Entomological Research Collection. The assignment of *Epeorella* to *Epeorus*, apart from minimal size and compact penis type is questionable, because its female presents a particular anal plate being almost square-shaped, not apically emarginated (Ulmer, 1939) as in true *Epeorus*. Provisionally, the author holds on to the genus *Epeorella* until capture of larva would allow its final placement. Webb (2010, pers. comm.) informed

the author that *E. borneonia* has a transverse suture on the mesothorax, whereby it belongs to the Ecdyonurinae and may be possibly aequivalent to *Afronurus* Le-stage.

***Epeorus* Eaton, 1881**

Nearly 30 species of *Epeorus* and *Iron* are known from southern China, the southern slopes of the Himalayas, India, South-East Asia, up to Sundaland including Borneo (Tong & Dudgeon 2003; Kluge 2004; Braasch 2006a, b). Only one species, *E. aculeatus* Braasch, was supplementary described as male adult from South-East Asia (Webb & McCafferty 2006b: Thailand). All other species have been described as larvae only. Their identification should be possible using descriptions by Braasch and Soldán (1979, 1984), Braasch (2006a, b), and keys by Nguyen and Bae (2004a, b). Edmunds and Polhemus (1990) and Iwata et al. (2003) reported the genus from Borneo without species level information. Webb (2010, pers. comm.) recorded, beside *E. boonsoongi*, a single specimen of a further species from Borneo with characters of the subgenus *Belovius* Tshernova, 1981. This suggests that more species of *Epeorus* or *Iron* may occur on the large island Borneo with many different ecological conditions. It is believed that *Epeorus* has spread from peninsular Malaysia (*E. hieroglyphicus* Braasch & Soldán, 1986b) via Sumatra and Java to Borneo. However, up till now, *Epeorus* and *Iron* are missing in the large Archipelago Philippines.

***Thalerosphyrus* Eaton, 1881**

Taxonomical aspects on species level are largely based on males and larvae (Kluge 2004; Wang & McCafferty 2004; Webb & McCafferty 2008). Due to the fact that only two females were available, the author refrains from a new species description of *Thalerosphyrus* sp. A.

Ulmer (1939: 550) distinguished two different lineages in order to identify species within *Thalerosphyrus* in South-East Asia. The first lineage is that of the *T. 'determinatus'* group having red- to umbra-brown stained costal and subcostal fields in forewing together with a larval type with relatively short abdominal posterolateral projections. An example of this is *T. determinatus* from the Sunda Islands. A second undescribed species from Sumatra (fide Webb) and *T. torridus* from Sumatra and the Philippines (Ulmer 1924) belong to this lineage. However, the species identity of *T. torridus* and its origin is questionable. *T. torridus* was described as female sub nom. *Baetis torrida* Walker, 1853 from the Philippines. Eaton (1871) came along with *Heptagenia torrida* and transferred it (1883–1888) to *T. torridus*. Later on, Navás (1922), erroneously, identified a female specimen from Baguio on Luzon as *T. horridus* (Walk.). Ulmer (1924) checked a dry female 'Nr. 101 from Majajajà, Luzon, 4.IV.1860 ex Coll. SELYS, Mu-

seum Brussels' and treated it as matching the holotype of *T. torridus* (Walker). For this reason, he gave a verbal redescription of the female. Additionally, Ulmer (1924: 81–83, figs 48–50) affiliated a Sumatran *T. torridus* male to the female *T. torridus* from Luzon, the Philippines. Now, there is some suspicion that this female could be confounded with *Afronurus* as previously *Ecdyonurus illotus*. Females of the *Thalerosphyrus* 'determinatus' group have analogous forewing stainings as in *Afronurus* species from the Philippines. The female in Ulmer (1924: 83) is characterized by 'Hinterleib, einfarbig rötlich pechfarben, nur die Hinterränder der Segmente schwärzlich, sonst ohne dunkle Zeichnung' but with wings 'wie bei *Th. determinatus* Walk. ... Costal- und Subcostalraum kräftig braun gefärbt'. Both characters combined fit well with an *Afronurus* from Luzon. In contrast to *Afronurus*, females of *Thalerosphyrus* of 'determinatus' group are conspicuously colored by abdominal markings (Ulmer 1924: 79; Braasch: own material). An assumption of a species identity of *T. torridus* (♂) from the home range in Sumatra and *T. torridus* (♀) on the far remote Luzon in the north of the Philippines, is unthinkable with regard to the zoogeographical experience with the island endemism.

The second lineage is the *T. sinuosus* group with imagos having forewings with a patch-like staining in the costal field at the beginning of the pterostigma and in the apex (Ulmer 1939) and, furthermore, a larval type with long and pointed postero-lateral projections on terga VI–VIII (Braasch & Soldán 1984b). This group represents *Thalerosphyrus* species having been transferred to *Ecdyonuroides* Dang, 1967 by Kluge (2004) encompassing *Thalerosphyrus flowersi* (patria India), *T. sumatranus* (Ulmer, 1939) and *T. vietnamensis*. However, the genus *Ecdyonuroides* was synonymized with *Thalerosphyrus* Eaton by Braasch & Soldán (1984b) on the basis of reared *Ecdyonuroides vietnamensis* Dang, 1967, which was recombined to *Thalerosphyrus vietnamensis*.

Webb et al. (2004) again confirmed the previous synonymization of *Ecdyonuroides* with *Thalerosphyrus*. Furthermore, Webb (2006, pers. comm.) has informed the author that *T. sinuosus* has been erroneously recorded in the list of "material examined" species by Wang & McCafferty (2004: 30, 'Philippines-L'). Nevertheless, the distribution map of the genus *Thalerosphyrus* covers the Philippines again in a more recent work (Webb & McCafferty 2008: 53, map 243). The possible presence of a Philippine *T. torridus* in the U.S. Purdue University's collection is to be confirmed (Webb, pers. comm.). Presumably, the current distributional pattern in this region is based on historical references by Ulmer (1924, 1939).

Ecdyonurus sumatranus was described by Ulmer (1939) as a female (holotype) having a cleft subanal plate as usual in *Epeorus* and at the same time with iterated pattern on its terga as often seen in Leptophlebiidae. However, this female is without any tinctures in

the fore wings to be expected both in 'determinatus' and 'sinuosus' groups of *Thalerosphyrus*. The absence of these characters in no case allows the availability of the taxon name *Thalerosphyrus*. Ulmer (1939) suggested a larva to be correctly associated with the female *E. sumatranus* in the same publication. Later on, this larva revealed as a *Thalerosphyrus* belonging to the 'sinuosus' group. Consequently, the species name *sumatranus* is not available for larva 'sumatranus'. The record of *Thalerosphyrus* (♀) of the 'sinuosus' group is the first in Borneo. Interestingly, Sartori et al. (2003) did not spot any *Thalerosphyrus* in Eastern Borneo (Kalimantan, Indonesia), although long-termed ephemeropterological studies have been carried out there. It may be that the larva from Sumatra belongs to the female of *Thalerosphyrus* sp. A ('sinuosus' group) from Borneo. On no account, it could pertain to *Thalerosphyrus torridus* ('determinatus' group) from Sumatra.

The recently published *Thalerosphyrus separatus* Nguyen & Bae, 2004b from Vietnam cannot be assigned to this genus, because its specimens are without the typical wing characters of this genus (see above), but look more like an *Cinygmina* (*Afronurus*) having a bilobed penis. Unfortunately, male genitalia are only succinctly illustrated; the possible existence of reduced titillators is neither recognizable nor mentioned. However, the larva has particular labial characters, e.g. the rounded glossae apically, that are not in conformity with those of *Thalerosphyrus*. The hypopharynx makes a rather odd impression in account of its short lingua and narrow supralinguae. Furthermore, there is no indication of acutely pointed supracoxal spurs present in true *Thalerosphyrus* (Webb & McCafferty 2008).

Zoogeographical viewpoints

Pleistocene events regarding the changes of continental and island flooding during the glacial times have caused the spread and radiation of the genus *Afronurus* within a period of 200,000 years (McCafferty 1999).

The trans-oceanic origins of *Afronurus* and *Compso-neuria* to Africa is not subject of discussion here (Schonbee 1968; Mey 2005; Monaghan et al. 2005; Webb et al. 2006). Coming from the order Trichoptera (*Hydropsyche*), Mey (2003) stated that 'at present one cannot be sure whether or not the vicariance hypothesis is a valid concept' for the Philippines, and 'The dispersal scenario must be accepted as fact, at least since Pleistocene times'.

The recent stock of Heptageniidae species lets recognise that the archipelago was inhabited by dispersal events with origin almost from Borneo. As happened in Hydropsychidae (Mey 2003), it may be assumed that the glacial periods repeatedly facilitated the migration of Heptageniidae in the Philippines. Once, 'when the sea level was lowered and the many islands fused to a few mega-islands, the species could easily spread over large areas' (Heany 1985), once 'intra-archipelagic dis-

persal crossing the sea channels' (Mey 2003) was chance for further speciation and ramification of Heptageniidae. According to the above mentioned author, the immigration routes might have been from Borneo through Palawan to Mindoro in the West, and from Borneo over the Sulu islands to Mindanao in the East.

The extant genera of Heptageniidae in the Philippines comprise *Afronurus*, *Atopopus* (throughout the Philippines) and *Asionurus* (Isl. Palawan) as well as *Compsoeuria* (Isl. Palawan) in a limited way. *Compsoeuria* (*Palawaneuria*) on Palawan and a particular *Afronurus* of Luzon require a taxonomic clarification before a zoogeographic classification may be assigned.

The most frequent genus in the archipelago is *Afronurus*, and its investigation revealed that speciation went along with island isolation. So far, all found *Afronurus* in the Philippines are endemics to their inhabited islands (Ulmer 1924; Flowers & Pescador 1984; Braasch 2005; Braasch & Freitag 2008). The recent experience shows that 1–2 species of *Afronurus* occur on every major island of the Philippines with a view to elevations and their ecological conditions.

Surprisingly, the genus *Afronurus* is comparatively poorly represented in Sumatra and Java. Only *A. javanicus*, a species unlike all other *Afronurus* of the region having odd knob-like penis lobes is known up till now. Mey (2003) confirmed in a way the above mentioned zoogeographic relations regarding rheobiont *Hydropsyche*; he wrote 'that species on Borneo ... have their closest relatives in the Philippines and not in Sundaland'.

The gradual colonization of the Philippines from Borneo suggests that northern-most Luzon would be reached at the latest. The distribution of *A. philippinensis* on the large Isl. Luzon seems to confirm this assumption. The reason why is the hardly measurable differentiation within the species here. Its penial type with the diverging cylindrical penis lobes (Flowers & Pescador 1984) is, except for small indistinct differences, obviously omnipresent in Luzon where it was originally found in low reaches of Molavin creek in an altitude of 300 m and now across the island up to almost 1650 m above sea level.

So, the *A. philippinensis* complex on Luzon could indicate the latest, not yet accomplished process of species diversification in the history of *Afronurus* spreading across the archipelago. However, starting from Borneo, a swarm formation like that in *Hydropsyche* with its numerous species in the Philippines has in no way occurred with *Afronurus*.

More knowledge about the distributional pattern of related *Afronurus* species from Borneo will be obtained by studying several different morphs (sub name *Cinygmina* spp.) found in southeastern Kalimantan (Sartori et al. 2003). A future increase in the number of species, recognizing their genetic stand, will improve the current picture of the relations between species of the Philippines islands and likewise of Borneo. Morphologically, evidence is for close relation of *A. bruneiensis* from

Borneo (Braasch 2005: 117, figs 18–19 to *A. panayensis* sp. n. (Panay, Philippines) with their jagged penis tips. Among the species of Borneo, those should be found, which indicate the origin of species in the Philippines. However, Monaghan et al. (2005) have pointed out that 'unilateral dispersal (i.g. *Baetidae*) is too simplistic', and it is noted that morphological comparisons alone are not reliable enough, but the implementation of 'a phylogenetic analysis' is needed.

With the exception of *Compsoeuria* (*Palawaneuria*), all Heptageniidae genera of the Philippines exist on Borneo as well, and constitute there, in particular *Afronurus* and *Atopopus*, a conspicuous part of the fauna. As with the Heptageniidae in the Philippines, examined so far, all species of the same genera on Borneo are endemics.

An assumption, in which direction exchange of Heptageniidae species has taken place in adjacent regions is currently speculative. Monaghan et al. (2005) argued that in *Baetidae* 'dispersal was most recent and frequent in species that spend the larval stage in standing water, adding to evidence that these evolutionarily unstable habitats may select for ecological traits that increase dispersal', and further 'that habitat type is an important predictor of aquatic insect range size'. Looking on *Compsoeuria* and *Asionurus* and their occurrence on Palawan, they are species with a relatively considerable spread in South-East Asia and may be expected to be species of broader ecological licenses, in particular lowered oxygen demands. Especially, this could apply to *Compsoeuria* as inhabitants of flat and slowly moving current waters with river-side submerge vegetation in the plain. This habitat has great consistency along coast-lines and is to be an available habitat during changes of water level. Somewhat less, this may be valid for *Asionurus* often living in leaf-filled pools fed by trickles or meadow brooks in low elevations. In accordance with their wide distribution in South-East Asia, their habits could have enabled *Compsoeuria* and *Afronurus* to more frequent and successful dispersal in the past.

Atopopus in the Philippine Archipelago is represented by *A. meyi* and *A. tibialis* which are seen to be derived from the Borneonian *A. tarsalis* and *A. edmundsi*. Therefore, Wang & McCafferty (1995) have delivered good arguments, for example, the apomorph acute angled hind wings of both species in the Philippines. The occurrence of *Atopopus* in the North of Palawan is questionable, because to date, despite many benthological activities for years (Freitag 2004b; Braasch & Freitag 2008), there is no evidence of its presence. Likewise, so far, they were missing on Mindoro. This suggests a preliminary conclusion that the ancestral *Atopopus* could have immigrated to the Philippines on the eastern route.

The reported occurrence of a larva of genus *Ecdyonurus* Eaton in the Philippines by Wang & McCafferty (2004) was puzzling with regard to its origin and real ranking. The only species from Sundaland having link

to the clade *Ecdyonurus*–*Nixe* so far, is *Rhithrogeniella ornata* Ulmer, 1939 from Java and Central Sumatra, not yet found in Borneo. A close relative to *R. ornata* is *Rhithrogeniella tonkinensis* Soldán & Braasch, 1986 from the mainland in Vietnam, Thailand and South China most likely identical with *Afronurus sangangensis* You et al., 1982. These species represent more likely a derived type from genus *Nixe* Flowers, 1980 (Kang & Yang 1994; Soldán & Yang 2003; Braasch 2006), where striking peculiarities, the so-called ‘scales and different setae types’ at caudal filaments are obvious (Soldán & Braasch 1986: 207, figs 14–15, *R. tonkinensis*). Descendants with similar characters were found on the large island Taiwan by Kang & Yang (1994), viz *Nixe littoralis*, *Nixe littorosus*, *Nixe obscurus* and *Nixe nitificus*. However, the taxonomic relevance is not evident without having checked their genetic background.

Compsoneturia (*Palawaneuria*) in Palawan is close to *Compsoneturia* from the outer appearance, but in view of the genitals quite different. The larval stage is unknown. Up till now, it is not reported from mainland or Sundaland and keeps the question open, where it has derived from.

Currently, it seems that the genus *Thalerosphyrus* reached Sundaland inclusively Borneo, but not the Philippines (Edmunds & Polhemus 1990). However, Borneo and the Philippines are included in the world-wide distribution map of *Thalerosphyrus* by Webb & McCafferty (2008). Whereas the incidence of *T. determinatus* in Borneo was confirmed (Wang & McCafferty 2004), older information is not reliable on the occurrence of the genus in the Philippines (s. above). An acquisition of additional data, including recent molecular phylogenetic studies, will be needed to elucidate the taxonomic status of questionable species and the migration routes from the countries of origin.

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References

- Belfiore, C., Barber-James, H. & Gaino, E. 2003. The eggs of *Afronurus* Lestage, 1924 (Ephemeroptera: Heptageniidae): A cue for phylogenetic relationships. *In* Gaino E. (ed.). Research update on Ephemeroptera & Plecoptera. Università di Perugia. Perugia, Italy: pp. 113–116.
- Braasch, D. 1990. Neue Eintagsfliegen aus Thailand, nebst einigen Bemerkungen zu deren generischem Status (Insecta, Ephemeroptera: Heptageniidae). – *Reichenbachia* 28 (2): 7–14.
- Braasch, D. 2005. Neue Arten der Gattung *Atopopus* und *Afronurus* aus Südostasien sowie einige Bemerkungen zur Gattung *Asionurus* von Malaysia (Insecta: Ephemeroptera: Heptageniidae). – *Entomologische Abhandlungen* 62 (2): 165–174.
- Braasch, D. 2006a. Kritische Anmerkungen zur Taxonomie einiger Heptageniidae (Ephemeroptera) aus Mittelasien und dem Fernen Osten. – *Entomologische Nachrichten und Berichte* 50: 197–204.
- Braasch, D. 2006b. *Iron suspicatus* n. sp. (Ephemeroptera, Heptageniidae) aus Nepal und aus dem Kulu-Valley des Himalaja in Indien. – *Entomologische Nachrichten und Berichte* 50 (3): 125–128.
- Braasch, D. & Freitag, H. 2008. *Palawaneuria*, a new subgenus of *Compsoneturia* and new species of *Compsoneturia* and *Afronurus* (Ephemeroptera, Heptageniidae) from Palawan, Philippines. – *Deutsche Entomologische Zeitschrift* 55 (1): 117–128.
- Braasch, D. & Soldán, T. 1979. Neue Heptageniidae aus Asien (Ephemeroptera). – *Reichenbachia* 17 (31): 261–272.
- Braasch, D. & Soldán, T. 1984. Eintagsfliegen (Gattungen *Epeorus* und *Iron*) aus Vietnam (Ephemeroptera, Heptageniidae). *In* Landa V., Soldán T. & Tonner M. (eds). Proceedings of the Fourth International Conference on Ephemeroptera. Institute of Entomology, Czechoslovak Academy of Sciences, České Budejovice: pp. 109–114.
- Braasch, D. & Soldán, T. 1984a. Zwei neue Arten der Gattung *Cinygmmina* Kimmins, 1937 aus Vietnam. (Ephemeroptera, Heptageniidae). – *Reichenbachia* 22 (26): 195–200.
- Braasch, D. & Soldán, T. 1984b. Beitrag zur Kenntnis der Gattung *Thalerosphyrus* Eaton, 1881 im Hinblick auf die Gattung *Ecdyonuroides* Thanh, 1967 (Ephemeroptera, Heptageniidae). – *Reichenbachia* 22 (27): 201–206.
- Braasch, D. & Soldán, T. 1986a. *Asionurus* n. gen., eine neue Gattung der Heptageniidae aus Vietnam (Ephemeroptera). – *Reichenbachia* 23 (28): 155–159.
- Braasch, D. & Soldán, T. 1986b. Die Heptageniidae des Gombak-River in Malaysia (Ephemeroptera). – *Reichenbachia* 24 (3): 41–52.
- Braasch, D. & Soldán, T. 1988. *Trichogenia* gen. n., eine neue Gattung der Eintagsfliegen aus Vietnam (Insecta, Ephemeroptera, Heptageniidae). – *Reichenbachia* 25: 119–124.
- Dang, Ngoc Thanh, 1967. New genera, new species of the invertebrate fauna of fresh and brackish waters of North Vietnam (in Vietnamese). – *Sinh Vật Địa Học* 6: 155–165.
- Eaton, A. E. 1868. Remarks upon the homologies of the ovipositor. – *Transactions of the Entomological Society*: 141–144.
- Eaton, A. E. 1871. A monograph on the Ephemeridae. – *Transactions of the Entomological Society of London* 1: 1–164.
- Eaton, A. E. 1881. An announcement of new genera of the Ephemeridae. – *Entomologist's Monthly Magazine* 18: 21–27.
- Eaton, A. E. 1883–1888. A Revisional Monograph of Recent Ephemeridae or Mayflies. – *Transactions of the Linnean Society of London, Section Series Zoology* 3: 1–352.
- Edmunds, G. F. & Polhemus, D. A. 1990. Zoogeographical patterns among mayflies (Ephemeroptera) in the Malay Archipelago, with special reference to Celebes. *In* Knight, W. J. & Holloway, J. D. (eds). *Insects and the Rain Forests of South East Asia* (Wallacea). The Royal Entomological Society of London, London: pp. 49–56.
- Flowers, R. W. 1980. Two new genera of Nearctic Heptageniidae (Ephemeroptera). – *Florida Entomologist* 63: 296–307.
- Flowers, R. W. & Pescador, M. 1984. A new *Afronurus* (Ephemeroptera: Heptageniidae) from the Philippines. – *International Journal of Entomology* 26 (4): 362–365.
- Freitag, H. 2004. Composition and longitudinal patterns of aquatic insect emergence in small rivers of Palawan Island, the Philippines. – *International Revue of Hydrobiology* 89 (4): 375–391.

- Heany, L. 1985. Zoogeographic evidence for middle and late Pleistocene land bridges to the Philippines. – *Modern Quaternary Research SE Asia* 9: 127–143.
- Hubbard, M. D. 1990. Mayflies of the world. A catalogue of the family genus group taxa (Insecta: Ephemeroptera). – *Flora and Fauna Handbook No. 8*, Sandhill Crane Press, Inc., Gainesville, Florida.
- Hubbard, M. D. & Pescador, M. L. 1978. A catalog of the Ephemeroptera of the Philippines. – *Pacific Insects* 19: 91–99.
- Iwata, T., Nakano, S. & Inoue, M. 2003. Impacts of past riparian deforestation on stream communities in a tropical rain forest in Borneo. – *Ecological Applications* 13: 461–473.
- Kang, S. C. & Yang, C. T. 1994. Heptageniidae of Taiwan (Ephemeroptera). – *Journal of Taiwan Museum* 47 (1): 5–36.
- Kimmins, D. E. 1937. Some new Ephemeroptera. – *Annals and Magazine of Natural History* (10) 19: 430–440.
- Kluge, N. 2004. *The Phylogenetic System of Ephemeroptera*. Kluwer Academic Publishers, Dordrecht, Boston, London.
- Lestage, J. A. 1924. Les Ephémères de l'Afrique du Sud. Catalogue critique et systématique des espèces connues et description de trois genres nouveaux et de sept espèces nouvelles. – *Revue Zoologique Africaine* 12: 316–352.
- McCafferty, W. P. 1999. Biodiversity and Biogeography: examples from global studies of Ephemeroptera. – *Proceedings Symposium Nature Conservation. Entomology 21st Century. The Entomological Society of Korea*, Nov. 5, 1999: pp. 3–22.
- Mey, W. 2003. Insular radiation of the genus *Hydropsyche* (Insecta, Trichoptera: Hydropsychidae) Pictet, 1834 in the Philippines and its implications for the biography of Southeast Asia. – *Journal of Biogeography* 30: 227–236.
- Mey, W. 2005. Genuine Africans or Tertiary immigrants? – The genus *Hydropsyche* in the Afrotropical region (Insecta, Trichoptera: Hydropsychidae). In Huber, B. A., Sinclair, B. J. & Lampe, K.-H. (eds). *African Biodiversity*. Springer, Berlin: pp. 141–150.
- Mol, A. 1987. *Afronurus sibuyanensis* spec. nov., a new mayfly from the Philippines (Ephemeroptera: Heptageniidae). – *Opuscula zoologica fluminensia* 15: 1–9.
- Monaghan, M. T., Gattolliat, J.-L., Sartori, M., Elouard, J.-M., James, H., Derleth, P., Glaizot, O., deMoor, F. & Vogler, A. P. 2005. Trans-oceanic and endemic origins of the small minnow mayflies (Ephemeroptera, Baetidae) of Madagascar. – *Proceedings of the Royal Society* 272: 1829–1836.
- Navás, R. P. L. 1922. Ephemeropteros nuevos o poco conocidos. – *Boletín de la Sociedad Entomológica de España* 5: 54–63.
- Navás, R. P. L. 1933. Insecta Orientalia, XII. Series, Neuroptera. – *Memorie della Pontefica Academia de Science Nuovi Lincei* 17: 75–108.
- Nguyen, V. V. & Bae, Y. J. 2003. Two new species of *Afronurus* (Ephemeroptera: Heptageniidae) from Vietnam. – *Korean Journal of Entomology* 33 (4): 257–261.
- Nguyen, V. V. & Bae, Y. J. 2004a. Larvae of the heptageniid mayfly genus *Epeorus* (Ephemeroptera: Heptageniidae) from Vietnam. – *Journal of Asia-Pacific Entomology* 7: 19–28.
- Nguyen, V. V. & Bae, Y. J. 2004b. Two Heptageniid Mayfly Species of *Thalerosphyrus* Eaton (Ephemeroptera: Heptageniidae) from Vietnam. – *The Korean Journal of Systematic Zoology* 20 (2): 215–223.
- Sangpradub, N., Hanjavanit, C. & Boonsoong, B. 2002. New records of Heptageniid Mayflies *Asionurus* and *Thalerosphyrus* (Ephemeroptera: Heptageniidae) from Northeastern Thailand. – *Science Asia* 28: 411–416.
- Sartori, M., Derleth, P. & Gattolliat, J.-L. 2003. New data about the mayflies (Ephemeroptera) from Borneo. – *Research Update on Ephemeroptera & Plecoptera* (ed.: Elda Gaino) Università de Perugia, Perugia-Italy 2003: pp. 403–406.
- Sartori, M., Derleth, P. & Webb, J. M. 2007. The nymph of *Atopopus tarsalis* Eaton, 1881 (Ephemeroptera, Heptageniidae): first description, ecology and behaviour. – *Zootaxa* 1586: 25–32.
- Schonbee, H. J. 1968. A revision of the genus *Afronurus* Lestage (Ephemeroptera): Heptageniidae in South Africa. – *Memoirs of the Entomological Society of Southern Africa* 10: 1–46.
- Sites, R. W., Wang, T., Permkam, S. & Hubbard, M. D. 2001. The mayfly genera (Ephemeroptera) of Southern Thailand. – *The Natural History Bulletin of the Siam Society* 49: 243–268.
- Soldán, T. & Braasch, D. 1986. *Rhithrogeniella tonkinensis* sp. n. (Ephemeroptera, Heptageniidae) from Vietnam, with description of the nymphal stages and biology of the genus. – *Acta Entomologica Bohemoslovaca* 83: 202–212.
- Soldán, T. & Yang, J.-T. 2003. Mayflies (Ephemeroptera) of Taiwan: Species composition, taxonomic shifts, distribution and biogeographical analysis. – *Research Update on Ephemeroptera & Plecoptera* (Ed. Elda Gaino), Università de Perugia, Perugia, Italia 2003: pp. 413–420.
- Tong, X.-L. & Dudgeon, D. 2003. Two new species of Heptageniidae from China (Insecta, Ephemeroptera). – *Acta Zootaxonomica Sinica* 28: 469–473.
- Tshernova, O. A. 1974. Rodovoj Sosstav podjenok sem. Heptageniidae (Ephemeroptera) v Golarktikje i Orientalnoj oblasti. – *Entomologitsheskoje Obozrenije* 51: 801–814.
- Tshernova, O. A. 1981. K sistematike imago podenok roda *Epeorus* Eaton, 1881 (Ephemeroptera, Heptageniidae). – *Entomologitsheskoje Obozrenije* 60: 323–336.
- Tshernova, O. A., Kluge, N. Yu., Sinitshenkova, N. D. & Belov, V. V. 1986. 5. Otrjad Ephemeroptera – Podenki (in Opredelitelj nasekomych Daljnevo Vostoka SSSR v 6 tomach) Leningrad 1: 99–142.
- Ulmer, G. 1920. Neue Ephemeropteren. – *Archiv für Naturgeschichte* 85: 1–80.
- Ulmer, G. 1924. Ephemeropteren von den Sunda-Inseln und den Philippinen. – *Treubia* 6: 28–91.
- Ulmer, G. 1939. Eintagsfliegen (Ephemeroptera) von den Sunda-Inseln. – *Archiv für Hydrobiologie, Supplement* 16: 443–692.
- Venkataraman, K. & Sivaramkrishnan, K. G. 1987. A new species of *Thalerosphyrus* from South India (Ephemeroptera: Heptageniidae). – *Current Science* 56 (21): 1126–1129.
- Venkataraman, K. & Sivaramkrishnan, K. G. 1989. A new species of *Cinygmina* (Ephemeroptera: Heptageniidae) from South India and reevaluation of generic traits of *Cinygmina* Kimmins 1937. – *Hexapoda (Insecta Indica)* 1 (1–2): 117–121.
- Walker, F. 1853. List of the specimens of neuropterous insects in the collection of British Museum. – *Termitidae–Ephemeridae* 3: 477–585.
- Walsh, B. D. 1863. Observations on certain N. A. Neuroptera, by H. Hagen, M. D., of Koenigsberg, Prussia; translated from original French ms., and published by permission of the author, with notes and descriptions of about 20 new N. A. species of Pseudoneuroptera. – *Proceedings of the Entomological Society of Philadelphia* 1862 (2): 167–272.
- Wang, T.-Q. & McCafferty, W. P. 1995. First larval descriptions, new species, and evaluation of the Southeast Asian genus *Atopopus* (Ephemeroptera, Heptageniidae). – *Bulletin de la Société d'Histoire Naturelle de Toulouse* 131: 19–25.
- Wang, T.-Q. & McCafferty, W. P. 2004. Heptageniidae (Ephemeroptera) of the World. Part I: Phylogenetic higher classification. – *Transactions of the American Entomological Society* 130 (1): 11–45.
- Webb, J. M., Braasch, D. & McCafferty, W. P. 2006. Reevaluation of the genera *Compsoeuria* Eaton and *Trichogenia* Braasch & Soldán (Ephemeroptera: Heptageniidae). – *Zootaxa* 1335: 55–68.
- Webb, J. M. & McCafferty, W. P. 2006. First description of the adult male of *Epeorus aculeatus* Braasch (Ephemeroptera, Heptageniidae). – *Zootaxa* 1277: 65–68.
- Webb, J. M. & McCafferty, W. P. 2007. A new genus and species of Heptageniidae (Ephemeroptera) from Borneo, with revisions to the classification of the Ecdyonurinae. – *Zootaxa* 1478: 41–48.

-
- Webb, J. M. & McCafferty, W. P. 2008. Heptageniidae of the world. Part II: Key to the genera. – Canadian Journal of Arthropod Identification 7: 1–55.
- You, D.-S., Wu, T. & Gui, H. 1981. Two new species and diagnostic characters of genus *Cinygmina* (Ephemeroptera: Ecdyonuridae). – Journal of Nanjing Normal College (Nature Science) 3: 26–31.
- You, D.-S., Su, C.-R. & Hsu, Y.-C. 1982. A new species of the genus *Afronurus* from Fujian Province (Ephemeroptera: Heptageniidae). – Journal of Nanjing Normal College (Nature Science) 4: 61–65.
- Zhou, C.-F. & Zheng, L.-Y. 2003. The genus *Cinygmina* (Ephemeroptera: Heptageniidae) in China, with a description of a new species. – Acta Entomologica Sinica 46 (6): 755–760.
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