

Preliminary study on the diversity of Orthoptera from Kuala Belalong Field Studies Centre, Brunei Darussalam, Borneo

MING KAI TAN¹, RODZAY BIN HAJI ABDUL WAHAB²

¹ Department of Biological Sciences, National University of Singapore, 14 Science Drive 4, Singapore 117543, Republic of Singapore.

² Institute for Biodiversity and Environmental Research, Universiti Brunei Darussalam, Jalan Universiti, BE1410, Brunei Darussalam.

Corresponding author: *Ming Kai Tan* (orthoptera.mingkai@gmail.com)

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Abstract

The Orthoptera, comprising grasshoppers, crickets, and katydids, is diverse and species rich in tropical Southeast Asia, including the island of Borneo. However, not every part of Southeast Asia is equally well sampled and studied. This includes Brunei Darussalam, specifically at the Kuala Belalong Field Studies Centre (KBFSC) within the Ulu Temburong National Park. We present here an annotated and illustrated checklist of Orthoptera from the primary dipterocarp forest around Kuala Belalong based on three field trips in 2016 and 2017. We provide notes on their taxonomy (including how each species was identified) and natural history of species. In total, 72 species were recorded, representing eight of the 16 monophyletic orthopteran superfamilies. In total, 73.6% of all species recorded were singletons and doubletons, indicating that many species are probably rare. The collection led to the discovery of ten species new to science already published separately, with more expected to be described from pending material and confirmation. More species, including undescribed ones (at least four new species), are expected with continued sampling effort. Despite the 21 day-long surveying efforts from three trips around KBFSC, we believe that the species list provided here is non-exhaustive and only a preliminary one.

Key words

checklist, diversity, natural history, Southeast Asia, species richness, taxonomy

Introduction

Orthoptera is an order of insects consisting of grasshoppers (suborder Caelifera), and crickets and katydids (suborder Ensifera). These are among the most diverse (around 28,000 species worldwide) and common terrestrial macro-invertebrates (Cigliano et al. 2018). There are about 2,000 species from Southeast Asia (Tan et al. 2017a). While some species are notoriously considered as agricultural pests (Willemse 2001), these species represent a small proportion of the overall diversity of orthopterans. In fact, far more species could be found hiding in the pristine forests from Southeast Asia.

Southeast Asia is made up of numerous biodiversity hotspots (Myers et al. 2000), yet, the knowledge of orthopteran diversity in this region is not completely understood, with some regions less surveyed than others (Tan et al. 2017a). So, although species new to science are continuously being described from this region, even more can be expected with further intensive surveys into uncharted parts of Southeast Asia.

On the island of Borneo, pockets of forests remained unstudied for orthopterans. This includes Brunei Darussalam, particularly in the Temburong District (Fig. 1). Within the primary dipterocarp forest of Ulu Temburong National Park lies the Kuala Belalong Field Studies Centre (KBFSC) (Fig. 2A). KBFSC, located along Sungai (= river in Malay) Belalong (Fig. 2B), is under the charge of Universiti (= University, in Malay) Brunei Darussalam. Sungai Belalong forms part of the Sungai Temburong drainage basin which is 1,100 km² and is the third largest catchment in Brunei Darussalam. While a huge range of biodiversity surveys were conducted in the field studies center since its opening in 1990, orthopteran diversity around KBFSC remained understudied and overlooked. There was no concerted effort to sample and examine the orthopterans there.

In 2016 and 2017, surveys were conducted around the forests of Kuala Belalong with the objectives of discovering species new to science, collecting new material for taxonomic treatments, and making revisions of poorly known or problematic taxa, as well as to present an annotated checklist of Orthoptera from KBFSC. While new species discovery and taxonomic treatments were published separately in taxonomic journals (Tan and Wahab 2017a, b, Tan et al. 2017c, d), we present here the first annotated and illustrated checklist of Orthoptera from KBFSC based on the collections made in 2016 and 2017. We provide references and notes on the taxonomy (including how each species was identified) and natural history of each species, whenever possible. While some of the species could not be promptly identified owing to the insufficient material, we aim to use this publication as a baseline for future work on the taxonomy of Orthoptera from Brunei Darussalam and Southeast Asia.

Materials and methods

Surveys were conducted by the first author (MKT) in the primary lowland and ridge dipterocarp forests (Fig. 2C) surrounding the KBFSC, Ulu Temburong National Park, Brunei Darussalam (Fig. 1) in September 2016, January 2017, and July 2017. Two main sites were surveyed: Ashton Trail (including the route to Sungai Mata Ikan) located behind the field studies center (Fig. 2D), as well as slightly downstream where the Ulu Ulu Resort and Canopy Tower of the Ulu Temburong National Park are located (Fig. 2E). Opportunistic collecting and sweep-netting were conducted during daytime (0830 to 1500 hours) and/or during night time (1930 to 2300 hours) (Fig. 2F). Light-trapping was also conducted by switching on the corridor lights on the laboratory building facing Sungai Belalong. Whenever possible, acoustic recordings of calling songs were done using the video-recording function of a Canon EOS 500D digital SLR camera or with a digital sound recorder (Olympus WS-750M, frequency response 40–21,000Hz). The specimens were preserved in absolute analytic-grade ethanol and later pinned and dry-preserved. A single hind leg was preserved in absolute analytic-grade ethanol for future molecular work.

Habitus images were made with a Canon EOS 500D digital SLR camera with a compact-macro lens EF 100mm f/2.8 Macro USM. Close-up images of morphological features (including male genitalia) were done using a Canon EOS 50D digital SLR camera with a macro photo lens MP-E 65mm f/2.8 USM (1-5x). Canon Macro Twin Lite MT-24EX and Canon Macro Ring Lite MR-14EX were used for lighting and flash. Image editing was accomplished using Adobe Photoshop CC 2014. Scales were given with the images. Acoustic analysis was done using the open source R package WarbleR (Araya-Salas and Smith-Vidaurre 2017) or Sound Ruler software.

Specimens were identified by the authors using relevant, published keys and descriptions (see remarks for each species) and by comparisons of voucher specimens and type specimens (sometimes only images available). Where doubtful, the identities of the orthopteran specimens were verified by orthopterists: Andrej V. Gorochov (for Grylloidea), Sigfrid Ingrisch (for Tettigonioidae), Tony Robillard (for Eneopterinae), Luc Willemse (for Acridoidea), Josip Skejo (for Tetrigoidea), Josef Tumbrinck (for Tetrigoidea), Sergey Storozhenko (for Tetrigoidea), and Xingbao Jin (for Tettigonioidae).

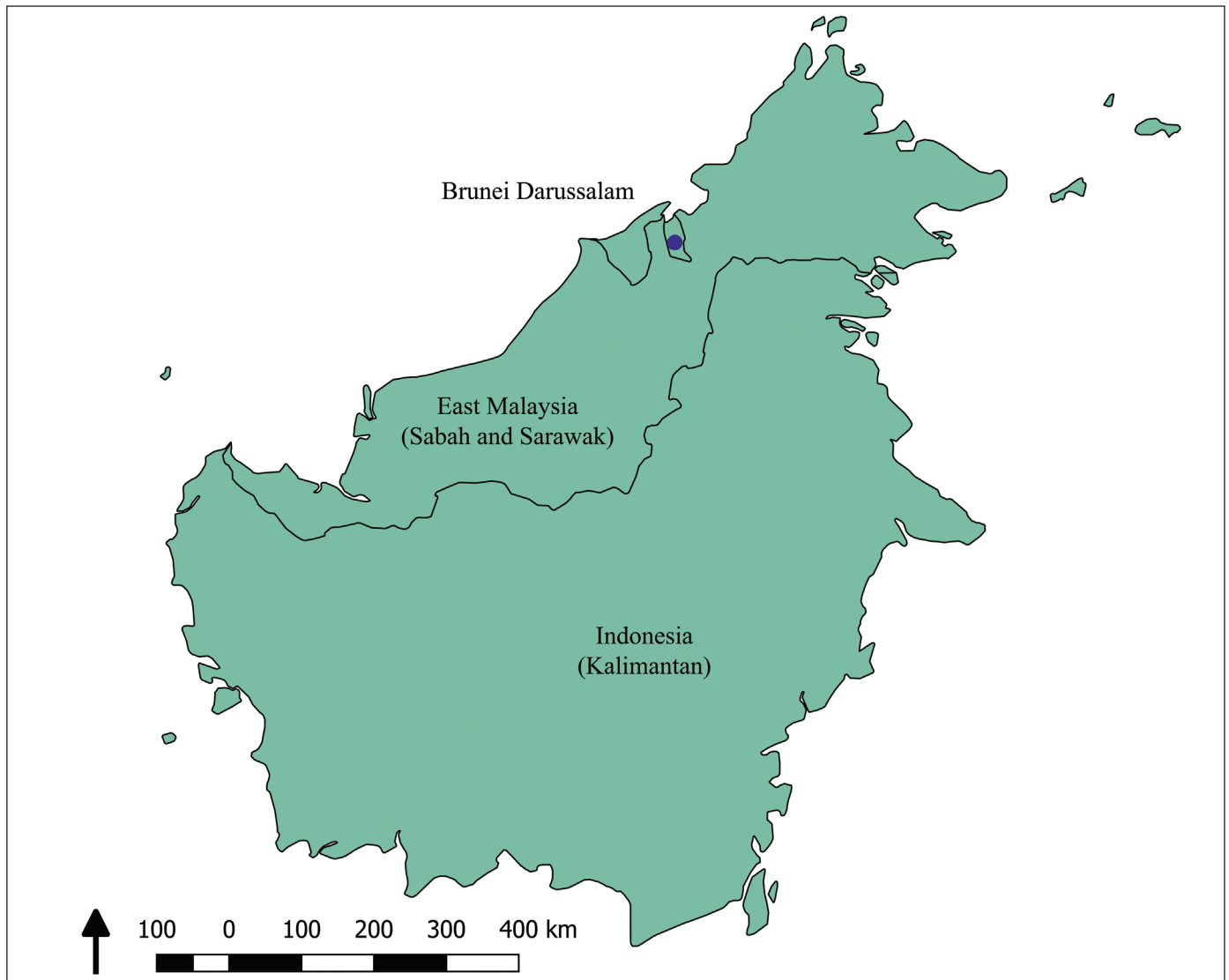


Fig. 1. Map of the island of Borneo with the dot indicating the location of KBFSC in Brunei Darussalam.



Fig. 2. Environment of KBFSC and surrounding habitats: A. View of the KBFSC from Sungai Belalong; B. View of Sungai Belalong from KBFSC; C. Afternoon view of the canopy on the ridge along Ashton Trail; D. Sungai Mata Ikan, a small forest stream near KBFSC; E. Morning view of the canopy at Ulu Temburong National Park; F. Dusk time at the Canopy Tower.

Classification and nomenclature of species were based on the Orthoptera Species File (OSF) Online Version 5.0/5.0 (Cigliano et al. 2018). The families, subfamilies, and genera are arranged alphabetically for ease of reference. All specimens collected will eventually be deposited in Institute for Biodiversity and Environmental Research (IBER), Universiti Brunei Darussalam and Zoological Reference Collection (ZRC), Lee Kong Chian Natural History Museum (former Raffles Museum of Biodiversity Research), National University of Singapore.

Results and discussion

Overall, 72 species representing nine families were collected between 2016 and 2017 (Table 1). The species from KBFSC represent eight of the sixteen monophyletic orthopteran superfamilies (*sensu* Song et al. 2015), thus covering 50% of the lineages in the orthopteran phylogeny. As expected, the monophyletic suborder Ensifera is represented with more species (53 species, 73.6%) than monophyletic suborder Caelifera (19 species, 26.4%). The

Table 1. A summary of the coverage of orthopteran superfamilies and families that were represented in the collection in KBFSC.

	Ranking	Nomenclature	Species Richness
1.	Order	Orthoptera	
1.1.	Suborder	Caelifera	
1.1.1.	Superfamily	Acridoidea	5
1.1.1.1.	Family	Acrididae	
1.1.2.	Superfamily	Tetragoidea	13
1.1.2.1.	Family	Tetrigidae	
1.1.3.	Superfamily	Trigonopterygoidea	1
1.1.3.1.	Family	Trigonopterygidae	
1.2.	Suborder	Ensifera	
1.2.1.	Superfamily	Grylloidea	21
1.2.1.1.	Family	Gryllidae	
1.2.1.2.	Family	Mogoplistidae	
1.2.2.	Superfamily	Gryllotalpoidea	1
1.2.2.1.	Family	Gryllotalpidae	
1.2.3.	Superfamily	Rhaphidophoroidea	1
1.2.3.1.	Family	Rhaphidophoridae	
1.2.4.	Superfamily	Stenopelmatoidea	5
1.2.4.1.	Family	Gryllacrididae	
1.2.5.	Superfamily	Tettigonioidea	25
1.2.5.1.	Family	Tettigoniidae	

most speciose groups are the Tettigonioidea (34.7%), followed by Grylloidea (29.2%), and Tetragoidea (18.1%). On the other hand, Trigonopterygoidea and Rhaphidophoroidea are only represented by a single species each. So far, ten species new to science had been described based on material from the collection. From the collection, 38 species (52.8%) recorded were singletons, whereas 15 species (20.8%) recorded were doubletons. This represents 73.6% of all species recorded, indicating that many species in the forest are likely to be rare and difficult to collect. More species, including undescribed ones (at least four new species), are expected with continued sampling effort. Despite the 21 day-long surveying efforts from three trips, we believe that the species list provided here is non-exhaustive and only a preliminary one.

Checklist

Order Orthoptera
Suborder Caelifera
Superfamily Acridoidea
Family Acrididae

1. *Craneopsis* sp.
Fig. 3

Remarks.—We tentatively identified this species to be close to *C. olivacea* Ramme, 1941. Both adults and nymphs of the species were found on *Citrus limon* at KBFSC. The grasshoppers feed on the leaves, and appear to prefer the older leaves to the younger ones. We identified our species based on the key to species by Willemse (1956) as well as images of type specimens (courtesy of L. Willemse). To date, this genus is endemic to Borneo. The male phallus was previously unexamined. Virtually nothing is known about the life history of these elusive grasshoppers.

2. *Perakia* sp.
Fig. 4A

Remarks.—We tentatively identified this species to be near to *P. borneensis* Willemse, 1936. This cryptic grasshopper was found on tree branches in the dipterocarp forest. The brown and elongated habitus of the grasshopper enables it to camouflage on branches. Interestingly, they were only encountered after the rain, perhaps suggesting that it is a canopy species, brought down to the understory by the rainfall. We identified our species based on the generic key by Willemse (1956). We only have females and can only identify the species name tentatively. Identification was based mainly on color patterns.

3. *Traulacris* sp.
Fig. 4B

Remarks.—A female specimen was identified using the generic key by Willemse (1956). The species is very similar to *Meltripata* Bolívar, 1923 but differs by: head distinctly elevated above level of pronotum and frontal ridge barely projecting, and female subgenital plate quadrate with a mucronate projection on apical margin. Only two species are currently known from this Bornean-endemic genus, but our specimen differs in coloration from both species, particularly in the hind femur and general body coloration, as well as tegmen length (Willemse 1957). Our specimen may represent an undescribed species, but more material is needed for confirmation.

4. *Traulia azureipennis* (Serville, 1838)

Remarks.—This species was found near the forest edge. It was identified based on the description of the color in Willemse (1957) and comparison with type images from OSF (Cigliano et al. 2018).

5. *Traulia borneensis* Willemse, 1921
Fig. 4C

Remarks.—The two *Traulia* species were found co-occurring in similar habitat, although this species can also be found in more forested areas of the Canopy Walk. This species was identified based on the description of the color in Willemse (1957) and comparison with type images from OSF (Cigliano et al. 2018).

Superfamily Tetragoidea
Family Tetrigidae
Subfamily Cladonotinae

1. *Boczkittix borneensis* (Günther, 1935)
Fig. 5A

Remarks.—This species was fairly common in the forest floor of Kuala Belalong, usually camouflaging among the leaf litter or forest trails. We used the key by Tumbrinck (2014) for identification and the material was also verified by J. Tumbrinck and J. Skejo.

2. *Epitettix punctatus* Hancock, 1907
Fig. 5B, C

Remarks.—This species was fairly common in the forest floor of Kuala Belalong, usually camouflaging among the leaf litter or forest trails. We used the key by Tumbrinck (2014) to identify to genus. Subsequently, type images and description were used for comparison. Identification was also verified by J. Tumbrinck and J. Skejo.

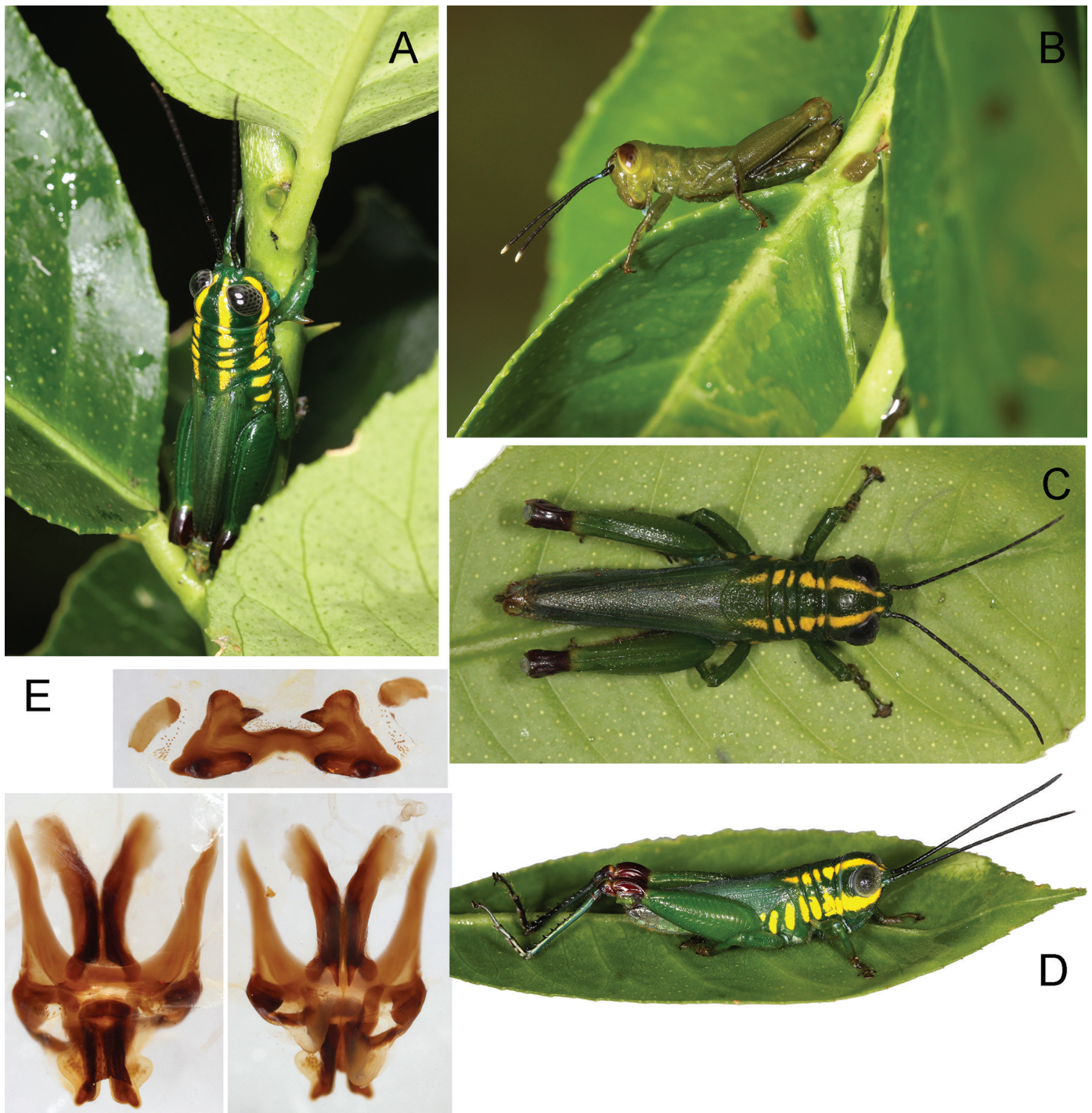


Fig. 3. Acrididae: *Craneopsis* cf. *olivacea*: A. Male adult; B. Nymph; C, D. Female adult; E. Male genitalia in dorsal (top and bottom left inset), ventral (bottom right inset) views.

3. *Potua morbillosa* (Walker, 1871)

Fig. 5D, E

Remarks.—We found this pygmy grasshopper on dead logs and tree trunks along Ashton Trail. We used the key by Tumbrinck (2014) to identify to genus. Subsequently, type images, and description were used for comparison. Identification was also verified by J. Tumbrinck and J. Skejo.

Subfamily Discotettiginae

4. *Discotettix belzebuth* (Serville, 1838)

Fig. 5F

Remarks.—This species was found on the wooden planks and ground along the trail to the Canopy Tower. We compared our specimens with type images from OSF (Cigliano et al. 2018). Identification was also verified by J. Skejo.

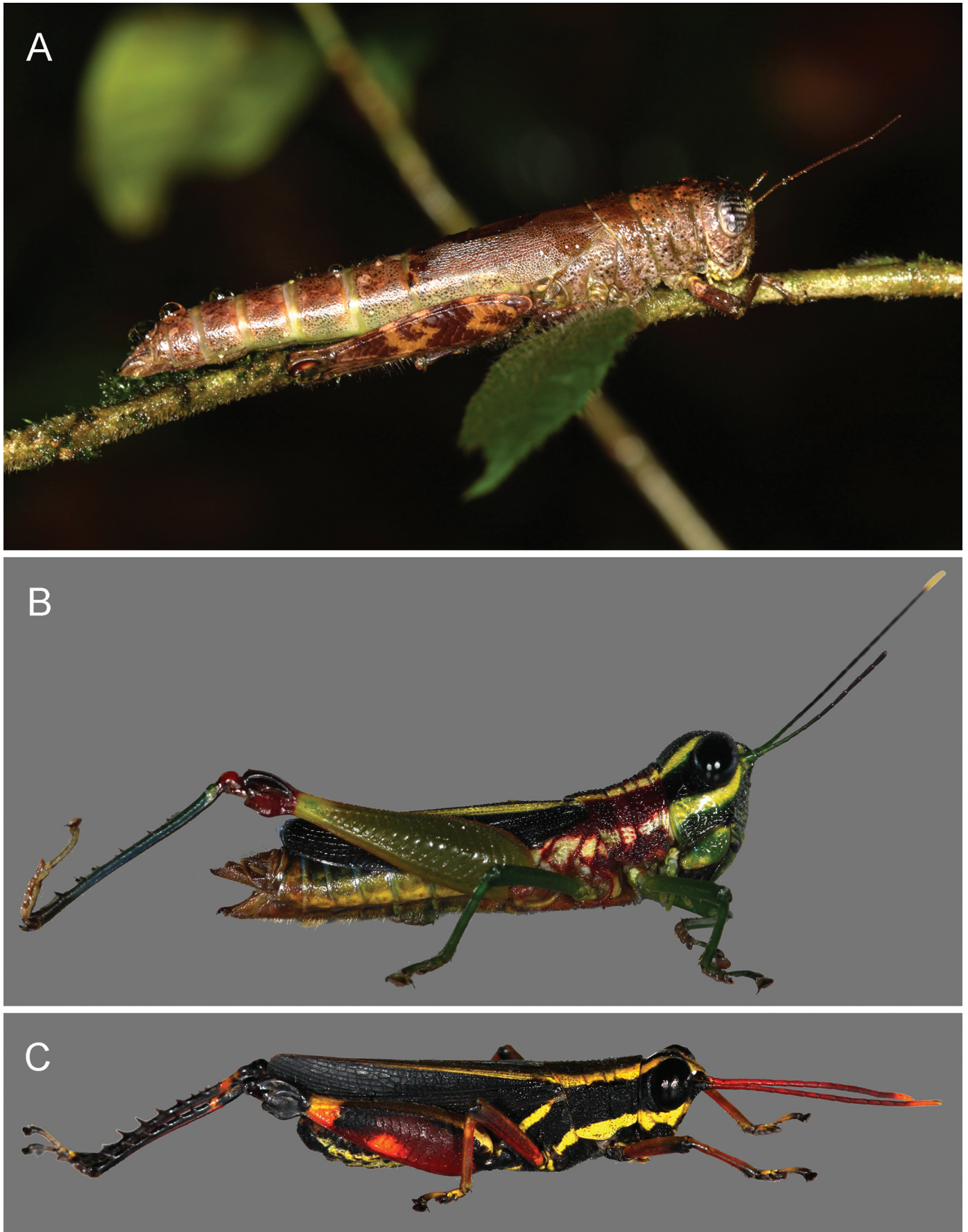


Fig. 4. Acrididae: A. *Perakia* nr. *borneensis*; B. *Traulacris* sp.; C. *Traulia borneensis*.

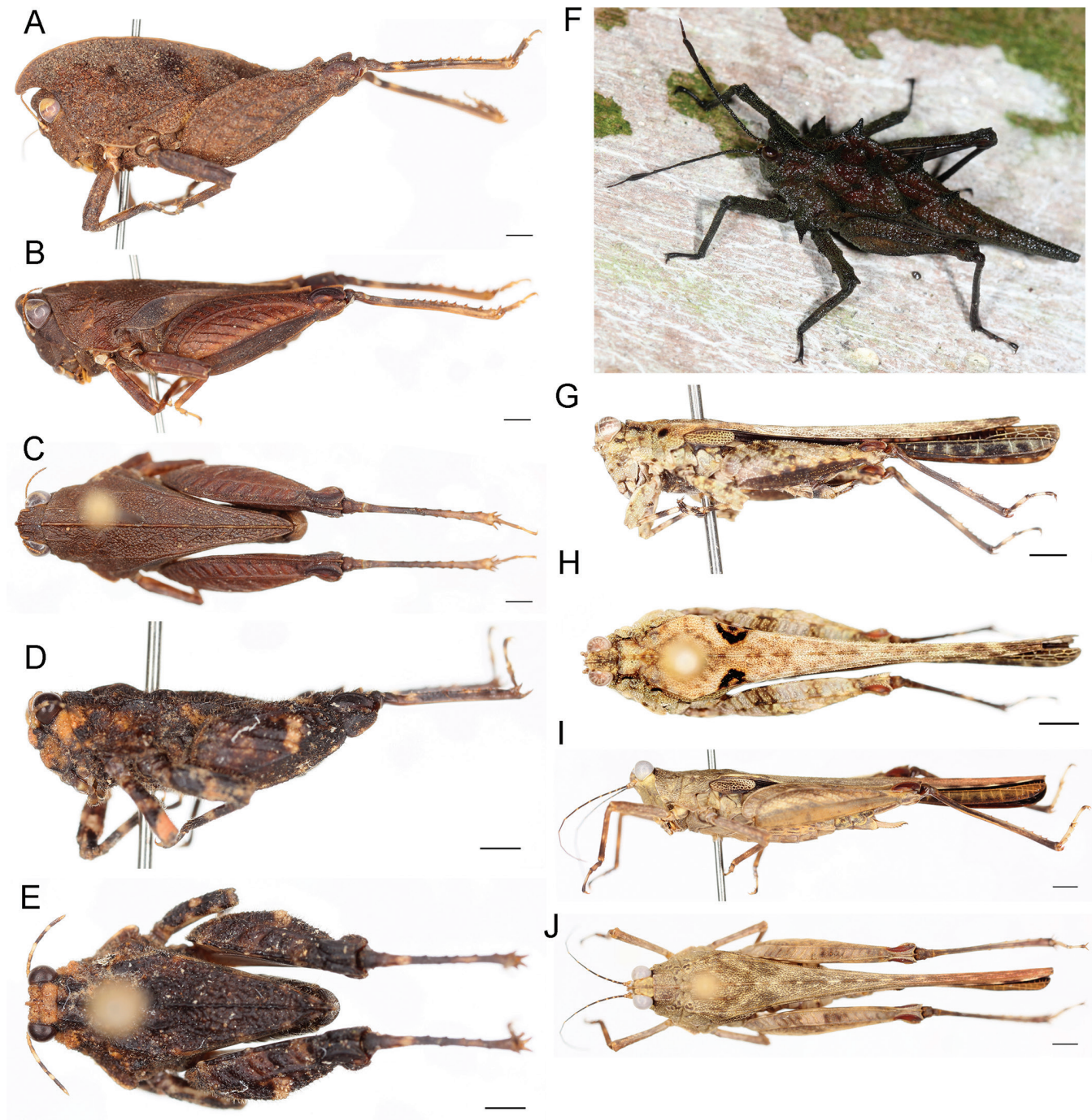


Fig. 5. Tettigidae: A. *Boczkitettix borneensis*; B, C. *Epitettix punctatus*; D, E. *Potua morbillosa*; F. *Discotettix belzebuth*; G, H. *Lamellitettigodes contractus*; I, J. *Pseudoparatettix lineatus*. Scale bars: 1 mm.

Subfamily Metrodorinae

5. *Lamellitettigodes contractus* (Bolívar, 1887)

Fig. 5G, H

Remarks.—A single specimen (a female) collected from the boardwalk en route to the Canopy Tower represents the first record of this species in Brunei Darussalam and Borneo. This species was identified by J. Tumbrinck.

6. *Pseudoparatettix lineatus* (Hancock, 1907)

Fig. 5I, J

Remarks.—Unlike most ground-dwelling pygmy grasshoppers, this species was found on foliage of understory plants. This species was identified by J. Tumbrinck.

Subfamily Scelimeninae

7. *Falconius clavatus* Bolívar, 1898

Fig. 6A, B

Remarks.—These pygmy grasshoppers were collected near the sandy bank of the Sungai Belalong at KBFSC. We compared our specimens with type images from OSF (Cigliano et al. 2018). Identification was also verified by J. Tumbrinck and J. Skejo.

8. *Falconius deceptor* Günther, 1938

Fig. 6C

Remarks.—A single female specimen was found attracted to light. We compared our specimen with type images from OSF (Cigliano et al. 2018). Identification was also verified by J. Tumbrinck and J. Skejo.

9. *Loxilobus* sp. 1

Fig. 6D

Remarks.—This pygmy grasshopper was found near small drains near the forest edge at KBFSC. The species was identified by J. Tumbrinck.

10. *Loxilobus* sp. 2

Fig. 6E

Remarks.—This pygmy grasshopper was also found near small drains near the forest edge at KBFSC. The species was identified by J. Tumbrinck.

11. *Scelimenina* sp.

Fig. 6F, G

Remarks.—We tentatively identified this species to be near to *S. dentumeris* (Hancock, 1907). This large pygmy grasshopper is a powerful flyer that was collected along the sandy river bank along Sungai Belalong at KBFSC. The type specimen of the species was from Brunei Darussalam. We compared our single female specimen with type images from OSF (Cigliano et al. 2018).

12. *Thoradonta nodulosa* (Stål, 1861)

Fig. 6H, I

Remarks.—We compared our single female specimen with type images from OSF (Cigliano et al. 2018). Identification was also verified by J. Tumbrinck and J. Skejo. This is also plausibly the first record of this species in Borneo (Cigliano et al. 2018).

Subfamily Tetrigininae

13. *Coptotettix* sp.

Fig. 6J

Remarks.—This pygmy grasshopper was found near small drains near the forest edge at KBFSC, probably because they are hydrophilic. The species was identified by J. Tumbrinck.

Superfamily Trigonopterygoidea

Family Trigonopterygidae

1. *Systema platyptera* (Haan, 1842)

Fig. 7

Remarks.—We found numerous individuals on the forest understory near the Canopy Tower. We compared our specimens with images from OSF (Cigliano et al. 2018) for identification.

Suborder Ensifera

Superfamily Grylloidea

Family Gryllidae

Subfamily Eneopterinae

1. *Cardiodactylus pelagus* Otte, 2007

Fig. 8A–D

Remarks.—These crickets are sometimes encountered among vegetation in the understory of the dipterocarp forest. The nymphs can sometimes be found on the forest floor. We compared our specimens with images from Robillard et al. (2013). Identification was verified by T. Robillard.

2. *Nisitrus vittatus* (Haan, 1844)

Fig. 8E–H

Remarks.—This species was found abundantly around the station at the forest edge. During the day, the males can be heard calling on plant foliage. We also observed them feeding on flowers (Tan et al. 2017b). We compared this species with other congeners from Malay Peninsula and Borneo with help from T. Robillard. Tentatively, we considered the specimens from Kuala Belalong as *Nisitrus vittatus*, which can also be found in Malay Peninsula and Sumatra (Robillard and Tan 2013). There are some minor differences in acoustic and morphological characters between our Bornean specimens and those from other parts of Southeast Asia. We need more material from Borneo to better understand the species.

Subfamily Gryllinae

3. *Gymnogryllus unexpectus trusmadi* Gorochoy, 2011

Fig. 9A–C

Remarks.—The understory can be filled with the loud male calling song of this large cricket during dusk (around 7 pm). The male lives in a burrow and produces loud and high-pitched (peak frequency = 4.2 kHz) trilling (mean pulse intervals = 9.1 ms) calls. As they can be quite abundant, the amount of noise produced can be very loud and heard a distance away. Specimens from Kuala Belalong resemble the images and description by Gorochoy (2011) and identification was verified by A.V. Gorochoy.

4. *Loxoblemmus* sp.

Fig. 9D, E

Remarks.—This ground cricket was found co-occurring with two species of *Velarifictorus* among short grasses and herbaceous plants at the Ulu Ulu resort. Despite similarities in habitus, this genus differs from the latter by the head morphology and male genitalia.

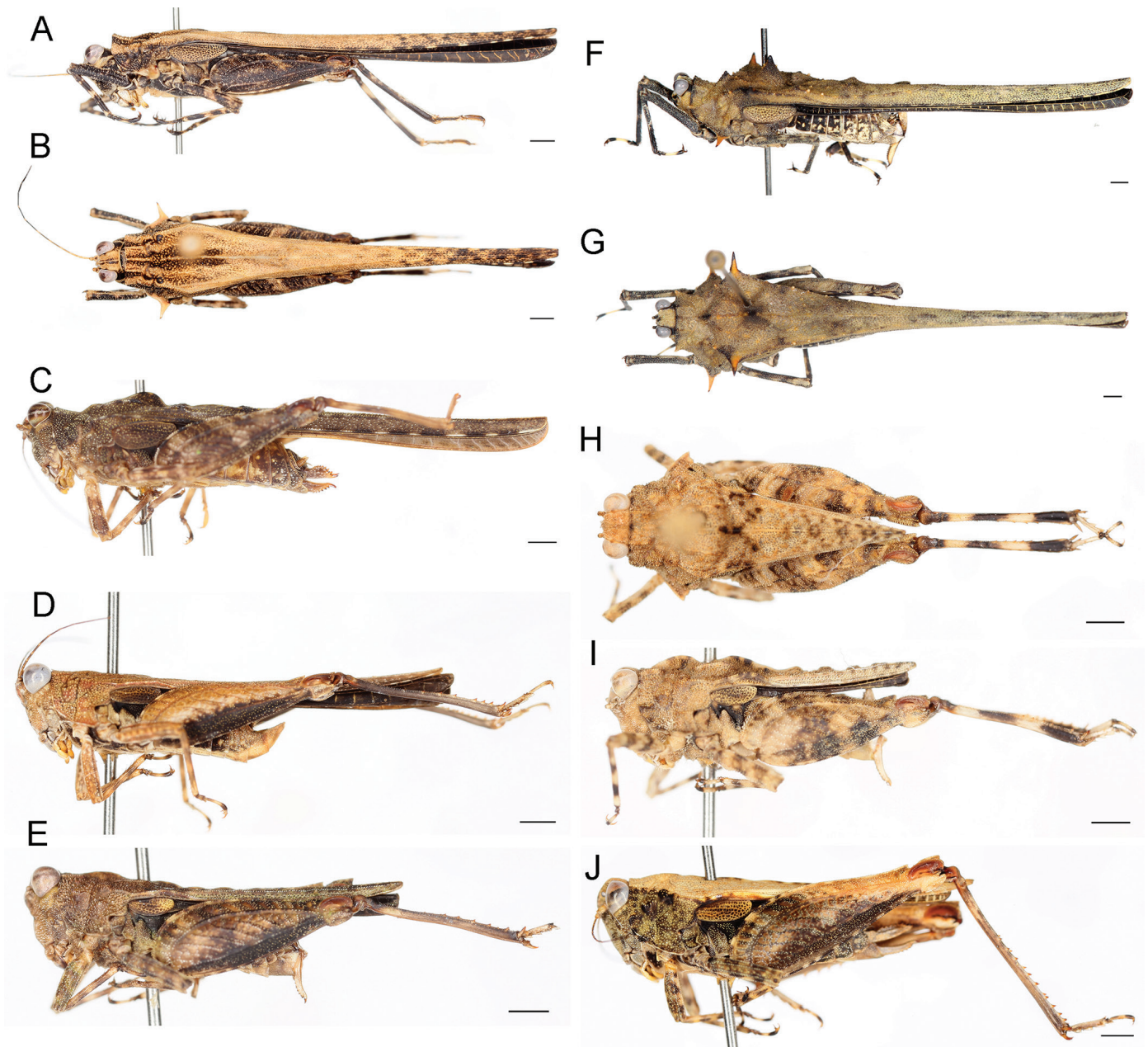


Fig. 6. Tetrigidae: A, B. *Falconius clavatus*; C. *Falconius deceptor*; D. *Loxilobus* sp. 1; E. *Loxilobus* sp. 2; F, G. *Scelimena* nr. *dentiumeris*; H, I. *Thoradonta nodulosa*; J. *Coptotettix* sp. Scale bars: 1 mm.

5. *Mimicogryllus* sp.

Fig. 9F–I

Remarks.—This rare and beautiful black cricket was encountered only once on the forest floor of the dipterocarp forest. A.V. Gorochoy assisted with the identification of this species and this could represent an undescribed species (see Gorochoy 1994). However, more material would be necessary before species description can be done.

6. *Velarifictorus (Velarifictorus) aspersus aspersus* (Walker, 1869)

Remarks.—This species is one of the two species of the cosmopolitan genus *Velarifictorus* Randell, 1964 (Modicogryllini) found in

Kuala Belalong. Male genitalia resemble that of the species illustrated in Ingrisch (1998a). This species is widespread in Southeast Asia, and can be found in Thailand, Singapore, and Peninsular Malaysia (Ingrisch 1998a, Tan 2012, Tan and Kamaruddin 2014, 2016, Dawwrueng et al. 2017). Refer to Tan et al. (2017c) for more details on the calling songs and species distribution.

7. *Velarifictorus (Velarifictorus) temburongensis* Tan et al., 2017

Remarks.—This species was found near river banks, among short grasses and herbaceous plants. It was identified as undescribed and the description was subsequently published in Tan et al. (2017c). This represents the first species of the genus *Velarifictorus* to be described from Borneo.

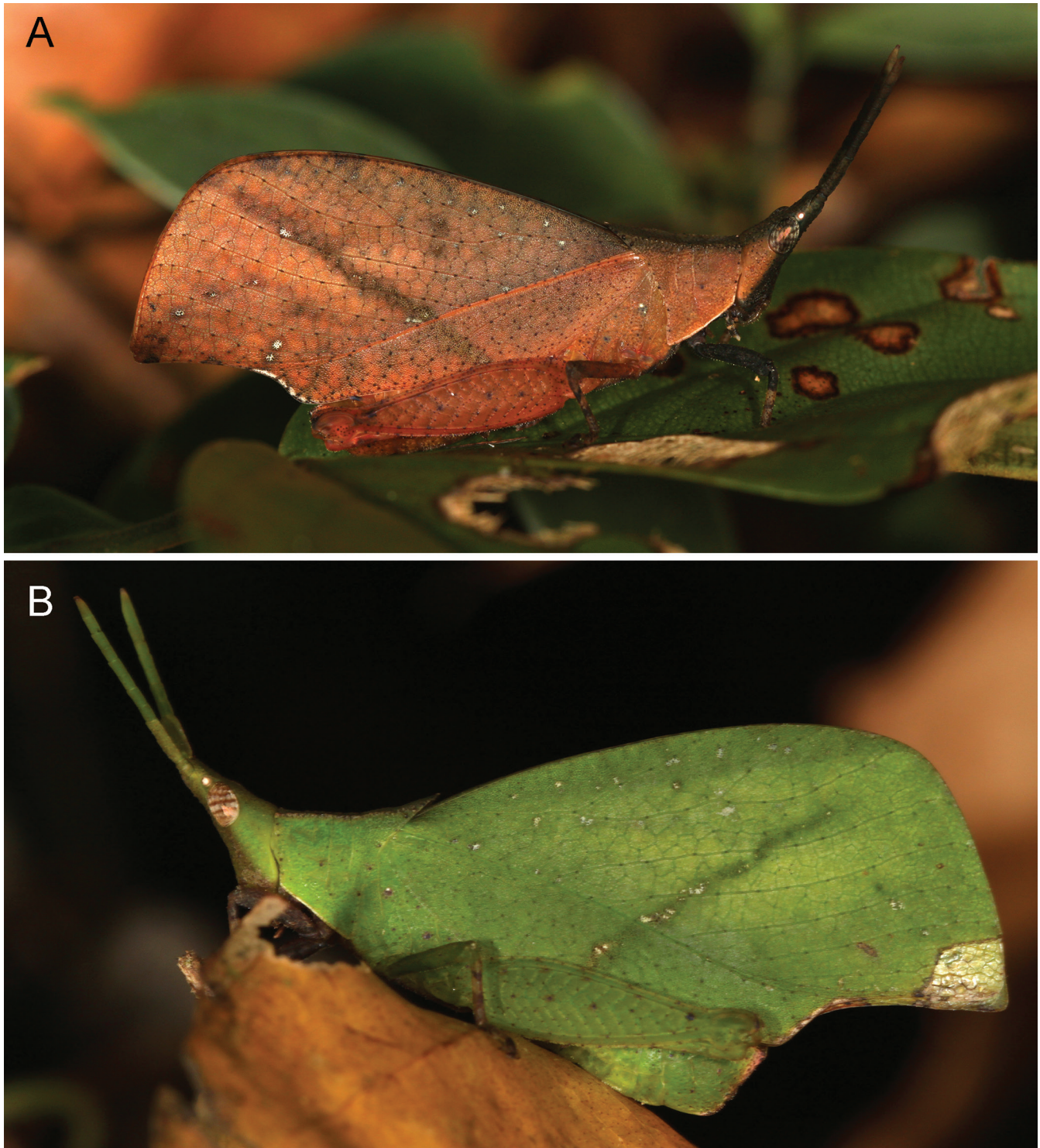


Fig. 7. Trigonopterygidae: *Systella platyptera* male adults.

Subfamily Landrevinae

8. *Duolandrevus (Bejorama) lambir* Gorochov, 2017

Remarks.—Prior to the description, we could only tentatively identify the male specimen to be close to *D. luzonensis* (Tan and Wahab 2017a), which was subsequently considered as a new species described from Lambir Hill National Park by Gorochov (2017a).

9. *Duolandrevus (Eulandrevus) kawataredoki*
Tan & Wahab, 2017

Remarks.—One of the two Landrevinae newly described from the collection; this cricket can be commonly heard after dusk in the dipterocarp forest, often while hiding among dead leaves hanging on branches. They were also observed to feed on dead leaves. Refer to Tan and Wahab (2017a) for species description and calling song description.

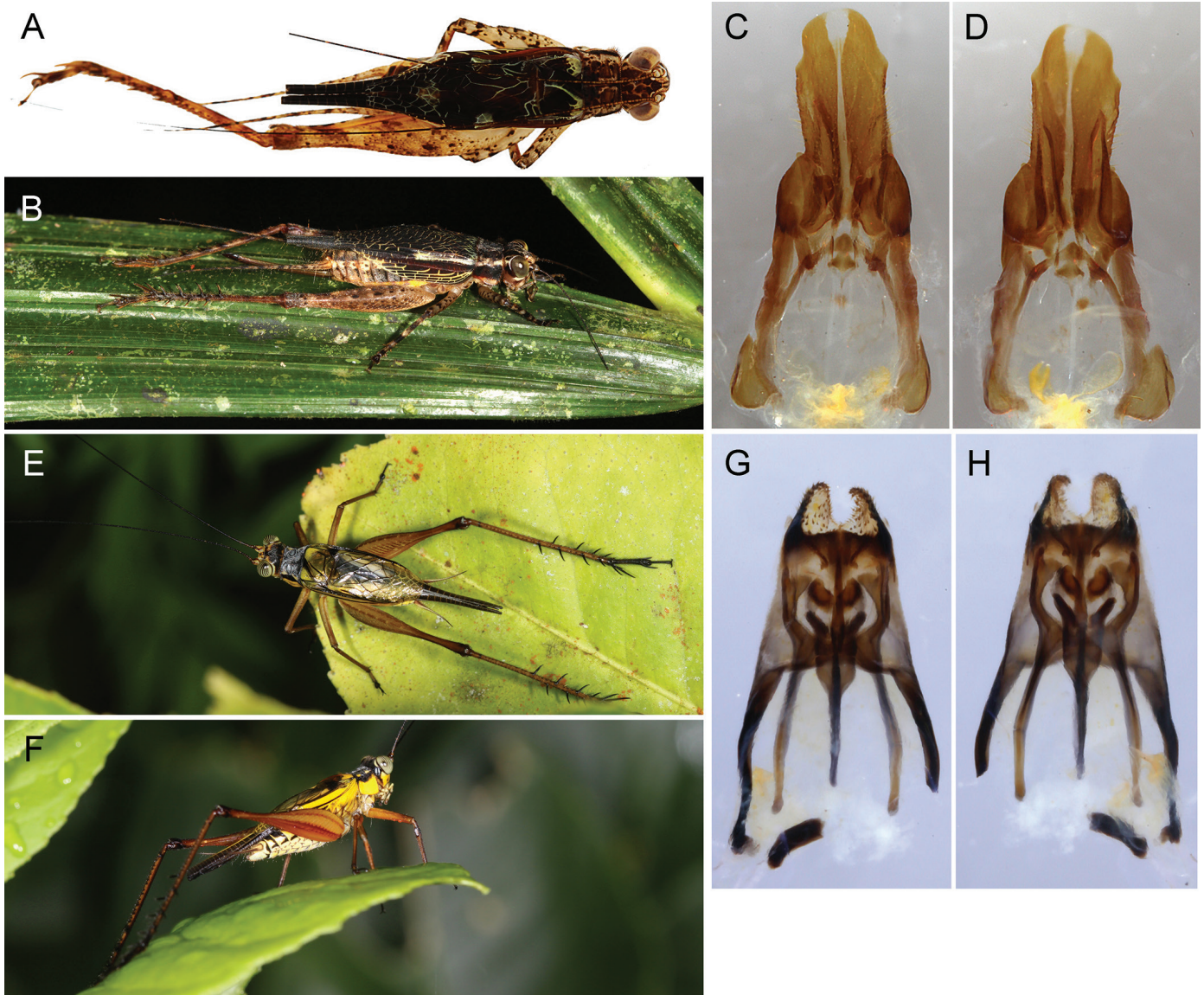


Fig. 8. Gryllidae: Eneopterinae: *Cardiodactylus pelagus*: A. Male; B. Female; C, D. Male genitalia in ventral and dorsal views respectively; *Nisitrus vittatus*: E, F. Male; G, H. Male genitalia in dorsal and ventral views respectively.

10. *Endodreelanva nympa* Tan & Wahab, 2017

Remarks.—One of the two Landrevinae newly described from the collection; this cricket was found among branches of trees in the dipterocarp forest. Refer to Tan and Wahab (2017a) for species description.

Subfamily Podoscirtinae

11. *Aphonoides* sp.

Fig. 10A

Remarks.—A single specimen (a female) was collected from a tree trunk in the dipterocarp forest. It resembles congeners of *Aphonoides* by: inner tympanum open, but outer one obliterated, tegminal Sc with several normal branches, ovipositor with apex rounded, and with large teeth on hind and ventral surfaces (Gorochov 2006). Many species from Borneo were described without the females, so determination of the species name is not possible without the males.

12. *Sonotrella* (*Megatrella*) sp.

Fig. 10B

Remarks.—Our female specimen may belong to *Sonotrella* (*Megatrella*) *optima* Gorochov, 2002 or *Sonotrella* (*Megatrella*) *remota* Gorochov, 2002 both known from Borneo. Only the males of both species are known and females are very similar among congeners.

Subfamily Pteroplistinae

13. *Pteroplistes* sp.

Fig. 10C, D

Remarks.—A single specimen (a female) was spotted camouflaging with the tree trunk of an old tree in the dipterocarp forest. It has characters diagnostic of the genus: large inner and small outer tympana of fore tibia and long ovipositor (Gorochov 2004). Two species have been described from Borneo (i.e. *P. borneoensis*

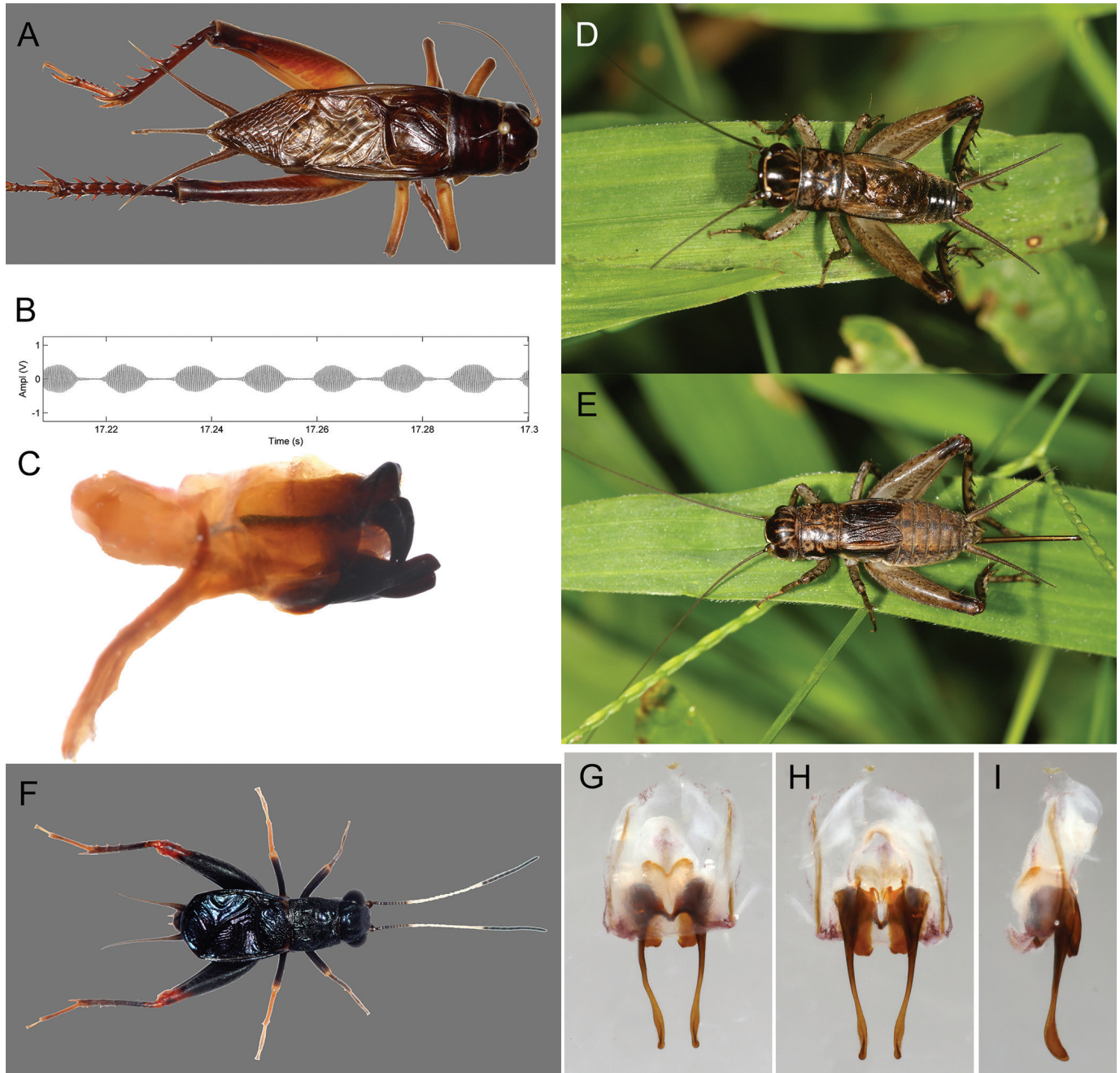


Fig. 9. Gryllidae: Gryllinae: *Gymnogryllus unexpectus trusmadi*: A. Male; B. Calling song; C. Male genitalia in lateral view; *Loxoblemmus* sp.: D. Male; E. Female; *Mimicogryllus* sp.: F. Male; G–I. Male genitalia in ventral, dorsal, and lateral views respectively.

Gorochov, 2004 and *P. lagrecai* Gorochov, 2004), neither of which has had the female described (Gorochov 2004). It is therefore difficult to affirm the species name.

Subfamily Trigonidiinae

14. *Amusurgus* or *Metiochodes* sp.?

Fig. 10E

Remarks.—Only a single specimen (a female) was collected. The species is characterized by tegmen pubescence, presence of only inner tympanum (very large), and ovipositor with apical valves broader than stem but with acute teeth apically.

15. *Amusurgus* or *Paratrigonidium* sp.?

Fig. 10F

Remarks.—Distinct from all other Trigonidiinae, we, however, only collected females, making it nearly impossible to differentiate them among closely related genera. Tegmen not pubescent and abdomen distinctly humped dorsally.

16. *Paratrigonidium* sp.

Fig. 10G

Remarks.—The male can be distinguished from the other Trigonidiinae above by the developed stridulatory apparatus, and foretib-



Fig. 10. Gryllidae: Podoscirtinae: A. *Aphonoides* sp.; B. *Sonotrella* (*Megatrella*) sp.; Grylloidea: Pteroplistinae: C, D. *Pteroplistes* sp.; Trigonidiidae: Trigonidiinae: E. *Amusurgus* or *Metiochodes* sp.?; F. *Amusurgus* or *Paratrigonidium* sp.?; G. *Paratrigonidium* sp.

ia with inner and outer tympana. The male genitalia also resemble that of a typical *Paratrigonidium*. More specimens will, however, be needed to ascertain the genus and species. This group is probably in need of further taxonomic revision.

Family Phalangopsidae
Subfamily Phalangopsinae

17. *Parendacustes (Minizacla) mulu* Gorochov, 2017
Fig. 11A–D

Remarks.—Juveniles and adults were found on the tree trunks of old trees in the dipterocarp forest. They were well camouflaged among the ridges of the tree trunk. A.V. Gorochov assisted with the identification of this species which he recently described from Mulu National Park, which is relatively close to KBFSC (Gorochov 2017b, c).

18. *Terrozacla borneo* Gorochov, 2014
Fig. 11E–G

Remarks.—This species was fairly common in the forest floor of Kuala Belalong, usually camouflaging among the leaf litter or forest trails. T. Robillard assisted with the identification of this species. We compared the genitalia of our specimens with images from Gorochov (2014). This species can be found in Sabah, Sarawak, and now Brunei Darussalam.

Subfamily Phaloriinae

19. *Phaloria (Papuloria) tristis* Gorochov, 2014
Fig. 11H–K

Remarks.—The males produce trilling calling songs after dusk, often on foliage of trees. They are quite common in the dipterocarp forest. The genitalia of our specimens resemble that of the type specimen, described from Mulu National Park (Gorochov 2014).

Family Mogoplistidae
Subfamily Mogoplistinae

20. *Cycloptiloides* sp.
Fig. 12A

Remarks.—These small scaly crickets are usually cryptic but were found hopping around on the forest floor. Only females and nymphs were collected but male genitalia is needed for species identification (Ingrisch 2006). This represents the first record of this genus in Borneo (Ingrisch 2006, Cigliano et al. 2018). Because this genus has rarely been studied (Ingrisch 2006), the species from Brunei could be an undescribed species.

21. *Ectatoderus* sp.
Fig. 12B

Remarks.—We tentatively identified this species to be close to *E. angusticollis* Chopard, 1969. The cricket was found among foliage and branches of understory trees. The key to Southeast Asian species was used for identification but this genus is likely to be paraphyletic and taxonomic work is needed (Ingrisch 2006).

Superfamily Gryllotalpoidea
Family Gryllotalpidae

1. *Gryllotalpa* (?) sp.
Fig. 12C

Remarks.—We recorded the calling songs heard in the evening sporadically across the forest floor, even though we did not manage to collect any specimen. The calling song is characteristic of congeners from the region. This species tends to call near dead and rotten logs at around 6:45–7pm and the male burrows clearly resemble that of congeners.

Superfamily Rhabdophoroidea
Family Rhabdophoridae

1. *Rhabdophora* (?) sp.
Fig. 12D–F

Remarks.—This group is speciose and can be hard to identify for Southeast Asian representatives (A.V. Gorochov, in litt.).

Superfamily Stenopelmatoidea
Family Gryllacrididae

1. *Asarcogryllacris (Pseudolarnaca)* sp.
Fig. 13A–E

Remarks.—Our single specimen (a male) resembles the drawing of the habitus of *A. genualis* (Walker, 1869) from Borneo. The abdominal apex (particularly the medial apical sclerotized processes of ninth abdominal tergite) also resembles that in Gorochov (2005). It clearly differs from the only subcongener, *A. (P.) nigroscutata* (Brunner von Wattenwyl, 1888) from Java, by color patterns and abdominal apex.

2. *Capnogryllacris* (?) (*Capnogryllacris*) sp.
Fig. 13F

Remarks.—We tentatively identified our female specimen to be close to *C. superba* (Brunner von Wattenwyl, 1888) using an old key (Murphy 1973). This species is characterized by red hind wings.

3. *Melaneremus* (?) sp.
Fig. 13G–J

Remarks.—This is among the most common Stenopelmatoidea that was found in the understory of the Kuala Belalong forest. Unfortunately, we could only tentatively identify our specimens to this genus using an old key (Murphy 1973). However, our specimens are also different in shape of male abdominal apices from described species of the genus. Until a revision of the genera of Asiatic Gryllacridinae is completed, the determination of the species is problematic (A.V. Gorochov, in litt.).

4. *Phlebogryllacris* (?) sp.
Fig. 14A–D

Remarks.—This stunningly red raspy cricket was found among foliage in the understory. Without comparison with the type specimen, we could only tentatively identify our single specimen (a male) to be close to *P. venosa* (Walker, 1869) as it appears superficially similar and was described from Sarawak close to Brunei Darussalam.

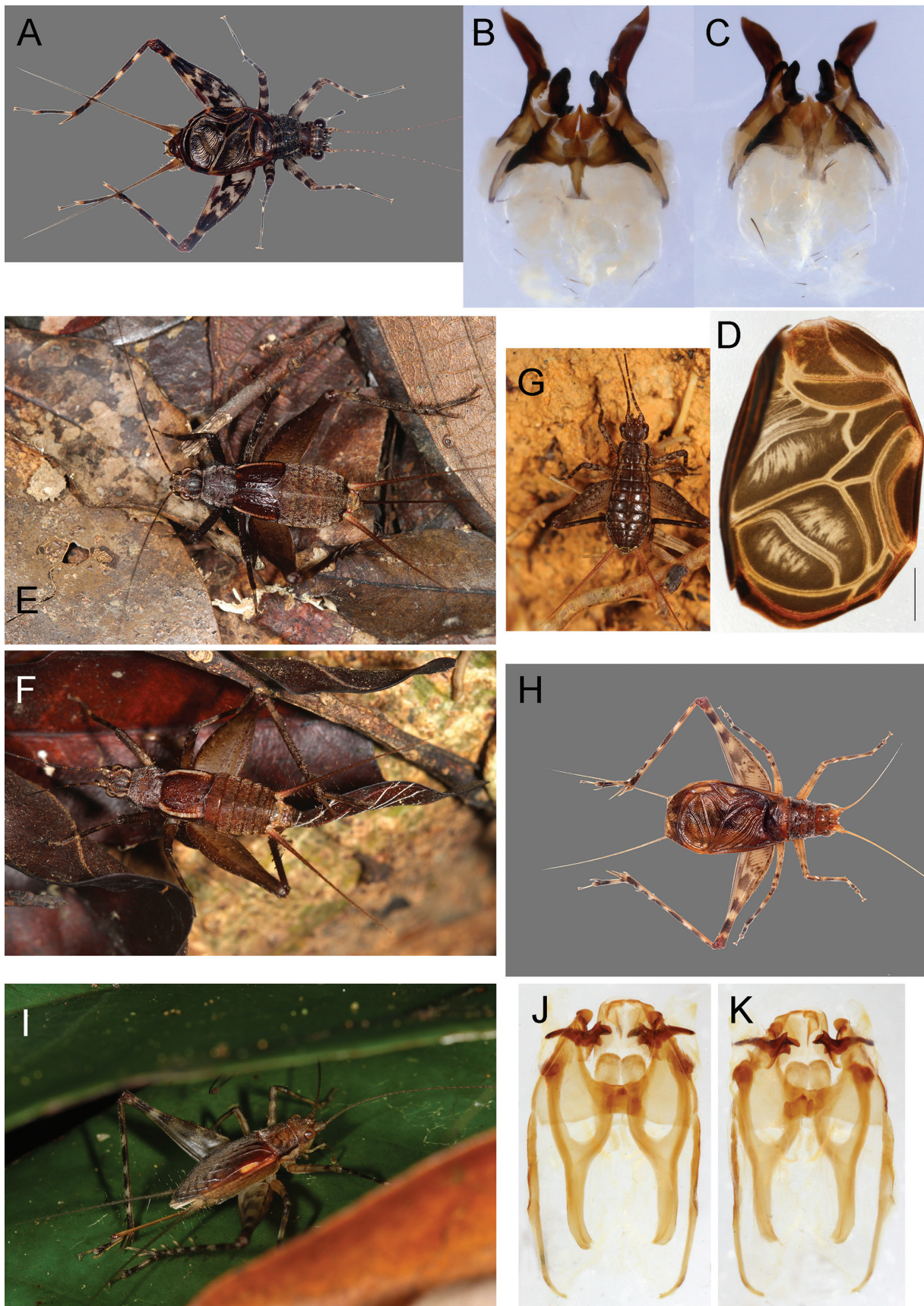


Fig. 11. Phalangopsidae: *Parentacustes (Minizacla) mulu*: A. Male; B, C. Male genitalia in dorsal and ventral views respectively; D. Male tegmen; *Terrozacla borneo*: E. Female; F. Male; G. Nymph; *Phaloria (Papuloria) trista*: H. Male; I. Female; J, K. Male genitalia in dorsal and ventral views respectively. Scale bar: 1mm.

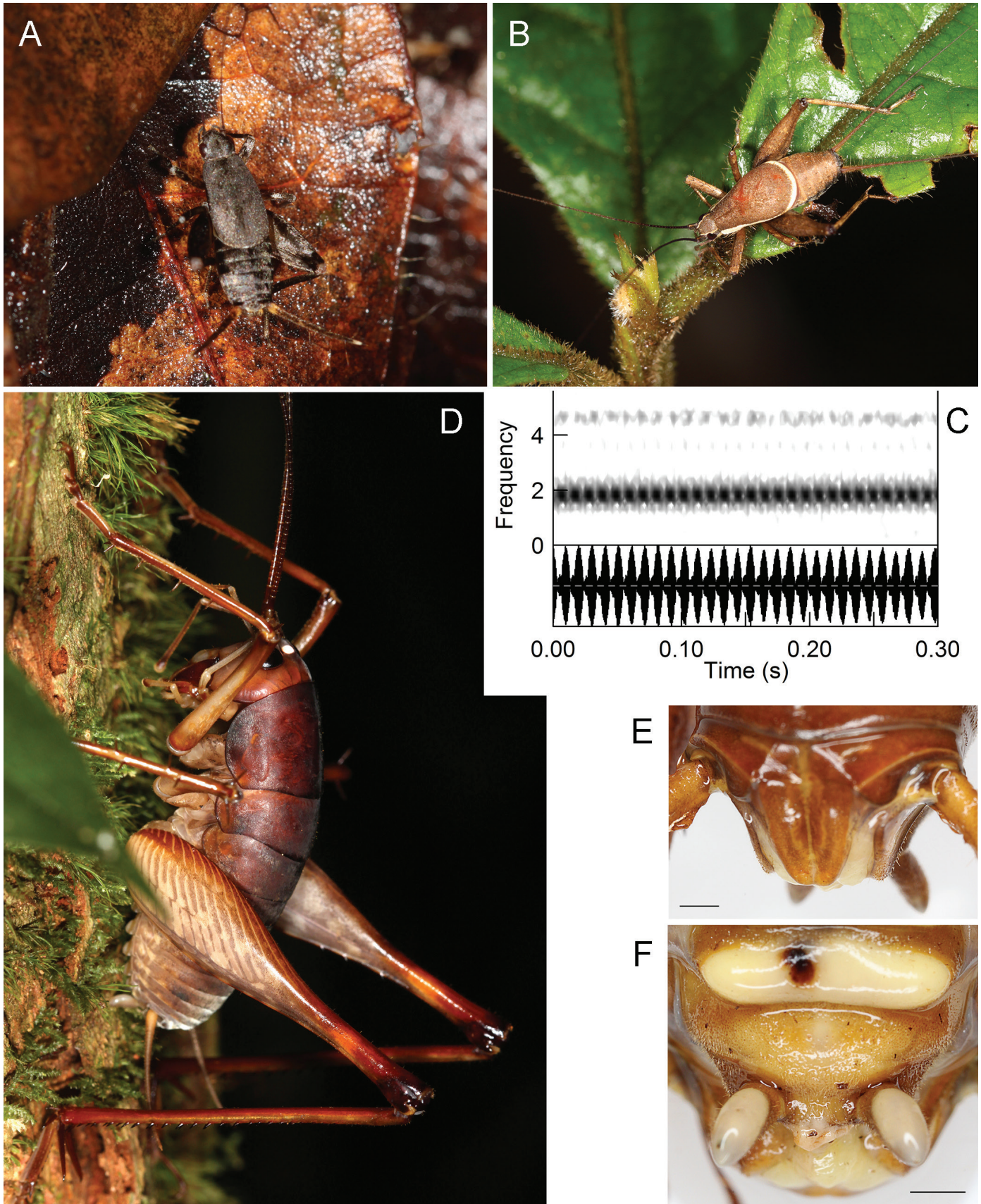


Fig. 12. Mogoplistidae, Gryllotalpidae, and Rhaphidophoridae: A. *Cycloptiloides* sp.; B. *Ectatoderus* cf. *angusticollis*; C. *Gryllotalpa* (?) sp. (frequency in kHz); D. *Rhaphidophora* (?) sp. male; E, F. Male abdominal apex. Scale bars: 1mm.

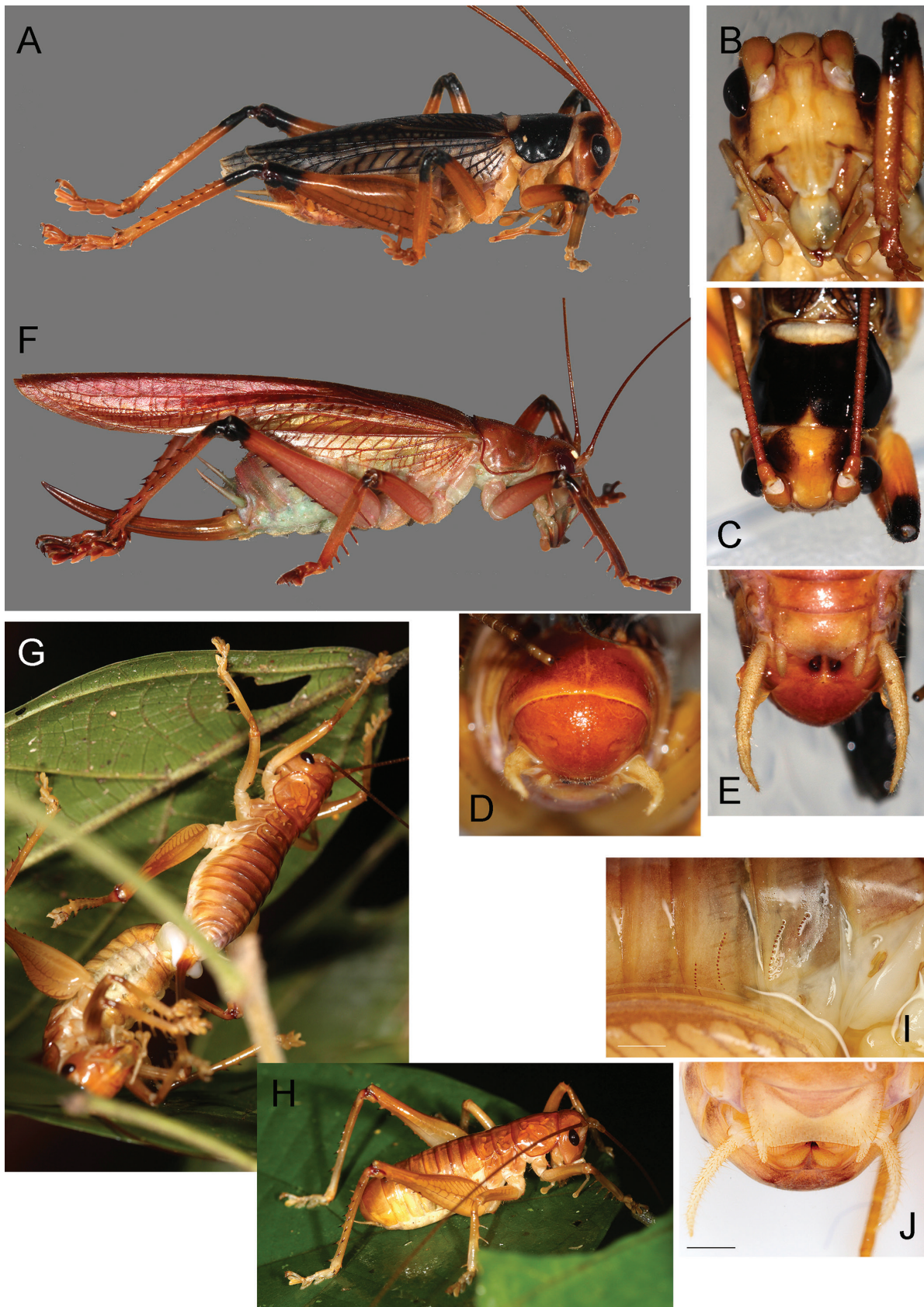


Fig. 13. Gryllacrididae: A. *Asarcogryllacris* (*Pseudolamaca*) cf. *genualis* male; B. Face; C. Dorsal view of head and pronotum; D, E. Abdominal apex; F. *Capnogryllacris* (*Capnogryllacris*) cf. *superba*; G. *Melaneremus* (?) sp. mating pair; H. Male adult; I. Male stridulatory file; J. Male subgenital plate. Scale bars: 1mm.

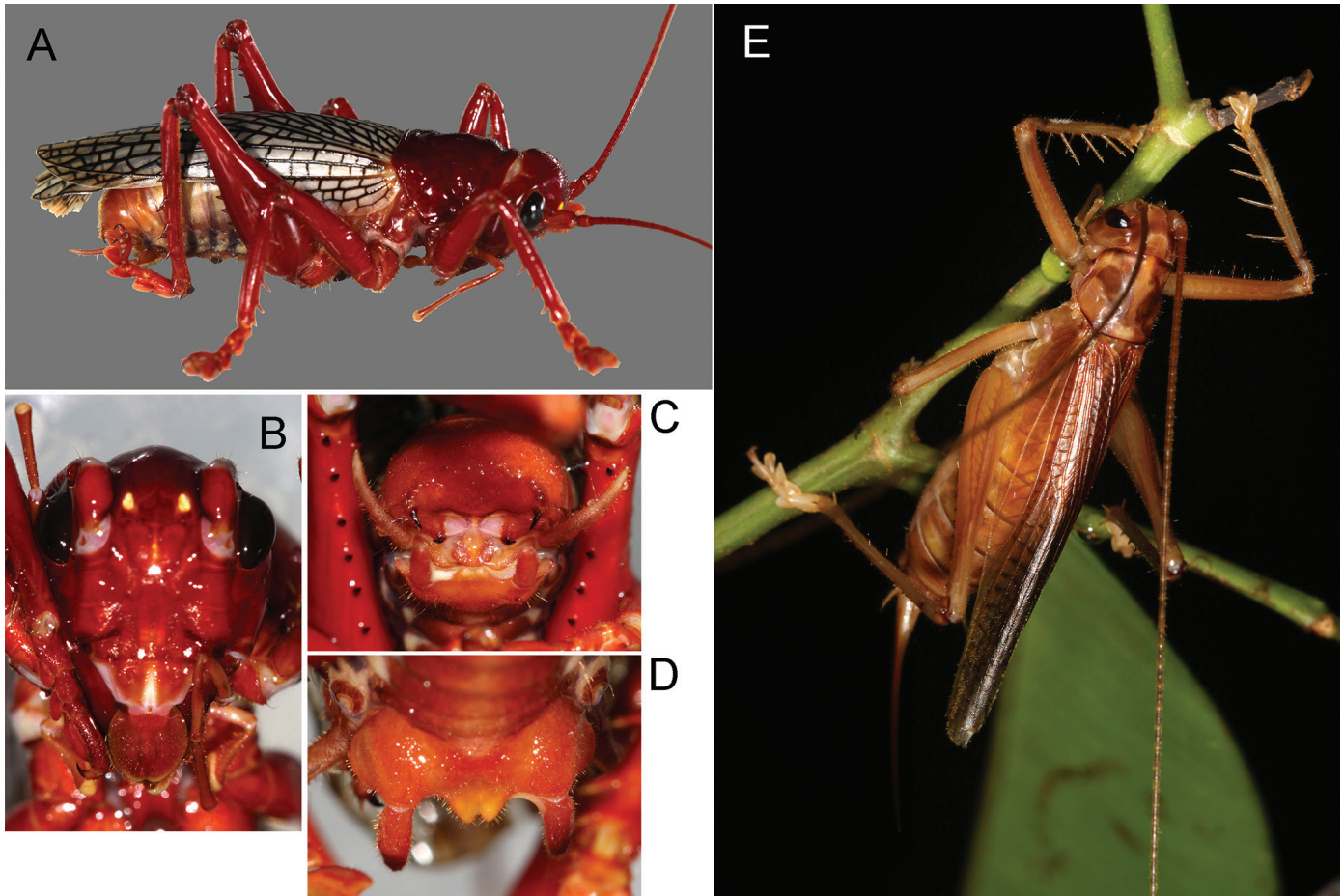


Fig. 14. Gryllacrididae: A. *Phlebogryllacris* (?) cf. *venosa* male; B. Face; C. Male abdominal apex; D. Male subgenital plate; E. *Phryganogryllacris* sp.

5. *Phryganogryllacris* sp.

Fig. 14E

Remarks.—We tentatively identified our specimens to this genus using an old key (Murphy 1973) and compared with images of the genus from Gorochov (2005). This genus is characterized by a cup-shaped ninth abdominal tergite, posteriorly with spines pointing downward far apart laterally, and tenth abdominal tergite without spine-like process.

Superfamily Tettigonioidea
Family Tettigoniidae
Subfamily Conocephalinae

1. *Viriacca modesta* Gorochov, 2013

Fig. 15A

Remarks.—This species was found on the foliage of understory plants in the dipterocarp forest. We used key to genera of Agraeciini by Ingrisch (1998b) to identify our specimens. Subsequently we compared our specimens with species descriptions in Ingrisch (1998b) and Gorochov (2011, 2013). This species was described from Mulu National Park.

Subfamily Lipotactinae

2. *Lipotactes alienus* Brunner von Wattenwyl, 1898

Fig. 15B

Remarks.—This katydid is not uncommon in the understory of Kuala Belalong forest. However, curiously, we have yet to encounter the males. Unfortunately, the male of this species has also not been described. Our females correspond to the description by Ingrisch (1995) and images from OSF (Cigliano et al. 2018) by color patterns, shapes of ovipositor, and subgenital plate.

Subfamily Meconematinae

3. *Alloteratura (Alloteratura) belalongensis* Tan et al., 2017

Remarks.—This is one of the four new species of Meconematini katydids collected and described from Kuala Belalong. This new species is very similar to *A. (A.) karnyi* Kästner, 1932 from northern Sumatra (Kästner 1932, Gorochov 1998a) and Thailand (see Sänger and Helfert 2000) but could belong to several different subspecies of the same species owing to the similarities in morphology (Tan et al. 2017d). We need more material around Southeast Asia and study of their population genetics to confirm species limits. Refer to Tan et al. (2017d) for the new species description.

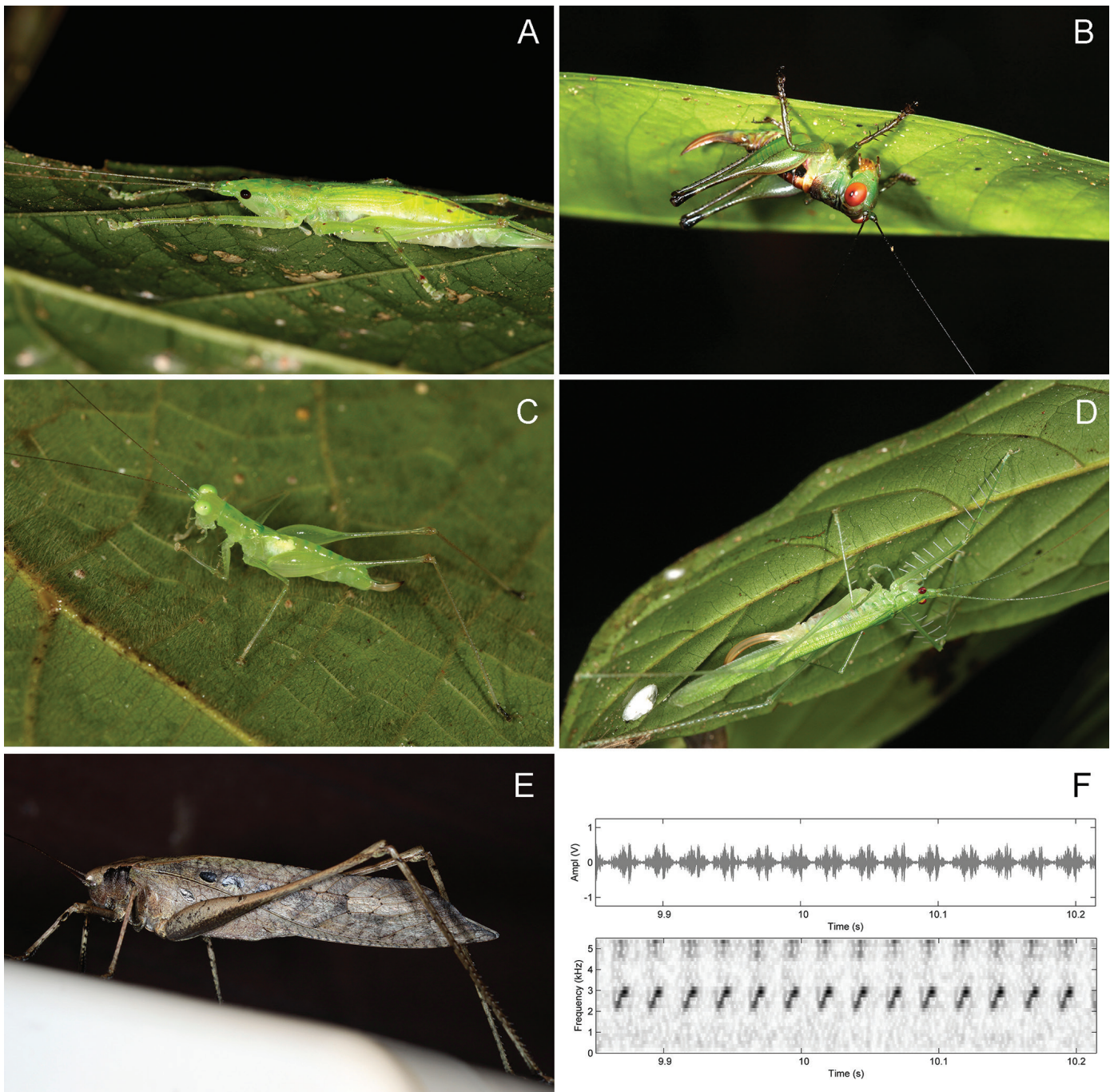


Fig. 15. Tettigoniidae: A. *Viriacca modesta*; B. *Lipotactes alienus*; C. *Asiophlugis longiuncus*; D. *Neophisis (Indophisis) cf. longipennis* or *curvata*; *Mecopoda elongata*: E. Female; F. Calling song.

4. *Asiophlugis longiuncus* Gorochov, 2013

Fig. 15C

Remarks.—This species was found on foliage of the dipterocarp forest understory at night. Usually, a few individuals (mix of adults and nymphs) were found on a single large leaf. Only the female was collected, and was compared with the original description (Gorochov 2013). This species was described from Mulu National Park.

5. *Kuzicus mirabilis* Tan & Wahab, 2018

Remarks.—This species was encountered on foliage of the dipterocarp forest understory at night. Refer to Tan and Wahab (2018a) for the new species description.

6. *Leptoteratura (Rhinoteratura) chela* Tan et al., 2017

Remarks.—This species was encountered on foliage of the dipterocarp forest understory at night. Refer to Tan et al. (2017d) for the new species description.

7. *Neophisis (Indophisis) sp.*

Fig. 15D

Remarks.—We tentatively identified this species to be close to either *N. longipennis* Jin, 1992 or *N. curvata* Jin, 1992. This species was found fairly frequently on foliage of the dipterocarp forest understory at night.

8. *Pulchroteratura huiqing* Tan et al., 2017

Remarks.—This species was quite frequently encountered on foliage of the dipterocarp forest understory at night. The peculiar shape of the abdominal apex led us to consider this to be a completely different genus. Refer to Tan et al. (2017d) for the new species description.

9. *Pseudoteratura (Pseudoteratura) kenuan* Tan et al., 2017

Remarks.—Refer to Tan et al. (2017d) for the new species description.

Subfamily Mecopodinae

10. *Mecopoda elongata* (Linnaeus, 1758)

Fig. 15E, F

Remarks.—This large katydid can be heard calling at night among shrubby bushes. The calling song resembles the train call (see Diwakar and Balakrishnan 2007). Sometimes, they were also attracted to light.

Subfamily Phaneropterinae

11. *Baryprostha bellua* Karsch, 1891

Fig. 16A

Remarks.—The only specimen (a female) we encountered was found on the forest floor of the dipterocarp forest along Ashton Trail. It is probable that it resides in the canopy but had dropped down to the forest floor. We used the key to the species of *Baryprostha* from Ingrisch (1990) and images of the type specimen from OSF (Cigliano et al. 2018) for identification.

12. *Casigneta bisinuata* Karny, 1926

Fig. 16B

Remarks.—This species was found attracted to light, thus appeared around the station. We compared our male specimens with images of type specimens from OSF (Cigliano et al. 2018).

13. *Hemimirollia gracilis* (Karny, 1925)

Fig. 16C

Remarks.—Only one male specimen was collected during light trapping. We used the key to genera of *Mirolliini* by Ingrisch (2011) and compared our specimen with the descriptions of the two other congeners.

14. *Holochlora sp.*

Fig. 16D

Remarks.—One male specimen was collected during light trapping. Upon freezing the katydid, a horsehair worm (Nematomorpha)

emerged from the abdominal apex. This parasite is not uncommon among katydids found near the water (i.e. Sungai Belalong). The Nematomorpha was preserved in ethanol. The katydid bears the male diagnostic characters of *Holochlora*: male tenth abdominal tergite with two apical lobes, area around left stridulatory file strongly swollen (Liu and Kang 2007).

15. *Mirollia sp.*

Fig. 16E

Remarks.—We tentatively identified this species to be close to *M. abnormis* Karny, 1926. One female specimen was collected from the foliage on a tree near the Canopy Tower. We used the key to genera of *Mirolliini* by Ingrisch (2011) and compared our female specimen with the descriptions. Male specimens are needed to examine the titillators and confirm the species identity.

16. *Liotrachela (?) sp.*

Fig. 16F

Remarks.—This species was found attracted to light and we postulate that it is also a canopy species. This species is superficially similar to *Holochlora* but the tenth abdominal tergite in males does not extend backwards into two lobes (Ingrisch 2002), and it possesses dorsal spines on fore tibia (Webber et al. 2003). We tentatively identified the specimens as belonging to this genus although it is not currently known from Borneo (Cigliano et al. 2018). More material is needed for verification.

17. *Liotrachela hyalina* Karny, 1926

Fig. 16G

Remarks.—We compared our male specimen with the original description (Karny 1926) and images of type specimen from OSF (Cigliano et al. 2018): male tenth abdominal tergite, cerci, and subgenital plate resemble our specimen. This species was described from Java, suggesting that our male specimen represents the first record of this species and genus in Borneo.

18. *Phygela sp.*

Fig. 16H

Remarks.—We tentatively identified the species to be close to *P. marginata* Brunner von Wattenwyl, 1878. One female was collected from a light trap. We recognized this species as *Phygela* owing to the tegmen with Rs and M angled at each cross vein and becoming obliterated in a series of large polygonal cells which occupy the radial field beyond the middle; and presence of a small lateral lobe between the subgenital plate and pileolus (this makes it different from an otherwise similar *Pseudopsyrha* Hebard, 1922). Our specimen appears to differ from the female of *P. marginata* from Borneo by a more elongated ovipositor and a stouter subgenital plate, but further examination of the three described species from Southeast Asia is needed to confirm species identity.

19. *Rectimarginalis sp.*

Fig. 16I

Remarks.—We tentatively identified this species to be similar to *R. profunda* Liu & Kang, 2007. We compared our single specimen (a male) with the descriptions of all species of *Rectimarginalis* Liu & Kang, 2007 (see Liu and Kang 2007) and images of the type specimen from OSF

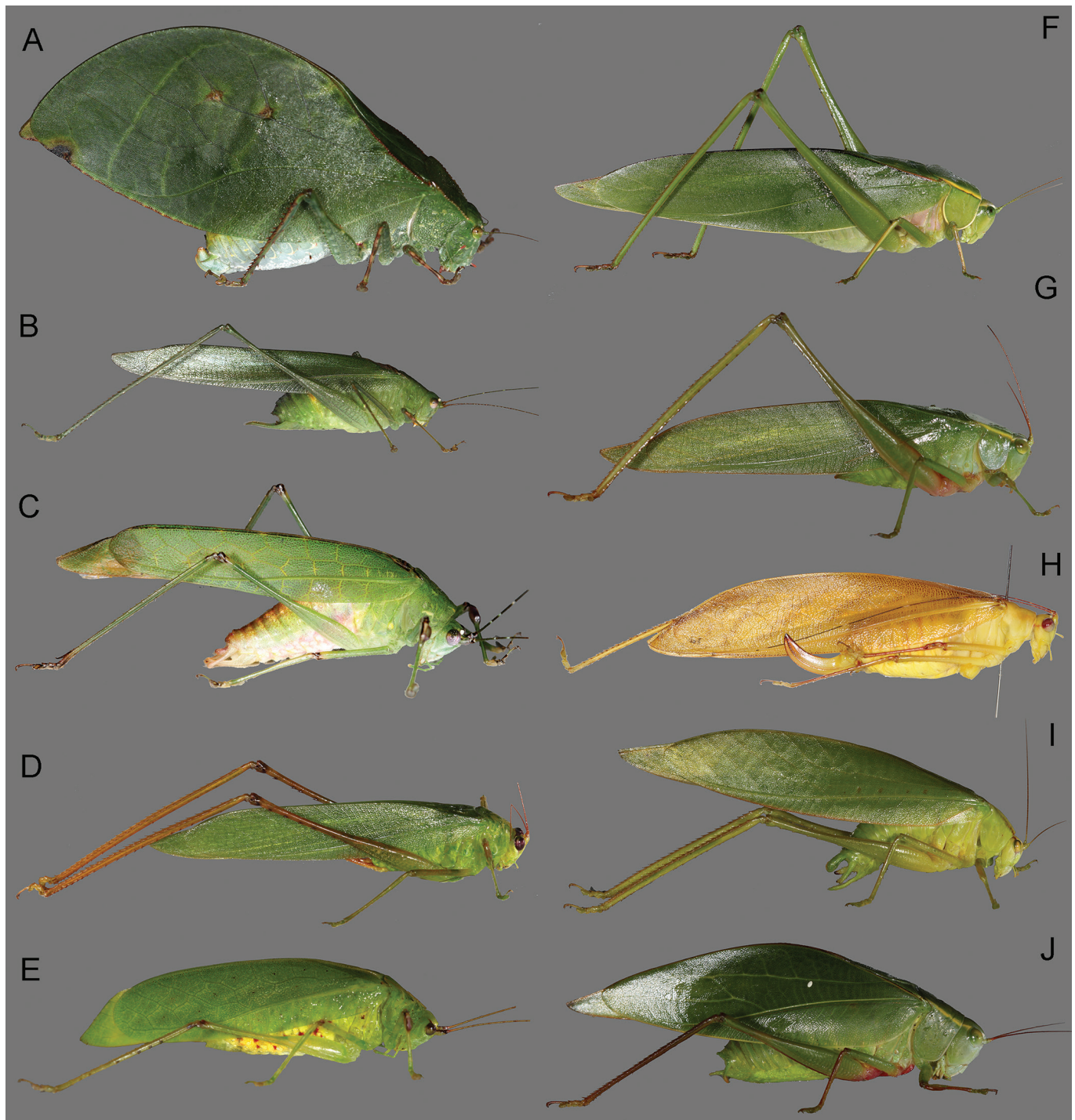


Fig. 16. Tettigoniidae: Phaneropterinae: A. *Baryprostha bellua*; B. *Casigneta bisinuata*; C. *Hemimirollia gracilis*; D. *Holochlora* sp.; E. *Mirollia* cf. *abnormis*; F. *Liotrachela* (?) sp.; G. *Liotrachela hyalina*; H. *Phygela* cf. *marginata*; I. *Rectimarginalis* nr. *profunda*; J. *Sympaestria lampra*.

(Cigliano et al. 2018). Although *R. profunda* is not found in Borneo, our specimen resembles this species in its tenth abdominal tergite, subgenital plate, and genitalia, and is more similar to *R. profunda* than to its congeners found closer to or in Borneo [i.e. *R. fuscospinosa* (Brunner von Wattenwyl, 1891) and *R. ensis* (Haan, 1843), respectively]. There are some small differences in the male tenth abdominal tergite and genitalia. We require more material for verification since only one specimen was collected from light trapping.

20. *Stictophaula brunei* Tan & Wahab, 2017

Remarks.—Only one specimen (a male) was collected during light trapping, perhaps suggesting that this is a canopy species rarely encountered in the forest understory. Extensive work recently on this Southeast Asian genus (see Ingrisch 1994, Gorochov 1998b, Gorochov and Kang 2004, Gorochov and Voltshenkova 2009) and images of type specimen from OSF (Cigliano et al. 2018) allowed

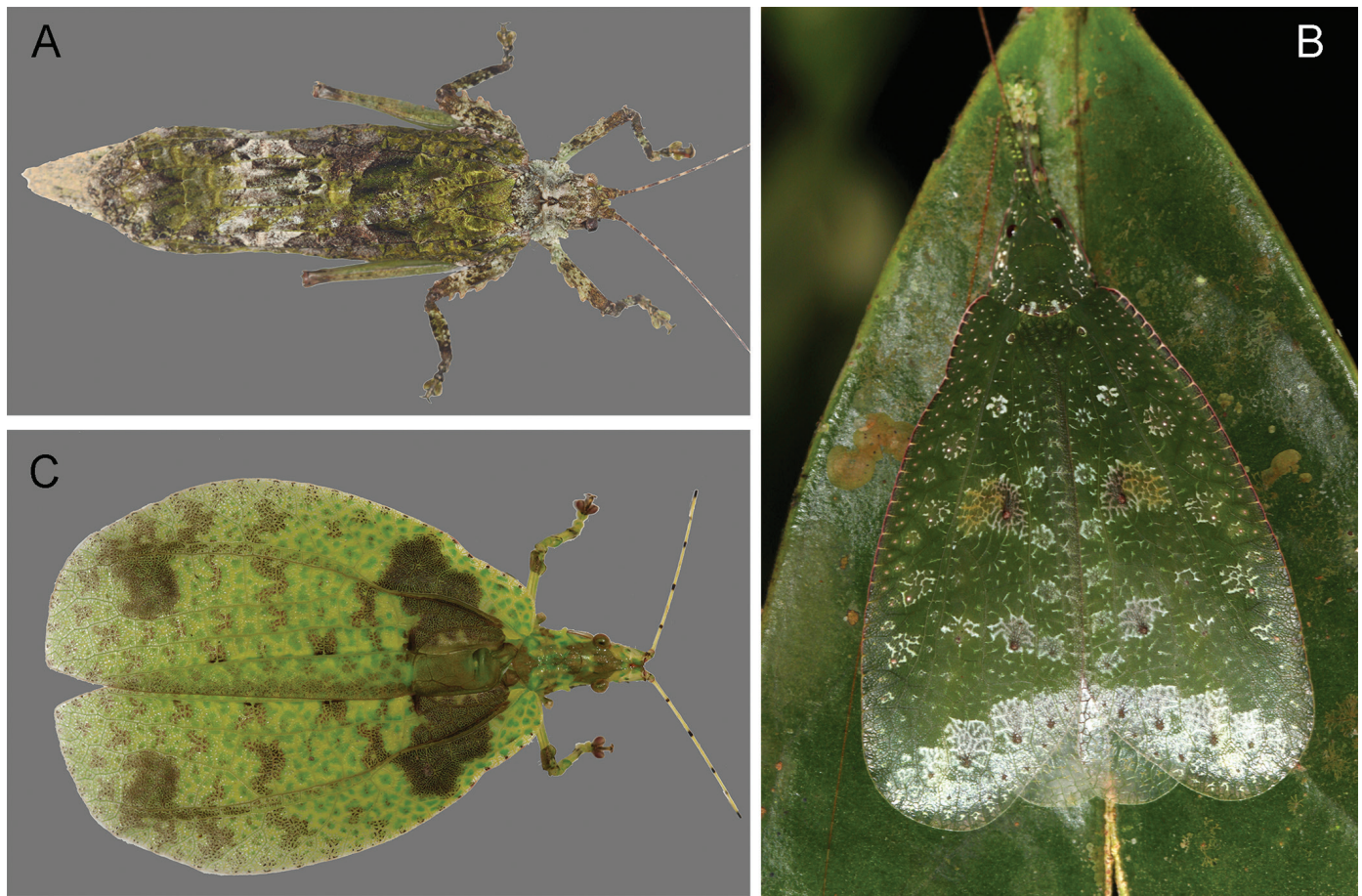


Fig. 17. Tettigoniidae: Pseudophyllinae: A. *Olcinia dentata*; B. *Phyllomimus* sp.; C. *Tympanophyllum* sp.

us to confirm that our specimen was undescribed. Full description of the new species and a key to all species can be found in Tan and Wahab (2017b).

21. *Sympaestria lampra* Hebard, 1922

Fig. 16J

Remarks.—This species is among the more common species of orthopterans attracted to light. They are, however, not encountered during opportunistic surveys in the understory, which is indicative of this being a canopy dweller. We used original descriptions (Hebard 1922) and type images from OSF (Cigliano et al. 2018) to identify our specimens.

22. *Tapiena paraincisa* Tan & Wahab, 2018

Remarks.—Our male specimen, collected during light trapping, resembles *Tapiena* (Tan et al. 2015). It is however unique in the shape of cercus and tenth abdominal tergite, and also differs from *T. incisa* Karny, 1923 from Sarawak. Refer to Tan and Wahab (2018b) for the new species description.

Subfamily Pseudophyllinae

23. *Olcinia dentata* de Jong, 1939

Fig. 17A

Remarks.—Only one specimen (a female) was collected during light trapping, perhaps suggesting that this is a canopy species rarely encountered on the forest understory. The crenulated costal margin of the tegmina distinguish our specimen from allied genera from the region (such as *Sathrophyllia* Stål, 1874 and *Tegra* Walker, 1870) (de Jong 1939, 1960, Bresseel and Vermeersch 2017). We also used the keys by De Jong (1960) and Bresseel and Vermeersch (2017) to identify our specimen.

24. *Phyllomimus* sp.

Fig. 17B

Remarks.—This species was found on the understory leaves, and can frequently be heard calling. Upon approaching the katydid, it flattened its body and extended its tegmina to camouflage against the background of the leaf. Patterns on the tegmina resemble epiphylls that were found commonly on the leaves of the trees in the forest around KBFSC (notice the leaf of Fig. 17B).

25. *Tympanophyllum* sp.

Fig. 17C

Remarks.—This species was found on the understory leaves. This genus is similar to *Chondroderella* in habitus and shape of tegmen, but differs by tegmen with Sc and R separated at the base and showing some short cross-veins between them (instead of lying closely appressed). Only a single specimen (a male) was collected but we need both male and female to compare with congeners and identify the species.

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