

New data on the calling songs of *Gymnogryllus* and *Macrogryllus* (Grylloidea, Gryllinae) from Sabah

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Abstract

We recorded the calling songs of two species of *Macrogryllus* Saussure, 1877 and four taxa of *Gymnogryllus* Saussure, 1877 from different parts of Sabah in Borneo, namely Mount Trus Madi, Maliau Basin and Meligan. The calling songs all consisted of a continuous trill. We found that the calling songs of the two genera exhibit clear differences in the dominant frequency, whereas each taxon also exhibits clear signature in the temporal domain of the calling songs, specifically the syllable duration, syllable interval and syllable period. The calling song of the genus *Macrogryllus* is described for the first time, and specifically the calling songs of *Macrogryllus canorus* Gorochoy, 2022 and *Macrogryllus ephippium* (Saussure, 1877). Taxonomic remarks, including on the morphology, are also presented for the studied taxa.

Key words: Borneo, bioacoustics, East Malaysia, Gryllidae, Gryllini, taxonomy

Introduction

Gryllini is a tribe of ground crickets that consists of some of the most well-studied species such as *Gryllus* (*Gryllus*) *bimaculatus* De Geer, 1773, *Acheta domesticus* (Linnaeus, 1758) and *Gryllodes sigillatus* (Walker, 1869) in various fields of biological research. These include the mating behaviours. In many Gryllini, the males produce calling songs and rely on phonotaxis by females to locate and choose males. Nevertheless, Gryllini is a very diverse and cosmopolitan group of crickets, with as many as 80 genera currently described (Cigliano *et al.*, 2025). Most genera remain poorly known in terms of calling songs.

In Southeast Asia, some of the ground crickets are particularly large, and the males create distinct burrows and sing at night near the entrance of their burrow (Gorochoy, 1983, 2001). These include species from the genera *Gymnogryllus* Saussure, 1877, *Macrogryllus* Saussure, 1877 and *Tarbinskiellus* Gorochoy, 1983. Gorochoy (2001, 2022) described the burrow of *Macrogryllus* and *Tarbinskiellus* and noted the loud calling songs of these crickets, but did not describe the calling songs. Desutter-Grandcolas (1996) described the calling song of *Gymnogryllus malayanus* Desutter-Grandcolas, 1996. Tan *et al.* (2018) used acoustic parameters of the calling songs, male tegminal venation and male genitalia to examine the species boundaries between five species of *Gymnogryllus* from different parts of Southeast Asia.

Recent fieldwork in different parts of Sabah in Borneo led to the encounters of more taxa of *Gymnogryllus* and *Macrogryllus*. We recorded the calling songs of two species of *Macrogryllus* and four taxa of *Gymnogryllus* from

Mount Trus Madi, Maliau Basin and Meligan. However, these crickets are also very agile and can easily escape collection by rushing into their burrows upon disturbance. As such, we were only able to collect two species of *Macrogyllus* and one species of *Gymnogyllus*. The newly collected material offers new insights into the taxonomy of these taxa.

Material and methods

In October–November 2023 and November 2024, opportunistic collections of crickets at day and night were conducted in Mount Trus Madi, as well as in Maliau Basin Conservation Area and around Meligan (including near Long Pasia and Sinipung Hill) in Sabah State (East Malaysia), Borneo. The permissions for collecting and exporting material were granted by the Sabah Biodiversity Centre (JKM/MBS.1000-2/2 JLD.16 (106) and JKM/MBS.1000-2/3 JLD.5 (40) for Mount Trus Madi; and JKM/MBS.1000-2/2 JLD.1 and JKM/MBS.1000-2/3 JLD.5 (106) for Maliau Basin and Meligan). The permission for research in Maliau Basin Conservation Area was also supported by the Maliau Basin Management Committee under the Yayasan Sabah (YS/MBMC(RA)/2024/3). The work of MKT and TR was supported by the National Geographic Grant NGS-73188R-20.

Whenever possible, live specimens were photographed using a Canon EOS 500D digital SLR camera with a compact-macro lens EF 100 mm f/2.8 Macro USM, and Canon Macro Twin Lite MT-24EX was used for lighting and flash. Sound recording was done in the field using a sampling frequency of 96 kHz-samples/s Zoom H1n with Stereo X/Y 90° microphones handle up to 120 dB SPL. A temperature logger, HOBO 8K Pendant® Temperature logger (model: UA-001-08, Onset, Bourne, MA), was used to record the ambient temperature.

The specimens were preserved in absolute analytical-grade ethanol and later pinned and dry-preserved. Typically, a single leg (not standardised) from each specimen was kept in absolute analytical-grade ethanol for future molecular work.

Male genitalia were dissected from softened specimens and removed by squeezing the cerci against one another laterally. The male genitalia were then cleaned using aqueous KOH and subsequently preserved in glycerine or hand sanitiser. Terminology used to describe the male genitalia follows Desutter-Grandcolas (2003) and also Gorochov (2015) [in square brackets]:

Pseudepiphallus (ps) [epiphallus]

Pseudepiphallic lophi (ps l) [posterolateral epiphallic lobe]

Pseudepiphallic paramere (ps p) [ectoparamere]

Ectophallic fold (ec f) [rachis (= guiding rod)]

Endophallic sclerite (en s) [formula (= mold of spermatophore attachment plate)]

Rami (ra)

These terminologies were also used to describe the pseudepiphallic paramere [ectoparamere] (Gorochov, 2022)

Apical (medial) sclerite (as)

Membranous area between apical and proximal sclerites (ma)

Mesal lobe (ml)

Posterodorsal sclerite (pds)

Proximal (anterior) portion (ps)

The pinned specimens were imaged using a Canon EOS 6D digital SLR camera attached to a Visionary Digital Passport system. For habitus, a compact-macro lens EF 50 mm at f/2.5 was used; for close-up images of morphological features, a macro photo lens MP-E 65 mm f/2.8 USM (1–5×) (sometimes with Tamron SP AF Tele-Converter 140F-CA 1.4×) was used. Image stacking was done using Zerene Stacker version 1.04. Image editing was accomplished using Adobe Photoshop 2025 (Adobe Systems Incorporated, San Jose, CA, USA).

Measurements of dry, pinned specimens were made from images using ImageJ 1.54g (Wayne Rasband, Research Services Branch, National Institute of Mental Health, Bethesda, MD, USA).

Parameters of the temporal domain (e.g., durations and intervals) were measured manually using Raven Lite 2.0.0. The dominant frequency was obtained using the ‘spectro_analysis’ function from the R package warbleR version 1.1.27 (Araya-Salas & Smith-Vidaurre, 2017) in the R software version 4.4.1. Acoustics analysis and song terminology generally follow Tan *et al.* (2022, 2023):

Calling song = spontaneous song produced by an isolated male to attract a female

Dominant frequency = frequency with highest energy from the mean spectrum

Syllable duration = length of time of the sound produced by a single complete stridulatory movement

Syllable interval = silent interval between syllable, or down-time

Syllable period = duration between the start of one syllable and the start of the subsequent syllable (i.e., syllable duration + syllable interval); = complete cycle of opening-closing

To visualise the differences in the calling songs of the recorded *Gymnogryllus* and *Macrogryllus*, the parameters were summarised into major gradients of variation by performing Principal component analysis (PCA) on scaled measurements using the 'pca.calc' function in the R package 'MorphoTools2' (Šlenker *et al.*, 2022). Biplots were then observed for any clustering or driving traits differentiating the calling songs using the functions 'plotPoints' and 'plotCharacters'.

The specimens were eventually deposited in:

FRC Forest Research Centre (Sepilok), Sabah Forestry Department, East Malaysia

OMNH Osaka Museum of Natural History, Ōsaka, Japan

ZRC Zoological Reference Collection, Lee Kong Chian Natural History Museum, Singapore

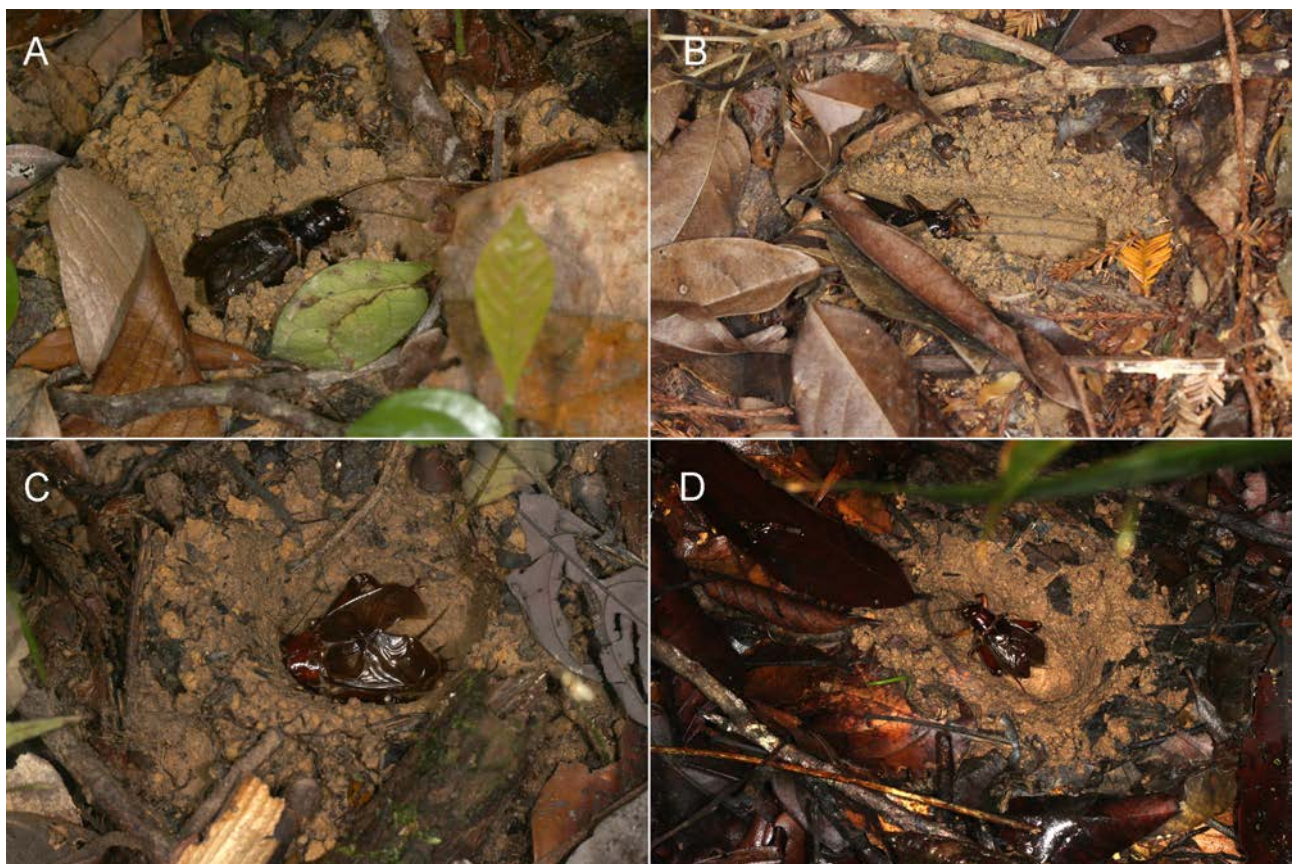


FIGURE 1. *Macrogryllus* and *Gymnogryllus* males calling at the entrances of their burrows: *Macrogryllus canorus* Gorochov, 2022 from Meligan (A); *Macrogryllus ephippium* (Saussure, 1877) from Maliau Basin (B); *Gymnogryllus* from Maliau Basin (C); *Gymnogryllus* from Meligan (D).

Results

In total, the calling songs of two species of *Macrogryllus* and four taxa of *Gymnogryllus* were recorded. *Macrogryllus* and *Gymnogryllus* share similarities in their calling behaviours. The males sing while stationed outside an opening to their burrow, typically after sunset (Fig. 1). The two species of *Macrogryllus* were observed to create a more

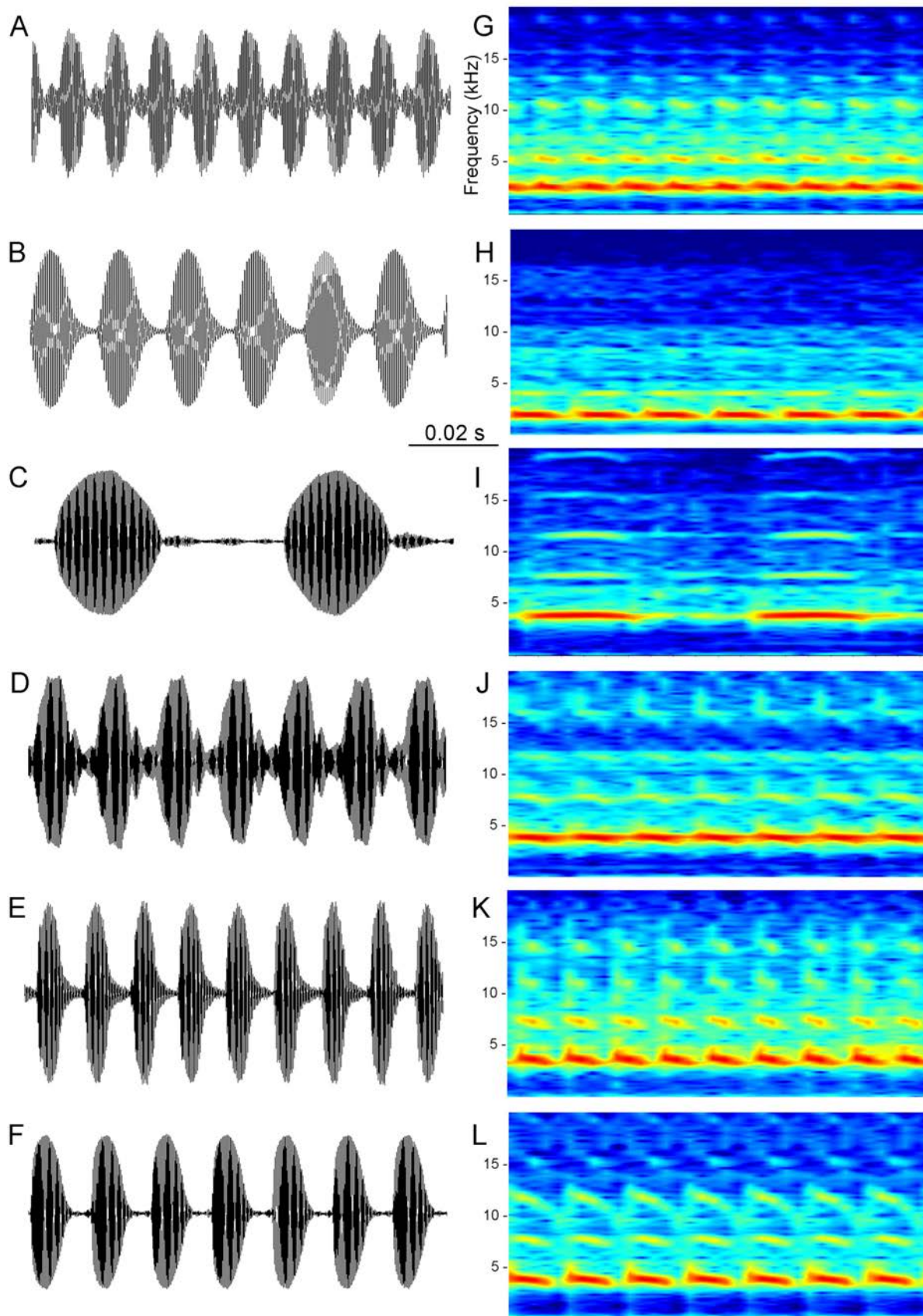


FIGURE 2. Oscillograms (A–F) and spectrograms (G–L) showing the calling songs of *Macrogyryllus* and *Gymnogryllus*: *Macrogyryllus canorus* Gorochoy, 2022 from Meligan (A, G); *Macrogyryllus ephippium* (Saussure, 1877) from Maliau Basin (B, H); *Gymnogryllus* from Maliau Basin (C, I); *Gymnogryllus* from Meligan (D, J); *Gymnogryllus borneensis* Ichikawa, 1996 from Mount Trus Madi (E, K); *Gymnogryllus* cf. *unexpectus trusmadi* Gorochoy, 2011 from Mount Trus Madi (F, L).

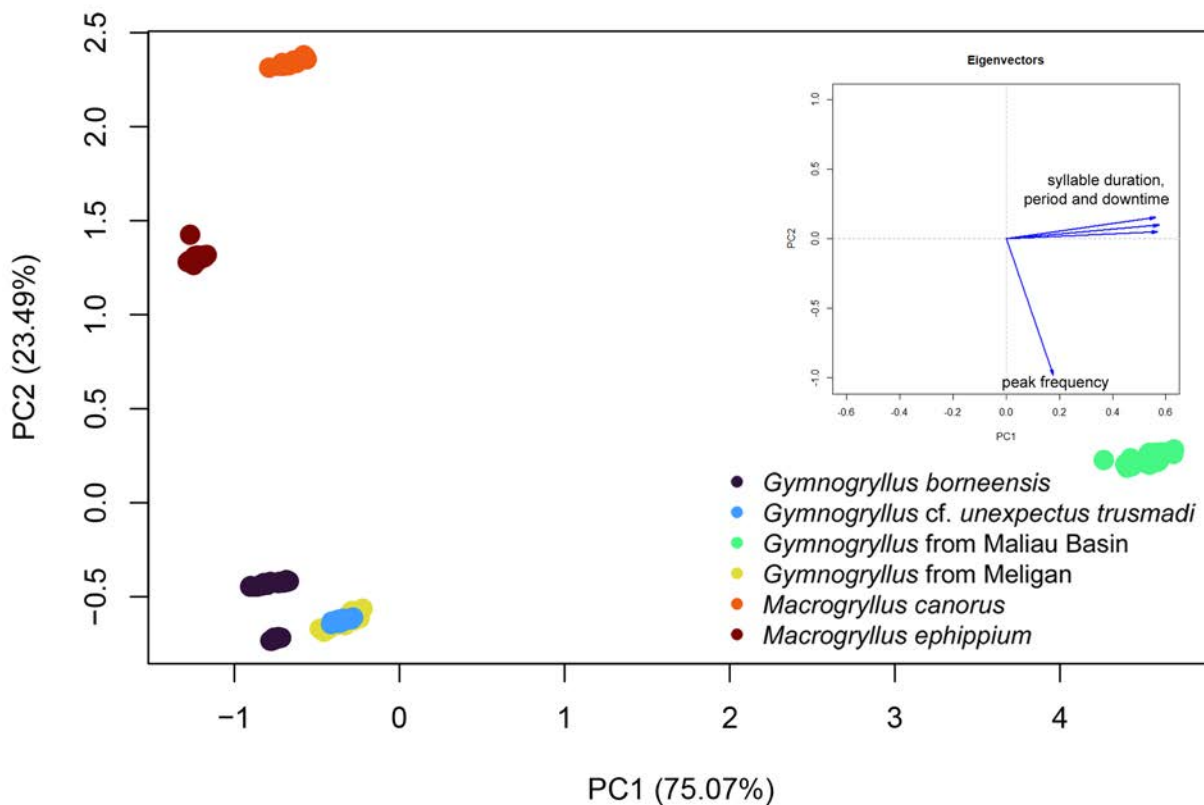


FIGURE 3. Biplot of Principal Component Analysis for the calling songs of two species of *Macrogyryllus* and four taxa of *Gymnogryllus*.

elongated cavity at the opening of the burrow, and to station themselves at the other end of this cavity farthest away from the opening (Figs 1A, 1B). The two taxa of *Gymnogryllus* from Maliau Basin and Meligan were observed to create different cavities (Figs 1C, 1D). The *Gymnogryllus* from Maliau Basin has a rounded cavity (Fig. 1C), whereas the *Gymnogryllus* from Meligan forms a slightly more elongated cavity with two depressions at both ends (Fig. 1D).

The calling songs of *Macrogyryllus* and *Gymnogryllus* are also similar in that they consist of continuous trills which can be very loud, forming a harmonic series with the dominant frequency corresponding to the fundamental frequency (Fig. 2). The most prominent difference in the calling songs between *Macrogyryllus* and *Gymnogryllus* is the dominant frequency (Table 1, Fig. 2). The dominant frequency is much lower in *Macrogyryllus* (always less than 3 kHz) than in *Gymnogryllus* (more than 3.5 kHz) (see also Tan *et al.*, 2018). The other call parameters in the time domain can overlap between the two genera, but each species tends to have a clear signature, especially among syntopic taxa (Table 1, Fig. 2).

The calling song of *Macrogyryllus canorus* Gorochoy, 2022 from Meligan differs from that of *Macrogyryllus ephippium* (Saussure, 1877) from Maliau Basin by the longer syllable duration and syllable period, as well as a lower dominant frequency. The two species have similar syllable interval (Table 1, Fig. 2). The differences in the calling songs between the two species corroborate the species previously delimited based only on morphology.

All the call parameters of the *Gymnogryllus* from Meligan and *Gymnogryllus cf. unexpectus trusmadi* Gorochoy, 2011 from Mount Trus Madi overlap, perhaps suggesting that they belong to the same species. But as we did not collect any specimens, we cannot confirm the identity of the calling songs.

The biplot based on the PCA shows that the first two axes accounts for 98.5% of variance (Fig. 3). The results confirm the differences between the taxa, as well as similarities between *Gymnogryllus* from Meligan and *Gymnogryllus cf. unexpectus trusmadi* (Fig. 3).

TABLE 1. Call parameters of six taxa of *Macrogyryllus* and *Gymnogryllus* from Sabah. * No specimen was collected.

Taxon	Syllable duration (ms)	Syllable interval (ms)	Syllable period (ms)	Dominant freq. (kHz)	Temperature (°C)
<i>Macrogyryllus canorus</i>	10.9±0.7 (10.1–12.7)	4.0±0.6 (2.6–4.9)	14.9±0.4 (14.0–15.7)	2.16	23.3
<i>Macrogyryllus ephippium</i>	5.9±0.6 (5.0–7.1)	3.9±0.6 (2.6–4.7)	9.8±0.2 (9.5–10.2)	2.72±0.02 (2.62–2.73)	25.1
<i>Gymnogryllus</i> from Maliau*	24.3±1.3 (22.1–25.8)	26.4±1.5 (22.7–28.9)	50.7±0.8 (48.2–51.8)	4.03	25.1
<i>Gymnogryllus</i> from Meligan*	8.3±1.1 (6.2–11.7)	5.3±1.0 (2.1–6.9)	13.6±0.4 (12.7–14.4)	4.03	23.6
<i>Gymnogryllus borneensis</i>	6.2±0.2 (5.8–6.7)	4.6±0.5 (3.6–5.7)	10.8±0.4 (9.9–11.8)	3.93±0.09 (3.84–4.03)	25.0
<i>Gymnogryllus</i> cf. <i>unexpectus</i> <i>trusmadi</i> *	9.0±0.3 (8.3–9.4)	4.4±0.3 (3.9–5.2)	13.4±0.2 (13.0–14.0)	4.03	29.0

Taxonomic parts

Superfamily Grylloidea Laicharting, 1781

Family Gryllidae Laicharting, 1781

Subfamily Gryllinae Laicharting, 1781

Tribe Gryllini Laicharting, 1781

***Macrogyryllus canorus* Gorochov, 2022**

(Figs 1A, 2A, 2G, 3, 4A–F, 5)

Macrogyryllus canorus Gorochov, 2022: 10.

New material examined. EAST MALAYSIA • 1♂; Sabah State, Sinipung Hill, near Long Pasia; N4.43658 E115.72371, 1322.0±7.0 m.a.s.l.; 20 November 2024, 18h26; calling at burrow; coll. M.K. Tan; SBH.24.172 (ZRC).

Remarks. Our specimen from Sinipung Hill in Meligan is most similar to *Macrogyryllus canorus* Gorochov, 2022 from Malay Peninsula by the general habitus (Figs 4A–F) and the male genitalia (Fig. 5) (the pseudepiphallallic paramere having its proximal (anterior) portion [ps] distinctly shorter [about as long as the apical (medial) sclerite (as)], the mesal lobe [ml] small and short but with similar membranous finger-like process at its apex, the posterodorsal sclerite [pds] narrow); but differs by the proximal (anterior) portion (ps) of the pseudepiphallallic paramere narrower, distal portion with lateral margin more convex and the posterodorsal sclerite (pds) having a stouter apical lobule.

Our specimen differs from *Macrogyryllus ephippium* (Saussure, 1877) from Borneo (including Mount Trus Madi), Sumatra and Java by the less robust habitus (Fig. 4), shape of the pseudepiphallus (pseudepiphallallic lophi in lateral view not tapering into a very slender and elongated apex, and posterior margin between the lobes more angularly concave rather than somewhat truncated) and shape of pseudepiphallallic paramere (latter proximal (anterior) portion [ps] with distinctly less convex lateral edge (in ventral view), mesal lobe (ml) somewhat smaller and its posterodorsal sclerite (pds) thinner (narrower) and with longer apical lobule).

It also differs from *Macrogyryllus bicolor* Chopard, 1930 from Borneo by the colouration (mostly dark brown or black rather than with its head and legs light brown) and larger size, as well as the shape of the pseudepiphallus



FIGURE 4. *Macrogryllus canorus* Gorochov, 2022 (A–F), *Macrogryllus ephippium* (Saussure, 1877) (G–L) and *Gymnogryllus borneensis* Ichikawa, 1996 (M–O) male: head and pronotum in dorsal (A, G, M) and lateral (C, I) views; face in anterior view (B, H, N); FW in dorsal view (D, J); body in lateral view (E, K, O); apex of FIII in dorsal view (F, L). Scale bar: 10 mm.

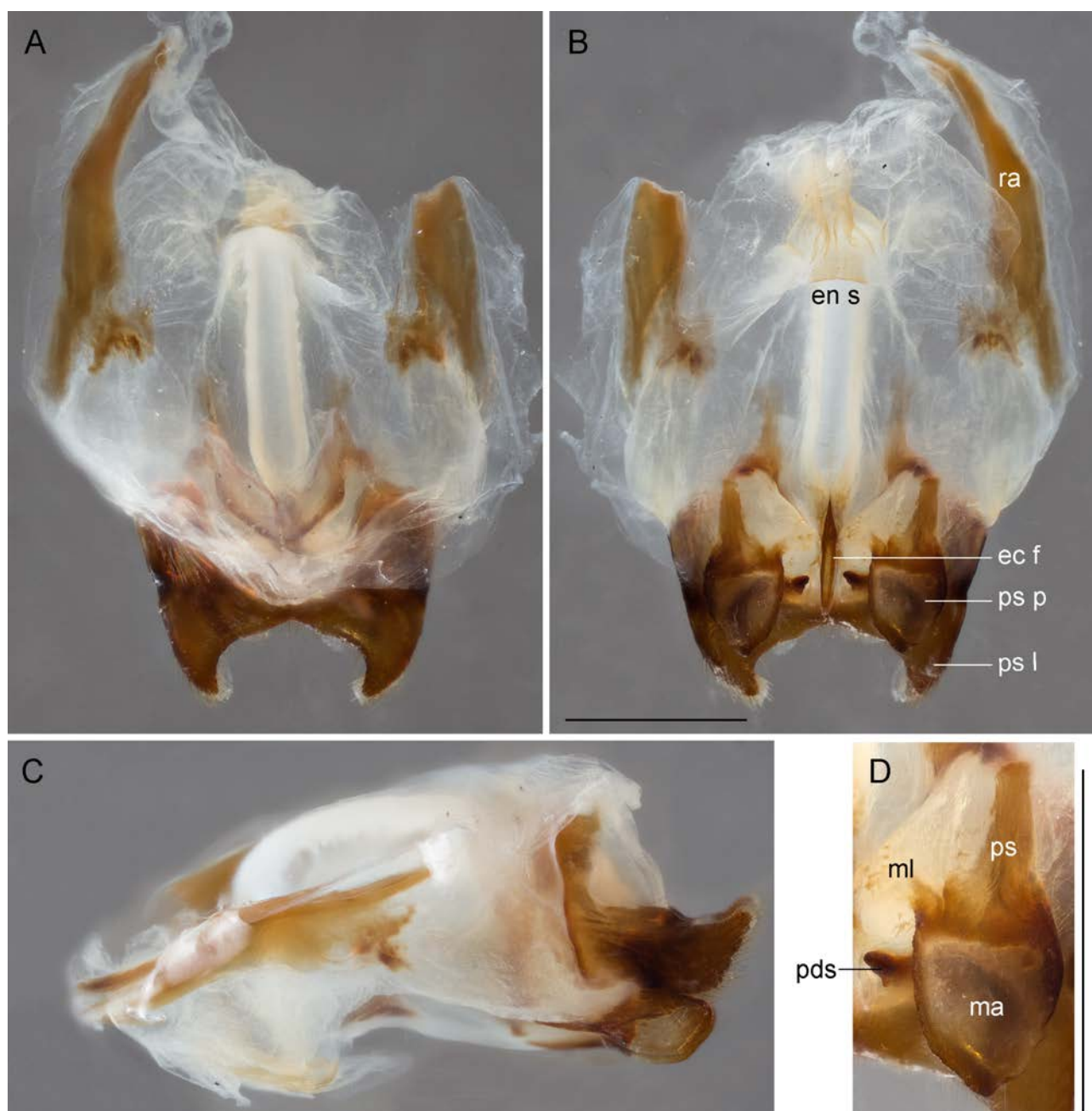


FIGURE 5. *Macrogyrillus canorus* Gorochov, 2022 male genitalia in dorsal (A), ventral (B) and lateral (C) views; pseudepiphallallic paramere [ectoparamere] in ventral view (D). Scale bars: 1 mm.

(pseudepiphallallic lophi in lateral view not tapering into a very slender and elongated apex, and posterior margin between the lobes more angularly concave rather than somewhat truncated) and the shape of pseudepiphallallic paramere (lateral edge more convex rather than concave and its posterodorsal sclerite (pds) much slenderer and with a distinct apical lobule).

Considering the differences between our specimen from Sinipung Hill and *Macrogyrillus canorus* are smaller than between ours and *Macrogyrillus ephippium* and *Macrogyrillus bicolor*, we postulate the differences observed between our specimen and *Macrogyrillus canorus* from Malay Peninsula may represent infra-specific variations. Moreover, since *Macrogyrillus ephippium* can be found across Sumatra and Borneo, it is not surprising that *Macrogyrillus canorus* may occur across major land masses in both Malay Peninsula and Borneo. Genetic and bioacoustics data on these taxa may reveal that they represent subspecies or even species, but based solely on morphology, we think it is more appropriate not to describe a new species or subspecies for our specimen from Sinipung Hill.

Distribution. Malay Peninsula (Pahang State: Fraser's Hill), Borneo (Sabah State: Sinipung Hill in Meligan [new locality record]).

Type locality. MALAYSIA: Pahang State: Fraser's Hill (Bukit Fraser).

Calling song (1♂, Figs 2A, 2G). See Results and Table 1.

***Macrogyllus ephippium* (Saussure, 1877)**

(Figs 1B, 2B, 2H, 3, 4G–L, 6, 7)

Brachytrypus (*Macrogyllus*) *ephippium* Saussure, 1877: 281 [113].

Macrogyllus ephippium (Saussure, 1877)—Kirby, 1906: 21; Chopard, 1931: 129; Chopard, 1967: 44; Chopard, 1969: 19.

Macrogyllus ephippium ephippium (Saussure, 1877)—Gorochoy, 2022: 8.

Macrogyllus ephippium vespertinus Gorochoy, 2001: 349.

New material examined. EAST MALAYSIA • 1♂; Sabah State, Maliau Basin, trail from Agathis–Nepenthes Camps, at 2-km mark; N4.70468 E116.89717, 843.6±8.5 m.a.s.l.; 12 November 2024, 21h18; walking on forest floor; coll. M.K. Tan; SBH.24.54 (ZRC).



FIGURE 6. *Macrogyllus ephippium* (Saussure, 1877) from Maliau Basin.

Remarks. Our specimen (Figs 4G–L) mostly resembles *Macrogyllus ephippium* most among the congeners by the shape of the pseudepiphallus (pseudepiphallic lophi in lateral view tapering into a very slender and elongated apex, and posterior margin between the lobes truncated—although that margin of our specimen at middle is also somewhat angular); and the shape of the pseudepiphallic paramere (Fig. 7).

The pseudepiphallic paramere of our specimen resembles that of *Macrogyllus ephippium vespertinus* from Sumatra in the shape of the apical (medial) sclerite (as) and the relative length of proximal (anterior) portion (ps) with apical (medial) sclerite (as), but resembles that of *Macrogyllus ephippium ephippium* from Borneo (sensu Gorochoy, 2022) by the shape of the mesal lobe (ml) and the posterodorsal sclerite (pds) more robust and stouter.

Distribution (sensu Gorochov [2001, 2022]). Sumatra (Lampung Province: Bukit Barisan Selatan; West Sumatra: Harau Valley), Borneo (Sabah State: Maliau Basin [new locality record], Mount Trus Madi; Kalimantan Province: Bukit Bangkirai).

Type locality. “tropical Africa or Java?” (see Gorochov, 2022); INDONESIA: West Sumatra, Harau Valley. National Park (for subspecies *Macrogyrillus ephippium vespertinus* Gorochov, 2001).

Calling song (1♂, Figs 2B, 2H). See Results and Table 1.

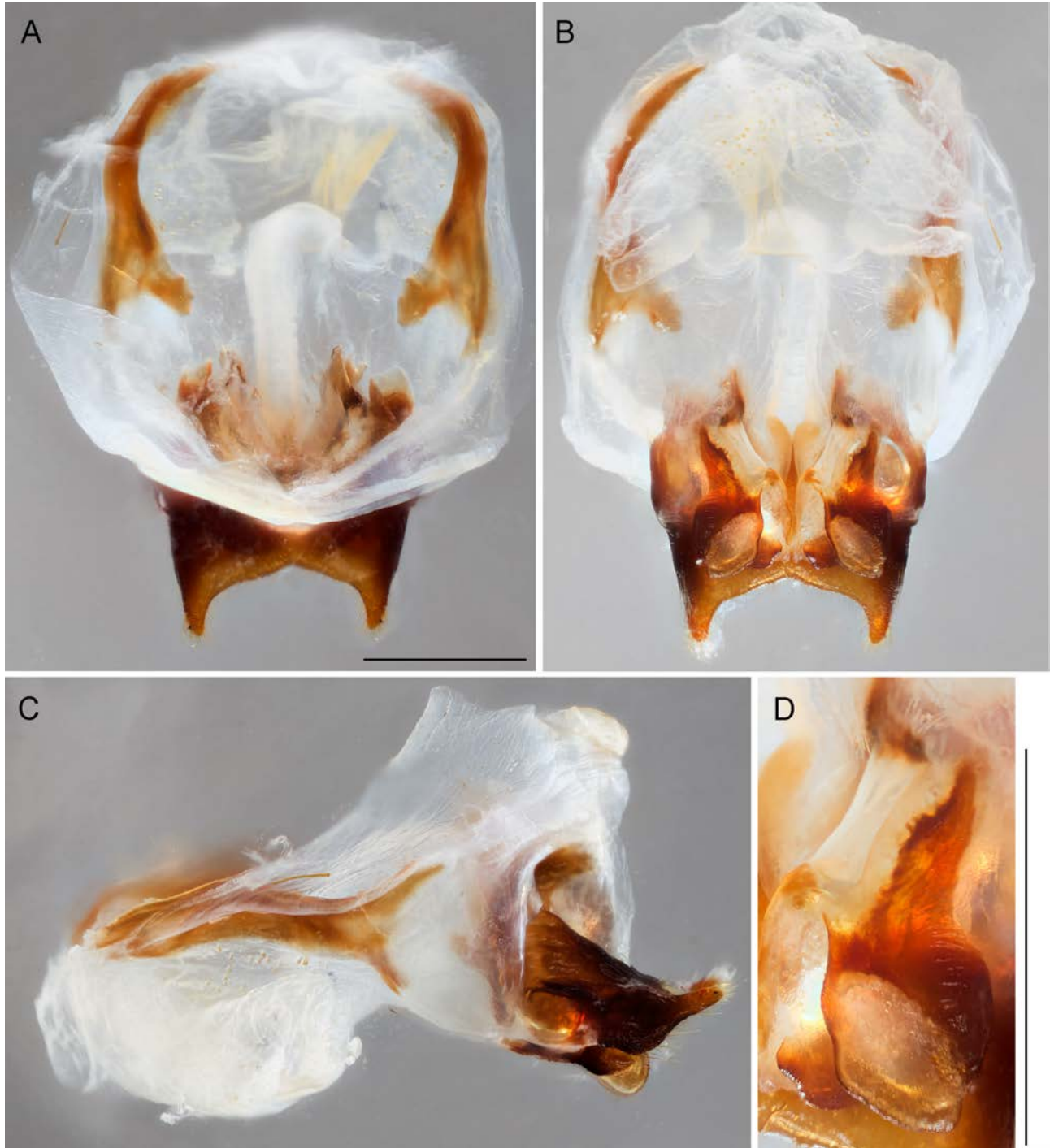


FIGURE 7. *Macrogyrillus ephippium* (Saussure, 1877) male genitalia in dorsal (A), ventral (B) and lateral (C) views; pseudepiphallic paramere [ectoparamere] in ventral view (D). Scale bars: 1 mm.



FIGURE 8. *Gymnogryllus borneensis* Ichikawa, 1996 at Mount Trus Madi attracted to light at night.



FIGURE 9. *Gymnogryllus borneensis* Ichikawa, 1996 male genitalia in dorsal (A), ventral (B) and lateral (C) views; pseudepiphallid paramere [ectoparamere] in ventral view (D). Scale bars: 1 mm.

***Gymnogryllus borneensis* Ichikawa, 1996**

(Figs 1B, 2E, 2K, 3, 4M–O, 8, 9)

Gymnogryllus borneensis Ichikawa, 1996: 29.

Type material examined (images of habitus only). EAST MALAYSIA • ♂; Sabah State, Keningau, Kimanis Road, 18-mile point; OMNH TI 54.

New material examined. EAST MALAYSIA • 1♂; Sabah State, Mount Trus Madi, Trusmadi Entomology Camp; N5.44300 E116.45140, 1184.0±11.6 m.a.s.l.; 31 October 2023, 19h34; attracted to light at camp; coll. M.K. Tan; SBH.23.2 (ZRC).

Type locality. EAST MALAYSIA: Sabah State, Keningau, Kimanis Road, 18-mile point.

Calling song (3♂, Figs 2E, 2K). See Results and Table 1.

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