



HAL
open science

Notes on the Eneopterinae (Orthoptera, Grylloidea, Gryllidae) from eastern Sabah

Tony Robillard, Ming Kai Tan, Razy Japir, Arthur Y.C. Chung

► To cite this version:

Tony Robillard, Ming Kai Tan, Razy Japir, Arthur Y.C. Chung. Notes on the Eneopterinae (Orthoptera, Grylloidea, Gryllidae) from eastern Sabah. *Zootaxa*, 2023, 5315 (3), pp.231-250. 10.11646/zootaxa.5315.3.2 . hal-04201059

HAL Id: hal-04201059

<https://hal.science/hal-04201059>

Submitted on 14 Sep 2023

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Notes on the Eneopterinae (Orthoptera, Grylloidea, Gryllidae) from eastern Sabah

Running title: Eneopterinae from eastern Sabah

Tony Robillard¹, **Ming Kai Tan**^{2*}, **Razy Japir**³ & **Arthur Y.C. Chung**³

¹ Institut de Systématique, Evolution, Biodiversité (ISYEB), Muséum national d'Histoire naturelle, CNRS, SU, EPHE, UA, 57 rue Cuvier, CP 50, 75231 Paris Cedex 05, France.

E-mail: tony.robillard@mnhn.fr; <https://orcid.org/0000-0002-2177-9549>

² Block 207A, Woodleigh Link, Singapore 361207, Republic of Singapore

E-mail: orthoptera.ming kai@gmail.com (*corresponding author); <https://orcid.org/0000-0002-4324-6305>

³ Forest Research Centre (Sepilok), Sabah Forestry Department, PO Box 1407, 90715 Sandakan, Sabah, Malaysia.

E-mail: razy.japir@sabah.gov.my (RJ); arthur.chung@sabah.gov.my, <https://orcid.org/0000-0002-9529-4114> (AYCC)

Abstract

Based on material collected during recent fieldwork in eastern Sabah, the males of *Nisitrus danum* Robillard & Tan and *Cardiodactylus variegatus* Gorochov & Robillard are described for the first time, along with their calling songs. New locality records of *N. danum*, *N. vittatus* (Haan), *Falcerminthus sandakan* (Tan *et al.*) and *Cardiodactylus borneoe* Robillard & Gorochov and *C. variegatus* are also presented. New material of *Nisitrus* species—*N. danum* and *N. vittatus*—allowed us to compare these syntopic species.

Key words: calling song, Lebinthini, new locality records, Nisitriini, Southeast Asia

Introduction

The subfamily Eneopterinae (Orthoptera, Gryllidae) is highly diversified in Southeast Asia, with as many as 10 genera and ca. 100 species currently known (Cigliano *et al.*, 2023). Numerous species and new genera have been recently discovered from this biodiverse region, which include *Fadinthus* Robillard & Tan, 2021 (two species recently described from this genus), *Falcerminthus sandakan* (Tan *et al.*, 2019), *Rugabinthus* Tan & Robillard, 2022 with 12 new species (Tan & Robillard, 2022), *Platybinthus* Robillard & Tan, 2023 with one new species (Robillard & Tan, 2023), five new species of *Nisitrus* Saussure, 1878 (Tan *et al.*, 2021a), one new species of *Gnominthus* Robillard & Vicente, 2015 and two new species of *Macrobithus* Robillard & Dong, 2016 (Tan & Robillard, 2021a). These new discoveries were made possible by examining old and unidentified specimens in natural history museums as well as recent fieldwork in localised parts of Southeast Asia. Consequently, we may still lack information on one of the sexes and juveniles, live colouration and bioacoustics information of species described from old specimens, as well as a more complete understanding of a species distribution for many species. Although Eneopterinae is probably the best studied cricket subfamily in Southeast Asia—ranging from ecology, behaviour and evolution (e.g., Robillard & Desutter-Grandcolas, 2004a, 2004b; Robillard *et al.*, 2013; ter Hofstede *et al.*, 2015; Tan & Robillard, 2021b, 2021c; Tan *et al.*, 2021b, 2021c; Ballesteros *et al.*, 2022)—many species still lack basic biological information.

Recently, an orthopteran sampling was conducted in different parts of eastern Sabah, including Sepilok, Mount Silam, forest reserves near Lahad Datu and Tabin Wildlife Reserve. This led to the discoveries of the previously unknown males of *Nisitrus danum* Robillard & Tan, 2021 and *Cardiodactylus variegatus* Gorochov & Robillard, 2014 for the first time, along with their calling songs. We also document new locality records for *N. danum*, *Nisitrus vittatus* (Haan, 1844), *Falcerminthus sandakan*, *Cardiodactylus borneoe* Robillard & Gorochov, 2014 and *C. variegatus* Gorochov & Robillard, 2014. In the case of *F. sandakan*, while the species was described from Sepilok (Tan *et al.*, 2019) it is found to be well distributed around eastern Sabah and occurs in high abundance in these localities.

Materials and Methods

Specimens

Collection of orthopterans were done by sight during day and night in different parts of Sabah between 11 and 19 May 2022: Kabili Sepilok Forest Reserve, Mount Silam, Kawag Forest Reserve, Sepagaya Forest Reserve and Tabin Wildlife Reserve under the collecting permit (JKM/MBS.1000-2/3 JLD.3 (99) and JKM/MBS.1000-2/2

JLD.10 (179)). Whenever possible, in-situ images of specimens were taken 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. The specimens were deposited in Forest Research Centre (Sepilok), Sabah Forestry Department, East Malaysia (FRC) and Muséum national d'Histoire naturelle, Paris, France (MNHN).

Acoustics

Sound recording was done using a modified Condenser Microphone Capsule CM16 (Avisoft Bioacoustics, Berlin), connected to a Fostex FR-2LE digital field recorder (96 kilo-samples per second sampling frequency, 16 bit) either in the field or in captivity. In captivity, the cricket was kept isolated in a small insect cage with nylon cover. A temperature logger, HOBO 8K Pendant® Temperature logger (model: UA-001-08, Onset, Bourne, MA), was used to record the ambient temperature. To document the circadian rhythms of the calling activity, we followed procedures described in Tan & Robillard (2021b).

The basic cricket song terminology generally follows Baker & Chesmore (2020):

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

Dominant frequency = frequency with highest energy from the mean spectrum;

Echeme = a first-order assemblage of syllables;

Echeme-sequence = a first-order assemblage of echemes;

Interval = silent interval between calls and/or pulses, or down-time;

Syllable = single complete stridulatory movement (i.e., opening and closing of wings);

Parameters of the temporal domain (e.g., durations and intervals) were measured manually using Raven Lite 2.0.0. The peak 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 4.1.3.

Morphology

The specimens were preserved in absolute analytical-grade ethanol and later pinned and dry-preserved. 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. Photographs of male genitalia were done with a binocular microscope Leica MZ16 with AMScope Microscope Eyepiece Camera (MU1000, 10 MP Aptina Colour, CMO50) and the software ToupView. Image editing was accomplished using CombineZP version 1.0 and Adobe Photoshop CC2014. To highlight the structural components of genitalia, water solution containing a drop of JBL Punktol was used. To fix orientations and stabilisation of genitalia for photography, a clear and viscous hand sanitiser was used following Su (2016). Terminology used to describe the male genitalia follows Desutter-Grandcolas (2003) and Tan *et al.* (2021a).

Abbreviations

General morphology: I, II, III = front, median, hind respectively (femora, legs, tibiae); F = femora; FW = forewing; T = tibiae; Tarsomere III-1 = basal segment of hind leg tarsomere.

Measurements: BL: body length; FIIIL = length of hind femora; FIIIW = width of hind femora; FWL = forewing length; FWW = forewing width (at the level of maximal width); PronL = pronotum length; PronW = pronotum width; TIIIL = length of hind tibiae.

Tegminal venation: 1A–4A = first to fourth anal veins;

c1–2 = first and second cells of C alignment; ch = chord veins;

CuA = anterior cubital vein; d1 cell (mirror) = first cell(s) of D alignment; d2 = second cell of D alignment; M = median vein; R = radial vein; Sc = subcostal vein.

Taxonomy

Subfamily Eneopterinae Saussure, 1874

Tribe Nisitrini Robillard, 2004

Genus *Nisitrus* Saussure, 1878

Type species: *Nisitrus marginatus* Walker, 1869 – According to the ICZN, and contrary to what was mentioned in the recent revision of the genus (Tan *et al.*, 2021a), the type species should remain *N. marginatus* even though this name is a junior synonym of *N. vittatus* Haan.

Nisitrus danum Robillard & Tan, 2021

(Figs 1–8)

Nisitrus danum Robillard & Tan, 2021, in Tan *et al.* 2021a: 31

Material examined

MALAYSIA – Sabah • 1♂; Kawag Forest Reserve, near rest house; N5.0502 E117.98286, 134.7 m.a.s.l. (GPS SAB22_6); 14.v.2022; afternoon; on plant; call recording MNHN-SO-2023-1478; M.K. Tan & T. Robillard; MNHN-EO-ENSIF11344 • 1♀; Kawag Forest Reserve, near rest house; N5.0502 E117.98286, 134.7 m.a.s.l. (GPS SAB22_6); 14.v.2022; afternoon; on plant; molecular sample N67; M.K. Tan & T. Robillard; MNHN-EO-ENSIF11345 • 1♀ (photographed, not collected); Tabin Wildlife Reserve, Lipad mud volcano; N5.20967 E118.50732, 168.9 m.a.s.l. (GPS SAB22_11); 16.v.2022; day; T. Robillard observation • 2 juveniles; Tabin Wildlife Reserve; N5.19534 E118.50365, 119.7 m.a.s.l. (GPS SAB22_9); 15.v.2022, night; molecular samples N65–N66; MNHN-EO-ENSIF10978–ENSIF10979 • 1 juvenile (not collected); Sepilok, Rainforest Discovery Centre; N5.87428 E117.93970, 1.x.2019 (Fig. 3B) • 1 juvenile; Lahad Datu, N4.962598 E117.801956; 19.viii.2022; [twan3253](https://www.inaturalist.org/observations/133043313) observation; <https://www.inaturalist.org/observations/133043313> • 1♀; Lahad Datu, N4.964485 E117.803471; [twan3253](https://www.inaturalist.org/observations/133303271) observation; <https://www.inaturalist.org/observations/133303271> • 1♀; Lahad Datu, N4.965797 E117.800246; [twan3253](https://www.inaturalist.org/observations/133431471) observation; <https://www.inaturalist.org/observations/133431471>

Additional description

Habitus as shown in Fig. 1A. Face, lateral lobes of pronotum and wide lateral band on FWs vivid yellow in living specimens (Figs 1A, 1B). Antennae with 2 main white rings, including 3–6 antennomeres and 2–3 thinner rings.

Male. Metanotal gland well developed, as shown in Fig. 1C. FWs (Figs 1D, 1E) dorsal field anterior part black (cells and veins); harp and mirror area infurcated, with black veins; apical field with black cells and yellow veins. Harp with two straight oblique veins. Mirror large, not rounded, separated by one transverse vein. Vein c1 wide. Lateral field with a wide vivid yellow band including veins M, R and Sc, and bases of veins bifurcating from Sc; ventral part of lateral field shiny black, as in females.

Male genitalia (Fig. 2) typical of genus, including ectophallic fold, endophallic sclerite, ectophallic arc and rami, but with pseudepiphallic lophi triangular and relatively stout in dorsal and profile views, narrowly spaced between pseudepiphallic lophi; pseudepiphallic parameres strongly bent at interno-anterior end.

Juvenile (Fig. 3). Colouration pale yellow or white, characterised by numerous dark stripes all around body in early instars; antennae with 2 wide whitish rings as in adults.

Measurements (in mm, means in brackets, N = 5 males). BL = 13.9–15.3 (14.6), PronL = 1.8–2.1 (1.9), PronW = 2.7–3.1 (2.9), FWL = 10.1–11.0 (10.4), FWW = 3.8–4.1 (3.9), HWT = 4.5–7.6 (6.6), FIIL = 13.4–15.5 (14.5), FIIW = 2.5–2.9 (2.6), TIIL = 13.5–15.5 (14.4), Stridulatory teeth = 94–95.

Comparison with *N. vittatus*

Larger, with dark shiny lateral field of FWs in both sexes, below a vivid yellow band; face yellow with dark brown to black mouthparts (entirely yellow with a few dark spots in *N. vittatus*); adults and juveniles (Fig. 3) are recognisable by the larger yellow rings on antennae (2 main rings, with 3–6 white antennomeres, while antennae are almost entirely black with in *N. vittatus*, with at best thin rings).

Comparison with *N. musicus*

Similar in size, but differing by dark shiny lateral field of FWs in both sexes, below a vivid yellow band; face vivid yellow (whitish in *N. musicus*).

Ecology

Found in syntopy with *Nisitrus vittatus*, the latter species being much more abundant, and has been observed to be outnumbered by at least 10 to 1. The males and females were found inter-mixing with *N. vittatus* on large foliage of *Leea indica* along roads (forest edge) (Fig. 4). Similar to *N. vittatus*, this species tends to occur in open areas (Fig. 5).

Distribution (Fig. 6)

Borneo (Sabah: Danum Valley, Tawau Hill Park, Kawag Forest Reserve [new locality record], Sepilok Kabili Forest Reserve [new locality record], Tabin Wildlife Reserve [new locality record])

Calling song (9♂, 23°C, in captivity)

The calling song consists of long homogeneous bouts (= trill) which can last between 3 s to more than 16 min (Fig. 7). The trill is made up of a sequence of short echemes. Each echeme is made up of two syllables and has an average duration of 41.3 ± 2.1 ms (36.6–45.9 ms). The average interval between consecutive echemes is 50.1 ± 5.2 ms (42.6–62.1 ms). On average, the first syllable has a slightly shorter duration of 15.2 ± 0.8 ms (13.2–17.3 ms) than the second syllable with a duration of 16.0 ± 1.2 ms (12.6–18.7 ms). The average interval between the two syllables is 10.0 ± 1.0 ms (7.9–12.3 ms). The call spectrum consists of a series of harmonics with three distinct peaks in the first three harmonics: first harmonic (fundamental frequency) at 6.13 ± 0.14 kHz (5.72–6.47 kHz), which is typically also the dominant frequency; second harmonic at 12.21 ± 0.31 kHz (11.34–12.84 kHz); third harmonic at 18.32 ± 0.43 kHz (16.97–19.22 kHz). While second and third harmonics are not dominant, their amplitude is high and sometimes almost co-dominant with the fundamental frequency.

The calling song of *N. danum* is very distinct from that of the syntopic species, *Nisitrus vittatus* (see Tan *et al.*, 2021a), by the echeme structure being made up of two syllables, rather than three syllables. The echeme duration is also distinctly longer in *N. danum* than in *N. vittatus* (average duration = 41.3 ms vs. 32.5 ms). Consequently, the syllable durations are also longer in *N. danum* than in *N. vittatus*. The interval between consecutive echemes is also distinctly longer in *N. danum* than in *N. vittatus* (average duration = 50.1 ms vs. 22.7 ms). Although the frequencies of *N. danum* is lower than that of *N. vittatus*, it could be an artefact of the lower ambient temperature when *N. danum* was recorded (23°C for *N. danum* vs. 27°C for *N. vittatus*).

Despite morphological similarities between *N. danum* and *N. musicus* (also from Sabah, but specifically from Mount Kinabalu), there are also differences in their calling song. Both species have similar echeme structure made up of two syllables, but the echeme duration is distinctly longer in *N. danum* than in *N. musicus* (average duration = 41.3 ms vs. 29.7 ms). While the durations of the two syllables in each echeme are somewhat similar in *N. danum* (15.2 ms vs. 16.0 ms), those in *N. musicus* are drastically different (7.5 ms vs. 18.7 ms).

We found that *N. danum* is also a diurnal species, similar to other *Nisitrus* (Fig. 8). The circadian rhythm of the calling activity was as follows: calling began at 6h in the morning and its activity increases to a maximum at 8h in the morning (amount of sound produced per hour = ca. 1683 s). This follows by a drop in calling activity. A second smaller peak in calling activity (amount of sound produced per hour = ca. 915 s) was detected in the afternoon around 16h. Most calling activity ceases at 19h in the evening. The two diurnal peaks were also observed in *N. vittatus* (see Tan & Robillard, 2021b) but they differ in that the highest peak for *N. danum* was in the morning whereas that for *N. vittatus* was in the afternoon.

***Nisitrus vittatus* (Haan, 1844)**

(Figs 3C, 4B)

Gryllus (Platydictylus) vittatus Haan, 1844: 234.

Nisitrus vittatus – Saussure, 1878: 511, 653; see Tan *et al.*, 2021: 64 for the complete list of references.

New locality records

Borneo: Sabah: Sepagaya Forest Reserve, Tabin Wildlife Reserve; Mount Silam, Kawag Forest Reserve.

Comparison with *N. danum*

See above.

Ecology

Found in syntopy with *Nisitrus danum* in some places in Sabah (Fig. 4B).

Distribution

Sumatra, Borneo (Sabah: Mount Kinabalu, Trus Madi, Crocker Range, Mulu, Sandakan, Kinabatangan, Danum Valley, Tawau; Sarawak; Kalimantan; Brunei Darussalam)

Tribe Lebinthini Robillard, 2004

Subtribe Cardiodactylina Robillard & Tan, 2021

Genus *Cardiodactylus* Saussure, 1878

***Cardiodactylus borneoe* Robillard & Gorochov, 2014**

Cardiodactylus borneoe Robillard & Gorochov, 2014, in Robillard *et al.*, 2014: 12 – Dong *et al.*, 2018: 6 (phylogeny and historical biogeography); Tan *et al.*, 2019a: 355 (calling song); Tan *et al.*, 2019b: 302.

New locality records

Borneo: Sabah: Tabin Wildlife Reserve, Mount Silam, Kawag Forest Reserve.

Distribution

Borneo (Sabah: Danum Valley, Mangalum Island, Crocker Range, Sukau Village, Sepilok-Kabili Forest Reserve, Tabin Wildlife Reserve, Mount Silam, Kawag Forest Reserve; Kalimantan: Marah [river], Long Petak, WWF station [Lalut Birai], Bukit Soeharto), Malay Peninsula (Peninsular Malaya: Pulau Tioman).

***Cardiodactylus variegatus* Gorochov & Robillard, 2014**

(Figs 9–11)

Cardiodactylus variegatus Gorochov & Robillard, 2014, in Robillard *et al.*, 2014: 100 – Dong *et al.*, 2018: 6 (phylogeny and historical biogeography)

Material examined

MALAYSIA – Sabah • 1♂; Mount Silam, near peak (end); N4.96878 E118.17189, 736.1 m.a.s.l. (GPS SAB22_3); 12.v.2022; TR22-08; on low plant at base of tree (night); molecular sample C241; call recording MNHN-SO-2023-1479; M.K Tan & T. Robillard; MNHN-EO-ENSIF11346

Additional description

Male. Habitus as shown in Fig. 9A; FWs (Fig. 9B). FW colouration mostly dark brown (cells and veins), with yellow areas including bases of anal veins and CuA, harp veins, oval region posterior to mirror. Apical field entirely dark brown, including transverse veins. Bases of chords orange brown. Lateral field: M/R/Sc area and cells dark orange brown. Sc with yellow projections. FW venation: 1A slightly bisinuated. CuP absent. Harp with 2 w-shaped oblique veins. Mirror (d1) oval, separated in two parts near mid-length; d2 as wide as mirror. Apical field with 4 cell alignments posterior to mirror. Lateral field with 6 projections of Sc and 4 more ventral veins.

Male genitalia (Fig. 10): Pseudepiphallus short, narrowed twice, at mid-length and preapically; apex slightly asymmetrical and curved laterally. Lateral ridges forming short and thick parallel walls, their dorsal edges lanceolate due to widening of anterior region, their dorsal edges carinated; pseudepiphallus bisinuated laterally. Pseudepiphallic sclerite with short latero-anterior expansions, membrane between them with thin setae. Posterior region of pseudepiphallus almost square, narrower than preapical part, apex with a translucent area including a small anterior sclerotization. Rami with semi-circular preapical plates and well visible apical stems. Ectophallic arc complete, v-shaped. Ectophallic fold with strong lateral sclerites; apex trilobate, membranous. Endophallic sclerite long, with a triangular posterior expansion and short lateral arms. Endophallic apodeme with a dorsal crest and wide lateral lamellae. Membrane of endophallic cavity finely plicate.

Measurement (in mm, 1 male). BL = 18.0, PronL = 2.5, PronW = 4.1, FWL = 12.9, FWW = 4.0, HWT = 3.9, FIIL = 14.1, FIHW = 3.7, TIIL = 12.4

Comparison with *C. pelagus* Otte, 2007

The new observations confirm that *C. variegatus*, initially described from a single female, is a valid species close to *C. pelagus*. *C. variegatus* differs by its characteristic colouration: face almost uniformly yellow, pronotum with two dark bands on each lateral lobe (one in *C. pelagus*), legs strongly spotted and FIILs with very dark apical part. Male FWs are almost similar in both species, but *C. variegatus* mirror is crossed by a dark vein (instead of yellow in *C. pelagus*) and its apical field is almost entirely dark brown (with yellow transverse veins in *C. pelagus*). Male genitalia similar in both species, but *C. variegatus* differs by pseudepiphallus with lateral ridges thicker than in *C. pelagus*; posterior pseudepiphallic apex narrower, almost square (wider and trapezoidal in *C. pelagus*), with a small rounded translucent area. Rami with longer apical stems (very short in *C. pelagus*).

Ecology

The only specimen collected occurred at a relatively high elevation in Mount Silam, on low vegetation at the base

of a tree near a forest path.

Distribution

Borneo (Sabah: Trus Madi Mountain, Long Pa Sia, Mount Silam [new locality record])

Calling song (Fig. 11)

The calling song consists of isolated syllables, with an average duration of 59.8 ± 4.4 ms (50.6–63.3 ms). The average interval between consecutive syllables is 3.5 ± 1.1 s (2.5–6.1 s). The call spectrum is broad-band with the energy peaking at 19.34 ± 1.22 kHz (16.97–20.91 kHz).

Subtribe Lebinthina Robillard, 2004

Genus *Falcerminthus* Robillard & Tan, 2021

***Falcerminthus sandakan* (Tan, Japir, Chung & Robillard, 2019)**

(Figs 12–14)

Lebinthus sandakan Tan *et al.*, 2019a: 350 (original description and calling song) – Tan *et al.*, 2019b: 302.

Falcerminthus sandakan – Tan *et al.*, 2021b: 1077 (phylogeny); Tan & Robillard, 2021b: 470–489 (circadian rhythm of calling activity).

New locality records

Borneo: Sabah: Tabin Wildlife Reserve, Sepagaya Forest Reserve, Mount Silam, Kawag Forest Reserve.

Ecology

Very abundant species in eastern Sabah. Juveniles and adults are readily spotted in the forest floor, either among leaf litters or on foliage of low-lying plants. They can be observed both in the day or at night (Fig. 12). This species was also observed to feed on leaves among the leaf litters (Fig. 13).

Distribution (Fig. 14)

Borneo (Sabah: Sepilok, Mount Silam, Kawag Forest Reserve, Sepagaya Forest Reserve, Tabin Wildlife Reserve)

Acknowledgements

The authors are grateful to John Lee Yukang, Saudi Bintang, Mohamad Azizan Bin Asidi and Vivian Rudolf for field assistance. The permission for research in Sabah was granted by the Sabah Biodiversity Centre (JKM/MBS.1000-2/3 JLD.3 (99) and JK/MBS.1000-2/2 JLD.10 (179)); Osman Bangkok [the District Forestry Officer (DFO) of Lahad Datu]; Geungnong Ah Jing (the assistant DFO of Lahad Datu); and Jackly Ambrose (the DFO of Ulu Segama-Malua). MKT and TR thank Camille Laurain and Lilian Van Peuter for preparing and curating the specimens in MNHN, Paris. The work of MKT was supported by the Orthoptera Species File Grant 2019 under the taxonomic research project titled “Contribution to the species diversity and acoustic data on Orthoptera from Sandakan (Borneo, East Malaysia, Sabah)”.

References

- Araya-Salas, M. & Smith-Vidaurre, G. (2017) warbleR: an R package to streamline analysis of animal acoustic signals. *Methods in Ecology and Evolution*, 8, 184–191. <https://doi.org/10.1111/2041-210X.12624>
- Baker, E. & Chesmore, D. (2020) Standardisation of bioacoustic terminology for insects. *Biodiversity Data Journal*, 8, e54222. <https://doi.org/10.3897/BDJ.8.e54222>
- Ballesteros, A.R., Tan, M.K. & Robillard, T. (2022) Phenotypic plasticity of acoustic traits in high-frequency lebinthine crickets (Orthoptera: Eneopterinae: Lebinthina). *The Science of Nature—Naturwissenschaften*, 109, 29. <https://doi.org/10.1007/s00114-022-01800-1>
- Cigliano, M.M., Braun, H., Eades, D.C. & Otte, D. (2023) Orthoptera Species File Online. Version 5 (5.0). Available from: <http://orthoptera.speciesfile.org/HomePage/Orthoptera/HomePage.aspx> (accessed 20 May 2023)
- Desutter-Grandcolas, L. (2003) Phylogeny and the evolution of acoustic communication in extant Ensifera (Insecta, Orthoptera). *Zoologica Scripta*, 32, 525–561. <https://doi.org/10.1046/j.1463-6409.2003.00142.x>
- Dong, J., Kergoat, G.J., Vicente, N., Rahmadi, C., Xu, S. & Robillard, T. (2018) Biogeographic patterns and

- diversification dynamics of the genus *Cardiodactylus* Saussure (Orthoptera, Grylloidea, Eneopterinae) in Southeast Asia. *Molecular Phylogenetics and Evolution*, 129, 1–14. <https://doi.org/10.1016/j.ympev.2018.06.001>
- Haan, W. (1844) Bijdragen tot de kennis der Orthoptera. In: Temminck C.J. (ed.) *Verhandelingen over de Natuurlijke Geschiedenis der Nederlandsche Overzeesche Bezittingen*, 24: 229–248. In commissie bij S. en J. Luchtmans, en C.C. van der Hoek, Leiden.
- Robillard, T. & Desutter-Grandcolas, L. (2004a) High-frequency calling in Eneopterinae crickets (Orthoptera, Grylloidea, Eneopteridae): adaptive radiation revealed by phylogenetic analysis. *Biological Journal of Linnean Society*, 83 (4), 577–584. <https://doi.org/10.1111/j.1095-8312.2004.00417.x>
- Robillard, T. & Desutter-Grandcolas, L. (2004b) Phylogeny and the modalities of acoustic diversification in extant Eneopterinae (Insecta, Orthoptera, Grylloidea, Eneopteridae). *Cladistics*, 20 (3), 271–293. <https://doi.org/10.1111/j.1096-0031.2004.00025.x>
- Robillard, T., Montealegre-Z., F., Desutter-Grandcolas, L., Grandcolas, P. & Robert, D. (2013) Mechanisms of high-frequency song generation in brachypterous crickets and the role of ghost frequencies. *Journal of Experimental Biology*, 216 (11), 2001–2011. <https://doi.org/10.1242/jeb.083964>
- Robillard, T., Gorochoy, A.V., Poulain, S. & Suhardjono, Y.R. (2014) Revision of the cricket genus *Cardiodactylus* (Orthoptera, Eneopterinae, Lebinthini): the species from both sides of the Wallace line, with description of 25 new species. *Zootaxa*, 3854 (1), 1–104. <https://doi.org/10.11646/zootaxa.3854.1.1>
- Robillard, T. & Tan, M.K. (2023) *Platybinthus*, a new genus of Lebinthina crickets (Orthoptera, Gryllidae, Eneopterinae) from Maluka, Indonesia. *European Journal of Taxonomy*, 856, 46–66. <https://doi.org/10.5852/ejt.2023.856.2027>
- Saussure, H. (1878) Mélanges orthoptérologiques. VI. Fascicule Gryllides. *Mémoires de la Société de Physique et d'Histoire naturelle de Genève* 25 (2), 369–704 [505–834].
- Su, Y.N. (2016). A simple and quick method of displaying liquid-preserved morphological structures for microphotography. *Zootaxa*, 4208 (6), 592–593. <https://doi.org/10.11646/zootaxa.4208.6.6>
- Tan, M.K., Japir, R., Chung, A.Y.C. & Robillard, T. (2019a) Crickets of the subfamily Eneopterinae (Orthoptera: Grylloidea) from Sandakan, Sabah: one new species and calling songs of a sympatric species. *Zootaxa*, 4619 (2), 347–363. <https://doi.org/10.11646/zootaxa.4619.2.9>
- Tan, M.K., Japir, R. & Chung, A.Y.C. (2019b) Uncovering the Grylloidea and Tettigonioidea (Orthoptera: Ensifera) in the Forest Research Centre (Sepilok) Entomological Collection. *Zootaxa*, 4701 (4), 301–349. <https://doi.org/10.11646/zootaxa.4701.4.1>
- Tan, M.K., Malem, J., Legendre, F., Dong, J., Baroga-Barbecho, J.B., Yap, S.A., Wahab, R.A., Japir, R., Chung, A.Y.C. & Robillard, T. (2021b) Phylogeny, systematics and evolution of calling songs of the Lebinthini crickets (Orthoptera, Grylloidea, Eneopterinae), with description of two new genera. *Systematic Entomology*, 46 (4), 1060–1087. <https://doi.org/10.1111/syen.12510>
- Tan, M.K. & Robillard, T. (2021a) New taxa of the subtribe Lebinthina (Orthoptera: Gryllidae: Eneopterinae: Lebinthini) from New Guinea and nearby islands. *Zootaxa*, 5082 (6), 583–599. <https://doi.org/10.11646/zootaxa.5082.6.5>
- Tan, M.K. & Robillard, T. (2021b) Highly diversified circadian rhythms in the calling activity of eneopterine crickets (Orthoptera: Grylloidea: Gryllidae) from Southeast Asia. *Bioacoustics*, 31 (4), 470–489. <https://doi.org/10.1080/09524622.2021.1973562>
- Tan, M.K. & Robillard, T. (2021c) Population divergence in the acoustic properties of crickets during the COVID-19 pandemic. *Ecology (The Scientific Naturalist)*, e03323. <https://doi.org/10.1002/ecy.3323>
- Tan, M.K. & Robillard, T. (2022) *Rugabinthus*, a new genus of Lebinthina (Orthoptera, Gryllidae, Eneopterinae) from New Guinea. *Journal of Orthoptera Research*, 31 (1), 9–40. <https://doi.org/10.3897/jor.31.73800>
- Tan, M.K., Wahab, R.A., Japir, R., Chung, A.Y.C. & Robillard, T. (2021a) Revision of the cricket genus *Nisitrus* Saussure (Orthoptera: Gryllidae: Eneopterinae) and description of five new species. *European Journal of Taxonomy*, 761, 1–75. <https://doi.org/10.5852/ejt.2021.761.1449>
- Tan, M.K., Schöneich, S. & Robillard, T. (2021c) Inter-individual differences of calling and exploratory behaviour in a lebinthine cricket species hint at different mate-finding strategies. *Behaviour*, 159 (6), 563–589. <https://doi.org/10.1163/1568539X-bja10141>
- ter Hofstede, H.M., Schöneich, S., Robillard, T., Hedwig, B. (2015) Evolution of a communication system by sensory exploitation of startle behaviour. *Current Biology*, 25 (24), 3245–3252. <https://doi.org/10.1016/j.cub.2015.10.064>

Figure captions

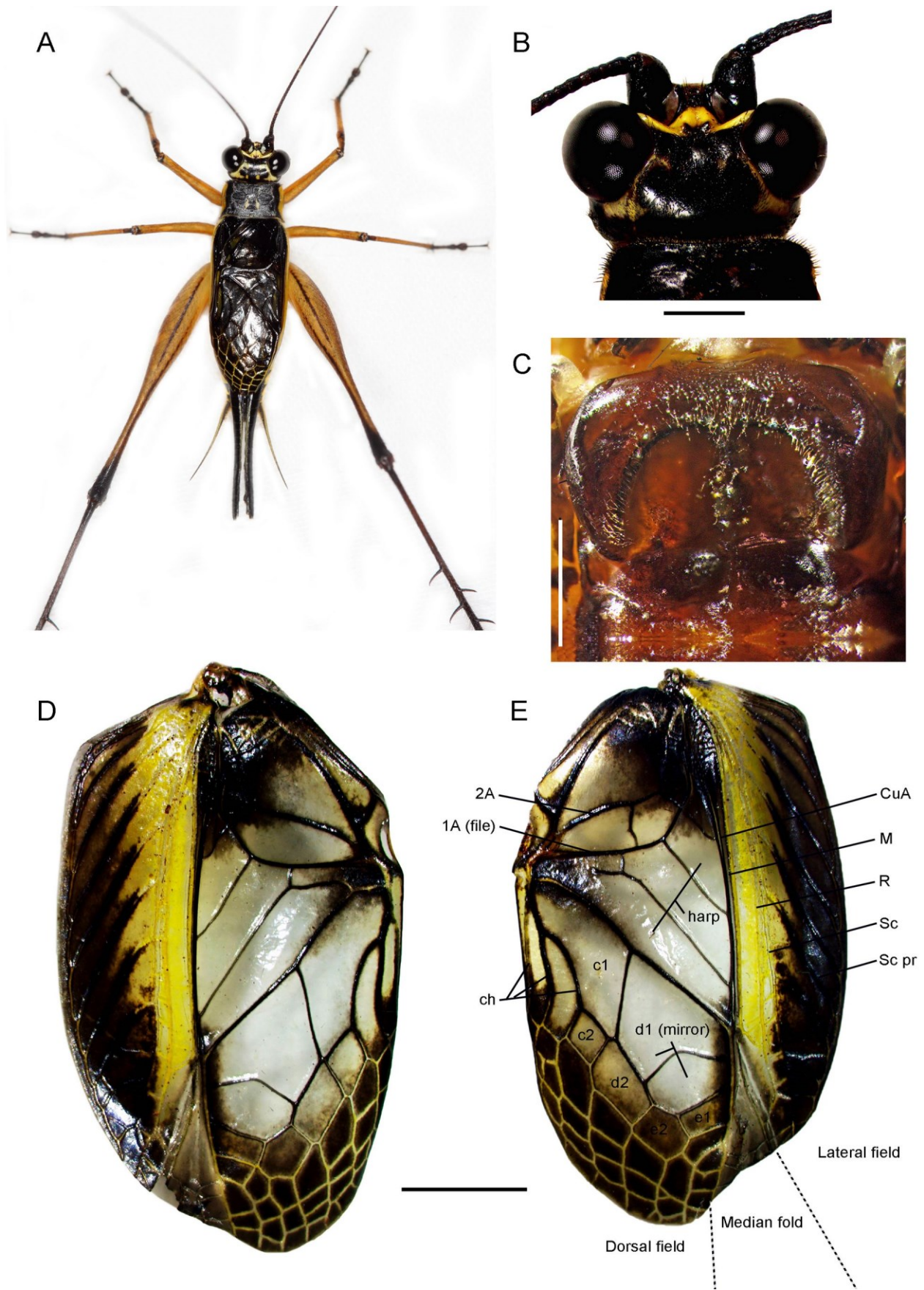


FIGURE 1. *Nisitrus danum*: Dorsal habitus of a living ♂ (A); head in dorsal view (B); metanotal gland in dorsal view (C); ♂ left (D) and right (E) FWs in dorsal views. Scale bars: 1 mm (B, C), 2 mm (D, E).

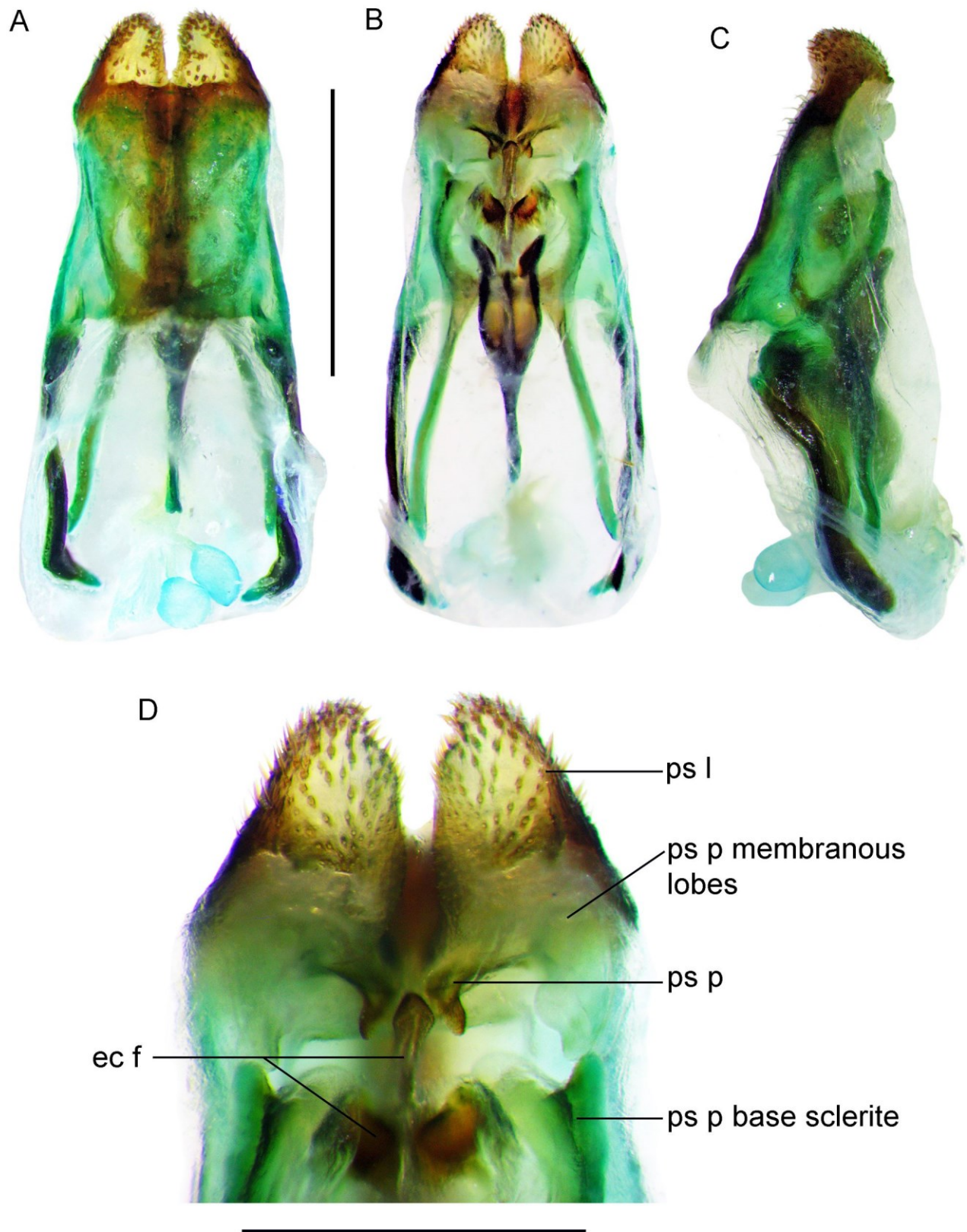


FIGURE 2. ♂ genitalia of *Nisitrus danum* in dorsal (A), ventral (B) and lateral (C) views; posterior end of genitalia in ventral view (D). Scale bars: 1 mm.

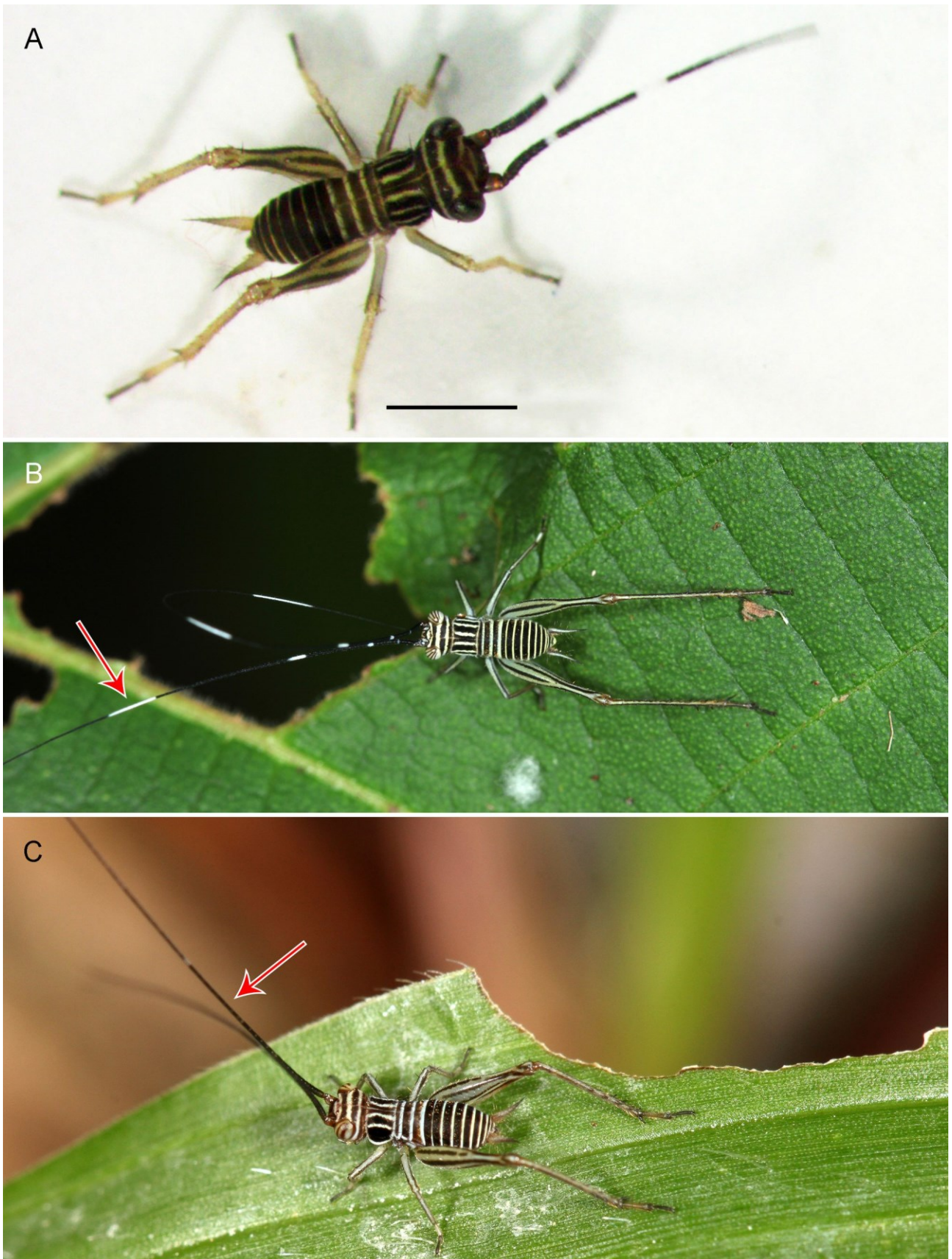


FIGURE 3. Juveniles of *Nisitrus*: A first instar *Nisitrus danum* in dorsal view (A); a young juvenile of *N. danum* in its natural environment in Tabin (B); a young juvenile of *N. vittatus* in its natural environment in Sepilok (C). The red arrows on the antennae in B and C indicate the key difference in the juveniles of sympatric *N. danum* and *N. vittatus*. Scale bar: 1 mm.



FIGURE 4. Natural habitat of *Nisitrus danum* in Kawag Forest Reserve (A) and a ♂ adult (in the red circle) singing in the presence of *Nisitrus vittatus* (in yellow circle).



FIGURE 5. *Nisitrus danum* in their natural habitat: ♂ adult singing in Kawag Forest Reserve (A); ♀ adult on foliage of a tree among tall grasses near Lipad Mud Volcano, Tabin (B).

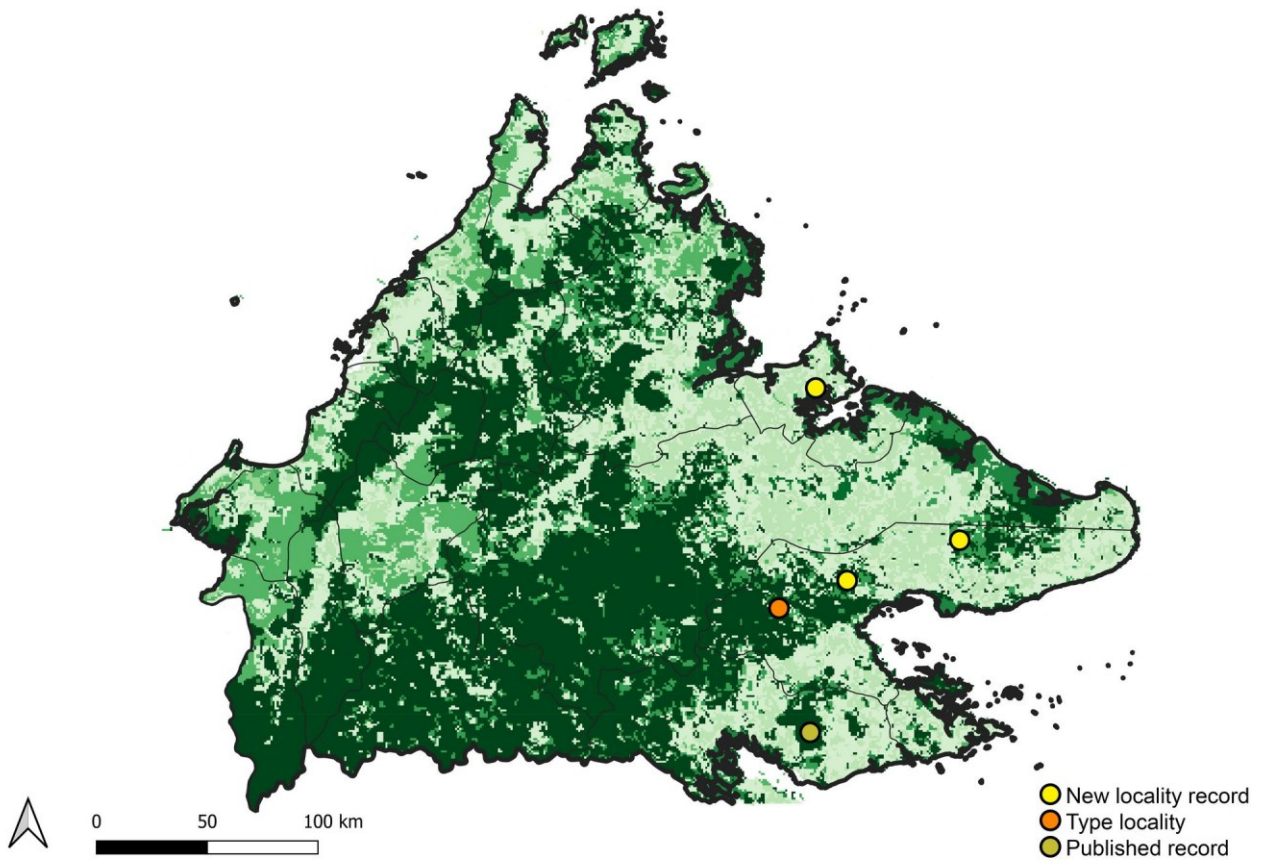


FIGURE 6. Map of Sabah State showing the current known distribution of *Nisitrus danum*.

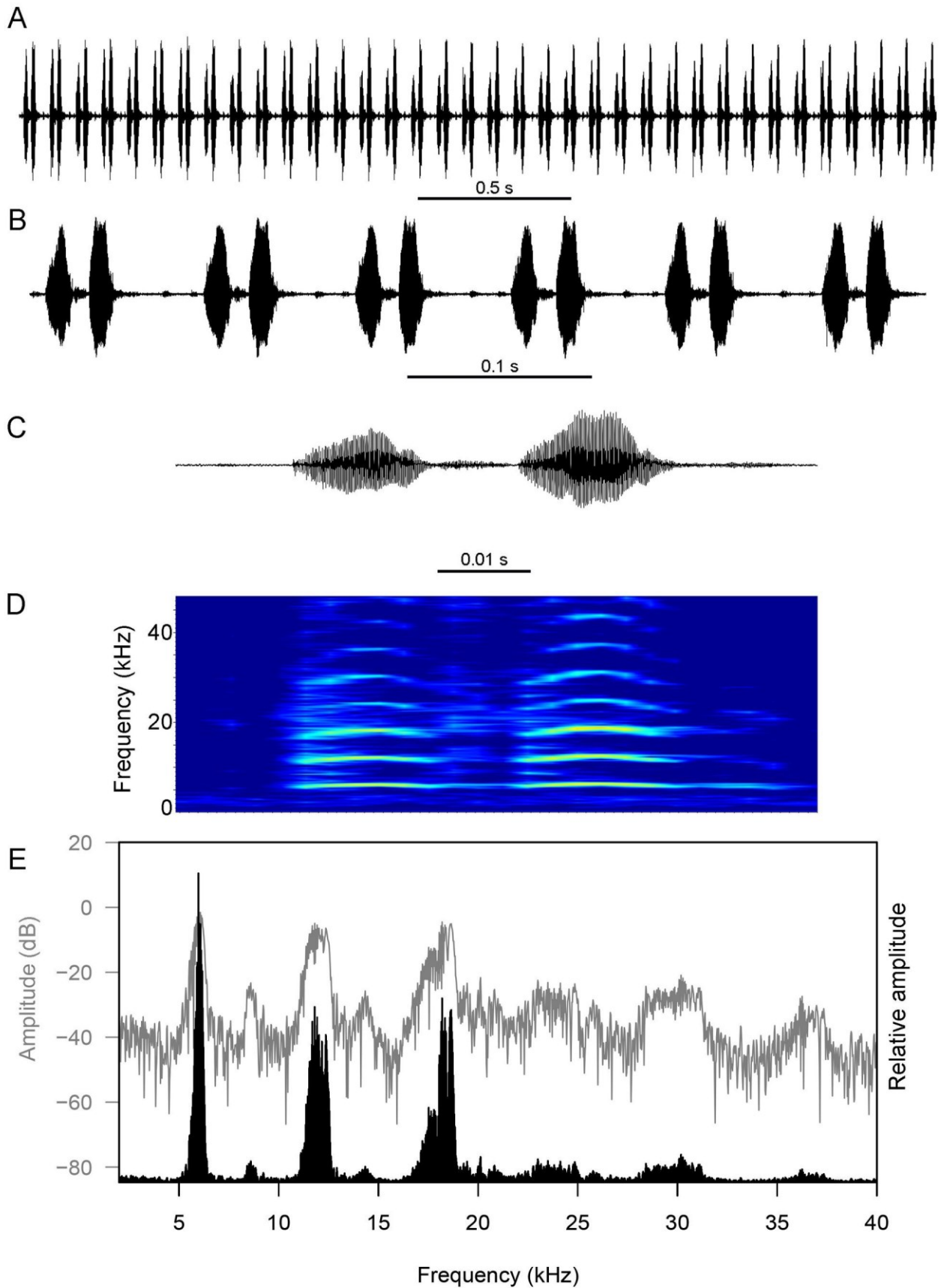


FIGURE 7. *Nisitrus danum* ♂ calling song: oscillograms showing the continuous trill (A), six echemes of doublet syllables (B) and an echeme (doublet syllable) (C); spectrogram of the same echeme (D); power spectra of a syllable (E) where the grey line represents the power [dB] (axis name and scale in grey) and the black solid peak represents the relative amplitude (axis name in black).

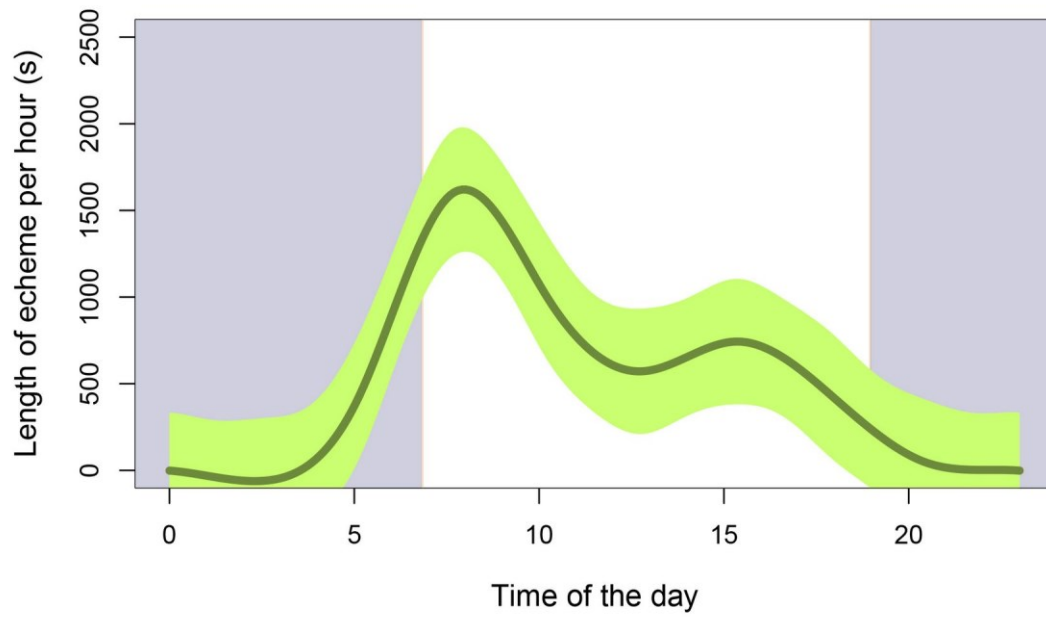


FIGURE 8. *Nisitrus danum* ♂ calling activity (amount of sound produced) over 24 hours. Smoothed lines were fitted using generalised additive mixed effects models with gaussian error structure. The grey area indicates dark hours; white areas indicates light hours.



FIGURE 9. *Cardiodactylus variegatus* ♂ adult in Mount Silam (A) and right FW (B). Scale bar: 1 mm.

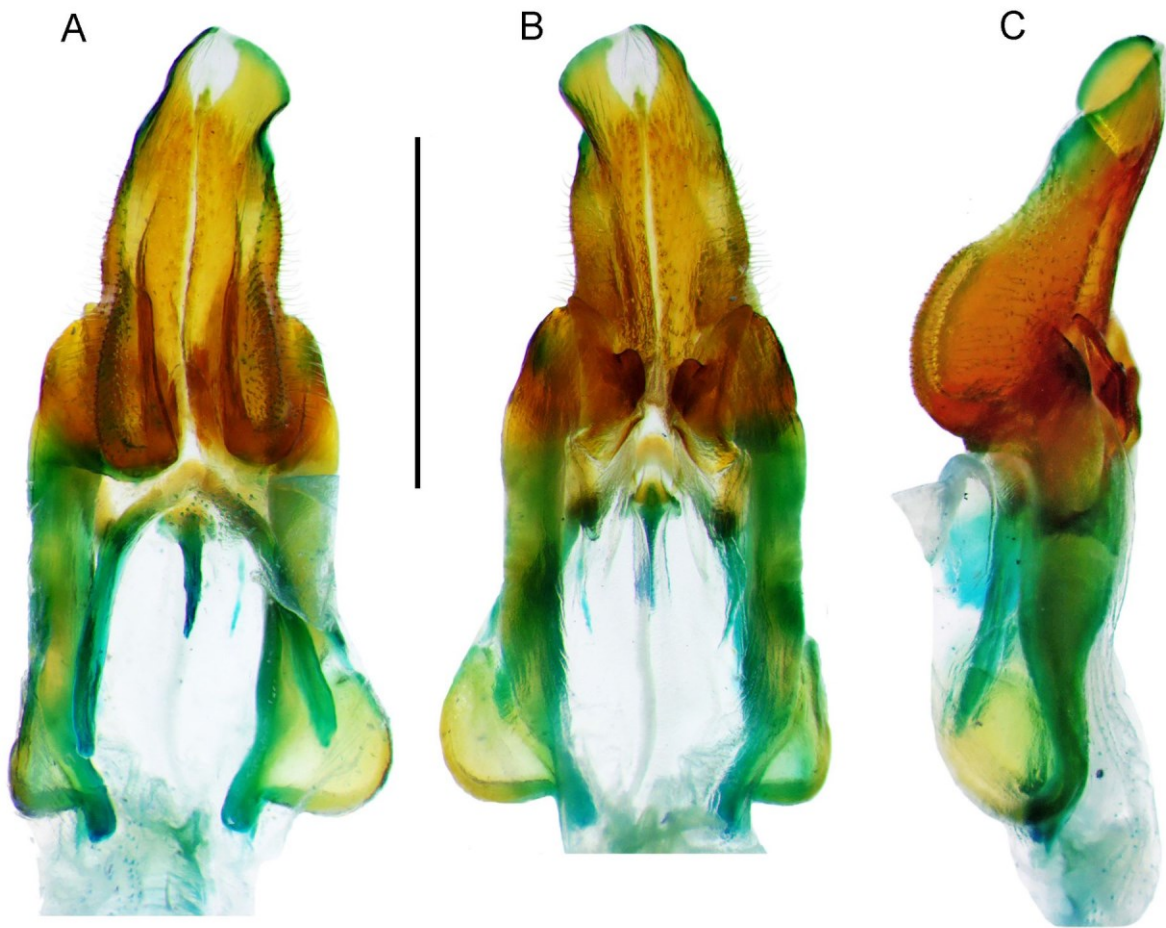


FIGURE 10. ♂ genitalia of *Cardiodactylus variegatus* in dorsal (A), ventral (B) and lateral (C) views. Scale bar: 1 mm.

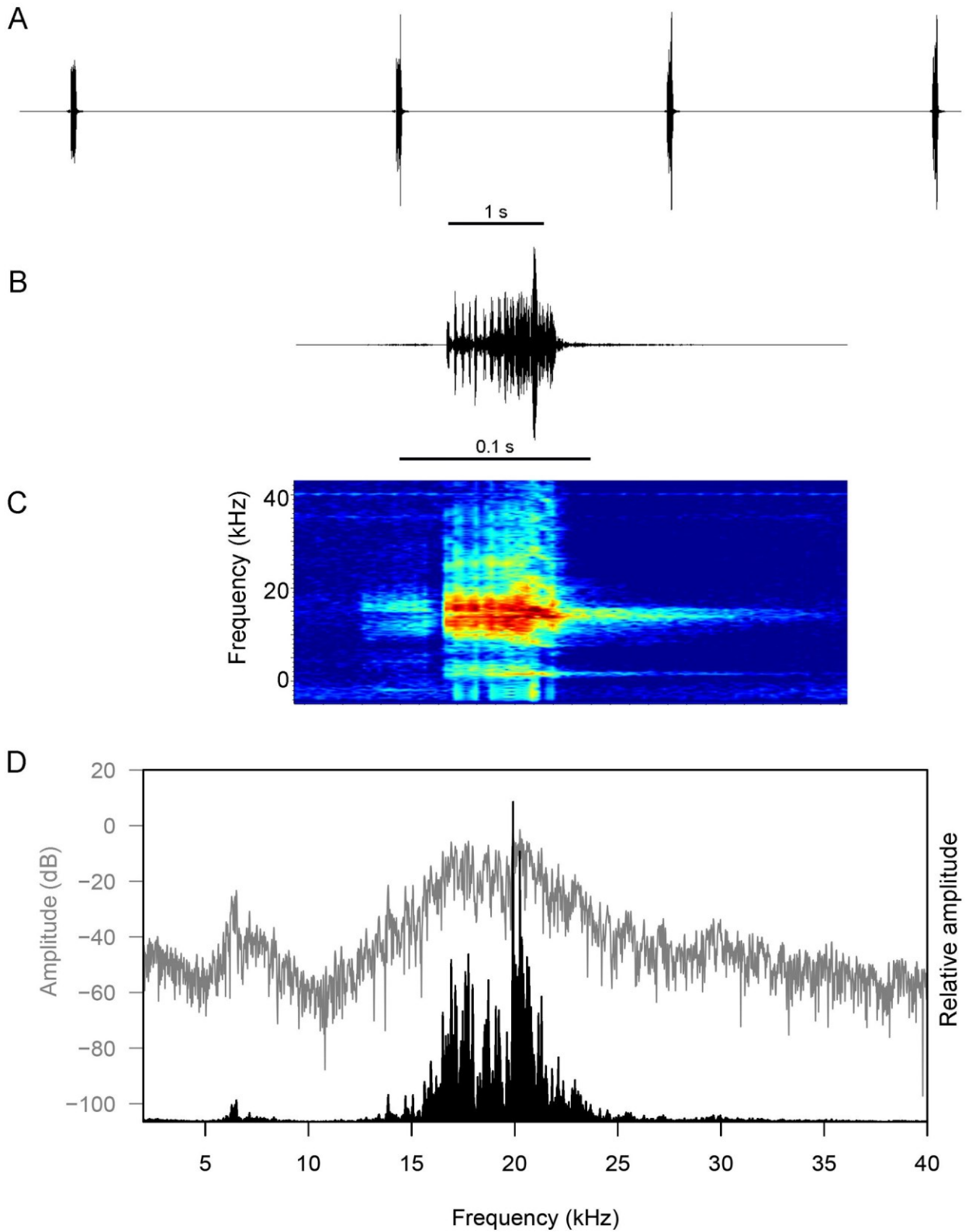


FIGURE 11. *Cardiodactylus variegatus* ♂ calling song: oscillograms showing four isolated syllables (A) and a syllable (B); spectrogram of the same syllable (C); power spectra of a syllable (D) where the grey line represents the power [dB] (axis name and scale in grey) and the black solid peak represents the relative amplitude (axis name in black).



FIGURE 12. *Falcerminthus sandakan* in their natural habitat: ♂ adult on a foliage on the leaf litter in Tabin Wildlife Reserve (A); ♀ adult on a foliage of a low-lying plant in Mount Silam (B); juvenile among the leaf litter in Mount Silam.



FIGURE 13. *Falcerminthus sandakan* in their natural habitat: ♀ adult feeding on a leaf fragment among the leaf litter in Sepilok.

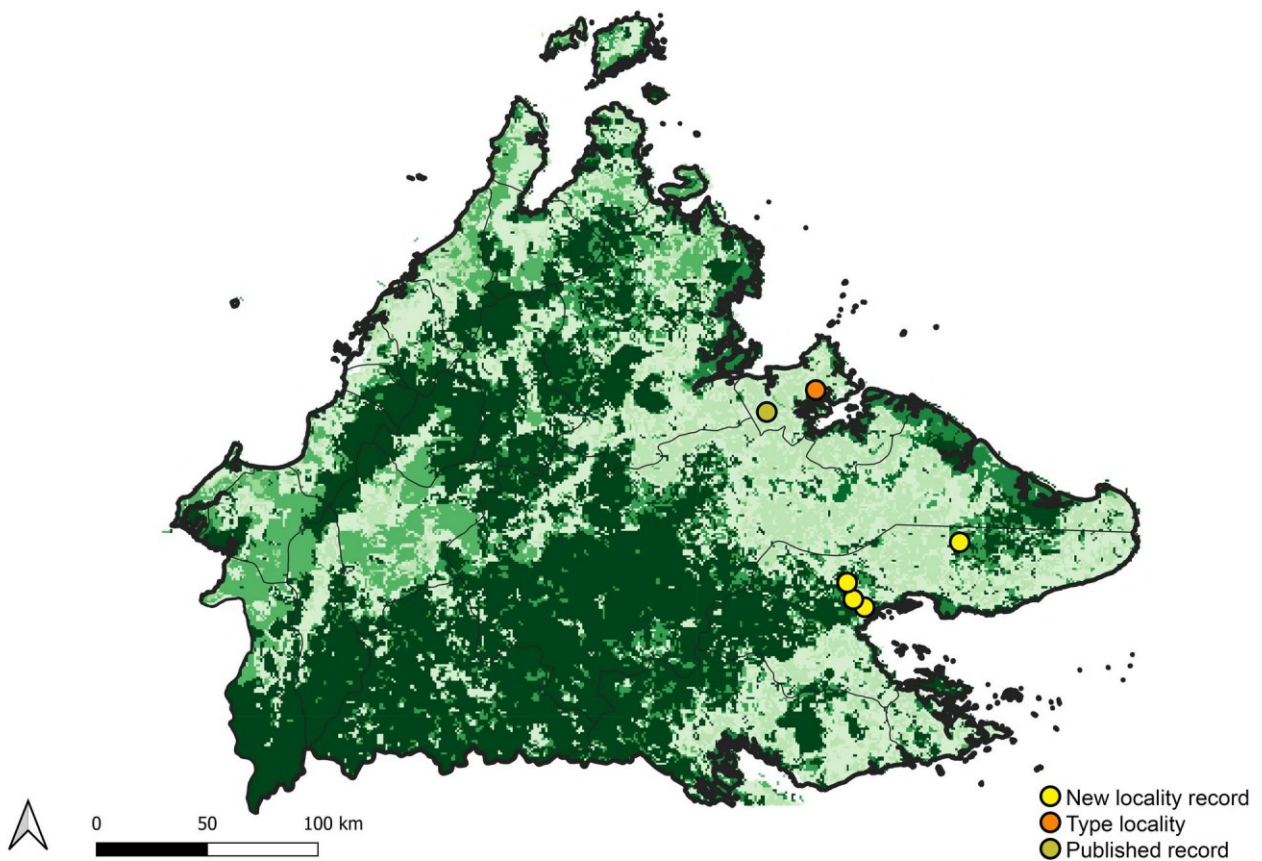


FIGURE 14. Map of Sabah State showing the current known distribution of *Falcerminthus sandakan*.