

## A TAXONOMIC REVIEW OF COMMON BUT LITTLE KNOWN CRICKETS FROM SINGAPORE AND THE PHILIPPINES (INSECTA: ORTHOPTERA: ENEOPTERINAE)

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**ABSTRACT.** — In the present paper, we study cricket species which are very common in Singapore but need formal description or systematic revision. We describe one new species of the genus *Lebinthus*, *Lebinthus laue* new species from Singapore, and we redescribe the species *Nisitrus vittatus* (Haan, 1842). We also redescribe the species *Lebinthus bitaeniatus* Stål, 1877 from the Philippines for comparison with the new species from Singapore. For each species we provide complete descriptions of morphology, including both male and female genitalia and forewing venation, distribution, habitat and calling songs. A neotype series is selected for *N. vittatus* and deposited in RMNH, Leiden; MNHN, Paris; ZRC, Singapore and in UPLB MNH, Philippines.

**KEY WORDS.** — *Nisitrus*, *Lebinthus*, new species, redescription, neotype, Singapore, Philippines

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### INTRODUCTION

Crickets of the subfamily Eneopterinae are not only encountered in primary forested areas, but are also often found in large numbers in secondary forests, gardens, and parks (Tan et al., 2012). These crickets are known for the diversity of their stridulatory apparatus (Robillard & Desutter-Grandcolas, 2004a) and for their acoustic signals which combine the usual diversity of cricket songs (Robillard & Desutter-Grandcolas, 2011), with original traits at the level of the frequency domain (Desutter-Grandcolas, 1998; Robillard & Desutter-Grandcolas, 2004b; Robillard et al., 2007, 2013; Robillard, 2009).

Here we address species of the two tribes of eneopterines known in the pacific part of South-East Asia and more precisely in Singapore: the Nisitriini Robillard, 2004 and the Lebinthini Robillard, 2004 (see Robillard & Desutter-Grandcolas, 2008). We describe or redescribe two cricket species, which belong to the most common ones in Singapore. Despite being common species, they need formal taxonomic clarification, either because the type series is lost or because the description needs to be completed or clarified using modern criteria of systematics.

*Nisitrus vittatus* is the type species (Kirby, 1906) and also the most common and widespread species of the diurnal genus *Nisitrus*. It is found in Singapore, the Malay Peninsula, and in South Sumatra. However, its original description by De Haan (1842) is rather vague and may correspond to any other species of the genus (most of them also in need of proper re-examination and redescription). *N. vittatus* is in fact only vaguely known and has often been cited and identified without type comparison. Since its description by De Haan in 1842, completed later by Saussure (1878), this species has never been formally redescribed based on modern examination of types and specimen series. The type specimens from Padang (Sumatra, Indonesia) supposed to be in Leiden were not found in this museum in 2006 (T. Robillard, pers. obs.), with no record mentioning them as loaned (R. De Vries, curator of the Orthopteran collection in RMNH, Leiden, pers. comm.; confirmation in 2007). Specimens possibly belonging to the original type series were also searched for in the collections of several other museums where they might be (Paris, London, Vienna, Basel), but none could be found so far. Before further systematic revision of the *Nisitrus* species, it is thus necessary to establish a reference neotype specimen and a consistent description upon which to base future descriptions or revision works.

One species of the genus *Lebinthus* has been observed in Singapore parks, Peninsular Malaysia and Java for long (Chopard, 1931; Tan, 2010, 2012; Tan et al., 2012; Tan & Wang, 2012) and determined as *Lebinthus bitaeniatus* Stål, 1877 (Robillard, 2011). Closer examinations of *L. bitaeniatus* and the specimens from Singapore and Malaysia using morphological, molecular and acoustic techniques however revealed that they are two distinct species. We describe here *Lebinthus luae* Robillard & Tan, new species, from Singapore, south Sumatra and western Java, and we redescribe *L. bitaeniatus*, from Luzon, Philippines.

## MATERIAL AND METHODS

**Material.** — Field collections and observations were made in several localities in Singapore between 2009 and 2013 (MKT & TR) and in the Philippines (Luzon) in Jul.2011 (TR). Specimens were collected by sight only, by night and day, in order to observe their habitat and period of activity. Newly collected specimens are deposited in the collections of the Muséum national d'Histoire naturelle, Paris (MNHN), in the Zoological Reference Collection, Singapore (ZRC), and/or in the Museum of Natural History of Los Baños (University of the Philippines, Los Baños; UPLB MNH). Square brackets are used for additional information not mentioned on specimen labels.

**Observations and morphological analysis.** — Direct observations and dissections have been made using a binocular microscope Leica MZ16 at magnifications up to 160×, equipped with a camera lucida for the line drawings. SEM observations were performed at the Plateforme de Microscopie électronique of the MNHN, using a JEOL-JSM 840 electronic microscope (7kV), after a 60 s gold-coating. Male tegminal veins and cells follow terminology by Desutter-Grandcolas (2003) and Robillard & Desutter-Grandcolas (2004a). Male and female genitalia have been dissected in softened specimens by cutting the membranes between the paraprocts and the subgenital plate, or between the ovipositor and the subgenital plate respectively; they have been observed after cleaning with cold KOH using a binocular microscope Leica MZ16 at magnifications up to 160×, and then kept in glycerine in vials pinned under specimens. Photographs of male genitalia have been done with a binocular microscope Leica MZ12 and the montage software Leica Application Suite ver. 2.8.1 (Leica Microsystems). Male genitalia are named according to Desutter (1987), modified in Desutter-Grandcolas (2003) and Robillard & Desutter-Grandcolas (2004a). Dotted parts in figures correspond to membranous areas. Abbreviations: see below.

**Acoustic data.** — The basic cricket song terminology follows Ragge & Reynolds (1998). One song unit is called a syllable and it corresponds to one opening-closure cycle of the male forewings.

The new species and the 2 redescribed species have been recorded in the field and/or in the laboratory from specimens collected in the field as juveniles or sub-adults. The recordings were made with a modified Condenser Microphone Capsule

CM16 (Avisoft Bioacoustics, Berlin), with a relatively flat frequency response from 3–150 kHz (R. Specht, pers. comm.), connected to a Fostex FR-2LE digital field recorder (96 kHz sampling frequency, 16 bit) in the field, or using or using Avisoft Triggering Harddisk Recorder version 2.97 and a 8-Pre MOTU sound card at a sampling frequency of 96 k-samples s<sup>-1</sup> (16 bit). Correlation between emitted sounds and FW movements were established using an AOS S-Pri high speed camera (AOS Technologies) at 1250 frames s<sup>-1</sup>. Acoustic analyses were performed using the computer software Avisoft-SASLab Pro version 4.40 (Specht, 2008). Song features were measured using the automatic commands under Avisoft-SASLab Pro. All recording files are deposited in the Sound Library of the Muséum national d'Histoire naturelle, Paris.

**Abbreviations.** — **Institutions.** BPBM, Bernice P. Bishop Museum, Honolulu, Hawaii, USA; MNHN, Muséum national d'Histoire naturelle, Paris, France; MZB, Museum Zoologicum Bogoriense, Bogor, Java, Indonesia; NHRM, Naturhistoriska Riksmuseet, Stockholm, Sweden; RMNH, Nationaal Natuurhistorisch Museum (formerly Rijksmuseum van Natuurlijke Historie), Leiden, The Netherlands; UPLB MNH, Museum of Natural History, University of the Philippines Los Baños; ZIN, Zoological Institute, Russian Academy of Sciences, S. Petersburg, Russia; ZRC, Zoological Reference Collection, Raffles Museum of Biodiversity Research, National University of Singapore, Singapore.

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

**Male genitalia.** ec arc, ectophallic arc; ec ap, ectophallic apodeme; ec f, ectophallic fold; en ap, endophallic apodeme; en s, endophallic sclerite; ps l, pseudepiphallic lophi; ps p, pseudepiphallic paramere; r, rami.

**Terminal venation.** 1A–4A, first to fourth anal veins; CuA, anterior cubitus; CuA1, CuA2, ..., first, second, ... bifurcations of CuA; CuP, posterior cubitus; MA, MP, anterior, posterior media veins; R, radial vein; c1–3, first to third cells of C alignment; d1 cell (mirror), first cell(s) of D alignment; d2, second cell of D alignment; e1, first cell of E alignment; ha, harp area.

**Measurements.** FIIIL, length of hind femora; FIIIW, width of hind femora; FWL, forewing length; FWW, forewing width (at the level of maximal width); HWT, Hind wing tail length (part of the hind wings longer than the FWs); Ias, inner spines on TIII dorsal side, above the spurs; Ibs, inner spines on TIII dorsal side, between the spurs; Oas, outer spines on TIII dorsal side, above the spurs; Obs, outer spines on TIII dorsal side, between the spurs; OL, ovipositor length; PronL, pronotum length; PronW, pronotum width; ST, number of stridulatory teeth; Tt, teeth on transverse section of the file; Lt, teeth on longitudinal section of the file; TIIIL, length of hind tibiae; TaIIIs, spines on outer edge of third hind tarsomere, not including the apical spine.

## TAXONOMY

**Nisitriini Robillard, 2004 (in Robillard & Desutter-Grandcolas, 2004a)****Genus *Nisitra* Saussure, 1878**

*Nisitra* Walker, 1869: 91; Chopard, 1940: 199

*Nisitra* Saussure, 1878: 511, 522 > *Nomen novum* for *Nisitra* Walker. Chopard, 1968: 352; Desutter-Grandcolas, 1990; Otte, 1994: 67 > Eneopteridae: Eneopterinae. Preston-Mafham, 2000: 2241 > behaviour. Robillard & Desutter-Grandcolas, 2004a: 276; 2004b: 578; 2004c: 304; 2006: 644; 2011: 637 > phylogeny and acoustic evolution. Robillard et al., 2007: 1265 > acoustics. Robillard & Desutter-Grandcolas, 2008: 67 > Nisitriini tribe. Desutter-Grandcolas et al., 2010: 616 > cerci evolution. Nattier et al., 2011: 2201 > phylogeny and molecular dating. Eades et al., 2012 > Orthoptera species file online.

**Type species.** — *Nisitra vittatus* (Haan, 1942)

**Diagnosis.** — Among the Eneopterinae genera, *Nisitra* is characterised by an elegant, wasp-like, slender and colourful body (Figs. 1, 3, 8). Size average for subfamily. Colouration vivid, dominantly yellow, whitish and black with species specific patterns. Characteristic head shape with narrow fastigium and large prominent yellow green eyes with dorso-ventral black stripes. Pronotum setose, square shaped to slightly trapezoidal, usually bisinuated posteriorly. Metanotum with large glandular structures in males, made of a wide pit on scutum and a pair of posterior pits on scutellum, with glandular pores mostly organised by groups of 2 or 3 (Fig. 2). FWs more or less as long as abdomen. Male *Nisitra* show modified FW venation and characteristic glossy transparency. Hind wings longer than FWs, bicoloured in some species. Legs long and thin, FIII with a characteristic narrowed area before knee. Other general traits: TI with two tympana, inner one slit-like, covered by a swollen cuticular expansion; outer tympanum oval, its membrane transversally plicate in dorsal half. TI with three apical spurs; outer dorsal spur missing. TII with four apical spurs, inner longest. TIII with three inner and three outer apical spurs, median longest on each side; four pairs of subapical spurs, inner and outer spurs almost straight, their apex hook-like; TIII serrulate over whole length and slightly furrowed dorsally. Tarsomeres III-1 with one row of dorsal spines on external edge in addition to apical spines. Apical claws of legs slightly indented. Both males and females show characteristic genitalia: male genitalia with membranous and setose lophi well individualised; female copulatory papilla conical, apex generally sclerotised and pointed (Fig. 7). *Nisitra* is very close morphologically to *Paranisitra* Chopard, 1925 (revised by Gorochoy, 2009), the second genus among the Nisitriini tribe (Robillard & Desutter-Grandcolas, 2008). *Paranisitra* is mostly characterised by lack of wings in both sexes, but except for this, it shares with *Nisitra* its general body shape, long thin legs with indented claws, colouration with yellow and black, head shape and the general structure of male and female genitalia. *Nisitra* is less easy to relate to other clades of Eneopterinae.

***Nisitra vittatus* (Haan, 1942)**

(Figs. 1–9)

*Gryllus* (*Platydictylus*) *vittatus* De Haan, 1842: 234

*Nisitra vittata* – Chopard, 1940: 199

*Nisitra vittatus* – Saussure, 1878: 511 > *Nomen novum* for *Nisitra* Walker. Chopard, 1968: 352; Otte, 1994: 67; Tan, 2012: 4; Tan et al., 2012: 66. Robillard & Desutter-Grandcolas, 2004a: 276; 2004b: 578; 2004c: 304; 2006: 644; 2011: 637 > phylogeny and acoustic evolution. Robillard et al., 2007: 1265 > acoustics. Robillard & Desutter-Grandcolas, 2008: 67 > Nisitriini tribe. Desutter-Grandcolas et al., 2010: 616 > cerci evolution. Nattier et al., 2011: 2201 > phylogeny and molecular dating. Eades et al., 2012 > Orthoptera species file online. Robillard et al., 2013: 2002 > mechanism of stridulation.

**Discussion.** — The initial type series of *Nisitra vittatus* (Haan, 1842) consisted of male and female specimens from Padang (Sumatra, Indonesia), supposed to be located in Leiden museum. The types were however not found in this museum in 2006 (T. Robillard, pers. obs.), with no record mentioning them as loaned (R. De Vries, curator of the Orthopteran collection in RMNH, Leiden, pers. comm.; confirmation in 2007). Specimens possibly belonging to the original type series were also searched for in the collections of several other museums where they might be (Paris, London, Vienna, Basel), but none could be found. Although vague, the original description may not correspond to others species of the genus known from Sumatra (*N. sumatrensis* (Rhen, 1909), *N. insignis* Saussure, 1878): the vertex is yellow with a black median pattern in the type of *N. insignis* (T. Robillard, pers. obs.; BMNH,

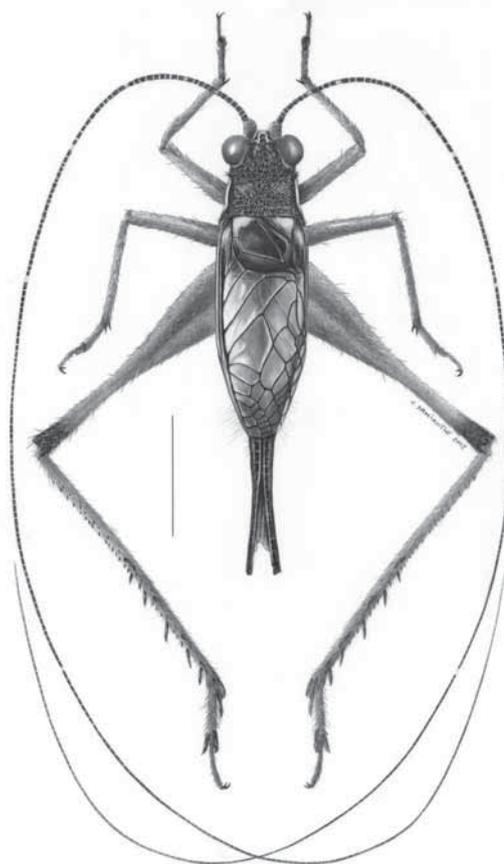


Fig. 1. Habitus of *Nisitra vittatus*, drawing by Vanessa Damianthe & Gilbert Hodebert (MNHN). Male specimen from Singapore. Scale bar = 5 mm.

2004) and in the description of *N. sumatrensis*, while it is black in Haan's (1842) description. The description however matches a series of specimens from the South of Sumatra (Lampung province), which are themselves very similar to the *Nisitrus* commonly found in Singapore and Malaysia (Peninsular). We thus use specimens from this area to redescribe formally and define a neotype series for the species *N. vittatus*, the most common species of the genus, upon which to base future description or revision work about *Nisitrus*.

**Material examined.** — Neotype (male): **Indonesia**, Lampung Province: male (RMNH), Wai Lima, Z. Sum. [South Sumatra], Lampongs (N°40), coll. Karny & Siebers, Nov.–Dec.1921.

Paraneotypes (3 males, 10 females): **Indonesia**, Lampung Province: 2 females (N°183, 108) (MNHN-ENSIF3200-3198); 1 female (N°48) (ZRC), same information as neotype; 1 male (N°422), identified *Nisitrus vittatus* Haan by L. Chopard, and *Nisitrus vittatus* Haan by T. Robillard (2004) (MNHN-ENSIF1742), Wai Lima, Z. Sum. [South Sumatra], Lampongs (N°40), coll. Karny, Nov.–Dec.1921. 1 male (MNHN-ENSIF1714), 1 male (ZRC), Pahoe, Djambi exp. 1925 (No3) [Jambi = South Sumatra], coll. O. Posthumus, 26 Oct.[1925]; 1 female (No1) (RMNH), 23 Oct.[1925]; 1 female (No2) (MNHN-ENSIF3199), 22 Oct.[1925]; 1 female (No5) (MNHN-ENSIF1723), 28 Oct.[1925]; 1 female (MNHN-ENSIF3201), S. Sumatra, 600 m, S. W. Lampongs, Mt. Tanggaamues, coll. Giesting, Lieftinck & Toxopeus, Dec.1934; 1 female (MNHN-ENSIF3202), S. Sumatra, Lalembang, Soeban Djerigi, coll. Soekarno, 15 Jun.1933. 1 female (MNHN-ENSIF3203), Damm[?] Muntok Banka, 25 Nov.[19]23. 1 female (MNHN-ENSIF3204), Pedada-B Lampongs, Jan.1922.

Other material examined: **Singapore**: 1 male (TR9), day, call recording (MNHN-ENSIF3102), Bukit Timah, [summit], 01°21'16.2"N, 103°46'35.9"E, 120 m, coll. T. Robillard, 29 Jun.2009; 1 male (TR1), day, on leaf (h = 40 cm) (MNHN), 10 Jun.2011; 1 male (TR3), day, call recording (MNHN-ENSIF3136), Bukit Timah, près de l'entrée de la réserve [near entrance], 01°21'06.7"N, 103°46'45.2"E, 92 m, coll. T. Robillard, 11 Jun.2011; 1 male (TR26), night, at rest on plant (MNHN), Bukit Timah Nature Reserve, Hindhede trail, 01°20'57.1"N, 103°46'33.6"E 68 m, coll. T. Robillard, 20 Jun.2011; 2 males (TR29-30), day, on plant (h = 2 m), call recording (MNHN-ENSIF2742-3135), MacRitchie Reserve, 01°21'10.2"N, 103°46'33.6"E, 68 m, coll. T. Robillard, 2 Jul.2009; 1 juvenile, night (TR13) (MNHN), Central Catchment Nature Reserve, secondary forest, 1, 01°22'49.0"N, 103°49'06.7"E, 79 m, coll. T. Robillard, 16 Jun.2011. 6 males, call recording and

copulation (MNHN); 7 males (MNHN); 5 females, recording of copulation (MNHN); 2 females (MNHN), Singapore, reared specimens (generations F1–F6), 2009–2012, coll. T. Robillard; 1 male, 1 female, grassy to shrubby plot, Neo Tiew Lane 2, Singapore, 17 Jul.2010, coll. M. K. Tan; 1 male, secondary forest, Hindhede Nature Park, Singapore, 30 Oct.2010, coll. M. K. Tan. **Malaysia**: 1 male, edge of swamp forest, Mersing, Johor, Malaysia, Jan.1993, coll. D. H. Murphy (ZRC); 3 males, call recording (MNHN-ENSIF3132-3134), 1 female, open area near track, Petalling Jaya, Mount Kiara, Selangor, Malaysia coll. T. Robillard, 7 Sep.2002; 15 males, 12 females, 6 juveniles (MNHN), reared specimens (generations F1–F4), 2002–2004, coll. T. Robillard.

**Diagnosis.** — Species of average size, colouration contrasting with black and yellow, characterised by black vertex, yellow face, orange brown legs, MA/MP area yellow in male, black in female, and details of male and female genitalia.

**Redescription.** — Habitus typical of this genus (Figs. 1, 3). Vertex black with yellow margin around eyes (Fig. 4). Fastigium black with yellow margins, with few white setae. Scapes yellow to brown, with black patterns. Antennae black with white rings widely spaced out, brown basally. Face yellow, sometimes with a few black spots; facial part of fastigium with 2 black stripes. Mouthparts variable, from brown to yellow. Maxillary palpi yellow; apical segment black apically. Head lateral side yellow, sometimes black behind eyes. Pronotum covered with white setae; disk rectangular to slightly trapezoidal, posterior margin slightly bisinuated; dark grey to black, with tint of yellow. Lateral lobes of pronotum black dorsally, yellow ventrally. Legs orange brown to yellowish brown. Hind femora brown, knees dark brown to black; hind tibiae brown with black spines and spurs, dark brown to black near distal end; tarsomeres dark brown to black. Tarsomeres III with 0–1 spines on dorso-external edges (n = 3). Hind wings bicoloured, hyalinous brown apically, basally transparent; longer than FWs, the dark brown tail exceeding the forewings more than twice as long as the pronotum. Tergites light brown mottled with black; sternites pale, with black median area. Cerci light brown, short and conical.

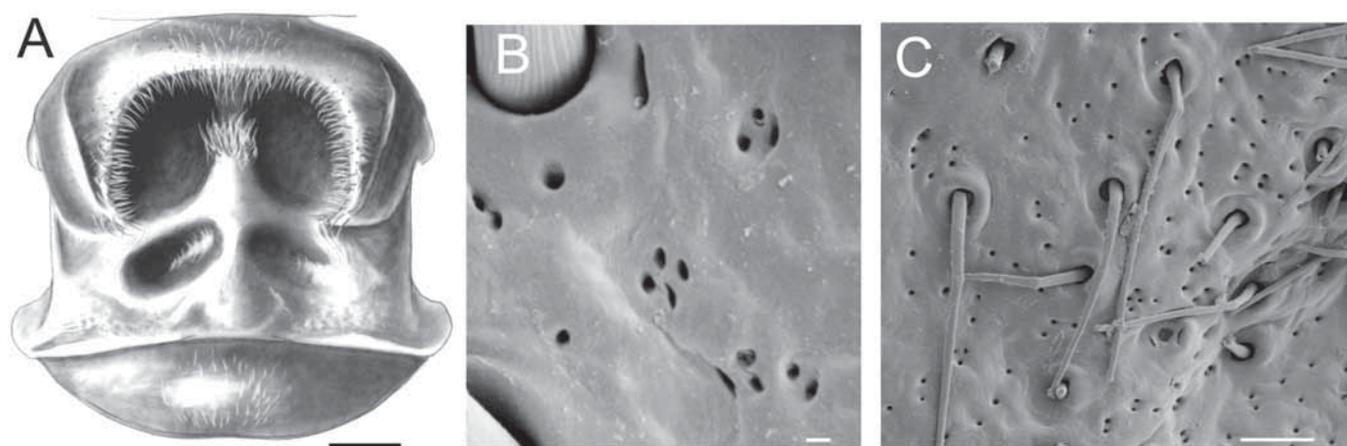


Fig. 2. Metanotal glandular structures in *Nisitrus vittatus*. A, glandular pits (drawing by G. Hodebert (MNHN) modified from Robillard & Desutter-Grandcolas, 2004a); B, SEM view of glandular pores on scutum; C, SEM view of glandular pores on scutellum. Scale bars = 5 mm (A), 1 µm (B), 10 µm (C).

Male. FW colouration (Fig. 5A): Dorsal field cells mostly transparent, veins mostly dark brown to black. Basal area velvety black, basally yellow, brown towards distal part. Cell between 2A and 3A at chordal area yellow. CuA, MA and MP black; R yellow, R projections yellow basally, black apically.

Lateral field basally yellow, MA/MP yellow, transparent ventrally to R. FW venation (Fig. 5A): 1A curved, slightly bisinuated; stridulatory vein with 80–110 teeth on transverse part of 1A only (Table 1; Fig. 5C), with a large hook-like tooth near base of 1A (Fig. 5D). Harp slightly longer than wide,

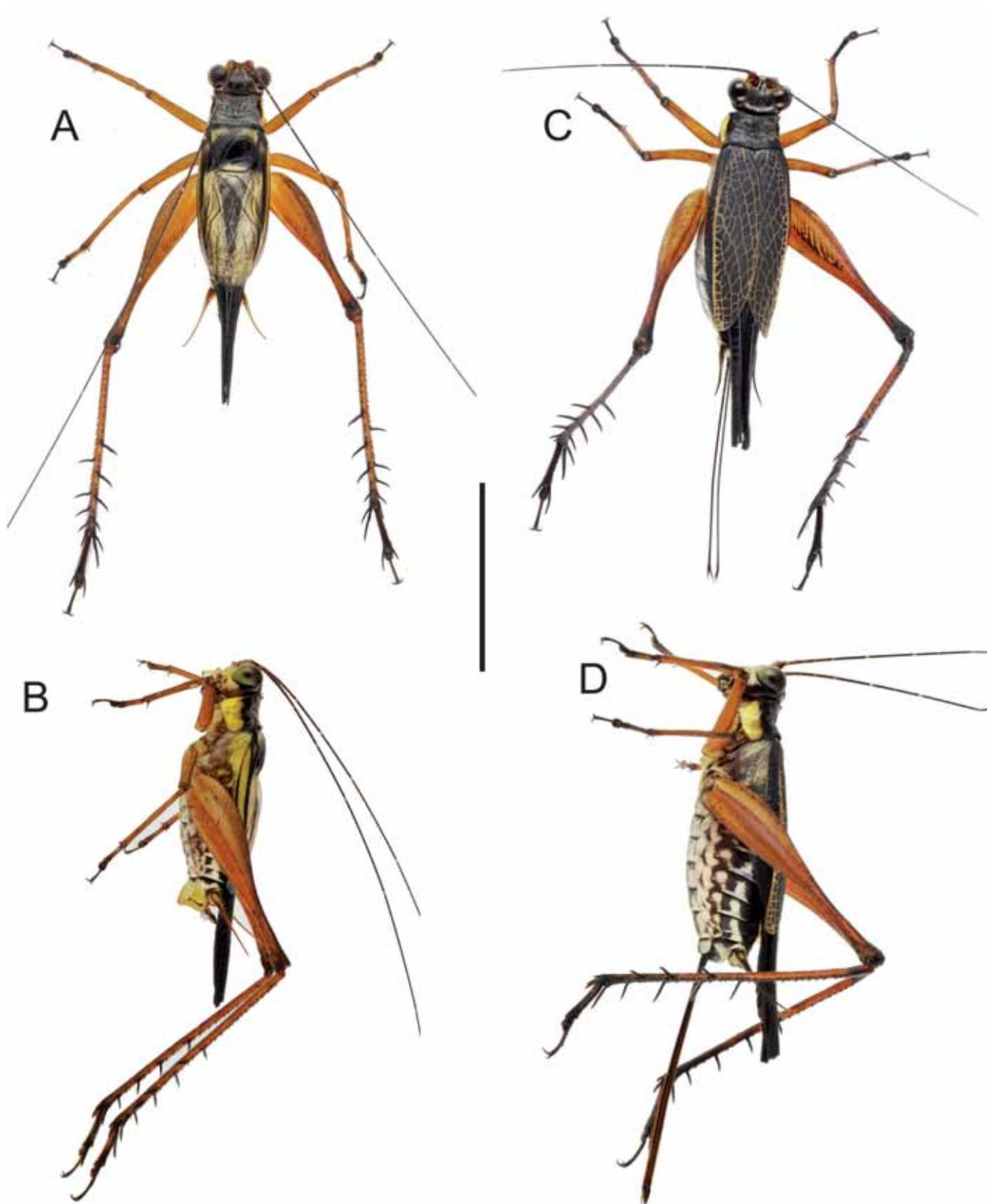


Fig. 3. *Nisitrus vittatus*: A, B, male; C, D, female. A, C, dorsal view; B, D, lateral view. Scale bar = 1 cm.



Fig. 4. *Nisitrus vittatus*, head: A, dorsal view; B, facial view; C, lateral view. Scale bar = 1 mm.

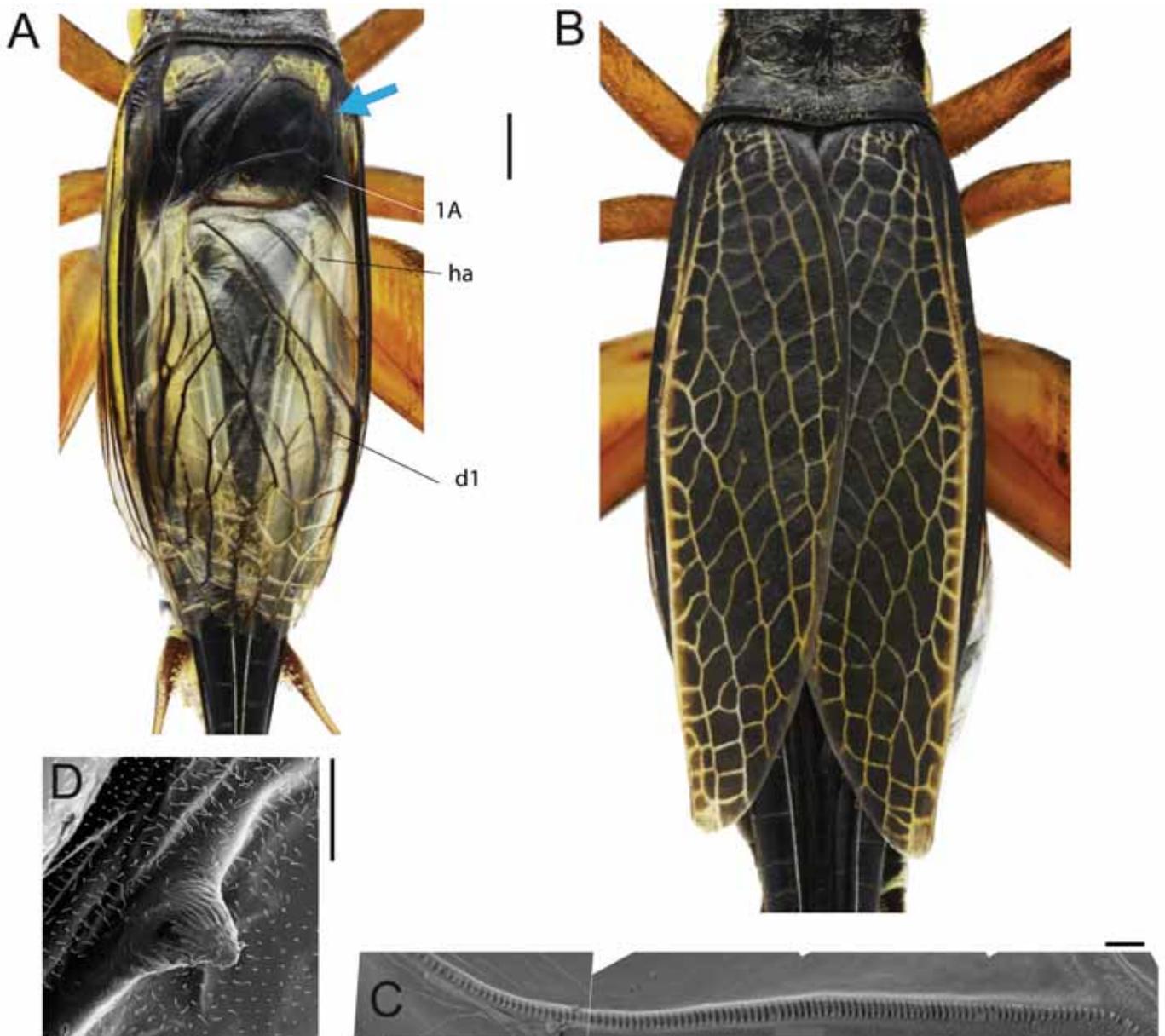


Fig. 5. *Nisitrus vittatus*: A, FW venation in male; B, FW venation in female; C, SEM view of stridulatory file; D, basal notch. Blue arrow shows approximate location of the basal notch on FW venation. Scale bars = 1 mm (A, B), 100  $\mu$ m (C, D).

with 2 harp veins, distal one bifurcate. c1 long and wide, c2 shorter and slightly narrower than c1; mirror (d1) longer than wide, not rounded, generally separated in two parts by a faint transverse vein, the posterior part rectangular, shorter than anterior part. Cell d2 as wide as d1, usually subdivided by accessory veins. Apical field short and rounded, with 3 wide cell alignments posterior to mirror and a narrow apical alignment. Lateral field with 5–7 projections of R ( $m = 6$ ,  $n = 4$ ) and 2–3 anterior ventral veins ( $m = 3$ ,  $n = 4$ ). Epiproct black. Subgenital plate pale with median area black.

Male genitalia (Fig. 6). Pseudepiphallus sclerotised, anterior and posterior margins slightly indented. Posterior apex with paired lophi longer than wide, sclerotised laterally only and covered with strong short setae; apex of lophi slightly folded dorsally. Rami slightly swollen preapically, their narrow apex convergent. Pseudepiphallic parameres narrow, divergent posteriorly, their basis membranous, with a sclerotised lobe on anterior apex. Ectophallic arc complete and wide. Ectophallic fold narrowed preapically, with strong rounded

lateral sclerites; apex narrow and membranous between anterior apex of pseudepiphallic parameres. Ectophallic apodemes long and slightly divergent. Endophallic sclerite large and sclerotised, its posterior apex with divergent lateral arms and with a short median expansion curved dorsally. Endophallic apodeme with lateral lamellas and dorsal crest longer than wide. Membrane of endophallic cavity smooth.

Female. FW colouration (Fig. 5B): cells dark grey to black, veins generally yellow brown, sometimes pale yellow to white, more or less distinct. CuA yellow to orange brown. Lateral field: MP orange brown, MA black, R yellow, including its bifurcations; except for veins, areas between veins CuA and R black; ventral part of lateral field transparent. FW venation: 7–10 strong longitudinal veins on dorsal field ( $m = 8.5$ ,  $n = 1$ ); lateral field with 4–6 projections of R ( $m = 5$ ,  $n = 4$ ) and 2–3 anterior ventral veins ( $m = 3$ ,  $n = 4$ ). Female genitalia. Ovipositor: nearly as long as hind femora; apex thin with both dorsal and ventral edges smooth (Fig. 7A). Copulatory papilla conical, apex folded ventrally, pointed and sclerotised; dorsal face with a sclerotised area (Fig. 7D).

Juvenile. First instars mostly black. Following instars characterised by black and pale yellow striped colouration. Subadult colouration light brown mottled with dark brown and black, with a black transverse band on abdomen (Fig. 8C).

**Variation.** — Populations from Singapore and Malaysia are very similar but they slightly differ from specimens from south Sumatra (neotypes) by details of colouration and proportions. Specimens from Sumatra tend to be larger (see Table 1), females have longer ovipositor and their venation is usually more distinct, with a yellowish line along lateral edge of dorsal field. Female copulatory papilla tend to be more sclerotised dorsally in specimens from Singapore.

**Life history traits.** — *N. vittatus* is a diurnal species living in many lowland secondary habitats, on low plants and bushes on forest edges, along tracks and in clearings. Males sing from leaves of plants from early morning to dusk. Mating

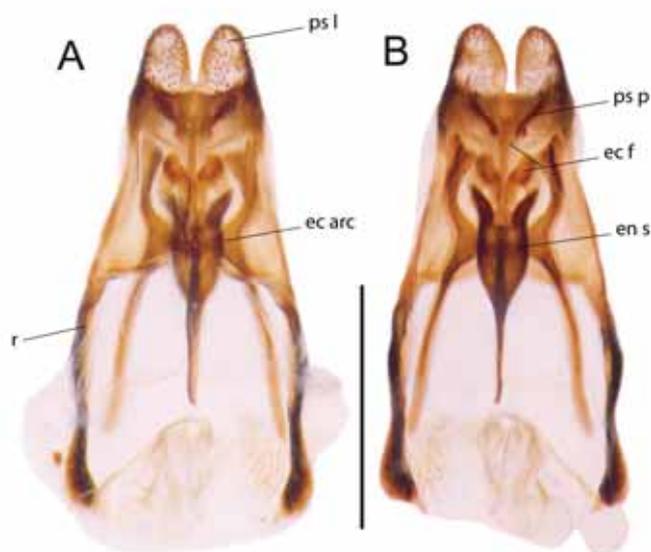


Fig. 6. *Nisitrus vittatus*, male genitalia: A, dorsal view; B, ventral view. Scale bars = 1 mm.

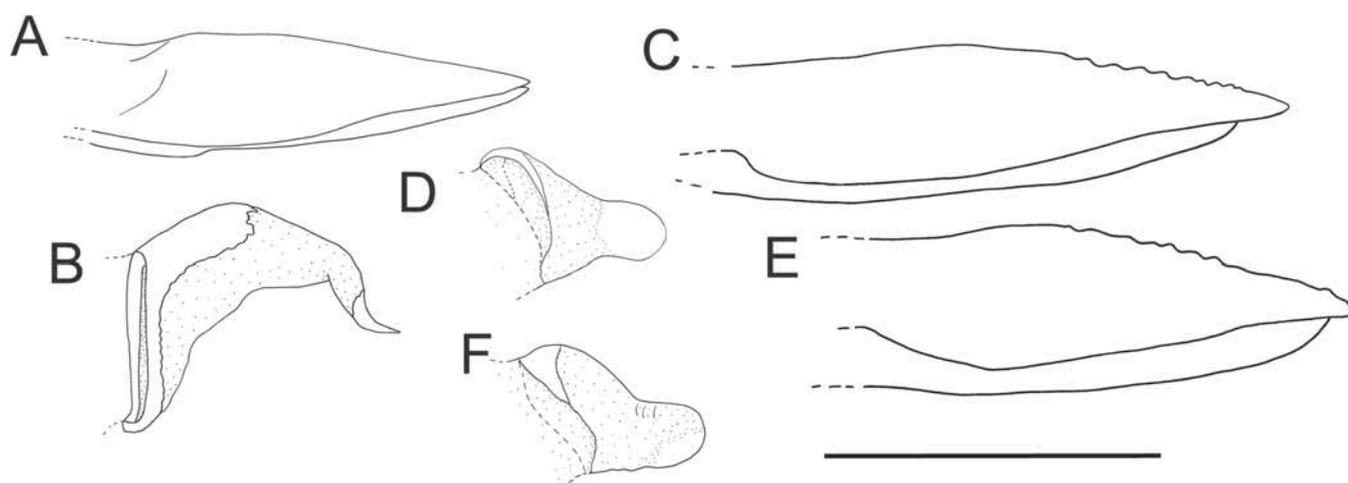


Fig. 7. Female genitalia: A–C, apex of ovipositor; D–F, copulatory papilla. A, D, *Nisitrus vittatus*; B, E, *Lebinthus bitaeniatus*; C, F, *Lebinthus luae*. Scale bars = 1 mm.

couples are generally observed on plant leaves during the day (Fig. 8).

**Behaviour.** — Calling song (Fig. 9): In the field ( $n = 4$ ;  $t^{\circ}\text{C} = 30\text{--}32^{\circ}\text{C}$ ), the calling song of *N. vittatus* consists in rapid triplets of syllables repeated at length to form a continuous trill. Each syllable has a duration of  $6.9 \pm 1.4$  ms. The spectrum shows a dominant peak at  $7.3 \pm 0.1$  kHz and several peaks harmonically related; the first peak of the spectrum slightly dominates over the other peaks. Mating behaviour: Observations in the field and in the laboratory showed multiple matings as described in another *Nisitrus* species by Preston-Mafham (2000) (T. Robillard, pers. obs.) (Fig. 8B).

Measurements. See Table 1.

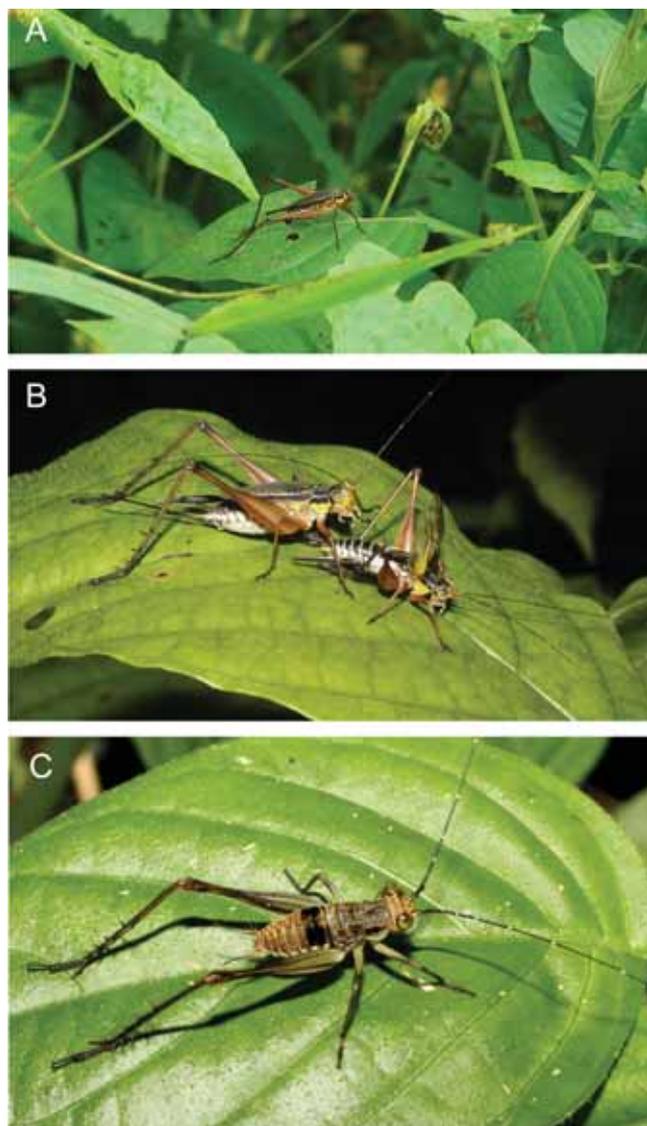


Fig. 8. *Nisitrus vittatus*: A, female on low vegetation along track in McRitchie reservoir park in Singapore; B, couple mating at night along Wallace Trail, Hindhede Nature Park, Singapore; C, subadult specimen in Wallace Trail, Hindhede Nature Park, Singapore.

## Tribe Lebinthini Robillard, 2004

### Genus *Lebinthus* Stål, 1877

**Type species.** — *Lebinthus bitaeniatus* Stål, 1877

**Diagnosis.** — Among Lebinthini genera, *Lebinthus* is closely related to *Agnotecous* Saussure, 1878, to which it resembles by microptery and FW venation. It is characterised by its rather smaller size, microptery in both sexes (FW short and hind wings absent), and male FW venation with mirror almost not differentiated from apical field, dorsal field as long as or longer than lateral field (it is shorter in *Agnotecous*), median fold short, triangular and located on dorsum.

### *Lebinthus bitaeniatus* Stål, 1877

(Figs. 10, 11A–D, 12A–C, 13A, B, 14A–C, 15A–C, 16)

*Lebinthus bitaeniatus* Stål, 1877: 50; Bolívar, 1889: 425; Chopard, 1968: 354; Robillard & Desutter-Grandcolas, 2004a: 275; 2006: 644; 2008: 67 (phylogeny and taxonomy)

#### Synonym names

##### *Paraeneopterus bitaeniatus* Saussure, 1878

*Paraeneopterus bitaeniatus* Saussure, 1878: 334; Brunner von Wattenwyl, 1898: 279; Chopard, 1968: 355

*Lebinthus bitaeniatus* – Robillard & Desutter-Grandcolas, 2008: 67 >> *Paraeneopterus bitaeniatus*, replaced by *Lebinthus saussureii*, synonym of *L. bitaeniatus*

##### *Lebinthus saussureii* Bolívar, 1889

*Lebinthus saussureii* Bolívar, 1889: 425

*Paraeneopterus bitaeniatus* – Chopard, 1968: 355

*Lebinthus bitaeniatus* – Robillard & Desutter-Grandcolas, 2008: 67 > synonym of *L. bitaeniatus*

**Discussion.** — Most *Lebinthus* specimens showing lateral yellow bands along the whole body have generally been identified as *L. bitaeniatus* by previous authors. However, close re-examination using modern taxonomic criteria suggests that many different species are probably mixed under *L. bitaeniatus*, such as *L. luae* Robillard & Tan, new species from Singapore and South Sumatra, *L. bifasciatus* Chopard, 1951 from Australia and *L. lanyuensis* Oshiro, 1996 from Taiwan. Combined to close examination of morphology, acoustic analysis of calling songs (Table 2) and molecular analyses reveal clear differences between *L. bitaeniatus* and *L. luae*.

**Material examined.** — Holotype (female): Philippines: Ins. Philipp., semper, 24-25/5-64 (NHRM-ORTH0012705) (examined on photograph, see Fig. 10).

Other material examined. **Philippines:** 2 females (BPBM), Luzon, Los Banos, Mount Makiling, coll. C. M. Yoshimoto, 17 Sep.1959; 1 male (BPBM), Luzon, Los Banos, Mount Makiling, coll. C. M. Yoshimoto, 19 Sep.1959; 2 males (MNHN: TR145, 151), 2 females (MNHN: TR146, 147), 2 juveniles (MNHN: TR15, 154), on leaf litter, 1 female (MNHN: TR127), on plant (h = 10 cm), 2 males (UPLB MNH: TR144, 228), 3 females (UPLB MNH: TR148, 149, 150), 2 juveniles (UPLB MNH: TR153, 155), leaf litter, 2 males (UPLB MNH: TR142, 143), on low plant, Luzon, Los Baños, Laguna, Mount Makiling, base, Flat Rock, West of Mulawin Creek, secondary forest,  $14^{\circ}08'50.2''\text{N}$ ,  $121^{\circ}13'41.5''\text{E}$ , 244 m, coll. T. Robillard, 28 Jun.2011, all night; 3 males (MNHN: TR81, 84, 85), leaf litter, night, 1 male (MNHN: TR86), on plant

(h = 10 cm), night, 1 male (MNHN: TR81), leaf litter, day, 1 male (MNHN-ENSIF3197: TR124), call recording, leaf litter, day, 1 male (MNHN-ENSIF3196: TR266), call recording, on plant (h = 30 cm), day, 1 male (MNHN: TR87), on plant (h = 80 cm), day, 1 juvenile (MNHN: TR107), leaf litter, day, 1 male (UPLB MNH: TR04), 2 females (UPLB MNH: TR105, 106), on plant (h = 30 cm), day, 1 juvenile (UPLB MNH: TR282), leaf litter, night, Luzon, Los Baños, Laguna, Mount Makiling, base, secondary forest on campus, 14°09'12.9"N, 121°14'05.0"E, 168 m, coll. T. Robillard, 27 Jun.2011 – 3 Jul.2011; 1 male (MNHN: TR230), 1 female (MNHN: TR233), on plant (h = 30 cm), 1 female (MNHN: TR235), on plant (h = 1 m), 1 female (MNHN: TR219), on plant (h = 1.7 m), 1 male (ZRC: TR227), on plant, 1 female (ZRC: TR231), on plant (h = 1 m), 1 male (UPLB MNH: TR229), on plant (h = 30 cm), 1 male (UPLB MNH: TR234), 1 female (UPLB MNH: TR232), on plant (h = 1 m), Luzon, Los Baños, Laguna, Mount Makiling, base, East of Mulawin Creek, secondary forest, 14°08'51.6"N, 121°13'46.7"E, 182 m, coll. T. Robillard, 29 Jun.2011; 2 males (MNHN: TR181, 182), 1 female (MNHN: TR183), grassland, Luzon, Los Baños, Laguna, arboretum, 14°09'52.8"N, 121°14'17.1"E, 45 m, coll. T. Robillard, 29 Jun.2011, all day.

**Diagnosis.** — Species similar to *L. luae* new species, but differing by general shape more slender, lighter colouration,

with a yellow longitudinal band along the body thinner and underlined ventrally by a narrow black line; male genitalia differ by details and proportions and by strong M-shaped sclerotisation of ectophallic fold, absent in *L. luae*, but close to that of other species (ex: *L. cyclopus* Robillard, *L. truncatipennis* Chopard: Robillard, 2010).

**Redescription.** — Species of average size for the genus, of slender shape. Colouration contrasting, with brown and dark brown areas and with narrow dorso-lateral yellow longitudinal bands along the whole body (Fig. 11A–D). Head dorsum yellow brown with 6 dark brown longitudinal bands more or less distinct (Fig. 12A–C). Fastigium wider than long, setose, dark brown, apex yellow with two wide black spots on facial part almost touching each other. Scapes yellow and brown; antennae brown. Face variable, from yellow brown to darker brown. Epistomal suture yellow. Mouthparts yellow brown, including maxillary palpi. Lateral part of head with a yellow area posterior to eye, underlined by a black band, then progressively lighter from dorsal to ventral region. Pronotum: dorsal disk yellow brown to brown, slightly mottled with brown, with black spots and with short black longitudinal

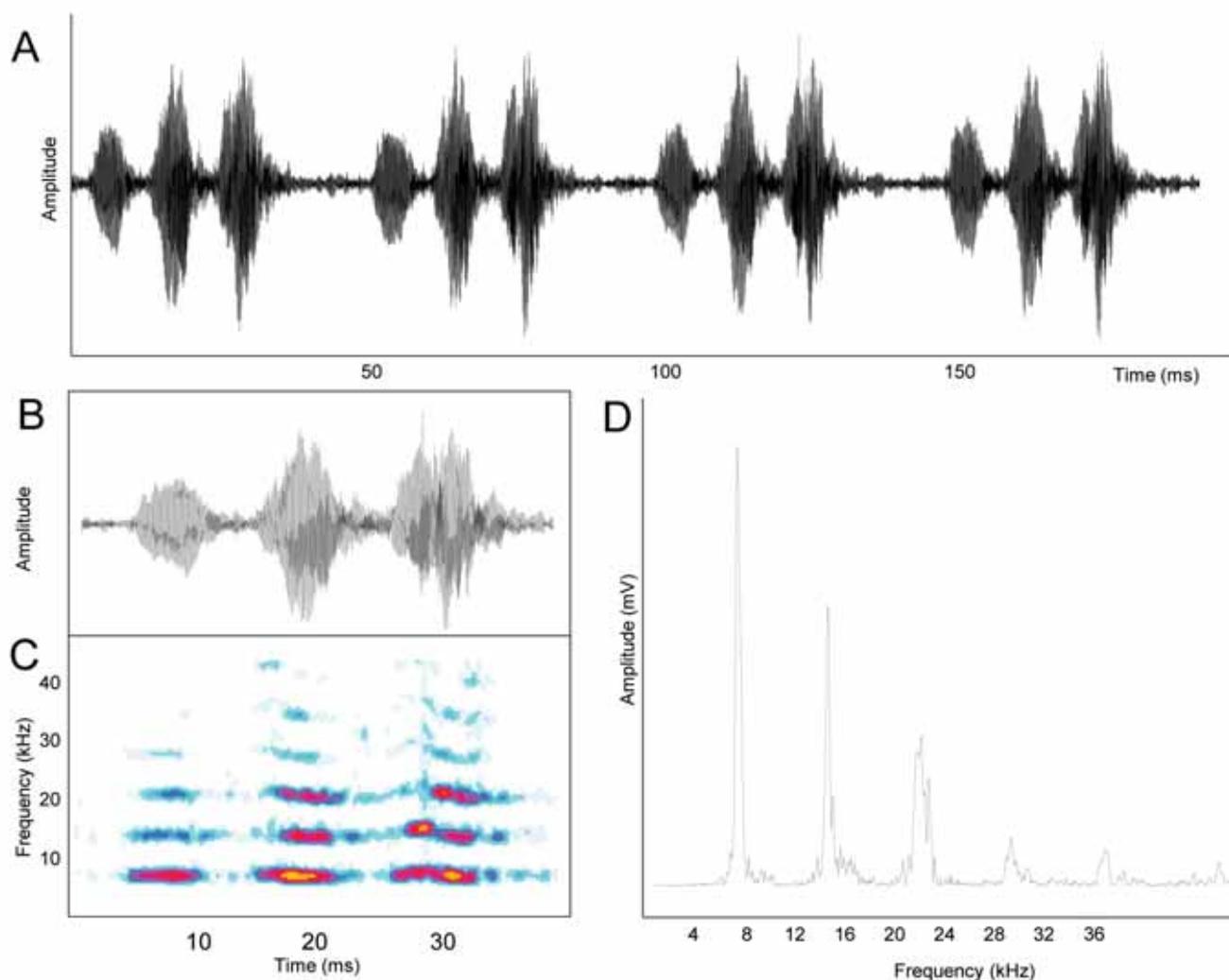


Fig. 9. Calling song of *Nisitrus vittatus*. Oscillogram of 4 echemes (A); oscillogram (B) and sonogram (C) of 1 echeme; linear power spectrum of 1 syllable (D).

Table 1. Measurements of *Nisitrus vittatus*.

South Sumatra	PronL	PronW	FWL	FWW	HWT	FIIL	FIIW	TIIL
Male neotype	1.9	2.8	9.6	3.4	5.4	14.1	2.9	13.7
Males (n = 4)	1.9–2	2.6–2.9	9.5–9.9	3.2–3.4	5.3–6.1	12.6–14.5	2.7–3	13–14.8
(mean)	(1.9)	(2.7)	(9.7)	(3.3)	(5.6)	(13.6)	(2.9)	(13.8)
Females (n = 2)	2–2.4	2.8–3.1	10.5–12.5	2.8–3.4	5.3–7.5	14.3–16.4	2.7–3.3	13.1–17
(mean)	(2.2)	(3.0)	(11.7)	(3.2)	(6.3)	(15.8)	(3.1)	(15.1)
<b>TIILs</b>								
	<b>Ias</b>	<b>Ibs</b>	<b>Oas</b>	<b>Obs</b>	<b>TaIII</b>	<b>ST (n=3)</b>	<b>OL</b>	
Male neotype	18	11	24	12	5	?	–	
Males (n = 4)	13–18	7–11	21–24	9–12	2–5	82–95	–	
(mean)	(15)	(10)	(23)	(11)	(4)	(87)	–	
Females (n = 5)	13–17	6–8	20–24	6–11	3–4	–	15.9–18.8	
(mean)	(15)	(7)	(22)	(9)	(4)	–	(17.2)	
<b>Singapore</b>								
	<b>PronL</b>	<b>PronW</b>	<b>FWL</b>	<b>FWW</b>	<b>HWT</b>	<b>FIIL</b>	<b>FIIW</b>	<b>TIIL</b>
Males (n = 3)	1.9	2.7–3.0	9–9.8	3.5–3.7	4.3–5.6	11.6–14.0	2.7–3.0	11.0–14.0
(mean)	(1.9)	(2.9)	(9.3)	(3.6)	(5)	(13.0)	(2.5)	(12.8)
Females (n = 4)	1.8–2.4	2.9–3.2	10.4–10.8	2.8–3.1	5.6–7.1	13.4–15.2	2.8–3.4	13.3–15.1
(mean)	(2.1)	(3)	(10.8)	(2.9)	(6.4)	(14.2)	(3.1)	(14.3)
<b>TIILs</b>								
	<b>Ias</b>	<b>Ibs</b>	<b>Oas</b>	<b>Obs</b>	<b>TaIII</b>	<b>ST (n=3)</b>	<b>OL</b>	
Males (n = 3)	11–12	3–4	19–23	3–5	2.5–3.2	98–110	–	
(mean)	(11.5)	(2.5)	(21)	(4)	(2.9)	(106)	–	
Females (n = 2)	13–17	2–10	17–22	5–12	0–3	–	13.2–14.3	
(mean)	(15)	(6)	(19)	(7)	(1)	–	(14)	

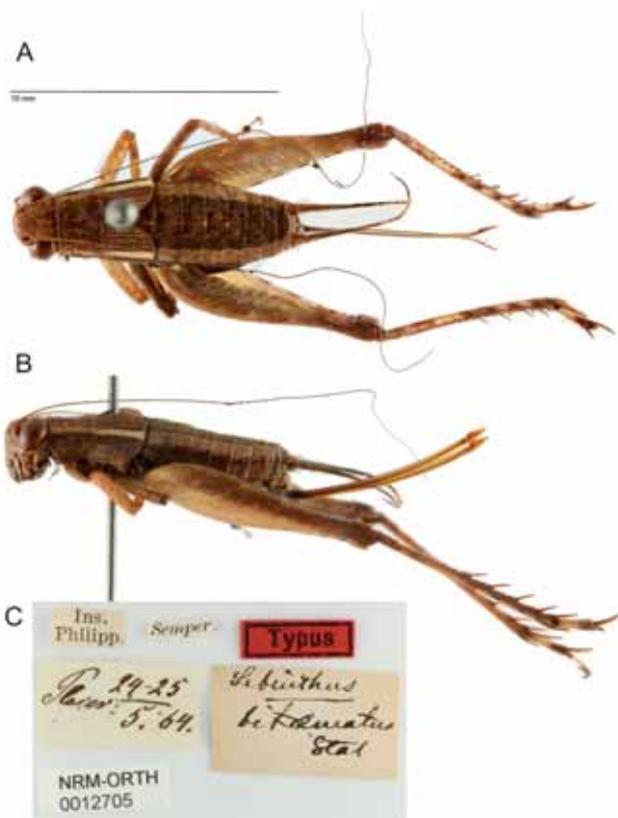


Fig. 10. Female holotype of *Lebinthus bitaeniatus* in dorsal (A) and lateral (B) views; labels (C). Type deposited in Swedish Museum of Natural History, Stockholm. (Photographs by: Gunvi Lindberg & Kjell Arne, NHRS).

lines on posterior apex; lateral edges yellow. Lateral lobes dark brown to black dorsally and progressively lighter ventrally. Legs I and II light brown to yellow brown, femora with brown spots and longitudinal patterns, tibiae with rings. FIII brown, sometimes with dark spots and with striated dark patterns on outer faces; hind knees black; hind tibiae black with yellow rings. For all pairs of legs, Ta1 and Ta3 yellow basally, dark brown apically. Abdomen homogeneously dark brown dorsally, covered with golden setae, lateral edges with yellow or whitish longitudinal bands. Sternites yellowish brown, with dark brown patterns laterally. Cerci yellowish basally, with black rings near apex, their ventral side black.

Male: FWs not reaching abdomen mid-length (Fig. 13A, B). FW colouration: Cells and veins brown, not translucent; angle between dorsal and lateral fields forming a narrow band, whitish to yellow, including basis and distal part of CuA (rest of CuA dark brown), basis of MP, CuA/MP area, and half MA/MP area; lateral field with a thin black line underlying the yellow longitudinal band, then brown ventrally; small median fold not included in the pale longitudinal band. FW venation (Fig. 13A): 1A angle wide (>100°); stridulatory file with 138–144 teeth (m = 141, n = 2), located on transverse and longitudinal parts of 1A. CuP absent. Area posterior to plectrum strongly sclerotised. Harp wide, with a longitudinal fold near angle of 1A (claval fold?); with 1 harp vein, sometimes bifurcated distally. Distal part of CuA straight. Mirror (d1) not differentiated, resembling the other few cells of D alignment. Apical field absent, with no bifurcation of CuA posterior to diagonal vein. Lateral field with 5 strong

longitudinal veins including MA, R and 3 more ventral veins; latero-dorsal angle made by MP; R without strong bifurcating veins. Subgenital plate elongate, clog-shaped.

Male genitalia (Fig. 14): Pseudepiphallic sclerite trapezoidal, convex dorsally, its apex slightly trilobate, including a short median expansion and 2 small lophi barely individualised, slightly divergent and finely setose. Anterior margin bisinuated, with a median indentation. Rami short, half as long as pseudepiphallic sclerite. Pseudepiphallic parameres

with a long sclerotised basis, trilobate, including a postero-dorsal lobe and two ventral ones, the posterior lobe square, the anterior one curved anteriorly and pointed, slightly denticulate. Ectophallic arc complete and wide. Ectophallic fold wide and triangular, with a wide M-shaped sclerotisation; apex membranous. Ectophallic apodemes long and parallel, exceeding anterior margin of pseudepiphallus. Bases of ectophallic apodemes with a pair of ventral membranous expansions, with a small apical sclerite. Endophallic sclerite

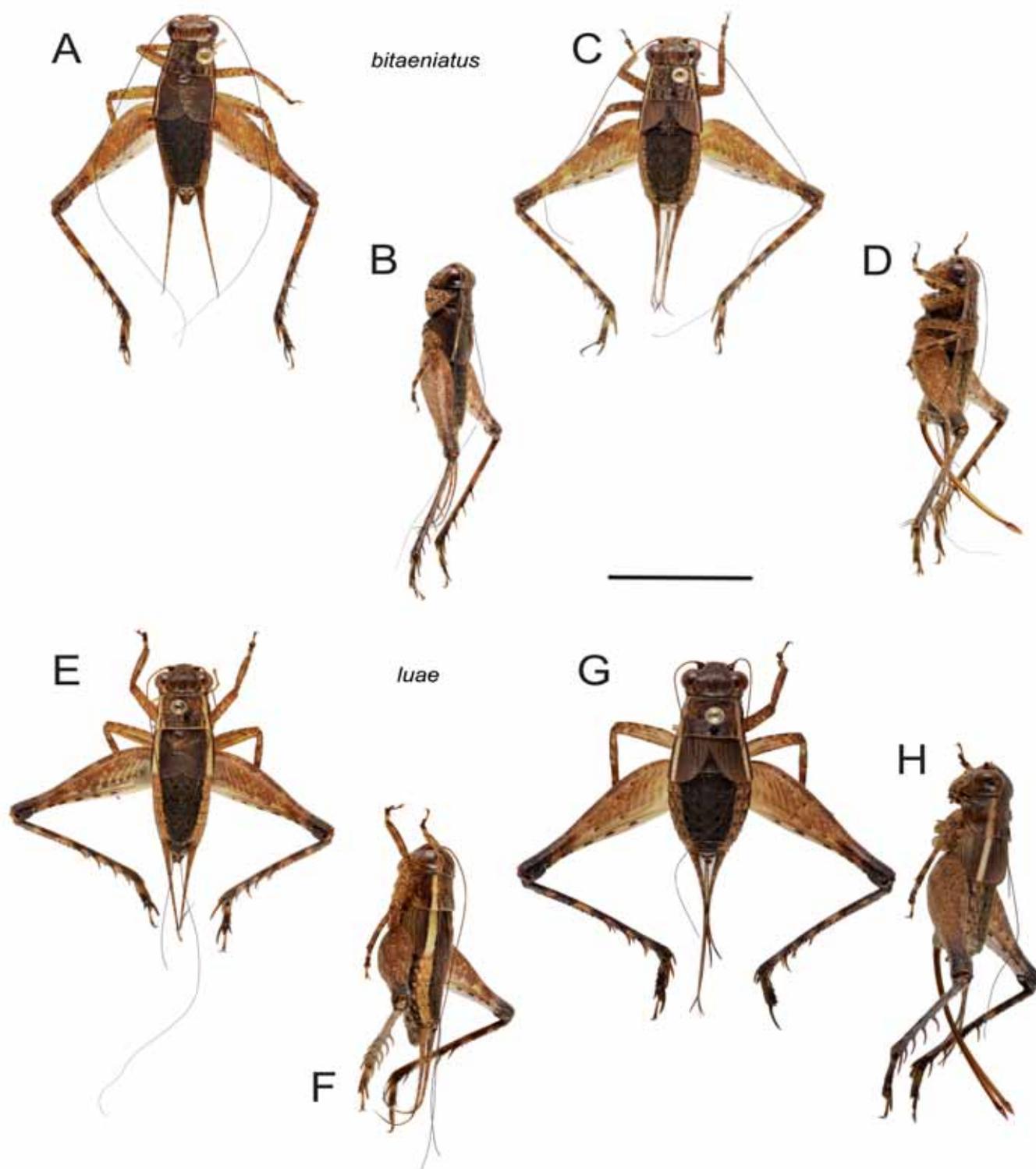


Fig. 11. *Lebinthus bitaeniatus* (A–D): A, B, male; C, D, female; A, C, dorsal view; B, D, lateral view. *Lebinthus luae* (E–H): E, F, male; G, H, female; E, G, dorsal view; F, H, lateral view. Scale bar = 1 mm.

long, exceeding anterior margin of pseudepiphallus, convex dorsally, its posterior apex with a small median triangular expansion and with short thick lateral arms; endophallic apodeme made of a narrow median crest.

Female: FWs short (Fig. 13B), slightly longer than pronotum, slightly overlapping basally; dorsal field grey brown, with 5–6

(n = 4; HTF = 6) strong, orange brown parallel longitudinal veins and weak cream transverse veins. Lateral angle of FWs with a narrow yellow longitudinal band including a faint vein. Lateral field with 3–4 (n = 4) strong straight longitudinal veins.

Female genitalia: Ovipositor almost as long as hind femora; apex lanceolate, denticulate on dorsal edge (Fig. 7B).

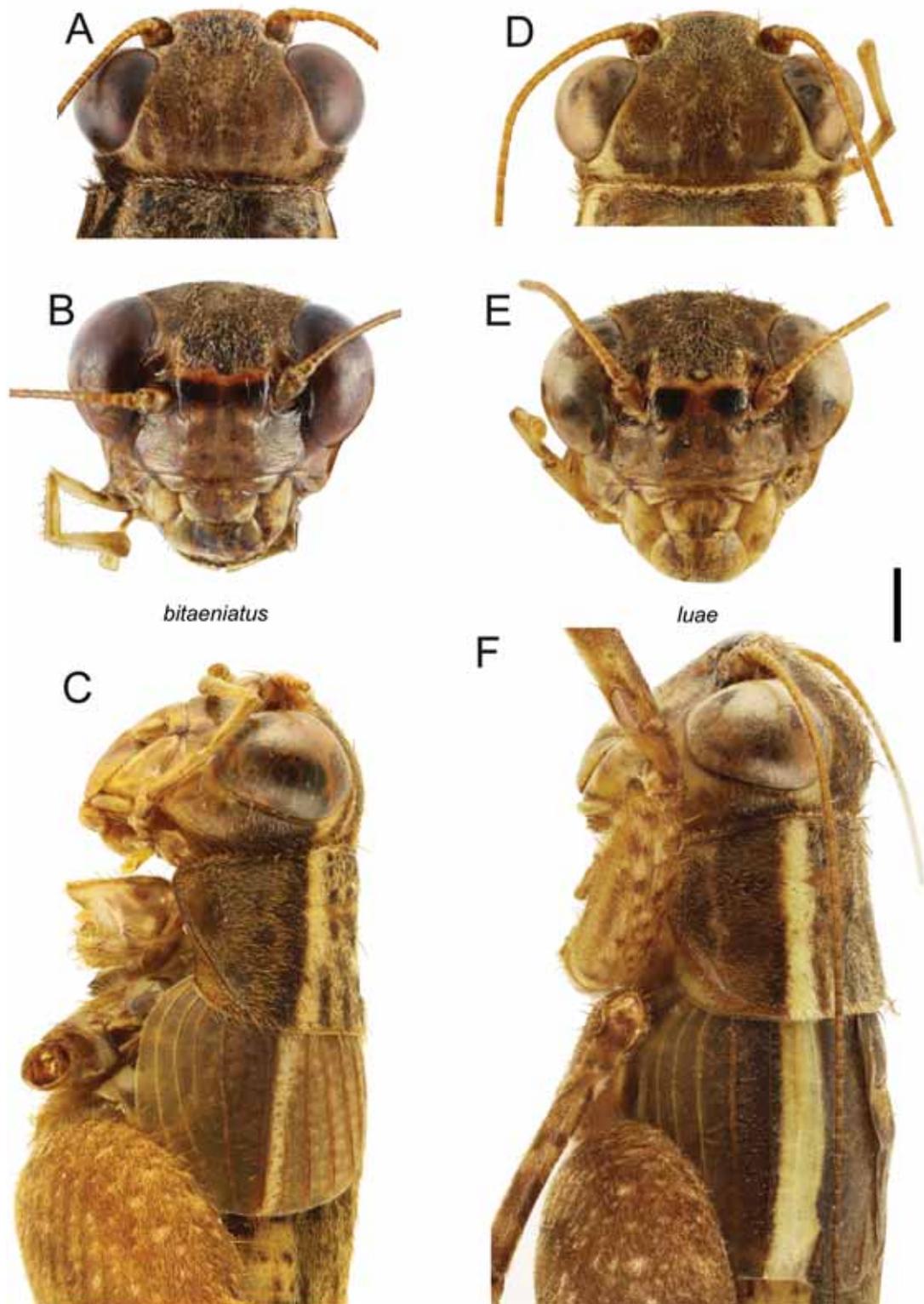


Fig. 12. Head: A–C, *Lebinthus bitaeniatus*; D–F, *Lebinthus luae*. A, D, dorsal view; B, E, facial view; C, F, lateral view. Scale bar = 1 mm.

Table 2. Comparison of characteristics of calling songs of *L. bitaeniatus* and *L. luae*.

	T°C	Dominant Frequency (kHz)	Syllable duration (ms)		Syllable period (ms)		Number of syllables per echeme			Echeme duration (s)
			Start	Trill	Start	Trill	Start	Trill	Total	
<i>L. bitaeniatus</i> (n = 2)	27.5–28.5	19.9 ± 1.3	42 ± 10	11 ± 5	273 ± 212	16 ± 6	35 ± 15	41 ± 8	76 ± 22	11.3 ± 5.1
<i>L. luae</i> (n = 4)	27.5–29.5	16.7 ± 1.3	28.1 ± 9.8	13.3 ± 2.2	219.9 ± 127.7	21.6 ± 3.7	11 ± 5	24 ± 3	38 ± 5	3.3 ± 1.2

Copulatory papilla (Fig. 7E) conical, with a narrow basal sclerotised area on ventral face; apex rounded, sclerotised. Juvenile: Similar to adults in colouration, light brown.

Life history traits: *L. bitaeniatus* is a diurnal species living in secondary habitats or open areas in forest (Fig. 15C). Males sing from low plants above the leaf litter from early morning

to dusk. Mating couples are generally observed during day and night on plant leaves or on top of the litter (Fig. 15A–C).

Behaviour. Calling song (Fig. 16; Table 2): In the field (n = 2; t°C = 27.5–28.5°C) the calling song of *L. bitaeniatus* lasts for 11.3 ± 5.1 s and is made of very indented syllables. This echeme is organised in two parts, the initial one consisting

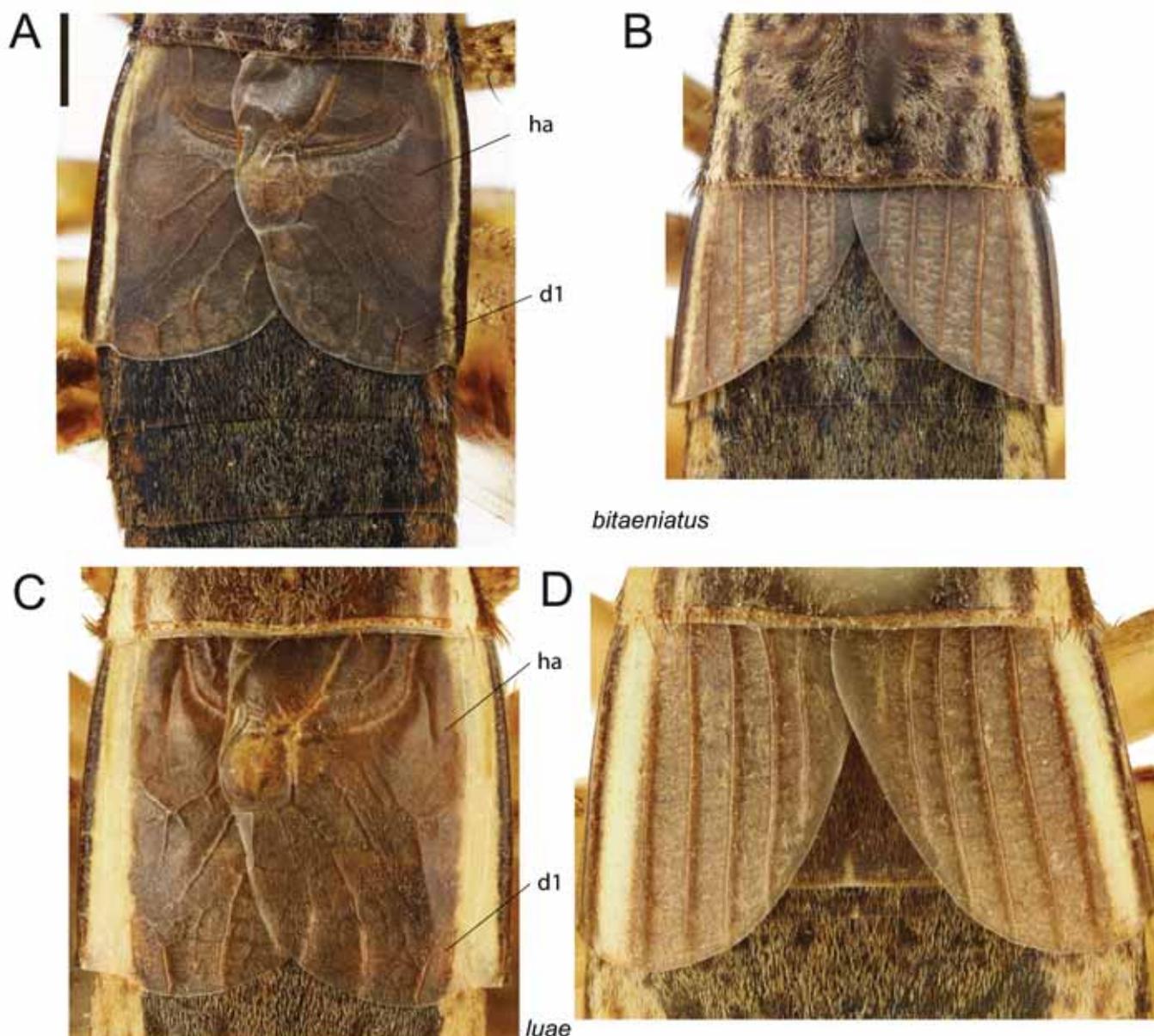


Fig. 13. Forewing venation in dorsal view: A, B, *Lebinthus bitaeniatus*; C, D, *Lebinthus luae*. A, C male; B, D, female. Scale bar = 1 mm.

Table 3. Measurements of *Lebinthus bitaeniatus*.

	PronL	PronW	FWL	FWW	HWT	FIHL	FIIHW	TIHL
Males (n = 5)	2.3–2.6	3.2–3.7	3.2–3.6	2.5–2.9	–	10.8–12.8	3.2–3.6	9.6–10.3
(mean)	(2.5)	(3.5)	(3.4)	(2.6)	–	(11.6)	(3.4)	(9.8)
Females (n = 5)	2.7–2.8	3.5–3.9	2.4–2.8	1.6–2.3	–	11.3–13.1	3.5–3.8	10.2–11.3
(mean)	(2.7)	(3.7)	(2.7)	(1.9)	–	(12.4)	(3.7)	(9.8)
	TIIIs				TaIIIs	ST (n=2)		OL
	Ias	Ibs	Oas	Obs		Tt	Lt	
Males (n = 5)	6–11	4–7	10–15	6–7	3–4	88–110	27–29	–
(mean)	(8)	(6)	(13)	(7)	(3)	(99)	(28)	–
Females (n = 5)	6–10	4–7	12–15	6–8	3–5	–	–	11.4–13.5
(mean)	(8)	(6)	(14)	(7)	(4)	–	–	(12.2)

of  $35 \pm 15$  longer, well-spaced syllables (longer duration =  $42 \pm 10$  ms and period =  $273 \pm 212$  ms), the second part being a short trill made of  $41 \pm 8$  shorter syllables set closer together (shorter duration =  $11 \pm 5$  ms and period =  $16 \pm 6$  ms). Each syllable is made of discrete pulses, produced by regular plectrum pauses, which in turn are caused by a discontinuous closing phase. Such a pattern produces a broad band spectrum between 12 and 30 kHz, with main energy centred at nearly  $19.9 \pm 1.3$  kHz, which corresponds to the first and only peak of the spectrum.

Measurements. See Table 3.

***Lebinthus luae* Robillard & Tan, new species**  
(Figs. 11E–H, 12D–F, 13C, D, 14D–F, 15D, E, 17)

*Lebinthus bitaeniatus* Stål, 1877 – Robillard & Desutter-Grandcolas, 2004a: 275; 2006: 644; Robillard, 2011: 25

*Lebinthus* sp. – Tan, 2010: 246; Tan et al., 2012: 66; Tan, 2012: 4; Tan & Wang, 2012: 315

*Lebinthus* n. sp. affinis *bitaeniatus* – Robillard et al., 2013: 2003 > mechanism of stridulation

**Material examined.** — Holotype (male): **Singapore:** male (TR6), day, leaf litter (ZRC), Labrador park, forêt secondaire littorale [coastal secondary forest],  $01^{\circ}15'59''\text{N}$ ,  $103^{\circ}48'8.1''\text{E}$ , 57 m (GPS Lab1), coll. T. Robillard, 12 Jun.2011. Allotype (female): **Singapore:** female (TR42bis), day, leaf litter (ZRC), Pulau Ubin Island, Jalan Endut Senin,  $01^{\circ}24'19.3''\text{N}$ ,  $103^{\circ}57'58.7''\text{E}$ , 0 m, coll. T. Robillard, 30 Jun.2009.

Paratypes (14 males, 7 females): **Singapore:** 1 male (TR4), call recording (MNHN-ENSIF3207), same information as HT. 1 male (TR17) (ZRC); 1 male (TR41) (UPLB MNH); 1 male (TR16), 1 female (TR53) (MNHN-ENSIF3206), same information as AT. 2 males (TR10, 11), leaf litter, call recording (MNHN-ENSIF3107-3209); 1 male (TR9) copulation recording in the field (MNHN-ENSIF3210), Labrador park, coastal secondary forest,  $01^{\circ}15'58.7''\text{N}$ ,  $103^{\circ}48'10.3''\text{E}$ , 46 m (GPS Lab3), day, coll. T. Robillard, 14 Jun.2011. 2 males (TR38, 54), day, leaf litter, enregistrement appel (MNHN-ENSIF2740-3208), Labrador park,  $01^{\circ}16'02.2''\text{N}$ ,  $103^{\circ}48'05.6''\text{E}$ , 46 m, coll. T. Robillard, 7 Jul.2009. 2 females, day, leaf litter (dead in captivity) (ZRC), 1 female, day, leaf litter (dead in captivity) (UPLB MNH), Sentosa Island,  $01^{\circ}14'49.4''\text{N}$ ,  $103^{\circ}50'01.1''\text{E}$ , 17 m, coll. T. Robillard, 6 Jul.2009. 1 female (MNHN-ENSIF3205), Semakan landfill, coll. RMBR Nature

guide, 5 Dec.2009. 1 male (ZRC), Pulau Tekong, 7 Apr.1984, coll. D. H. Murphy; 1 male (ZRC), Sentosa, 20 Jan.1985, coll. D. H. Murphy; 1 male, 1 female (ZRC), Pulau Ubin, along Sensory Trail, 4 Dec.2009, coll. M. K. Tan; 1 male, 1 female (ZRC), Hindhede Nature Park, secondary forest, 2 Jun.2011, coll. M. K. Tan; 1 male (TR23), night (MNHN-ENSIF3090), Bukit Timah Nature Reserve, Hindhede trail,  $01^{\circ}15'57''\text{N}$ ,  $103^{\circ}46'33.6''\text{E}$ , 68 m, 20 Jun.2011, coll. T. Robillard.

Other material examined: **Singapore:** 1 male, 2 females (MNHN), Labrador park, coastal secondary forest, reared specimens (generations F0–F1), 2011, coll. T. Robillard. 1 juvenile, leaf litter, (TR7) (MNHN), Labrador park, coastal secondary forest, day,  $01^{\circ}15'57.8''\text{N}$ ,  $103^{\circ}48'11.2''\text{E}$ , 42 m, 12 Jun.2011, coll. T. Robillard. **Indonesia:** 3 females (MNHN-ENSIF1432-1434), Doerian [Durian Island], Riouw-Arch [Riau Islands], Nov.1923, Coll. Dammerman; 1 male, 2 females (MNHN-ENSIF1431, 1435, 1436), 1 female, identified *L. bitaeniatus* by T. Robillard (2004, in Robillard & Desutter-Grandcolas, 2004a), Doerian [Durian Island], Riouw-Arch [Riau Islands], Nov.1923, coll. Dammerman; 1 female (MZB. ORTH.10425), Java (Lee??), 22 Oct.1921, coll. L. Wachter. 2 females (MZB. ORTH.9743-9744), Sumatra, Lampong, 4 Feb.1972, coll. Dulhoer; 1 male (MNHN), 1 female (MNHN-ENSIF1424), 2 males, identified *L. bitaeniatus* by L. Chopard (MZB. ORTH.10417, 10419), [Western Java], Tjibodas, 1400 m, No259, Aug.1921.

**Diagnosis.** — Species similar to *L. bitaeniatus*, but differs by general shape more stocky, darker colouration, wider yellowish or whitish longitudinal band along body, without a black line ventrally. Male genitalia wider and shorter than in *L. bitaeniatus*, differing by shape of pseudepiphallic parameres, ectophallic fold membranous (without strong M-shape sclerotisation).

**Description.** — Species of average size for the genus, of stocky shape. Colouration dark brown with wide yellow or whitish dorso-lateral longitudinal bands along the whole body (Fig. 11 E–H). Head dorsum with 6 wide dark brown longitudinal bands more or less distinct and sometimes fused together. Fastigium wider than long, setose, dark brown, apex yellow with two black spots on facial part. Scapes yellow and brown; antennae brown. Face variable, from yellow brown to darker brown. Epistomal suture yellow. Mouthparts yellow brown, including maxillary palpi. Lateral part of head with a yellow area posterior to eye, underlined by a large brownish area more or less homogeneous. Pronotum: Dorsal disk dark brown, its lateral edges yellow. Lateral lobes dark brown

to orange brown, with little distinct lighter patterns near ventral margin, including the ventral corner and a brownish longitudinal line. Legs I and II light brown to yellow brown, femora with brown spots and longitudinal patterns, tibiae with rings. FIII brown, sometimes with dark spots and with striated dark patterns on outer faces; hind knees black; TIII black with yellow rings. For all pairs of legs, Ta1 and Ta3 yellow basally, dark brown apically. Abdomen homogeneously dark

brown dorsally, covered with golden setae, lateral edges with yellow or whitish longitudinal bands. Sternites yellowish brown, with dark brown patterns laterally. Cerci yellowish basally, with black rings near apex, ventral side black.

Male: FWs not reaching abdomen mid-length (Fig. 13C). FW colouration: Cells and veins brown, not translucent; angle between dorsal and lateral fields whitish to yellow, forming a

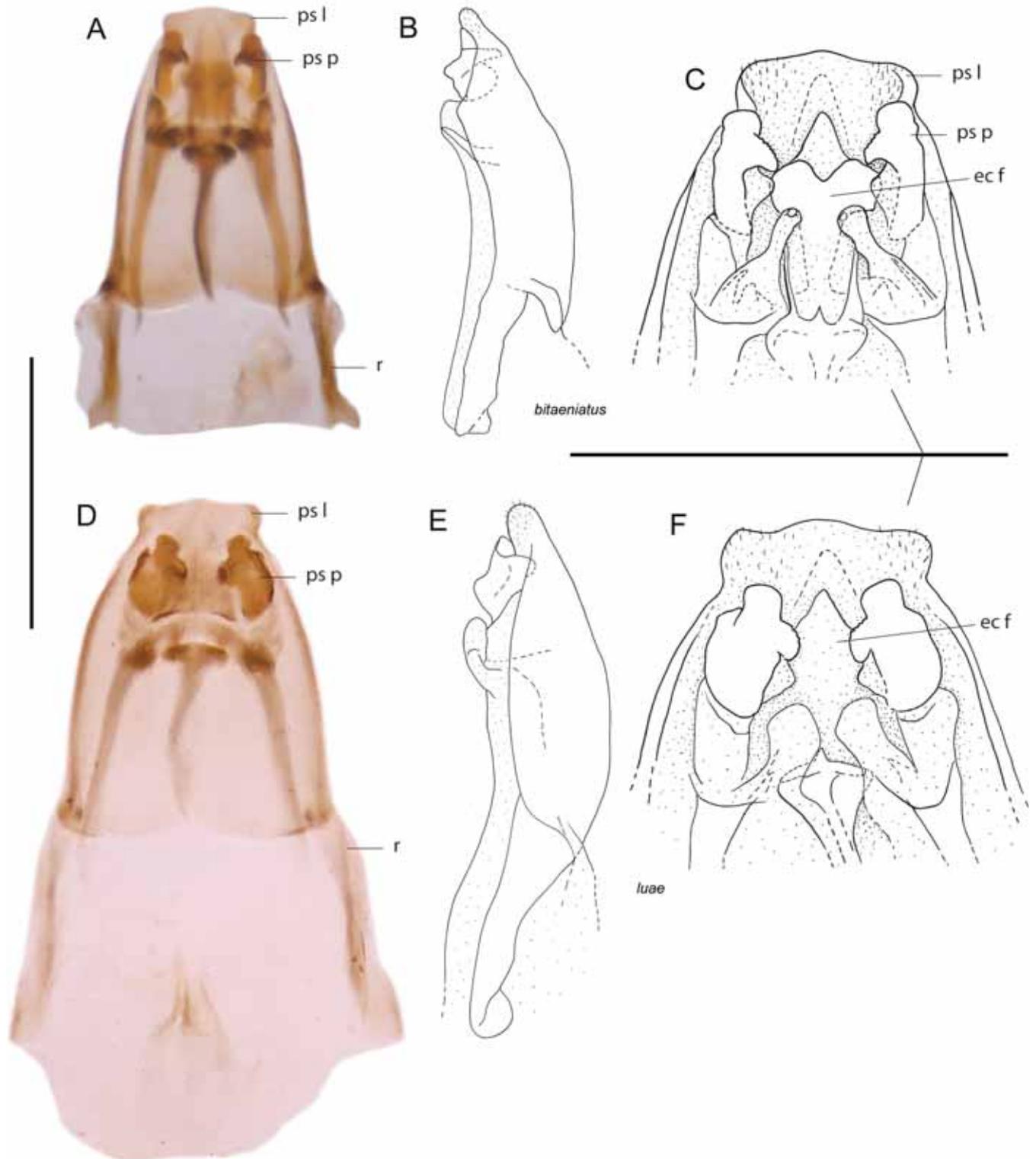


Fig. 14. Male genitalia: A–C, *Lebinthus bitaeniatus*; D–F, *Lebinthus luae*. A, D, dorsal view; B, E, lateral view; C, F, ventral view. Scale bars = 1 mm.

wide longitudinal band including CuA over its whole length, external margin of harp, MP, CuA/MP area, most MA/MP area, and small median fold; lateral field brown, without a black line underlying the yellow longitudinal band. FW venation (Fig. 13C): 1A angle wide ( $>100^\circ$ ); stridulatory file with 117–133 teeth ( $m = 126$ ,  $n = 4$ ), located on transverse and longitudinal parts of 1A. CuP absent. Area posterior to plectrum strongly sclerotised. Harp wide, with a longitudinal fold near angle of 1A (claval fold?); with 1 harp vein, strong and sometimes bifurcated at distal end. Distal part

of CuA straight. Mirror (d1) not differentiated, resembling the other few cells of D alignment. Apical field absent, with no bifurcation of CuA posterior to diagonal vein. Lateral field dark brown to brown, with 5 strong longitudinal veins including MA, R and 3 more ventral veins; latero-dorsal angle made by MP; R without strong bifurcating veins. Subgenital plate elongate, clog-shaped.

Male genitalia (Fig. 14D–F): Pseudepiphallic sclerite trapezoidal, shorter and wider than in *L. bitaeniatus*, convex dorsally, its apex slightly trilobate, including a short median



Fig. 15. *Lebinthus bitaeniatus* (A–C), in Mount Makiling (Luzon, Philippines) on campus near UPLB MNH: A, female on plant at night; B, male courting a female during afternoon on leaf litter; C, view of secondary habitat. *Lebinthus luae* (D, E), in Labrador Park, Singapore: D, male and female mating on branch ( $h = 30$  cm) in the afternoon; E, male and juvenile foraging on fallen fruit.

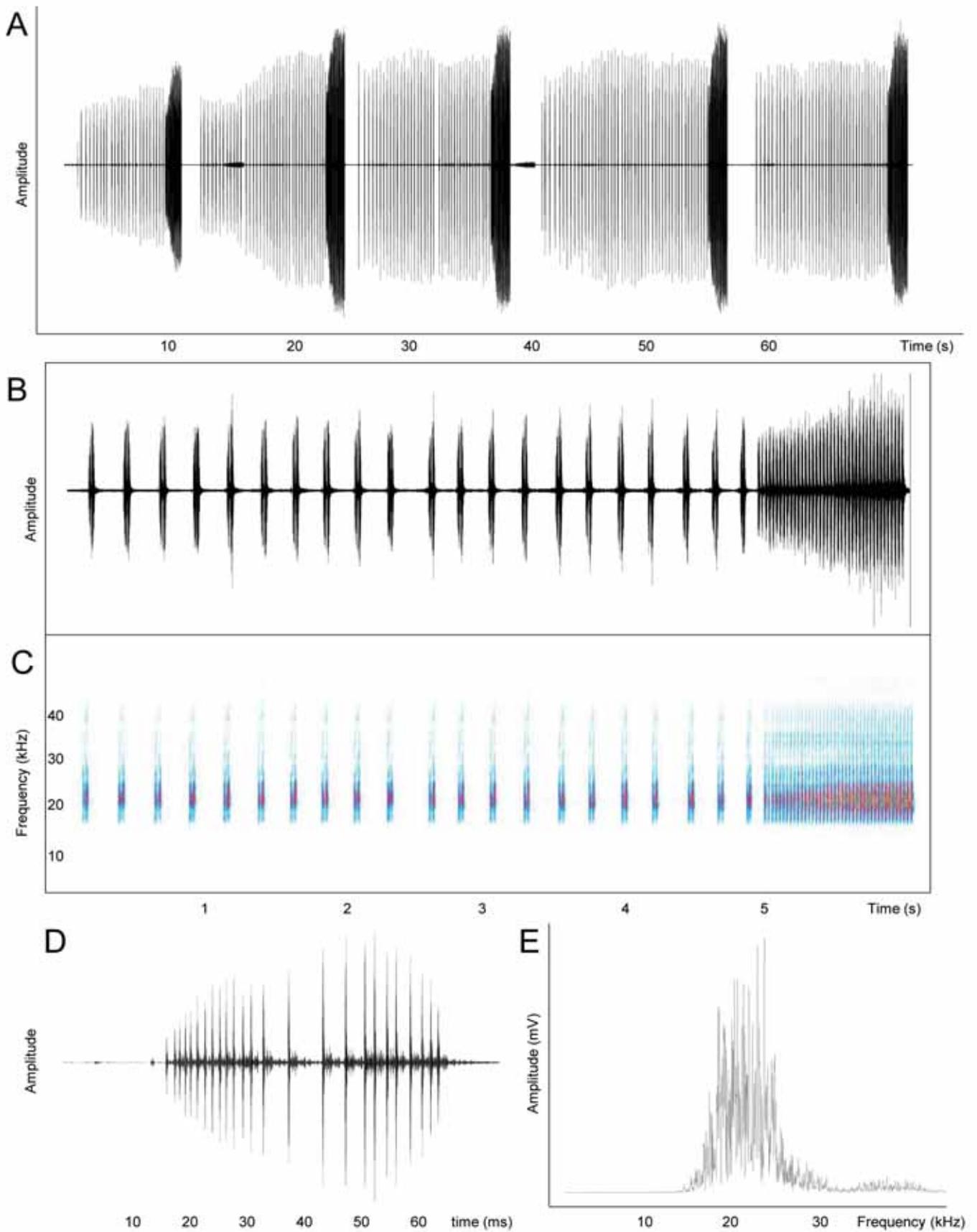


Fig. 16. Calling song of *Lebinthus bitaeniatus*. Oscillogram of 5 echemes (A); oscillogram (B) and sonogram (C) of 1 echeme; oscillogram (D) and linear power spectrum (E) of 1 syllable in the starting part of the echeme.

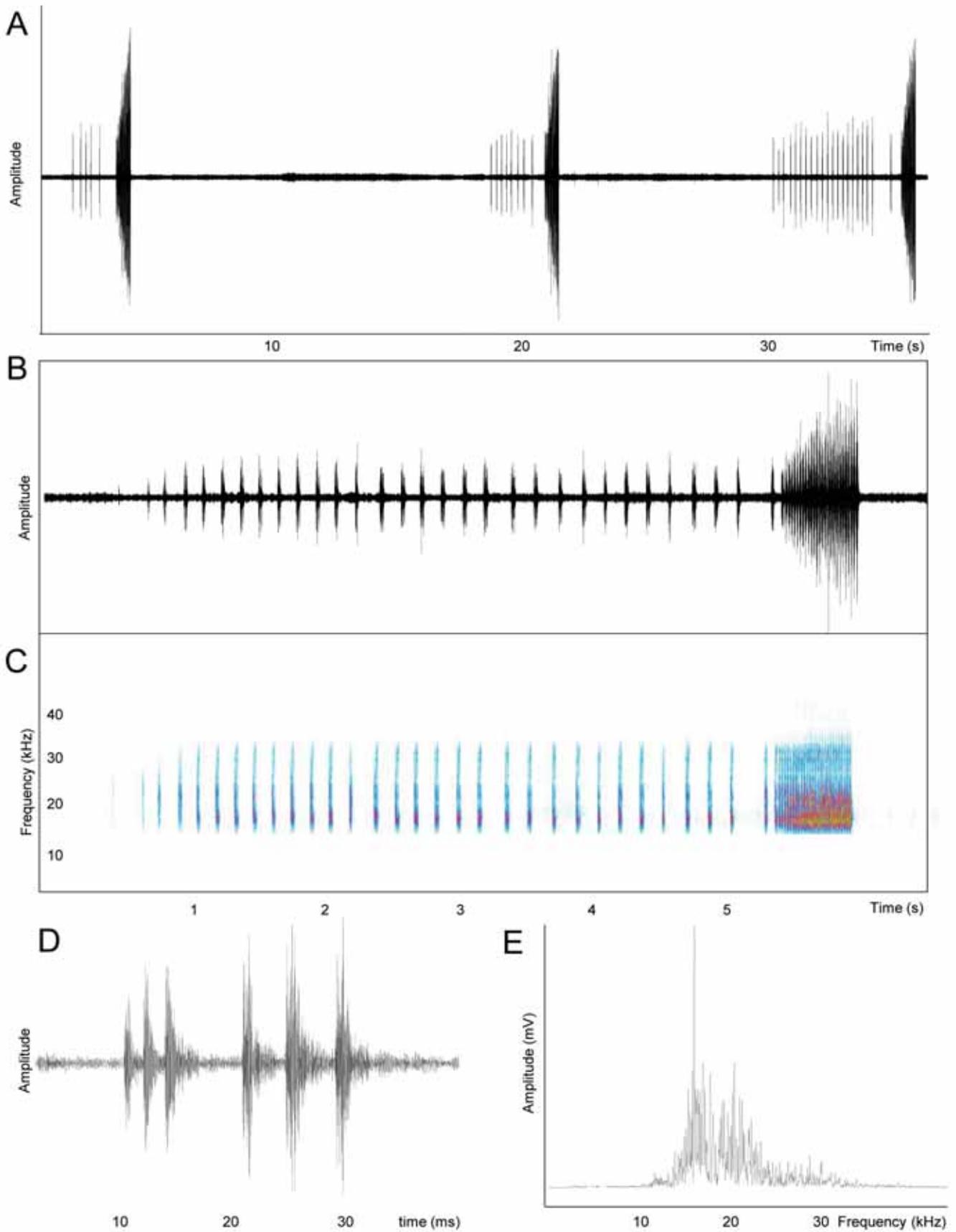


Fig. 17. Calling song of *Lebinthus luae*. Oscillogram of 3 echemes (A); oscillogram (B) and sonogram (C) of 1 echeme; oscillogram (D) and linear power spectrum (E) of 1 syllable in the starting part of the echeme.

Table 4. Measurements of *Lebinthus luae*.

	PronL	PronW	FWL	FWW	HWT	FIIL	FIHW	TIIL
Male holotype	2.9	3.9	4.2	3	–	12.2	3.9	10.5
Males (n = 4)	2.4–3.0	3.5–3.9	4.1–4.9	2.6–3	–	12.0–12.6	3.5–3.9	10.2–11.0
(mean)	(2.8)	(3.8)	(4.6)	(2.9)	–	(12.3)	(3.6)	(10.6)
Female allotype	3.2	4.6	3.5	2.3	–	15.7	4	13.2
Females (n = 3)	2.8–3.2	4.1–4.6	3.5–3.9	2.3–2.5	–	13.0–15.7	3.8–4.9	11.9–13.2
(mean)	(3)	(4.4)	(3.9)	(2.3)	–	(14.7)	(4.2)	(12.8)
	TIILs				TaIII	ST (n=2)		OL (n=5)
	Ias	Ibs	Oas	Obs		Tt	Lt	
Male holotype	9	5	13	7	2	?	?	–
Males (n = 4)	9–11	4–5	12–15	5–7	2–3	98–108	19–25	–
(mean)	(9.8)	(4)	(13.5)	(6)	(2.6)	(105)	(21)	–
Female allotype	9	5	15	7	–	–	–	15.3
Females (n = 3)	7–11	4–5	14–17	6–7	3–4	–	–	11.6–15.3
(mean)	(9)	(4.3)	(15)	(6)	(3)	–	–	(13.1)

expansion and 2 lophi barely individualised, slightly divergent and finely setose. Anterior margin bisinuated, with a median indentation. Rami as long as 2/3 pseudepiphallic sclerite, proportionally longer than in *L. bitaeniatus*. Pseudepiphallic parameres with a wide sclerotised basis, trilobate, including a postero-dorsal lobe and 2 ventral lobes, the anterior one rounded and curved anteriorly. Ectophallic arc complete and wide. Ectophallic fold triangular and membranous. Ectophallic apodemes rather wide, long and parallel, exceeding anterior margin of pseudepiphallus, their bases with a pair of ventral membranous expansions. Endophallic sclerite long, exceeding anterior margin of pseudepiphallus, convex dorsally, its posterior apex with a small median triangular expansion and with short thick lateral arms; endophallic apodeme made of a narrow median crest.

Female: FWs short (Fig. 13D), slightly longer than pronotum, slightly overlapping basally; dorsal field grey brown, with 6 (n = 3) strong orange brown to brown longitudinal veins, less straight than in *L. bitaeniatus*, sometimes bifurcated; with weak transverse veins. Lateral edge of dorsal field with a wide yellow area including a faint longitudinal vein; first (external) strong longitudinal vein yellow basally. Lateral field with 4–5 (n = 4) strong straight longitudinal veins.

Female genitalia: Ovipositor shorter than hind femora; apex lanceolate, denticulate on dorsal edge (Fig. 7C). Copulatory papilla (Fig. 7F) conical, with a narrow basal sclerotised area on ventral face; apex rounded, sclerotised on dorsal face only.

Juvenile: Similar to adults in colouration, mostly dark brown.

Life history traits: *L. luae* is a diurnal species living in more or less forested secondary habitats. Males sing from low plants above the leaf litter from early morning to dusk. Mating couples are generally observed on plant leaves or on top of the litter (Fig. 15D, E).

Behaviour. Calling song (Fig. 17): In the field (n = 4; t°C = 27–30°C) the calling song of *L. luae* n. sp. lasts for 3.3 ± 1.2 s (echeme period = 30.1 ± 16.5 s) and is made of

very indented syllables (amplitude modulation resulting in pauses within the syllable). As in *L. bitaeniatus*, this call is organised in two parts, the initial one consisting of 11 ± 5 well-spaced syllables (longer duration = 28.1 ± 9.8 ms; longer period = 219.9 ± 127.7 ms), the second part being a short trill made of 24 ± 3 syllables set closer together (shorter duration = 13.3 ± 2.2 ms; shorter period = 21.6 ± 3.7 ms). Each syllable is made of discrete pulses, produced by regular plectrum pauses, which in turn are caused by a discontinuous closing phase. Such a pattern produces a broad band spectrum between 12 and 30 kHz, with main energy centred at nearly 16.7 ± 1.3 kHz, which corresponds to the first and only peak of the spectrum.

Measurements: See Table 4.

**Etymology.** — This species is dedicated to H. K. Lua (ZRC curator).

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#### LITERATURE CITED

- Bolivar, I., 1889. Enumeracion de Grilidos de Filipinas. *Anales de la Sociedad espanola de Historia natural*, **18**: 415–431.
- Brunner von Wattenwyl, C. (ed.), 1898. *Orthopteren des Malayischen Archipels, gesammelt von Prof. Kükenthal in den Jahren 1893 und 1894. (Vol. 24)*. Frankfurt: In commission bei Moritz Diesterweg.
- Chopard, L., 1925. Results of Dr. E. Mjöberg's swedish scientific expeditions to Australia 1910–1913. 46. Gryllidae. *Arkiv för Zoologi*, **18**: 1–57.
- Chopard, L., 1931. On *Gryllidae* from the Malay Peninsula. *Bulletin of the Raffles Museum*, **6**: 124–149.
- Chopard, L., 1940. Results of the Oxford University expedition to Sarawak (Borneo), 1932. Gryllacrididae and Gryllidae (Orthoptera). *The Entomologist's Monthly Magazine*, **76**: 184–204.
- Chopard, L., 1951. A revision of the Australian Grylloidea. *Records of the South Australian Museum*, **9**: 397–533.
- Chopard, L., 1968. Family Gryllidae: Subfamilies Mogoplistinae, Myrecophilinae, Scleropterinae, Cachoplistinae, Pteroplistinae, Pentacentrinae, Phalangopsinae, Trigoniidiinae, Eneopterinae; Family Oecanthidae, Gryllotalpidae. In: Beier, M. (ed.), *Orthopterorum Catalogus. Volume 12*. Uitgeverij Dr. W. Junk N. V.'s, Gravenhage. Pp. 215–500.
- De Haan, W., 1842. Bijdragen tot de Kennis de Orthoptera. In: Temminck, K. J. (ed.), *Verhandlingen over de Natuurlike Geschiedenis der Nederlandsche Overzeesche Bezittingers*. Natuurkundige Commissie in Indie, Leiden. Pp. 95–138.
- Desutter, L., 1987. Structure et évolution du complexe phallique des Gryllidae (Orthoptera) et classification des genres néotropicaux de Grylloidea. 1ère partie. *Annales de la Société Entomologique de France (N.S.)*, **23**: 213–239.
- Desutter-Grandcolas, L., 1990. Etude Phylogénétique, biogéographique et écologique des grylloidea néotropicaux (Insectes, Orthoptères). PhD thesis. Université Paris XI–Orsay, Orsay. 347 pp.
- Desutter-Grandcolas, L., 1998. Broad-frequency modulation in cricket (Orthoptera, Grylloidea) calling songs: Two convergent cases and a functional hypothesis. *The Canadian Journal of Zoology*, **76**: 2148–2163.
- Desutter-Grandcolas, L., 2003. Phylogeny and the evolution of acoustic communication in extant Ensifera (Insecta, Orthoptera). *Zoologica Scripta*, **32**: 525–561.
- Desutter-Grandcolas, L., E. Blanchet, T. Robillard, C. Magal, F. Vannier & O. Dangles, 2010. Evolution of the cercal sensory system in a tropical cricket clade (Orthoptera: Grylloidea: Eneopterinae): A phylogenetic approach. *Biological Journal of the Linnean Society*, **99**: 614–631.
- Eades, D. C., D. Otte, M. M. Cigliano & H. Braun, 2012. *Orthoptera Species File Online. Version 2.0/4.1*. <http://Orthoptera.SpeciesFile.org>. (Accessed 1 Apr.2012).
- Gorochoy, A. V., 2009. A review of the genus *Paranisitra* Chopard (Orthoptera: Gryllidae: Eneopterinae). *Proceedings of the Zoological Institute RAS*, **313**: 435–439.
- Kirby, W. F., 1906. *A Synonymic Catalogue of Orthoptera. Vol. 2*. The trustees of the British Museum, London.
- Nattier, R., T. Robillard, L. Desutter-Grandcolas, A. Couloux & P. Grandcolas, 2011. Older than New Caledonia emergence? A molecular phylogenetic study of the eneopterine crickets (Orthoptera: Grylloidea). *Journal of Biogeography*, **38**: 2195–2209.
- Oshiro, Y., 1996. Description of a new species of the genus *Lebinthus* Stal (Orthoptera, Gryllidae) from Lan Yu Island, Taiwan. *Japanese Journal of systematic Entomology*, **2**: 117–121.
- Otte, D., 1994. Orthoptera species file. 1. Crickets (Grylloidea). Orthopterists's Society and the ANSP, Philadelphia, PA.
- Preston-Mafham, K., 2000. Diurnal mating behaviour of a *Nisitrus* sp cricket (Orthoptera : Gryllidae) from Sumatra. *Journal of Natural History*, **34**: 2241–2250.
- Ragge, D. R., & W. J. Reynolds, 1998. *The Songs of the Grasshoppers and Crickets of Western Europe*. Harley Books, Colchester, England.
- Rehn, J. A. G., 1909. A contribution to the knowledge of the Orthoptera of Sumatra. *Bulletin of the American Museum of Natural History*, **26**: 191–211.
- Robillard, T., 2004. *Phylogénie et évolution de la communication acoustique chez les grillons Eneopterinae (Orthoptera, Grylloidea, Eneopteridae)*. PhD thesis. Université Paris VI, UPMC, Paris.
- Robillard, T., 2009. Eneopterinae crickets (Insecta, Orthoptera, Grylloidea) from Vanuatu. *Zoosystema*, **31**: 577–618.
- Robillard, T., 2010. New species of the genus *Lebinthus* (Orthoptera, Grylloidea, Eneopterinae, Lebinthini) from Indonesia and the Solomon Islands. *Zootaxa*, **2386**: 25–48.
- Robillard, T., 2011. New *Cardiodactylus* species from unsuspected places in Southeast Asia (Orthoptera, Grylloidea, Eneopterinae). *Zootaxa*, **2909**: 14–26.
- Robillard, T. & L. Desutter-Grandcolas, 2004a. Phylogeny and the modalities of acoustic diversification in extant Eneopterinae (Insecta, Orthoptera, Grylloidea, Eneopteridae). *Cladistics*, **20**: 271–293.
- Robillard, T. & L. Desutter-Grandcolas, 2004b. High-frequency calling in Eneopterinae crickets (Orthoptera, Grylloidea, Eneopteridae): An adaptive radiation revealed by phylogenetic analysis. *Biological Journal of the Linnean Society*, **83**: 577–584.
- Robillard, T. & L. Desutter-Grandcolas, 2004c. Acoustic evolution in crickets: need for phylogenetic study and a reappraisal of signal effectiveness. *Anais da Academia Brasileira de Ciências*, **76**: 301–315.
- Robillard, T. & L. Desutter-Grandcolas, 2006. Phylogeny of the cricket subfamily Eneopterinae (Insecta, Orthoptera, Grylloidea, Eneopteridae) based on four molecular loci and morphology. *Molecular Phylogenetics and Evolution* **40**: 643–661.
- Robillard, T. & L. Desutter-Grandcolas, 2008. Clarification of the taxonomy of extant crickets of the subfamily Eneopterinae (Orthoptera: Grylloidea; Gryllidae). *Zootaxa*, **1789**: 66–68.

- Robillard, T. & L. Desutter-Grandcolas, 2011. Evolution of calling songs as multicomponent signals in crickets (Orthoptera: Grylloidea: Eneopterinae). *Behaviour*, **148**: 627–672.
- Robillard, T., P. Grandcolas & L. Desutter-Grandcolas, 2007. A shift toward harmonics for high-frequency calling shown with phylogenetic study of frequency spectra in Eneopterinae crickets (Orthoptera, Grylloidea, Eneopteridae). *Canadian Journal of Zoology*, **85**: 1264–1275.
- Robillard, T., F. Montealegre-Z., L. Desutter-Grandcolas, P. Grandcolas & D. Robert, 2013. Mechanisms of high frequency song generation in brachypterous crickets and the role of ghost frequencies. *Journal of Experimental Biology*, **216**: 2001–2011.
- Saussure, H. D., 1878. Melanges Orthopterologiques. VI. Fascicule Gryllides. *Mémoires de la Société de Physique et d'Histoire Naturelle de Genève*, **25**: 369–704.
- Specht, R., 2008. *Avisoft-SASLab Pro: Sound Analysis and Synthesis Laboratory*. Avisoft Bioacoustics, Berlin.
- Stål, C., 1877. Orthoptera nova ex Insulis Philippinis. *Oefv. k. svenska Vet.-Akad. Förh.*, **34**: 33–58.
- Tan, M. K., 2010. Orthoptera in Pulau Ubin. *Nature in Singapore*, **3**: 245–268.
- Tan, M. K., 2012. *Orthoptera in the Bukit Timah and Central Catchment Nature Reserves (Part 2): Suborder Ensifera*. Raffles Museum of Biodiversity Research, National University Singapore, Singapore. 70 pp. Uploaded 14 Nov.2012.
- Tan, M. K., R. W. J. Ngiam & M. R. B. Ismail, 2012. A checklist of Orthoptera in Singapore parks. *Nature in Singapore*, **5**: 61–67.
- Tan, M. K. & L. K. Wang, 2012. The Orthoptera of Semakau Landfill, Singapore: A Project Semakau checklist. *Nature in Singapore*, **5**: 309–318.
- Walker, F., 1869. *Catalogue of the specimens of Dermaptera Saltatoria, and supplement to the Blattariae, in the collections of the British Museum*. British Museum (Natural History), Londres.