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## Taxonomy and bioacoustics of Meconematinae (Orthoptera: Tettigoniidae) from Laguna (Philippines: Luzon)

Short title: Meconematinae from Laguna

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### Abstract

Katydid from the subfamily Meconematinae sing at ultrasonic frequencies. Owing that many of them are nocturnal, elusive and low in abundance (since they are predatory), there is a dearth of information on these katydids and their bioacoustics, especially for species in the understudied yet mega-diverse Southeast Asia. Recent orthopteran surveys in Laguna, Luzon Island in the Philippines led to the discovery of two interesting Meconematinae katydids. Based on the collection, we describe a new species of Phisidini: *Neophisis (Indophisis) montealegrei* **sp. nov.** We also describe the male for the first time and redescribe the female of *Asiophlugis philippina*. The ultrasonic calling songs of both Meconematinae are also recorded, analysed and described here.

**Key words:** *Asiophlugis*, new species, Phisidini, Southeast Asia, stridulation, ultrasonic frequencies

### Introduction

Meconematinae is a non-monophyletic group of katydids (Orthoptera: Tettigoniidae) comprising of the three tribes: Meconematini, Phisidini and Phlugidini (Mugleston *et al.*, 2018). These katydids are typically predatory and possess large spines on their legs, capable of leaping onto small insects and capturing them using the predatory legs while in flight (Rentz, 2001). Worldwide, Meconematinae is very diverse, including in Asia where many new species are still being discovered (e.g., Rentz, 2001; Gorochoy 2016; 2019; Tan *et al.*, 2017; Tan & Wahab, 2018; Cui *et al.*, 2019; Wang *et al.*, 2019a, b).

Phisidini and Phlugidini are particularly peculiar in shape and form. Phisidini are characterised by very long and movable spurs on the forelegs. Asiatic Phisidini has been heavily revised by Jin (1992). She described fourteen genera and 96 species, of which eight genera and 59 species are new to science. She also detailed the distribution and hypothesised the evolution of Phisidini in Asia. Since then, new taxa were added, including new subgenera such as *Anaphisis* Gorochoy, 2019, *Platyphisis* Gorochoy, 2019 (see Gorochoy, 2019). Owing that many species are restricted in distribution or can occur in sympatry (Jin, 1992), we can expect that many more species are still awaiting discovery. Likewise, Phlugidini are characterised by exceptionally large eye. Asiatic Phlugidini consists of the following genera—*Asiophlugis* Gorochoy, 1998; *Papuaphlugis* Gorochoy, 2012; and *Stenophlugis* Gorochoy, 2012—and are generally less well studied than their relatives from the New World (Tan *et al.*, 2019). For example, some species previously described under the genus *Phlugis* (considered a genus endemic to New World sensu Gorochoy [1998]) was transferred to *Asiophlugis* without verification (e.g., Gorochoy & Tan, 2011). This includes *Asiophlugis (?) philippina* (Jin, 1993) in which only the female was known and there was no way to verify the male diagnostic characters.

These further highlights that the taxonomy of Phisidini and Phlugidini still warrant large amount of work and attention.

Furthermore, very little is known about the biology of these katydids in Asia. Knowledge on the bioacoustics of Asiatic Meconematinae is also underwhelming, even though it can be a useful tool in understanding species boundaries and ecology. This can be attributed to various reasons: (1) Meconematinae are nocturnal, shy and sing at ultrasonic frequencies, making them elusive to researchers; and (2) insufficient thorough sampling and taxonomic experts on Southeast Asian Meconematinae. Tan *et al.* (2019) recently reported the calling songs of six *Asiophlugis* species from Malay Peninsula and Borneo. Wang *et al.* (2019) also examined the calling songs of *Sinocyrtaspis* Liu, 2000 from China and we are not aware of other similar studies on Asiatic species. Rentz (2001) also reported Australian Phlugidini (e.g., *Austrophlugis* Rentz, 2001, *Indiamba* Rentz, 2001) sing at ultrasonic frequencies, both throughout the day and during night time, and males aggregate to sing and attract females from nearby plants. Here, the stridulatory files of numerous Phlugidini were also presented, which are not dissimilar to that of the species from Southeast Asia (*sensu* Tan *et al.*, 2019). However, considering the high diversity of Meconematinae in this region, a large knowledge gap on their bioacoustics still exists.

To address this knowledge gap on the bioacoustics of Asiatic ultrasonic-singing katydids, new materials need to be collected and songs be recorded using ultrasound-sensitive recorders. Based on recent sampling in Laguna, Luzon Island in the Philippines (Southeast Asia), we ‘rediscovered’ *Asiophlugis philippina*—previously described from an old museum female specimen—and describe the males for the first time. In the same forest, we also discovered a species of *Neophisis* new to science: *Neophisis (Indophisis) montealegrei* **sp. nov.** The calling songs of both Meconematinae are also described for the first time.

## Materials and methods

### *Specimen Collection and Curation*

Day and night surveys involving opportunistic collections were conducted by M.K. Tan, J.B. Baroga-Barbecho, and S.A. Yap in the lowland mixed dipterocarp and secondary growth forests of the University of the Philippines (UP) Laguna Land Grant (Luzon, Laguna, Paete, Barangay Ilaya Norte, Fig. 1) from 11 to 13 May 2019 and 6 to 8 September 2019. Habitus images were made with a Canon EOS 500D digital SLR camera with a macro photo lens MP-E 65mm f/2.8 USM (1–5×). Canon Macro Twin Lite MT-24EX was used for lighting and flash.

The specimens were preserved in absolute analytical-grade ethanol and later pinned and dry-preserved. A single hind leg from each specimen was also preserved in absolute analytic-grade ethanol for future molecular work. The left tegmen in males was removed using micro-scissor. The specimens were deposited in the University of the Philippines Los Baños, Museum of Natural History, Philippines (UPLBMNH) and the Zoological Reference Collection (ZRC), Lee Kong Chian Natural History Museum Singapore.

### *Morphology*

Macro-imaging of the morphology was done using Canon EOS 6D digital SLR camera with a macro photo lens MP-E 65mm f/2.8 USM (1–5×). Image editing was accomplished using Adobe Photoshop CC 2014. Measurements of specimen were accomplished using Vernier calipers.

Microscopic-imaging of the stridulatory file was done using Olympus BX53 compound light microscope with Hamamatsu digital CMOS camera C11440 attached. Measurements of stridulatory file were accomplished using ImageJ 1.51j8 (Wayne Rasband, Research Services Branch, National Institute of Mental Health, Bethesda, MD, USA).

### *Bioacoustics*

Acoustic recording and analysis followed that in Tan *et al.* (2019). Calling by male katydids kept in insect cages with nylon netting was recorded using a sampling frequency of 256 kHz-samples/s Echo Meter Touch (based on Knowles FG sensor) placed horizontally and at about 1–4 m away from the cage. Ambient temperature was logged using a HOBO 8K Pendant® Temperature logger (model: UA-001-08, Onset, Bourne, MA) or a temperature-humidity meter (Smartsensor AR867). The recorded signals were saved in 12-bit WAV format. Acoustic analyses were done using the open source R package WarbleR version 1.1.14 (Araya-Salas & Wright, 2017) in the R software version 3.5.1 (R Development Core Team, 2018) and Raven Lite 2.0 (Bioacoustics Research Program, 2016). The 'specan' function was used to obtain peak frequency. Pulse and song durations were measured. The 'spec' function was used at 256,000 sampling frequency to generate power spectra using FFT. All sound files were uploaded to the Orthoptera Species File Online Version 5.0/5.0 (Cigliano *et al.*, 2019).

### **Terminologies**

For the description of songs, terminologies follow that by Tan *et al.* (2019): peak frequency = frequency with highest energy from the mean spectrum; pulse duration = duration of the pulse; pulse repetition rate = number of discrete pulses per second.

For the description of stridulum morphology, terminologies follow that by Béthoux (2012) and Chivers *et al.* (2017): CuPb = posterior branch of posterior cubitus (CuP); h1 = anterior portion of harp area; h2 = median portion of harp area; h3 = posterior part of harp area.

For the description of male genitalia, terminologies follow that by Jin (1992) and the following abbreviations are used: pa = paraproct; d.p = dorsal phallomere; v.p = ventral phallomere; l.p = lateral phallomere; ep = epiphallus.

For the measurements, the following abbreviations are used: BL = body length; HL = head length; HW = head width (including eye); PL = pronotum length; PW = pronotum width; TL = tegmen length; HFL = hind femur length; HTL = hind tibia length; OL = ovipositor length.

## **Results**

### **Tribe Phisidini**

#### ***Neophisis (Indophisis) montealegrei* new species**

(Figs. 2–7)

**Material examined.** Holotype (male, UPLBLG.19.74): **Philippines**, Luzon, Laguna, Paete, Brgy Ilaya Norte, UP Laguna Land Grant, N14.39764, E121.54068, 345.4±6.3 m, 1959 h, 7 September 2019, under foliage, coll. M.K. Tan, J.B. Baroga-Barbecho, and S.A. Yap (UPLBMNH).

Paratypes (2 males and 1 female, **Philippines**, same locality, all coll. M.K. Tan, J.B. Baroga-Barbecho, and S.A. Yap): 1 male (UPLBLG.19.58), N14.39858, E121.54280, 349.1±5.6 m, 2043 h, 6 September 2019, on rattan; 1 male (UPLBLG.19.67), N14.39848, E121.54047, 334.5±5.5 m, 1916 h, 7 September 2019, under foliage of tree; 1 female (UPLBLG.19.75), N14.39672, E121.54018, 355.1±6.6 m, 2030 h, 7 September 2019, under rattan leaf.

**Diagnosis.** The new species differs from all known *Neophisis (Indophisis)* congeners by the following combination of characters: male phallus with ventral phallomere with spatulate apex; cephalic lobe of epiphallus oblong, tapered into an obtuse narrow apical third, lateral margins after middle crenulate; cercus small and stout, with a small stout basal nodule at the inner surface and apical third somewhat cylindrical; posterior margin of male tenth abdominal apex with broad lateral lobe with truncated apex, and small stout nodule produced ventral of this lobe; short tegmenal length and shape of mirror.

**Comparison with congeners.** The new species is similar to Philippine species *Neophisis (Indophisis) philippinarum* (Karny, 1920) from Laguna, Luzon Island, *Neophisis (Indophisis) curvata*

Jin, 1992 from Davao, Mindanao Island; and *Neophisis (Indophisis) gracilipennis* Jin, 1992 from Laguna, Luzon Island.

It is most similar to *N. (I.) curvata* by shape of sclerotized epiphallus, male subgenital plate, mirror with dark, ring-like mark; but differs by ventral phallomere with spatulate apex (instead of bifurcated); male tenth abdominal tergite without distally-directed lateral projections along posterior margin not hook-like; male cercus with small basal inner lobes (instead of broad); and wings not surpassing well beyond hind femur, mirror of male left tegmen distinctly wider than long (instead of longer than wide); female subgenital plate transverse with longitudinal ridge in the middle, posterior margin broader than anterior margin (instead of fairly narrow); female ovipositor more strongly curved with serrated margins.

It also differs from *N. (I.) gracilipennis* by mirror with dark, ring-like mark, shape of female subgenital plate; but differs by shape of sclerotized epiphallus not rod-like (although both have denticulated margins); ventral phallomere not bifurcated; male tenth abdominal tergite without posterior margin tapering into a truncated (slightly emarginated) apex (instead of a large right-angular incision); female ovipositor more strongly curved with serrated margins

The new species also differ from the possibly sympatric short-winged *N. (I.) philippinarum* by sclerotized epiphallus not dentate ventrally, ventral phallomere not bifurcated; male cercus not strongly curved upward; presence of mirror with dark, ring-like mark. The female of the new species also differs from that of short-winged *Neophisis (Indophisis) philorites* Jin, 1992 from Mindanao (only female adult known) by female subgenital plate with posterior margin having a lobe in the middle.

**Distribution.** UP Land Grant, Laguna on Luzon Island.

**Description.** Habitus typical of *Neophisis (Indophisis)* (Fig. 2). Eye almost globular, slightly longitudinally elongate (when viewed laterally). Vertex conical, apex obtuse. Antennal cavity nearly contacting with each other. Antennal scapus elongated, wider than vertex, longer than length of eye and nearly as long as head; pedicel shorter, slightly less than half the length of scapus. Face high, hardly concave in profile. Maxillary palps slender and elongated, apical segment with apical part club-shaped. Pronotum dorsal disc rectangular, fairly broad, ca. 1.2 times longer than wide; with metazona barely elevated, having posterior margin straight and elevated. Pronotum lateral lobe distinctly longer than tall. Thoracic auditory foramen tiny; thoracic spiracle elongated and oval, not covered by pronotum. Outer and inner tympana on fore tibia conchate with orifices oval and equal in size. Fore coxa without distinct spines. Fore femur with 4 and 5 long spurs on the inner and outer edges respectively; fore tibia with 7 and 7 long and thin spurs on the inner and outer edges respectively; middle femur with 0 and 5 spurs on the inner and outer edges respectively; middle tibia with 5–6 and 7 thin spurs on the inner and outer edges respectively. Spurs on forelegs longer than those on middle legs; spur on both fore and middle legs with acute apex. Hind femur with 9 short outer ventral spines; no inner ventral spine. Knees on all legs with genicular lobes spinose.

**Male.** Tegmen reduced, reaching to posterior end of third abdominal tergite; apex obtuse. CuPb with stridulatory file transverse, crescent shaped. Stridulatory file straight at anal end, feebly curved in the middle and strongly curved anteriorly at basal end; 1.5–1.8 mm long. Harp area 1 (h1) narrow in basal half, widening posteriorly; in apical half with margins parallel. Harp area 2 and 3 (h2, h3) transverse, widened at both ends, narrow in the middle. Mirror fully developed, rectangular, 1.2–1.3 times wider than long.

Tenth abdominal tergite enlarged, with posterior end projected and concealing epiproct; posterior end tapering into a truncated (slightly emarginated) apex; posterior margin with broad lateral lobe (pll) with truncated apex, and small stout nodule produced ventral of this lobe (Figs. 4A–C). Paraproct with a stout nodule produced apically (Figs. 4B–D). Cercus small and stout, with a small stout basal nodule (bn) at the inner surface; base widened, then flattened and bent (nearly 90°) dorsally (in lateral view) and inwardly (in dorsal view); apical third somewhat cylindrical, enlarging apically (in dorsal view); apex obtuse (Figs. 4A–D). Subgenital plate wide, forming two large obtuse lobes at the apex, triangularly and deeply emarginated between the lobes; each lobe projected outward into a stout process at which stylus inserts (Figs. 4B, 4E). Stylus short, but longer than apical process of subgenital plate; cylindrical and gently taper into subacute apex (Figs. 4B, 4E).

Phallic complex with moderate-sized lateral phallomeres, apical third pointing dorsal; short dorsal phallomere, with mix of long, short, more sclerotized denticles and chitinous plate forming an acute

apex; ventral phallomere with spatulate apex (Figs. 4A, 4B). Cephalic lobe of epiphallus oblong, tapered into an obtuse narrow apical third, lateral margins after middle crenulate (Figs. 4C, 4D).

**Female.** Epiproct with basal half transverse, swollen laterally and furrowed in the middle; apical half rounded with obtuse apex (Fig. 5A). Paraproct concealed under epiproct, rounded (Fig. 5A). Cercus simple, swollen in the middle before tapering gently into obtuse apex (Fig. 5A). Subgenital plate transverse with longitudinal ridge in the middle, posterior margin broader than anterior margin, concave and emarginated in the middle (Fig. 5B). Ovipositor upwardly curved with finely serrated dorsal and ventral margins at apical third (Fig. 5C).

**Colouration.** Pale green when alive, yellow when preserved in ethanol. Eye dark red. Head, including vertex (slightly darker green), face, maxillary palps, antennal scapus, genae pale green; pedicel and antennal segments slightly yellowish. Pronotum dorsal disk pale green, with green elongated spot in the middle, one near the anterior and posterior margins each; lateral lobe also pale green, with a darker green spot near ventral margin. Male tegmen yellow green; mirror with frame reddish brown, mirror area with dark ring-like markings. Legs all pale green; spurs whitish with black apices; tympana with basal half of conchate covering black. Abdomen green; sternites white, tergites with apical area darker green. Female ovipositor generally pale green, with only apex and the dorsal and ventral margins brown.

**Measurements** (mean in brackets; in mm). Males (n = 3): BL = 11.8–13.5 (12.9), HL = 1.6–1.7 (1.6), HW = 2.4–2.7 (2.5), PL = 3.1–3.4 (3.3), PW = 2.6–2.8 (2.7), TL = 4.0–4.5 (4.3), HFL = 15.3–16.5 (15.8), HTL = 18.3–19.5 (18.7); female (n = 1): BL = 12.2, HL = 1.6, HW = 2.4, PL = 3.1, PW = 2.3, TL = 3.4, HFL = 16.2, HTL = 18.8, OL = 7.4.

**Bioacoustics.** At  $30.2 \pm 0.1$  °C (29.9–30.5 °C), the male calling song consists of two pulses with song duration  $0.10 \pm 0.01$  s (0.09–0.12 s) (Figs. 7B, 7C). The first pulse peaks at  $0.022 \pm 0.002$  s (0.016–0.027 s) after start of song; the second pulse peaks at  $0.042 \pm 0.002$  s (0.039–0.048 s); and the peaks of both pulses are  $0.020 \pm 0.002$  s (0.015–0.025 s) apart (Figs. 7B, 7C). Mean peak frequency is  $43.3 \pm 2.5$  (36.3–45.3 kHz) (Fig. 7D).

**Etymology.** This species is named after a renowned Orthopterist, Fernando Montealegre-Zapata, who has made immense contribution to the bioacoustics of katydids.

## Tribe Phlugidini

### *Asiophlugis philippina* (Jin, 1993) (Figs. 8–12)

*Phlugis philippina*—Jin, 1993: 1599; *Asiophlugis philippina*—Gorochov and Tan, 2011: 129.

**Material examined.** 4 males and 2 females, **Philippines**, Luzon, Laguna, Paete, Brgy Ilaya Norte, UP Laguna Land Grant, all coll. M.K. Tan, J.B. Baroga-Barbecho, and S.A. Yap: 2 males (UPLBLG.19.4, 5), N14.40063, E121.54218, 312.3±6.0 m, 2011 h, 11 May 2019; 1 female (UPLBLG.19.10), N14.40081, E121.54195, 324.4±6.8 m, 0905 h, 12 May 2019; 1 male (UPLBLG.19.35), N14.40032, E121.54284, 342.9±6.1 m, 1954 h, 12 May 2019; 1 male (UPLBLG.19.39), N14.39944, E121.54413, 336.2±6.5 m, 2041 h, 12 May 2019; 1 female (UPLBLG.19.66), N14.39983, E121.54133, 320.5±5.1 m, 1835 h, 7 September 2019.

**New diagnosis.** This species is particularly unique among Asiatic Phlugidini and differs from congeners by male tegmen tear-shaped, male stridulatory anatomy obsolete, presence of long, finger-like lateral process on male tenth abdominal tergite, male cercus complex, and shape of female subgenital plate.

**Distribution.** UP Land Grant, Laguna on Luzon Island.

**Redescription.** Habitus typical of *Asiophlugis* but with contrasting patterns on body (Figs. 8, 9). Eye very large, almost globular, somewhat longitudinally elongate; antennal cavity nearly contacting with each other; rostral tubercles absent; face high, oblique and hardly concave in profile. Pronotum dorsal disc slender and elongated, with metazona barely elevated, having broadly rounded posterior margin. Pronotum lateral lobe distinctly longer than tall. Thoracic auditory foramen tiny, thoracic spiracle slit. Outer and inner tympana on fore tibia open, oval and large. Fore coxa with very long and

thin spine, slightly curved; fore femur with 3–4 and 1 ventral spines on the inner and outer edges respectively, fore tibia with 5 and 3–4 long and thin ventral spines on the inner and outer edges respectively; middle leg with one tibial spine; hind leg with only moderately numerous small spinules on both dorsal edges of tibia, hind knee lobe blunt.

**First description of male.** Tegmina tear-shaped, not reaching beyond hind margin of first tergite. Venation and stridulatory anatomy obsolete (Fig. 12A). Last abdominal tergite concealed beneath ninth abdominal tergite, apical margin slightly produced in the middle, laterally produced into a pair of long processes; apical lateral process finger-like, long and surpasses epiproct, dorso-ventrally flattened, straight but slightly bent outwards at apical third before tapering into a subobtuse apex (Figs. 10B, 10E). Epiproct simple, broadly rounded with longitudinal furrow (Figs. 10B, 10E). Cercus complicated: with inner basal process (ibp) long and flattened, narrow abruptly in the middle and then strongly curved (nearly perpendicularly) into an obtuse apex; bent dorsad in the middle when viewed laterally; with ventral lobe (vl) in the middle long, curved, flattened, slightly dilated apically and with apex subacute; apex with two lobes; dorso-inner apical lobe (dil) spine-like, slightly sinuous, sclerotized with acute apex, ventro-outer apical lobe (vol) shorter, stout with apex obtuse (Figs. 10A–E). Subgenital plate stout, about as long as broad, with lateral margin faintly converging apically, posterior margin broadly rounded and slightly convex, with lateral lobe barely produced; stylus stout with obtuse apex (Fig. 10F).

**Female (Fig. 11).** Well described in the original description by Jin (1993).

**Colouration.** Green or yellow-green when alive, yellow when preserved in ethanol. Head green, face, gena and mouthparts pale green; apex of palpal segments brownish. Scapus green, pedicel yellow green; antennal segments yellow and black. Eye pale yellow with red longitudinal band that continues towards posterior end of eye. Pronotum green, with yellow brown longitudinal band in the middle of pronotum dorsal disc; posterior margin brown. Fore and middle femora pale green with spurs brownish; knees yellow brown. Fore and middle tibiae also pale green, basally and apically yellow brown; area around tympanum also yellow brown; spurs with tint of brown and black. Hind femur green, apically yellow brown and with a black ring around knee. Hind tibia pale brown, apical end pale, then black. Hind tarsus black. Tegmen transparent, with anal and apical ends brown. Abdominal tergite pale to pale green, with yellow brown dorsal longitudinal band in the middle. With numerous black spots along this longitudinal band that become more defined apically. Lateral process of tenth abdominal tergite pale green, with inner margin yellow brown and apical third black. Epiproct with black spot. Cercus pale green, inner basal process, ventral lobe, dorso-inner apical lobe and ventro-outer apical lobe all black. Stylus mostly black.

**Measurements** (mean in brackets; in mm). Males (n = 4): BL = 11.4–12.6 (11.9), HL = 1.4–1.9 (1.7), HW = 3.0 (3.0), PL = 3.7–4.3 (4.0), PW = 1.9–2.0 (2.0), TL = 2.1–2.6 (2.4), HFL = 12.3–13.1 (12.7), HTL = 13.0–13.6 (13.3); females (n = 2): BL = 13.4–14.8 (14.1), HL = 1.5–1.9 (1.7), HW = 2.8–3.0 (2.9), PL = 3.6–3.8 (3.7), PW = 2.0 (2.0), TL = 2.4 (2.4), HFL = 12.2–12.3 (12.3), HTL = 13.0 (13.0), OL = 5.6 (5.6).

**Bioacoustics.** At  $29.1 \pm 0.4$  °C (28.6–29.9 °C), the calling song is made up of rapid-decay pulses (Fig. 12B). Each rapid-decay pulse is about  $65.7 \pm 9.6$  ms (n = 78 pulses) in duration. Each pulse comprises of multiple impulses, and the first two impulses has the highest amplitude, followed by ca. four impulses with much lower amplitude (Figs. 12B, 12C). The pulse repetition rate and hence down time between consecutive pulses can be highly variable. The mean peak frequency is  $36.2 \pm 3.1$  kHz (25.3–38.3 kHz) (Fig. 12D).

## Discussion

The male songs of both *Neophisis (Indophisis) montealegrei* sp. nov. and *Asiophlugis philippina* are predictably ultrasonic and incorporate a sequence of short impulses or very discrete pulses. Typical of Phisidini and Phlugidini, the generated ultrasonic frequency probably resulted from elastic energy stored when the scraper pauses along the file teeth and becomes deformed, and then released as kinetic energy. This leads to an increased scraper velocity and tooth strike rate, which end in ultrasonic frequency generated beyond what the wing muscle in a sustained closing wing phase alone

can generate (Montealegre-Z *et al.*, 2006; Siarra-S *et al.*, 2014; Chamorro-Rengifo & Braun, 2016; Tan *et al.*, 2019).

The song of *Neophisis (Indophisis) montealegrei* **sp. nov.** represents the first known song for Southeast Asian Phisidini. The song of *Neophisis (Indophisis) montealegrei* **sp. nov.** differs from that of other Phisidini from the neotropics (i.e., *Arachnoscelis* and *Supersonus* species) by lower peak frequencies (songs neotropical species peaks at >100 kHz) (Montealegre-Z *et al.*, 2006; Siarra-S *et al.*, 2014). The time duration of *Neophisis (Indophisis) montealegrei* **sp. nov.** is also more complex, comprising of numerous impulses; whereas that of *Arachnoscelis* and *Supersonus* species typically consist of a few discrete rapid-decaying pulses (Montealegre-Z *et al.*, 2006; Siarra-S *et al.*, 2014). A more meaningful comparison of the call structures in Phisidini can only be possible after songs of more Asiatic Phisidini are known. Likewise, how the songs (e.g., extreme ultrasonic frequencies in *Arachnoscelidina*) evolve and/or how the tegminal biomechanics to produce such songs evolve in Phisidini and Meconematinae warrant further investigations, but still requires a robust sampling of songs and stable phylogeny for these elusive katydids.

The song of *A. philippina* is distinct from that of other congeners measured in Tan *et al.* (2019). The song of *A. philippina* is considerably more complex than most recorded species having made up of numerous impulses. The pulse duration of *A. philippina* of  $65.7 \pm 9.6$  ms is drastically longer than all recorded species of *Asiophlugis*, with *Asiophlugis thaumasia* (Hebard, 1922) having the longest pulse duration among *Asiophlugis* at only around 30 ms (Tan *et al.*, 2019). The peak frequency of  $36.2 \pm 3.1$  kHz is also lower than that of the recorded species of *Asiophlugis* (although the peak frequency of *A. rete* appears to be similar to that of *A. philippina*).

Owing to the profoundly different acoustics and complex male cercus in *A. philippina*, we question whether *A. philippina* may belong to a separate genus. *Asiophlugis philippina* also happens to be the only *Asiophlugis* species known to occur in the biogeographic region of the Philippines archipelago. Nonetheless, this species still bears the diagnostic characters of *Asiophlugis* (sensu Gorochoff, 1998). As of now, we refrain from describing a new genus until the evolutionary phylogeny has been established and sufficient sampling around the region is conducted to better define the species boundary of these katydids.

In conclusions, we attempt to address the dearth of information on the ultrasonic bioacoustics of Asiatic katydids by actively documenting their calling songs. This is particularly critical because many Asiatic Meconematinae may occur only in low abundance and be found only in particular time of the year (pers. obs.). Meconematinae katydids generally survive in captivity when fed with ample food (e.g., fruit flies) and kept under high humidity; and sing when left undisturbed (pers. obs.). These data may eventually be useful for soundscape or acoustic ecology or conservation of these katydids threatened by anthropogenic activities.

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### Figure captions

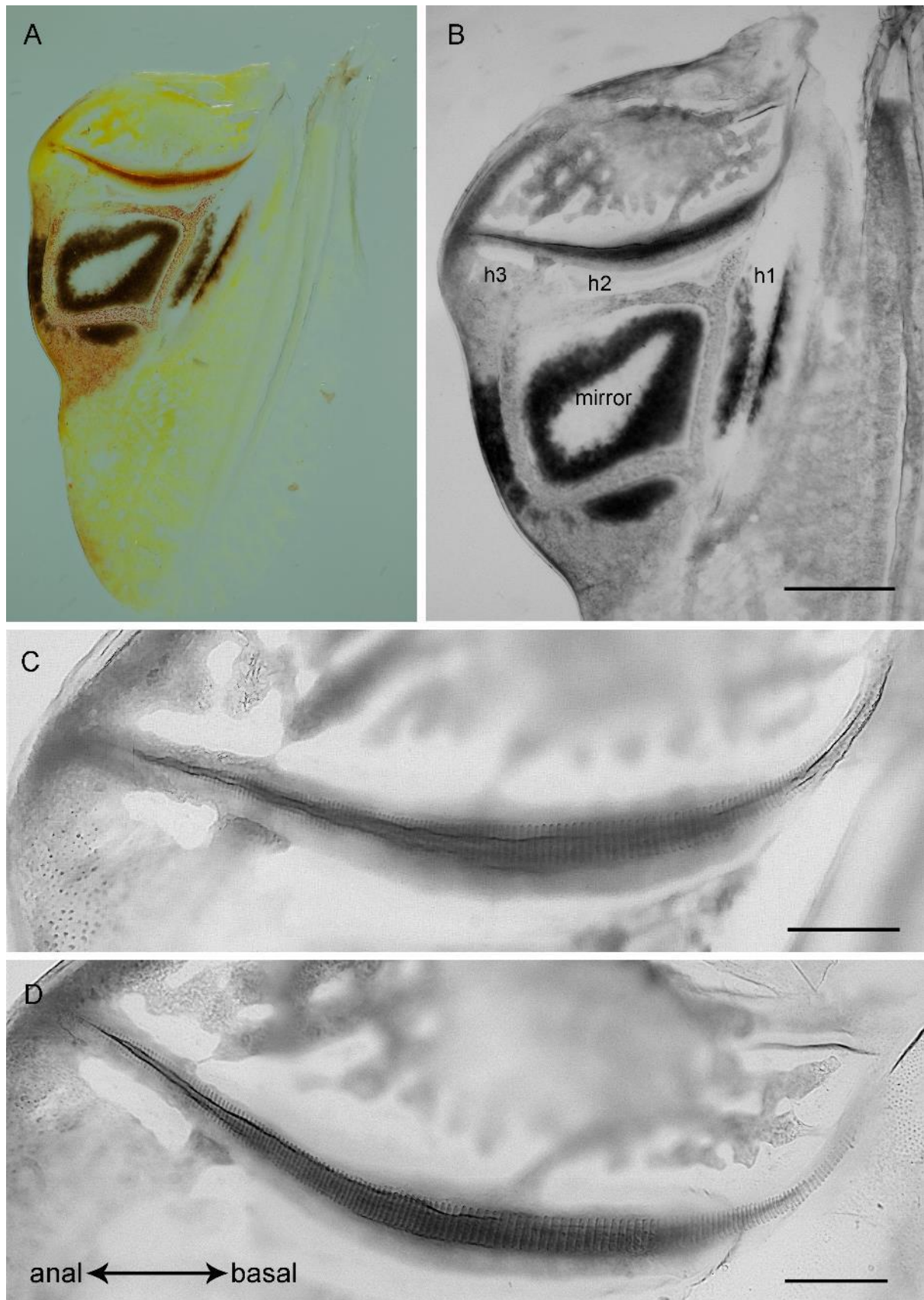


**FIGURE 1.** Environment of the UP Laguna Land Grant in Barangay Ilaya Norte (Luzon, Laguna).

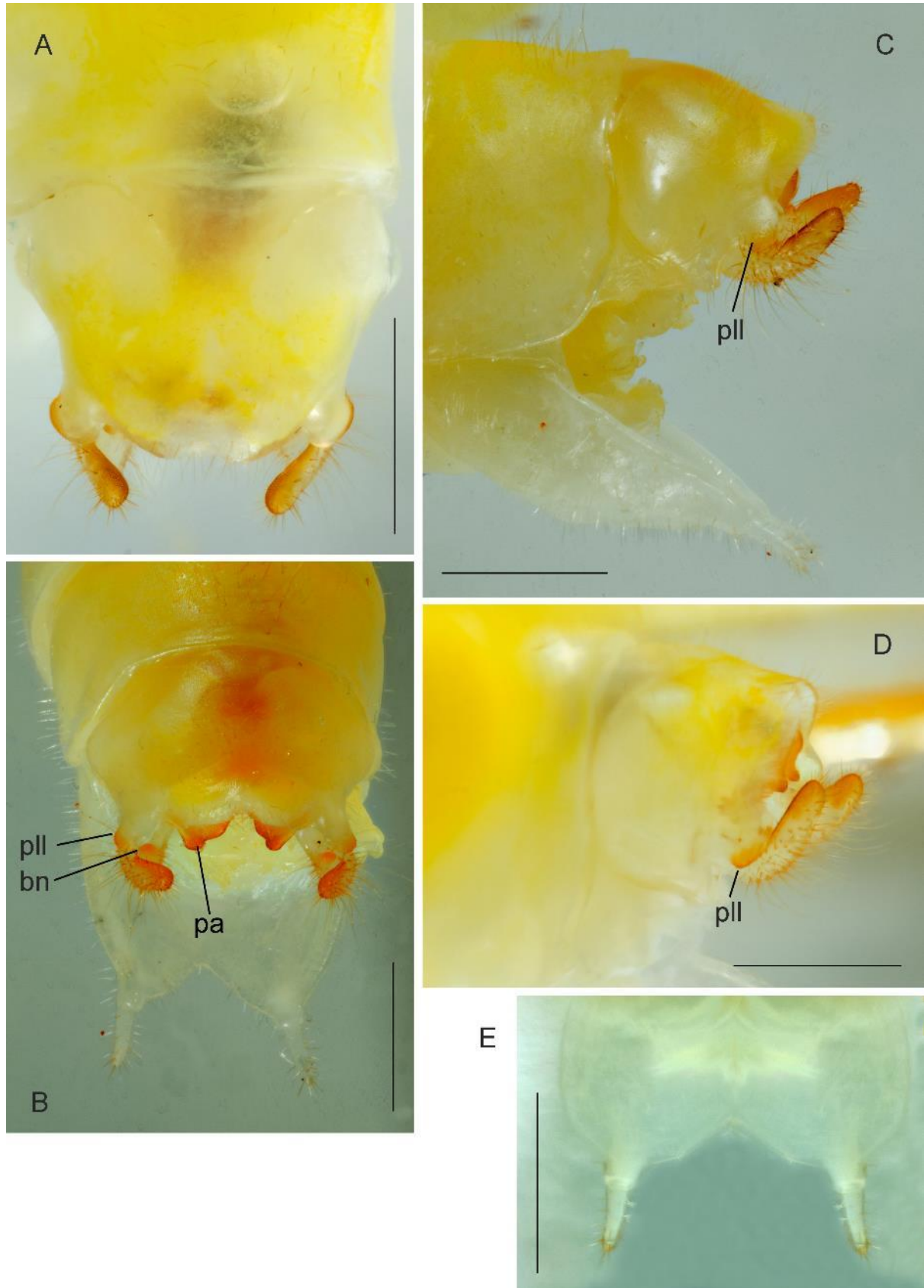


**FIGURE 2.** *Neophisis (Indophisis) montealegrei* **sp. nov.** male (A) and female (B) in their natural environment.

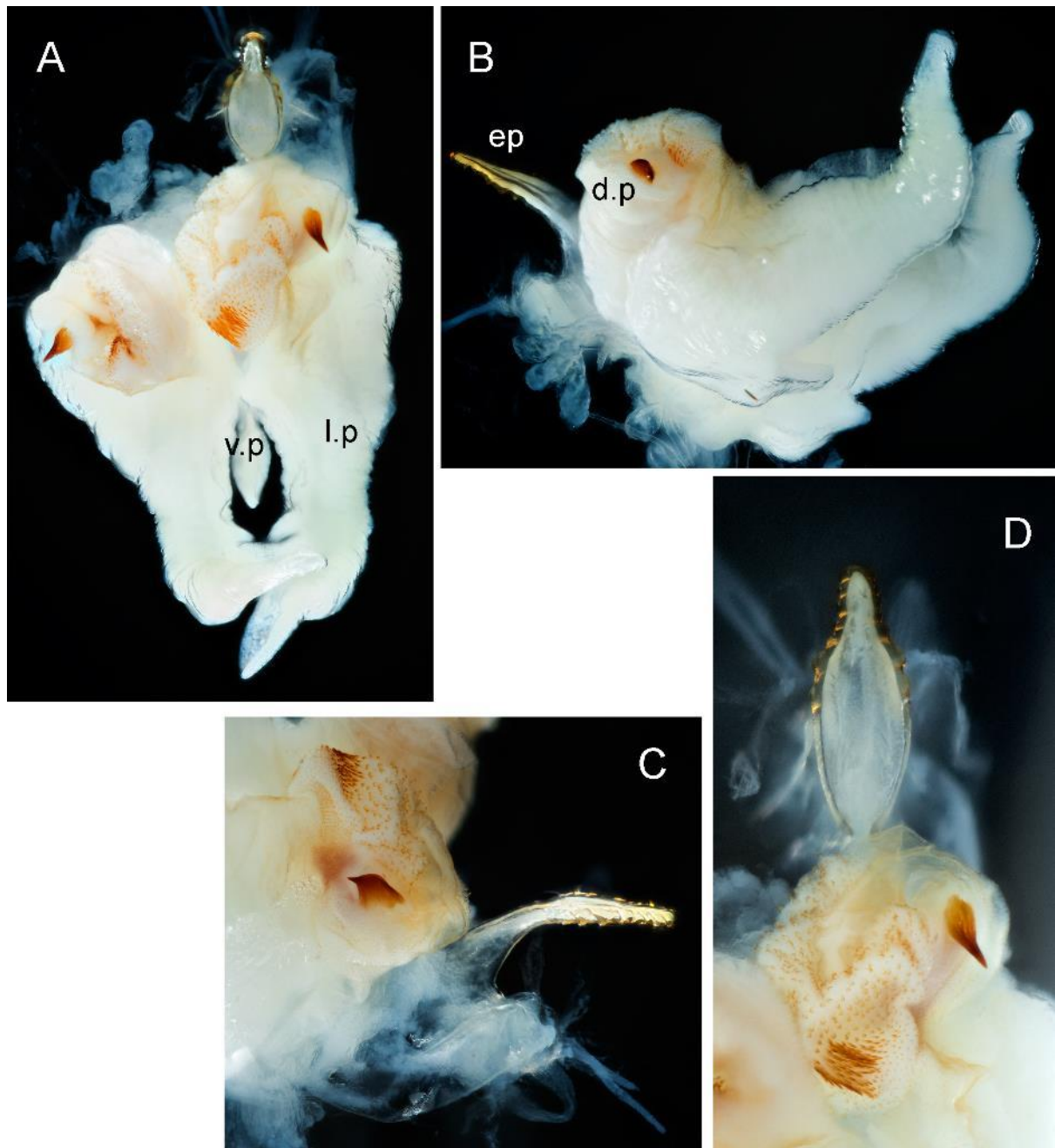




**FIGURE 3.** *Neophisis (Indophisis) montealegrei* sp. nov. male left tegmen (A), stridulatory area (B), stridulatory file (C, D) in ventral views. Scale bars: 0.5 mm (B), 0.2 mm (C, D).

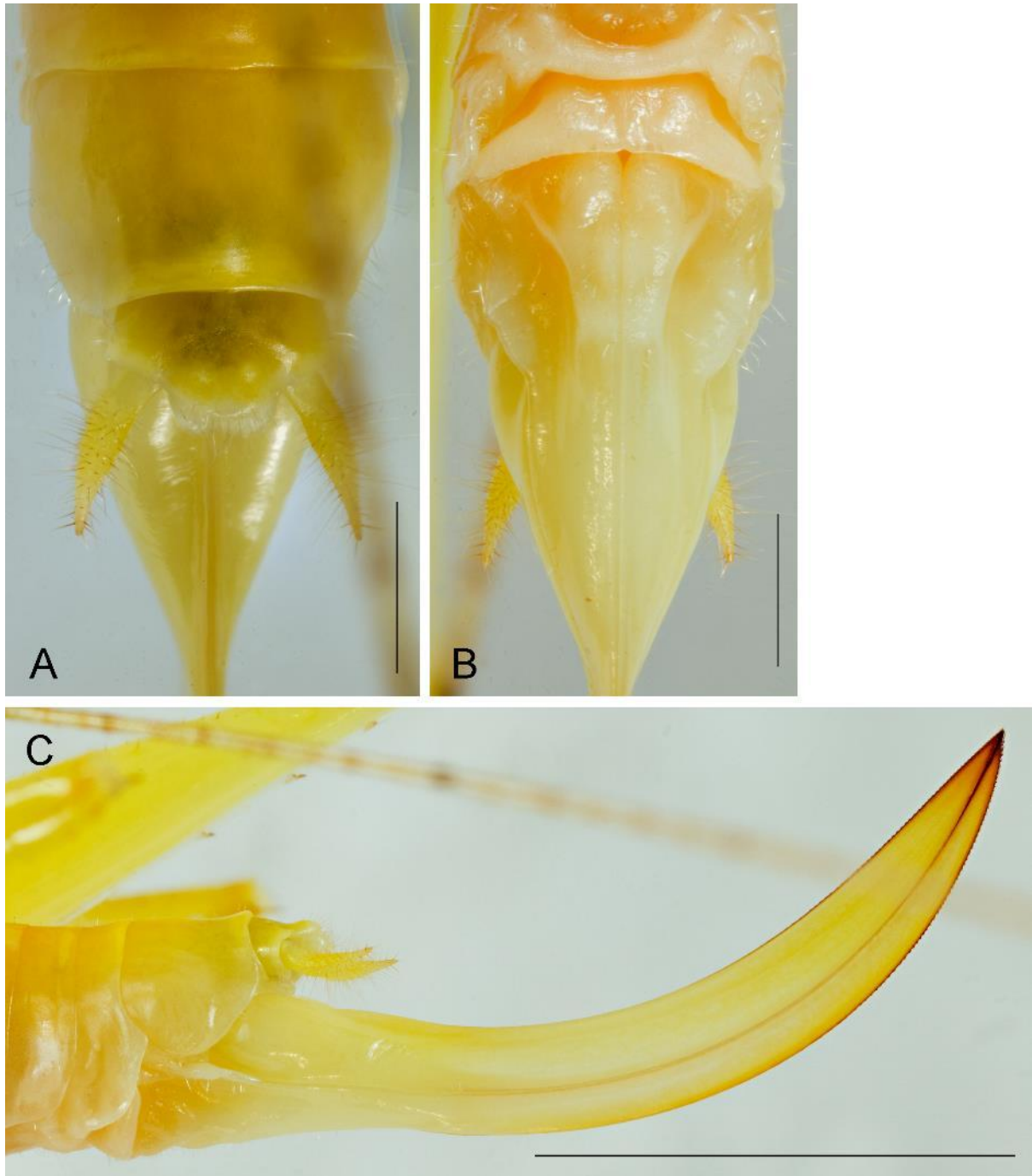


**FIGURE 4.** *Neophisis (Indophis) montealegrei* sp. nov. male abdominal apex in dorsal (A), dorso-posterior (B), lateral (C), and latero-posterior (D) views; subgenital plate in ventral view (E). Scale bars: 1 mm.

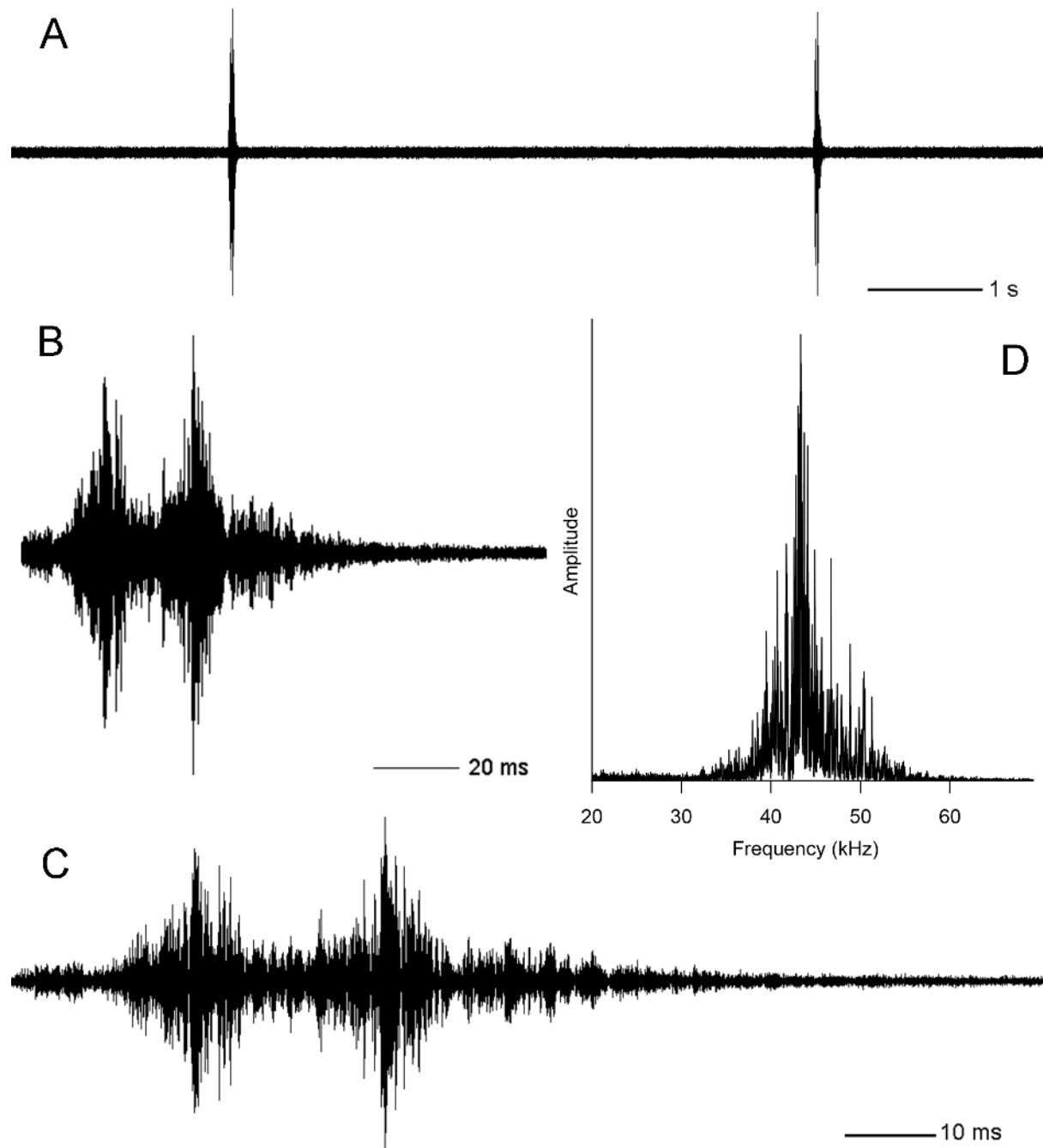


**FIGURE 5.** *Neophisis (Indophisis) montealegrei* sp. nov. male phallus in dorsal (A) and lateral (B) views; epiphallus in dorsal (C) and lateral (D) views.



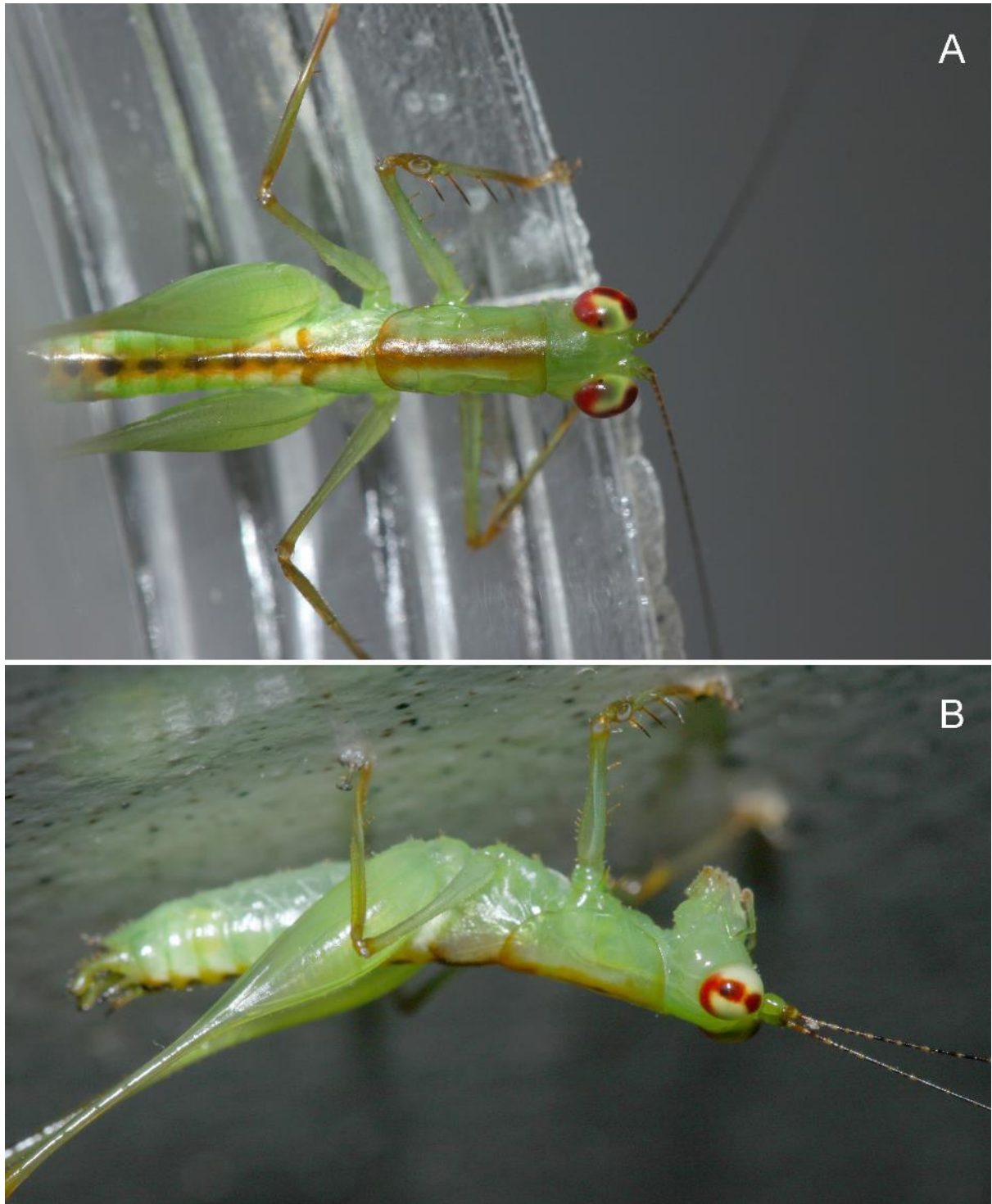


**FIGURE 6.** *Neophisis (Indophisis) montealegrei* **sp. nov.** female abdominal apex in dorsal (A), ventral (B), and lateral (C) views. Scale bars: 5 mm (C), 1 mm (A, B).

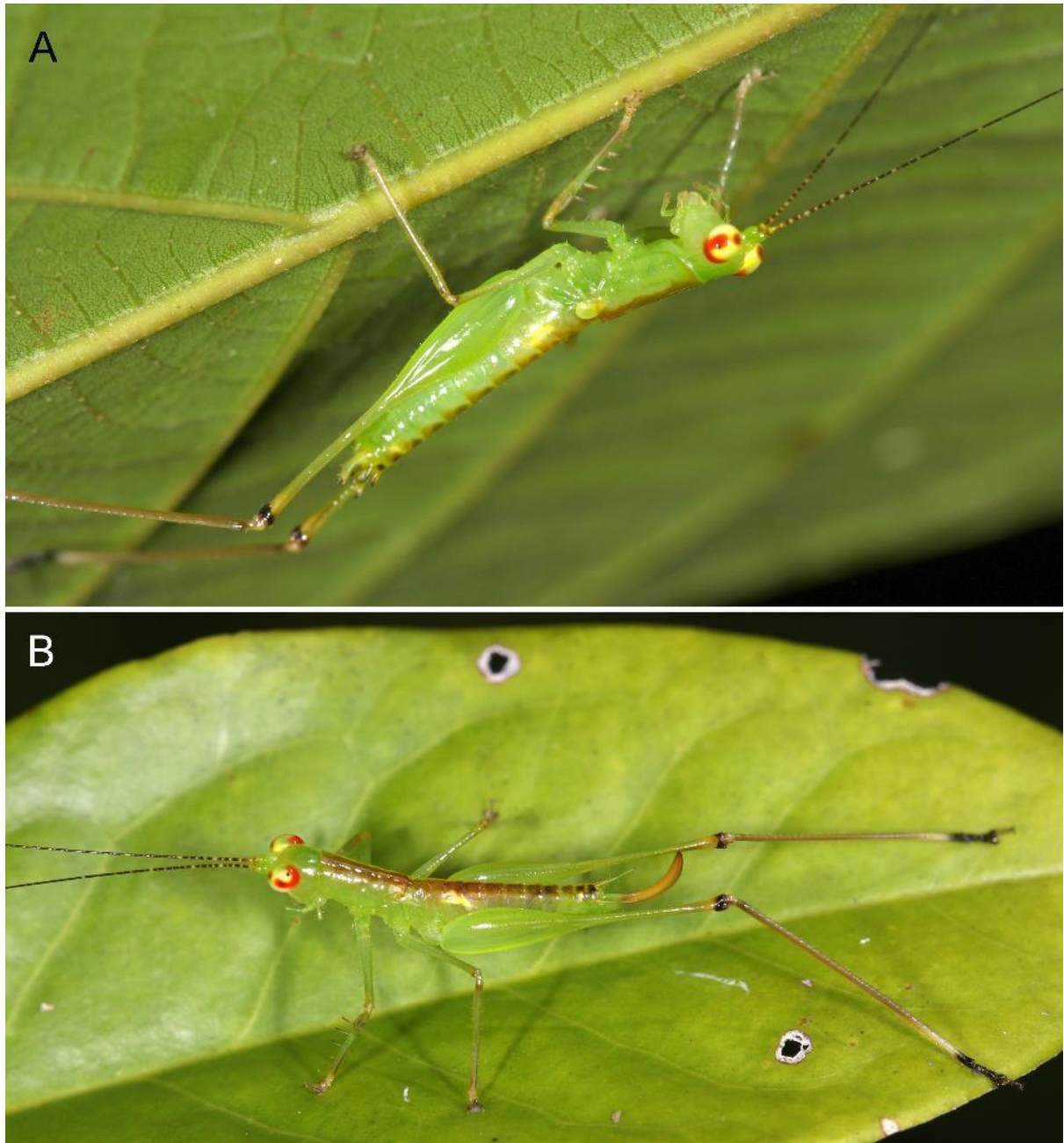


**FIGURE 7.** *Neophisis (Indophrisis) montealegrei* sp. nov. male calling song: oscillograms (A–C) and power spectrum (D).

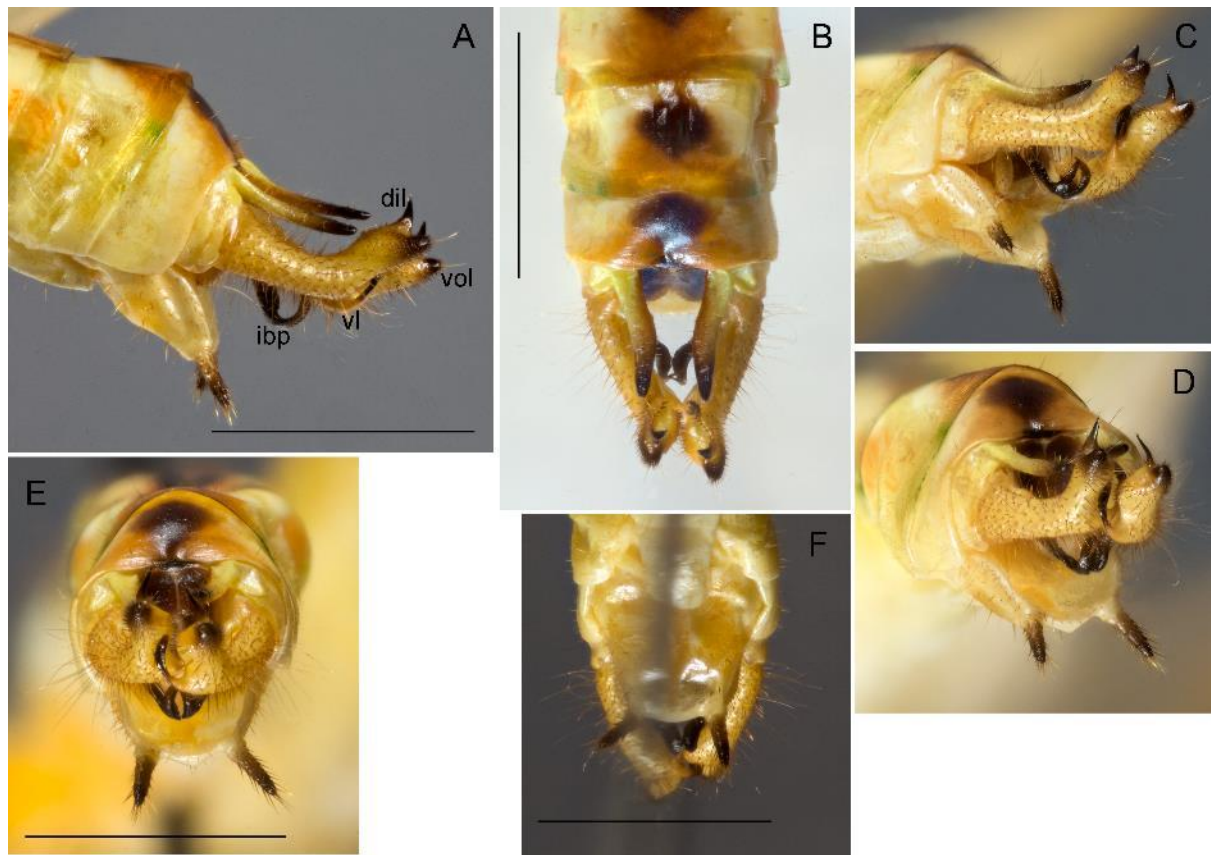




**FIGURE 8.** *Asiophlugis philippina* (Jin, 1993) male adult when alive.

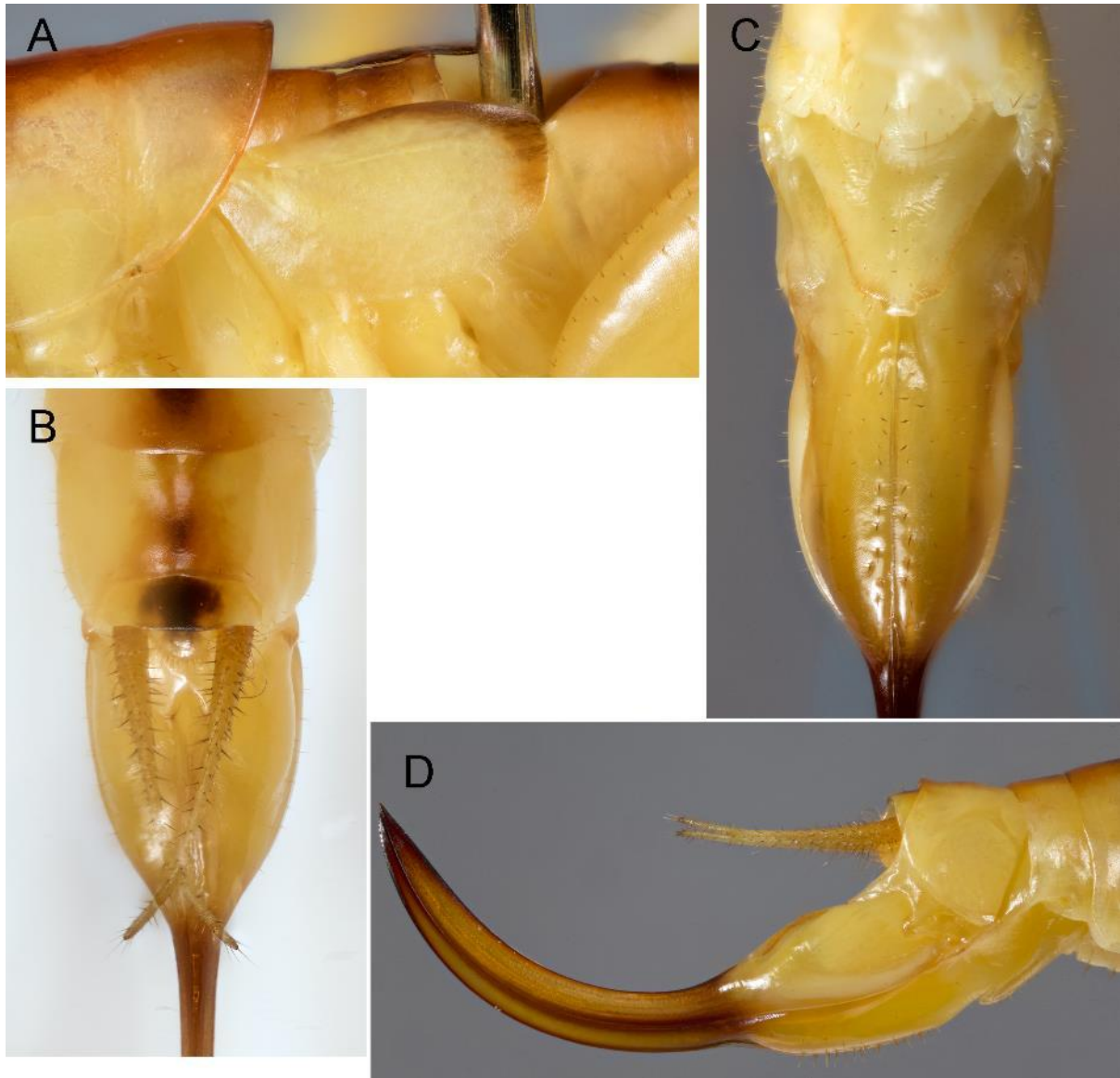


**FIGURE 9.** *Asiophlugis philippina* (Jin, 1993) male nymph (A) and female adult (B) in their natural environment.

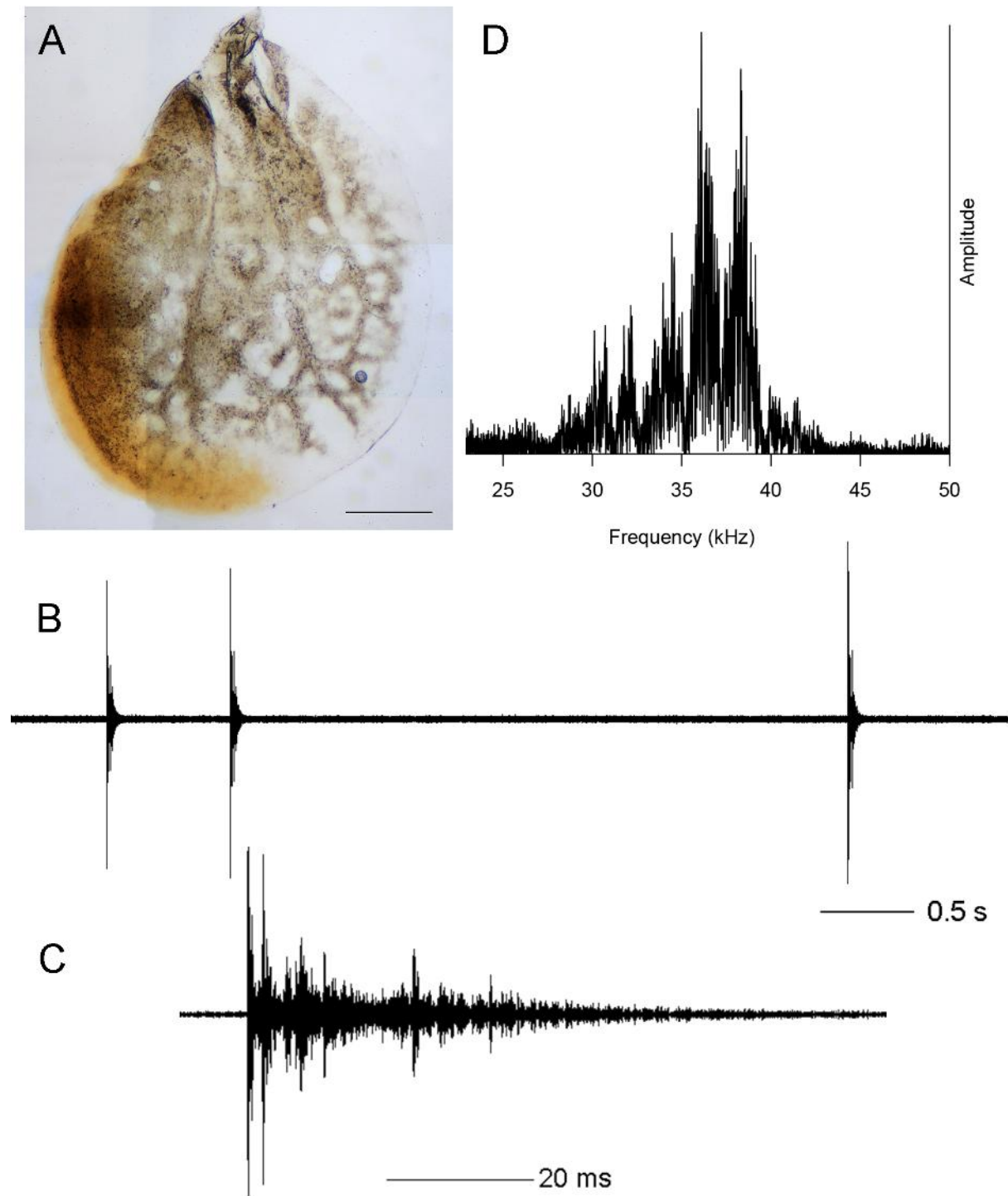


**FIGURE 10.** *Asiophlugis philippina* (Jin, 1993) male abdominal apex in lateral (A), dorsal (B), ventro-posterior (C), latero-posterior (D), posterior (E), and ventral (F) views. Scale bars: 1 mm.





**FIGURE 11.** *Asiophlugis philippina* (Jin, 1993) female wings in lateral view (A), abdominal apex in dorsal (B), ventral (C), and lateral (D) views.



**FIGURE 12.** *Asiophlugis philippina* (Jin, 1993) male left tegmen in ventral view (A), male calling song: oscillograms (B, C) and power spectrum (D). Scale bar: 1 mm.