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Short communication

A New Record of *Palaeoagraecia lutea* (Orthoptera: Tettigoniidae: Conocephalinae: Agraeciini) in Korea

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ABSTRACT

The bamboo katydid, *Palaeoagraecia lutea* (Matsumura et Shiraki, 1908) is newly reported in South Korea. Previously, the species was only known in Japan, but currently its occurrence is confirmed in the far southern locality of Hampyeong, Jeollanam-do province of Korean Peninsula. This katydid was collected using a light trap and sound tracing in the bamboo forest. It is regarded as a rare stenotopic species. The features of male *Palaeoagraecia lutea* are illustrated and discussed in terms of song characteristics, and a key is provided for the genus *Palaeoagraecia*. A new synonym is proposed: *P. philippina* (Karny, 1926) = *P. globicerata* (Vickery et Kevan, 1999) syn. nov.

Keywords: Katydid, Agraeciini, *Palaeoagraecia lutea*, new record, Korea

INTRODUCTION

The tribe Agraeciini Redtenbacher (1891) is restricted to the tropical and subtropical regions of the world (Ingrisch, 1997). The oriental Agraeciini has been successively reviewed as a hidden treasure of the tropical forest (Ingrisch, 1998, 2008, 2009, 2015). The genus *Palaeoagraecia* Ingrisch (1998) belongs to the oriental Agraeciini, which is mainly dispersed in Southeastern Asia (Ingrisch, 1998: Map 1). Currently, the genus includes six recognized species (Cigliano et al., 2018), with the northern limits reaching Japan following transfer of *Conocephalus luteus* (Ito and Ichikawa, 2003) and eastern distribution extending to Micronesia following the transfer of *Macroxiphus globicerатus* into *Palaeoagraecia* (Ingrisch, 2015).

An estimated 177 species are included in Orthoptera of Korea according to the last comprehensive monograph by Storozhenko et al. (2015). However, a new record may still be discovered from sparsely investigated habitats such as the farthest provinces, or remote islands, or stenotopic species that have particular preference for narrow habitats.

The second author (Holoce Ecological Conservation Research Institution [HECRI]) collected unidentified katydids attracted by a light trap in the summer of 2016 based on a natural environmental survey in Hampyeong-gun located in far southern Jeollanam-do province. Initially, it resembled the Conocephalinae, but neither belonged to the two subgroups known as tribes Conocephalini and Copiphorini in Korea (Kim and Kim, 2002a, 2002b). Only two females were confirmed at the time, which prompted further surveys for detailed investigation.

The first author (National Institute of Biological Resources [NIBR]) made a field trip at the same locality in August 2017 and successfully collected additional specimens including the males via sound tracing around the bamboo forest. The results confirmed *Palaeoagraecia lutea* (Matsumura et Shiraki, 1908) based on the comparison with prior references and analysis of the male's calling song. The katydid belongs to the oriental Agraeciini which has never been recognized before in Korea; however, it represents the most widely distributed *Palaeoagraecia* species among the three known species in Japan (Ichikawa et al., 2006).

We revised a key to all the six known species of *Palaeoagraecia* in the world, including *P. globicerata* (Vickery et Kevan, 1999) which is similar to *P. philippina* (Karny, 1926) based on their descriptions and illustrations (see the key). Therefore, five valid species are newly recorded and established from the different localities, for example, *Palaeoagraecia* has not been reported in China until now. We provide a revised description, illustrations, and sound characters of *Palaeoagraecia lutea*, specifically focused on the males, which were poorly described in previous studies.

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Sound recording and analyzing

Live katydids were collected and held in a 24 × 24 × 24 cm cage (Bugdorm, Taiwan) made of plastic frames with fabric walls, and fed with cut bamboo stems for two days. In the acoustic laboratory, the male's calling songs were passively recorded overnight using a digital recorder PCM-D50 (Sony, Japan) with two built-in stereo microphones set on the tripod at a distance of 30 cm from the cage. The recording options were as follows: maximum sampling rate 96 kHz (24 bit) for ultrasonic emissions of katydids limited to prevent sudden inputs of high pitch noise, a low-cut filter used for needless environmental noise, and the sound files were saved in the original WAV format. The acoustic signals in the files were analyzed according to different time domains within one minute or every 10 s, and the oscillograms and spectrograms were drawn using Raven Pro 1.5 (Cornell Lab of Ornithology, Ithaca, NY, USA). The sound characters of Japanese *Palaeoagraecia lutea* were compared with the extracted CD sounds (Ichikawa et al., 2006) and the on-line website 'Insect sound world from Japan' (Hashimoto, 2018). The glossary for song description was traced to Moore (1989).

SYSTEMATIC ACCOUNTS

Order Orthoptera Olivier, 1789
Family Tettigoniidae Krauss, 1902
Subfamily Conocephalinae Burmeister, 1838
Tribe Agraeciini Redtenbacher, 1891

Description. General coloration was brown, seldom green; fastigium of verticis and fastigium of frontis were separated by a shallow groove connected by a median keel; fastigium of verticis often strongly projecting, usually spine-shaped, but fastigium frontis usually not projecting; ventral teeth of vertices were absent. The lateral lobe of pronotum showed an auditory swelling, and the ovipositor was lanceolate, usually recurved.

Genus *Palaeoagraecia* Ingrisch, 1998
Type species: *Palaeoagraecia brunnea* Ingrisch, 1998

Description. Pronotum was rugous, disc flat with rounded lateral angles, without spines or tubercles; tegmina macropterous, surpassing hind knee, with round apex; stridulatory files 47−65 teeth in male; prosternum bispinose; mesosternal lobes subacute; metasternal lobes triangular; fore femora with ventral spines of subequal length on both inner and outer margins; middle femur with ventral spines on the outer margin only; hind femur with ventral spines on both margins, but inner ones smaller and fewer than the external spines. The male carries a spheroid 10th abdominal tergite, with ventro-apical lobes; cerci short, globular, with a baso-internal projection and with an apical projection. The ovipositor is long, compressed and blade-shaped, and the highest in the middle.

A key to the species of Palaeoagraecia
(modified from Ingrisch, 1998; Ichikawa et al., 2006)

1. Vertex and pronotum unicolor, without dark median band ····· *P. philippina* (Karny, 1926) (Philippines [type locality], Indonesia, East Malaysia, Japan [Yonaguni]) = *P. globicerata* (Vickery et Kevan, 1999) syn. nov.* (Yap: Dinay [type locality])
− Vertex and pronotum with a dark brown median band····· 2
2. MALE: 10th abdominal tergite divided into three lobes, styli in dorsal view with two transverse lamellae; FEMALE: subgenital plate with projecting apico-lateral angles, hind margin slightly convex ····· *P. chyzeri* (Bolívar, 1905) (Papua New Guinea [type locality], New Britain, Solomon Islands, Philippines)
− MALE: 10th abdominal tergite divided into two lobes, styli compressed, but otherwise normal; FEMALE: subgenital plate with apico-lateral angles obtusely projecting, or hind margin deeply exicsed ····· 3
3. MALE: 10th abdominal tergite large and bulging with angul ar apical lobes, subgenital plate with hind margin deeply excised in the middle; FEMALE: subgenital plate triangular, with hind margin deeply excised at apex ····· *P. brunnea* Ingrisch, 1998 (Thailand [type locality], Vietnam, Malaysia, Singapore, Bhutan, India)
− MALE: 10th abdominal tergite short and compressed with round apical lobes, pointing dorso-apicad and subgenital plate with hind margin nearly truncated or weakly excised in the middle; FEMALE: subgenital plate trapezoidal, with the hind margin weakly projecting or hardly excised in the middle ····· 4
4. MALE: left Cu2 vein with numerous stridulatory files, approximately 60, and the subgenital plate with rather round hind margin, hardly excised in middle; FEMALE: subgenital plate as long as wide, with hind margin convex, weakly projecting at middle apex, and ovipositor 22−26 mm ····· ····· *P. ascenda* Ingrisch, 1998 (Thailand [type locality], Laos, Japan [Tokara; Amami; Okinawa Islands])
− MALE: left Cu2 vein with 47−56 stridulatory files, and a subgenital plate with rather concave hind margin weakly excised in the middle; FEMALE: subgenital plate wider than long, with hind margin truncated, weakly emarginated at middle apex, and ovipositor 18−22 mm····· *P. lutea* (Matsumura et Shiraki, 1908) (Japan [type locality], South Korea [new record])

**Macroxiphus globiceratus* was identified in the Microne-

Table 1. Measurements of *Palaeoagraecia lutea* (lengths in mm)

	Body (head to abdomen)	Head (fastigium of vertex to mandible)	Pronotum	Tegmina	Stridulatory file number	Hind femur	Ovipositor
Male 1 (NIBR)	25.9	10.0	5.8	33.1	53	16.0	–
Male 2 (NIBR)	27.8	10.4	6.2	38.1	56	16.8	–
Male 3 (NIBR)	25.9	10.0	5.7	36.4	47	16.7	–
Male 4 (NIBR)	24.0	9.9	5.7	33.7	51	16.5	–
Male 5 (NIBR)	25.5	10.2	6.2	34.3	55	16.7	–
Female 1 (NIBR)	29.7	12.8	7.2	46.2	–	19.5	22.6
Female 2 (HECRI)	30.0	12.0	6.5	42.0	–	17.0	22.0
Female 3 (HECRI)	29.0	13.0	6.8	42.5	–	17.5	21.8
Female (Holotype)	–	12.3	7.2	42.1	–	18.0	20.0

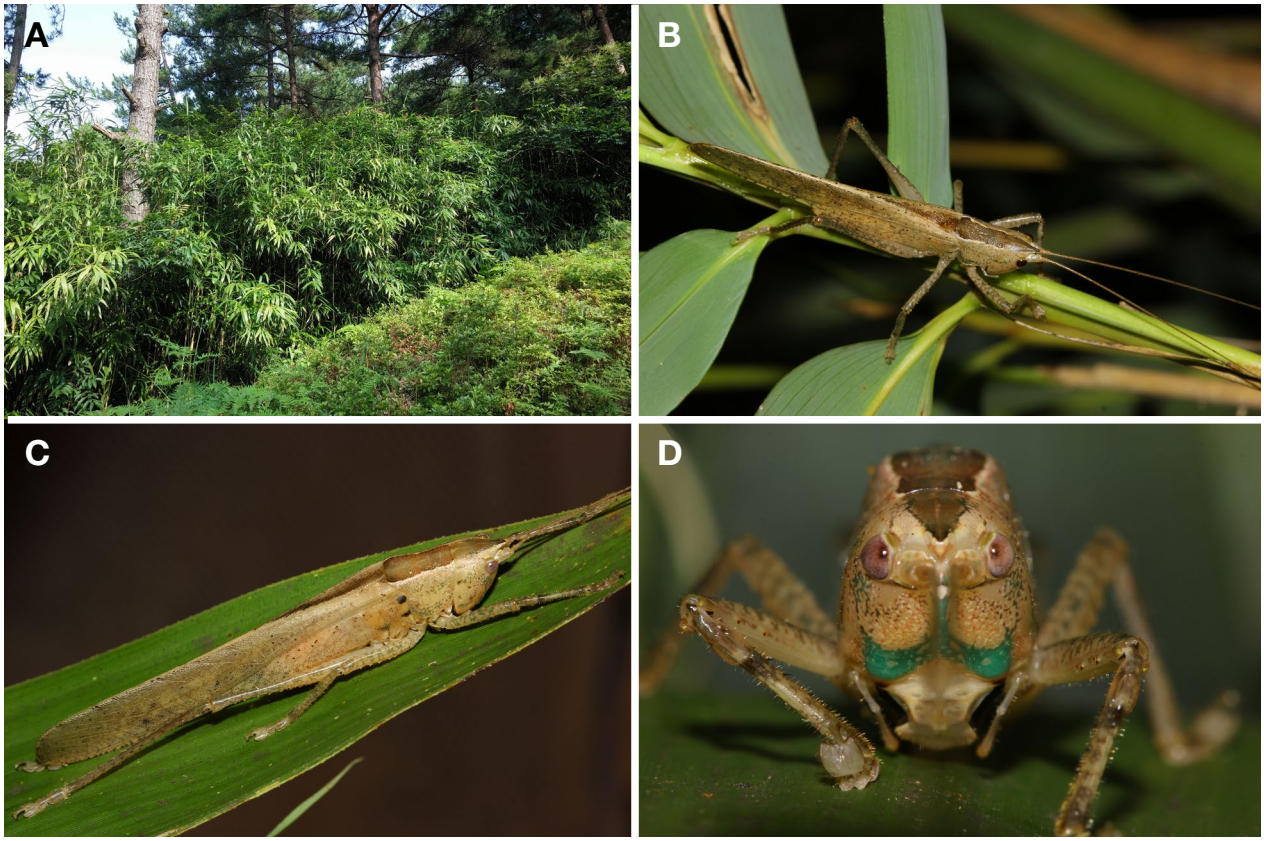

Fig. 1. Habitat and habitus of *Palaeoagraecia lutea*. A, Bamboo forest in Hampyeong Ecological Park; B, A male in nature; C, A female in nature; D, Frontal view of head showing a remarkable green pattern (female).

sia based on the single holotype male specimen deposited in Bishop Museum. It was later transferred to the genus *Palaeoagraecia* by Ingrisch (2015), with characteristics almost identical to *P. chyzeri* from Papua New Guinea. However, based on their diagnostic descriptions and drawings, *P. globicerata* was closer to *P. philippina* rather than *P. chyzeri* suggesting that *P. globicerata* and *P. philippina* lacked a dark median band along the vertex and pronotum initially. As well, no significant differences existed between body size, coloration, and spination on the legs including important copulating structures. Therefore a new synonym was proposed based on a consensus with Dr. Sigfrid Ingrisch (personal communication).

[1]**Palaeoagraecia lutea* (Matsumura et Shiraki, 1908) (Table 1, Figs. 1–4)

Conocephalus luteus Matsumura et Shiraki, 1908: 45, taf.

Korean name: [1]*함평매부리 (신칭)

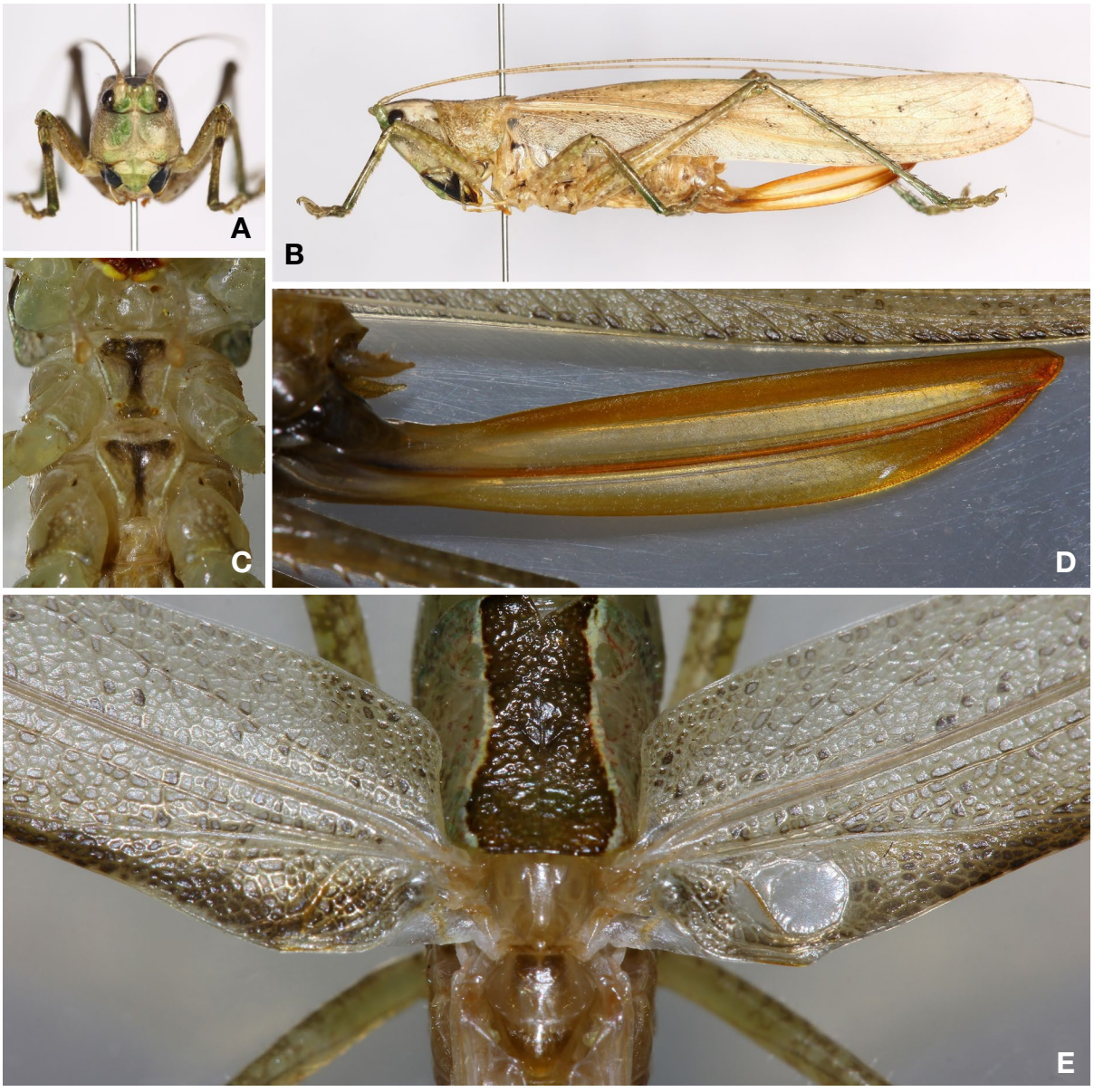

Fig. 2. Specimens of *Palaeoagraecia lutea*. A, Head of female, frontal view; B, Body of female, lateral view; C, Thoracic sternum of male; D, Ovipositor; E, Stridulatory apparatus.

2, fig. 23ab (type locality: Japan, Gifu, Kawashima Town, Kasada; Holotype female, 6 Sep 1902, K. Tanaka leg., Hokkaido University).

Homorocoryphus luteus: Karny, 1912: 36; Hukusima, 1956: 6.

Agroecia [sic: *Agraecia*] *luteus*: Tadauchi, 1989: 53.

Ruspolia luteus: Otte, 1997: 68.

Palaeoagraecia lutea: Ito and Ichikawa, 2003: 58, figs. 3, 8; Ichikawa et al., 2006: 76, 408, Disc 1–29; Senaga, 2010: 168; Murai and Ito, 2011: 109; Murai, 2015: 46, Disc 1–44; Kano et al., 2016: 298, fig. 114–06, 07.

Material examined (8 specimens in Korea). 5 males and 1 female, Korea: Jeollanam-do, Hampyeong-gun, Daedong-myeon, Hakdong-ro, Hampyeong Ecological Park (in bamboo forest), 9 Aug 2017, leg. Kim Taewoo (NIBR); 2 females, 8 Aug 2016, *ibid*. leg. Lee Kang-Woon (HECRI)

Description. General: Body was mottled brown, brightly shining; vertex and pronotum with a dark brown median band (Fig. 1B, C); face with remarkable ^-shaped green marks (Fig. 1D); however, the green pigment was lost upon death (Fig. 2A); secondary sexual dimorphism not so significant except

for body size indicating a slightly smaller male than female.

Male. Head: Strongly oblique, conical, with a shorter longitudinal length dorsally than pronotum; occiput with dark-brown median band from the tip of fastigium of vertex; fastigium of vertex sharply pointed, with a shallow median furrow; fastigium of frons not blunted, connected with fastigium of vertex by a shallow groove. Frons was rugous, and convex with ^-shaped green marks on the face, with the green pigment dispersed on the face in dead specimens. The compound eyes were small, semi-circular, but prominent, and purplish brown when alive; median ocellus bright, located below the fastigium of frons. Lateral ocelli were indistinguishable. Antennae were unicolor, filiform, and 2.5−3.0 times longer than the total length of head and abdomen, with painted annulations. The length of the scape was double the width, more projected than the fastigium of vertex, with rather blunted inner margin; pedicel twice as long as wide. Antennal socket carried a blackish low margin, and a rimmed upper inner margin. Clypeus was trapezoidal, and was as long as labrum; labrum was white-yellow, almost circular. Mandibles were dark black. Labial tip was whitish yellow, and reddish towards the end. Maxillary palpi were bristle-shaped, moderately long, yellowish brown, with narrow apical black rings.

Thorax: Pronotum was strongly rugous, black brown above the median pronotal disc with bright lateral margins; anterior margin truncated, rounded toward lateral lobes; posterior margin slightly concave, and 1.3 times wider than anterior margin. The principal sulcus was located at the anterior third, curved toward anterior, but not reaching the lateral margin. A v-shaped notch was present on the anterior metazona behind the prozona. The lateral lobe of pronotum was a little shorter, with humeral sinus, covering prothorasic auditory opening; and the anterior margin gently curved downward. Prosternum was bispinose, with widely separated spine-like projections; mesosternum was T-shaped and dark black, with a pair of subacute lobes, and narrow and pointed apex. Metasternum was T-shaped and dull dark black, with a pair of triangular lobes rather blunted apically, and shorter than mesosternal lobes (Fig. 2C).

Wings: Tegmina was macropterous, with a rounded apex, surpassing hind knees; nearly parallel surface with small dark spots irregularly scattered; dorsal base further dark brown; left Cu2 vein nearly transverse, not sinuated, with comb-like stridulatory files carrying about 47−56 teeth; right mirror circular, subdivided by a basal cross vein (Fig. 2E). Hind wings did not project beyond the tegminal apex, and were transparent, without remarkable coloration.

Legs: Generally short and stout, dirty yellow, spotted brown; fore coxa carried an anterior spine-like projection and fore femora with ventral spines, 1−3 on external carina and 2−3 on the internal carina; middle femora with ventral spines, 4−5 on the external carina and 0−1 on the internal carina; hind femora with ventral spines, 7−10 on the external carina and 2−4 on the internal carina. Fore knees were lobe-like bilaterally; middle knees lobe-like on the external margin, but spine-like on the internal margin; hind knees spine-like bilaterally. Fore tibia carried slit-like tympana open on both sides, with about 7 pairs of ventral spines; middle tibia with about 8−9 pairs of ventral spines; hind tibia subsquare in cross section, with about 13−14 pairs of dorsal spines, 8−11 pairs of ventral spines. Tarsomeres contained flat pads extending beneath next segment, with the broadest apical pads. All claws were symmetrical.

Abdomen: The 10th abdominal tergite was semi-globular, slightly split by a suture along the midline; with a short apical projection, roundly bilobate, upwardly pointing, and the hind margin deeply V-emarginated in the middle. Epiproct was triangular, paraproct projected than epiproct, upwardly blunted resembling a pair of short tail processes. Cerci were thick and conical, granular and hairy, with remarkable globular expansion near the base, apically very acute forming an elongated

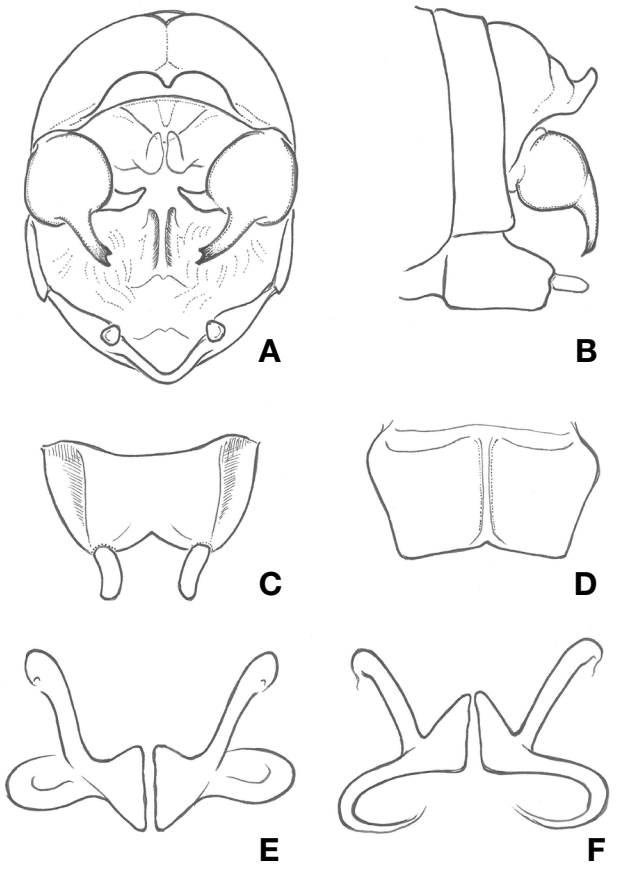

Fig. 3. Copulatory structures of *Palaeoagraecia lutea*. A, Terminalia of male, posterior view; B, Terminalia of male, lateral view; C, Subgenital plate of male, ventral view; D, Subgenital plate of female, ventral view; E, Titillators, posterior view; F, Titillators, ventral view.

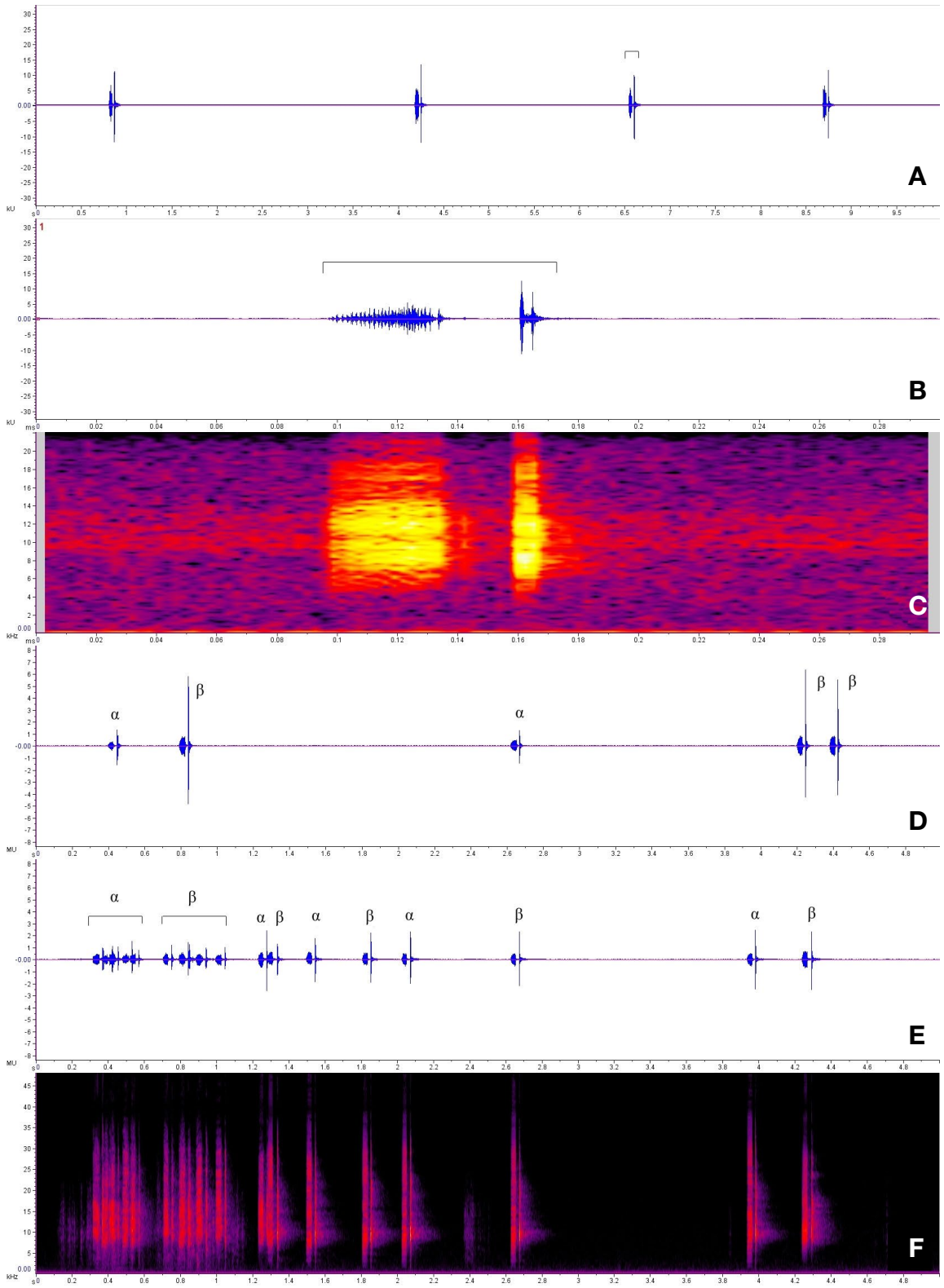

Fig. 4. Calling songs of *Palaeoagraecia lutea*. A, Four chirps (solo) for 10 s (29 Jul 2000, Japan: Setoaraya) (Hashimoto, 2018); B, A chirp for 0.3 s (24°C, Autumn, Japan) (Ichikawa et al., 2006); C, Spectrogram of 17 (see highlight); D, Competition (α, β) sounds for 5 s (25°C at night, 9 Aug 2017, Korea, Hampyeong); E, Competition (α, β) sounds for 5 s (25°C at night, 10 Aug 2017, Korea, Hampyeong); F, Spectrogram of 20.

projection, which terminated into two downwardly curved teeth; middle of the cerci showed a hook-shaped internal projection (Fig. 3A). The subgenital plate was broader than long, trapezoidal, lateral sides darker than the ventral side; hind margin nearly truncated but with faintly notched V-emargination (Fig. 3C). Styli were short, club-like, and depressed. Titillators were composed of three parts, with the apical part longer than the basal part; elongated apical parts showed a smooth and rounded apex. The median process of central parts was largely right-angled triangular; the basal part was roundly incurved and apically tapered (Fig. 3E, F).

Female. The body dimension was larger than in males. The 10th abdominal tergite was short, and truncated. The cerci were thick, conical, incurved, with a suddenly narrowed and pointed apex, and 4.0 times longer than wide in the center. The subgenital plate was trapezoidal, wider than long, with a median longitudinal carina, and nearly truncated hind margin, which was weakly excised in the middle (Fig. 3D). Styli were absent. The ovipositor was pale yellow, gently recurved, blade-shaped, broad and mostly widened in the middle, a little longer than the hind femur, with a pointed and narrow apex, not surpassing the tegminal end (Fig. 2B, D).

Calling songs. The single male produces a discontinuous chirping sound, which is irregularly repeated at intervals of 2.5−3.5 s (Fig. 4A). The chirp duration was less than 0.1 s, and composed of distinctive diplo-syllable units (Fig. 4B). The prolonged pro-syllable consisted of low undulating pulses, whereas short post-syllables consisted of two high peak pulses. When two (α, β) or more males were in competition, the rapid chirping sound is interrupted by short intervals; however, the basic song structure was not different with a solo signal unit (Fig. 4D). Occasionally, two chirping sounds are successively repeated by a male, or the chirp is hardly transformed to short continuous thrills (Fig. 4E). The dominant frequency of the spectrum was 6−14 KHz (Fig. 4C).

Habitat. This katydid prefers the bamboo forest (Fig. 1A) and a small katydid population has been reported from Japan (Murai and Ito, 2011). It is macropterous and appears to fly well, and occasionally attracted to a light trap. As an obligate nocturnal insect, the katydid is mostly resting in the bush during the day, but actively gnawing at bamboo stems of the genus *Pseudosasa* (food plant) at night, and the males produce weak calling sounds on the leaves (Fig. 1B, C). It shares the habitat with another insectivorous butterfly *Taraka hamada* (Lycaenidae) and another lesser bamboo katydid *Conocephalus bambusanus* (Conocephalini). The bamboos have been restricted to southern areas in Korea in the past; however, their northern limits have been recently extended further north (Kong, 1985; Heo et al., 2006).

Distribution. South Korea (new record), and Japan (Southern part of Honshu; Shikoku; Kyushu; Tsushima).

DISCUSSION

The primary distribution of *Palaeoagraecia* falls outside of the oriental region as already reported by Ingrisch (1998). Among congeneric members, *Palaeoagraecia lutea* has the most northern descent in Korea and Japan and is characterized by a small size of 41−52 mm (from head to tegminal end). The male's stridulatory files are also few (47−56), which is beyond the scope of the original definition (55−65) of the genus *Palaeoagraecia* presented by Ingrisch (1998). In morphological aspects of copulatory structure, *Palaeoagraecia lutea* strongly resembles *Palaeoagraecia ascenda*; however, the subgenital plates of both sexes and titillators of male differ in shape.

Although the Korean Peninsula biogeographically belongs to Palaearctic Region, the subtropical species complex constitute about 31.9% of all known Orthoptera (Storozhenko et al., 2015) as illustrated by *Palaeoagraecia* in this study. The relationship between such northern shifts in habitat and recent trends in global warming or the other anthropogenic factors should be further elucidated.

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