



## Two new species of *Rhagophthalmus* Motschulsky (Coleoptera: Rhagophthalmidae) from Matzu Archipelago, Taiwan with biological commentary

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### Abstract

Two new species of *Rhagophthalmus* Motschulsky, *R. beigansis* Ho **sp. nov.** and *R. giallolateralus* Ho **sp. nov.** collected in a vulnerable environment in two small islets of Matzu Archipelago, Lienchiang County are described and illustrated. This brings the total number of species in this genus to 35, and the number known from small off shore islets and islands to 10. Their importance to the conservation of such small and fragile island habitats is discussed.

**Key words:** Rhagophthalmidae, *Rhagophthalmus*, new species, Matzu Archipelago

### Introduction

*Rhagophthalmus* spp. are unusual because of the preservation of the incompletely larviform stage in the female (Kawashima *et al.*, 2010), the distribution of paired light organs along the sides of the body, and the luminescent signals of their mating system (Suzuki, 1997; Ohba, 2004). Li *et al.* (2008) gave an historical review of the genus *Rhagophthalmus*, indicated the various forms in which the family has been considered, and listed 33 species from SE Asia (Li *et al.*, 2008). They emphasized the important characters of male genitalia for taxonomy. Most species occur in China with the greatest diversity in Southern China. Only eight species from islands and islets adjacent to the continent have been reported: *R. confusus* Olivier (Sri Lanka), *R. filiformis* Olivier (Sri Lanka), *R. formosanus* Kawashima *et* Sugaya (Taiwan), *R. jenniferae* Kawashima *et* Satô (Taiwan), *R. motschulskyi* Olivier (Hong Kong, China), *R. notaticollis* Pic (Sri Lanka), *R. ohbai* Wittmer (Japan & Taiwan), and *R. sumatrensis* Olivier (Sumatra) (Olivier, 1911; Wittmer and Ohba, 1994; Wittmer, 1997; Kaeashima and Satô, 2001; Kawashima and Sugaya, 2003; Li *et al.*, 2008). Three species of *Rhagophthalmus* are known from Taiwan (Chen & Ho, 1998; Kawashima & Satô, 2001; Kawashima & Sugaya, 2003), but no *Rhagophthalmus* species have been found in other affiliated islands or islets.

Matzu Archipelago is in Lienchiang County near the Fujian province, and the islands are scattered over the coastal estuary of the Min Jiang River. The archipelago consists of 36 islands and islets, between 119°51' to 120°31'E, and 25°55' to 26°44'N (Figs 1–3).

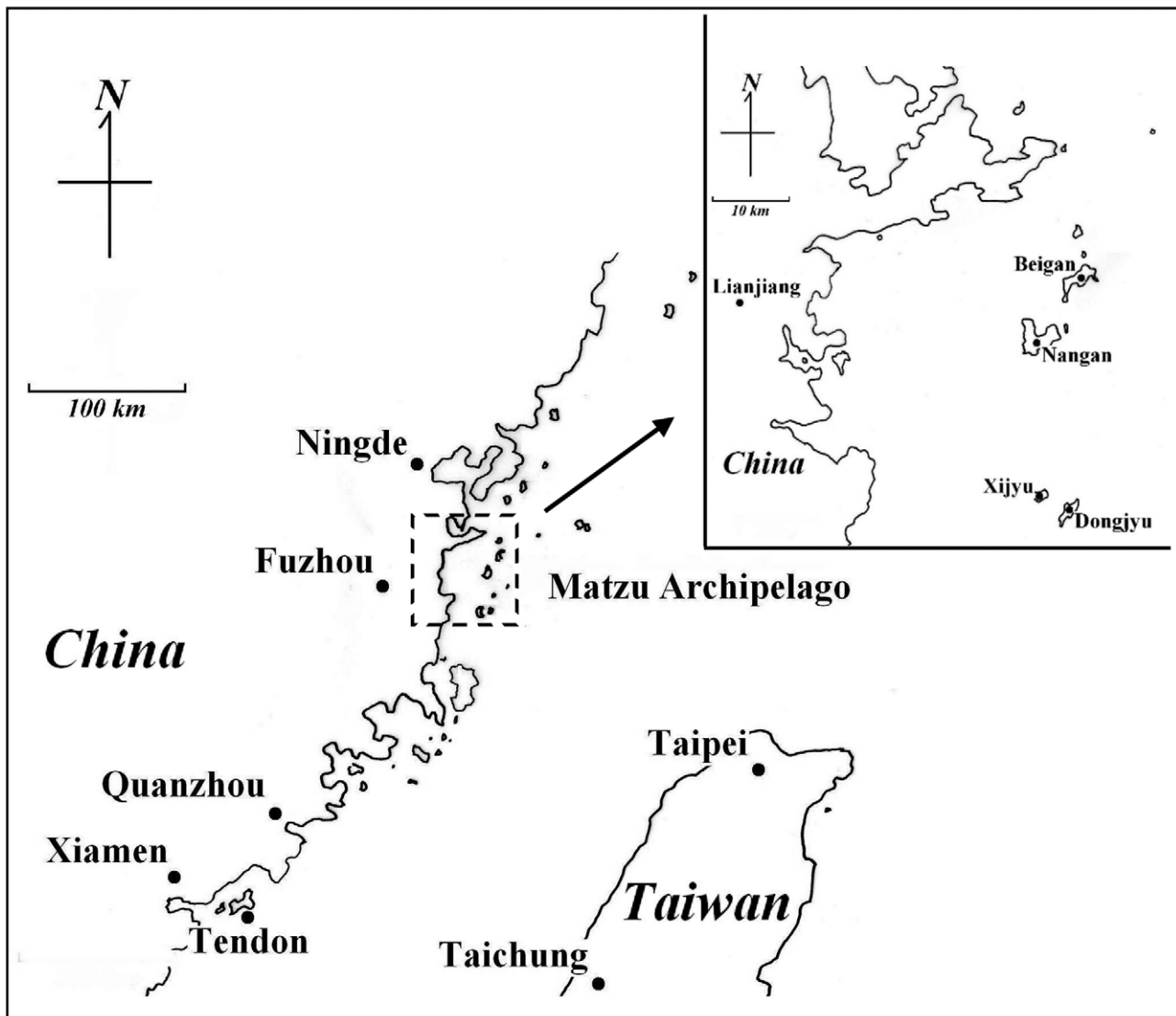
Here we describe two new species of *Rhagophthalmus* found in Matzu Archipelago, viz. *R. beigansis* Ho **sp. nov.** and *R. giallolateralus* Ho **sp. nov.** By agreement of all the authors of this paper the species are attributable to Ho alone.

### Material and methods

#### Collection and identification

Specimens were collected on the islets of Beigan and Dongjyu in Matzu Archipelago, Lienchiang County. Collectors searched for luminous adult females at night, and at the same time used Malaise traps, sex-attraction, and

pitfall traps to catch males in the same habitat. Specimens were identified from morphological characters (Wittmer & Ohba, 1994; Kawashima & Satô, 2001; Kawashima & Sugaya, 2003; Li *et al.*, 2008).



**FIGURE 1.** Location of Matzu Archipelago, lying between  $119^{\circ}51'$  to  $120^{\circ}31'E$ , and  $25^{\circ}55'$  to  $26^{\circ}44'N$ .

#### Treatment and preservation of sample

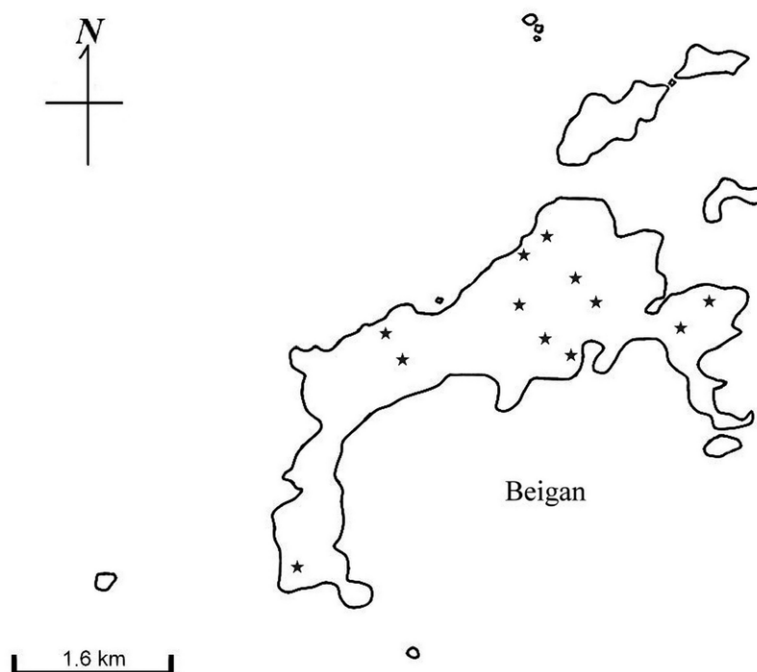
Adult males were collected into 75% ethanol; females were reared for egg collection and behavioral observation in laboratory, and immersed in 75% ethanol after death. All ethanol preserved samples were kept under  $-4^{\circ}$  to prevent discoloration. Male genitalia were dissected and immersed in 10% NaOH in small petri dishes at room temperature for 8–10 h after dissection. The material was then rinsed in 75% ethanol and then observed under a Leica MZ12 stereo microscope. Photos were taken using a digital single lens reflex camera (Canon 50D) or by external imaging on computer by digital camera (Infinity X) and photographed by Delta Pix 1.8.B2 under the stereo microscope.

#### Measurement of morphological characteristics

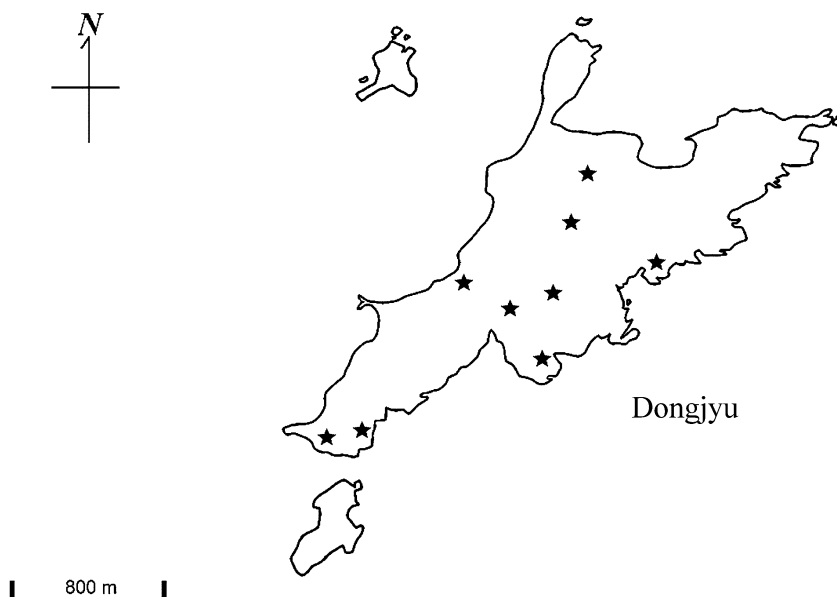
Measurements were taken using either a cursor graduated scale or calibrated eyepiece under the microscope. The following abbreviations will be used in the descriptions: BL- length of body, from anterior margin of head to apex of elytra; HW- maximum width of head, including compound eyes; PL- length of pronotum, along the mid-line of pronotum; PA- apical width of pronotum, across the anterolateral corners; PB- basal width of pronotum, across the posterolateral corners; PW- maximum width of pronotum; EL- length of elytra; EW- maximum width of elytra; EHW- humeral width of elytra; HFL- length of femur of hind leg; HTL- length of tibiae of hind leg. Morphological characters follow Kawashima & Satô (2001).

Abbreviations for institutions:

ARI	Agricultural Research institute, Taichung, Taiwan
ESRI	Endemic Species Research Institute, JiJi, Nantou, Taiwan
NMNS	National Museum of Natural Science, Taichung, Taiwan



**FIGURE 2.** Distribution of *Rhagophthalmus beigansis* Ho **sp. nov.** in Beigan islet of Matzu Archipelago. Asterisks represent location.



**FIGURE 3.** Distribution of *Rhagophthalmus giallolaratus* Ho **sp. nov.** in Dongjyu islet of Matzu Archipelago. Asterisks represent location.

#### Characteristics of genus *Rhagophthalmus*

The characteristics of *Rhagophthalmus* are as follows (Olivier, 1911; McDemott, 1964; Ohba *et al.*, 1996; Kawashima *et al.*, 2010): **Male.** Body size from small to large. Outline elliptic to subparallel. Pronotum short, convex, rarely wider than head. Compound eyes very large covering most of head and dorsally nearly or completely

separated into two parts by a posterior indentation. Antennae very short, 12 segmented, segments 4 to 10 slightly dentate. Elytra oblong, parallel sided, posterior sharp, and surface rugose, sometimes shorter than the abdomen. Abdomen 8 segmented, narrowing posteriorly; last segment acutely conical. No trace of luminous organs. **Female.** Larviform. Antennae 7–8 segmented; With compound eyes; tarsus fully-developed with paired claws; with large luminous organ on 7th ventral abdominal segment, emitting strongly continuous light for sexual communication, and with three spot-like luminous organs on most segments, emitting weakly continuous light for egg attendance. **Larva.** Head without compound eyes; antennae 3 segmented; none fully-developed legs with the pretarsus of single claw.

***Rhagophthalmus beigansis* Ho sp. nov.**

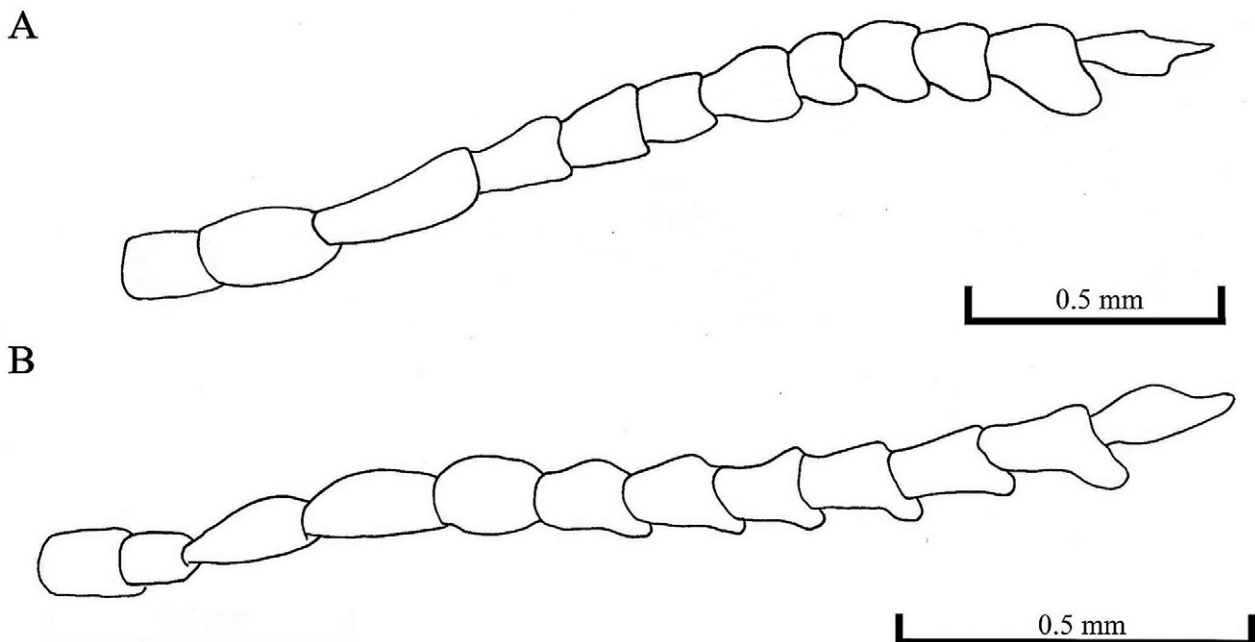
(Figs 4A, 5A, 5B, 5C, 6A, 6B, 7A, 7B, 8A, 8B, 9B, 10A, 10B, 11, 12, 13)

**Type.** Holotype. Male. TAIWAN: Beigan, Lienchiang County, Taiwan, 29-IV-2011, Jing-Han Hu. (ARI).

Paratypes: TAIWAN: Beigan, Lienchiang County, Taiwan, 4 males, 4 females, 8-V-2011, Hua-Te Fang. (ESRI, NMNS).

**Etymology.** This species is named after Beigan islet where it was collected.

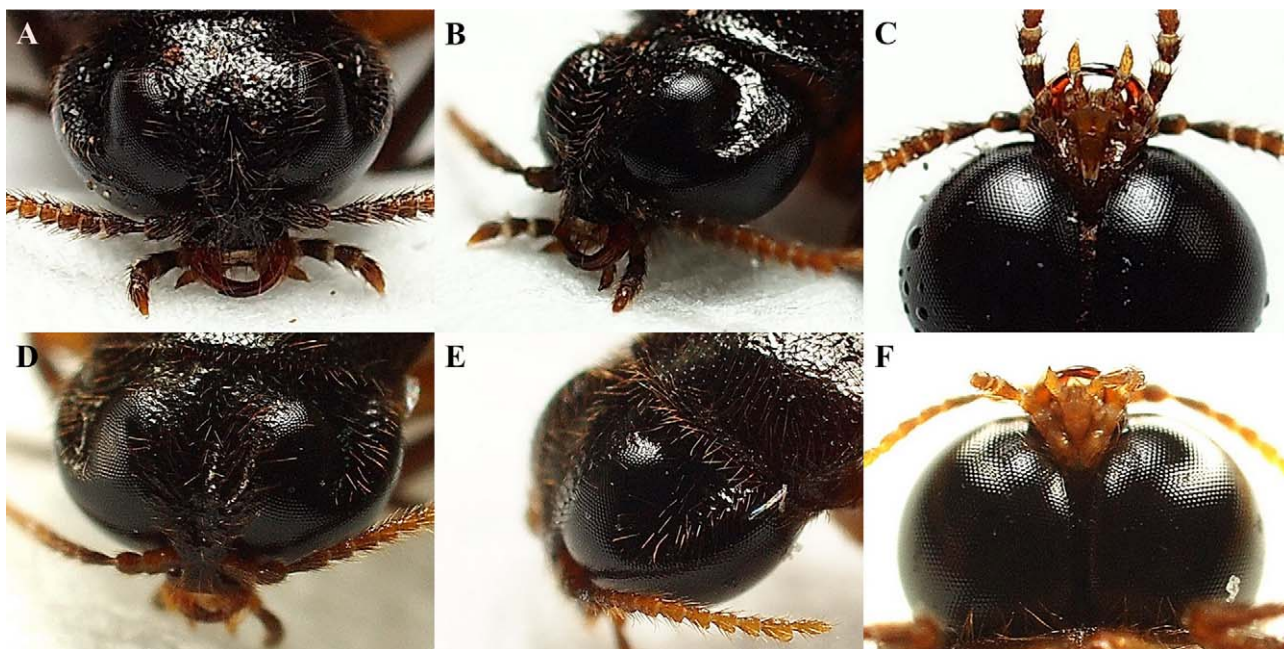
**Diagnosis.** This new species is similar to *R. ohbai* but differs in the male genitalia, the female luminous organ and the appendage of the female head. In the male genitalia of *R. beigansis*, the posterior basal piece is sharp and a space exists between the paramere and medial lobe; whereas in *R. ohbai*, the posterior basal piece is cylindrical and the paramere is almost attached to the medial lobe. The female in *R. beigansis* has three spot-like luminous organs, two on both sides of the body between the mesothorax and the 9<sup>th</sup> abdominal segment and one in the middle (dorsally) between them mesothorax and the 8<sup>th</sup> abdominal segments. This is significantly different from *R. ohbai* where the 9<sup>th</sup> abdominal segment has no luminous organs (Ohba *et al.*, 1996). In labial palps of *R. beigansis* also protrudes more at the position of the base attachment than in *R. ohbai*. Finally the number segments of the antennal and maxillary palps in *R. beigansis* are 5 and 4, but in *R. ohbai*, are 7 or 8 and 5.



**FIGURE 4.** Male antennae of *Rhagophthalmus* spp. A. *R. beigansis* Ho sp. nov.; B. *R. giallolateralus* Ho sp. nov.

**Male.** Body mostly dark brown or black, moderately shiny, pubescence light yellow, covering almost all the dorsal surface. Head capsule black, not glossy; compound eyes blackish; antennae brown to orange-yellowish; mandibles dark brown; maxillae dark brown; labrum brownish; pronotum dark brown, darker in center of disk and paler brown towards the sides; elytra dark brown, paler brown towards the base; ventral thorax orange-yellowish or yellowish brown; coxae, trochanters, and femora of all legs orange-yellowish or yellowish brown; tibiae and tarsi

brownish or dark brown; abdomen dark brown in anterior segments, then darker brown to blackish in the terminal segments, with orange-yellowish or yellowish brown posterior margins.



**FIGURE 5.** Male head of *Rhagophthalmus* spp. A. *R. beigansis* Ho sp. nov. (dorsal); B. *R. beigansis* Ho sp. nov. (lateral); C. *R. beigansis* Ho sp. nov. (ventral); D. *R. giallolateralus* Ho sp. nov. (dorsal); E. *R. giallolateralus* Ho sp. nov. (lateral); F. *R. giallolateralus* Ho sp. nov. (ventral).

Body spindle or oval-shaped when viewed from above, tiny punctures scattered on the dorsal side of elytra.

Head longer than wide, width of posterior margin wider than the apical margin of pronotum, but slightly narrower than the basal width of pronotum, odontoid protrusions surrounding whole surface of head besides appendages, more clearly and more closely clustered around compound eyes.

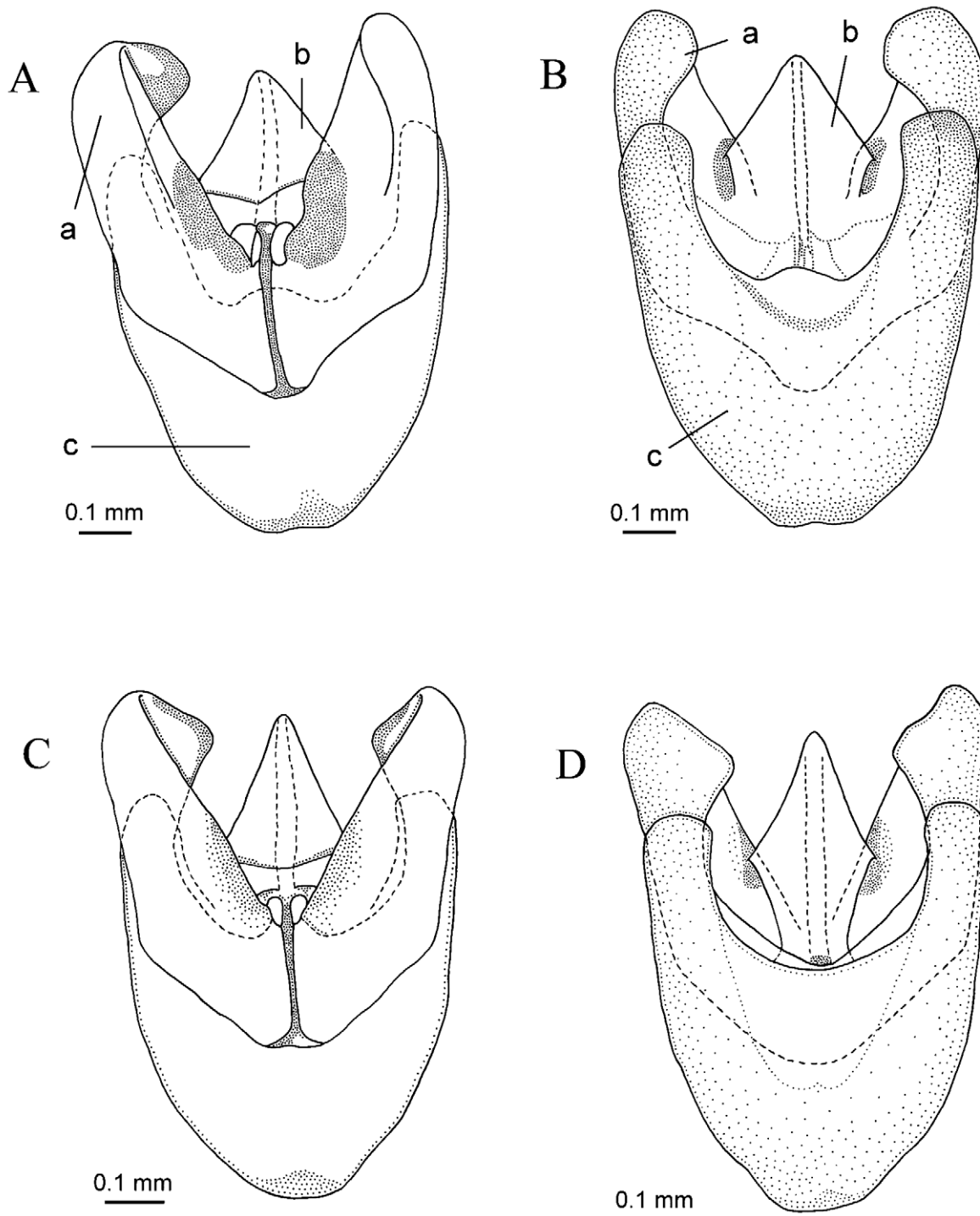
Antennae 12 segmented, 1.68 mm (range: 1.37–1.68) long; scape cylindrical; barrel-shaped pedicel longer than scape in length; 1st flagellar segment longer than remaining segments, slightly clavate, broader towards the apex; 2nd to 4th flagellar segments also slightly expanded towards their apices with flagellar segment 2 about half as long as 1, 3 and 4 subequal slightly shorter than 2, 5–8 more broadly expanded at their apices than preceding segments, approximately subequal in length and shorter than more basal segments; flagellar segment 9 weakly expanded to one side, (asymmetrically clavate) with a lens-like sensillum located at the antero-ventral side of the segment; 10th flagellar segment very narrow in apical half.

Pronotum approximately semi-circular from above, basal margin slightly less than the width across elytral humeri; apical margin protruding forwardly, broadly rounded and anterolateral corners are broadly rounded and obtuse; basal margin straight or slightly arcuate; posterolateral corners acute and pointed; separated odontoid protrusions spread all over the surface of pronotum, more densely aggregated over central disc, gradually reducing in number from center to edges; PW/HW 1.12, PW/PL 1.46, PW/PA 1.39, PW/EW 0.73, PW/EHW 0.95.

Elytra elongate slightly oval in outline, inner margins contiguous along their length and outer margins very slightly convex sided; contracting in apical 1/3 where the elytra are narrowest, discrete punctures and pubescence over surface of elytra; EL/PL 4.96, EL/EW 2.48, EW/EHW 1.30.

Legs slender, femur slightly enlarged at the middle; tibia straight, slightly thinner than femur; tarsus 5-segmented, pretarsus with 2 claws and no empodium or arolium obvious between the claws; HFL/HTL 0.95.

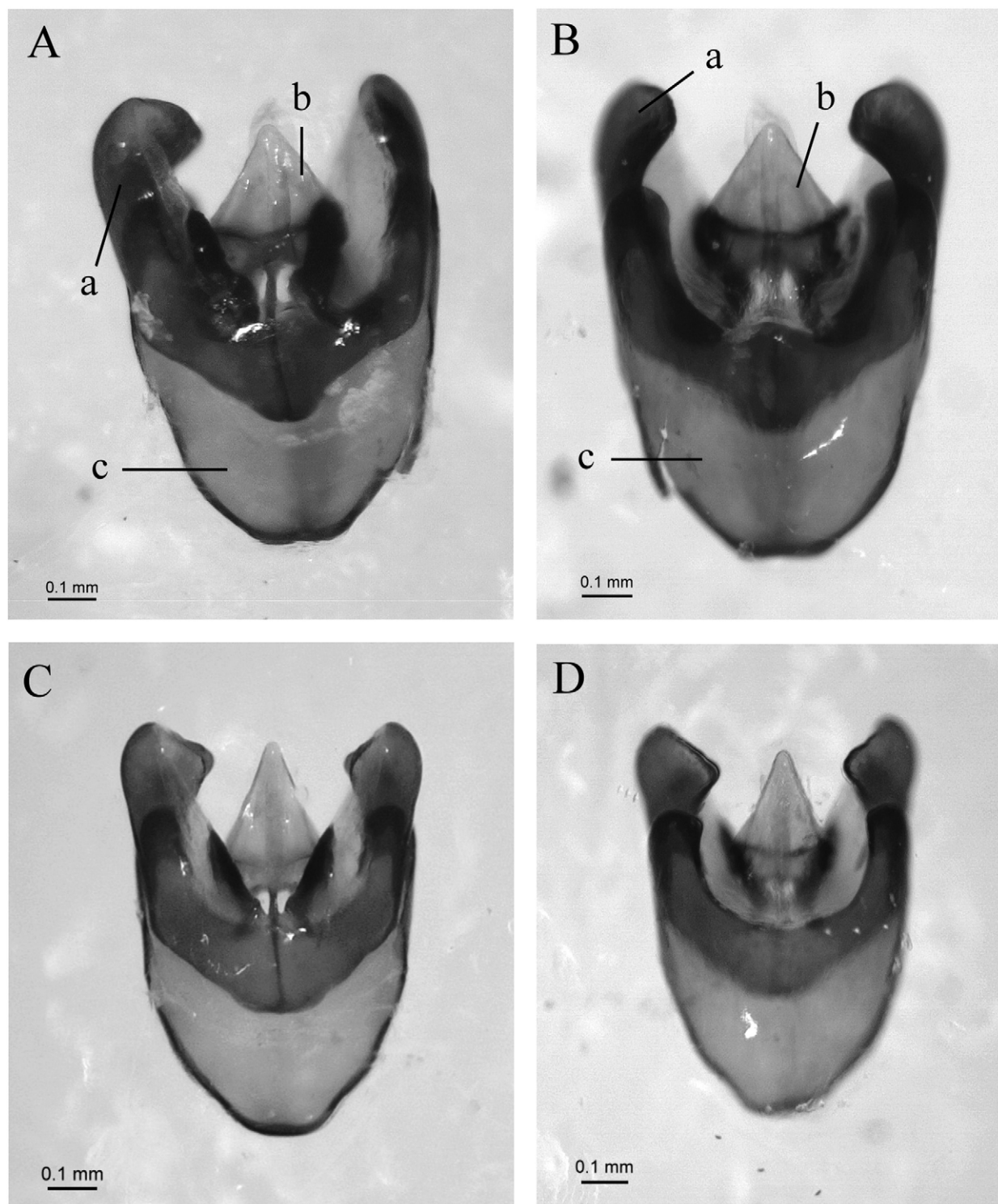
Male genitalia 0.95 mm long, trilobate, glabrous, with no punctures, odontoid protrusions and pubescence; basal plate large and well sclerotized, covering basal 1/2 of parameres when viewed from below, anterior margin blunt and round, slightly arcuate, lateral margins subparallel, with a broad straight vertical groove formed at the center of the apex; aedeagus subequal to parameres in length, tapering to a rounded apex; parameres with strongly developed apices inturning but not reaching to the aedeagus; clear dark banks at basal 1/3. Basal plate of male genitalia large and roughly straight in each margin, is a critical characteristic on identify.



**FIGURE 6.** Male genitalia of *Rhagophthalmus* spp. (a. paramere; b. medial lobe; c. base-piece). A. *R. beigansis* Ho sp. nov. (dorsal); B. *R. beigansis* Ho sp. nov. (ventral); C. *R. giallolateralus* Ho sp. nov. (dorsal); D. *R. giallolateralus* Ho sp. nov. (ventral).

**Female.** Larviform,  $17.26 \pm 2.97$  mm (range: 10.48–23.41,  $n=27$ ) in length,  $2.05 \pm 0.30$  mm (range: 1.44–2.97,  $n=27$ ) wide across basal margin of pronotum. Body color yellowish or brownish. Head small, with small compound eyes. Antennae 5 segmented, maxillary palp 4 segmented, labial palp 3 segmented. Labial palps are protruding beyond the anterior head margin. There are two sets of luminous organs in female. The first set is a large luminous

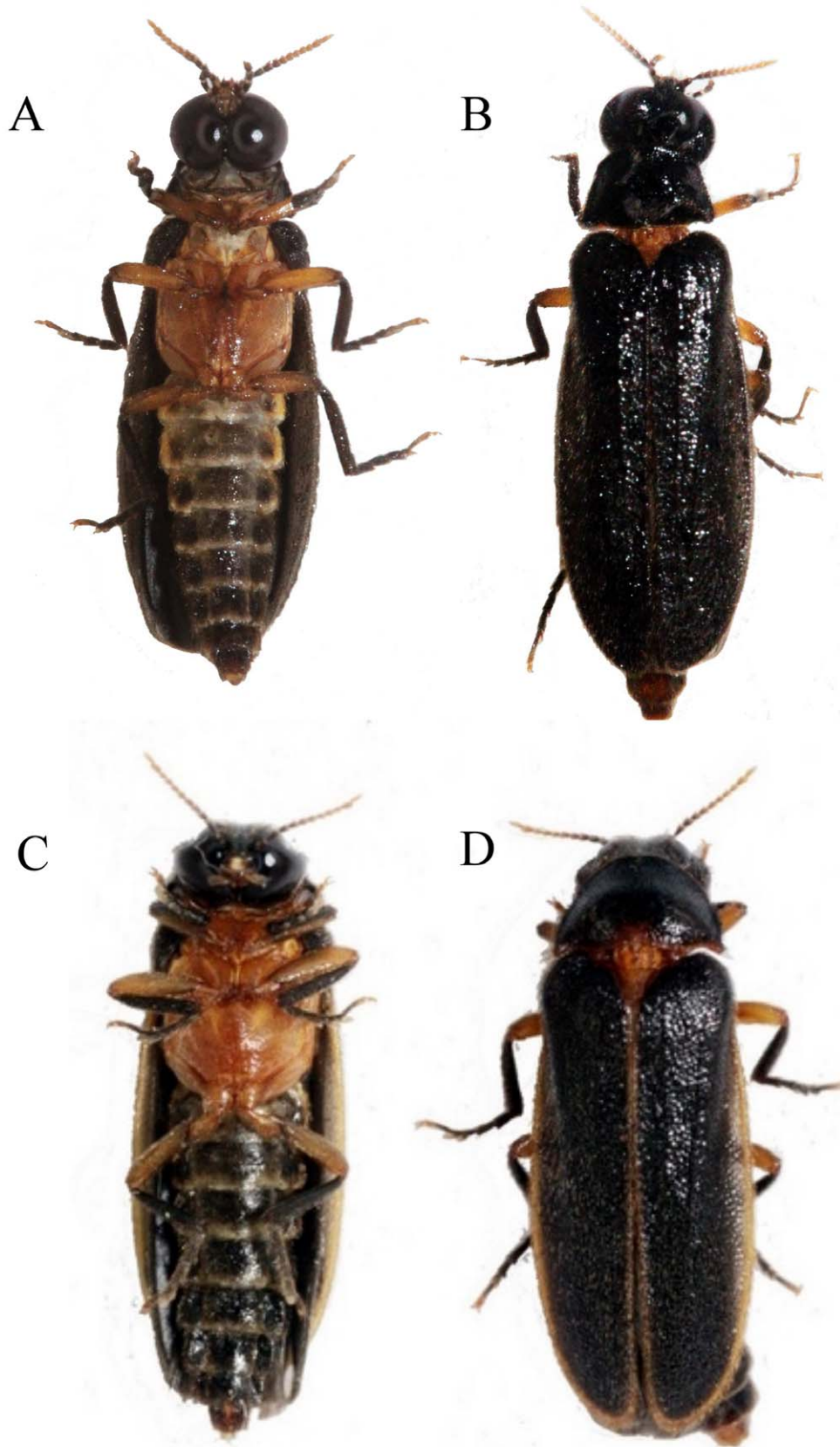
organ on 7th ventral abdominal segment and the second has three spot-like luminous organs on most segments. Each segment has three small spot-like luminous organs, two on both body sides from mesothorax to 9<sup>th</sup> abdominal segments and one on dorsal middle from mesothorax to 8<sup>th</sup> abdominal segments.



**FIGURE 7.** Photographs of male genitalia of *Rhagophthalmus* spp (a. paramere; b. medial lobe; c. base-piece). A. *R. beigansis* Ho **sp. nov.** (dorsal); B. *R. beigansis* Ho **sp. nov.** (ventral); C. *R. giallolateralus* Ho **sp. nov.** (dorsal); D. *R. giallolateralus* Ho **sp. nov.** (ventral).

**Measurement in mm.** BL: 8.86 (holotype)(range: 8.34–11.72); HW: 2.11 (range: 2.06–2.13); PL: 1.62 (range: 1.57–1.64); PA: 1.70 (range: 1.69–1.70); PB: 2.37 (2.37–2.37); PW: 2.37 (range: 1.2–2.69); EL: 8.04 (range:

8.00–8.11); EW: 3.24 (range: 3.20–3.25); EHW: 2.49 (range: 2.41–2.49); HFL: 1.81 (range: 1.79–1.86); HTL: 1.91 (range: 1.88–1.93).



**FIGURE 8.** Male of *Rhagophthalmus* spp. A. *R. beigansis* Ho sp. nov. (ventral); B. *R. beigansis* Ho sp. nov. (dorsal); C. *R. giallolaratus* Ho sp. nov. (ventral); D. *R. giallolaratus* Ho sp. nov. (dorsal).



A



B



**FIGURE 9.** Female of *Rhagophthalmus* spp. A. *R. giallolateralus* Ho **sp. nov.**; B. *R. beigansis* Ho **sp. nov.**

**Distribution.** TAIWAN: Beigan, Matzu Archipelago, Lienchiang County.

**Remarks.** Individuals of *R. beigansis* are nocturnal throughout their life cycle. The vegetation within the habitat is either thick grass or forest. Larvae prey on millipedes observed in the laboratory. Adults appeared in April to May, with the female displaying the luminous behavior between 7:00 to 8:30 p.m. (Fig. 10). After mating, the female laid  $101.4 \pm 26.26$  eggs (range: 68–151,  $n=10$ ) that were 0.8–1.1mm in size, oval-shaped and yellow-white in color. In addition, eggs were attended (Fig. 11).

***Rhagophthalmus giallolateralus* Ho **sp. nov.****

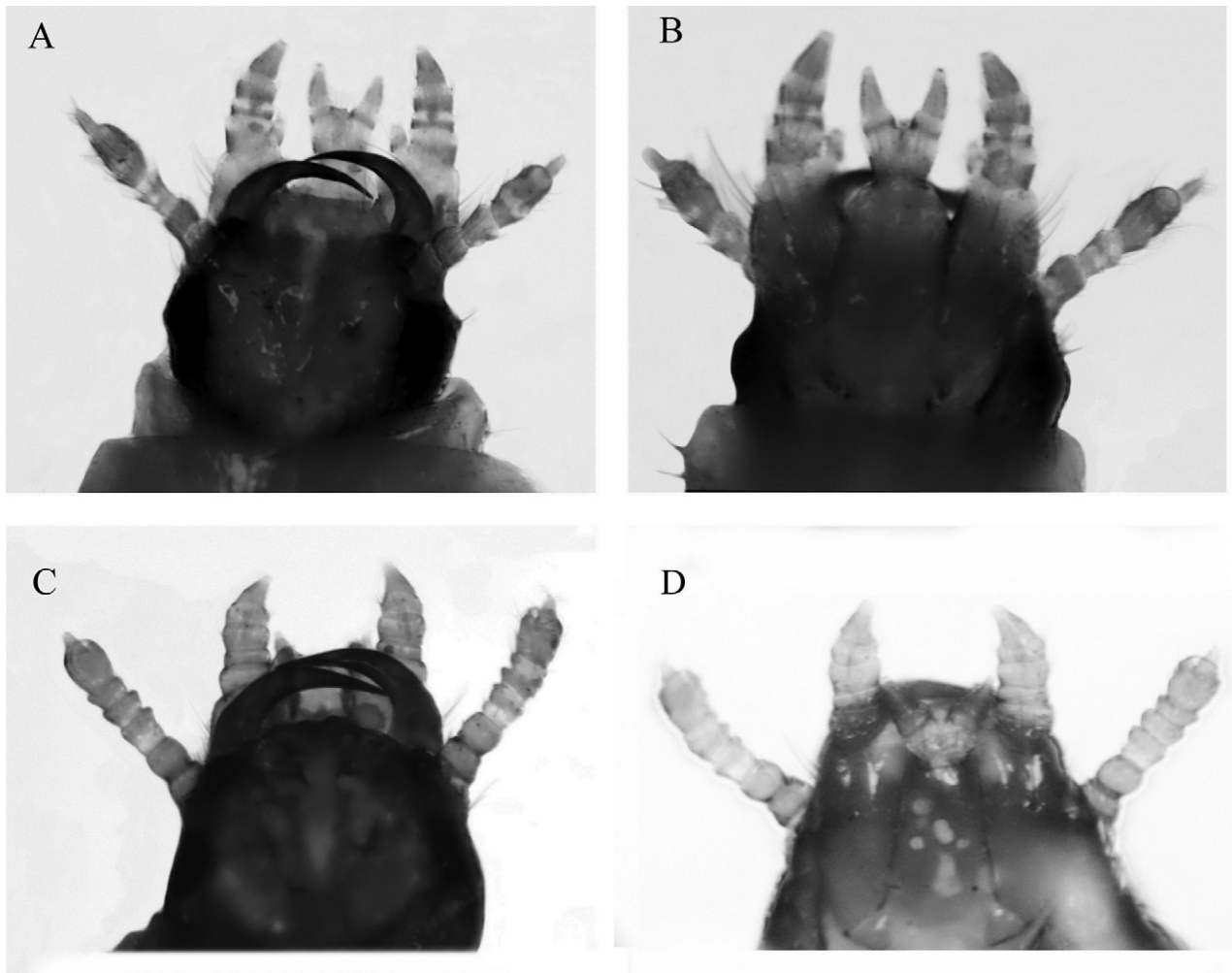
(Fig. 4B, 5D, 5E, 5F, 6C, 6D, 7C, 7D, 8C, 8D, 9A, 10C, 10D, 13)

**Type.** Holotype, TAIWAN: Dongjyu, Lienchiang County, Taiwan, 1 male (bathed samples), 26-IV-2010, Jian-Hua Wang. (ESRI);

Paratype: TAIWAN: Dongjyu, Lienchiang County, Taiwan, 2males, 2 females, 23-V-2011, Hua-Te Fang. (ESRI). Holotype is deposited in ARI; four paratypes are deposited in NMNS and ESRI.

**Etymology.** This species is named for its yellowish margin on the elytra. Giallo- means the color yellow and -lateralus means the lateral margin.

**Diagnosis.** The enlarged flagellar segments 4–9 are similar to *R. flavus* which occurs in Malaysia and Thailand, but in *R. flavus* a lens-like sensillum adheres to each enlarged segment (Kawashima and Satô, 2001). In Matzu Archipelago, *R. beigansis* and *R. giallolateralus* can be simply distinguished from males in the elytra, and the genitalia. The elytra of *R. giallolateralus* have a yellow margin which is lacking in *R. beigansis*. Also, there are clear differences in the number of segments of the antennae and maxillary palps, and in the relative position and shape of the female labial palps. In *R. beigansis* the antennae are 5-segmented, the maxillary palps are 4 segmented, and the labial palps (Fig. 9A, 9B) are slender and protrude beyond the anterior margin of the head. In *R. giallolateralus* the antennae are 8-segmented, the maxillary palps are 5 segmented, and the labial palps are wider and shorter, almost not reaching the anterior head margin.



**FIGURE 10.** Photographs of head of female *Rhagophthalmus* spp. A. *R. beigansis* Ho **sp. nov.** (dorsal); B. *R. beigansis* Ho **sp. nov.** (ventral); C. *R. giallolateralus* Ho **sp. nov.** (dorsal); D. *R. giallolateralus* Ho **sp. nov.** (ventral).

**Male.** Body mostly dark brown, dorsal surface covered with light yellow pubescence. Head and pronotum shiny. Head capsule black; compound eyes blackish, extending to upper and lower area, concave dorsally; antennae brown; mandibles dark brown; maxillae dark brown; labium dark brown to brownish; pronotum dark brown; elytra dark brown, with obvious orange-yellowish or yellowish brown on each margin; ventral surface of thorax orange-yellowish; coxae and trochanters orange-yellow, femora mainly brown to dark brown, orange-yellow at base and apex, tibiae and tarsi dark brown; abdomen dark brown to blackish, with light yellow or white markings along posterior margin of segments.

Body ovoid from above, blunt at front and thinnest behind, punctuation separated in dorsal view.

Head wider than long, semi-circular, widest at basal margin, but narrower than the apical and basal width of pronotum, punctures separated and surrounding antenna and mouthparts; compound eyes meniscus-like in dorsal-lateral view, concave basally.

Antennae 12-segmented, 1.77 mm in length; scape short and thick; pedicel, similar to scape in shape; 1st to 3rd flagellar segments filiform, weakly broad posteriorly with length longer than scape and pedicel; 4th to 9th flagellar segments slightly serrate, length and shape are almost the same, lens-like sensillum located at antero-ventral side of 9th flagellomere; 10th flagellomere (terminal segment) spindle shaped, slender, and tapering at its apex.

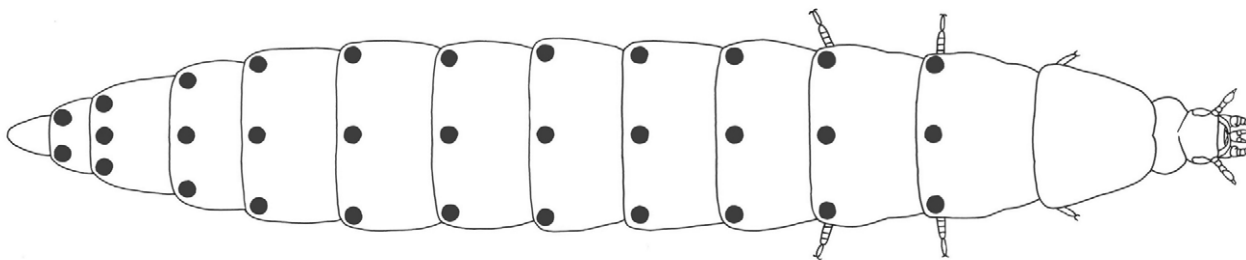
Pronotum transverse, semi-circular in dorsal view, anterior margin very broadly rounded with no distinct anterolateral corners and merging into the divergent lateral margins; right angles formed at the junction of lateral and basal margin, basal margin straight or weakly wavy, the widest part of pronotum, but a little narrower than humeral width of elytra; punctuation separated, spread uniformly over surface; PW/HW 1.14, PW/PL 1.51, PW/PA 1.17, PW/EW 0.68, PW/EHW 0.83.



**FIGURE 11.** Courtship behavior of female of *R. beigansis* Ho **sp. nov.** Female extends her abdomen and emits a continuous light from the apex of the abdomen. Red arrow represents the luminous organ.



**FIGURE 12.** Female of *R. beigansis* Ho **sp. nov.** lays egg mass and with the parental behavior. The luminescent organs are present as pairs on the sides of the mesothorax, metathorax, and the first nine abdominal segments of the female.



**FIGURE 13.** Model of female luminous organ for egg attendance in *Rhagophthalmus beigansis* Ho **sp. nov.** and *R. giallolateralus* Ho **sp. nov.**. Circles present the small spot-like luminous organs.

Elytra elongate, contiguous along inner margin, outer margins slightly expanded; extending to, or slightly before abdominal apex; lateral margin straight and nearly parallel-sided, width contracting over apical 1/7; punctuation separated, pubescence uniform over surface; EL/PL 5.37, EL/EW 2.40, EW/EHW 1.24.

Legs slender; femur with lateral margin straight and parallel-sided; tibia slightly conical, thicker at apex than base; tarsi 5-segmented, each segment clavate, with 2 claws apically, empodium or arolium not distinguished; HFL/HTL 0.96.

Male genitalia 0.9 mm in length, trilobed without punctuation and pubescence, basal plate large, covering the basal part of aedeagus and parameres in ventral view, basal margin arcuate and protruded towards base without angle, basal 1/2 of lateral margins dispersed, gradually separated towards apex, then subparallelled on apical 1/2; aedeagus shorter than parameres, bluntly cone-like, lateral margin arcuate, gradually converging towards bluntly rounded apex, grooves not apparent over surface; parameres dipper-like, apical parts protruding towards apex ventrally and surrounding the outer side of the aedeagus; basal margin narrow, forming an incisive arcuate-shape at the basal end, the outer lateral margin straight, converging rapidly towards inner side near apex, forming right angles at marginal junction, inner side straight in dorsal view, dark bands located at basal 1/2.

**Female.** Larviform,  $18.52 \pm 1.64$  mm (range: 16.32–20.44,  $n=9$ ) in length,  $2.35 \pm 0.17$  mm (range: 2.18–2.72,  $n=9$ ) wide at basal margin of pronotum. Body yellowish or brownish. Head small, with small compound eyes. Antennae 8-segmented, maxillary palp 5-segmented, labial palp 3-segmented. Labial palps are tightly shrunk. There are two sets of luminous organs. The first set is a large luminous organ on 7th ventral abdominal segment and the second consists of three spot-like luminous organs on most segments. Two on both body sides extending from the mesothorax to the 9<sup>th</sup> abdominal segment, and one dorsally from the middle of the mesothorax to the 8<sup>th</sup> abdominal segment.

**Measurement in mm.** BL: 10.99 (holotype) (range: 10.84–11.02); HW: 2.35 (range: 2.33–2.38); PL: 1.77 (range: 1.77–1.82); PA: 2.29 (range: 2.29–2.31); PB: 2.68 (2.68–2.99); PW: 2.68 (range: 2.68–2.74); EL: 9.51 (range: 9.51–10.17); EW: 3.97 (range: 3.91–3.97); EHW: 3.21 (range: 3.21–3.30); HFL: 2.12 (range: 2.11–2.15); HTL: 2.20 (range: 2.12–2.20).

**Distribution.** TAIWAN: Dongjyu, Matsu Archipelago, Lienchiang County.

**Remark.** The vegetation in habitats of *R. giallolateralus* consists of thick grass mainly, or of forests or lofty herbs, e.g. *Miscanthus floridulus* (Labill.). Adults occur in February to April, females are active between 6:30 and 8:00 at night. The behavioral display, fecundity and characteristics of the eggs are similar to *Rhagophthalmus beigansis*.

#### Discussion

Rhagophthalmidae species have little capacity to migrate due to the wingless form of adult females, and it would be expected that isolated populations like the two described here would diverge significantly. Two *Rhagophthalmus* species addressed here were found in Beigan islet and Dongjyu islet separately. These islets are less than 40 km apart, but no population of these species was found in other neighboring islands. With virtually no capacity to migrate the species are totally dependent on the existing habitat of these islets and conservation of these fragile environments is thus very important. Habitat fragmentation and human activities have already been identified as the major stress to such island populations (Atkinson, 1989; Hess, 1990). Since the populations of these two *Rhagophthalmus* species were distributed in a somewhat fragmentary nature across the islands, further study could evaluate the habitat fragmentation.

Wittmer and Ohba (1994) discovered *R. ohbai* in Iriomote island. Because of its distinctive distribution, ecological habitat, and biological features, the Ministry of the Environment, Japan designated *R. ohbai* as an emergency conservative species. The species was then investigated in a series of related studies (Ohba, 1997). The islets of Beijan and Dongjyu, are only 6.44 and 2.64 km<sup>2</sup> in area. Because of the instability and vulnerability in island ecology, and the dependence of *Rhagophthalmus* on the existing habitat, further investigation of the two *Rhagophthalmus* distributed in Matsu Archipelago is necessary with the aim of protecting the fragile environment.

Few investigations thus far have focused on the behavior, habitat and breeding methods of Rhagophthalmidae (Ohba *et al.*, 1996; Ohba, 1997, 2004). Male genitalia have to date presented the most useful characteristics for identification of *Rhagophthalmus* species (Wittmer & Ohba, 1994; Kawashima & Satô, 2001; Kawashima & Sugaya, 2003; Li *et al.*, 2008). Males, being nocturnal and non-luminous are difficult to collect (Li *et al.*, 2008). Increased awareness of the genus and its distribution and improved collection methods should hopefully address this situation.

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