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A New Species of the Genus *Rapisma* (Insecta: Neuroptera: Ithonidae) from Taiwan

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A new species of the genus *Rapisma*, *Rapisma taiwanense* sp. nov., is described from Taiwan. The new species represents the first of its genus and family recorded in Taiwan. By collecting both genders, the hypothesis of sexual dimorphism is examined. This finding also expands the easternmost distribution border of *Rapisma* in the Oriental region. This discovery can be attributed to the development of social media which helps researchers access rare species.

Key words: Taxonomy, New species, Neuroptera, Ithonidae, Taiwan.

BACKGROUND

The family Ithonidae is a rare and small group of the order Neuroptera, with a large body size and moth-like appearance. To date, 45 extant species in 10 genera have been described worldwide (Oswald 2021). The genus *Rapisma* currently contains 22 valid species, representing the only extant ithonid genus in Asia (Liu 2018 2020).

Ithonidae contain three families in the previous classification, including Ithonidae, Polystoechotidae and Rapismatidae, but some studies suggested that they may not be a monophyletic group (Penny 1996; Winterton and Markakin 2010). Barnard (1981) revised the family Rapismatidae and provided 8 diagnostic characters to distinguish it from Ithonidae. Subsequently Penny (1996) described a new genus *Adamsiana*; however, he found that the genus failed to accommodate either of the above two families and suspected the validity of the Rapismatidae. After that, Winterton and Markarkin (2010) presented the phylogeny of above-mentioned families based on molecular and morphological characters. Their results showed a clear clade of three Australian genera in the family Ithonidae and the remaining genera (including *Rapisma*) nested into an expanded Polysteochotidae. Eventually the authors combined the two families (Polystoechotidae and Rapismatidae) in a broad sense of Ithonidae.

In recent years, the Asian genus *Rapisma*, particularly the Chinese fauna, has been revised by Liu (2018). *Rapisma* lives in a mid- and high-altitude deciduous forest in the Oriental region. Until now, *Rapisma* has been recorded in China, India, Indonesia, Malaysia, Myanmar, Nepal, and Thailand (Barnard 1981; Barnard and New 1985 1986; New 1985; Liu 2018 2020; Liu et al. 2018). They are difficult to collect in the field due to their well-concealed life history and behavior. Therefore, there are very few specimens in collection. Thirteen *Rapisma* species were described based on a single specimen for each species. As a result, the distribution pattern of the genus is only based on the records of a few specimens. Additionally, *Rapisma* shows sexual dimorphism and thus causes taxonomic problems (mainly synonyms). For example, *Rapisma zayuanum* Yang, 1993 and *R. xizangense* Yang, 1993 were recognized as two species with apparently different appearances, and it turned out that both are conspecific based on molecular evidence (Wang et al. 2013).

The bionomics of the Ithonid remain mysterious. So far, what we know is limited to the studies of three genera: *Ithone*, *Polystoechote* and *Oliarces*. Ithonid larvae look like the larva of superfamily

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Scarabaeoidea and live in the soil (Grebennikov 2004). There is a debate on whether they are phytophagous or sarcophagous. Tillyard (1922) inferred that ithonid larvae are sarcophagous. He noticed scarabaeid larvae often coinhabit with larvae of *Ithone fusca* in the field. By settling them in the same container, all scarabaeid larvae were killed, with one sucked dry, some partly sucked, and the rest wounded. However, Gallard (1932) found that the larvae of *I. fusca* only sucked the liquid from dead scarabaeid larvae, rather than attacking the living scarabaeid larvae. Also, larvae of *I. fusca* can only live for 2 months fed by the body of scarabaeid larvae, which is much shorter than *I. fusca* fed by only soil and bark or decaying bark with small Hempitera and woodlice or slaters, both of which can live 6 to 12 months. Besides, Faulkner (1990) observed that all instar larvae and empty cocoons of *Oliarces clara* were around *Larrea tridentata* (Zygophyllaceae), and Penny et al. (1997) found pupal skins of *Platystoechotes* around the roots of *Calocedrus decurrens* (Cupressaceae). Their observations support the general thought that ithonid larvae are phytophagous (Grebennikov 2004).

In Taiwan, the earliest record of Ithonidae was documented in the insect faunistic survey (Tang et al. 2010); however, no voucher specimens were available, leaving the present authors unable to clarify its identity. Later on, a few more photo records were posted on social-media platforms. The first one was posted on the Facebook group "Neuropterida of Taiwan" in 2017. An additional three photos were taken in different localities in 2020. Such available records with clear locality information motivated us to collect them. Luckily, we collected both gender specimens in northern Taiwan in June about 1000 meters above the sea level.

In this paper, we provide descriptions of *Rapisma taiwanense* sp. nov. and discuss whether sexual dimorphism exists. In addition, specimens of both sexes were confirmed to be the same species through molecular identification. This finding also expands the easternmost distribution border of *Rapisma* in the Oriental region.

MATERIALS AND METHODS

Specimen collection and examination

Specimens for the present study were collected by net-sweeping and deposited in the National Museum of Natural Science (NMNS) and the Museum of Entomology, National Chung Hsing University (NCHU), Taichung, Taiwan. A whole leg was cut from each fresh specimen and subsequently placed directly into 95% EtOH and stored at -20°C for DNA extraction.

Genitalia preparations were made by clearing the apex of the abdomen in a hot 10% potassium hydroxide (KOH) solution for 5–10 min. After rinsing the KOH with water, the apex of the abdomen was transferred to glycerin for further dissection and examination. Habitus photographs of adults were taken by Nikon 810D digital camera with Nikon AF-S Micro Nikkor 60mm lens. The genitalic photographs were taken by Leica MZ125 microscope with Canon EOS 80D digital camera and Leica Z16APO microscope with Leica DMC5400 CMOS camera using the LAS software (Version 4.13.0) and were then stacked using the Helicon Focus software (Version 7). The terminology of the genitalia generally follows Aspöck and Aspöck (2008) and Liu (2018).

Molecular analysis

Total genomic DNA was extracted from the legs using the QuickExtract™ DNA Extraction Solution (QE0905T, Lucigen, USA) according to the manufacturer's instructions. Fragments of *COI* were amplified by polymerase chain reactions (PCR). The reaction was conducted in a final volume of 25 μL consisting of 12.5 μL Fast-Run™ 2X Taq Master Mix With Dye (PT-TMM228-D, Protech Technology Enterprise, Taiwan), 10.5 μL of ddH_2O, 0.5 μL (10 μM) of each of the primers and 1 μL DNA template. Primer sequences used to amplify and sequence the *COI* gene fragments were Ram1490F (5'–TTTCAACTAACCATAAAGATATTGG–3') and Ram2198R (5'–TAAACTTCAGGATGCCCAAAAAA TCA–3'). The PCR amplifications were run under the following conditions: initial denaturation at 95°C for 30 seconds, followed by 40 cycles of 10 seconds at 95°C, 50 seconds at 47°C, and 2 minutes at 65°C; final extension at 65°C for 10 minutes. The PCR products were subjected to electrophoresis in 1% agarose gel and stained with HealthView™ Nucleic Acid Stain (GN-NAS-100, Genomics, Taiwan) to confirm amplification.

The *COI* sequences were proof-read and aligned into contigs by overlapping both forward and reverse sequences with Clustal W (Thompson et al. 1994) in BioEdit 7.2.5 (Hall 1999). All sequence data were deposited into GenBank (accession number OM936905, OM936906, OM936907). We also compared the sequences with another montane lacewing *Rampisma xizangense* (GenBank: KF626446, KF626447) that has a similar appearance from the National Center Biotechnology Information (NCBI, https://www.ncbi.nlm.nih.gov/). The pairwise genetic distance was computed based on *p*-distance with MEGA 7.0.21 (Kumar et al. 2016).

RESULTS

TAXONOMY

Order Neuroptera Linnaeus, 1758
Family Ithonidae Newman, 1853
Genus *Rapisma* McLachlan, 1866

Rapisma McLachlan, 1866: 353.
Type species: *Hemerobius viridipennis* Walker, 1853: 276 (original designation).
Generic characters: See Liu (2018).
Distribution: China, India, Indonesia, Malaysia, Myanmar, Nepal, Thailand, Taiwan.

Rapisma taiwanense sp. nov. Hsiao and Lai

(Figs. 1–3)
urn:lsid:zoobank.org:act:9B3A2383-882E-4F6C-A787-0DBA645B70B3

Material examined: Holotype: male, Taiwan, Xinbei, Mt. Badaoer, 1110 m, 24.852859°N, 121.514524°E, 2020-VI-26, Shih-Hsiang Hsiao (NMNS). Paratypes: 1 female, same collecting site as holotype, but collecting by Kai-Wei Chan (NMNS); 1 female, Taiwan, Hsinchu, Beidelaman Trail, 2018-VI-25, Jhen-Ruei Lin and Yu-Chun Lin (NCHU).

Etymology: The specific epithet is named after the type locality: Taiwan.

Diagnosis: Body and forewings generally greenish in both male and female. Forewing with sparse small grayish brown spots in the female. Head medially with dark markings on vertex. Antenna moniliform. In the male, gonocoxites 9 paired, glabrous; each with subtrapezoidal lobe, which dorsally bears a subtriangular accessory lobe, and with a slender, arcuately curved lateral arm; fused gonocoxites 11 generally arched, anteriorly broadly concaved, posteriormedially truncate, posteriorlaterally produced in dorsal view; gonostyli 11 with a pair of dorsal lobe and a single ventral lobe; each dorsal lobe subtriangular, distally and posterolaterally with a few long setae; ventral lobe flat, distally with a pair of tufts of long setae.

Description: Male (Fig. 1A, C). Body length 17.1 mm; forewing length 23.7 mm, hindwing length 21.4 mm. Head nearly semiglobular, largely retracted under prothorax, barely visible in dorsal view. Head yellowish; vertex dark brownish; a narrow

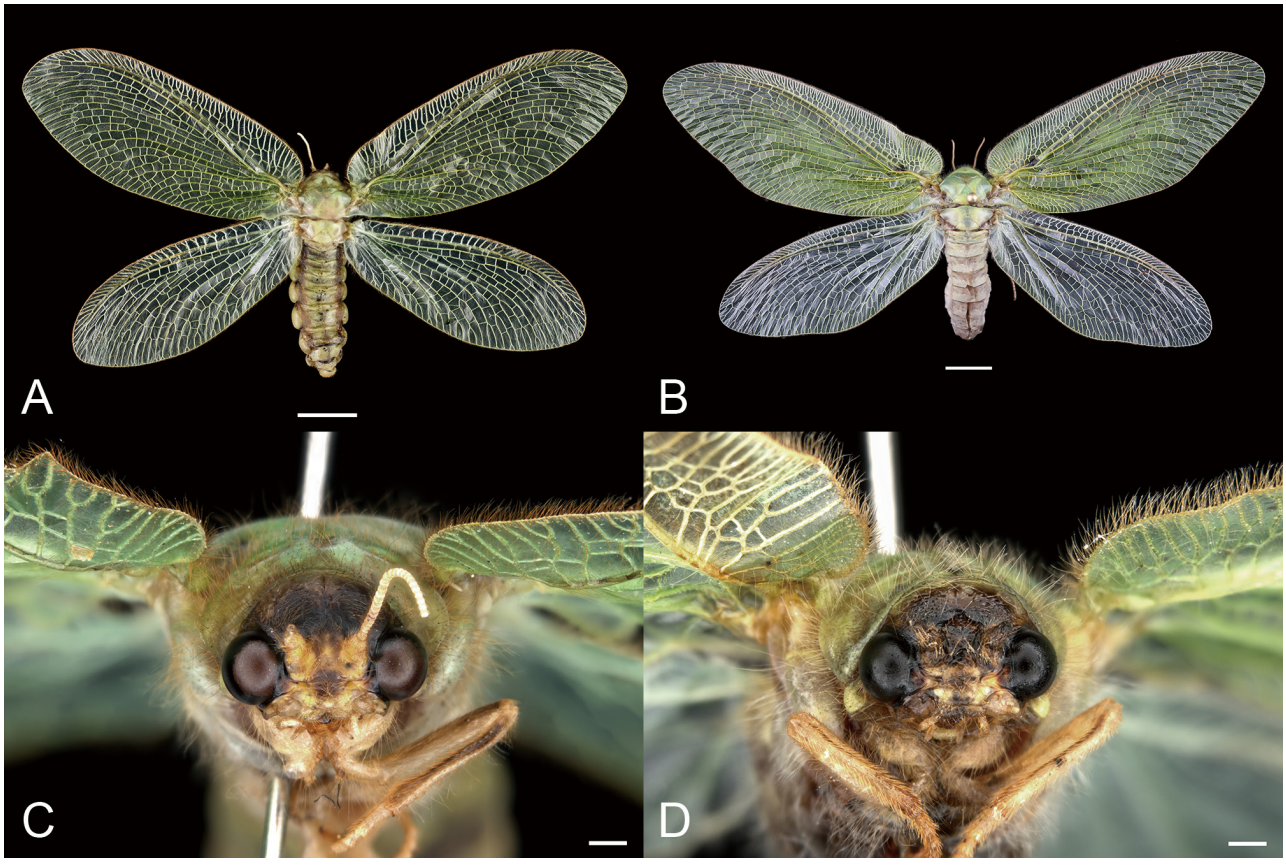

Fig. 1. *Rapisma taiwanense* sp. nov. (A) holotype male, habitus photo; (B) paratype female, habitus photo; (C) head, frontal view, holotype male; (D) head, frontal view, paratype female. Scale bars: A–B = 5.0 mm; C–D = 0.5 mm.

blackish stripe present around compound eye; two blackish parallel stripes present between antennae; frons and clypeus medially with a brown marking. Compound eyes blackish brown; EI ratio 0.8. Antenna partly damaged, nearly moniliform, short, at least 3.91 mm long, with at least 28 flagellomeres; yellowish throughout; a black spot on scape in ventral part. Mandibles with tips black. Thorax greenish, with few brownish markings. Legs yellowish throughout; pretarsal claws reddish brown with base yellowish. Forewing greenish, immaculate. Trichosors present only along costal margin. A proximal nygma present between RP+MA and MP, brownish. RP with 8 pectinate branches. Hindwing paler than forewing. A proximal nygma present between RP+MA and MP, greenish. RP with 7 pectinate branches. Abdomen yellowish green, with terga brownish in margin.

Male genitalia (Fig. 2): Tergum 9 moderately setose. Sternum 9 nearly as long as tergum 9, about 1.5 times as wide as long, subtrapezoidal. Ectoprocts nearly as long as tergum 9; callus cerci present. Gonocoxites 9 paired, glabrous; each with subtrapezoidal lobe, which dorsally bears a subtriangular accessory lobe, and with a slender, arcuately curved lateral arm. Fused gonocoxites 11 generally arched, anteriorly broadly concaved, posteriormedially truncate, posteriorlaterally produced in dorsal view. Gonostyli 11 with a pair of dorsal lobes and a single ventral lobe; each dorsal lobe subtriangular, distally and posterolaterally with a few long setae; ventral lobe flat, distally with a pair of tufts of long setae.

Female (Fig. 1B, D). Body length 17.4–21.4 mm; forewing length 25.4–31.3 mm, hindwing length 23.0–26.8 mm. Head nearly semiglobular, largely retracted under prothorax, barely visible in dorsal view. Head pale yellowish green; a bow-tie-like blackish brown marking present on anterior portion of vertex and a narrow blackish stripe present around compound eye; frons medially with a brown marking. Compound eyes blackish brown; EI ratio 0.84. Antenna moniliform, 6.15 mm long, with 40 flagellomeres; pale yellowish, but on distal 1/5 of flagellum slightly darker. Mandibles with tips dark brown. Thorax entirely greenish, metathorax slightly paler than pro-

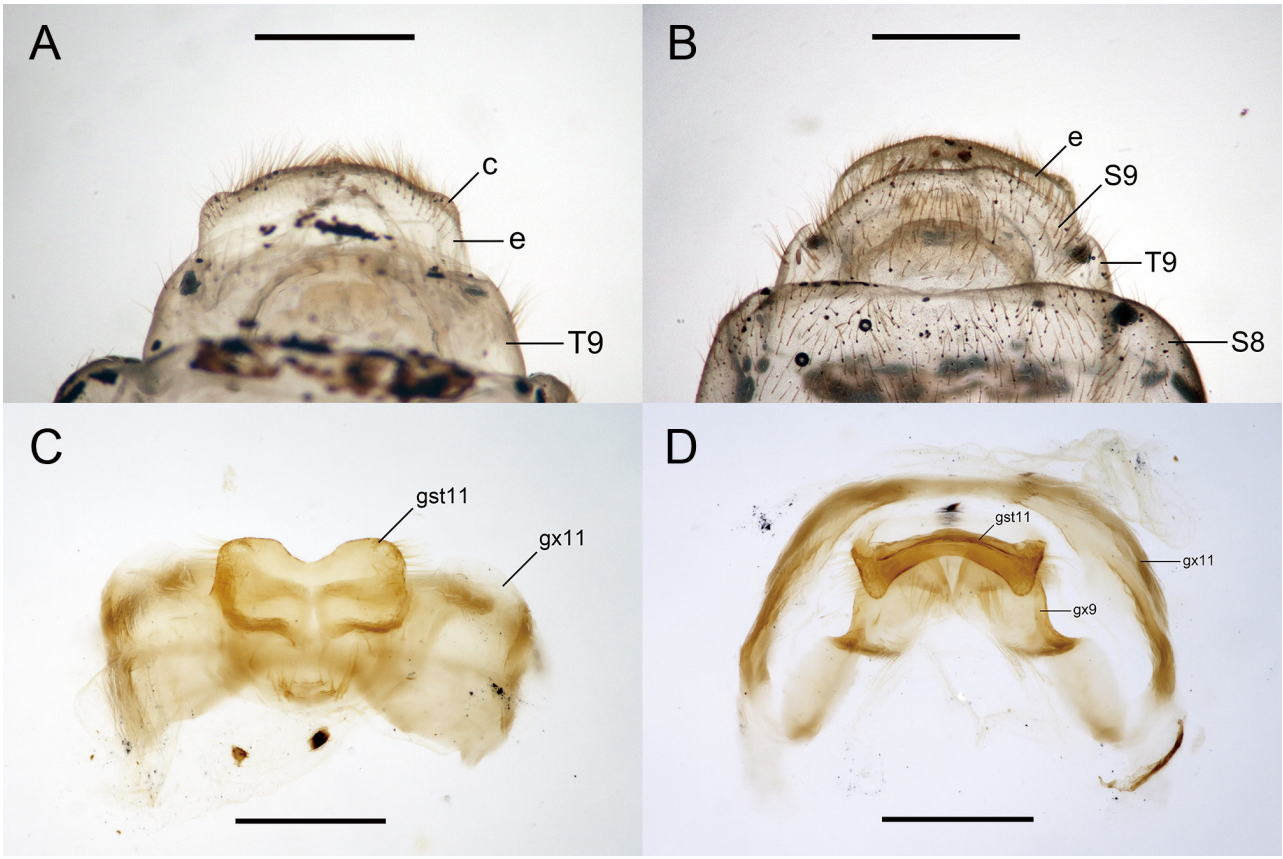

Fig. 2. *Rapisma taiwanense* sp. nov. (A) male genitalia, dorsal view; (B) male genitalia, ventral view; (C) male gonocoxites and gonostyli 11, dorsal view; (D) male gonocoxites and gonostyli 11, ventral view. c, callus cercus; e, ectoproct; gx, gonocoxite; gst, gonostylus; T, tergum; S, sternum. Scale bars: A–B = 1.0 mm; C–D = 0.5 mm.

and mesothorax, without any distinct markings. Legs pale yellowish; slightly darkened on apices of tibiae and all tarsomeres; pretarsal claws reddish brown with base yellowish. Forewing greenish, with sparse small grayish brown spots. Trichosors present only along the costal margin. A proximal nygma present between RP+MA and MP, blackish, covered with a blackish spot. RP with 7 pectinate branches. Hindwing much paler than forewing, immaculate. A proximal nygma present between RP+MA and MP, pale greenish. Costal space with a few interlink veinlets among costal crossveins on proximal half. RP with 8 pectinate branches. Abdomen yellowish green.

Female genitalia (Fig. 3): Sternum 7 large, posteromedially with a narrow groove. Gonocoxites gonapophyses 8 fused, broadly subtrapezoid, notched distally, with a pair of weak projections and a weak median projection. Gonocoxites 9 nearly semicircular in lateral view; a pair of setose ovoid gonapophyses 9 present posteriad gonocoxites 8 and beneath gonocoxites 9. Ectoprocts nearly semicircular in lateral view.

Distribution: The three specimens in the type series were found in Xinbei and Hsinchu, northern region of Taiwan at middle altitude.

Remarks: This species is similar to *Rapisma xizangense* Yang, 1993. The former has gonocoxites 9 with subtrapezoidal lobes, while the latter has gonocoxites 9 with ovoid lobes. Observing the specimens of both genders, it seems that this new species shows sexual dimorphism. The female forewings have lots of sparse small grayish brown spots while the male absent.

Molecular: The present study generated 5 sequences of 658 bp each, with an average nucleotide composition of 42.0% thymine (T), 15.3% cytosine (C), 27.9% adenine (A), and 14.8% guanine (G). The above *COI* sequences belong to 2 species of *Rapisma*. Intraspecific distances ranged from zero to 0.15%. Interspecific distances ranged between 9.27% and 9.42%. The genetic distance of *COI* between male and female is apparently smaller than 1%, which indicates likely intraspecific divergence.

DISCUSSION

No phylogenetic analysis has been done on the genus *Rapisma* because of its rarity and insufficient molecular data. We can only refer to Barnard's classification (1981) which classified *Rapisma* as three groups by seven characters. It should be noted that the derived state is decided via comparison with the superfamily Osmyloidea, consisting of Ithonidae, Polystoechotidae, Dilaridae, Osmylidae, and Nevrorthidae at that time (Barnard 1981). However, even though the phylogenetic relationship among families of Neuroptera is still debated, Ithonidae is either considered a member of or sister to the superfamily Myrmeleontoidea (*e.g.*, Wang et al. 2017; Winterton et al. 2018; Vasilikopoulos et al. 2020). Here, we still adopt Barnard's classification (1981) in order to compare other *Rapima* species. The new species should be placed in a putative monophyletic group with short antennae (Barnard 1981; Liu 2020), *i.e.*, *R. viridipenne* (Walker, 1853), *R. nepalense* Barnard, 1981, *R.*

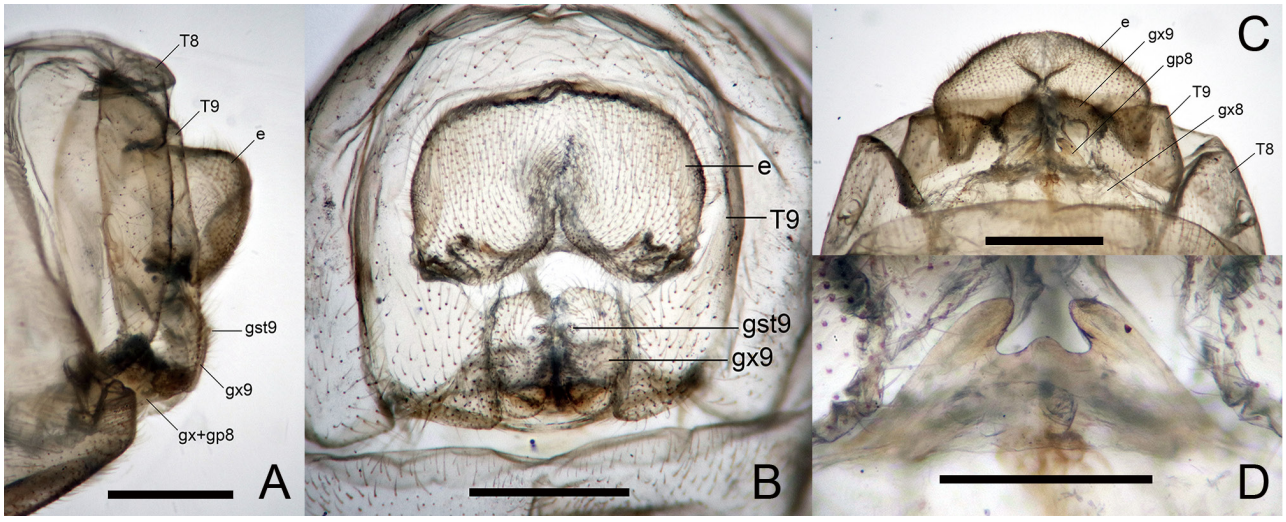

Fig. 3. *Rapisma taiwanense* sp. nov. (A) female genitalia, lateral view; (B) female genitalia, caudal view; (C) female genitalia, ventral view; (D) female gonapophyses 8, ventral view. e, ectoproct; gx, gonocoxite; gp, gonapophysis; gst, gonostylus; T, tergum. Scale bars: A–C = 1.0 mm; D = 0.5 mm.

almoranum Barnard, 1981, *R. xizangense* Yang, 1993, *R. changqingense* Liu, 2018, *R. yanhuangi* Yang, 1993, and *R. weixiense* Liu, 2020. In previous records, the *Rapisma* was distributed in China, India, Indonesia, Malaysia, Myanmar, Nepal, Thailand (Barnard 1981; Barnard and New 1985 1986; New 1985; Liu 2018 2020; Liu et al. 2018). Now, the genus *Rapisma* has been reported for the first time in Taiwan, considerably extending its known easternmost range, which was originally Quoin Hill in Malaysia (New 1985).

Entomological research in Taiwan has been developing ever since Japanese Rule. However, surprisingly, such large-sized insects were not discovered until recently. The possible reasons are likely due to their well-concealed life history including poorly known bionomics and ephemeral occurrence in the adult stages. The ithonid seems to have a short-living imago stage with few days and a short emerging period which is about 1 to 2 months (Faulkner 1990; Tillyard 1922). Our field data and other photo records from Facebook also agreed with the short occurrence in adult stages. Additionally, their well-concealed appearance makes them cryptic in the habitat (Fig. 4). On the other hand, the recent increasing primary records and real-time communication channels mediated by the social networks (such as Facebook group, Neuropterida of Taiwan) make the rare species visible. The information of precise locality and occurrence period led us collect the specimens successfully and confirmed the existence of Ithonidae. Citizen science and social networking make the taxonomy of Taiwanese Ithonidae move a step forward.

CONCLUSIONS

A new species of *Rapisma* was described from Taiwan, which is also the newly-recorded family Ithonidae of Taiwan. It belongs to the putative monophyletic group with short antennae. This discovery expands the easternmost boundary of genus *Rapisma*. The character of sparse small grayish brown spots on forewings of females is absent on males, which seems to indicate sexual dimorphism. The finding of this rare group should be attributed to developed social networks.

Fig. 4. Live specimen and habitat of *Rapisma taiwanense* sp. nov. (A) paratype female adult, dorsal view. Photo by Yu-Chun Lin; (B) habitat of *R. taiwanense* in Beidelaman Trail, Hsinchu.

List of abbreviations

EI, E being the maximum eye diameter and I being the minimum interocular distance.
MA, media anterior.
NCHU, National Chung Hsing University, Taichung, Taiwan.
NMNS, National Museum of Natural Science, Taichung, Taiwan.
NTU, National Taiwan University, Taipei, Taiwan.
RP, radius posterior.

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Authors' contributions: SHH collected the specimens, photographed the specimens and wrote the manuscript. BCL designed the study, processed the molecular analysis, dissected the specimens, photographed the genitalia and prepared figures. All authors participated in revising the manuscript and approved the final manuscript.

Competing interests: All authors declare that they have no conflict of interests.

Availability of data and materials: All specimens are deposited in museum collections stated in the paper. All DNA sequences data has been deposited in GenBank (accession number OM936905, OM936906, OM936907).

Consent for publication: All authors consent to the publication of this manuscript.

Ethics approval consent to participate: No applicable.

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