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Taxonomic revision of the antlion tribe Myrmeleontini (Neuroptera: Myrmeleontidae) of Taiwan

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Abstract. The species of the antlion tribe Myrmeleontini from Taiwan are revised. In total, nine species from two genera *Baliga* (2 spp.) and *Myrmeleon* (7 spp.) are redescribed and an identification key is provided. One new combination, *B. brunneipennis* (Esben-Petersen, 1913) comb. nov., and one new synonymy, *M. alticolus* Miller & Stange, 1999 syn. nov. = *B. brunneipennis* (Esben-Petersen, 1913), are proposed. *Myrmeleon wangi* Miller & Stange, 1999 stat. rev. is resurrected from the synonymy as a valid species under *M. trivialis* Gerstaecker, 1885. In addition, four species groups are proposed for *Myrmeleon*: the *M. tenuipennis*, *M. littoralis*, *M. wangi* and *M. punctinervis* groups. A phylogenetic analysis of the COI gene of the Taiwanese Myrmeleontini species is also provided.

Keywords. Antlions, Myrmeleontidae, Myrmeleontini, Taiwan, taxonomic revision.

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Introduction

The antlion tribe Myrmeleontini Latreille, 1802 is one of the most diverse tribes within Myrmeleontidae Latreille, 1802, with more than 200 species distributed worldwide (Stange 2004; Machado *et al.* 2019; Oswald 2024). This tribe is also one of the four tribes within Myrmeleontidae with pit-building larvae (the other three tribes being Brachynemurini Banks, 1927, Nesoleontini Markl, 1954 and Myrmecaelurini Esben-Petersen, 1918), a unique behavior for which the antlions are well known (Wheeler 1930; Stange 2004; Badano & Pantaleoni 2014; Machado *et al.* 2019). The monophyly of Myrmeleontini has been well supported in several phylogenetic studies (Michel *et al.* 2017; Machado *et al.* 2019); however, the relationships of different genera within the tribe remain unclear. The tribe currently comprises ten genera separated into two subtribes, Porrerina Navás, 1913 and Myrmeleontina Latreille, 1802.

The monogeneric Porrerina contains around five species in the genus *Porrerus* Navás, 1913, and is currently unsampled in existing phylogenetic reconstructions. Myrmeleontina, on the other hand, contains most of the genera within Myrmeleontini, including one major genus, *Myrmeleon* Linnaeus, 1767, the largest of the entire family, and eight minor genera: *Australeon* Miller & Stange, 2012, *Baliga* Navás, 1912, *Dictyoleon* Esben-Petersen, 1923, *Euroleon* Esben-Petersen, 1918, *Hagenomyia* Banks, 1911, *Kirghizoleon* Krivokhatsky & Zakharenko, 1994, *Megistoleon* Navás, 1931, and *Weeleus* Navás, 1912. Molecular phylogenetic studies have recovered *Myrmeleon* as paraphyletic, with several minor genera nested within, leaving important issues such as phylogenetic and taxonomic works focusing on Myrmeleontini to resolve the chaotic status of the taxa within it (Stange 2004; Michel *et al.* 2017; Machado *et al.* 2019).

To date, twelve species of Myrmeleontini have been recorded in Taiwan, but some records are questionable (Miller *et al.* 1999; Stange *et al.* 2003; Lin *et al.* 2019). Most species were named and described by Miller *et al.* (1999), who executed a relatively thorough but brief survey of antlions in Taiwan. Lin *et al.* (2021) provided detailed descriptions and figures of nine Myrmeleontini antlion larvae, as well as a new record of *M. bimaculatus* Yang, 1999 for the country (now synonymized under *M. tenuipennis* Rambur, 1842 by Hassan *et al.* 2022). Although the Taiwanese Myrmeleontini have been surveyed in the past, the data are still insufficient, including the need of clear images and more detailed distributions of species, especially on islands that have never been explored. In the present study, nine species of Myrmeleontini from Taiwan are redescribed and detailed figures are provided. Here, *Hagenomyia brunneipennis* Esben-Petersen, 1913 is transferred to *Baliga* based on morphological characters, with *M. alticolus* Miller & Stange, 1999 syn. nov. as a new synonym. Additionally, *M. wangi* Miller & Wang, 1999 stat. rev. is resurrected as a valid species from the synonymy with *M. trivialis* Gerstaecker, 1885. Four species groups of *Myrmeleon* from Taiwan are also proposed: the *tenuipennis* group, *littoralis* group, and *wangi* group contains one species each, while the *punctinervis* group contains four species (*M. punctinervis* Banks, 1937, *M. heppneri* Miller & Stange, 1999, *M. persimilis* Miller & Stange, 1999, *M. taiwanensis* Miller & Stange, 1999). Finally, an identification key and a phylogenetic analysis based on the COI marker of Taiwanese species of Myrmeleontini are provided.

Material and methods

Sample collecting

The antlion specimens were mostly collected as larvae and reared into adults. The larvae were collected directly in the field by searching for pitfalls built by the larvae. The rearing of the larvae is as in Lin *et al.* (2021). The adults were captured with insect nets in flight at night or by searching near light sources. The specimens are either pinned or preserved in 95% ethanol.

Specimen depository

The following abbreviations are used for collections:

CAU	=	China Agricultural University, Beijing, China
FSCA	=	Florida State Collection of Arthropods, Gainesville, Florida, USA
KWC	=	personal collection of Kai-Wei Chan, Taipei, Taiwan
MCZ	=	Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts, USA
MFNB	=	Museum für Naturkunde Berlin, Leibniz-Institut für Evolutions- und Biodiversitätsforschung, Berlin, Germany
NCHU	=	National Chung Hsing University, Taichung, Taiwan
NMNS	=	National Museum of Natural Science, Taichung, Taiwan
NTM	=	National Taiwan Museum, Taipei, Taiwan

NTU = National Taiwan University, Taipei, Taiwan
SDEI = Senckenberg Deutsches Entomologisches Institut, Müncheberg, Germany
SEHU = Laboratory of Systematic Entomology, Hokkaido University, Sapporo, Japan
TAMUIC = Texas A&M University Insect Collection, Texas, USA
TARI = Taiwan Agricultural Research Institute, Taichung, Taiwan
TFRI = Taiwan Forestry Research Institute, Taipei, Taiwan
THC = personal collection of Tein Hsieh, Taipei, Taiwan
USNM = National Museum of Natural History, Washington, D.C., USA

Terminalia preparation and imaging

The tip of the adult abdomen from the 7th segment was cut off and placed in heated 10% KOH solutions for about 20 minutes, later rinsed in 75% ethanol. The genitalia were preserved within glycerin in a small glass vial, and the vial was either pinned with the dried specimens or preserved together with the ethanol-preserved specimens.

Photographic images of the adults were taken with a Canon® EOS 850D digital camera equipped with a Contax Carl Zeiss® lens S-Planar 60 mm F 2.8, then stacked using Helicon Soft® software Helicon Focus; photographic images of the terminalia were taken and stacked with a Leica® DVM6 digital microscope; photographic images of the male genitalia were taken and stacked with a Keyence® VHX-6000 digital microscope. The obtained images were processed using the software Adobe Photoshop® CC 2019.

Terminology

Terminology of adults mainly follows New (1985) and Stange (1994); terminology of wing venation and wing fields follows Breitkreutz *et al.* (2017) and Machado & Oswald (2020). Abbreviations of wing veins are as follows:

1A, 2A, 3A = anal veins
CuA = cubitus anterior
CuP = cubitus posterior
MA = media anterior
MP = media posterior
RA = radius anterior
RP = radius posterior

DNA sequencing

DNA was extracted from one or two legs of adult or larva specimens using NautiaZ Tissue DNA Extraction Mini Kit (Nautia, Taipei, Taiwan). A total of 79 specimens of Myrmeleontini belonging to 9 species had DNA extracted, as well as 3 adult specimens of *Distoleon* Banks, 1910 to be used as outgroup (see Supp. file 1). Mitochondrial cytochrome c oxidase subunit I (COI) sequence was amplified and sequenced by polymerase chain reaction (PCR) using LCO-1490 (5′-GGTCAACAAATCATAAAGATATTGG-3′) and HCO-2198 (5′-TAAACTTCAGGGTGACCAAAAAATCA-3′) primers (Folmer *et al.* 1994). The PCR reaction premix contained 12.5 µl GoTaq® Green Master Mix (Promega, Madison, WI, USA), 1.0 µl of each of the forward and reverse primers (10 pM), 9.5 µl distilled deionized water, and 1.0 µl template DNA. The PCR reaction was performed using a MiniAmpTM Plus thermal cycler (Thermo Fisher Scientific, Waltham, MA, USA). The PCR protocol was as follows: an initial 2-min denaturing step at 95°C; 35 cycles of 30 sec at 95°C, 70 sec at 50°C, and 60 sec at 72°C; with a final 5-min extension at 72°C. Sequencing was conducted by Tri-I Biotech Inc. (New Taipei, Taiwan).

Sequence alignment and phylogenetic analysis

The extracted COI sequences were aligned using MUSCLE alignment in program MEGA X (Kumar *et al.* 2018), resulting in a 687 bp dataset. Phylogenetic analyses were performed with maximum likelihood (ML) (bootstrap replicates = 1000) using MEGA X (Kumar *et al.* 2018). The analysis was based on the General Time Reversible model following gamma distribution with invariant sites (GTR+I+G) that was selected as the best evolutionary model using jModelTest ver. 2.1.10 (Posada 2008; Darriba *et al.* 2012). Pairwise genetic distances of the Taiwanese Myrmeleontini were calculated under the Kimura 2-parameter model using MEGA X (Kumar *et al.* 2018).

Results

Taxonomy

Class Insecta Linnaeus, 1758
Order Neuroptera Linnaeus, 1758
Family Myrmeleontidae Latreille, 1802
Subfamily Myrmeleontinae Latreille, 1802

Tribe **Myrmeleontini** Latreille, 1802

Diagnosis of adult

Forewing vein CuP arising at or very near basal crossvein; forewing vein 2A running close to 1A for short distance, then bending at a sharp angle toward 3A. Hindwing with four or more crossveins at presectoral area. Forewing and hindwing vein RP arising distant from base. Tarsomere 1 of hind leg shorter than tarsomere 5. Male with or without pillula axillaris.

Identification key to the adults of Myrmeleontini species in Taiwan

1. Hindwing longer than or as long as forewing 2
– Hindwing shorter than forewing 5

2. Wings broad, acute at apex; male mediuncus three-pronged shaped from caudal view (Figs 4C, 7C); female anterior gonapophyses widely separated, long, and shorter than posterior gonapophyses; lateral gonapophyses long (Figs 3A–B, 6A–B) .....3 (genus ***Baliga***)
– Wings variable; male mediuncus not as above; female anterior gonapophyses not widely separated, short, lobed .....4 (genus ***Myrmeleon***)

3. Wings with large, white pterostigma; costal area with interconnected crossveins from apical ⅓ to stigma (Fig. 2C); ventral side of the abdomen whitish-yellow (Fig. 1A) .... ***B. asakurae*** (Okamoto, 1910)
– Wings with small pterostigma; costal area with only few interconnected crossveins (Fig. 5C); ventral side of the abdomen dark brown (Fig. 1B) ..... ***B. brunneipennis*** (Esben-Petersen, 1913)

4. Vertex mostly yellow with dark brown spots; pronotum and mesonotum mostly dark brown with whitish-yellow markings (Fig. 11B); ventral side of the abdomen paler than dorsal side (Fig. 1C) .. .. ***M. littoralis*** Miller & Stange, 1999
– Vertex mostly dark brown with a pair of yellow spots; pronotum mostly whitish-yellow with two pairs of dark brown spots on the anterior half and dark brown markings on the posterior half (Fig. 8B) .. ..***M. tenuipennis*** Rambur, 1842

5. Large sized; pronotum dark brown with a thin yellow line in the middle and a pair of yellow bands on the side of the anterior margin (Fig. 14B) .....***M. wangi*** Miller & Stange, 1999
– Small to medium-sized; pronotum not as above 6

6. Vertex completely dark brown (Figs 20B, 26B) 7
– Vertex with yellow or brown markings (Figs 17B, 23B) 8

7. Pronotum, mesonotum and metanotum almost fully dark brown (Fig. 26B) .... ***M. taiwanensis*** Miller & Stange, 1999
– Pronotum dark brown with a yellow medial line, anterior half with yellow spots; mesonotum and metanotum with thin yellow line on the posterior margin (Fig. 20B) .... ***M. persimilis*** Miller & Stange, 1999

8. Pronotum brown with yellow bands on the side of anterior margin (Fig. 23B) .... ***M. punctinervis*** Banks, 1937
– Pronotum mostly whitish-yellow with brown markings (Fig. 17B) .... ***M. heppneri*** Miller & Stange, 1999

Genus ***Baliga*** Navás, 1912

Baliga Navás, 1912a: 110. Type species: *Myrmeleon asakurae* Okamoto, 1910: 297. Original designation.
Balaga Navás, 1912a: 111. Type species: *Myrmeleon micans* McLachlan, 1875: 176. Original designation.
Baga Navás, 1930a: 37. Type species: *Balaga montana* Navás, 1930a: 37. Monotypy.

Diagnosis

Medium to large-sized antlions. Wings relatively broad, without markings, hyaline; hindwing longer than forewing. Forewing presectoral area with 5–10 crossveins; RP arising almost opposite to CuA fork, often with an extra row of cells under the hypostigmatic cell. Hindwing presectoral area with 4–7 crossveins; RP arising almost opposite to MP fork, at origin runs equidistant to RA and MA. Anterior Banksian line absent, posterior Banksian line distinct on both wings. Femoral sense hair present on fore and mid legs, absent on hind leg. Female ectoproct simple; posterior gonapophyses long, slender; anterior

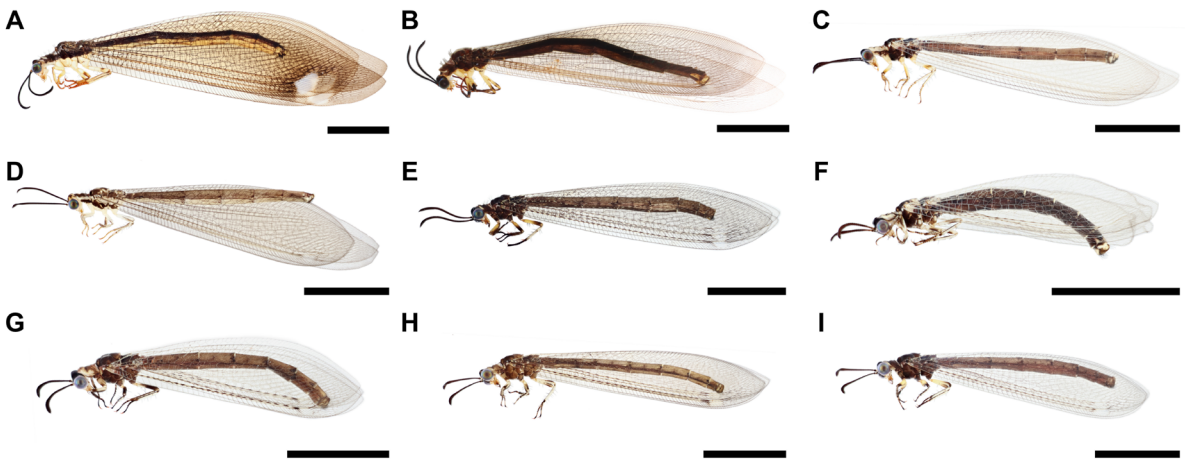

Fig. 1. Adult habitus of species of Myrmeleontini Latreille, 1802 of Taiwan, lateral view. **A**. *Baliga asakurae* (Okamoto, 1910), ♀ (NTU). **B**. *B. brunneipennis* (Esben-Petersen, 1913), ♀ (NTU). **C**. *Myrmeleon tenuipennis* Rambur, 1842, ♀ (NTU). **D**. *M. littoralis* Miller & Stange, 1999, ♀ (NTU). **E**. *M. wangi* Miller & Stange, 1999, ♂ (NTU). **F**. *M. heppneri* Miller & Stange, 1999, ♂ (NTU). **G**. *M. persimilis* Miller & Stange, 1999, ♂ (NTU). **H**. *M. punctinervis* Banks, 1937, ♀ (NTU). **I**. *M. taiwanensis* Miller & Stange, 1999, ♂ (NTU). Scale bars = 10.0 mm.

gonapophyses long, shorter than posterior gonapophyses, well separated. Male ectoproct simple, often with ventral projection; gonarcus arched, with lateral arms producing posteriorly; mediuncus three-pronged in caudal view, with two projections in lateral view; parameres strongly sclerotized, oblique, separated.

Remarks

The relationship between the genera *Baliga* and *Hagenomyia* is still unclear. *Baliga* has been assigned as a synonym of *Hagenomyia* in several works, including Esben-Petersen (1913), Markl (1954) and Wang *et al.* (2018), while Stange (2004), Hayashi *et al.* (2020) and Oswald (2024) considered an opposing opinion. Here, we agree with the latter view. By comparing the Taiwanese and the Japanese species in Hayashi *et al.* (2020), *Baliga* is an independent genus that can be determined by a series of characters, including female anterior gonapophyses almost as long as posterior gonapophyses, the shape of the male genitalia, especially the three-pronged mediuncus, as well as the long, slender mandible and the few abdominal digging setae of the larvae. Most species inhabit moist forest environment (Stange *et al.* 2003; Hayashi *et al.* 2020; Lin *et al.* 2021).

Baliga asakurae (Okamoto, 1910)
Figs 1A, 2–4

Myrmeleon asakurae Okamoto, 1910: 297. Type locality: Taiwan (Nantou).
Myrmeleon ochraceopennis Nakahara, 1913: 299. Type locality: Taiwan (Nantou).

Baliga asakurae – Navás 1912a: 110. — Stange *et al.* 2003: 106. — Stange 2004: 296. — Lin *et al.* 2019: 138. — Hayashi *et al.* 2020: 244.
Hagenomyia asakurae – Esben-Petersen 1913: 223. — Markl 1954: 233. — Wang *et al.* 2018: 85.
Myrmeleon asakurae – Nakahara 1913: 96.
Baliga eurystictus – Stange & Wang 1997: 52; 1998: 239 (misidentification).
Baliga ochraceopennis – Stange *et al.* 2003: 106.

Material examined

Syntypes
TAIWAN • 2 ♂♂, 1 ♀ (photos examined); Nantou County, "Horisha" [now Puli]; Jul. 1909; H. Kawamura leg.; SEHU.

Additional material

TAIWAN • 1 ♀; "Formosa" [now Taiwan], no further locality; no date; Poldanski leg.; MFN. – **Hualien County** • 1 ♀; Fuli Township, Cilamitay Tribe; 19 Dec. 2016; Tein Hsieh leg.; THC • 1 ♀; Jian Township, Maple Tree Trail; 5 Nov. 2017; Tien-Chen Chao leg.; by hand; NCHU • 1 ♂, 1 ♀; Xiulin Township, Wenlan; 29 May–24 Jul. 2012; W.T. Yang leg.; Malaise trap; NMNS. – **Kaohsiung City** • 1 ♀; "Kosempo" [now Jiaxian District]; Jan. 1910; H. Sauter leg.; USNM • 2 ♂♂; same data as for preceding; 1911; H. Sauter leg.; USNM. – **Miaoli County** • 1 ♀ (larva reared to adult); Shitan Township, Mingfeng Historic Trail; 16 Jan. 2021; Kai-Wei Chan leg.; preserved in alcohol; NTU. – **Nantou County** • 1 ♀ (larva reared to adult); Renai Township, Huisun Forest Area; 4 Apr. 2021; Kai-Wei Chan *et al.* leg.; NTU. – **New Taipei City** • 1 ♂, 1 ♀; Xindian District, An Kang High School; 12 Jul. 2018; Jhih-Rong Liao leg.; NTU • 1 ♂; Sanzhi District, Erzhiping; 29 Jul. 2019; Po-Cheng Huang leg.; NTU • 2 ♀♀; Zhonghe District, Hongludi; 24 Jun. 2020; Po-Cheng Huang leg.; 1 preserved in alcohol; NTU • 1 ♂; Shiding District, Huangdidian; 22 Jun. 2016; Tein Hsieh leg.; THC • 1 ♀; Tamsui District; Miantian Mountain; 30 Oct. 1983; Shu-Ling Yu leg.; NTU • 1 ♀ (larva reared to adult); Sanxia District; The Great Roots Forestry Spa Resort; 13 Feb. 2021; Sheng-Hong Lin leg.; preserved in alcohol; NTU • 1 ♀; Tucheng District, Tonghua Park; 1 Sep. 2021; Chian-Yu Huang leg.; NTU • 1 ♀;

Tamsui District. Xingfuliao (Hsing-Fu-Liao); 4 Jun. 1976; F.S. Santana leg.; TAMU ENTO X0863917. – **Pingtung County** • 1 pupa; Hengchun Township, Kenting National Forest Recreation Area; 14 Nov. 2021; Yu-Hsiu Lin leg.; molting failed, preserved in alcohol; NTU • 1 ♂, 1 ♀ (2 larvae reared to adults); Chunri Township, Tahan Forest Road Km 16.5; 28 Jan. 2021; Yu-Hsiu Lin leg.; preserved in alcohol; NTU. – **Taichung City** • 1 ♀; Heping District, Basianshan (Pahsienshan); 9 Sep. 1993; W.T. Yang and M.L. Chan leg.; NMNS • 1 ♂; Heping District, Wushiken Workstation; 30 Aug. 2014; Mei-Ling Chan leg.; NMNS. – **Taipei City** • 1 ♂; Beitou District, Guiziken Trail; 22 Sep. 2021; You-Sheng Lin leg.; preserved in alcohol; NTU • 1 ♂; Neihu District, Jinrui Zhishui Park; 29 Jul. 2020; Pin-Chun Chou leg.; preserved in alcohol; NTU • 1 ♂, 1 ♀; Shilin District, Neishuangxi; 8 Sep. 1985; unknown collector; NCHU • 1 ♀; Beitou District, Qingtian Temple; 6 Jul. 2020; Chun-Yu Lin leg.; preserved in alcohol; NTU • 1 ♀; Beitou District, Shamaoshan; 3 Jun. 2016; Tsung-Hsueh Wu leg.; THC • 1 ♂; Shilin District, Shanzihou; 5 Aug. 1973; P.P. Lien leg.; NCHU • 1 ♀; Wulai District, Wulai; 16 Sep. 1958; S.C. Chiu leg.; TARI • 1 ♀; Wenshan District, Xianjiyan; 24°59′31.1″ N, 121°32′49.0″ E; 18 Sep. 2017; Tein Hsieh leg.; THC • 1 ♂, 1 ♀; Beitou District, Yangminshan (Tsaoshan); 9 Jul. 1958; S.C. Chiu leg.; TARI • 1 ♂; same collection data as for preceding; 11 Aug. 1973; P.P. Lien leg.; NCHU • 1 ♀; Beitou District, Yangtou Road; 1 Jul. 1991; Chiung-Fang Lin leg.; NTU. – **Taitung County** • 1 ♀; Lanyu Township, Chungaichiao; 30 Apr. 1997; Mei-Ling Chan leg.; NMNS • 1 ♀; Guanshan Township, Dianguang; 8 Jul. 2021; Po-Cheng Huang leg.; preserved in alcohol; NTU • 1 ♂; same data as for preceding; 10 Sep. 2021; Po-Cheng Huang leg.; preserved in alcohol; NTU • 1 ♀; Lanyu Township, Hongtou Forest Trail; 4 Apr. 2021; Ching-Ya Chang leg.; molting failed, preserved in alcohol; NTU • 4 ♂♂, 1 ♀; Haiduan Township, Lidao; 6 Oct. 2012; Yu-Tang Wang leg.; NMNS • 1 ♂; Beinan Township, Lijia Forest Road; 10 Oct. 2015; Tein Hsieh leg.; THC. – **Yilan County** • 1 ♂; Yuanshan Township, Fushan Botanical Garden; 5 Jul. 1991; Yi-Bin Fan leg.; TFRI • 1 ♀; same data as for preceding; 15 Aug. 2013; Yu-Tang Wang leg.; NMNS • 1 ♂ (larva reared to adult); same data as for preceding; 6 Apr. 2021; Yu-Hsiu Lin *et al.* leg.; molting failed, preserved in alcohol; NTU • 1 ♂; Datong Township, Taipingshan; 24 Jul. 1940; M. Chûjô leg.; TARI.

Re-description of the adult

Measurements (♂ n = 5, ♀ n = 8). Body length: ♂ 29.1–37.7 mm, ♀ 28.8–39.4 mm; forewing: length ♂ 31.4–41.8 mm, ♀ 34.6–47.9 mm; width ♂ 10.0–12.7 mm, ♀ 10.2–14.5 mm; width/length ratio ♂ 0.3053, ♀ 0.2956; hindwing: length ♂ 32.4–43.1 mm, ♀ 35.5–49.4 mm; width ♂ 8.6–10.5 mm, ♀ 8.8–12.1 mm; width/length ratio ♂ 0.2458, ♀ 0.2400.

Head (Fig. 2A–B). Vertex strongly raised, rounded, black, 4 dark brown spots along anterior margin and 4 dark brown spots along posterior margins, with sparse short black hairs; occiput dark brown. Frons shiny black, covered with sparse short hyaline hairs; gena black, ventral margin yellow, with a whitish-yellow line along ocular rim; clypeus whitish-yellow, with sparse hyaline hairs. Antenna black, short, with slightly defined club, covered with short dark hairs; scape dark brown with a ring of white band at base; pedicel reddish-orange; flagellum comprising approximately 45 flagellomeres, 1st flagellomere reddish-orange. Mouthparts reddish-yellow, labrum reddish-yellow, with several hyaline hairs; maxillary palps yellow, labial palps yellow, 3rd palpomere fusiform, tapering to acute apex, with yellow round palpimacula on apical ⅓; submentum with long dark hairs.

Thorax (Fig. 2B). Pronotum broad, shorter than wide, dark brown, anterior margin with whitish-yellow bands on the side, membrane dark brown, with white markings on lateral side, with hyaline hairs and long dark hairs. Cervical sclerites dark brown. Mesonotum dark brown. Metanotum dark brown, covered with sparse hyaline hairs. Meso- and metapleuron dark brown, moderately covered with long hyaline hairs. Sternum whitish-yellow.

Legs. Whitish-yellow, short. Coxae moderately covered with long hyaline hairs, whitish-yellow; hind coxae with a small dark brown spot. Femora moderately covered with short dark hairs, mixed with sparse long black setae; fore femur whitish-yellow; mid femora whitish-yellow on the basal half and dark brown on distal half; hind femora whitish-yellow, with brown markings near apex; femoral sense hair length about ½ as long as femur on fore and mid legs, absent on hind leg. Tibiae moderately covered with short dark hairs, mixed with sparse long black setae, brown. Tibial spurs reddish-brown,

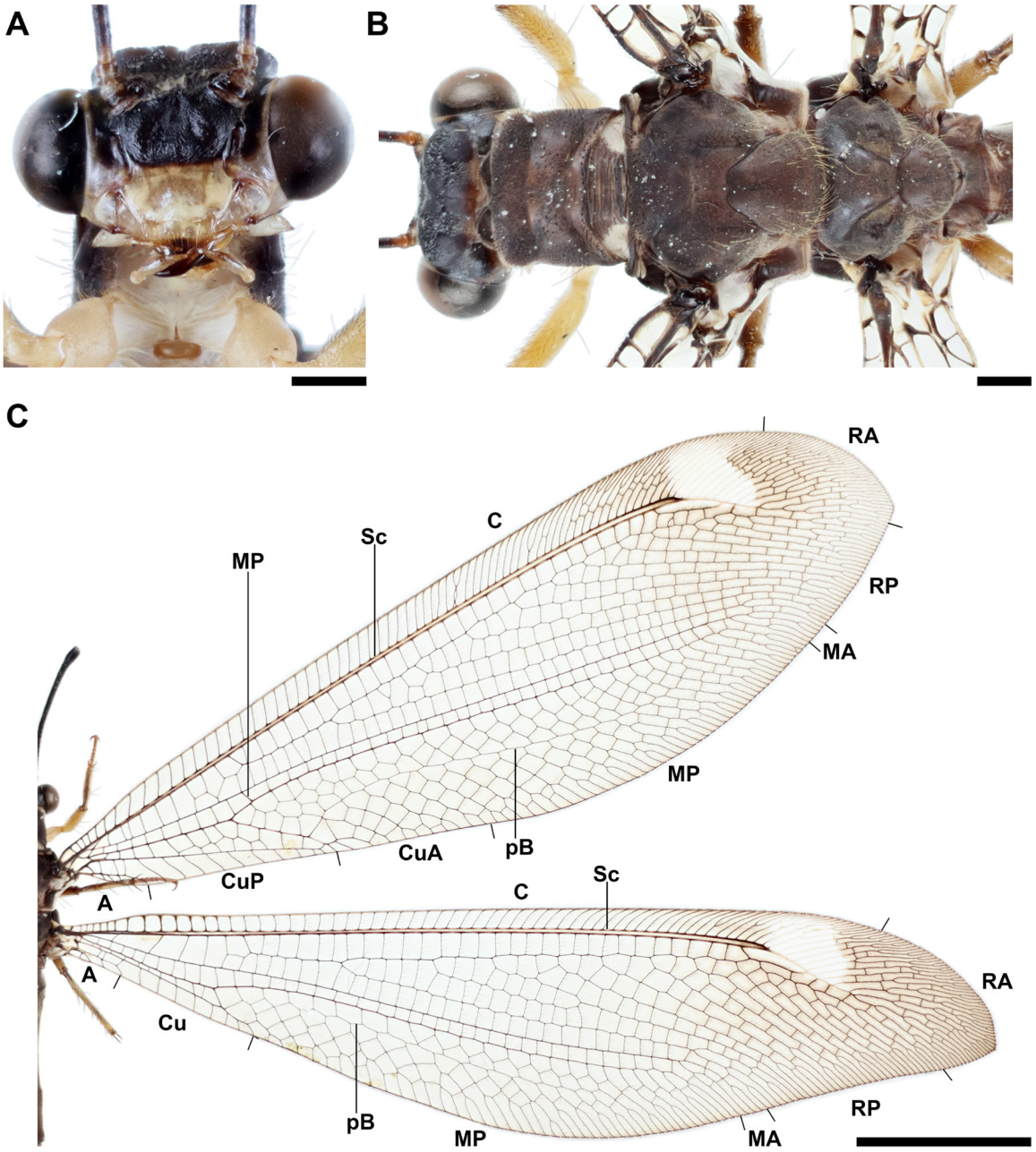

Fig. 2. *Baliga asakurae* (Okamoto, 1910) (NTU). **A**. Head, frontal view. **B**. Head and thorax, dorsal habitus. **C**. Wings. Abbreviations: A = anal veins; C = costa; Cu = cubitus; CuA = cubitus anterior; CuP = cubitus posterior; MA = media anterior; MP = media posterior; pB = posterior Banksian line; RA = radius anterior; RP = radius posterior; Sc = subcosta. Scale bars: A–B = 1.0 mm; C = 10.0 mm.

short, slender, almost straight, longer than tarsomere 1. Tarsi reddish-brown, sparsely covered with short dark hairs dorsally, short black setae ventrally; tarsomere 1 shorter than combined length of tarsomeres 2–4; tarsomere 5 longer than combined length of tarsomeres 1–4. Pretarsal claws reddish-brown, short, simple, curved, shorter than tibial spurs.

Wings (Fig. 2C). Without markings, hyaline, with brownish coloring. Forewings slightly rounded at apex; veins and crossveins mostly brown, Sc and RA finely alternating brown and pale yellow; costal area with interconnected crossveins from apical ⅓ to stigma, distal crossveins often branched; presectoral area with 9–10 crossveins and 0–5 irregular cells; RP arising almost opposite to CuA fork, with 28–32 crossveins from origin of RP to hypostigmatic cell, often with an extra row of cell under hypostigmatic cell; CuP supporting 1 cell before fusing with 1A; 3A mostly fused with 2A; hypostigmatic cell short; pterostigma white, longer than hypostigmatic cell; anterior Banksian line absent, posterior Banksian line distinct. Hindwings slightly longer and narrower than forewings; slightly acute at apex; presectoral area with 5–6 crossveins and 0–2 irregular cells; RP arising slightly beyond MP fork, at origin runs equidistant to RA and MA, with 24–28 crossveins from origin of RP to hypostigmatic cell; hypostigmatic cell as

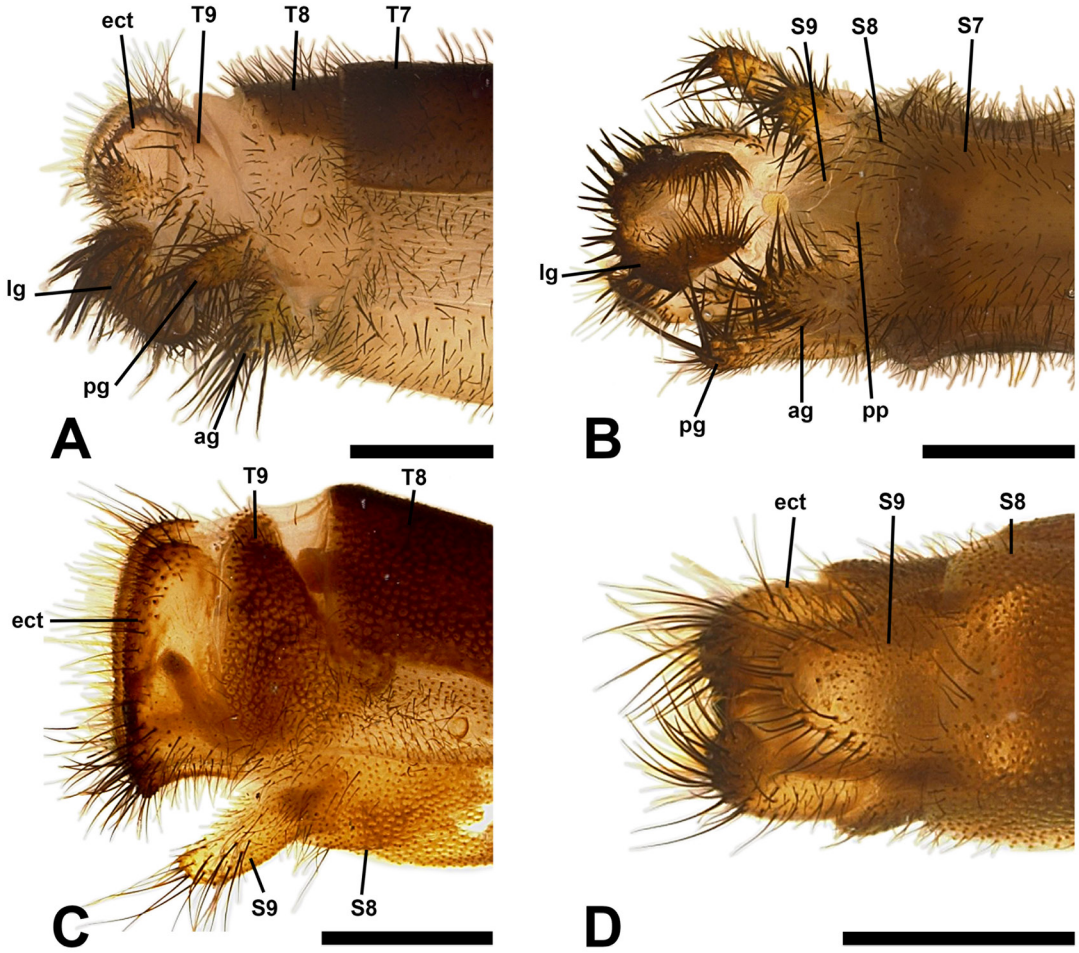

Fig. 3. *Baliga asakurae* (Okamoto, 1910) (NTU). **A**. Female terminalia, lateral view. **B**. Same, ventral view. **C**. Male terminalia, lateral view. **D**. Same, ventral view. Abbreviations: ag = anterior gonapophysis; ect = ectoproct; lg = lateral gonapophysis; pg = posterior gonapophysis; pp = pregenital plate; S = sternites; T = tergites. Scale bars = 1.0 mm.

long as forewing; pterostigma white, longer than hypostigmatic cell; anterior Banksian line absent, posterior Banksian line distinct; male with pilula axillaris.

Abdomen (Fig. 1A). Shorter than hindwing, tergites dark brown, sternite whitish-yellow, densely covered with short dark hairs dorsally and laterally, hyaline hairs ventrally.

Female terminalia (Fig. 3A–B). Tergite VIII at least 2 times as wide as tergite IX. Tergite IX narrow, triangular in lateral view. Ectoproct semicircular in lateral view, with long, black digging setae on ventral half. Lateral gonapophyses relatively long, rectangular in lateral view, slightly smaller than ectoproct, with long, black digging setae on posterior side and long, thin, black setae on ventral side. Posterior gonapophyses long, stout, with long, black setae. Anterior gonapophyses almost as long as posterior gonapophyses, stout, well separated, with long, thick, black setae. Pregenital plate indistinct, linear, presented on posterior margin of sternite VII.

Male genitalia (Figs 3C–D, 4). Ectoproct rectangular in lateral view, with an indistinct ventral projection, dorsal margin slightly shorter than ventral margin, covered with short pale brown hair, ventral half with long black setae. Sternite IX almost as long as combined length of tergite IX and ectoproct, tapered in ventral view, with long black setae posteriorly. Gonarcus brown, arched, with short lateral arm produced posteriorly in lateral view, arms long. Mediuncus well sclerotized, dark brown, with two projections in lateral view, ventral one extending toward parameres, caudal view with a three-pronged shape. Parameres well sclerotized, large, dark brown, teardrop-shaped and oblique in caudal view, nearly separated, with a small ventral projection in lateral view.

Distribution

Taiwan (widespread, also on the associated island of Lanyu) (Fig. 31A).

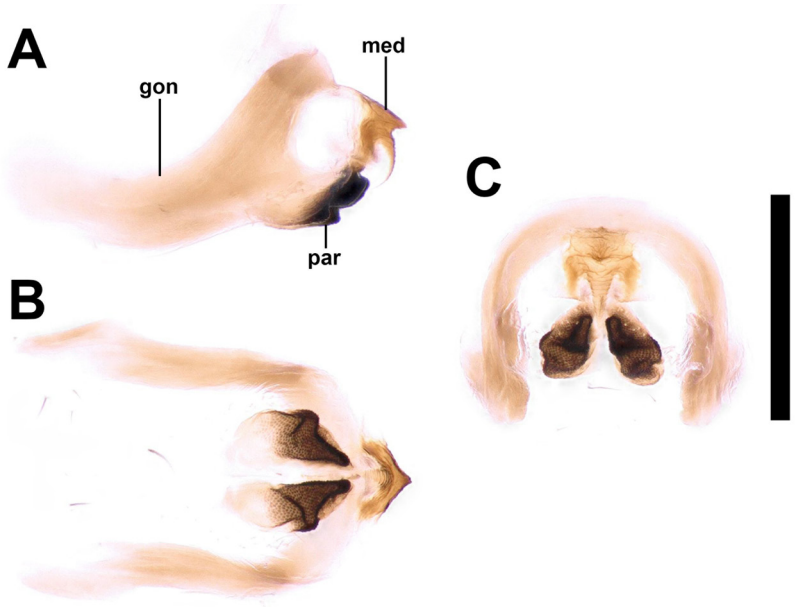

Fig. 4. *Baliga asakurae* (Okamoto, 1910), male genitalia (NTU). **A**. Lateral view. **B**. Ventral view. **C**. Caudal view. Abbreviations: gon = gonarcus; med = mediuncus; par = parameres. Scale bar = 0.5 mm.

Biology

From the collecting and emergence date of the examined specimens, the adults fly from May to December. The larvae inhabit forest environments below 1400 m a.s.l. (Lin *et al.* 2021).

Remarks

This is the largest species of Myrmeleontini in Taiwan and can be easily recognized by the large white pterostigma on the wings (Fig. 2C). The adults are very similar to those of *B. kimurai* Hayashi *et al.*, 2020 from Ishigaki Island, Japan, but with a larger pterostigma (Hayashi *et al.* 2020). Stange & Wang (1998) recorded this species as *B. eurystictus* (Gerstaecker, 1885), but in later publications, the name *B. asakurae* was used instead (Miller *et al.* 1999; Stange *et al.* 2003).

Baliga brunneipennis (Esben-Petersen, 1913) comb. nov.
Figs 1B, 5–7

Hagenomyia brunneipennis Esben-Petersen, 1913: 223. Type locality: Taiwan (Kaohsiung).
Hagenomyia pterostigma Yang, 1999: 149. Type locality: China (Fujiang).
Myrmeleon alticola Miller & Stange, 1999: 61. Type locality: Taiwan (Taoyuan). **Syn. nov.**

Hagenomyia sagax – Esben-Petersen 1913: 223 (misidentification).
Myrmeleon alticola – Stange *et al.* 2003: 111. — Wang *et al.* 2018: 106.
Baliga brunneipennis – Stange 2004: 297.
Baliga pterostigma – Stange 2004: 298.
Myrmeleon (*Myrmeleon*) *alticola* – Stange 2004: 318.
Hagenomyia brunneipennis – Bao *et al.* 2007: 45. — Wang *et al.* 2018: 86. — Lin *et al.* 2019: 139.
Myrmeleon (*Myrmeleon*) *alticolus* – Lin *et al.* 2019: 139.

Material examined

Holotype of *Hagenomyia brunneipennis*
TAIWAN • ♀ (labeled as ♂) (photos examined); Kaohsiung City, "Kosempo" [now Jiaxian]; 7 Aug. 1911; H. Sauter leg.; SDEI.

Holotype of *Myrmeleon alticola*
TAIWAN • ♂ (photos examined); Taoyuan City, Fuxing District, "Da-Kwan-Shan Giant Forest Reserve" [also known as Lala Mountain]; 1100 m a.s.l.; 12 Apr. 1998; Robert A. Miller, Lionel A. Stange and Hsiau-Yue Wang leg.; collected as larva, emerged 24 Apr. 1998; FSCA 00091045.

Additional material
TAIWAN – **Hualien County** • 1 ♀; Xiulin Township, Hualushi; 23 Jun.–24 Aug. 2009; W.T. Yang and K.W. Huang leg.; Malaise trap (KCN); NMNS. – **Kaohsiung City** • 1 ♀; Taoyuan District, Tengchih; 22 Aug. 1996; Mei-Ling Chan leg.; NMNS • 2 ♂♂, 1 ♀; Taoyuan District, East Tengchih Mountain; 12 Jul. 2022; Kai-Wei Chan leg.; preserved in alcohol; NTU. – **Nantou County** • 1 ♂; "Chip Chip" [now Jiji Township]; Jun. 1908; F.Y. Lanter leg.; MFN • 1 ♂; Xinyi Township, Dongbu; 6 Sep. 1990; Shun-Chun Hong leg.; NTU • 1 ♀; Lugu Township, Fenghuang Mountain; 28 Nov. 2020; Yu-Hsiu Lin leg.; collected as larva, emerged 16 Apr. 2021; molting failed, preserved in alcohol; NTU • 1 pupa, 1 ♂ (1 larva reared to adult); Renai Township, Highland Experimental Farm N.T.U., Meifeng Farm; 17 May 2020; Yu-Hsiu Lin leg.; molting failed, preserved in alcohol, NTU. – **Yilan County** • 1 ♀; Datong Township, Jianqing Historic Trail; 29 Jul. 2020; Hsuan-Pu Chen leg.; NTU.

Re-description of the adult

Measurements (♀ n = 1). Body length: ♀ 37.2 mm; forewing: length ♀ 47.8 mm; width ♀ 12.9 mm; width/length ratio ♀ 0.2699; hindwing: length ♀ 48.9 mm; width ♀ 10.7 mm; width/length ratio ♀ 0.2188.

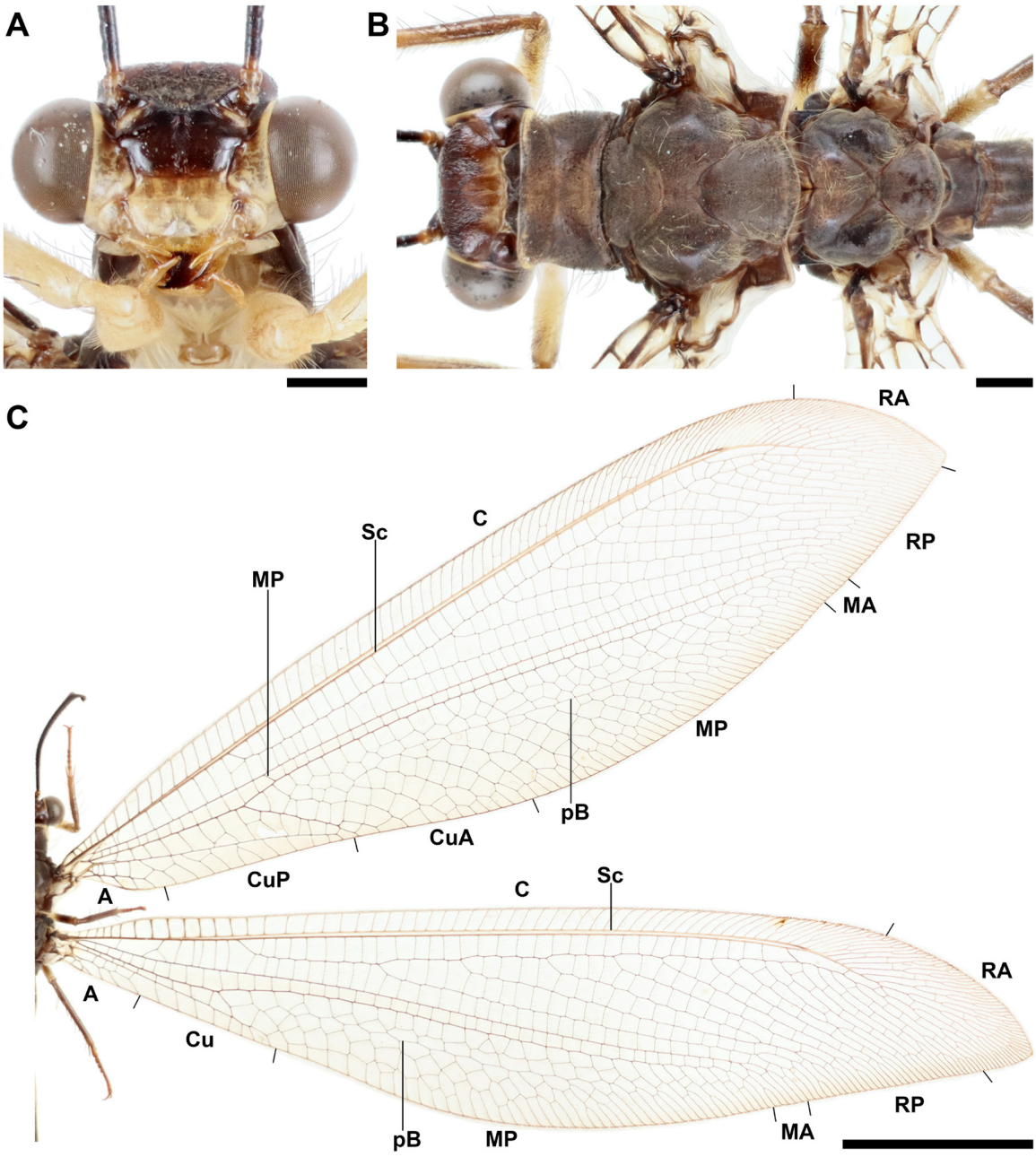

Fig. 5. *Baliga brunneipennis* (Esben-Petersen, 1913) comb. nov. (NTU). **A**. Head, frontal view. **B**. Head and thorax, dorsal habitus. **C**. Wings. Abbreviations: A = anal veins; C = costa; Cu = cubitus; CuA = cubitus anterior; CuP = cubitus posterior; MA = media anterior; MP = media posterior; pB = posterior Banksian line; RA = radius anterior; RP = radius posterior; Sc = subcosta. Scale bars: A–B = 1.0 mm; C = 10.0 mm.

Head (Fig. 5A–B). Vertex strongly raised, rounded, reddish-brown, 4 brown spots along anterior margin and 4 brown spots along posterior margins, with sparse short black hairs; occiput dark brown. Frons shiny black, slightly reddish, covered with sparse short hyaline hairs, ventral margin pale yellow; gena whitish-yellow, with a whitish-yellow line along ocular rim; clypeus whitish-yellow, with sparse hyaline hairs. Antenna black, short, with slightly defined club, covered with short dark hairs; scape dark brown with a ring of white band at base; pedicel reddish-orange; flagellum comprising approximately 35 flagellomeres, 1st flagellomere reddish-orange at base. Mouthparts reddish-yellow, labrum reddish-yellow, with several hyaline hairs; maxillary palps yellow, with the 5th and 6th palpomere black, labial palps reddish-yellow, 3rd palpomere fusiform, tapering to acute apex, with round orange palpimacula on apical ⅓; submentum with long dark hairs.

Thorax (Fig. 5B). Pronotum broad, shorter than wide, dark brown, anterior margin with yellow bands on lateral, membrane dark brown, with hyaline hairs and long dark hairs. Cervical sclerites dark brown. Mesonotum dark brown. Metanotum dark brown, covered with sparse hyaline hairs. Meso- and metapleuron dark brown, moderately covered with long hyaline hairs. Sternum whitish-yellow.

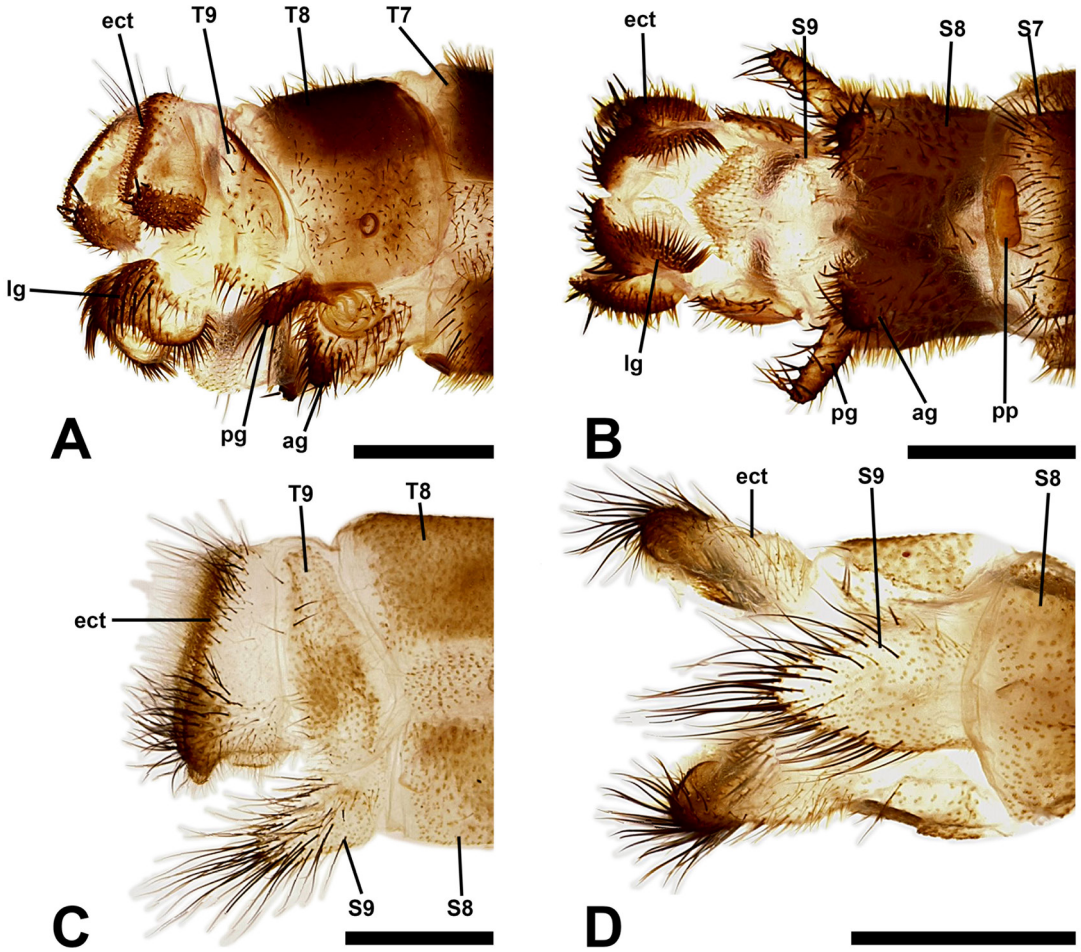

Fig. 6. *Baliga brunneipennis* (Esben-Petersen, 1913) (NTU). **A**. Female terminalia, lateral view. **B**. Same, ventral view. **C**. Male terminalia, lateral view. **D**. Same, ventral view. Abbreviations: ag = anterior gonapophysis; ect = ectoproct; lg = lateral gonapophysis; pg = posterior gonapophysis; pp = pregenital plate; S = sternites; T = tergites. Scale bars = 1.0 mm.

Legs. Whitish-yellow, short. Coxae moderately covered with long hyaline hairs, whitish-yellow; hind coxae with a brown line. Femora moderately covered with short dark hairs, mixed with sparse long black setae; fore femur whitish-yellow, with several small pale brown spots at apex; mid femora whitish-yellow on basal half and dark brown on distal half; hind femora whitish-yellow, with pale brown marking in middle; femoral sense hair length about ½ length of femur on fore legs and about ⅓ length of femur on mid legs, absent on hind leg. Tibiae moderately covered with short dark hairs, mixed with sparse long black setae, brown, fore tibia slightly pale on ventral surface. Tibial spurs reddish-brown, short, slender, almost straight, longer than tarsomere 1 (shorter on hind leg). Tarsi reddish-brown, sparsely covered with short dark hairs dorsally, short black setae ventrally; tarsomere 1 shorter than combined length of tarsomeres 2–4 (longer on hind leg); tarsomere 5 approximately as long as combined length of tarsomeres 1–4. Pretarsal claws reddish-brown, short, simple, curved, shorter than tibial spurs.

Wings (Fig. 5C). Without markings, hyaline, with yellowish coloring. Forewings acute at apex; veins and crossveins mostly brown; costal area without or with very few interconnected crossveins, distal crossveins often branched; presectoral area with 8–10 crossveins and 0–2 irregular cells; RP arising almost opposite to CuA fork, with 24–32 crossveins from origin of RP to hypostigmatic cell, with an extra row of cell under hypostigmatic cell; CuP supporting 1 cell before fusing with 1A; 3A mostly fused with 2A; hypostigmatic cell short; pterostigma pale white; anterior Banksian line absent, posterior Banksian line distinct. Hindwings slightly longer and narrower than forewings; acute at apex; presectoral area with 4–7 crossveins and 0–3 irregular cells; RP arising almost opposite to MP fork, at origin runs equidistant to RA and MA, with 22–29 crossveins from origin of Rs to hypostigmatic cell; hypostigmatic cell as long as forewing; pterostigma pale white; anterior Banksian line absent, posterior Banksian line slightly distinct; male with pale pilula axillaris.

Abdomen (Fig. 1B). Shorter than hindwing, tergites brown, sternite brown, densely covered with short dark hairs dorsally and laterally, hyaline hairs ventrally.

Female terminalia (Fig. 6A–B). Tergite VIII at least 2 times as wide as tergite IX. Tergite IX narrow, triangular in lateral view. Ectoproct rectangular in lateral view, with long, black digging setae on ventral

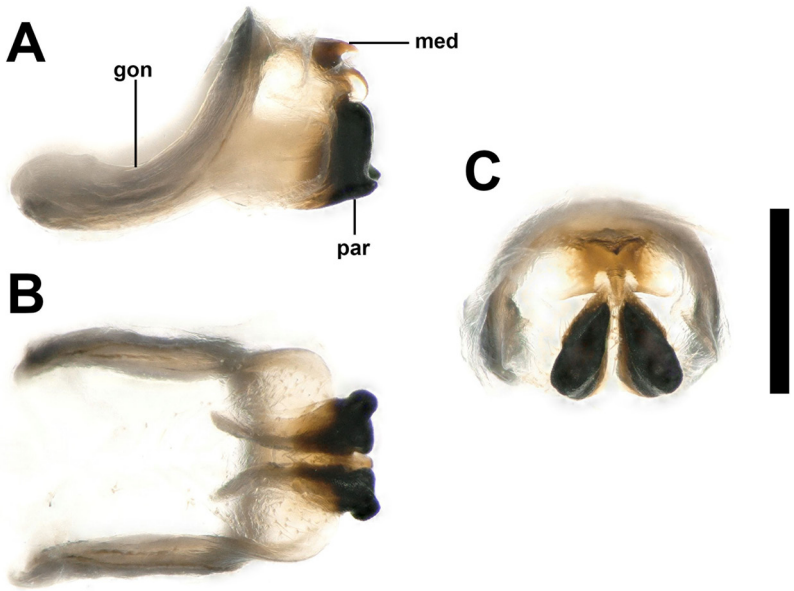

Fig. 7. *Baliga brunneipennis* (Esben-Petersen, 1913), male genitalia (NTU). **A**. Lateral view. **B**. Ventral view. **C**. Caudal view. Abbreviations: gon = gonarcus; med = mediuncus; par = parameres. Scale bar = 0.5 mm.

half. Lateral gonapophyses relatively long, rectangular in lateral view, slightly smaller than ectoproct, with long, black digging setae on posterior side and long, thin, black setae on ventral side. Posterior gonapophyses long, slender, with long, black setae. Anterior gonapophyses almost as long as posterior gonapophyses, thick at base, well separated, with long, thick, black setae. Pregenital plate distinct, rectangular, presented on posterior margin of sternite VII.

Male genitalia (Figs 6C–D, 7). Ectoproct rectangular in lateral view, with a ventral projection, dorsal margin slightly shorter than ventral margin, covered with short pale brown hair, ventral half with long black setae. Sternite IX almost as long as combined length of tergite IX and ectoproct, tapered in ventral view, with long black setae posteriorly. Gonarcus hyaline, arched, with short lateral arm produced posteriorly in lateral view. Mediuncus well sclerotized, dark brown, with two projections in lateral view, ventral one extending over parameres, caudal view with a three-pronged shape. Parameres well sclerotized, large, dark brown, oval and oblique in caudal view, slightly separated, with a small ventral projection in lateral view.

Distribution

Taiwan (central mountainous area) (Fig. 31B) and China (Fujiang, Henan, Sichuan, Zhejiang) (Wang *et al.* 2018).

Biology

From the collecting and emergence date of the examined specimens, the adults appear from April to September. The larvae inhabit a forest environment with altitudes above 1600 m a.s.l. (Lin *et al.* 2021).

Remarks

This species is similar to *B. asakurae* in characters, including wing venation (forewing RP arising almost opposite to CuA fork, often with an extra row of cells under the hypostigmatic cell; hindwing RP arising almost opposite to MP fork, at origin runs equidistant to RA and MA), genitalia (male mediuncus three-pronged in caudal view; female anterior gonapophyses more than half length of posterior gonapophyses), and larval morphology (IX abdominal sternite without or with few reduced digging setae) (Figs 5C, 6A–B, 7; Lin *et al.* 2021: figs 3b, 4b, 6). Such a combination of characters can also be observed in other species of *Baliga* from Japan (Hayashi *et al.* 2020). Due to such, this species should be placed in *Baliga*. This species differs from *B. asakurae* by the smaller pterostigma and fully dark brown abdomen of the adult (Figs 1B, 5C).

Since the original description, there have been no records of *Baliga brunneipennis* collected from Taiwan. During their 1998 collecting trip to the island, Stange and Miller did not collect this species and mentioned that only the holotype is known. As a result of this collecting trip, they described six new species of *Myrmelon*, including *Myrmeleon alticola* Miller & Stange, 1999 (Miller *et al.* 1999; Stange *et al.* 2003). After comparing images of the holotypes of each nominal species, we conclude that *M. alticola* is a junior synonym of *B. brunneipennis*. In the identification key provided by Stange *et al.* (2003), *B. brunneipennis* is described to have several interconnected veins in the costal area of the fore wings and the wing membranes yellowish-brown, thus differing from the species *M. alticola*. However, the interconnected veins are not present in the holotype, and the yellowish-brown coloring of the wings is likely only a variation.

In Wang *et al.* (2018), *B. brunneipennis* was described to have large, white pterostigma as in *B. asakurae*, which is not present in the holotype. Such a misunderstanding might be caused by an error in a figure of the wing tip of *B. asakurae* wrongly captioned as *B. brunneipennis* in Stange *et al.* (2003: fig. 63b). Additionally, *Hagenomyia pterostigma* Yang, 1999 from China was synonymized with *B. brunneipennis* mainly due to the large pterostigma (Bao *et al.* 2007; Wang *et al.* 2018). This synonym may be wrong

and that name could be a synonym of *B. asakurae*, but because we have not examined any specimen from China, we do not propose this synonymy here.

Genus ***Myrmeleon*** Linnaeus, 1767

Myrmeleon Linneaus, 1767: 913. Type species: *Myrmeleon formicarium* Linnaeus, 1767: 914. Subsequent designation by Latreille 1810: 435.
Macroleon Banks, 1909: 4. Type species: *Myrmeleon validus* McLachlan, 1894: 515. Original designation.
Enza Navás, 1912a: 113. Type species: *Enza otiosus* Navás, 1912a: 114. Monotypy.
Myrmeleodes Navás, 1912c: 242. Type species: *Myrmeleodes medius* Navás, 1912c: 243. Monotypy.
Moreyus Navás, 1914a: 55. Type species: *Moreyus brasiliensis* Navás, 1914a: 55. Monotypy.
Morter Navás, 1915a: 466. Type species: *Myrmeleon hyalinus* Olivier, 1811: 126. Original designation.
Neleon Navás, 1915b: 53. Type species: *Myrmeleon immaculatum* De Geer, 1773: 564. Original designation.
Neseurus Navás, 1916: 53. Type species: *Myrmeleon alternans* Brullé in Webb & Berthelot, 1839: 83. Original designation.
Myrmeleonellus Esben-Petersen, 1918b: 17. Type species: *Myrmeleonellus pallidus* Esben-Petersen, 1918b: 18. Monotypy.
Leptoleon Esben-Petersen, 1918b: 18. Type species: *Leptoleon regularis* Esben-Petersen, 1918b: 18. Monotypy.
Cocius Navás, 1919: 296. Type species: *Cocius angustatus* Navás, 1919: 297. Monotypy.
Dicholeon Navás, 1920: 193. Type species: *Dicholeon nigritarsis* Navás, 1920: 193. Monotypy.
Tafanerus Navás, 1921: 62. Type species: *Tafanerus indicus* Navás, 1921: 63. Original designation.
Talosus Navás, 1923a: 35. Type species: *Talosus oberthuri* Navás, 1923a: 35. Monotypy.
Banya Navás, 1923b: 145. Type species: *Banya trifasciata* Navás, 1923b: 145. Monotypy.
Grocus Navás, 1925: 185. Type species: *Grocus gerstaeckeri* Navás, 1925: 185. Original designation.
Colinus Navás, 1925: 187. Type species: *Colinus philippinus* Navás, 1925: 187. Monotypy.
Afroleon Navás, 1927: 13. Type species: *Afroleon basutus* Navás, 1927: 13. Monotypy.
Neurocolinus Navás, 1930b: 42. Type species: *Colinus philippinus* Navás, 1925: 187. Monotypy.
Nemeyus Navás, 1934a: 502. Type species: *Nemeyus sanaanus* Navás, 1934a: 503. Monotypy.
Nezuela Navás, 1934b: 155. Type species: *Nezuela geayana* Navás, 1934b: 156. Monotypy.
Bordus Navás, 1936a: 165. Type species: *Bordus temeratus* Navás, 1936a: 166. Monotypy.
Congoleon Navás, 1936b: 337. Type species: *Congoleon sociatus* Navás, 1936b: 337. Monotypy.
Hypsoleon Navás, 1936c: 103. Type species: *Hypsoleon chappuisinus* Navás, 1936c: 103. Monotypy.
Nelneja Navás, 1936c: 104. Type species: *Nelneja guttata* Navás, 1936c: 104. Monotypy.

Diagnosis

Small to large-sized antlions. Adult. Wings narrow to broad, without markings, hyaline. Forewing presectoral area with 5–10 crossveins; RP arising almost opposite to CuA fork, seldom with an extra row of cell under the hypostigmatic cell. Hindwing presectoral area with 4–5 crossveins; RP arising almost opposite to CuA fork. Anterior Banksian line absent, posterior Banksian line distinct on both wings. Femoral sense hair present on fore and mid legs, absent on hind leg. Female ectoproct simple; posterior gonapophyses long, slender; anterior gonapophyses short or lobed, shorter than posterior gonapophyses. Male ectoproct usually simple, sometimes with ventral projection; gonarcus arched; mediuncus usually sclerotized.

Remarks

Myrmeleon consists of around 180 species with similar combination of characters (Stange 2004; Machado *et al.* 2019; Oswald 2024). Due to the recovery of this genus as paraphyletic by Michel *et al.*

(2017) and Machado *et al.* (2019), more morphological characters are needed for resolving the complex relationship among *Myrmeleon* and the other Myrmeleontini genera. Here, the Taiwanese species can be assigned to four distinct species groups due to several morphological characters.

Myrmeleon tenuipennis group

Diagnosis

The *M. tenuipennis* group is characterized by the hindwing nearly as long as the forewing; hindwing RP at origin runs closer to MA; male genitalia with gonarcus flat, mediuncus reduced, parameres well sclerotized, rectangular in caudal view.

Included species

Myrmeleon tenuipennis Rambur, 1842.

Myrmeleon tenuipennis Rambur, 1842
Figs 1C, 8–10

Myrmeleon tenuipennis Rambur, 1842: 405. Type locality: India (Maharashtra, Mumbai).
Myrmeleon fryeri Navás, 1914b: 135. Type locality: Sri Lanka.
Myrmeleon bimaculatus Yang, 1999: 149. Type locality: China (Fujian: Nanping).

Myrmeleon (*Myrmeleon*) *bimaculatus* – Stange 2004: 320.

Material examined

Paratype of *Myrmeleon bimaculatus*
CHINA • 1 ♀ (photos examined); Fujian Province, Sha County (Shaxian), Sanming City; 27 Aug. 1978; Bangkan Huang leg.; CAU.

Additional material
TAIWAN – **Hsinchu County** • 1 ♂, 1 ♀ (2 larvae reared to adults); Hengshan Township, Hengshan Street Wood Factory; 26 Nov. 2019; Jia-Wei Chuang leg.; collected in wood dust; molting failed, preserved in alcohol; NTU. – **Kinmen County** • 1 ♂, 1 ♀ (2 larvae reared to adults); Lieyu Township, Qilinshan Forest Park; 3 Sep. 2020; Yu-Hsiu Lin leg.; preserved in alcohol; NTU • 1 ♀ (larva reared to adult); Jinchen Township, Zhaishan; 3 Sep. 2020; Yu-Hsiu Lin leg.; preserved in alcohol; NTU. – **Miaoli County** • 1 ♀ (larva reared to adult); Zaoqiao Township, Shangrila Paradise Amusement Park; 6 Aug. 2017; Yu-Jen Tsao leg.; NTU • 1 ♂, 1 ♀ (2 larvae reared to adults); same data as for preceding; 23 Sep. 2017; Yu-Jen Tsao leg.; NTU • 2 ♀♀ (2 larvae reared to adults); same data as for preceding; 1 Apr. 2018; Yu-Jen Tsao leg.; NTU • 2 ♀♀ (2 larvae reared to adults); same data as for preceding; 5 May 2018; Yu-Jen Tsao leg.; NTU • 3 ♂♂, 2 ♀♀ (5 larvae reared to adults); same data as for preceding; 7 Jul. 2018; Yu-Jen Tsao leg.; NTU • 5 ♀♀ (5 larvae reared to adults); same data as for preceding; 4 Aug. 2018; Yu-Jen Tsao leg.; NTU • 3 ♀♀ (3 larvae reared to adults); same data as for preceding; 1 Sep. 2018; Yu-Jen Tsao leg.; NTU • 1 ♂, 3 ♀♀ (4 larvae reared to adults); same data as for preceding; 6 Oct. 2018; Yu-Jen Tsao leg.; NTU • 5 ♂♂, 5 ♀♀ (10 larvae reared to adults); same data as for preceding; 4 Nov. 2018; Yu-Jen Tsao leg.; 3 specs preserved in alcohol; NTU • 5 ♂♂, 9 ♀♀ (14 larvae reared to adults); same data as for preceding; 1 Dec. 2018; Yu-Jen Tsao and Yu-Hsiu Lin leg.; 3 specs preserved in alcohol; NTU • 3 ♂♂, 1 ♀ (4 larvae reared to adults); same data as for preceding; 12 Jan. 2019; Yu-Jen Tsao leg.; NTU • 1 ♀ (larva reared to adult); same data as for preceding; 17 Mar. 2019; Yu-Hsiu Lin leg.; NTU • 1 ♂, 5 ♀♀ (6 larvae reared to adults); same data as for preceding; 6 Jul. 2019; Yu-Jen Tsao leg.; 3 specs preserved in alcohol; NTU • 1 ♂ (larva reared to adult); Tongxiao Township; 21 Dec. 2019; Yu-Jen Tsao leg.; preserved in alcohol; NTU. – **New Taipei City** • 4 ♀♀ (4 larvae reared to adults); Bali District,

Bali District 3rd Cemetery; 30 Oct. 2018; Chien-Yu Chiang leg.; 1 spec. preserved in alcohol; NTU • 1 ♀ (larva reared to adult); same data as for preceding; 6 Nov. 2018; Chien-Yu Chiang leg.; NTU • 3 ♂♂, 2 ♀♀ (5 larvae reared to adults); same data as for preceding; 29 Aug. 2019; Yu-Hsiu Lin leg.; 4 specs preserved in alcohol; NTU • 1 ♂, 2 ♀♀ (3 larvae reared to adults); same data as for preceding; 4 Sep. 2019; Yu-Hsiu Lin leg.; 1 spec. preserved in alcohol; NTU • 1 ♂, 3 ♀♀ (4 larvae reared to adults); same

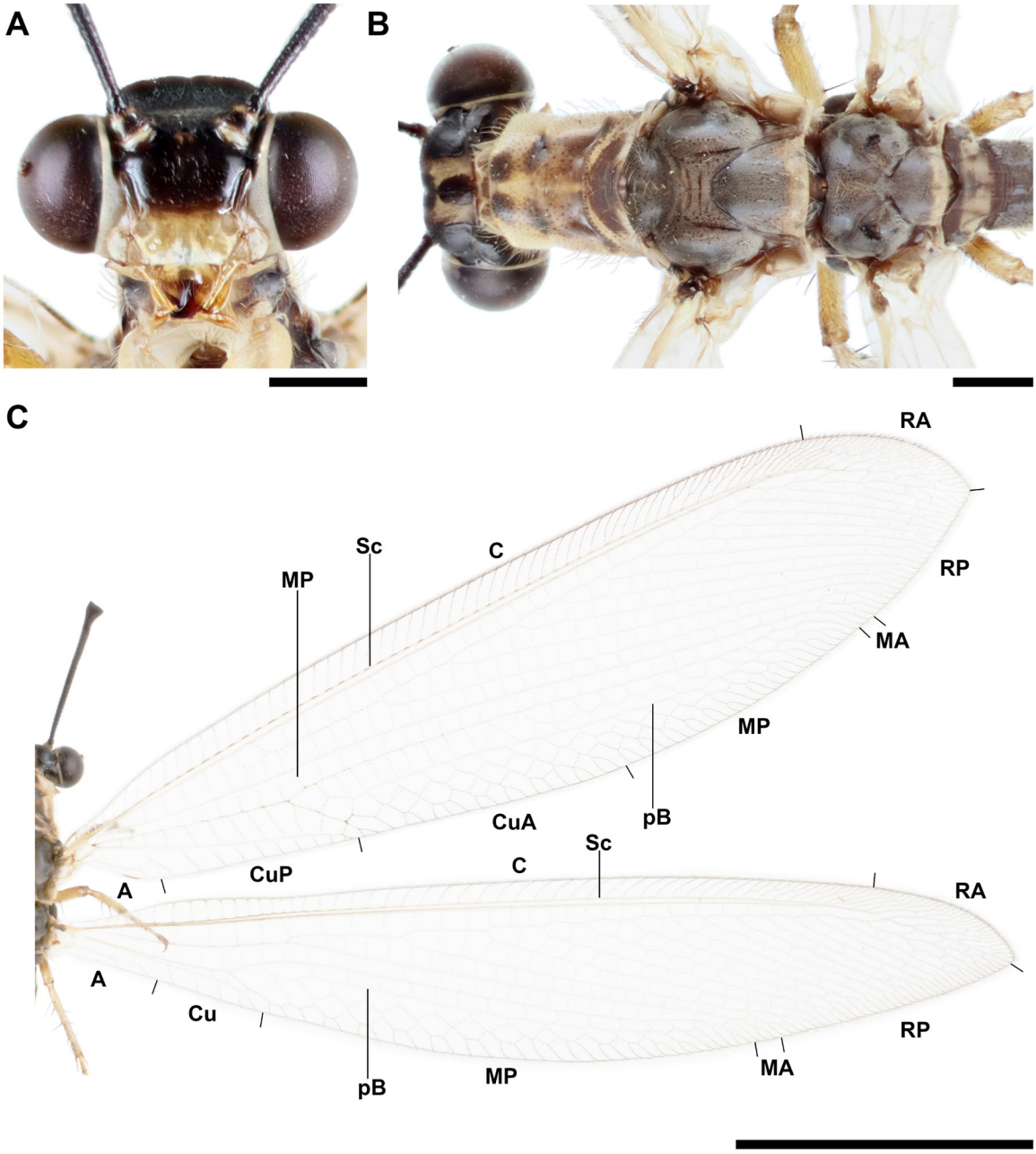

Fig. 8. *Myrmeleon tenuipennis* Rambur, 1842 (NTU). **A**. Head, frontal view. **B**. Head and thorax, dorsal habitus. **C**. Wings. Abbreviations: A = anal veins; C = costa; Cu = cubitus; CuA = cubitus anterior; CuP = cubitus posterior; MA = media anterior; MP = media posterior; pB = posterior Banksian line; RA = radius anterior; RP = radius posterior; Sc = subcosta. Scale bars: A–B = 1.0 mm; C = 10.0 mm.

data as for preceding; 24 Feb. 2020; Yu-Hsiu Lin leg.; 3 specs preserved in alcohol; NTU. – **Taichung City** • 1 ♀ (larva reared to adult); Beitun District; Dakeng Trail; 24 Jun. 2020; Yu-Hsiu Lin leg.; NTU.

Re-description of the adult

Measurements (♂ n = 7, ♀ n = 13). Body length: ♂ 23.1–28.3 mm, ♀ 23.6–28.1 mm; forewing: length ♂ 23.3–29.7 mm, ♀ 25.8–31.1 mm; width ♂ 5.9–7.0 mm, ♀ 6.4–7.7 mm; width/length ratio ♂ 0.2481, ♀ 0.2502; hindwing: length ♂ 23.1–29.6 mm, ♀ 25.5–31.0 mm; width ♂ 4.9–5.9 mm, ♀ 5.5–6.6 mm; width/length ratio ♂ 0.2058, ♀ 0.2123.

Head (Fig. 8A–B). Vertex strongly raised, rounded, black, with a pair of shiny yellow markings, 4 shiny black spots along anterior margin and 4 shiny black spots along posterior margins, with sparse short black hairs; occiput pale brown. Frons shiny black, covered with sparse short hyaline hairs; gena whitish-yellow, with a whitish-yellow line along ocular rim; clypeus whitish-yellow, sometimes dark brown on dorsal half, with sparse hyaline hairs. Antenna brown, short, with slightly defined club, covered with short dark hairs; scape dark brown with a ring of white band at base and apex; pedicel dark brown;

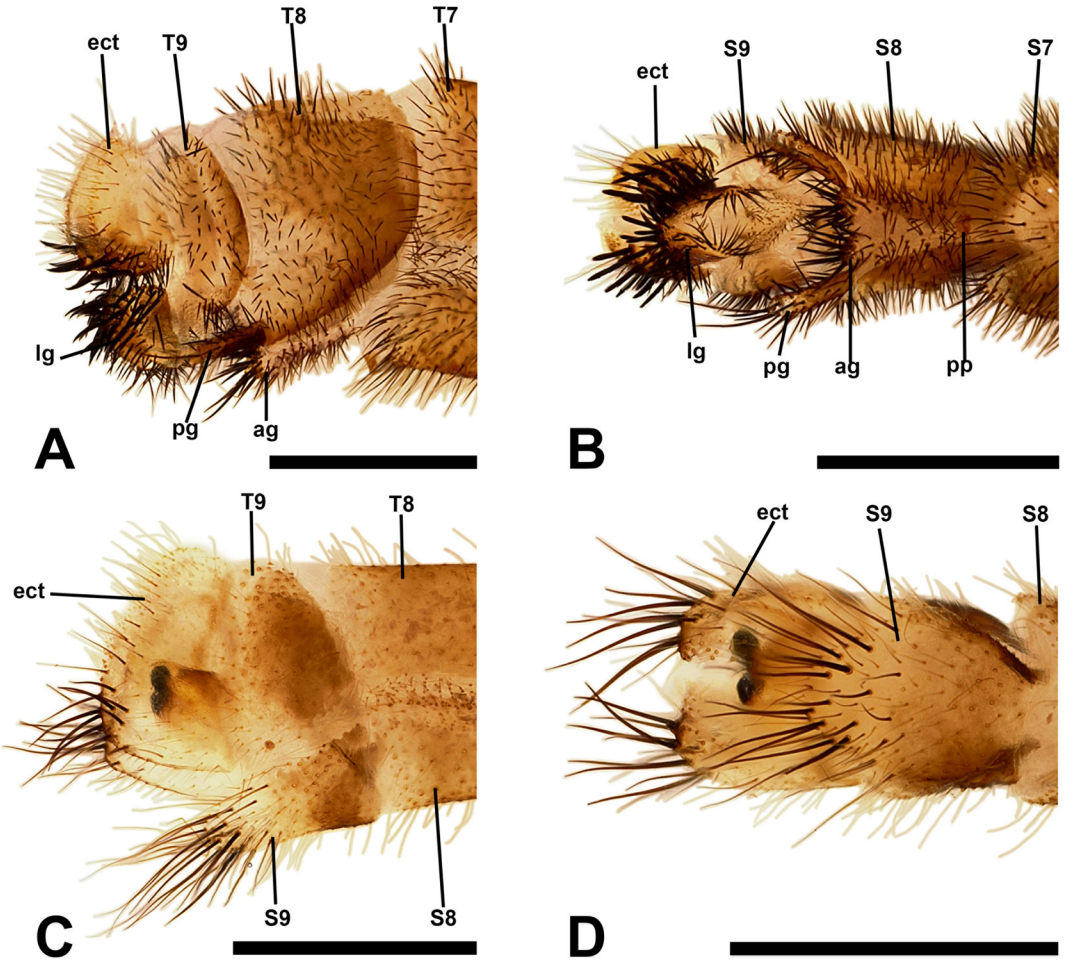

Fig. 9. *Myrmeleon tenuipennis* Rambur, 1842 (NTU). **A**. Female terminalia, lateral view. **B**. Same, ventral view. **C**. Male terminalia, lateral view. **D**. Same, ventral view. Abbreviations: ag = anterior gonapophysis; ect = ectoproct; lg = lateral gonapophysis; pg = posterior gonapophysis; pp = pregenital plate; S = sternites; T = tergites. Scale bars = 1.0 mm.

flagellum comprising approximately 50 flagellomeres. Mouthparts yellow, labrum yellow, with several hyaline hairs; maxillary palps yellow, labial palps whitish-yellow, 3rd palpomere darker, fusiform, tapering to acute apex, with brown round palpimacula on apical ⅓; submentum with long dark hairs.

Thorax (Fig. 8B). Pronotum broad, approximately as long as wide, mostly whitish-yellow, anterior margin with a pair of dark brown spots, posterior half with a pair of broad, dark brown markings (markings on pronotum sometimes paler or smaller), membrane mostly brown, with hyaline hairs and long dark hairs. Cervical sclerites dark brown. Mesonotum dark brown, with sparse hyaline hairs; mesoscutum dark brown, with a whitish-yellow band on posterior margin. Metanotum dark brown, covered with sparse hyaline hairs; metascutum dark brown, with a whitish-yellow band on posterior margin. Meso- and metapleuron dark brown, moderately covered with long hyaline hairs.

Legs. Whitish-yellow, short. Coxae whitish-yellow, moderately covered with long hyaline hairs. Femora moderately covered with short dark hairs, mixed with sparse long black setae; fore femur whitish-yellow; mid femur yellow, darker on apex; hind femur whitish-yellow with a dark brown spot on distal half; femoral sense hair length about ½ of femur length on fore and mid legs, absent on hind leg. Tibiae moderately covered with short dark hairs, mixed with sparse long black setae; fore tibia yellow; mid tibia yellow, dark brown on anterior surface; hind tibia whitish-yellow, dark brown on ventral surface. Tibial spurs reddish-yellow, short, slender, almost straight, slightly shorter than tarsomere 1. Tarsi brownish-yellow, sparsely covered with short dark hairs dorsally, short black setae ventrally; tarsomere 1 approximately as long as combined length of tarsomeres 2–4; tarsomere 5 approximately as long as combined length of tarsomeres 1–4. Pretarsal claws reddish-yellow, short, simple, curved, longer than tibial spurs.

Wings (Fig. 8C). Without markings, hyaline. Forewings subacute at apex; veins and crossveins pale brown, Sc finely alternating brown and pale yellow; costal area without interconnected crossveins, distal crossveins often branched; presectoral area with 7–8 crossveins and 0–4 irregular cells; RP arising almost opposite to CuA fork, with 19–28 crossveins from origin of RP to hypostigmatic cell; CuP supporting 1 cell before fusing with 1A; 3A mostly fused with 2A; hypostigmatic cell long; pterostigma

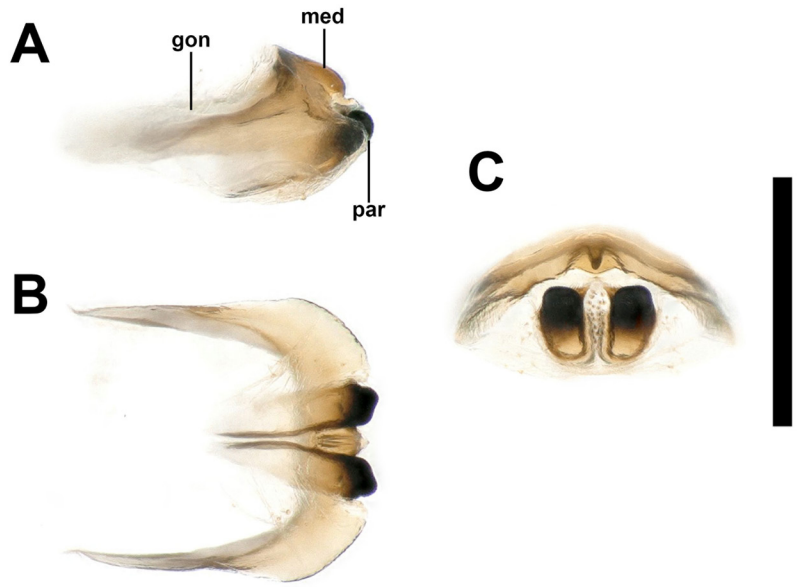

Fig. 10. *Myrmeleon tenuipennis* Rambur, 1842, male genitalia (NTU). **A**. Lateral view. **B**. Ventral view. **C**. Caudal view. Abbreviations: gon = gonarcus; med = mediuncus; par = parameres. Scale bar = 0.5 mm.

absent; anterior Banksian line absent, posterior Banksian line distinct. Hindwings approximately as long and narrower than forewings; acute at apex; presectoral area with 4 crossveins and 0 irregular cells; RP arising beyond MP fork, at origin runs closer to MA, with 16–20 crossveins from origin of RP to hypostigmatic cell; hypostigmatic cell as long as forewing; pterostigma absent; anterior Banksian line absent, posterior Banksian line distinct; male with brown pilula axillaris.

Abdomen (Fig. 1C). Shorter than hindwing, tergites dark brown, sternite dark brown, densely covered with short dark hairs dorsally and laterally, hyaline hairs ventrally.

Female terminalia (Fig. 9A–B). Tergite VIII at least 2 times as wide as tergite IX. Tergite IX narrow, oval in lateral view. Ectoproct semicircular in lateral view, with long, black fossorial bristles on ventral half. Lateral gonapophyses semicircular in lateral view, smaller than ectoproct, with long, black fossorial bristles on posterior side and long, thin, black setae on the ventral side. Posterior gonapophyses long, slender, with long, black setae. Anterior gonapophyses slightly lobed, slightly separated, with long, thick, black setae. Pregenital plate distinct, oval, presented on posterior margin of sternite VII.

Male genitalia (Figs 9C–D, 10). Ectoproct trapezoid in lateral view, dorsal margin shorter than ventral margin, covered with short pale brown hair, ventral half with long black setae. Sternite IX shorter than combined length of tergite IX and ectoproct, diamond-shaped in ventral view, with long black setae posteriorly. Gonarcus wide, arched, flat, U-shaped in dorsal view, arms producing posteriorly in lateral view. Mediuncus reduced. Parameres well sclerotized, large, dark brown, rectangular in caudal view, separated, with short black setae in between.

Distribution

Pakistan (Punjab Province), India (Maharashtra), Sri Lanka, Vietnam, China (Fujian, Guangdong, Guangxi, Hainan, Zhejiang) and Taiwan (Hsinchu, Miaoli, Nantou, New Taipei, Taichung, also on associated island of Kinmen) (Fig. 31C) (Wang *et al.* 2018; Hassan *et al.* 2022).

Biology

The adults appear from April to November based on the collecting and emergence date of the examined specimens. The larvae inhabit low-elevation areas and are usually found beneath rock overhangs or artificial structures (Lin *et al.* 2021).

Remarks

A small to medium-sized species, the adults can be distinguished by the markings on the head and pronotum and the pale-colored wing veins (Fig. 8A–C). Its male genitalia are unique among Myrmeleontini species from Taiwan, with relatively flattened gonarcus and reduced mediuncus (Fig. 10). There is no difference between adult specimens from Taiwan and the *M. bimaculatus* paratype from China, which we can conclude that the specimens from Taiwan are *M. tenuipennis*.

Myrmeleon littoralis group

Diagnosis

The *M. littoralis* group is characterized by the hindwing longer than the forewing; hindwing RP at origin runs equidistant to RA and MA; male genitalia with gonarcus narrow, arched, mediuncus weakly sclerotized, parameres well sclerotized, hooked in lateral view.

Included species

Myrmeleon littoralis Miller & Stange, 1999.

Possible candidate: *Baliga kashimirensis* Hassan *et al*., 2022 (see below).

Remarks

Several characters of the sole species of this group, including longer hindwings and the interconnected crossveins on the costal area (Fig. 11C), are similar to the species of *Baliga*, but remaining characters such as the overall morphology of the larvae (IX abdominal sternite with one or more row of digging setae) (Lin *et al.* 2021: figs 3e, 4e, 10), and the male genitalia and female terminalia (female anterior gonapophyses about half length of posterior gonapophyses) (Figs 12–13) suggest that this species group is distinct from *Baliga*. Hassan *et al.* (2022) described *Baliga kashimirensis* from Pakistan but based on the male genitalia and female terminalia, this species should belong to the *M. littoralis* group as well. Since we have not yet examined specimens of *B. kashmirensis*, taxonomic changes are not made here.

Myrmeleon littoralis Miller & Stange, 1999
Figs 1D, 11–13

Myrmeleon littoralis Miller & Stange in Miller *et al.*, 1999: 64. Type locality: Taiwan (Miaoli).

Myrmeleon littoralis – Stange *et al.* 2003: 116. — Wang *et al.* 2018: 106.
Myrmeleon (*Myrmeleon*) *littoralis* – Stange 2004: 331. — Lin *et al.* 2019: 140.

Material examined

Holotype

TAIWAN • ♂ (photos examined); Miaoli County, Tongxiao Township, Tongxiao Resort Beach (Tonshou Resort Beach); 24°29′47.5″ N, 120°40′20.5″ E; 3 May 1998; Robert A. Miller, Lionel A. Stange and Hsiau-Yue Wang leg.; collected as larva, emerged 4 Jul. 1998; FSCA 00091129.

Paratypes

TAIWAN – **Miaoli County** • 1 ♂, 1 ♀ (2 larvae reared to adults); same data as for holotype; NTM 3620-001, 3620-003. – **Pingtung County** • 1 ♂; Hengchun Township, Fengchuisha Beach (Feiha-Tre-Sha Area, Kenting Nat'l Park); 21°56′55.7″ N, 120°50′11.6″ E; 20 Apr. 1998; Robert A. Miller, Lionel A. Stange and Hsiau-Yue Wang leg.; on beach; TAMU ENTO X0405012. – **Taitung County** • 1 ♂ (larva reared to adult); Donghe Township, Donghe (Dungha); 22°58′43.6″ N, 121°18′12.2″ E; 18 Apr. 1998; Robert A. Miller, Lionel A. Stange and Hsiau-Yue Wang leg.; NTM 3620-002 • 1 ♂ (larva reared to adult); same data as for preceding; TAMU X0405662.

Additional material

TAIWAN – **Hsinchu County** • 1 ♂ (larva reared to adult); Hengshan Township, Hengshan Street Wood Factory; 26 Nov. 2019; Jia-Wei Chuang leg.; collected in wood dust; molting failed, preserved in alcohol; NTU • 1 ♀ (larva reared to adult); same data as for preceding NMNS. – **Kaohsiung City** • 1 ♂ (larva reared to adult); Jiaxian District, Baiyun Mountain; 27 Jan. 2021; Yu-Hsiu Lin leg.; molting failed, preserved in alcohol; NTU • 2 ♂♂, 2 ♀♀ (4 larvae reared to adults); Yanchao District, Jinshan Temple; 22°48′19.01″ N, 120°23′29.18″ E; 13 Feb. 2021; Hsuan-Pu Chen leg.; preserved in alcohol; NTU • 4 ♂♂, 2 ♀♀ (6 larvae reared to adults); Qijing District, Qijing Beach; 16 Nov. 2019; Yu-Hsiu Lin leg.; 4 specs preserved in alcohol; NTU • 1 ♂, 4 ♀♀ (5 larvae reared to adults); Meinong District, Shuangxi Arboretum Trail; 29 Jan. 2021; Yu-Hsiu Lin leg.; preserved in alcohol; NTU. – **Kinmen County** • 1 ♂; Jincheng Township, Tongan Wharf; 23 May 2020; Kai-Ti Lin leg.; preserved in alcohol; NTU. – **Miaoli County** • 1 ♂ (larva reared to adult); Zhunan Township, Qiding Seaside Park; 8 Nov. 2019; Yu-Hsiu Lin leg.; preserved in alcohol; NTU • 1 ♂ (larva reared to adult); Zaoqiao Township, Shangrila Paradise Amusement Park; 23 Sep. 2017; Yu-Jen Tsao leg.; NTU • 1 ♂, 1 ♀ (2 larvae reared to adults); same data as for preceding; 12 Jan. 2018; Yu-Jen Tsao leg.; NTU • 2 ♂♂ (2 larvae reared to adults); same data as for preceding; 3 Mar. 2018; Yu-Jen Tsao leg.; 1 spec. preserved in alcohol; NTU • 1 ♀ (larva reared to adult); same data as for preceding; 5 May 2018; Yu-Jen Tsao leg.; NTU • 1 ♀ (larva reared to adult);

same data as for preceding; 9 Jun. 2018; NTU • 1 ♂ (larva reared to adult); same data as for preceding; 7 Jul. 2018; Yu-Jen Tsao leg.; NTU • 1 ♂ (larva reared to adult); same data as for preceding; 4 Aug. 2018; Yu-Jen Tsao leg.; NTU • 1 ♂ (larva reared to adult); same data as for preceding; 1 Sep. 2018; Yu-Jen Tsao leg.; NTU • 1 ♂ (larva reared to adult); same data as for preceding; 6 Oct. 2018; Yu-Jen Tsao leg.; NTU • 1 ♂, 3 ♀♀ (4 larvae reared to adults); same data as for preceding; 4 Nov. 2018; Yu-Jen Tsao leg.; NTU • 4 ♂♂, 4 ♀♀ (8 larvae reared to adults); same data as for preceding; 1 Dec. 2018; Yu-Jen Tsao and Yu-Hsiu Lin leg.; NTU • 2 ♂♂, 1 ♀ (3 larvae reared to adults); same data as for preceding; 12 Jan. 2019; Yu-Jen Tsao leg.; NTU • 2 ♂♂ (2 larvae reared to adults); same data as for preceding; 6 Jul. 2019; Yu-Jen Tsao leg.; 1 spec. preserved in alcohol; NTU • 1 ♂ (larva reared to adult); same data as for preceding; 17 Aug. 2019; Yu-Jen Tsao leg.; NTU • 1 ♂, 1 ♀; same data as for holotype; TAMU X0068719, X0068674. – **New Taipei City** • 1 ♂, 1 ♀ (2 larvae reared to adults); Gongliao District, Fulong Seaside Park; 7 Jun. 2019; Yu-Hsiu Lin leg.; 1 spec. preserved in alcohol; NTU • 1 ♂; Jinshan District, Jinshan; 14 Oct. 1989; Wen-Jer Wu leg.; NTU • 2 ♀♀ (2 larvae reared to adults); Shimeng District, Laomei; 4 Aug. 2019; Yu-Hsiu Lin leg.; 1 spec. preserved in alcohol; NTU • 3 ♀♀ (3 larvae reared to adults); Bali District, Laoqiankeng Road; 30 Oct. 2019; Yu-Hsiu Lin leg.; preserved in alcohol; NTU • 1 ♂ (larva reared to adult); Linkou District, Linkou Canyon; 8 Nov. 2019; Yu-Hsiu Lin leg.; preserved in alcohol; NTU • 1 ♂, 3 ♀♀ (4 larvae reared to adults); same data as for preceding; 7 Nov. 2020; Yu-Hsiu Lin, Bin-Hong Ho and Yun Ho leg.; 3 specs preserved in alcohol; NTU • 1 ♀ (larva reared to adult); Gongliao District, Longmeng Bridge; 15 Dec. 2019; Yu-Hsiu Lin leg.; NTU • 2 ♂♂ (2 larvae reared to adults); Gongliao District, Longmeng Camping Ground; 15 Dec. 2019; preserved in alcohol; NTU • 1 ♂ (larva reared to adult); Tamsui District, Shalun Seaside Resort; 4 Jul. 2018; Yu-Hsiu Lin leg.; NTU • 2 ♂♂, 4 ♀♀ (6 larvae reared to adults); same data as for preceding; 1 Jun. 2019; Yu-Jen Tsao leg.; 3 specs preserved in alcohol; NTU • 4 ♂♂, 2 ♀♀ (5 larvae reared to adults); same data as for preceding; 3 Sep. 2019; Yu-Hsiu Lin leg.; 4 specs preserved in alcohol; NTU • 2 ♂♂, 3 ♀♀ (5 larvae reared to adults); Jinshan District, Shitoushan Park; 21 Dec. 2020; Yu-Hsiu Lin leg.; 4 specs preserved in alcohol; NTU • 2 ♂♂ (2 larvae reared to adults); Bali District, Wazihwei Beach; 11 Sep. 2019; Yu-Hsiu Lin leg.; 2 specs preserved in alcohol; NTU. – **Penghu County** • 2 ♂♂, 2 ♀♀ (4 larvae reared to adults); Huxi Township, Aimen Beach; 16 Jan. 2020; Yu-Hsiu Lin leg.; preserved in alcohol; NTU • 2 ♀♀ (2 larvae reared to adults); Baisha Township, Houliao Beach; 13 Jan. 2020; Yu-Hsiu Lin leg.; 1 spec. preserved in alcohol; NTU • 1 ♂, 1 ♀ (2 larvae reared to adults); Magong City, Shanshui Beach; 16 Jan. 2020; Yu-Hsiu Lin leg.; preserved in alcohol; NTU. – **Pingtung County** • 1 ♀ (larva reared to adult); Checheng Township, Baoli Forest Area; 29 Jan. 2021; Yu-Hsiu Lin leg.; preserved in alcohol; NTU • 1 ♂ (cocoon reared to adult); Checheng Township, Baoli River; 11 Feb. 2019; Kai-Wei Chan leg.; NTU • 1 ♀ (larva reared to adult); Hengchun Township, Houbihu Beach; 4 Feb. 2020; Yu-Hsiu Lin leg.; preserved in alcohol; NTU • 1 ♂ (larva reared to adult); Hengchun Township, Kenting National Forest Recreation Area; 30 Jan. 2021; Yu-Hsiu Lin leg.; preserved in alcohol; NTU • 1 ♂ (larva reared to adult); Hengchun Township, South Bay; 3 Feb. 2020; Yu-Hsiu Lin leg.; preserved in alcohol; NTU. – **Taichung City** • 1 ♀; Beitun District, Dakeng Trail; 26 Nov. 2017; Yu-Ching Huang leg.; by hand; NCHU • 1 ♂, 2 ♀♀ (1 cocoon, 2 larvae reared to adults); same data as for preceding; 24 Jun. 2020; Yu-Hsiu Lin leg.; 2 specs preserved in alcohol; NTU. – **Tainan City** • 1 ♀; Xinhua District, NCHU Hsinhua (Xinhua) Forest Station; 11 Oct. 1984; J.T. Yang leg.; NCHU. – **Taoyuan City** • 1 ♂ (larva reared to adult); Guanyin District, Caota Sand Dunes; 8 Nov. 2019; Yu-Hsiu Lin leg.; NTU • 3 ♀♀ (3 larvae reared to adults); Xinwu District, Yongan Seaside Park; 8 Nov. 2019; Yu-Hsiu Lin leg.; preserved in alcohol; NTU.

Re-description of the adult

Measurements (♂ n =11, ♀ n = 12). Body length: ♂ 25.9–33.2 mm, ♀ 26.5–31.1 mm; forewing: length ♂ 27.4–35.1 mm, ♀ 28.3–33.4 mm; width ♂ 7.1–9.1 mm, ♀ 7.3–9.0 mm; width/length ratio ♂ 0.2660, ♀ 0.2604; hindwing: length ♂ 28.2–37.1 mm, ♀ 29.0–34.3 mm; width ♂ 6.0–7.6 mm, ♀ 6.2–7.8 mm; width/length ratio ♂ 0.2151, ♀ 0.2185.

Head (Fig. 11A–B). Vertex strongly raised, rounded, shiny yellow, 4 shiny black spots along anterior margin and 4 shiny black spots along posterior margins, with sparse short black hairs; occiput pale yellow, with a pair of black spots in middle and a pair of pale brown spots on lateral side. Frons shiny black dorsally, whitish-yellow ventrally, with a pair of triangular dark brown near middle, covered with sparse short hyaline hairs; gena whitish-yellow, with a whitish-yellow line along ocular rim; clypeus whitish-yellow with a pair of dark brown spots, with sparse hyaline hairs. Antenna blackish-brown,

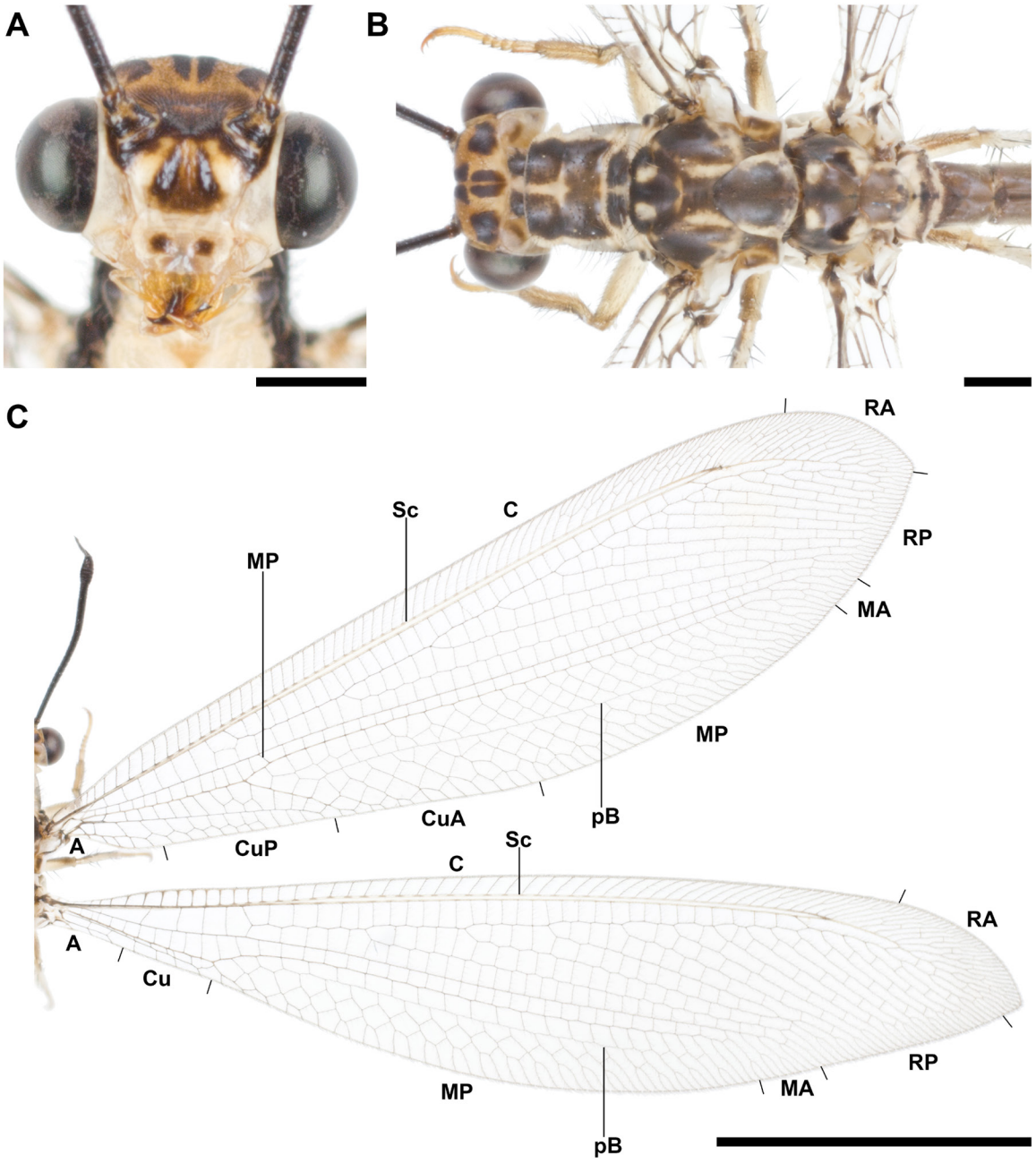

Fig. 11. *Myrmeleon littoralis* Miller & Stange, 1999 (NTU). **A**. Head, frontal view. **B**. Head and thorax, dorsal habitus. **C**. Wings. Abbreviations: A = anal veins; C = costa; Cu = cubitus; CuA = cubitus anterior; CuP = cubitus posterior; MA = media anterior; MP = media posterior; pB = posterior Banksian line; RA = radius anterior; RP = radius posterior; Sc = subcosta. Scale bars: A–B = 1.0 mm; C = 10.0 mm.

short, with slightly defined club, covered with short dark hairs; scape whitish-yellow with a ring of black band; pedicel blackish-brown; flagellum comprising approximately 43 flagellomeres. Mouthparts yellow, labrum yellow, with several hyaline hairs; maxillary palps yellow, labial palps whitish-yellow, 3rd palpomere darker, fusiform, tapering to acute apex, with brown round palpimacula on apical ⅓; submentum with long dark hairs.

Thorax (Fig. 11B). Pronotum broad, approximately as long as wide, mostly blackish-brown, with a whitish-yellow median stripe on anterior half, lateral side with whitish-yellow stripe, lateral margin blackish-brown, membrane with a pair of dark brown markings, with hyaline hairs and long dark hairs. Cervical sclerites whitish-yellow with dark brown markings. Mesonotum dark brown, with a U-shaped whitish band with sparse hyaline hairs; mesoscutum with a pair of white spots. Metanotum dark brown with two pairs of whitish-yellow spots, covered with sparse hyaline hairs. Meso- and metapleuron whitish-yellow with a medial dark brown stripe, moderately covered with long hyaline hairs.

Legs. Whitish-yellow, short. Coxae whitish-yellow, moderately covered with long hyaline hairs. Femora moderately covered with short dark hairs, mixed with sparse long black setae; fore femur whitish-

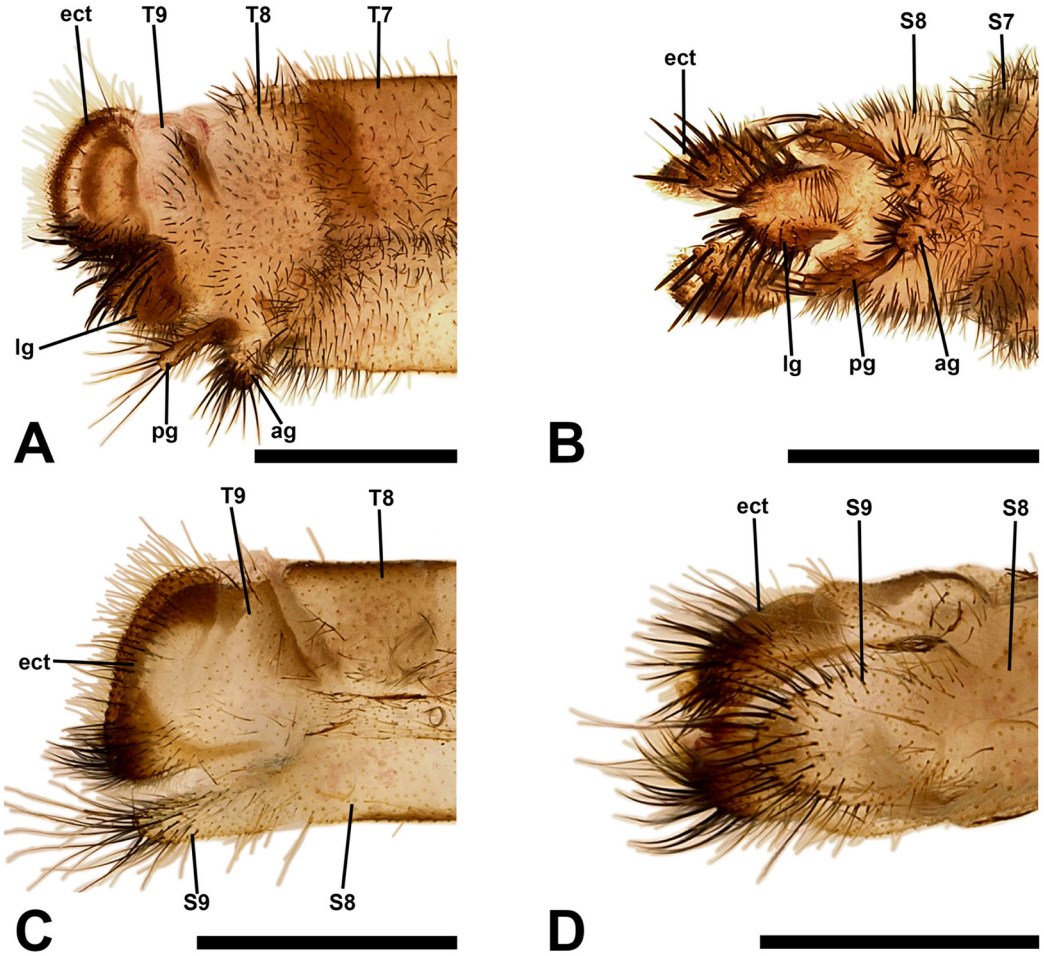

Fig. 12. *Myrmeleon littoralis* Miller & Stange, 1999 (NTU). **A**. Female terminalia, lateral view. **B**. Same, ventral view. **C**. Male terminalia, lateral view. **D**. Same, ventral view. Abbreviations: ag = anterior gonapophysis; ect = ectoproct; lg = lateral gonapophysis; pg = posterior gonapophysis; S = sternites; T = tergites. Scale bars = 1.0 mm.

yellow, slightly brownish on posterior surface; mid- and hind femora dark brown on distal half of anterior surface; femoral sense hair length ½ to ⅔ of femur length on fore and mid legs, absent on hind leg. Tibiae moderately covered with short dark hairs, mixed with sparse long black setae; fore tibia dark brown on anterior surface; mid tibia brownish-yellow, darker on posterior surface. Tibial spurs reddish-brown, short, slender, almost straight, approximately as long as tarsomere 1 (slightly shorter on hind leg). Tarsi brownish-yellow, sparsely covered with short dark hairs dorsally, short black setae ventrally; tarsomere 1 approximately as long as combined length of tarsomeres 2–4; tarsomere 5 approximately as long as combined length of tarsomeres 1–4. Pretarsal claws reddish-brown, short, simple, curved, approximately as long as tibial spurs.

Wings (Fig. 11C). Without markings, membrane with metabolic colorations. Forewings subacute at apex; veins and crossveins mostly brown, Sc finely alternating brown and pale yellow; costal area with interconnected crossveins from apical ⅓ to stigma, distal crossveins often branched; presectoral area with 7–10 crossveins and 0–6 irregular cells; RP arising almost opposite or slightly beyond CuA fork, with 26–39 crossveins from origin of RP to hypostigmatic cell, seldom with an extra row of cell under hypostigmatic cell; CuP supporting 1 cell before fusing with 1A; 3A mostly fused with 2A; hypostigmatic cell long; pterostigma pale white; anterior Banksian line absent, posterior Banksian line distinct. Hindwings slightly longer and narrower than forewings; acute at apex; presectoral area with 4–5 crossveins and 0–1 irregular cells; RP arising almost opposite or slightly beyond MP fork, at origin runs equidistant to RA and MA, with 26–37 crossveins from origin of RP to hypostigmatic cell; pterostigma pale white; anterior Banksian line absent, posterior Banksian line distinct; male with pilula axillaris.

Abdomen (Fig. 1D). Shorter than hindwing, tergites brown, sternite whitish-yellow, densely covered with short dark hairs dorsally and laterally, hyaline hairs ventrally.

Female terminalia (Fig. 12A–B). Tergite VIII slightly wider than tergite IX. Tergite IX narrow, rectangular in lateral view. Ectoproct semicircular in lateral view, with long, black fossorial bristles on

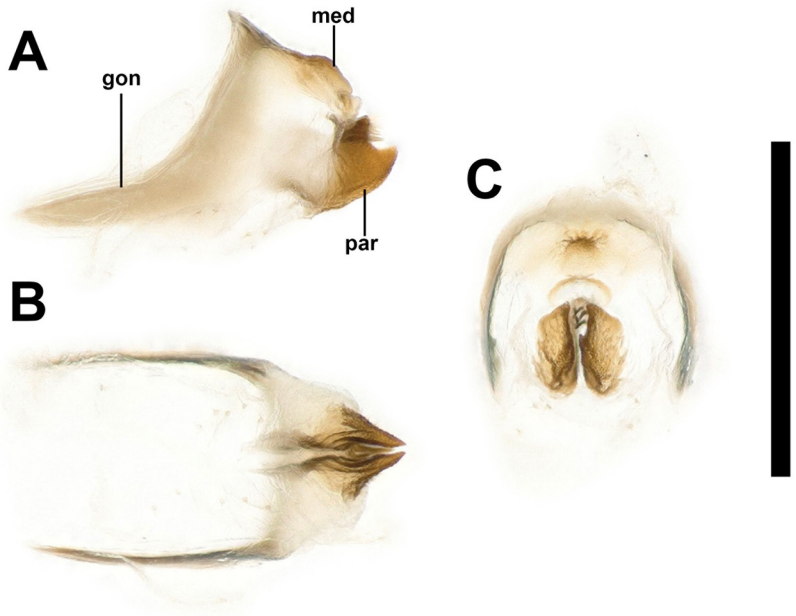

Fig. 13. *Myrmeleon littoralis* Miller & Stange, 1999, male genitalia (NTU). **A**. Lateral view. **B**. Ventral view. **C**. Caudal view. Abbreviations: gon = gonarcus; med = mediuncus; par = parameres. Scale bar = 0.5 mm.

ventral half. Lateral gonapophyses semicircular in lateral view, smaller than ectoproct, with long, black fossorial bristles on posterior side and long, thin, black setae on ventral side. Posterior gonapophyses long, slender, with long, black setae. Anterior gonapophyses short, about half length of posterior gonapophyses, slightly separated, with long, black setae. Pregenital plate absent.

Male genitalia (Figs 12C–D, 13). Ectoproct parallelogram in lateral view, dorsal margin as long as ventral margin, covered with short pale brown hair, ventral half with long black setae. Sternite IX almost as long as combined length of tergite IX and ectoproct, tapered in ventral view, with long black setae posteriorly. Gonarcus narrow, arched, long, arms curved ventral-posteriorly in lateral view. Mediuncus weakly sclerotized, two pale brown arches in caudal view, dorsal one longer. Parameres well sclerotized, separated, with short black setae in between, hooked in lateral view.

Distribution

Taiwan (widespread, also on associated islands of Penghu and Kinmen) (Fig. 31D).

Biology

From the collecting and emergence date of the examined specimens, the adults appear from late March to November. The larvae can be observed from the coastal wind-break forests to low-elevation forests (Lin *et al.* 2021).

Remarks

This is a dominant species in Taiwan, the overall markings on the head and thorax make this species easy to identify (Fig. 11A–B). This species is similar to *Myrmeleon coalitus* Yang, 1999 from southeastern China in overall appearance and the species status of whether *M. littoralis* is a junior synonym of *M. coalitus* requires further confirmation (Yang 1999; Wang *et al.* 2018).

Myrmeleon wangi group

Diagnosis

The *M. wangi* group can be characterized by the hindwing shorter than the forewing; hindwing RP at origin runs closer to MA; male genitalia with gonarcus arched, membrane with short black setae, mediuncus well sclerotized, inverted V-shaped in caudal view, parameres well sclerotized, triangular in caudal view, the larvae with brown markings on coxae.

Included species

Myrmeleon wangi Miller & Stange, 1999 **stat. rev.**

Possible candidates: *Myrmeleon formicarius* Linnaeus, 1767, *M. punicanus* Pantaleoni & Badano, 2012, *M. trivialis* Gerstaecker, 1885

Remarks

Several other Old World species have a similar structure in the male genitalia comparing with *M. wangi*, including *M. formicarius*, *M. punicanus* and *M. trivialis*. The male genitalia of these species are similar to those of *M. wangi* in the overall shape of the gonarcus and with short, black setae on the membrane. However, the mediuncus of *M. wangi* is an inverted V-shape in caudal view (Fig. 16C), as the mediuncus of the other three species appears to be three-pronged. The male genitalia of these species can be distinguished from those of *Baliga* by the presence of short, black setae on the membrane, as well as the lack of an additional dorsal process on the mediuncus, which is present in species of *Baliga* in lateral view (Figs 4A, 7A) (Pantaleoni & Badano 2012; Sekimoto 2014; Hassan *et al.* 2022). The

above-mentioned species likely belong to a closely related or the same species group as *M. wangi*, but additional research is required. If these species are proven to be in the same species group, this group should be redesignated as *Myrmeleon formicarius* group.

Myrmeleon wangi Miller & Stange, 1999 stat. rev.
Figs 1E, 14–16

Myrmeleon wangi Miller & Stange in Miller *et al.*, 1999: 70. Type locality: Taiwan (Hualien).

Myrmeleon formicarius – Esben-Petersen 1913: 222 (misidentification).
Myrmeleon formicalynx – Stange & Wang 1997: 52 (misidentification).
Myrmeleon wangi – Stange *et al.* 2003: 126. — Wang *et al.* 2018: 107.
Myrmeleon (*Myrmeleon*) *wangi* – Stange 2004: 338. — Lin *et al.* 2019: 140.

Material examined

Holotype
TAIWAN • ♂ (photos examined); Hualien County, Xiulin Township, Dayulin (Tayuling); 24°11′16.0″ N, 121°19′25.0″ E; 2600 m a.s.l.; 1 May 1998; Robert A. Miller, Lionel A. Stange and Hsiau-Yue Wang leg.; collected as larva, emerged 5 Jun. 1998; FSCA 00091076.

Paratypes
TAIWAN – **Hualien County** • 1 ♂ (larva reared to adult); same data as for holotype; NTM 3626-001. – **Nantou County** • 1 ♂, 1 ♀ (2 larvae reared to adults); Renai Township, Qingjing (Chingjing) Farm; 1800 m a.s.l.; 1 May 1998; Robert A. Miller, Lionel A. Stange and Hsiau-Yue Wang leg.; NTM 3626-003, 3626-004 • 1 ♂; Renai Township, Wushe; 24°00′33.7″ N, 121°06′29.8″ E; 950 m a.s.l.; 28 Apr. 1998; Robert A. Miller, Lionel A. Stange and Hsiau-Yue Wang leg.; TAMU X0405502 • 1 ♀ (larva reared to adult); same data as for preceding; NTM 3626-002.

Additional material
TAIWAN – **Hsinchu County** • 1 ♀; Jianshi Township, Smangus; 8 Sep. 2018; Jia-Yu Ci leg.; KWC • 1 ♀ (larva reared to adult); same data as for preceding; 19 Aug. 2020; Yu-Hsiu Lin leg.; NTU. – **Hualien County** • 1 ♀; Xiulin Township, Bilu (Pilu); 9 Jul. 2007; W.Z. Tsao leg.; NMNS • 1 ♀; Xiulin Township, Cien (Tzuen); 1900 m a.s.l.; 23 Jul. 2001; W.I. Chou leg.; NMNS • 1 ♂, 1 ♀ (2 larvae reared to adults); Wanrong Township, Yikan River; 23°52′48.01″ N, 121°21′23.46″ E; 16 Jan. 2021; Yi Sun leg.; 1 spec. preserved in alcohol; NTU. – **Nantou County** • 1 ♂; Renai Township, Biluxi; 20 Sep. 1997; Hsiau-Yue Wang leg.; det. as *Myrmeleon fornicalynx*; NTM • 1 ♀; Renai Township, Chunyang; 31 May 1995; M.L. Chan and C.S. Lin leg.; by UV light; NMNS • 1 ♀; Renai Township, Cuifeng; 12 Jul. 1998; Guo-Long Lin leg.; NTU • 2 ♀♀ (2 larvae reared to adults); Renai Township, Highland Experimental Farm N.T.U., Chunyang Farm; 16 May 2020; Yu-Hsiu Lin leg.; 1 spec. preserved in alcohol; NTU • 1 ♀; Renai Township, Huisun Forest Area; 4 May 1985; C.F. Yan leg.; NCHU • 1 ♂ (larva reared to adult); Renai Township, Provincial Highway No. 14 Km 94.5; 7 Oct. 2021; Bao-Cheng Lai and Jing-Fu Tsai leg.; NMNS • 1 ♂; Renai Township, Wushe; 1150 m a.s.l.; 19–23 Jun. 1979; K.S. Lin and B.H. Chen leg.; TARI • 1 ♀; same data as for preceding; 3 Jun. 1994; S.T. Yang leg.; NCHU • 2 ♂♂, 2 ♀♀; Renai Township, Meifeng, 30 km S of Tayuling; 2200 m a.s.l.; 1–8 Jun. 1980; D.R. Davis leg.; forest; USNM. – **Taichung City** • 1 ♀; Heping District, Anmachan Cottage (Anma Lodge); 1 Aug. 2005; Y.L. Chen leg.; by hand; NMNS.

Re-description of the adult

Measurements (♂ n =1, ♀ n = 4). Body length: ♂ 28.0 mm, ♀ 28.3–32.9 mm; forewing: length ♂ 31.8 mm, ♀ 37.7–42.3 mm; width ♂ 6.8 mm, ♀ 7.5–8.5 mm; width/length ratio ♂ 0.2138, ♀ 0.2036;

hindwing: length ♂ 29.9 mm, ♀ 34.5–40.5 mm; width ♂ 5.6 mm, ♀ 6.4–6.7 mm; width/length ratio ♂ 0.1873, ♀ 0.1777.

Head (Fig. 14A–B). Vertex strongly raised, rounded, black, 4 shiny black spots along anterior margin and 4 shiny black spots along posterior margins, with sparse short black hairs; occiput dark brown, with a pale-yellow line in middle. Frons shiny black, covered with sparse short hyaline hairs; gena whitish-

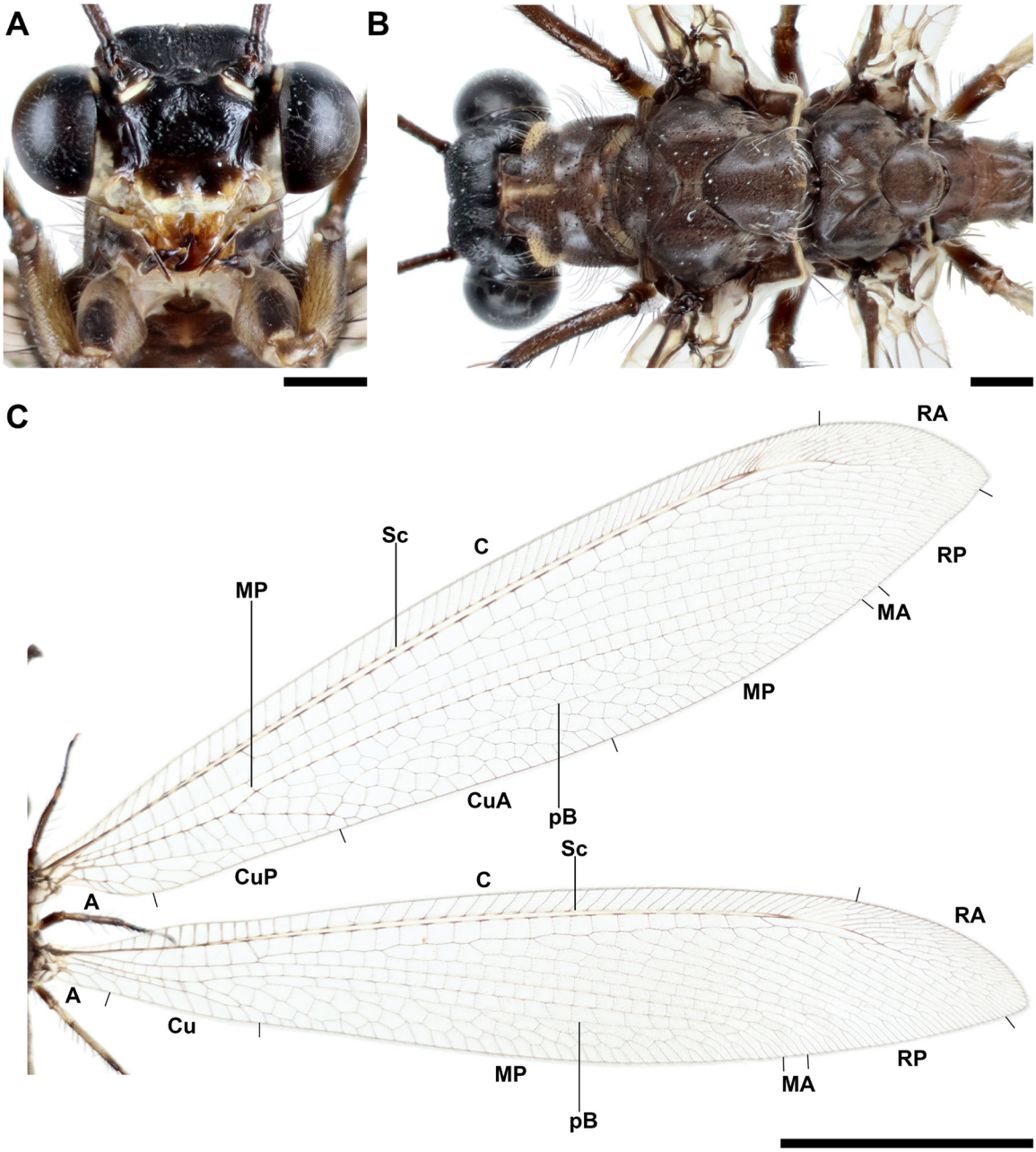

Fig. 14. *Myrmeleon wangi* Miller & Stange, 1999 (NTU). **A**. Head, frontal view. **B**. Head and thorax, dorsal habitus. **C**. Wings. Abbreviations: A = anal veins; C = costa; Cu = cubitus; CuA = cubitus anterior; CuP = cubitus posterior; MA = media anterior; MP = media posterior; pB = posterior Banksian line; RA = radius anterior; RP = radius posterior; Sc = subcosta. Scale bars: A–B = 1.0 mm; C = 10.0 mm.

yellow, with an incomplete white line along ocular rim; clypeus whitish-yellow with a pair of dark brown spots (sometimes covering dorsal half of clypeus), with sparse hyaline hairs. Antenna brown, short, with slightly defined club, covered with short dark hairs; scape dark brown with a ring of white band at base; pedicel dark brown; flagellum comprising approximately 30 flagellomeres. Mouthparts reddish-yellow, labrum reddish-yellow, with several hyaline hairs; maxillary palps yellow, with 5th and 6th palpomeres black, labial palps yellow, 3rd palpomere black, fusiform, tapering to acute apex, with black round palpimacula on apical ⅓; submentum with long dark hairs.

Thorax (Fig. 14B). Pronotum broad, shorter than wide, dark brown, anterior margin with a yellow medial line and yellow bands on lateral side, membrane brown in middle, white on lateral side, with hyaline hairs and long dark hairs. Cervical sclerites dark brown, with whitish-yellow markings. Mesonotum dark brown. Metanotum dark brown, covered with sparse hyaline hairs. Meso- and metapleuron dark brown, moderately covered with long hyaline hairs.

Legs. Whitish-yellow, short. Coxae moderately covered with long hyaline hairs; fore coxae whitish-yellow, with brown spot on anterior surface; mid- and hind coxae dark brown. Femora moderately

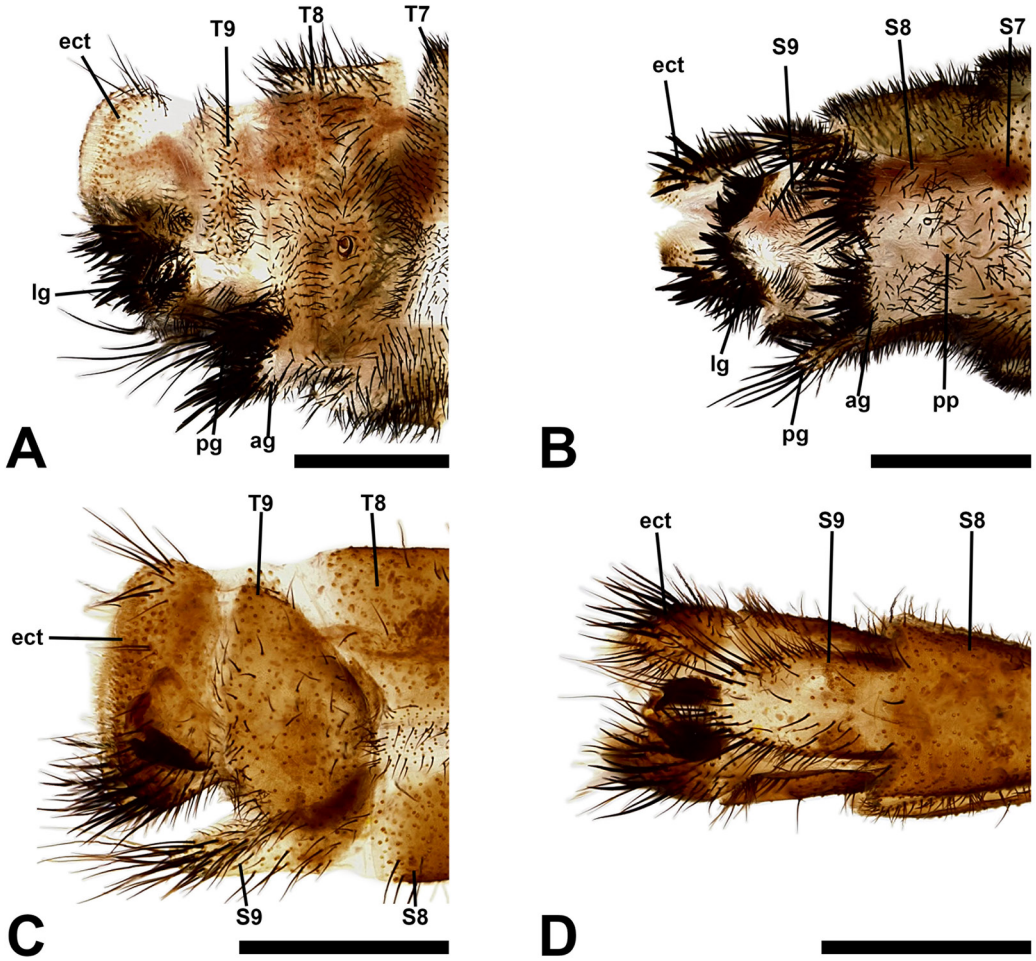

Fig. 15. *Myrmeleon wangi* Miller & Stange, 1999 (NTU). **A**. Female terminalia, lateral view. **B**. Same, ventral view. **C**. Male terminalia, lateral view. **D**. Same, ventral view. Abbreviations: ag = anterior gonapophysis; ect = ectoproct; lg = lateral gonapophysis; pg = posterior gonapophysis; pp = pregenital plate; S = sternites; T = tergites. Scale bars = 1.0 mm.

covered with short dark hairs, mixed with sparse long black setae; fore femur whitish-yellow, brown on posterior surface and apex; mid- and hind femora whitish-yellow on basal half and brown on distal half; femoral sense hair length about ½ length of femur on fore and mid legs, absent on hind leg. Tibiae moderately covered with short dark hairs, mixed with sparse long black setae; fore tibia brown; mid- and hind tibia brown, slightly yellow on ventral surface. Tibial spurs red, short, slender, almost straight, approximately as long as tarsomere 1 (shorter on hind leg). Tarsi black, reddish at base, sparsely covered with short dark hairs dorsally, short black setae ventrally; tarsomere 1 as long as combined length of tarsomeres 2–4; tarsomere 5 approximately as long as combined length of tarsomeres 1–4. Pretarsal claws red, short, simple, curved, shorter than tibial spurs.

Wings (Fig. 14C). Without markings, hyaline. Forewings narrow, acute at apex; veins and crossveins mostly pale brown, Sc, RA and CuA finely alternating brown and pale yellow; costal area without interconnected crossveins, distal crossveins often branched; presectoral area with 7–9 crossveins and 0–2 irregular cells; RP arising slightly beyond CuA fork, with 18–24 crossveins from origin of RP to hypostigmatic cell; CuP supporting 1 cell before fusing with 1A; 3A mostly fused with 2A; hypostigmatic cell long; pterostigma pale white; anterior Banksian line absent, posterior Banksian line distinct. Hindwings slightly shorter and narrower than forewings; acute at apex; presectoral area with 5 crossveins and 0 irregular cells; RP arising beyond MP fork, at origin runs closer to MA, with 16–23 crossveins from origin of RP to hypostigmatic cell; hypostigmatic cell as long as forewing; pterostigma pale white; anterior Banksian line absent, posterior Banksian line distinct, directly below CuA; male with pilula axillaris.

Abdomen (Fig. 1E). Shorter than hindwing, tergites brown, sternite brown, densely covered with short dark hairs dorsally and laterally, hyaline hairs ventrally.

Female terminalia (Fig. 15A–B). Tergite VIII at least 2 times as wide as tergite IX. Tergite IX narrow, rectangular in lateral view. Ectoproct trapezoid in lateral view, with long, black digging setae on ventral

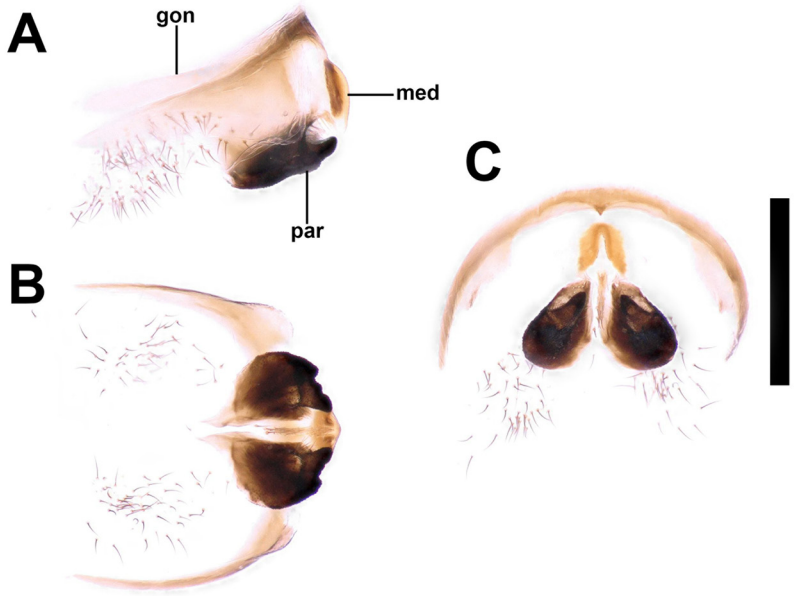

Fig. 16. *Myrmeleon wangi* Miller & Stange, 1999, male genitalia (NTU). **A**. Lateral view. **B**. Ventral view. **C**. Caudal view. Abbreviations: gon = gonarcus; med = mediuncus; par = parameres. Scale bar = 0.5 mm.

half. Lateral gonapophyses semicircular in lateral view, smaller than ectoproct, with long, black digging setae on posterior side and long, thin, black setae on ventral side. Posterior gonapophyses long, slender, with long, black setae. Anterior gonapophyses slightly lobed, wide, separated, with long, thick, black setae. Pregenital plate absent.

Male genitalia (Figs 15C–D, 16). Ectoproct rectangular in lateral view, dorsal margin as long as ventral margin, covered with short pale brown hair, ventral half with long black setae. Sternite IX shorter than combined length of tergite IX and ectoproct, tapered in ventral view, with long black setae posteriorly. Gonarcus hyaline, arched, with very short lateral arm produced posteriorly in lateral view, membrane with short black setae. Mediuncus well sclerotized, brown, semicircular in lateral view, inverted V-shaped in caudal view. Parameres well sclerotized, large, dark brown, triangular in caudal view, separated, with short black setae in between, lateral view with a ventral projection.

Distribution

Taiwan (central mountainous area) (Fig. 31E).

Biology

From the collecting and emergence date of the examined specimens, the adults appear from April to November. The larvae inhabit mountainous areas, usually found under rock overhangs, artificial structure or river sand deposits in altitudes above 1000 m a.s.l. (Lin *et al.* 2021).

Remarks

Myrmeleon wangi Miller & Stange, 1999 was proposed as a junior synonym of *Myrmeleon trivialis* by Ábrahám (2017). However, he did not mention whether he compared types of both names, but only stated that *M. trivialis* is widely distributed in the Oriental region and the species is morphologically variable. After comparing the specimens from Taiwan with specimens of *M. trivialis* from Yunan, China, and images of specimens from Pakistan in Hassan *et al.* (2022), the two species are different in the male genitalia, particularly the shapes of the mediuncus and parameres (Hassan *et al.* 2022: fig. 19e–g). Due to this, it is clear that *M. wangi* is a separate species from *M. trivialis*.

This species is large-sized, and the adults can be distinguished from the other species from Taiwan by the markings on pronotum (Fig. 14B).

Myrmeleon punctinervis group

Diagnosis

The *M. punctinervis* group is characterized by the hindwing shorter than the forewing; hindwing RP at origin runs closer to MA; male genitalia with gonarcus narrow, arched, crescent-shaped in lateral view, mediuncus well sclerotized, large, trapezoid in caudal view, parameres well sclerotized, large, rectangular in caudal view.

Included species

Myrmeleon heppneri Miller & Stange, 1999, *M. persimilis* Miller & Stange, 1999, *M. punctinervis* Banks, 1937, and *M. taiwanensis* Miller & Stange, 1999.

Remarks

In Miller *et al.* (1999), the *M. punctinervis* complex was mentioned, stating that four species were recognized, including *M. confusus*, *M. persimilis*, *M. taiwanensis*, and *M. punctinervis*, of which *confusus* being a nomen nudum. Another invalid name *M. nigriventris* was also mentioned, which is

likely an erratum of *punctinervis* depending from the text. The *punctinervis* group recognized here is likely to be consistent with the species complex they mentioned. While Miller *et al.* (1999) suggested that there may be additional species from Taiwan, this has not been confirmed by our investigation.

The four species within this group are similar in body size, general appearance, and the shape of the male genitalia. The larvae of this group can all be found on the coast, with *M. punctinervis* also inhabiting inland riverbanks (Miller *et al.* 1999; Stange *et al.* 2003; Lin *et al.* 2021). A similar structure of the male genitalia is also seen in many species of *Myrmeleon*, including *M. otiosus* (Navás, 1912), *M. solers* Walker, 1853, *M. mariaemathildae* Pantaleoni *et al.*, 2010, *M. almohadarum* Badano *et al.*, 2016, *M. regularis* (Esben-Petersen, 1918), *M. immanis* Walker, 1853 *M. inconspicuus* Rambur, 1842 and *M. capito* Navás, 1912 (New 1985, 1990; Pantaleoni *et al.* 2010; Krivokhatsky 2011; Sekimoto 2014; Badano *et al.* 2016). This may indicate a close relationship among these species and the *punctinervis* group from Taiwan, resulting in a larger species group. Confirmation will require additional material and research.

Myrmeleon heppneri Miller & Stange, 1999
Figs 1F, 17–19

Myrmeleon heppneri Miller & Stange in Miller *et al.*, 1999: 63. Type locality: Taiwan (New Taipei).

Myrmeleon heppneri – Stange *et al.* 2003: 114. — Wang *et al.* 2018: 106.
Myrmeleon heppner – Stange *et al.* 2003: 114 (misspelling).
Myrmeleon (*Myrmeleon*) *heppneri* – Stange 2004: 327. — Lin *et al.* 2019: 140.

Material examined

Holotype
TAIWAN • ♂ (photos examined) (larva reared to adult); "Taipei County" [now New Taipei City], Tamshui District, Shalun Seaside Resort (Damshuei Beach); 6 May 1998; Robert A. Miller, Lionel A. Stange and Hsiau-Yue Wang leg.; FSCA 00091125.

Paratypes
TAIWAN – **New Taipei City** • 1 ♂, 1 ♀ (2 larvae reared to adults); same data as for holotype; NTM 3619-001, 3619-002.

Additional material
TAIWAN – **New Taipei City** • 1 ♂, 1 ♀; same data as for holotype; TAMU X0068708, X0068765. – **Taoyuan City** • 1 ♂, 1 pupa (1 larva reared to adult); Dayuan District, Zhuwei Beach; 27 Oct. 2019; Yu-Hsiu Lin leg.; 2 specs preserved in alcohol; NTU • 1 ♀ (larva reared to adult); same data as for preceding; 14 Jun. 2020; Yu-Hsiu Lin leg.; NTU.

Re-description of the adult

Measurements (♂ n = 1, ♀ n = 1). Body length: ♂ 17.8 mm, ♀ 21.2 mm; forewing: length ♂ 18.2 mm, ♀ 23.0 mm; width ♂ 4.4 mm, ♀ 5.6 mm; width/length ratio ♂ 0.2406, ♀ 0.2418; hindwing: length ♂ 16.7 mm, ♀ 21.3 mm; width ♂ 3.6 mm, ♀ 4.8 mm; width/length ratio ♂ 0.2158, ♀ 0.2258.

Head (Fig. 17A–B). Vertex strongly raised, rounded, black, 4 shiny black spots along anterior margin and 4 shiny black spots along posterior margins, with sparse short black hairs; occiput pale yellow, with a pair of pale brown spots on lateral side. Frons shiny black, covered with sparse short hyaline hairs; gena whitish-yellow, with a whitish-yellow line along ocular rim; clypeus whitish-yellow with a pair of pale brown spots, with sparse hyaline hairs. Antenna pale brown, short, with slightly defined club,

covered with short dark hairs; scape whitish-yellow with a ring of black band; pedicel whitish-yellow, with brown bands; flagellum comprising approximately 30 flagellomeres, the first 5 flagellomeres with pale brown band. Mouthparts yellow, labrum yellow, with several hyaline hairs; maxillary palps yellow, darker toward the distal end, labial palps yellow, 3rd palpomere black, fusiform, tapering to acute apex, with black round palpimacula on apical ⅓; submentum with long dark hairs.

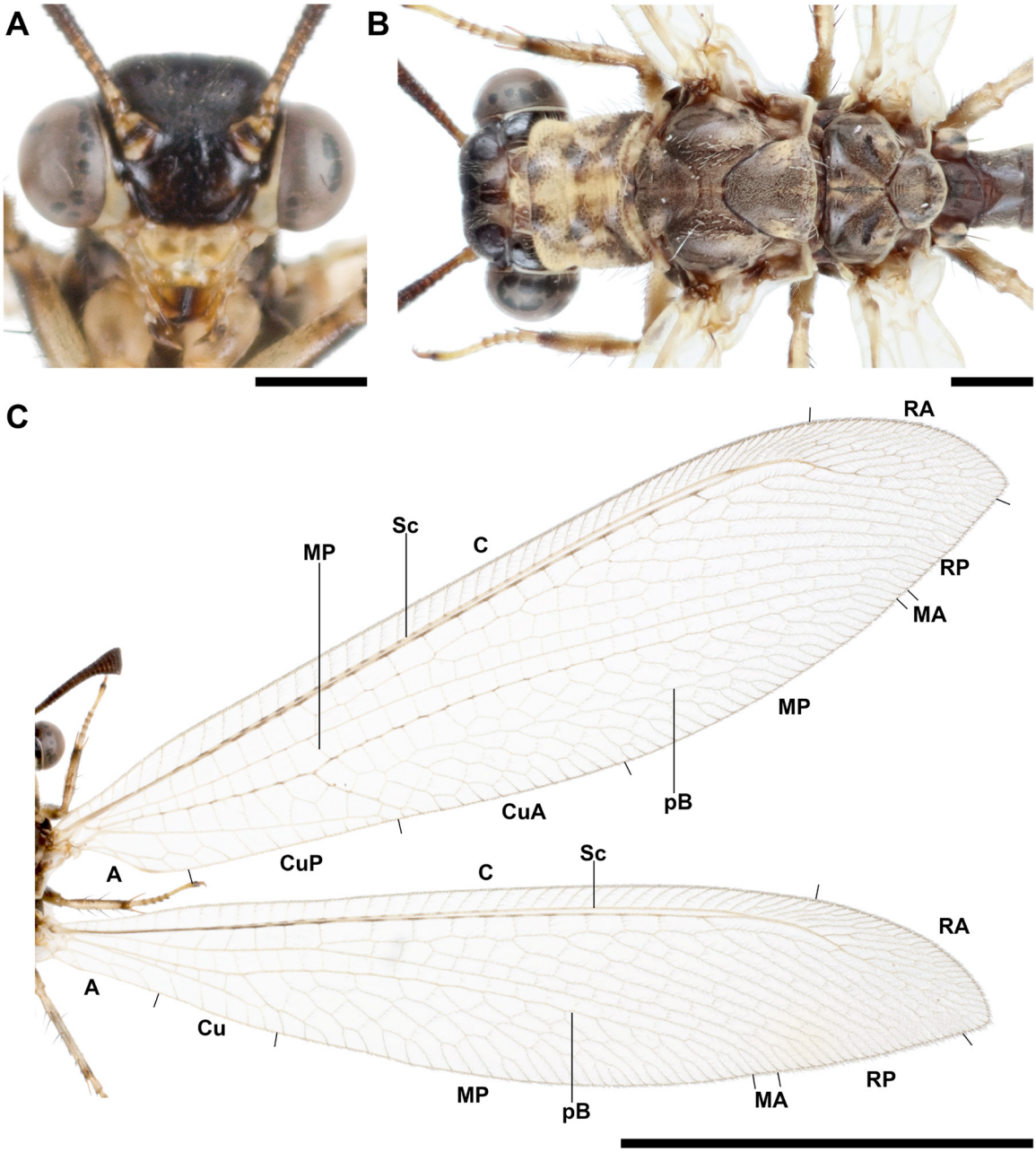

Fig. 17. *Myrmeleon heppneri* Miller & Stange, 1999 (NTU). **A**. Head, frontal view. **B**. Head and thorax, dorsal habitus. **C**. Wings. Abbreviations: A = anal veins; C = costa; Cu = cubitus; CuA = cubitus anterior; CuP = cubitus posterior; MA = media anterior; MP = media posterior; pB = posterior Banksian line; RA = radius anterior; RP = radius posterior; Sc = subcosta. Scale bars: A–B = 1.0 mm; C = 10.0 mm.

Thorax (Fig. 17B). Pronotum broad, shorter than wide, whitish-yellow, with a pair of brown spots on anterior half, a pair of brown markings in middle, sometimes covering most of posterior half, posterior margin with a pair of brown bands, membrane with a pair of brown spots in middle, with hyaline hairs and long dark hairs. Cervical sclerites dark brown. Mesonotum brown; mecoscutellum with a pair of pale yellow spots. Metanotum brown, anterior half with a black line in middle, covered with sparse hyaline hairs. Meso- and metapleuron dark brown, moderately covered with long hyaline hairs.

Legs. Whitish-yellow, short. Coxae moderately covered with long hyaline hairs; fore coxae whitish-yellow, with brown markings; mid- and hind coxae dark brown, with a whitish-yellow spot. Femora moderately covered with short dark hairs, mixed with sparse long black setae; fore femur whitish-yellow, slightly brownish on apex; mid femora dark brown on anterior surface of distal half; hind femora brown on anterior and posterior surface on distal half; femoral sense hair length about ½ of femur length on fore and mid legs, absent on hind leg. Tibiae moderately covered with short dark hairs, mixed with sparse long black setae; fore- and mid tibia yellow, with sparse brown markings on anterior surface; hind tibia whitish-yellow, with dark brown markings on posterior surface. Tibial spurs reddish-brown, short, slender, almost straight, approximately as long as tarsomere 1 (slightly longer on fore leg). Tarsi

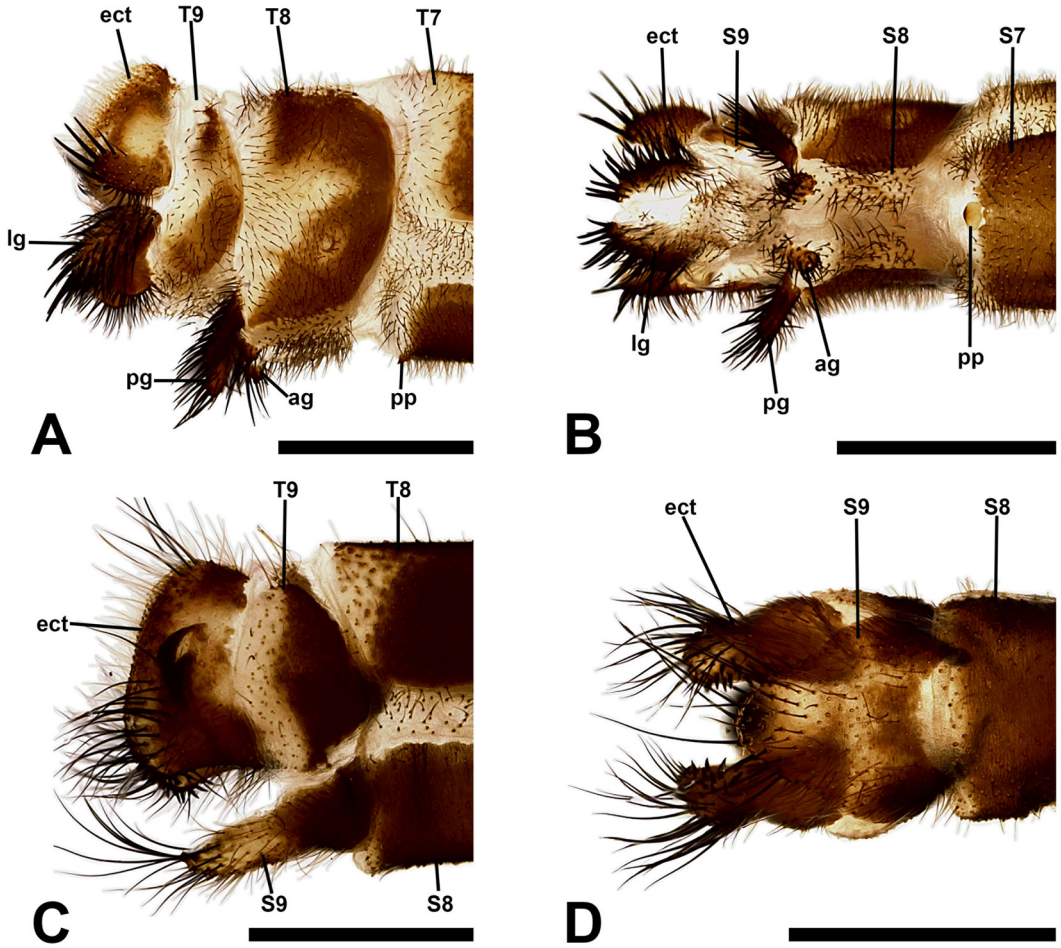

Fig. 18. *Myrmeleon heppneri* Miller & Stange, 1999 (NTU). **A**. Female terminalia, lateral view. **B**. Same, ventral view. **C**. Male terminalia, lateral view. **D**. Same, ventral view. Abbreviations: ag = anterior gonapophysis; ect = ectoproct; lg = lateral gonapophysis; pg = posterior gonapophysis; pp = pregenital plate; S = sternites; T = tergites. Scale bars = 1.0 mm.

reddish-brown, sparsely covered with short dark hairs dorsally, short black setae ventrally; tarsomere 1 shorter than combined length of tarsomeres 2–4; tarsomere 5 approximately as long as combined length of tarsomeres 1–4. Pretarsal claws reddish-brown, short, simple, curved, approximately as long as tibial spurs.

Wings (Fig. 17C). Without markings, hyaline. Forewings acute at apex; veins and crossveins mostly pale brown, Sc, RA and CuA finely alternating brown and pale yellow; costal area without interconnected crossveins, distal crossveins often branched; presectoral area with 7–8 crossveins and 0 irregular cells; RP arising almost opposite or slightly beyond CuA fork, with 10–12 crossveins from origin of RP to hypostigmatic cell; CuP supporting 1 cell before fusing with 1A; 3A mostly fused with 2A; hypostigmatic cell long; pterostigma pale white, slightly visible; anterior Banksian line absent, posterior Banksian line slightly distinct. Hindwings slightly shorter and narrower than forewings; acute at apex; presectoral area with 5 crossveins and 0 irregular cells; RP arising beyond MP fork, at origin runs closer to MA, with 8–9 crossveins from origin of Rs to hypostigmatic cell; hypostigmatic cell longer than forewing; pterostigma pale white, slightly visible; anterior Banksian line absent, posterior Banksian line absent; male with large, whitish-yellow pilula axillaris.

Abdomen (Fig. 1F). Shorter than hindwing, tergites brown, sternite brown, densely covered with short dark hairs dorsally and laterally, hyaline hairs ventrally.

Female terminalia (Fig. 18A–B). Tergite VIII at least 2 times as wide as tergite IX. Tergite IX narrow, rectangular in lateral view. Ectoproct semicircular in lateral view, with long, black fossorial bristles on ventral half. Lateral gonapophyses semicircular in lateral view, smaller than ectoproct, with long, black fossorial bristles on posterior side and long, thin, black setae on ventral side. Posterior gonapophyses long, slender, with long, black setae. Anterior gonapophyses slightly lobed, separated, with long, thick, black setae. Pregenital plate distinct, oval, presented on posterior margin of sternite VII.

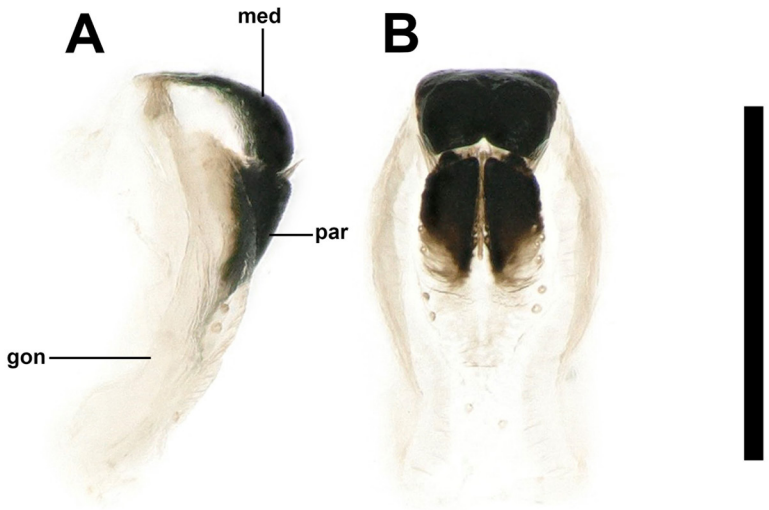

Fig. 19. *Myrmeleon heppneri* Miller & Stange, 1999, male genitalia (NTU). **A**. Lateral view. **B**. Caudal view. Abbreviations: gon = gonarcus; med = mediuncus; par = parameres. Scale bar = 0.5 mm.

Male genitalia (Figs 18C–D, 19). Ectoproct trapezoid in lateral view, dorsal margin shorter than ventral margin, covered with short pale brown hair, ventral half with long black setae. Sternite IX as long as combined length of tergite IX and ectoproct, diamond-shaped in ventral view, with long black setae posteriorly. Gonarcus narrow, arched, crescent-shaped in lateral view. Mediuncus well sclerotized, large, black, trapezoid in caudal view, ventral margin with a median groove. Parameres well sclerotized, large, black, triangular in lateral view, rectangular in caudal view, separated, with short black setae in between.

Distribution

Taiwan (New Taipei, Taoyuan) (Fig. 31F).

Biology

From the collecting and emergence date of the examined specimens and the notes of the types in Miller *et al.* (1999), the adults appear from April to August. This species is the least common in Taiwan, recorded only on a few beaches in the northern part of the island, and larvae can be found on open sand dunes (Lin *et al.* 2021).

Remarks

This is the smallest species of *Myrmeleon* in Taiwan. The overall morphology of the adult resembles *M. persimilis* in several characters such as small body size, shorter hindwings, the disposition of digging setae on IX abdominal sternite, and the absence of setae on the ventral side of the mandibles of the larvae (Lin *et al.* 2021). The two species can be distinguished by the markings on the pronotum of the adults (Figs 17B, 20B). This species also resembles *M. solers* in the markings on the pronotum of the adults (Sekimoto 2014: figs 1e–f), and comparison of specimens will be needed to confirm the relationship between, *M. solers* and *M. heppneri*.

Myrmeleon persimilis Miller & Stange, 1999
Figs 1G, 20–22

Myrmeleon persimilis Miller & Stange in Miller *et al.*, 1999: 67. Type locality: Taiwan (Pingtung).

Myrmeleon persimilis – Stange *et al.* 2003: 118. — Wang *et al.* 2018: 107.
Myrmeleon (*Myrmeleon*) *persimilis* – Stange 2004: 334. — Lin *et al.* 2019: 140.

Material examined

Holotype

TAIWAN • ♂ (photos examined); Pingtung County, Hengchun Township, Fengchuisha Beach (Feiha-Tre-Sha Area, Kenting Nat'l Park); 21°56′55.7″ N, 120°50′11.6″ E; 20 Apr. 1998; Robert A. Miller, Lionel A. Stange and Hsiau-Yue Wang leg.; collected as larva, emerged 28 Jun. 1998; on beach; FSCA 00090997.

Paratypes

TAIWAN – **Miaoli County** • 1 ♂ (larva reared to adult); Tongxiao Township, Tongxiao Beach (Tonshou); 24°29′47.5″ N, 120°40′20.5″ E; 3 May 1998; Robert A. Miller, Lionel A. Stange and Hsiau-Yue Wang leg.; NTM 3623-007. – **New Taipei City** • 1 ♂, 1 ♀ (2 larvae reared to adults); Tamsui District, Shalun Seaside Resort (Damshuei); 6 May 1998; Robert A. Miller, Lionel A. Stange and Hsiau-Yue Wang leg.; NTM 3623-005, 3623-006 • 1 ♂, 1 ♀ (2 larvae reared to adults); same data as for preceding; TAMU X0405606, X0405458. – **Pingtung County** • 2 ♂♂, 2 ♀♀ (4 larvae reared to adults); same data as for holotype; NTM 3623-001 to 3623-004.

Additional material

TAIWAN – **Kinmen County** • 1 ♂ (larva reared to adult); Jinsha Township, Tianpu Reservoir; 3 Apr. 2021; Bin-Hong Ho and Yun Ho leg.; preserved in alcohol; NTU • 1 ♂ (larva reared to adult); Jinhu Township, Xibian Seawater Bathing Pool; 4 Apr. 2021; Bin-Hong Ho and Yun Ho leg.; preserved in alcohol; NTU. – **Miaoli County** • 2 ♂♂, 1 ♀ (3 larvae reared to adults); Tongxiao Township, Tongxiao Beach; 4 May 2020; Yu-Hsiu Lin leg.; 3 specs preserved in alcohol; NTU. – **New Taipei City** • 2 ♀♀ (2 larvae reared to adults); Gongliao District, Fulong seaside park; 7 Jun. 2019; Yu-Hsiu Lin leg.; 1 spec. preserved in alcohol; NTU • 1 ♂ (larva reared to adult); Tamsui District, Shalun Seaside Resort; 30 Jan. 2019; Kai-Wei Chan leg.; NTU • 1 ♂ (larva reared to adult); same data as for preceding; 3 Sep. 2019; Yu-Hsiu Lin leg.; NTU. – **Penghu County** • 1 ♀ (larva reared to adult); Huxi Township, Aimen Beach; 16 Jan. 2020; Yu-Hsiu Lin leg.; NTU • 2 ♂♂ (2 larvae reared to adults); Baisha Township, Houliao Beach; 13 Jan. 2020; Yu-Hsiu Lin leg.; 1 spec. preserved in alcohol; NTU • 1 ♀ (larva reared to adult); Huxi Township, Lintou Park; 13 Jan. 2020; Yu-Hsiu Lin leg.; preserved in alcohol; NTU • 2 ♂♂ (2 larvae reared to adults); Huxi Township, Lizhengjiao Beach; 16 Jan. 2020; Yu-Hsiu Lin leg.; preserved in alcohol; NTU • 1 ♂ (larva reared to adult); Magong City, Shili Beach; 13 Jan. 2020; Yu-Hsiu Lin leg.; NTU. – **Pingtung County** • 1 ♂; Hengchun Township, Fengchuisha Beach; 12 Feb. 2019; Kai-Wei Chan leg.; NTU • 1 ♂ (larva reared to adult); Manzhou Township, Jiupeng Desert; 4 Feb. 2020; Yu-Hsiu Lin leg.; NTU.

Re-description of the adult

Measurements (♂ n =7, ♀ n = 4). Body length: ♂ 20.1–23.7 mm, ♀ 21.5–22.4 mm; forewing: length ♂ 19.2–23.1 mm, ♀ 22.9–24.4 mm; width ♂ 4.8–6.1 mm, ♀ 5.8–6.3 mm; width/length ratio ♂ 0.2451, ♀ 0.2539; hindwing: length ♂ 18.1–21.2 mm, ♀ 21.5–22.9 mm; width ♂ 4.2–4.9 mm, ♀ 4.8–5.4 mm; width/length ratio ♂ 0.2287, ♀ 0.2286.

Head (Fig. 20A–B). Vertex strongly raised, rounded, black, 4 shiny black spots along anterior margin and 4 shiny black spots along posterior margins, with sparse short black hairs; occiput brown. Frons shiny black, covered with sparse short hyaline hairs; gena whitish-yellow, with an incomplete white line along ocular rim; clypeus whitish-yellow with a pair of dark brown spots, with sparse hyaline hairs. Antenna brown, short, with slightly defined club, covered with short dark hairs; scape dark brown with a ring of white band at base and apex; pedicel dark brown; flagellum comprising approximately 30 flagellomeres. Mouthparts yellow, labrum yellow, with several hyaline hairs; maxillary palps dark brown, whitish-yellow between each palpomere, labial palps dark brown, 3rd palpomere black, fusiform, tapering to acute apex, with brown round palpimacula on apical ⅓; submentum with long dark hairs.

Thorax (Fig. 20B). Pronotum broad, shorter than wide, dark brown, with whitish-yellow markings on anterior-lateral margin, a whitish-yellow medial line and a pair of whitish-yellow spots in middle, close to anterior margin, membrane whitish-yellow, with brown marking in middle (sometimes fully whitish-yellow on anterior half), with hyaline hairs and long dark hairs. Cervical sclerites dark brown. Mesonotum dark brown, with sparse hyaline hairs; mesoscutum dark brown, with a whitish-yellow band on posterior margin. Metanotum dark brown, covered with sparse hyaline hairs; metascutum dark brown, with a whitish-yellow band on posterior margin. Meso- and metapleuron dark brown, moderately covered with long hyaline hairs.

Legs. Whitish-yellow, short. Coxae dark brown, fore coxae whitish-yellow with dark brown markings, moderately covered with long hyaline hairs. Femora moderately covered with short dark hairs, mixed with sparse long black setae; fore femur whitish-yellow, dark brown on ventral margin and apex; mid femora dark brown, paler at base; hind femora whitish-yellow, with dark brown marking on distal half; femoral sense hair length about ⅓ of femur length on fore and mid legs, absent on hind leg. Tibiae moderately covered with short dark hairs, mixed with sparse long black setae; all tibia pale brown on

dorsal suface and dark brown on ventral surface. Tibial spurs reddish-brown, short, slender, almost straight, approximately as long as tarsomere 1. Tarsi dark brown, tarsomere 1 whitish-yellow on dorsal surface, sparsely covered with short dark hairs dorsally, short black setae ventrally; tarsomere 1 shorter than combined length of tarsomeres 2–4; tarsomere 5 shorter than combined length of tarsomeres 1–4. Pretarsal claws reddish-brown, short, simple, curved, shorter than tibial spurs.

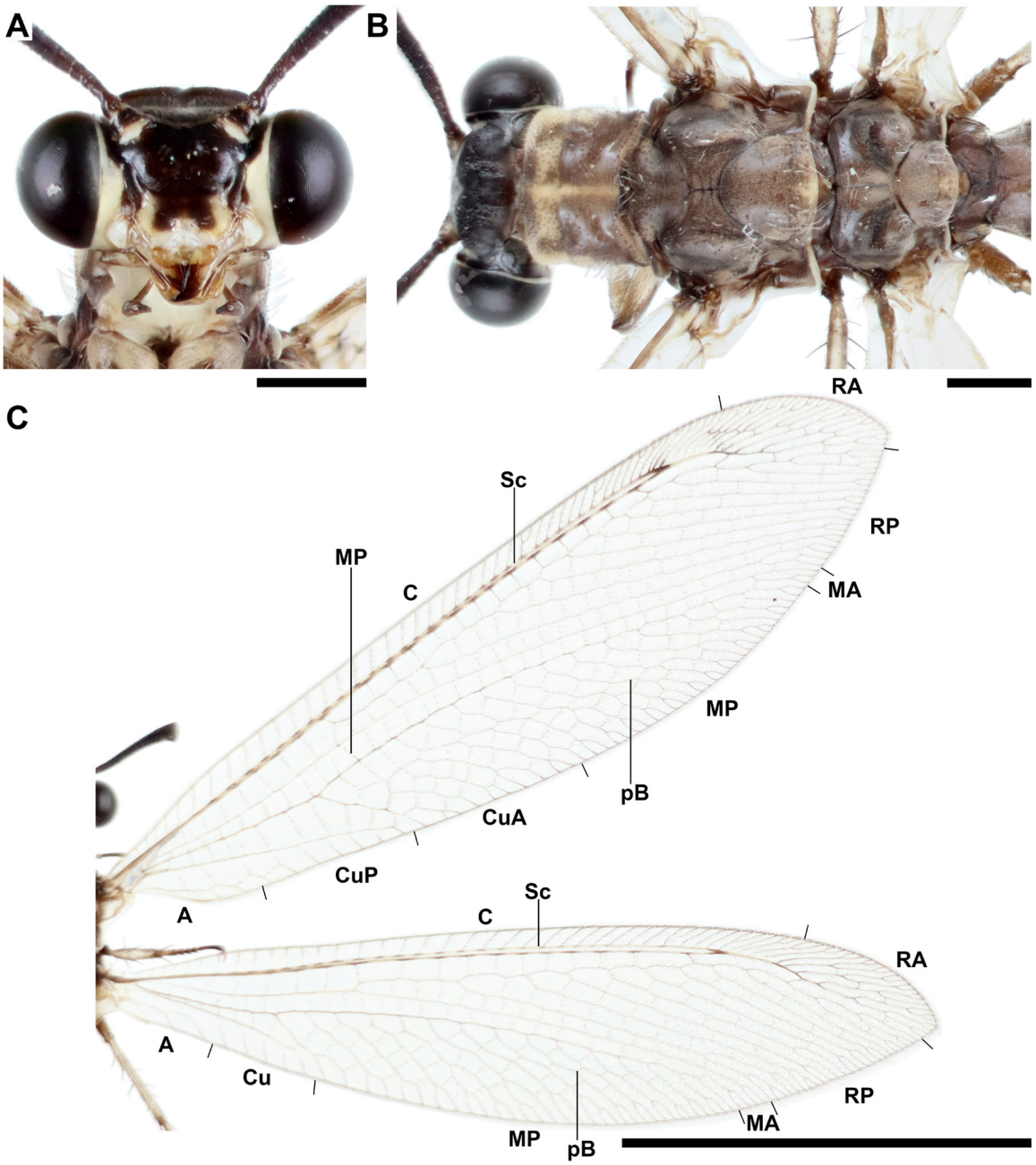

Fig. 20. *Myrmeleon persimilis* Miller & Stange, 1999 (NTU). **A**. Head, frontal view. **B**. Head and thorax, dorsal habitus. **C**. Wings. Abbreviations: A = anal veins; C = costa; Cu = cubitus; CuA = cubitus anterior; CuP = cubitus posterior; MA = media anterior; MP = media posterior; pB = posterior Banksian line; RA = radius anterior; RP = radius posterior; Sc = subcosta. Scale bars: A–B = 1.0 mm; C = 10.0 mm.

Wings (Fig. 20C). Without markings, hyaline. Forewings acute at apex; veins and crossveins mostly pale brown, Sc, RA and CuA finely alternating brown and pale yellow; costal area without interconnected crossveins, distal crossveins often branched; presectoral area with 8–9 crossveins and 0 irregular cells; RP arising slightly beyond CuA fork, with 10–14 crossveins from origin of RP to hypostigmatic cell; CuP supporting 1 cell before fusing with 1A; 3A mostly fused with 2A; hypostigmatic cell long; pterostigma pale white; anterior Banksian line absent, posterior Banksian line slightly distinct. Hindwings slightly shorter and narrower than forewings; acute at apex; presectoral area with 5 crossveins and 0 irregular cells; RP arising beyond MP fork, at origin runs closer to MA, with 9–11 crossveins from origin of RP to hypostigmatic cell; hypostigmatic cell longer than forewing; pterostigma pale white, slightly visible; anterior Banksian line absent, posterior Banksian line slightly distinct; male with large, dark brown pilula axillaris.

Abdomen (Fig. 1G). Shorter than hindwing, tergites dark brown, sternite dark brown, densely covered with short dark hairs dorsally and laterally, hyaline hairs ventrally.

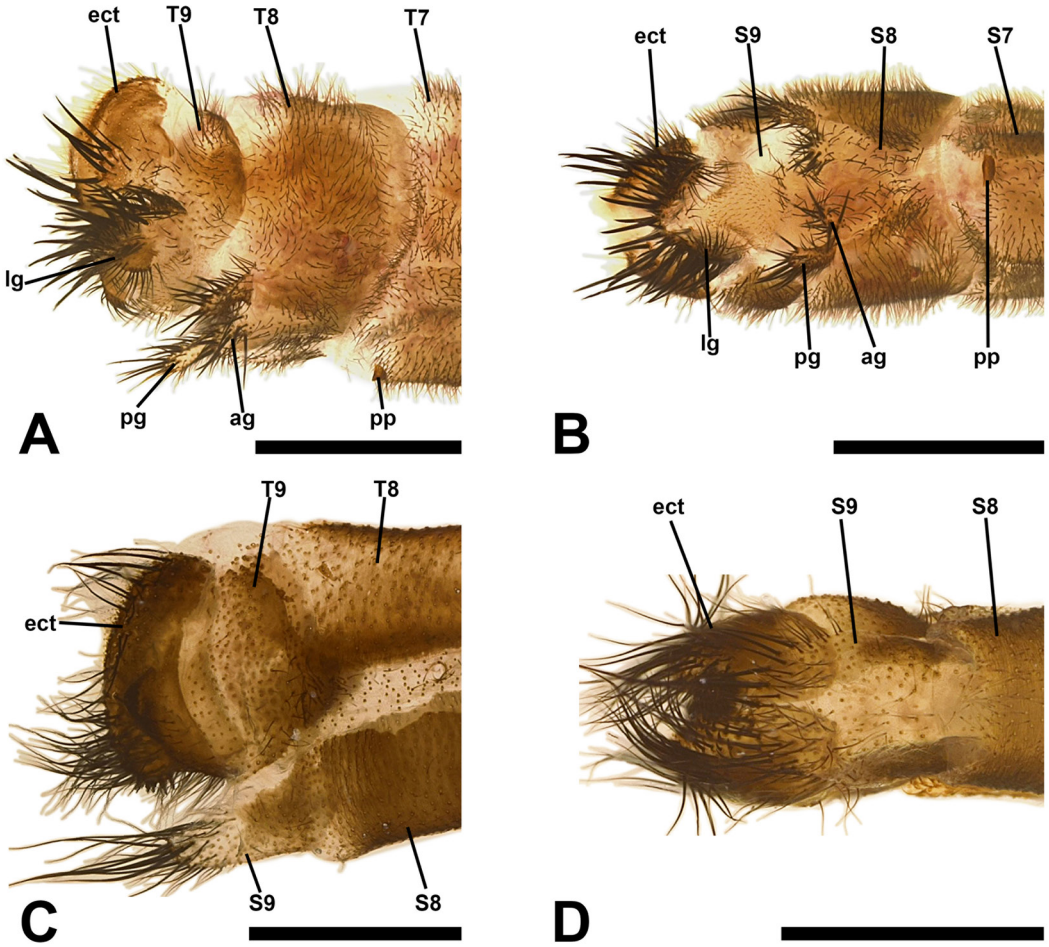

Fig. 21. *Myrmeleon persimilis* Miller & Stange, 1999 (NTU). **A**. Female terminalia, lateral view. **B**. Same, ventral view. **C**. Male terminalia, lateral view. **D**. Same, ventral view. Abbreviations: ag = anterior gonapophysis; ect = ectoproct; lg = lateral gonapophysis; pg = posterior gonapophysis; pp = pregenital plate; S = sternites; T = tergites. Scale bars = 1.0 mm.

Female terminalia (Fig. 21A–B). Tergite VIII at least 2 times as wide as tergite IX. Tergite IX narrow, rectangular in lateral view. Ectoproct semicircular in lateral view, with long, black fossorial bristles on ventral half. Lateral gonapophyses rounded in lateral view, smaller than ectoproct, with long, black fossorial bristles on posterior side and long, thin, black setae on ventral side. Posterior gonapophyses long, slender, with long, black setae. Anterior gonapophyses slightly lobed, separated, with long, thick, black setae. Pregenital plate distinct, semicircular, presented on posterior margin of sternite VII.

Male genitalia (Figs 21C–D, 22). Ectoproct trapezoid in lateral view, curved toward posterior, dorsal margin shorter than ventral margin, ventral margin slightly curved upward, covered with short pale brown hair, ventral half with long black setae. Sternite IX as long as combined length of tergite IX and ectoproct, tapered in ventral view, with long black setae posteriorly. Gonarcus narrow, arched, crescent-shaped in lateral view. Mediuncus well sclerotized, large, black, rectangular in caudal view. Parameres well sclerotized, large, black, triangular in lateral view, semicircular in caudal view, separated, with short black setae.

Distribution

Taiwan (coastal area, also on the associated islands of Penghu and Kinmen) (Fig. 31G).

Biology

From the collecting and emergence date of the examined specimens, the adults appear from June to October. This is a coastal species; the larvae can be found on the open sand dunes on most of the western beaches in Taiwan (Lin *et al.* 2021).

Remarks

This is a relatively small species, the overall morphology of the adult resembles *M. taiwanensis*, *M. heppneri* and *M. punctinervis*, and can be recognized by the paler thorax coloring (Fig. 20B).

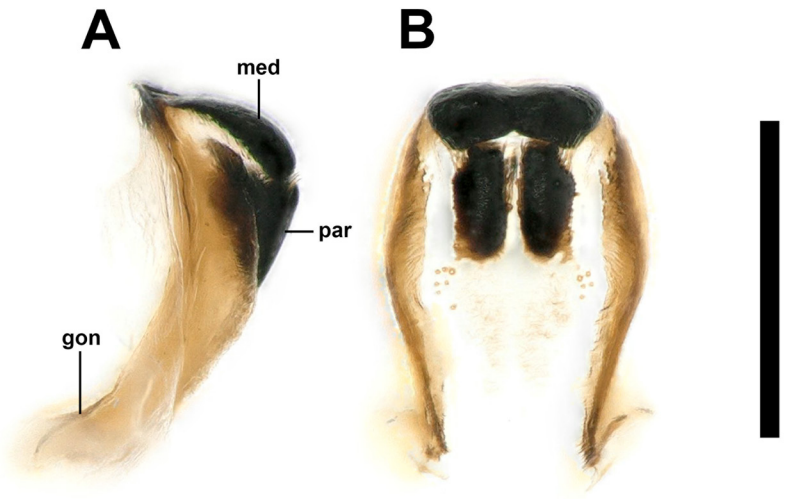

Fig. 22. *Myrmeleon persimilis* Miller & Stange, 1999, male genitalia (NTU). **A**. Lateral view. **B**. Caudal view. Abbreviations: gon = gonarcus; med = mediuncus; par = parameres. Scale bar = 0.5 mm.

Myrmeleon punctinervis Banks, 1937
Figs 1H, 23–25

Myrmeleon punctinervis Banks, 1937: 287. Type locality: Taiwan (Nantou).

Myrmeleon punctinervis – Stange *et al.* 2003: 121. — Wang *et al.* 2018: 107.
Myrmeleon (*Myrmeleon*) *punctinervis* – Stange 2004: 335. — Lin *et al.* 2019: 140.

Material examined

Holotype
TAIWAN • ♂ (photos examined); Nantou County, Puli Township, "Hori" [now Puli]; 15 Jun. 1934; L. Gressitt leg.; MCZC MCZ-ENT 00020200.

Additional material
TAIWAN – **Kaohsiung City** • 1 ♂, 1 ♀; Liugui District, Liugui (Liukuei) River Basin; 23°00′3.6″ N, 120°38′11.3″ E; 23 Apr. 1998; Robert A. Miller, Lionel A. Stange and Hsiau-Yue Wang leg.; TAMU X0405710, X0068838 • 1 ♀; Taoyuan District, Tengjhih; 21 Sep. 1995; W.I. Chou leg.; NMNS. – **Kinmen County** • 1 ♀ (larva reared to adult); Jinsha Township, Kinmen County Forest Affair Place; 2 Sep. 2020; Yu-Hsiu Lin leg.; preserved in alcohol; NTU • 1 ♀ (larva reared to adult); Jinhu Township, Qingnian Farm; 2 Sep. 2020; Yu-Hsiu Lin leg.; preserved in alcohol; NTU • 1 ♀ (larva reared to adult); Jinsha Township, Tianpu Reservoir; 3 Apr. 2021; Bin-Hong Ho and Yun Ho leg.; preserved in alcohol; NTU • 1 ♂ (larva reared to adult); Jinhu Township, Xibian Seawater Bathing Pool; 4 Apr. 2021; Bin-Hong Ho and Yun Ho leg.; preserved in alcohol; NTU. – **Miaoli County** • 1 ♀ (larva reared to adult); Zhunan Township, Qiding Beach; 8 Nov. 2019; Yu-Hsiu Lin leg.; preserved in alcohol; NTU • 2 ♂♂, 1 ♀ (2 larvae reared to adults); same data as for preceding; 4 May 2020; Yu-Hsiu Lin leg.; preserved in alcohol; NTU • 1 ♂; Taian Township, Taian; 19–23 Sep. 1988; C.S. Lin leg.; by UV light-trap; NMNS • 1 ♂, 1 ♀ (2 larvae reared to adults); Tongxiao Township, Tongxiao Beach; 4 May 2020; Yu-Hsiu Lin leg.; 1 spec. preserved in alcohol; NTU. – **New Taipei City** • 2 ♀♀ (2 larvae reared to adults); Linkou District, Linkou Canyon; 8 Nov. 2019; Yu-Hsiu Lin leg.; 1 spec. preserved in alcohol; NTU • 1 ♂, 1 ♀ (2 larvae reared to adults); Tamsui District, Shalun Seaside Resort; 30 Jan. 2019; Kai-Wei Chan leg.; NTU. – **Taichung City** • 1 ♂; Beitun District, Dakeng Trail; 10 May 1991; C.H. Tung leg.; NCHU • 1 ♀; South District, National Chung-Hsing University; 16 May 2003; W.T. Wu leg.; by hand; NMNS. – **Tainan City** • 1 ♂ (larva reared to adult); Anping District, Yuguangdao; 25 Jan. 2021; Bin-Hong Ho and Yun Ho leg.; NTU. – **Taoyuan City** • 1 ♂, 1 ♀ (2 larvae reared to adults); Dayuan District, Zhuwei Beach; 14 Jun. 2020; Yu-Hsiu Lin leg.; 1 spec. preserved in alcohol; NTU. – **Yilan County** • 1 ♂, 1 ♀; Datong Township, Yingshi (Yinshih) Bridge; 320 m a.s.l.; 24°36′32.1″ N, 121°31′36.3″ E; Robert A. Miller, Lionel A. Stange and Hsiau-Yue Wang leg.; TAMU X0068844, X0404947.

Re-description of the adult

Measurements (♂ n =5, ♀ n = 7). Body length: ♂ 22.9–26.6 mm, ♀ 23.6–27.5 mm; forewing: length ♂ 24.3–27.5 mm, ♀ 26.7–29.5 mm; width ♂ 5.1–5.6 mm, ♀ 5.3–6.0 mm; width/length ratio ♂ 0.2070, ♀ 0.2012; hindwing: length ♂ 22.6–26.2 mm, ♀ 24.6–27.1 mm; width ♂ 4.5–5.0 mm, ♀ 4.4–5.0 mm; width/length ratio ♂ 0.1924, ♀ 0.1834.

Head (Fig. 23A–B). Vertex strongly raised, rounded, yellow, 4 shiny black spots along anterior margin and 4 shiny black spots along posterior margins, with sparse short black hairs; occiput dark brown, pale yellow in middle. Frons shiny brown, covered with sparse short hyaline hairs; gena whitish-yellow, with a nearly complete white line along ocular rim; clypeus whitish-yellow, with sparse hyaline hairs. Antenna brown, short, with slightly defined club, covered with short dark hairs; scape brown with rings of white bands at base and apex; pedicel dark brown; flagellum comprising approximately 30 flagellomeres.

Mouthparts yellow, labrum yellow, with several hyaline hairs; maxillary palps dark brown, whitish-yellow between each palpomere, labial palps yellow, 3rd palpomere black, fusiform, tapering to acute apex, with black round palpimacula on apical ⅓; submentum with long dark hairs.

Thorax (Fig. 23B). Pronotum broad, shorter than wide, brown, anterior margin with yellow bands on side, membrane whitish-yellow, with a pair of brown markings in middle, with hyaline hairs and long

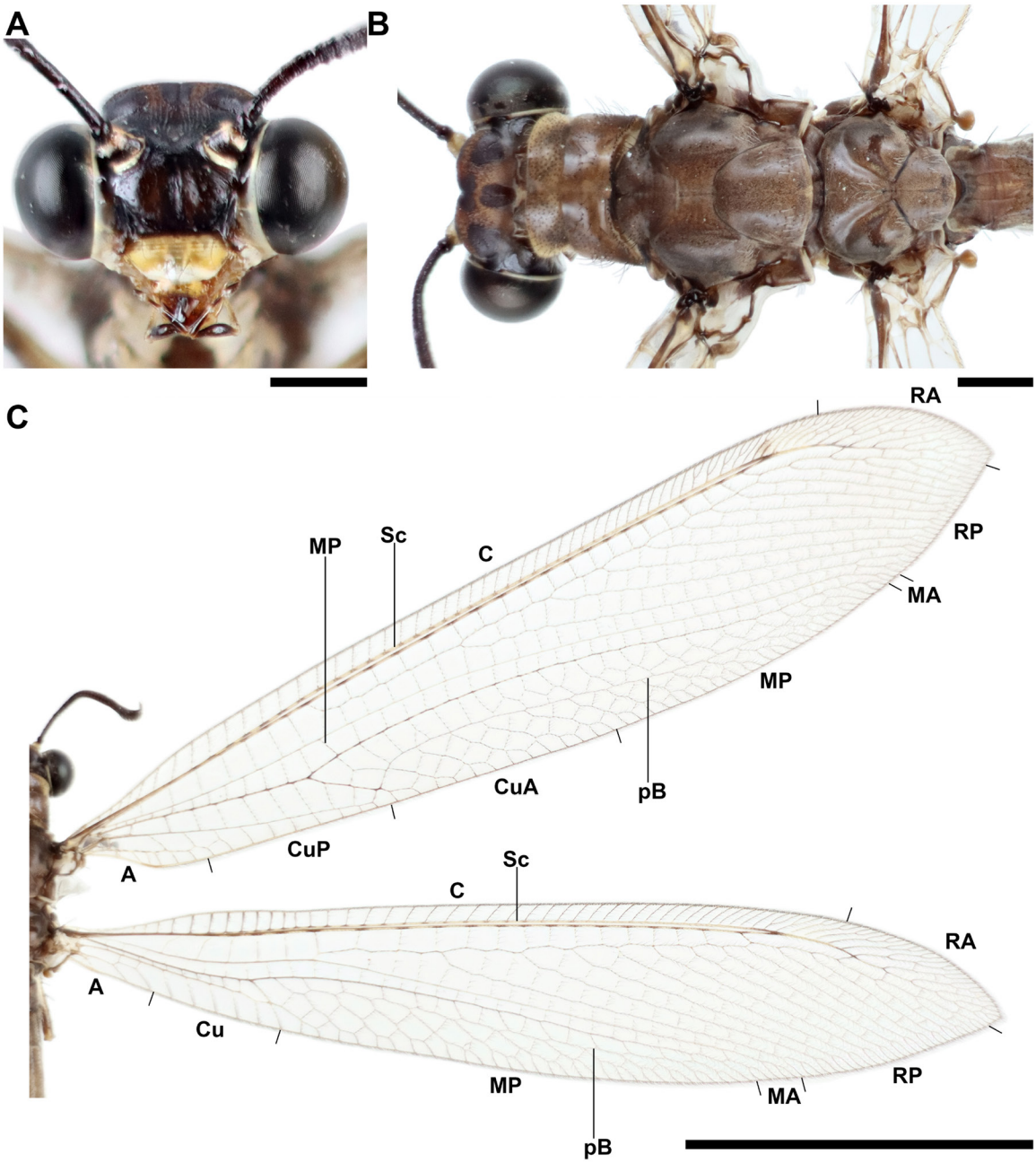

Fig. 23. *Myrmeleon punctinervis* Banks, 1937 (NTU). **A**. Head, frontal view. **B**. Head and thorax, dorsal habitus. **C**. Wings. Abbreviations: A = anal veins; C = costa; Cu = cubitus; CuA = cubitus anterior; CuP = cubitus posterior; MA = media anterior; MP = media posterior; pB = posterior Banksian line; RA = radius anterior; RP = radius posterior; Sc = subcosta. Scale bars: A–B = 1.0 mm; C = 10.0 mm.

dark hairs. Cervical sclerites brown. Mesonotum brown, with a pale brown band on posterior margin. Metanotum brown, covered with sparse hyaline hairs. Meso- and metapleuron brown, moderately covered with long hyaline hairs.

Legs. Whitish-yellow, short. Coxae moderately covered with long hyaline hairs; fore coxae whitish-yellow, with brown marking on dorsal surface; mid- and hind coxae dark brown. Femora moderately covered with short dark hairs, mixed with sparse long black setae; fore femur whitish-yellow, with dark brown marking on apex on dorsal surface and dark brown on ventral surface; mid femora whitish-yellow, dark brown on ventral surface; hind femora whitish-yellow with brown marking at apex; femoral sense hair length about ⅓ to ½ of femur length on fore and mid legs, absent on hind leg. Tibiae moderately covered with short dark hairs, mixed with sparse long black setae; fore- and mid tibia whitish-yellow, dark brown at apex, dorsal surface with a dark brown marking interpreted with a whitish-yellow line, ventral surface reddish-brown; hind tibia whitish-yellow, dark brown on ventral surface and apex. Tibial spurs red, short, slender, almost straight, longer than tarsomere 1 (approximately as long on hind leg). Tarsi whitish-yellow, dark brown at apex of each tarsomere, sparsely covered with short dark hairs dorsally, short black setae ventrally; tarsomere 1 shorter than combined length of tarsomeres 2–4;

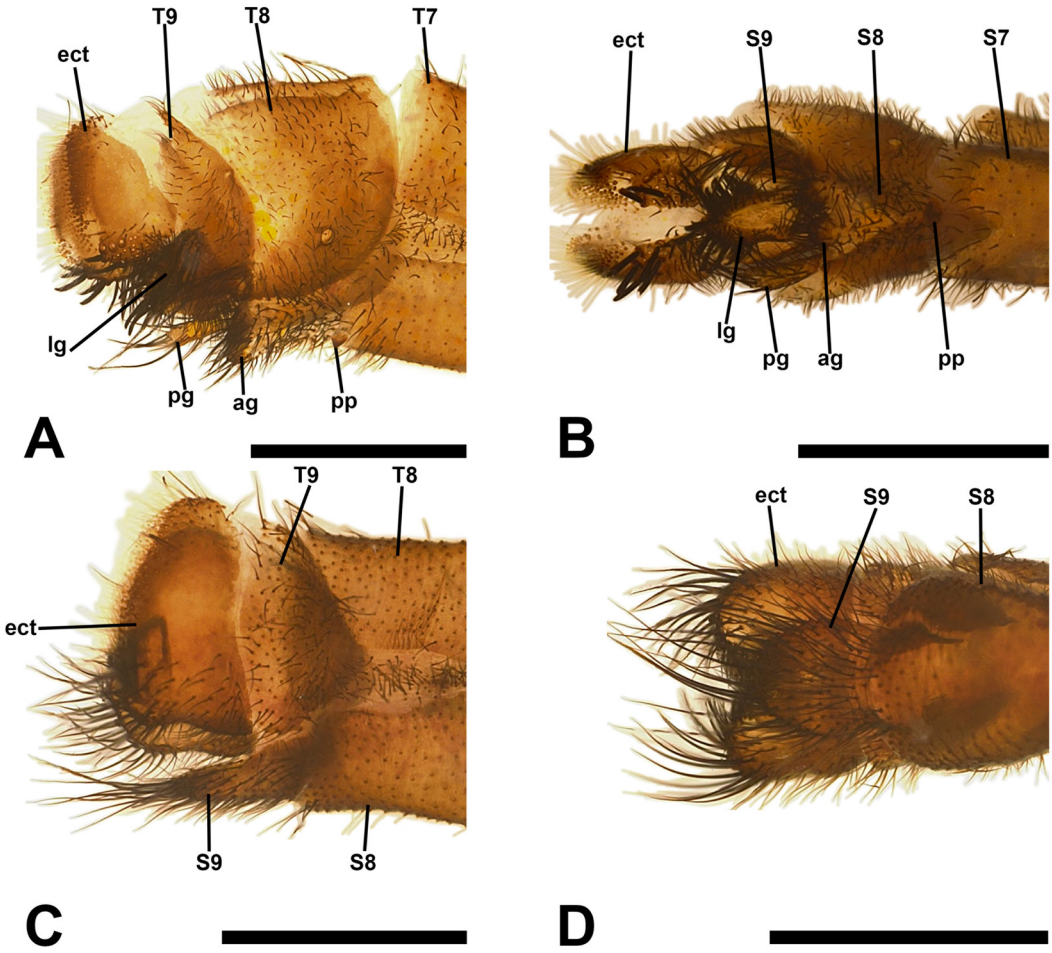

Fig. 24. *Myrmeleon punctinervis* Banks, 1937 (NTU). **A**. Female terminalia, lateral view. **B**. Same, ventral view. **C**. Male terminalia, lateral view. **D**. Same, ventral view. Abbreviations: ag = anterior gonapophysis; ect = ectoproct; lg = lateral gonapophysis; pg = posterior gonapophysis; pp = pregenital plate; S = sternites; T = tergites. Scale bars = 1.0 mm.

tarsomere 5 approximately as long as combined length of tarsomeres 1–4. Pretarsal claws red, slightly black at base, short, simple, curved, shorter than tibial spurs.

Wings (Fig. 23C). Without markings, hyaline. Forewings narrow, acute at apex; veins and crossveins mostly pale brown, Sc, RA and CuA finely alternating brown and pale yellow; costal area without interconnected crossveins, distal crossveins often branched; presectoral area with 7–8 crossveins and 0–1 irregular cells; RP arising slightly beyond CuA fork, with 13–18 crossveins from origin of RP to hypostigmatic cell; CuP supporting 1 cell before fusing with 1A; 3A mostly fused with 2A; hypostigmatic cell long; pterostigma pale white; anterior Banksian line absent, posterior Banksian line distinct. Hindwings slightly shorter and narrower than forewings; acute at apex; presectoral area with 5 crossveins and 0 irregular cells; RP arising beyond MP fork, at origin runs closer to MA, with 9–13 crossveins from origin of Rs to hypostigmatic cell; hypostigmatic cell longer than forewing; pterostigma pale white; anterior Banksian line absent, posterior Banksian line slightly distinct, directly below CuA1; male with large pilula axillaris.

Abdomen (Fig. 1H). Shorter than hindwing, tergites brown, sternite brown, densely covered with short dark hairs dorsally and laterally, hyaline hairs ventrally.

Female terminalia (Fig. 24A–B). Tergite VIII at least 2 times as wide as tergite IX. Tergite IX narrow, rectangular in lateral view. Ectoproct trapezoid in lateral view, with long, black fossorial bristles on ventral half. Lateral gonapophyses semicircular in lateral view, smaller than ectoproct, with long, black fossorial bristles on posterior side and long, thin, black setae on ventral side. Posterior gonapophyses long, slender, with long, black setae. Anterior gonapophyses slightly lobed, slightly separated, with long, thick, black setae. Pregenital plate distinct, oval, presented on posterior margin of sternite VII.

Male genitalia (Figs 24C–D, 25). Ectoproct trapezoid in lateral view, slightly curved toward posterior, dorsal margin shorter than ventral margin, ventral margin slightly curved upward, covered with short pale brown hair, ventral half with long black setae. Sternite IX shorter than combined length of tergite IX

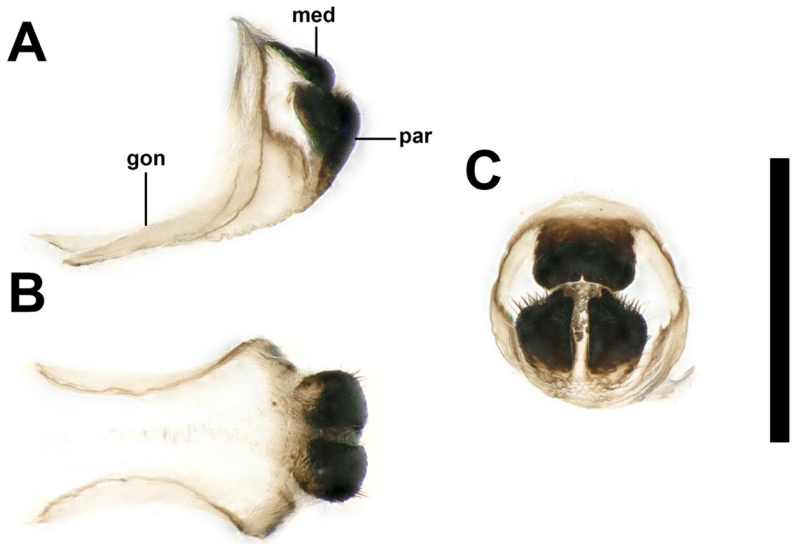

Fig. 25. *Myrmeleon punctinervis* Banks, 1937, male genitalia (NTU). **A**. Lateral view. **B**. Ventral view. **C**. Caudal view. Abbreviations: gon = gonarcus; med = mediuncus; par = parameres. Scale bar = 0.5 mm.

and ectoproct, tapered in ventral view, with long black setae posteriorly. Gonarcus arched, crescent-shaped in lateral view, arms curved inward. Mediuncus well sclerotized, large, black, rectangular in caudal view. Parameres well sclerotized, large, black, triangular in lateral view, rectangular in caudal view, separated, with short black setae.

Distribution

Taiwan (Kaohsiung, Miaoli, Nantou, New Taipei, Taichung, Tainan, Taoyuan, Yilan, also on the associated island of Kinmen) (Fig. 31H).

Biology

From the collecting and emergence date of the examined specimens, the adults appear from May to October, with one specimen emerging in February. The larvae prefer open environments and can be found on beaches or riverbank sand deposits (Lin *et al.* 2021).

Remarks

This medium-sized species is relatively easy to identify by the ring of yellow marking on the vertex (Fig. 23B), the overall morphology of the adult resembles *M. heppneri*, *M. persimilis*, and *M. taiwanensis*, but with narrower wings than *M. heppneri* and *M. persimilis*.

Myrmeleon taiwanensis Miller & Stange, 1999
Figs 1I, 26–28

Myrmeleon taiwanensis Miller & Stange in Miller *et al.*, 1999: 69. Type locality: Taiwan (Pingtung).

Myrmeleon taiwanensis – Stange *et al.* 2003: 123. — Sekimoto 2014: 21. — Wang *et al.* 2018: 107.
Myrmeleon (*Myrmeleon*) *taiwanensis* – Stange 2004: 336. — Lin *et al.* 2019: 140.

Material examined

Holotype

TAIWAN • ♂ (photos examined); Pingtung County, Hengchun Township, Fengchuisha Beach (Feiha-Tre-Sha Area, Kenting Nat'l Park); 21°56′55.7″ N, 120°50′11.6″ E; 20 Apr. 1998; Robert A. Miller, Lionel A. Stange and Hsiau-Yue Wang leg.; collected as larva, emerged 24 Jun. 1998; on beach; FSCA 00091192.

Paratypes

TAIWAN – **Pingtung County** • 3 ♂♂, 1 ♀ (4 larvae reared to adults); same data as for holotype; NTM 3624-001 to 3624-003 • 1 ♀ (larva reared to adult); Checheng Township, Haikou Desert; 22°05′10.4″ N, 120°42′15.4″ E; 22 Apr. 1998; Robert A. Miller, Lionel A. Stange and Hsiau-Yue Wang leg.; NTM 3624-004.

Additional material

TAIWAN – **Pingtung County** • 1 ♂; Hengchun Township, "Kenting Bot. Garden" [now Kenting National Forest Recreation Area]; 260 m a.s.l.; 22–25 Jul. 1980; D.R. Davis leg.; subtropical forest; USNM • 2 ♂♂, 2 ♀♀ (4 larvae reared to adults); Hengchun Township, Baisha Beach (White Sand Bay); 4 Feb. 2020; Yu-Hsiu Lin leg.; 3 specs preserved in alcohol; NTU • 2 ♂♂, 1 ♀ (3 larvae reared to adults); Hengchun Township, Dawan Beach; 3 Feb. 2020; Yu-Hsiu Lin leg.; 2 specs preserved in alcohol; NTU • 2 ♂♂, 2 ♀♀ (4 larvae reared to adults); Hengchun Township, Fengchuisha Beach; 3 Feb. 2020; Yu-Hsiu Lin leg.; 3 specs preserved in alcohol; NTU • 1 ♂, 2 ♀♀ (3 larvae reared to adults); Manzhou Township, Gangkou beach; 3 Feb. 2020; Yu-Hsiu Lin leg.; 2 specs preserved in alcohol; NTU • 1 ♂ (larva reared to adult); Checheng Township, Haikou Desert; 31 Jan. 2021; Yu-Hsiu Lin leg.; NTU • 2 ♂♂ (2 larvae

reared to adults); Manzhou Township, Jiupeng Desert; 4 Feb. 2020; Yu-Hsiu Lin leg.; preserved in alcohol; NTU • 2 ♂♂ (2 larvae reared to adults); Hengchun Township, Little Bay Beach; 31 Jan. 2021; Yu-Hsiu Lin leg.; 1 spec. preserved in alcohol; NTU • 1 ♂ (larva reared to adult); Hengchun Township, Shuiwaku; 7 Feb. 2021; Yu-Hsiu Lin, Bin-Hong Ho and Yun Ho leg.; preserved in alcohol; NTU. – **Taitung County** • 1 ♀ (larva reared to adult); Taitung City, Haibin Park; 6 Feb. 2021; Yu-Hsiu Lin, Bin-Hong Ho and Yun Ho leg.; preserved in alcohol; NTU • 2 ♀♀ (2 larvae reared to adults); Taimali

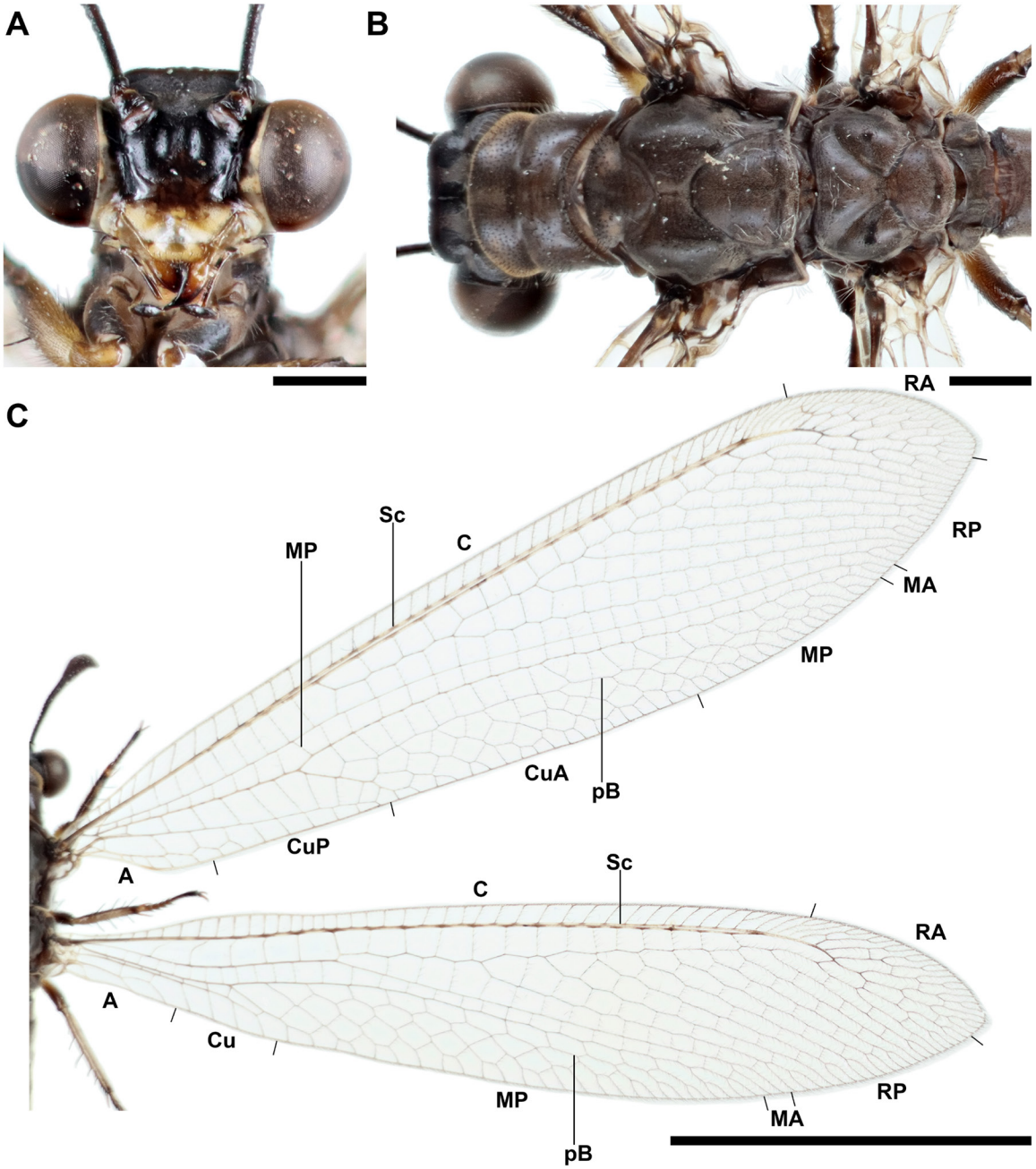

Fig. 26. *Myrmeleon taiwanensis* Miller & Stange, 1999 (NTU). **A**. Head, frontal view. **B**. Head and thorax, dorsal habitus. **C**. Wings. Abbreviations: A = anal veins; C = costa; Cu = cubitus; CuA = cubitus anterior; CuP = cubitus posterior; MA = media anterior; MP = media posterior; pB = posterior Banksian line; RA = radius anterior; RP = radius posterior; Sc = subcosta. Scale bars: A–B = 1.0 mm; C = 10.0 mm.

Township, Jinlun Beach; 6 Feb. 2021; Yu-Hsiu Lin, Bin-Hong Ho and Yun Ho leg.; 1 spec. preserved in alcohol; NTU • 2 ♀♀ (2 larvae reared to adults); Chenggong Township, Sanxiantai; 5 Feb. 2021; Yu-Hsiu Lin, Bin-Hong Ho and Yun Ho leg.; preserved in alcohol; NTU • 3 ♀♀ (3 larvae reared to adults); Lanyu Township, Yeyin Beach; 15–16 Jul. 2020; Yu-Hsiu Lin leg.; 2 specs preserved in alcohol; NTU • 1 ♂ (larva reared to adult); Lanyu Township, Yeyou River mouth; 17 Jul. 2020; Yu-Hsiu Lin leg.; preserved in alcohol; NTU.

Re-description of the adult

Measurements (♂ n =10, ♀ n = 9). Body length: ♂ 22.8–27.1 mm, ♀ 23.3–26.2 mm; forewing: length ♂ 22.5–27.4 mm, ♀ 25.1–28.3 mm; width ♂ 5.3–6.5 mm, ♀ 5.8–6.5 mm; width/length ratio ♂ 0.2338, ♀ 0.2324; hindwing: length ♂ 21.4–25.3 mm, ♀ 22.7–25.9 mm; width ♂ 4.4–5.6 mm, ♀ 4.6–5.7 mm; width/length ratio ♂ 0.2115, ♀ 0.2116.

Head (Fig. 26A–B). Vertex strongly raised, rounded, black, 4 shiny black spots along anterior margin and 4 shiny black spots along posterior margins, with sparse short black hairs; occiput dark brown,

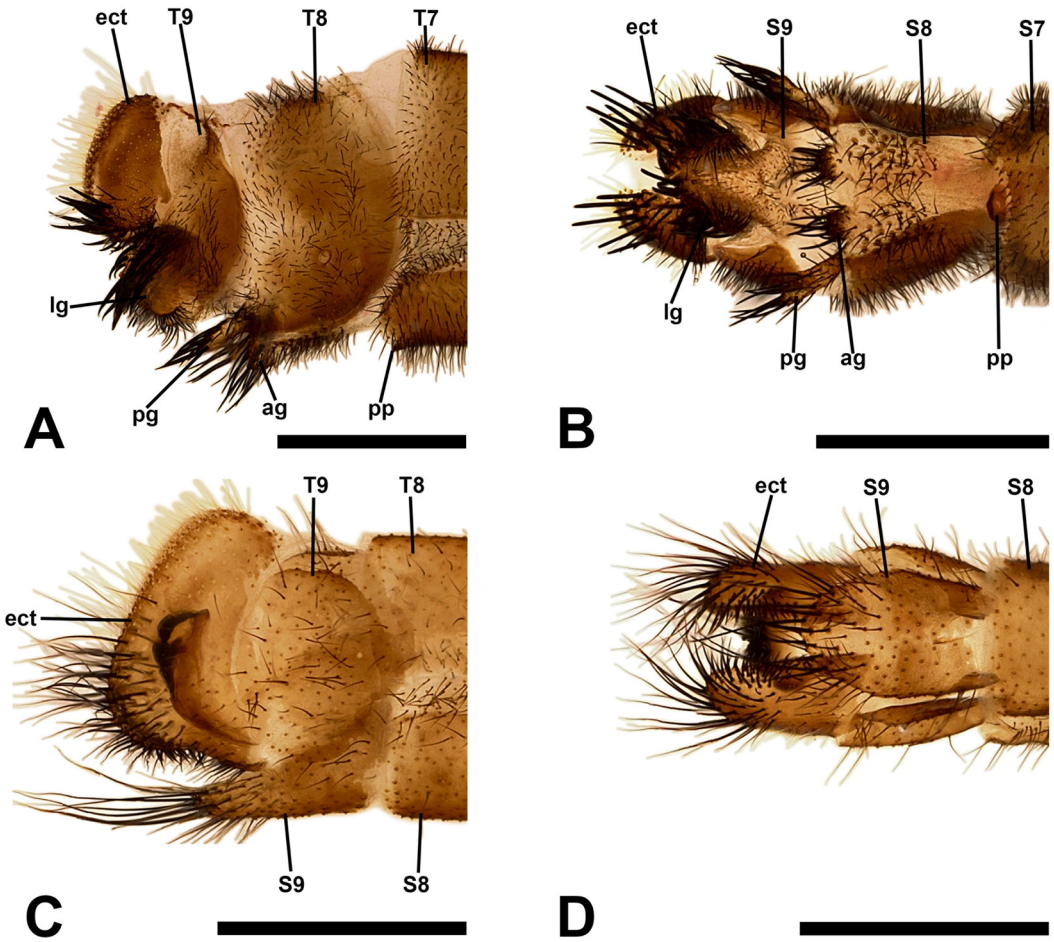

Fig. 27. *Myrmeleon taiwanensis* Miller & Stange, 1999 (NTU). **A**. Female terminalia, lateral view. **B**. Same, ventral view. **C**. Male terminalia, lateral view. **D**. Same, ventral view. Abbreviations: ag = anterior gonapophysis; ect = ectoproct; lg = lateral gonapophysis; pg = posterior gonapophysis; pp = pregenital plate; S = sternites; T = tergites. Scale bars = 1.0 mm.

paler in middle. Frons shiny black, covered with sparse short hyaline hairs; gena whitish-yellow, with an incomplete white line along ocular rim; clypeus whitish-yellow with a pair of dark brown spots (sometimes pale), with sparse hyaline hairs. Antenna brown, short, with slightly defined club, covered with short dark hairs; scape dark brown with a ring of white band at base; pedicel dark brown with a ring of white band at base; flagellum comprising approximately 30 flagellomeres. Mouthparts yellow, labrum yellow, with several hyaline hairs; maxillary palps dark brown, whitish-yellow between each palpomere, labial palps dark brown, 3rd palpomere black, fusiform, tapering to acute apex, with brown round palpimacula on apical ⅓; submentum with long dark hairs.

Thorax (Fig. 26B). Pronotum broad, shorter than wide, dark brown, anterior margin with whitish-yellow bands on lateral side, membrane whitish-yellow, with triangular brown marking in middle, with hyaline hairs and long dark hairs. Cervical sclerites dark brown. Mesonotum dark brown, with sparse hyaline hairs; mesoscutum dark brown. Metanotum dark brown, covered with sparse hyaline hairs. Meso- and metapleuron dark brown, moderately covered with long hyaline hairs.

Legs. Whitish-yellow, short. Coxae dark brown, fore coxae with yellow markings, moderately covered with long hyaline hairs. Femora moderately covered with short dark hairs, mixed with sparse long black setae; all femora whitish-yellow, dark brown on distal half; femoral sense hair length about ½ of femur length on fore and mid legs, absent on hind leg. Tibiae moderately covered with short dark hairs, mixed with sparse long black setae; fore tibia dark brown; mid- and hind tibia whitish-yellow, dark brown on ventral surface. Tibial spurs reddish-brown, short, slender, almost straight, slightly longer than tarsomere 1 (approximately as long on hind leg). Tarsi dark brown, tarsomere 1 whitish-yellow on dorsal surface, sparsely covered with short dark hairs dorsally, short black setae ventrally; tarsomere 1 shorter than combined length of tarsomeres 2–4; tarsomere 5 approximately as long as combined length of tarsomeres 1–4. Pretarsal claws reddish-brown, short, simple, curved, shorter than tibial spurs.

Wings (Fig. 26C). Without markings, hyaline. Forewings acute at apex; veins and crossveins mostly pale brown, Sc, RA and CuA finely alternating brown and pale yellow; costal area without interconnected crossveins, distal crossveins often branched; presectoral area with 8–10 crossveins and 0 irregular cells; RP arising slightly beyond CuA fork, with 12–16 crossveins from origin of RP to hypostigmatic cell; CuP supporting 1 cell before fusing with 1A; 3A mostly fused with 2A; hypostigmatic cell long; pterostigma pale white, slightly visible; anterior Banksian line absent, posterior Banksian line distinct. Hindwings slightly shorter and narrower than forewings; acute at apex; presectoral area with 5 crossveins and 0 irregular cells; RP arising beyond MP fork, at origin runs closer to MA, with 10–12 crossveins from origin of RP to hypostigmatic cell; hypostigmatic cell longer than forewing; pterostigma pale white, slightly visible; anterior Banksian line absent, posterior Banksian line slightly distinct; male with dark brown pilula axillaris.

Abdomen (Fig. 1I). Shorter than hindwing, tergites dark brown, sternite dark brown, densely covered with short dark hairs dorsally and laterally, hyaline hairs ventrally.

Female terminalia (Fig. 27A–B). Tergite VIII at least 2 times as wide as tergite IX. Tergite IX narrow, rectangular in lateral view. Ectoproct semicircular in lateral view, with long, black fossorial bristles on ventral half. Lateral gonapophyses semicircular in lateral view, smaller than ectoproct, with long, black fossorial bristles on posterior side and long, thin, black setae on ventral side. Posterior gonapophyses long, slender, with long, black setae. Anterior gonapophyses slightly lobed, separated, with long, thick, black setae. Pregenital plate well sclerotized, semicircular, presented on posterior margin of sternite VII.

Male genitalia (Figs 27C–D, 28). Ectoproct trapezoid in lateral view, slightly curved toward posterior, dorsal margin shorter than ventral margin, covered with short pale brown hair, ventral half with long black setae. Sternite IX shorter than combined length of tergite IX and ectoproct, tapered in ventral

view, with long black setae posteriorly. Gonarcus arched, cresent-shaped in lateral view. Mediuncus well sclerotized, black, rectangular in caudal view, ventral margin with a median groove. Parameres well sclerotized, large, black, triangular in lateral view, parallelogram in caudal view, separated, with short black setae.

Distribution

Taiwan (Pingtung, Taitung, also on the associated island of Lanyu) (Fig. 31I), Japan (Iriomote Island, Ishigaki Island, Okinawa Island).

Biology

The larvae inhabit coastal environments in the southern parts of Taiwan, preferring sheltered conditions like beneath coastal vegetation (Lin *et al.* 2021).

Remarks

This is a medium-sized species, the overall morphology of the adult resembles *M. persimilis*, *M. heppneri* and *M. punctinervis*, but with narrower wings and can be recognized by the fully dark-colored vertex and thorax (Fig. 26A–C).

Phylogenetic analyses based on COI

A maximum likelihood tree of the Taiwanese species of Myrmeleontini was constructed based on a 687 bp COI dataset (Fig. 29), including both larvae and adult specimens. The result revealed that the nine Taiwanese species all form well-supported monophyletic groups, with bootstrap values over 99%. *Baliga* species cluster within *Myrmeleon*, consistent with the current knowledge that *Myrmeleon* is paraphyletic. However, interspecific relationships have low bootstrap values and cannot resolve the relationships among species.

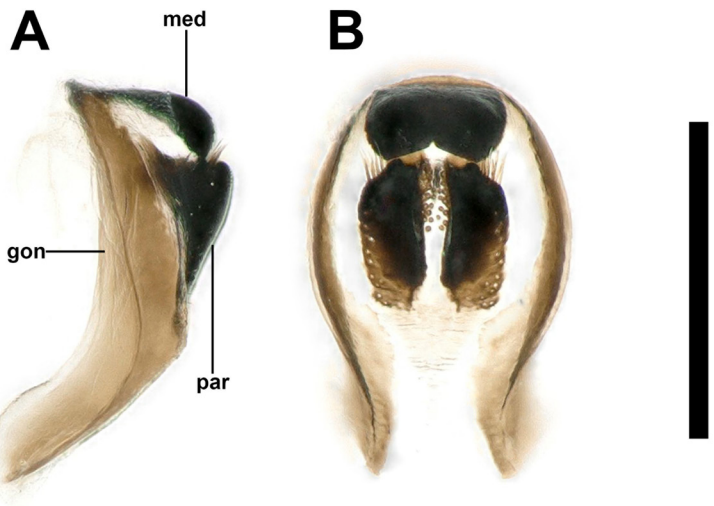

Fig. 28. *Myrmeleon taiwanensis* Miller & Stange, 1999, male genitalia (NTU). **A**. Lateral view. **B**. Caudal view. Abbreviations: gon = gonarcus; med = mediuncus; par = parameres. Scale bar = 0.5 mm

Genetic differences (Table 1; Supp. file 2) among specimens from different localities can be seen in some species. Specimens of *Baliga asakurae* collected from northern and central Taiwan formed a well-supported clade, separated from specimens from the southern part of the island. Individuals of *Baliga brunneipennis* and *M. wangi* collected from the northern, central and eastern parts of Taiwan are separated into different groups, although some of the nodes have low bootstrap values. In *M. tenuipennis*, specimens from northern Taiwan and Kinmen Island clustered together, separated from several central Taiwanese specimens. In contrast, almost no genetic difference was observed between different populations in Taiwan or adjacent islands in species such as *M. littoralis*, *M. persimilis* and *M. punctinervis* (except for the *M. persimilis* specimens from Kinmen Island).

Discussion

Although many species have been described in the tribe, Myrmeleontini is still understudied. Most members of the tribe are very similar in appearance, especially species of *Myrmeleon*; therefore, species delimitation within the tribe was considered to be quite difficult (Hayashi *et al.* 2020). In the Taiwanese species, several characters including wing venation and structures of the genitalia are distinct among species. By comparing these characters, it is possible to assign them to different groups. In the two species of *Baliga* and *M. littoralis*, the hindwings are significantly longer than their forewings. These species also have the hindwing RP vein at origin running equidistant to RA and MA veins (Fig. 30A). On the other hand, the species of the *M. punctinervis* group and *M. wangi* have their hindwings shorter than the forewings, while *M. tenuipennis* has a similar wing length. These species also have the hindwing RP vein arising very close to the MA vein (Fig. 30B); such feature can also be observed in many species of *Myrmeleon*, including *M. mariaemathildae*, *M. punicanus*, *M. almohadarum*, *M. noacki* Ohm, 1965, *M. hyalinus*, *M. inconspicuus*, *M. gerlindae* Hölzel 1974, *M. trivialis*, *M. formicarius*, and *M. otiosus* from the Palearctic region; *M. territorius* New, 1985, *M. acer* Walker, 1853, *M. regularis*, *M. iridescens* Kirby, 1900, *M. houstoni* New, 1985, and *M. commoni* New, 1985 from the Australasian region (Navás 1912a; New 1985; Pantaleoni *et al.* 2010; Pantaleoni & Badano 2012; Monserrat & Acevedo 2013; Sekimoto 2014; Badano *et al.* 2016; Hajiesmaeilian *et al.* 2020; Hassan *et al.* 2022).

Aside from the wings, the genitalia and terminalia also show crucial characters in assigning groups within Myrmeleontini. The female terminalia of species of *Baliga* were used to define the genus, with the length of the anterior gonapophyses over half-length of the posterior gonapophyses, differentiating the genus from *Myrmeleon*, whose anterior gonapophyses are much shorter, and *Hagenomyia*, which have the anterior gonapophyses as long as the posterior gonapophyses (Stange 2004). In the male genitalia, evident differences can be observed between genera and species groups (Figs 4, 7, 10, 13, 16, 19, 22, 25, 28). All the different groups of the Taiwanese species show different structures in the male genitalia. For species of *Baliga*, the overall genitalia structure can also be observed in the Japanese species (Hayashi *et al.* 2020). The genitalia structure of species groups like the *M. punctinervis* group and the *M. wangi* group are also found to be somewhat similar when compared to species of *Myrmeleon* from other regions (see Remarks of *littoralis* group, *wangi* groups and *punctinervis* group).

Based on our phylogenetic analysis of COI, the genus *Baliga* was clustered within *Myrmeleon*, but with low bootstrap values, which unsurprisingly suggests that the barcode COI is inadequate on its own for constructing phylogenetic relationships of genera within Myrmeleontini, although the sequence can be useful in species delimitation. Some species seem to have a genetic structure among different populations, while some have not; whether the genetic structure is due to a different dispersal ability or different habitat preference among species, or if it underlies a different phylogeographical history, is a matter for future research.

Myrmeleontini is a group that is in need of a complete revision and re-classification. Machado *et al.* (2019) suggested that it will be best to group most of the minor genera except *Porrerus* into *Myrmeleon*,

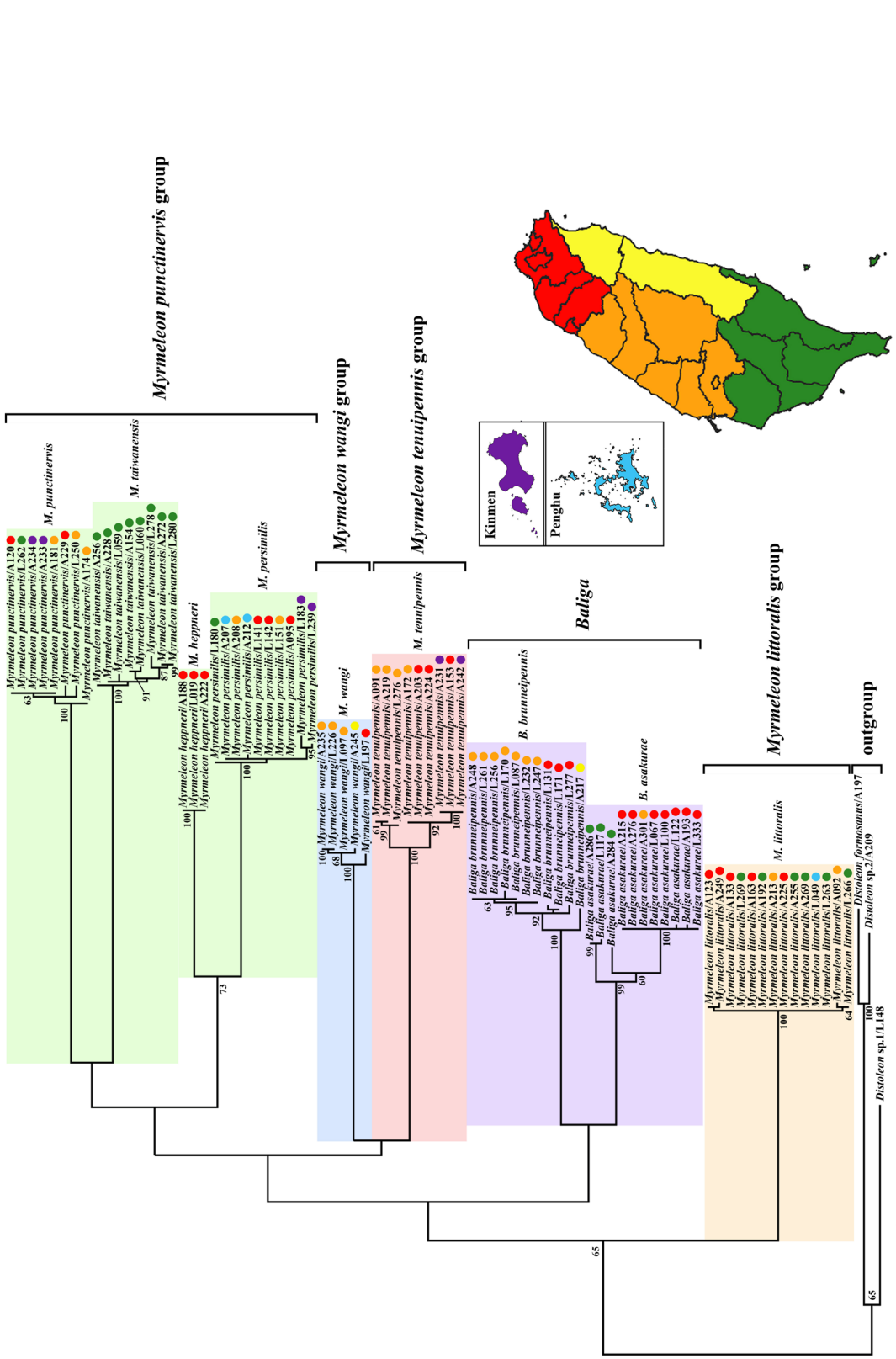

Fig. 29. Maximum likelihood tree of Taiwanese Myrmeleontini Latreille, 1802 based on 687 bp of COI sequences. The numbers on the nodes show the bootstrap values, numbers lower than 60 are not shown.

Table 1. Pairwise distance of COI sequences between Taiwanese species of Myrmeleontini Latreille, 1802. Grids framed in red show intraspecific distances, others show interspecific distances.

	B. asakurae	*B. brunneipennis*	*M. tenuipennis*	*M. littoralis*	*M. wangi*	*M. heppneri*	*M. persimilis*	*M. punctinervis*	*M. taiwanensis*
B. asakurae	0–0.037								
B. brunneipennis	0.115–0.135	0–0.024							
M. tenuipennis	0.174–0.192	0.166–0.180	0–0.023						
M. littoralis	0.147–0.170	0.139–0.154	0.160–0.167	0–0.006					
M. wangi	0.143–0.161	0.149–0.167	0.173–0.177	0.144–0.153	0–0.010				
M. heppneri	0.160–0.174	0.172–0.178	0.175–0.179	0.164–0.168	0.166–0.171	0			
M. persimilis	0.171–0.200	0.172–0.186	0.189–0.203	0.179–0.189	0.155–0.166	0.121–0.133	0–0.010		
M. punctinervis	0.184–0.196	0.187–0.198	0.194–0.216	0.179–0.188	0.177–0.189	0.196–0.208	0.179–0.193	0–0.009	
M. taiwanensis	0.198–0.213	0.166–0.182	0.177–0.187	0.193–0.208	0.186–0.198	0.174–0.181	0.208–0.224	0.193–0.207	0–0.013

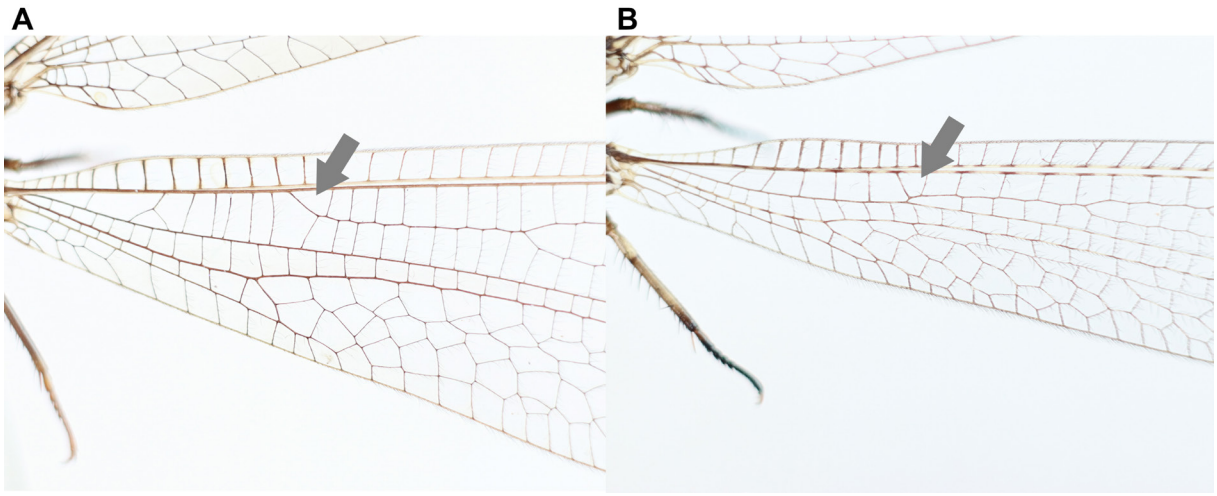

Fig. 30. Base of hind wings of Myrmeleontini Latreille, 1802. **A**. *Baliga brunneipennis* (Esben-Petersen, 1913). **B**. *Myrmeleon wangi* Miller & Stange, 1999. Gray arrows indicate origin of vein RP.

then redivide the genus into separate monophyletic species groups or genera. Here, we do not propose new names or synonyms, but group the species of *Myrmeleon* into species groups according to morphological characters. Our morphological comparison can provide a foundation and new insight for future taxonomic studies of the Myrmeleontini, and that by combining morphological and molecular studies, a reliable taxonomic system will emerge in the near future.

Conclusion

The cosmopolitan tribe Myrmeleontini consists of species of antlions with similar morphological characters and pit-building larvae. In the present study, nine species of Myrmeleontini from Taiwan were redescribed and compared in detail. Differences were observed in structures such as wing venation and the terminalia, and they can be applied to assign the Taiwanese species into groups. These groups can likely also be used as clues for solving the complex systematics of the tribe, one of the most diverse tribes within the Myrmeleontidae, as their phylogenetic relationships within Myrmeleontini have not been thoroughly reconstructed yet. Our study can serve not only as a piece in understanding of the Taiwanese antlion fauna, but also as a basis for the future systematic works of Myrmeleontini.

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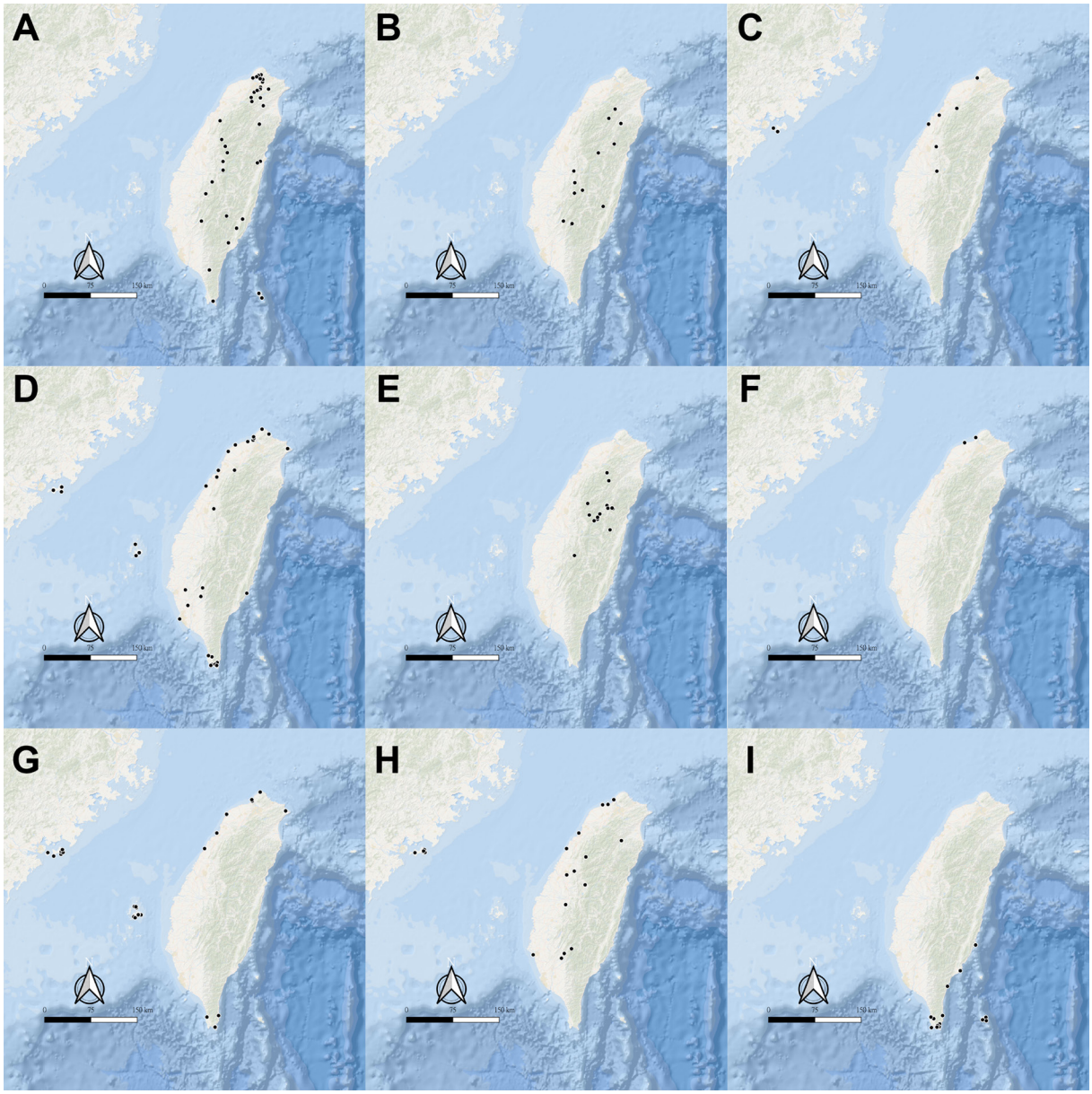

Fig. 31. Distribution of Myrmeleontini Latreille, 1802 from Taiwan and adjacent islands. **A**. *Baliga asakurae* (Okamoto, 1910). **B**. *B. brunneipennis* (Esben-Petersen, 1913). **C**. *Myrmeleon tenuipennis* Rambur, 1999. **D**. *M. littoralis* Miller & Stange, 1999. **E**. *M. wangi* Miller & Stange, 1999. **F**. *M. heppneri* Miller & Stange, 1999. **G**. *M. persimilis* Miller & Stange, 1999. **H**. *M. punctinervis* Banks, 1937. **I**. *M. taiwanensis* Miller & Stange, 1999.

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Supplementary files

Supp. file 1. Information of specimens used in present phylogenetic analysis.
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Supp. file 2. Pairwise genetic distances of 687-bp COI of analyzed Taiwanese Myrmeleontini Latreille, 1802. https://doi.org/10.5852/ejt.2024.969.2743.12575