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Hierodula confusa sp. nov., a new species of *Hierodula* Burmeister, 1838 (Mantodea: Mantidae: Hierodulinae: Hierodulini)

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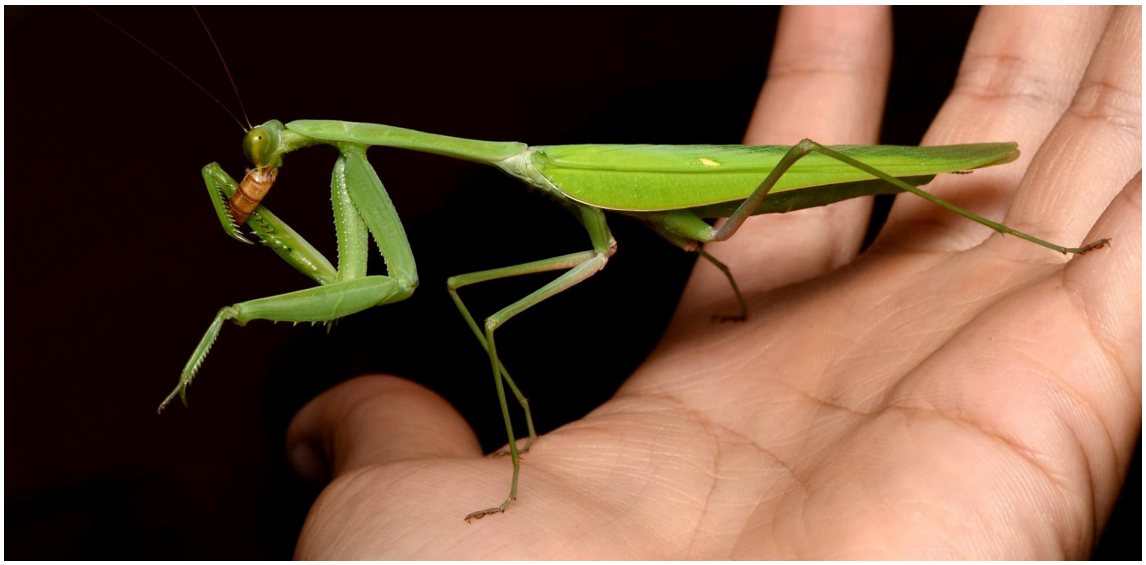

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Abstract

Hierodula confusa sp. nov. is described and figured based on material from Thailand. Habitus images of both sexes and photographs of the dissected male genitalia are given. Additionally, the male genitalia are compared with those of *Hierodula membranacea* Burmeister, 1838 and *Rhombodera extensicollis* Serville, 1839 and figured. The new species shows great similarity in external morphology with *H. membranacea*, which is the type species of the genus. However, it can be readily distinguished from *H. membranacea* by the morphology of the male genitalia, which have sufficiently different and constant characters across specimens within the known distribution range to justify the description of a new species. Given the similarity in their external morphology, *H. confusa* sp. nov. could easily have been misidentified as *H. membranacea* in the past, thus requiring a reassessment of collection material attributed to the species. *R. extensicollis* also shares morphological characters with the new species and is briefly discussed. A distribution map with confirmed records for *Hierodula confusa* sp. nov. is provided.

Keywords: Oriental region, Praying mantis, South-East Asia

Introduction

The oriental genus *Hierodula* Burmeister, 1838 is a very diverse and taxonomically problematic genus in need of complete revision (VERMEERSCH, 2020; SCHWARZ & ROY, 2019). The type species of the genus, *Hierodula membranacea* Burmeister, 1838, was described by BURMEISTER (1838) in a very brief fashion, mentioning two males stored at "Königl. Museum" from unknown location, noting a possible but not further substantiated origin in East India. EHRMANN & BORER (2015) mention these two specimens as syntypes, currently deposited at the Museum fur Naturkunde der Humboldt-Universitat Berlin (ZMHB). The species has always been considered widely distributed across the oriental region. SCHWARZ *et al*. (2018) mention distribution records from Southern China, India, Java, Nepal, Sri Lanka and Thailand, but question the validity of the one from Java. The dissection of *Hierodula* specimens from Bangkok (Thailand) that resemble the type species *Hierodula membranacea* Burmeister, 1838 revealed the existence of a new species, here described as *Hierodula confusa* sp. nov. The genitalia were compared to the syntype material of *H. membranacea* revealing clear differences, yet with enough similarities to attribute with certainty the specimens from Thailand to *Hierodula*. The new species undoubtedly passed unnoticed for a very long time given its strong resemblance in external morphology to *H. membranacea.* Additionally, the existence of *H. confusa* sp. nov. requires a revision of the distribution data that were previously attributed to *H. membranacea*. Awaiting the much-needed revision of *Hierodula* we currently only consider for

differential diagnosis the type species *H. membranacea* which also appears to be the closest to the new species in terms of external morphology. Interestingly, the morphology of the male genitalia in *H. confusa* sp. nov. revealed some shared characters with the Javanese species *Rhombodera extensicollis* Serville, 1839. This paper aims to provide a description of the new species *H. confusa* sp. nov. and to compare it with *H. membranacea* and *R. extensicollis*.

Material & methods

Specimen data is provided by the RBINS entomological collections and specimens recently collected by the second author, which are deposited at the Thailand Natural History Museum (THNHM) and in the author's personal collection (TUPC). Recent specimens were collected manually by visual inspection of the vegetation, then euthanised with ethyl acetate fumes and subsequently mounted with insect pins and dried. For genitalia preparations the tip of the abdomen was separated from the specimens and macerated in a 10% potassium hydroxide (KOH) solution, then rinsed with demineralised water and placed in 70% ethanol for further dissection to isolate the genital complex from the last abdominal tergite and coxosternite. After study, all the dissected parts were transferred to a small plastic vial with glycerine for long-term preservation and pinned under the respective specimen. Observation of the external structures, male genitalia and colouration was done by TU with an OPTIKA® microscope (OPTIKA Microscopes, Italy) and by XV with a Leica EZ4W stereo-microscope. Live photographs were taken by TU with a Nikon AF-S Micro NIKKOR 60mm lens attached to a Nikon D7200 camera. The classification system is according to SCHWARZ & ROY (2019). The followed morphological nomenclature and measurements are the same as in VERMEERSCH (2020). The distribution map was produced with SimpleMappr (SHORTHOUSE, 2010) and adapted accordingly.

ABBREVIATIONS:

Asl = Above sea level

AvS = Anteroventral spine

DS = Discoidal spine

HT = Holotype

MzL = Metazona length

PT = Paratype

PvS = Posteroventral spine

PzL = Prozona length

COLLECTION ACRONYMS:

RBINS = Royal Belgian Institute of Natural Sciences, Brussels, Belgium

THNHM = Thailand Natural History Museum, Pathum Thani, Thailand

TUPC = Thornthan Unnahachote Personal Collection, Bangkok, Thailand.

Taxonomy

Order Mantodea Burmeister, 1838
Superfamily Mantoidea Latreille, 1802
Family Mantidae Burmeister, 1838
Subfamily Hierodulinae Brunner von Wattenwyl, 1893
Tribe Hierodulini Brunner von Wattenwyl, 1893

Genus *Hierodula* Burmeister, 1838

TYPE-SPECIES: *Hierodula membranacea* Burmeister, 1838.

Hierodula confusa Vermeersch & Unnahachote, 2020 sp. nov.

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(Figs 1−6)

DIFFERENTIAL DIAGNOSIS. *Hierodula confusa* sp. nov. can be separated from the closest species *H. membranacea* by:

(1) The punctuation of the inner side of the procoxae: *H. confusa* sp. nov. (Figs 1 A−C; 2 E) − small whitish tubercles are covering the entire anterior surface of the procoxae at irregular intervals, these also form a more or less straight row running parallel with the dorsal coxal margin; *H. membranacea* − only one single row of small whitish tubercles arranged in a straight row running parallel with the dorsal coxal margin (only faintly visible in some specimens), remaining anterior surface of procoxae smooth.

(2) Morphology of the male genitalia: *H. confusa* sp. nov. (Figs 4; 5 D−F) – afa with a strongly sclerotised and acute spine-shaped anterior process aafa, posterior process pafa irregularly shaped, wrinkled and membranous, completely and densely covered with very small and short spine-like setae, distal process with long and slender sdpl, bifurcating around the middle with very small sdpm (see also description below); *H. membranacea* (Fig. 6 A−C) – aafa and pafa both small and sclerified, pafa longer than aafa, distal process sdpl very long and slender, without sdpm.

Hierodula confusa sp. nov. differs from *R. extensicollis* by the shape of the pronotum without large lateral expansion, the missing expansion of the dorsal procoxal edge, smaller dark spots on the ventral side of meso- and metathorax, and the differences in male genitalia illustrated in Fig. 6.

ETYMOLOGY. The species epithet, from the Latin ‘confusa’ means vague/indefinite or obscure. The name is referring to the great similarity in external morphology with its close relative *Hierodula membranacea* and the subsequent confusions and misidentifications that resulted from it.

TYPE MATERIAL. Holotype ♂ and paratypes (3♂, 4♀): Holotype ♂: Thailand, Bangkok, Kannayao dist., Ramintra subdist., 25.IV.2019, leg. T. Unnahachote, THNHM-I-19528 (THNHM). Paratype (1♀): Thailand, Bangkok, Kannayao dist., Ramintra subdist., 15.IV.2020, leg. T. Unnahachote, THNHM-I-19529 (THNHM). Paratype (1♀): Thailand, Bangkok, Kannayao dist., Ramintra subdist., 15 XII.2019, leg. T. Unnahachote, THNHM-I-19530 (THNHM). Paratype (1♂): Thailand, Ratchaburi prov., Suan Phueng dist., 13°35′03.8”N; 099°13′56.0”E, 200m. asl., light trap, 23.IV.2020, K. Jiaranaisakul leg. (TUPC). Paratype (1♀): Thailand, Nonthaburi prov., Pak Kret dist., 30.X.2019, W. Chanaparn leg. (TUPC). Paratypes (1♂, 1♀): Thailand, Bangkok, Kannayao dist., Ramintra subdist., 20.VII.2019, leg.

T. Unnahachote. I.G.:34.197 (RBINS). Paratype (1♂): Thailand, Bangkok, Genitalia prep. Vermeersch Nr. GEN1804, leg. P. Rolin. (RBINS).

MATERIAL EXAMINED FROM PHOTOGRAPHS. Thailand: 1 ♂ (Fig. 3 D): Baan Maka Nature Resort, Song Pe Nong, Kaeng Krachan, Phetchaburi, 12°50'37.9"N; 99°35'27.2"E, 15.IV.2018, I. Dugdale & P. Phetsri.

DESCRIPTION. MALE (holotype): (Figs 1 A–B; 2 C–D).

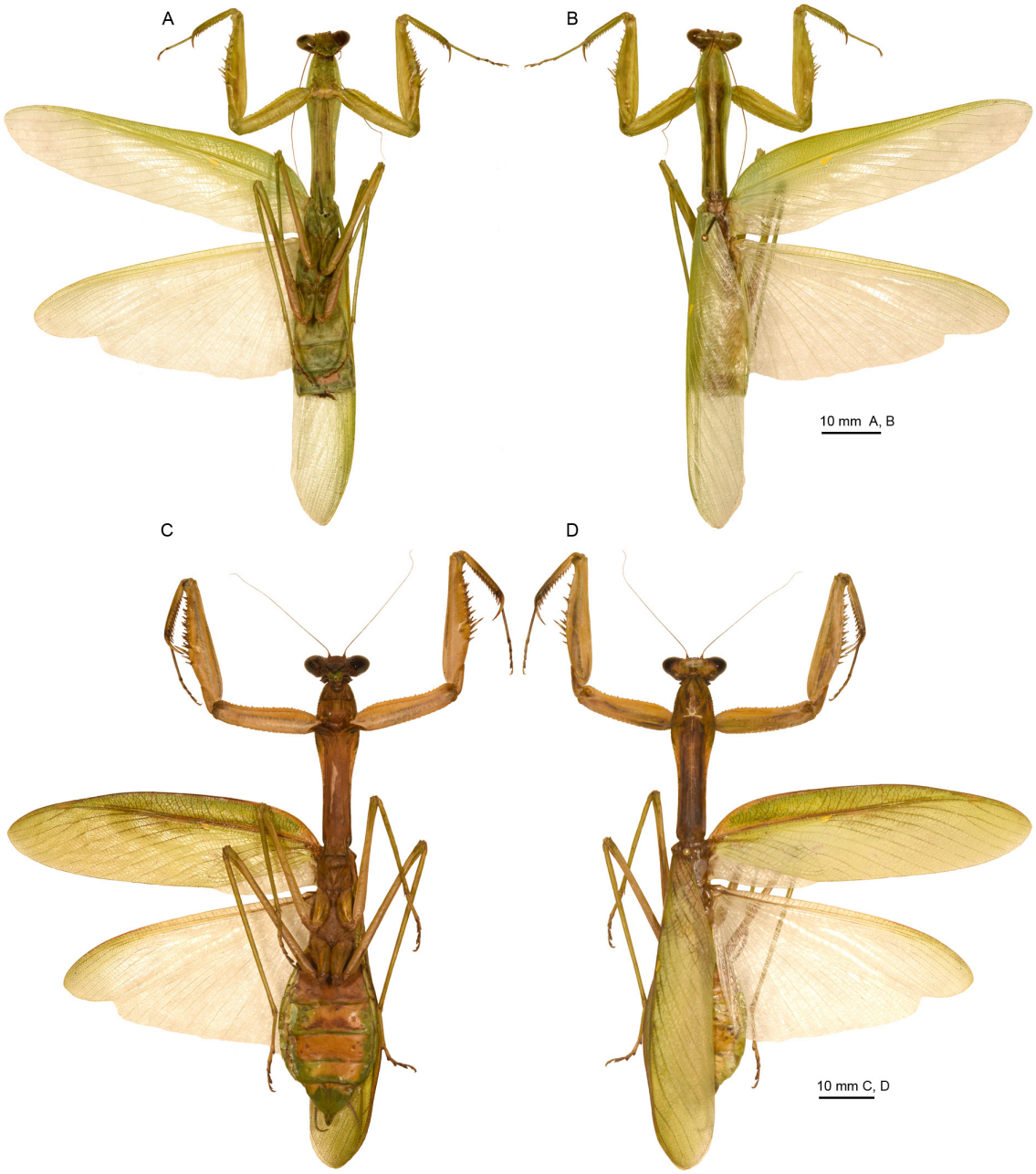

Fig. 1. *Hierodula confusa* sp. nov. Holotype ♂ (THNHM). A, habitus, ventral view. B, habitus, dorsal view. Paratype ♀ [PT1] (THNHM) C, habitus, ventral view. D, habitus, dorsal view.

Measurements: Table 1.

Table 1. Measurements of the genus diagnostic morphological parts.

Measurements	**HT** (♂)	**PT1** (♀)
Total length	79.4	91.9
Head width	8.6	11.4
Head height	6.2	8.8
Pronotum length	24.1	30.5
Pronotum width	5.9	7.9
Pronotum narrow width	3.6	4.8
Prozona length	6.0	7.5
Metazona length	18.1	23.0
Tegmen length	52.2	55.4
Ala length	45.5	47.6
Procoxa length	14.7	19.6
Profemur length	17.0	22.7
Protibia length	10.6	13.9
Mesofemur length	18.1	22.5
Mesotibia length	14.4	19.7
Metafemur length	21.9	26.7
Metatibia length	22.4	30.9
Metatarsus length	6.0	7.2
Anteroventral femoral spine count	15	15
Anteroventral tibial spine count	14/15	14
Posteroventral tibial spine count	9/11	10/11

Ratios ♂: MzL/PzL: 3.

Head (Figs 1 A−B; 2 C): Wider than long with large, rounded compound eyes. Vertex flat. Ocellar tubercle not elevated, in same plane as frons, without protruding ridges. Ocelli relatively large. Lower frons transverse with external margins posteriorly and laterally, no margin anteriorly, posterior margin almost flat, with two faintly defined vertical ridges internally. Clypeus and labrum smooth.

Thorax (Figs 1 A−B; 2 D): Pronotum long, broadest point at level of procoxal insertion site. Lateral margins gently sinusoidal in prozona and anterior half of metazona, parallel sided in posterior half of metazona. Margins smooth, without denticulations or projections, flattened along the edges, in particular posteriorly from the widest point until half the metazona, yet not wide enough to be considered as a distinct lateral expansion of pronotum. Dorsal surface entirely smooth. Cervix with strongly sclerotized lateral and intercervical sclerites, touching in middle. Postcervical plate and posterior ventral part of pronotum entirely smooth.

Prothoracic legs (Figs 1 A−B; 2 E): Coxa with 10−16 small and very weakly developed blunt spinules of more or less equal size with same colour as coxa (amount and size of spinules can strongly vary between individuals). Coxal anterior surface completely covered with irregularly interspaced small whitish tubercles of roughly same size as spinules on dorsal edge. Dorsal and

ventral coxal lobes rounded, equal in shape, length and adjacent, both lobes equally as broad. Femur with straight dorsal margin, surface entirely smooth. Femoral brush ellipse-shaped, starting from 12th AvS and ending at 15th AvS. Genicular lobes large and rounded, with small genicular spur. Colouration of prothoracic legs entirely uniform to body colour. Tibial spine groove placed slightly proximally from middle of femur. AvS unequal in size and arranged as follows: **iIiIiIiIiIiIiI**. AvS 12 and 15 larger but with 2 smaller spines of equal size between them. All spines apically infuscate only. PvS 4 smaller than others, others about equal in size; all slightly apically infuscate. DS 2 and 4 more or less equal in size, DS 2 longest and DS1 smallest. Tibial AvS gradually elongated towards tibial spur, all concolour to tibia and slightly apically infuscate. PvS slightly more procumbent, spines gradually longer towards distal end. Tibial spur apically infuscate. Protarsi with dark spot at distal end; first tarsomere longer than others combined. Spinal formula: F = 4DS/15AvS/4PvS; T = 14−15AvS/9−11PvS.

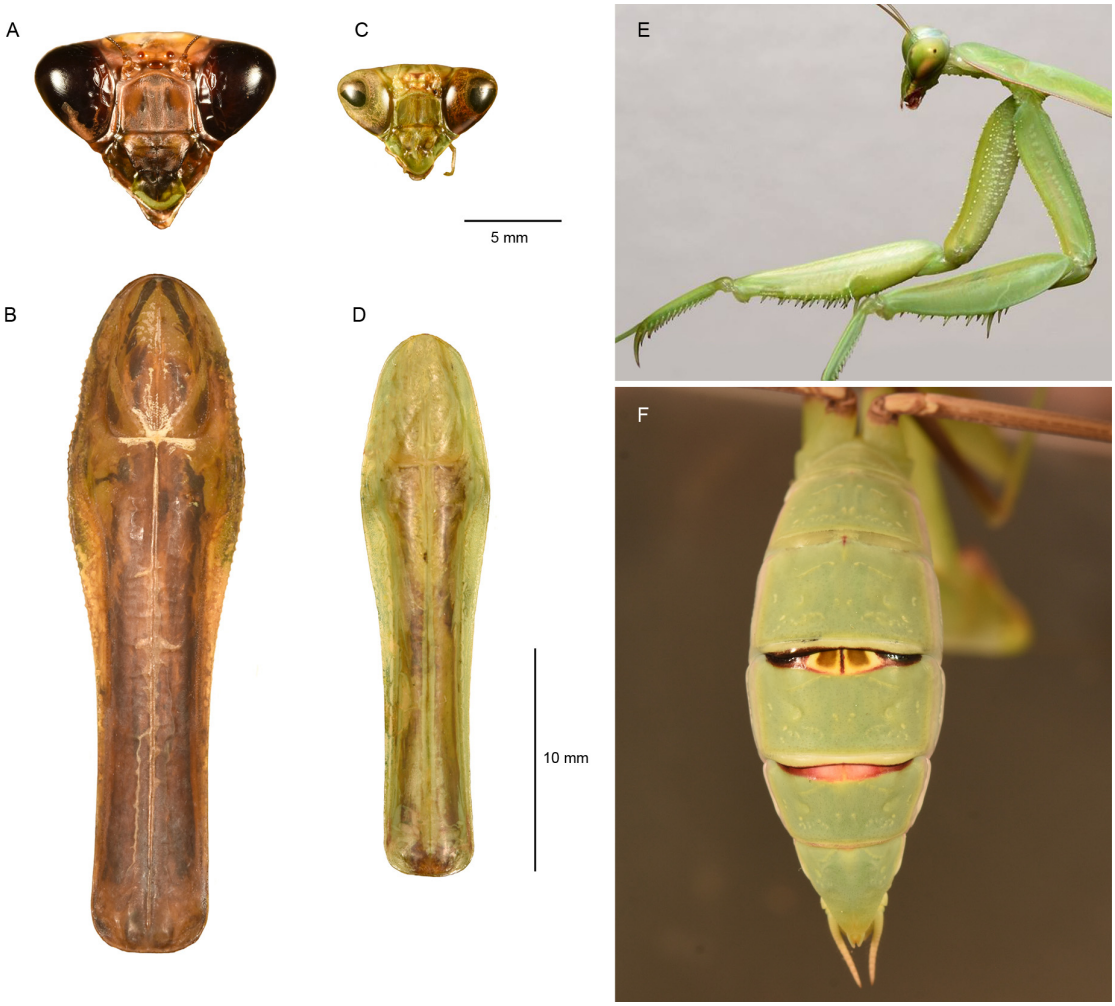

Fig. 2. *Hierodula confusa* sp. nov. Paratype ♀ [PT1] (THNHM). A, head, frontal view. B, pronotum, dorsal view. Holotype ♂ (THNHM). C, head, frontal view. D, pronotum, dorsal view. Live specimens. E, detail of prothoracic legs. F, dentral view of nymph abdomen with visible intersegmental colouration, typically shown during deimatic display.

Meso- and metathoracic legs (Fig 1 A–B): Long and slender, without dilatations or projections. Femora with rounded genicular lobes and a short genicular spur. Tibiae with two apical spurs. Tarsi 5-segmented, concolour and slightly darkened apically on ventral surface; 3rd and 4th tarsomere with small black spot proximally near the joint with previous tarsomere. First tarsomere of mesotarsus slightly shorter than remaining segments combined, first tarsomere of metatarsus about equal in length compared to remaining segments combined.

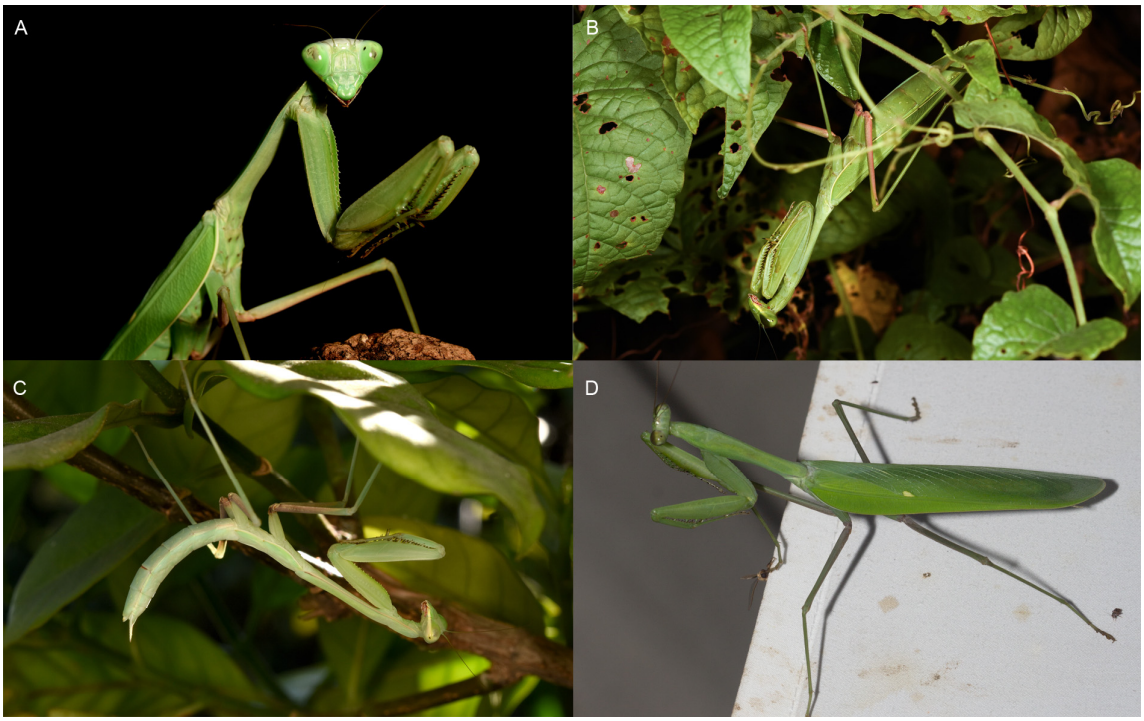

Fig. 3. *Hierodula confusa* sp. nov., live photographs: A–B, paratype ♀ [PT1]. C, sub-adult female nymph. D, adult male at light trap, Baan Maka Nature Resort, Thailand, © I. Dugdale & P. Phetsri.

Tegmina and alae (Fig 1 A–B): Tegmina uniformly concolour to the body (usually green) on costal area, hyaline in discoidal area, longer than tip of abdomen when folded in rest. Veins green, stigma white with strong hue of yellowish-green. Stigma located proximally from middle of tegmen. Alae fully developed, hyaline.

Abdomen (Fig. 1 A–B): Fusiform. Cerci setose, not flattened.

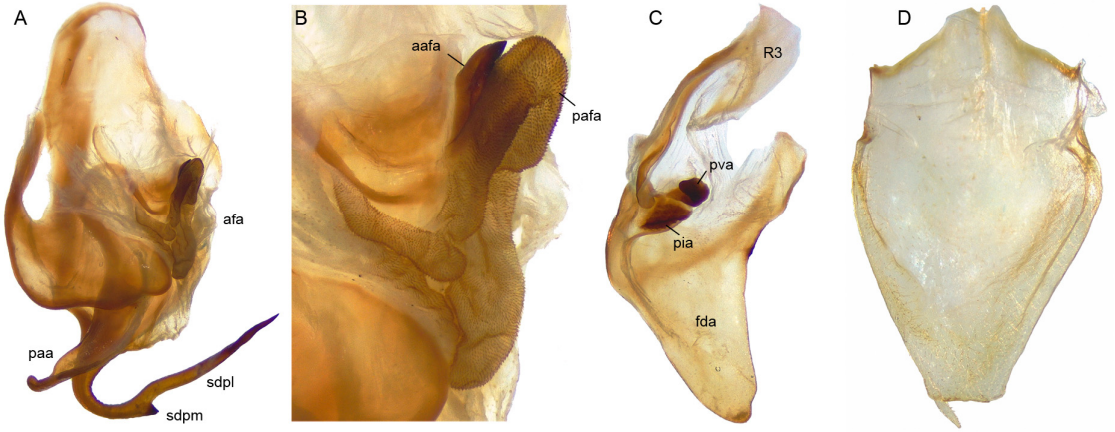

Fig. 4. *Hierodula confusa* sp. nov., genitalia prep. Vermeersch GEN1804. A, left phallic complex. B, detail of anterior process of left phallomere. C, right phallic complex. D, coxosternite IX (subgenital plate).

Genitalia (Figs 4; 5 D−F): Ventral phallomere of left phallic complex elongated, longer than broad. At about half its length the distal process bifurcates into a very small medial process (sdpm) and a long more or less straight lateral process (sdpl) with acute apex. Apical process of left phallomere (paa) broad and flattened. Phalloid apophysis (afa) with a strongly sclerotised and spine-shaped anterior process (aafa). Posterior process (pafa) irregularly shaped, wrinkled and membranous, completely and densely covered with very small and short spine-like setae. Right phallomere with main posterior lobe fda triangular but rather elongated (longer than broad), sclerite R3 shovel-shaped; very wide at its anterior end, pia and pva both strongly sclerified. Coxosternite IX (subgenital plate) smooth, with small hair-like setae near the edges, without spikes or other sclerified structures.

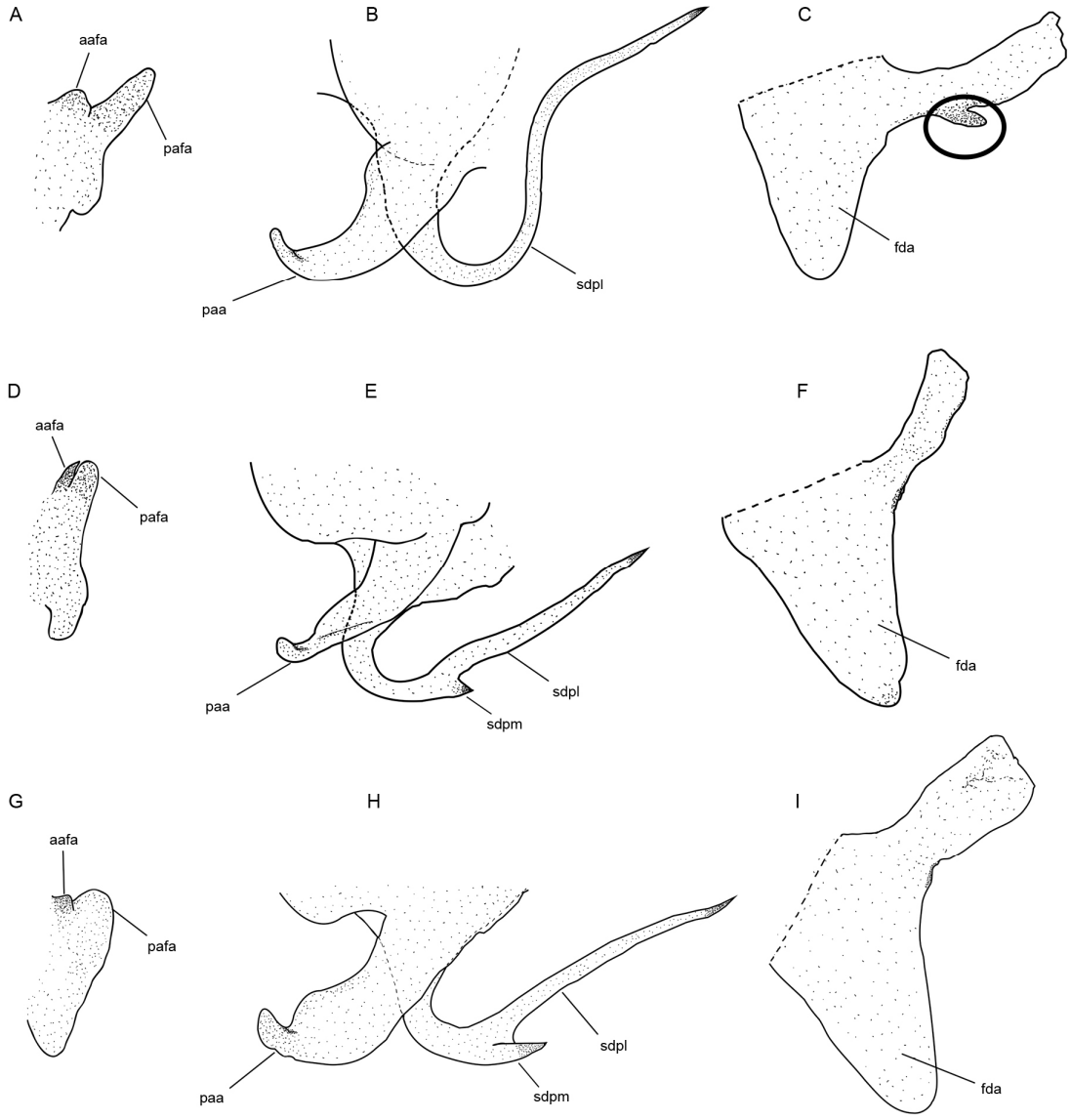

Fig. 5. *Hierodula membranacea*, genitalia ♂: A, anterior process of left phallomere, dorsal view. B, distal part of left phallic complex, dorsal view. C, distal part of right phallic complex, ventral view. *Hierodula confusa* sp. nov., genitalia ♂: D, anterior process of left phallomere, dorsal view. E, distal part of left phallic complex, dorsal view. F, distal part of right phallic complex, ventral view. *Rhombodera extensicollis*, genitalia ♂: G, anterior process of left phallomere, dorsal view. H, distal part of left phallic complex, dorsal view. I, distal part of right phallic complex, ventral view.

Colouration (Figs 1; 3A−C): All currently known specimens of *Hierodula confusa* sp. nov. feature a uniformly green colouration, although it is likely that brown individuals exist as is occasionally observed in *H. membranacea*.

FEMALE (Paratype: PT1): (Figs 1 C−D; 2 A−B, F; 3 A−C).

Measurements: Table 1. *Ratios* ♀: MzL/PzL: 3.

Very similar to male but more robust, different in the following characters:

(1) More acute spinules on dorsal margin of procoxae (approximately 20−22 in female vs 10−16 in male);

(2) Pronotum more robust, finely denticulated in prozona and anterior part of metazona, denticulations fading away distally, smooth edges in distal part of metazona;

(3) Tegmina completely opaque, reaching tip of abdomen;

(4) Costal area of forewing wider distally;

(5) Abdomen broad and ovaliform.

DISTRIBUTION. The distribution of *Hierodula confusa* sp. nov. as currently confirmed includes Thailand and Southern China (Fig. 6).

Fig. 6. Distribution map of *Hierodula confusa* sp. nov.

Discussion

TAXONOMIC CONSIDERATIONS

An additional comparison of the habitus and male genitalia of *H. membranacea*, *H. confusa* sp. nov. and collection material of *Rhombodera extensicollis* Serville, 1839 from Java revealed a surprising similarity between these three species regarding both aspects of their external morphology and male genitalia. The genitalia of *H. confusa* sp. nov. represent a somewhat intermediate state between *H. membranacea* and *R. extensicollis* (Fig. 5). *R. extensicollis* appears indeed to be an atypical member of the genus as it doesn't share many characters with other *Rhombodera* species apart from the presence of a lateral pronotal extension. The pronotal extension is however less broad and more elongated compared to typical *Rhombodera* species such as the type species *R. valida* Burmeister, 1838, and the male genitalia are also overall very different. Our findings may indicate that *R. extensicollis* is in fact much closer to *Hierodula* than to *Rhombodera* and the three species here considered could be part of the same evolutionary clade. However, the unresolved taxonomy of some problematic genera such as *Hierodula* and *Rhombodera* greatly complicates taxonomic research on Hierodulinae. A long overdue in-depth revision of several Hierodulinae genera and their phylogenetic relationships is absolutely necessary to provide solid support for the taxonomic placement of species such as *R. extensicollis*. The presence of a distinct lateral extension of the pronotum is currently a diagnostic character of *Rhombodera* and not *Hierodula*. However, transferring *R. extensicollis* to *Hierodula* at this time would imply to redefine the diagnosis of these two problematic genera. Although we do not formally propose to transfer *R. extensicollis* to *Hierodula* at this moment, we acknowledge that once *Hierodula* is properly revised, this transfer might be required for this species to be naturally placed with its closest relatives.

DISTRIBUTION

A complete re-assessment of specimens in museum collections that were identified as *H. membranacea* in the past is needed, especially for the records from China and Thailand corresponding with the confirmed distribution for *H. confusa* sp. nov. Based on the morphology of the male genitalia illustrated in WANG *et al.* (2020), their record of *H. membranacea* from Southern China needs to be attributed to *H. confusa* sp. nov instead (see Fig. 6). *H. confusa* sp. nov. is likely present in Myanmar and Laos given the large gaps between known distribution datapoints, but the species has not been reported from these very poorly sampled countries so far. Concomitantly the distribution of *H. membranacea* also needs to be re-evaluated and is likely limited to India and Nepal (EHRMANN & BORER, 2015; SCHWARZ *et. al*., 2018). Records of *H. membranacea* in Vietnam (THINH, 2010) require confirmation. Co-occurrence of both species or specimens with intermediate genitalia have not been recorded to date.

NATURAL HISTORY

Hierodula confusa sp. nov was found in several parts of Bangkok, the capital of Thailand, which is characterised by heavily urbanised landscapes with strong anthropologic influences. The surprising ability of the species to thrive in such strongly disturbed environments suggests that it is a highly adaptative and opportunistic species capable of maintaining a healthy population in very small and fragmented habitats.

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