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A Key to Species of the Scorpionflies of Thailand with the Description of New Species of *Panorpa* and *Neopanorpa* (Mecoptera: Panorpidae) based on Morphology and DNA Barcodes

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ABSTRACT

The first *Panorpa* was recently discovered in Thailand even though the genus had not been thought to occur south of the Himalaya. We now add a second new species, *Panorpa apscisacera* **n. sp.**, also from Northern Thailand, which has nearly immaculate pale-yellow wings with only a pronounced stigma. The male has a blunt, vestigial bifid anal horn, and thin, bare ventral parameres. Additionally, we describe *Neopanorpa appendicema* **n. sp.** with mesad-curved male hypovalve apices and large, basomesal lobes, a relatively large species, *N. inchoata* **n. sp.**, with overlapping elliptical hypovalves and incomplete apical bands, *N. setosiloba* **n. sp.** with huge bristly lobes on the mesal margin of the male gonostyles, and *N. mandangensis* **n. sp.** with a narrow 3rd tergum process extending to the posterior margin of the 4th tergum. *Neopanorpa nielsenii* Byers, 1965, previously known from northern Vietnam and southern China, has recently been discovered in northern Thailand. *Bittacus leptocaudus* Byers, 1965, known from a lone male has been rediscovered and locality details and photo of the habitat provided. These bring the number of species of Mecoptera occurring in Thailand to 22 (19 *Neopanorpa*, two *Panorpa*, and one *Bittacus*) and the number of Mecoptera species known from Indochina to 56 (48 *Neopanorpa*, three *Panorpa*, 4 *Bittacus*, and one *Bicaubittacus*). A key to the species of Mecoptera in Thailand with illustrations is provided. DNA was extracted from specimens and the DNA Barcode, mitochondrial cytochrome oxidase I (COI) gene fragment sequenced and analyzed for 19 of the 22 species of Thai Mecoptera. The results are figured as a Neighbor-Joining tree.

Key words: *Bittacus*, Cambodia, COI, distribution records, hangingfly, K2P, Project Tiger, scorpionfly, Vietnam.

บทคัดย่อ

แมลงแมงป่องสกุล *Panorpa* ไม่เคยมีรายงานจากทางตอนใต้ของเทือกเขาฮิมาลายา (Himalaya) มาก่อน จนกระทั่งในปี พ.ศ. 2562 แมลงแมงป่องสกุลนี้ได้ถูกรายงานเป็นครั้งแรกในประเทศไทย งานวิจัยนี้ได้ค้นพบแมลงแมงป่องชนิดใหม่ *Panorpa apscisacera* n. sp. จากภาคเหนือและเป็นชนิดที่สองของประเทศไทย ลักษณะเด่นของปีกสีเหลืองอ่อนเกือบทั่วปีก มีตาปีก (stigma) ชัดเจน anal horn ในเพศผู้สั้นและแยกเป็นสองแฉกแต่ไม่ชัดเจน ventral paramere บางและไม่มีขนปกคลุม นอกจากนี้ยังค้นพบแมลงแมงป่องในสกุล *Neopanorpa* 4 ชนิดใหม่ ได้แก่ ชนิด *N. appendicema* n. sp. เป็นชนิดที่มีขนาดค่อนข้างใหญ่ ส่วนกลางของ hypovalve มวนขด และ basomesal lobe ขนาดใหญ่ ชนิด *N. inchoata* n. sp. มี hypovalve รูปร่างยาวและวางซ้อนทับกัน แถบสีที่ปลายปีกไม่สมบูรณ์ ชนิด *N. setosiloba* n. sp. ในเพศผู้มี bristly lobes ขนาดใหญ่ที่ gonostyles และชนิด *N. mandangensis* n. sp. ด้านบนของทองป่องที่สามมี notal organ เรียวและยื่นยาวไปถึงส่วนท้ายของป่องที่สี่ แมลงแมงป่องชนิด *N. nielsenii* Byers, 1965 ถูกค้นพบเป็นครั้งแรกในประเทศไทยจากภาคเหนือ ซึ่งเคยมีรายงานจากภาคเหนือของประเทศไทยและทางตอนใต้ของประเทศไทย และได้มีการค้นพบชนิด *Bittacus leptocaudus* Byers, 1965 อีกครั้งจากที่เคยรายงานเพศผู้เพียงหนึ่งตัว มีการเพิ่มเติมข้อมูลของพื้นที่เก็บตัวอย่างและภาพถ่ายในธรรมชาติ การรายงานนี้ทำให้จำนวนชนิดของแมลงแมงป่องในประเทศไทยเพิ่มขึ้นเป็น 22 ชนิด ใน 3 สกุล ได้แก่ สกุล *Neopanorpa* จำนวน 19 ชนิด สกุล *Panorpa* จำนวน 2 ชนิด และสกุล *Bittacus* จำนวน 1 ชนิด และทำให้ในภูมิภาคอินโดจีน (Indochina) มีจำนวนชนิดเพิ่มขึ้นเป็น 56 ชนิด (สกุล *Neopanorpa* 48 ชนิด, *Panorpa* 3 ชนิด, *Bittacus* 4 ชนิด, และ *Bicaubittacus* 1 ชนิด) ทั้งนี้ยังได้จัดทำรูปพรรณและรูปภาพประกอบการระบุชนิดของแมลงแมงป่องในประเทศไทย ทำการวิเคราะห์ลำดับยีนของไมโทคอนเดรียในส่วนของ cytochrome oxidase I (COI) ของแมลงแมงป่องจำนวน 19 ชนิด จาก 22 ชนิดของประเทศไทย และรายงานผลโดยใช้ Neighbor Joining tree.

INTRODUCTION

Mecoptera are unique among insects of other orders for having a rostrum with mouthparts at the apex, and fore- and hind wings of similar size and venation. Only Bittacidae and Panorpidae of the 9 extant families of Mecoptera occur in Southeast Asia. Members of the family Panorpidae are commonly called scorpionflies because the males have characteristic recurved, bulbous abdominal terminalia resembling the stinger of scorpions. Scorpionflies are saprophagous, feeding on dead insects and other soft-bodied, small animals, but have also been observed feeding on pollen and fermenting berries (Bicha 2018; Bicha, et al. 2020). The adults are typically observed sitting on the upper surfaces of herbaceous vegetation growing in moist forest ecotone and are noted for their mating behavior, which may include males offering nuptial gifts of food (Thornhill & Alcock 1983). Members of the family Bittacidae are commonly known as hangingflies because the adults typically hang from undersides of vegetation in moist forest and are predaceous, capturing small insects with their raptorial hind tarsi.

Panorpidae was recently divided into two subfamilies, Neopanorpiniae and Panorpiniae (Wang & Hua 2021). Two genera of Neopanorpiniae (*Leptopanorpa* MacLachlan, 1875 and *Neopanorpa* Weele, 1909) and six genera of Panorpiniae (*Panorpa* Linnaeus, 1758, *Sinopanorpa* Cai & Hua in Cai, et al., 2008, *Furcatopanorpa* Ma & Hua, 2011, *Dicerapanorpa* Zhong & Hua, 2013, *Cerapanorpa* Gao, Ma, & Hua, 2016, and *Megapanorpa* Wang & Hua 2019) are currently recognized worldwide and all occur in Asia. Nearly all Southeast and South Asian scorpionflies are currently assigned to *Neopanorpa* with only two currently described species of *Panorpa* known from the region. Bittacidae has 18 currently recognized genera and approximately 218 species worldwide. Thailand has one described species of Bittacidae in the genus *Bittacus*, although *Bicaubittacus* Tan & Hua, 2009 is known from nearby Burma.

Panorpid larvae have cruciform larvae with compound eyes and bear long setae that tend to trap soil. They have similar biology with four instars of larvae dwelling in the soil and feeding on debris (Mampe & Neunzig 1965, Boese 1973). Both *Neopanorpa* and *Panorpa* larvae are euedaphic, inhabiting the soil most of their lifetime, however *Panorpa* larvae

were found to be nocturnal coming to the surface at night to feed, while only a comparatively small fraction of *Neopanorpa* were found to venture to the surface at night (Jiang, et al. 2019). We presume this behavior might be an adaptation to competition with ants, which dominate tropical regions. *Neopanorpa* adults may be active all months of the year in Thailand but appear to fly most abundantly in April, May, and September. In contrast, *Panorpa* are active in late October and into November in the mountains of northern Thailand. In Taiwan, where both *Neopanorpa* and *Panorpa* are active at the same time of year, *Neopanorpa* are typically found below 1200 m and *Panorpa* at elevations above 2000 m, where it is often cool, and vegetation moistened from morning mist. Panorpid pupae are decticous, exarate (Yie 1951, Boese 1973). Larvae of bittacids also dwell in the soil and are eruciform appearing similar to the larvae of panorpid with compound eyes and long setae (Setty 1940). Bittacids tend to live at much lower elevations than panorpids.

Neopanorpinæ typically have wings narrowed basally compared to the other panorpid genera and the 1A vein usually, but not exclusively, proximal to the origin of the radial sector (ORs) rather than distal in the case of the Panorpinæ genera. The male genitalia of *Neopanorpa* in Southeast Asia lack or have vestigial ventral parameres, while the Panorpinæ have well-developed ventral parameres, which are typically taxonomically diagnostic. Thus, other characters such as wing patterns or the shape of the male hypovalves or gonostyles must be used for *Neopanorpa* species determination.

We previously reported on the Mecoptera collected during Project Tiger, a collaborative effort involving Thai field researchers surveying the insect fauna in national parks throughout Thailand (Sharkey 2018), which provided a much better understanding of temporal and spatial species distribution (Bicha 2019). A remarkable find was the discovery of the genus *Panorpa* in Thailand when it has been assumed that the genus was restricted north of the Himalaya. We herein describe an additional species of *Panorpa* from northern Thailand later discovered among unsorted Project Tiger material as well as 4 additional *Neopanorpa*. We previously considered one of these species of *Neopanorpa* occurring in northwest Thailand to merely be a variant of

Neopanorpa panda Byers, 1965, when we reported its distribution in Thailand (Bicha 2019). Subsequent morphological and mitochondrial cytochrome oxidase I (COI) DNA comparison of a number of specimens of these two forms has since lead us to conclude that *Neopanorpa panda* is endemic to the Vietnam Central Highlands and adjacent Cambodia and a larger form without twisted hypovalves occurring in Vietnam, Cambodia, and Thailand to be an undescribed species.

We increase the number of described Mecoptera species in Thailand to two *Panorpa*, 19 *Neopanorpa*, and one *Bittacus* (Byers 1965, Webb & Penny 1979, Bicha 2010, 2019) and the number of Mecoptera species in Indochina to 56, which includes 3 *Panorpa*, 48 *Neopanorpa*, and 5 Bittacidae (Byers 1965, 1999; Willmann 1976; Bicha 2018, 2019). We provide an updated, illustrated key to the Mecoptera species of Thailand.

MATERIAL AND METHODS

The majority of the specimens from Project Tiger were collected by malaise traps or pan traps set up at a number of Thailand national parks, supplemented by hand netting. Bulk samples were sorted by local parataxonomists and distributed to taxonomic specialists for determination. Follow up collecting after the Project Tiger survey was conducted by baiting using raw squid followed by hand netting (Bicha, et al. 2020). Additional Project Tiger material, which was discovered at Chiang Mai University and in the QSBG collection, following our initial report (Bicha 2019) was examined.

Cytochrome Oxidase 1 DNA barcodes (Hebert et al. 2003) were generated using the protocols described in Schiff, et al. (2012) and Bicha, et al. (2017). Individual legs were collected from either pinned dried specimens or specimens stored in alcohol and their total genomic DNA extracted using the Biosearch Technologies, Epicentre line, MasterPure Complete DNA and RNA Purification Kit. DNA was amplified using one of three primer combinations: LCO1490 and HCO2198, Wes1 and HCO2198 and Wes1 and Nancy. LCO1490, 5'-GGT-CAA-CAA-ATC-ATA-AAG-ATA-AAG-ATA-TTG-G-3', HCO219 5'-TAA-ACT-TCA-GGG-TGA-CCA-AAA-AAT-CA-3' and Nancy 5'-CCC-GGT-AAA-

ATT-AAA-ATA-TAA-ACT-CT-3' are described in detail by Simon et al. (1994). Wes1, 5'-GGC-TTT-TCT-CTA-CTA-ATC-ATA-AGG-ATA-TTG-G-3', is a minor modification of LCO1490 of our own design first used for scorpionflies in Bicha et al. (2015). The amplified DNA was sequenced in both directions following the protocols in Schiff et al. (2012) and the sequences combined to form individual specimen contigs using Seqman Pro by DNASTar. Individual specimen contigs were aligned using Clustal W and a Neighbor-joining tree produced and K2P values calculated in Megalign also by DNASTar. Bootstrap values (1000 trials starting with a random seed of 111) for branches of the tree were also generated by Megalign. We generated two sets of trees and bootstrap values. The first tree includes all 134 sequences of Thai Mecoptera available to us but it is too large to fit on a single page, so we generated a more easily viewed tree using two representative sequences from each species. We present two sets of Bootstrap values for each branch, the first is the value using two representative sequences and the second in parentheses is the value for that branch based on the larger sample size. A Maximum likelihood tree was also computed using MEGA X (Kumar et al, 2018).

Photographs and measurements of wings, genitalia, and other features of each species for this paper were taken with a Keyence VHX7000 digital microscope system. Plates were prepared from photographs using GIMP image manipulation program (www.gimp.org). Descriptive nomenclature for wing venation and markings follows Esben-Petersen (1921); terminology for male genitalia used follows that of Issiki (1933).

RESULTS

Panorpa apscisacera Bicha & Suttiaprapan, new species

(Figs. 1–5)

urn:lsid:zoobank.org:act:8C133989-3EAB-41BD-84B5-154CBA759388

Diagnosis — Pale-yellow immaculate wings, blunt slightly bifid anal horn, thin, widely-separated hypovalves, and two-branched, long, thin, bare ventral parameres. Male of only other described Southeast Asian *Panorpa* (*P. auripennis* Bicha,

2019) has brown pterostigmal and basal bands on intensely orange wings and males have thick, bushy ventral parameres.

Description — One male preserved in ethanol. Body length approximately 10.1 mm; fore wing length 8.8 mm; hind wing length 8.2 mm,

Head yellowish orange including rostrum. Ocellar triangle black. Ocelli and eyes brown. Antennae with 41 flagellomeres; scape and pedicel yellowish orange, flagellomeres black.

Pronotum pale brown, anterior margin with approximately 10 black setae, posterior margin dark brown; mesonotum and metanotum pale brown with median sordid white stripe one-third tergum width anteriorly, narrowing to one-fourth width mid-length for remainder, clothed with fine light brown caudad setae, posterior margin dark brown, scutellum sordid white. Pleural areas, coxae, femora, tibiae, and tarsi sordid white; anterior of fore- and mesocoxae with apicad fine, black setae; femora and tibiae with numerous apicad shorter, fine, black setae; tibiae with few sparse, longer, black setae; tarsomeres brown, tarsal claws, dark brown, serrate.

Wings (Fig. 1) broad with rounded apices; membranes pale yellowish; veins ochre; distal two crossveins pale, basal crossveins ochre to brown. Pterostigma pronounced, yellow. Forewing with apical and pterostigmal bands reduced to a few small faint brown markings, and basal band represented by a small spot between CuP and 2A. Hind wing completely immaculate. R₂ in forewings with two branches. Thyridium and nygma present. Two to six rows of macrotrichia in center of cells distal to M₃₊₄. Posterior base of forewings with 4–6 stout setae and anterior base of hindwings with 2–3 stout setae. Two cross veins between 1A and 2A in forewings, and 1A terminating at wing posterior margin distal to origin of Rs (ORs).

Male terga 2–5 lateral margins pale brown with sordid white midline stripe and posterior margins; no obvious posterior median process of tergum 3, however posterior margin broadly curved caudad and setose (Fig. 2). Sterna 2–5 and pleural areas sordid white. Segments 6–8 yellowish brown; each segment comparatively short (Figs. 3 & 4). Segment 6 posterior margin bluntly truncate, with slightly bifid anal horn. Segment 7 length 60% of segment 6; with dorsal hump 50% of width at mid-length. Segment

8 elliptical; 75% length of segment 6. Genital bulb (Fig. 5) yellowish brown in its entirety. Epandrium (tergum 9) tapered toward apex; deeply emarginated, with two digitate lobes; clothed in fine, black apical setae; cerci yellowish-brown. Hypandrium (sternum 9) with no stalk, bearing two, narrow, widely separated sordid white hypoalves extending four-fifths distance to bases of gonostyles. Gonocoxites (basistyles) fused basal one-third length, elliptical with width four-fifths length, apical margins truncate. Gonocoxites, gonostyles, and epandrium covered with fine brown caudad hairs. Ventral and dorsal valves white dorsal valves approximately similar in size and shape as ventral valves; ventral parameres bifurcated with dorsal and ventral branches, both long, slender, lacking “barbs,” extending to base of gonostyles, acuminate. Gonostyles (dististyles) bearing large, rounded basomesal lobe; prominent median tooth; outer margins slightly concave with falcate, slightly darkened apices.

Female unknown.

Material examined — Holotype male, THAILAND, Chiang Mai, Doi Pha Hom Pok National Park, Kiewlom montane forest, 20°3.549'N, 99°8.552'E 2174 m elevation, 28 October–4 November 2007, leg. P. Wongchai, Project Tiger malaise trap sample T6782-1. Holotype resides in the Queen Sirikit Botanic Garden, Chiang Mai, Thailand (QSBG).

Etymology — The specific epithet, *apscisacera*, a combination of, *apscisa* (= blunt) and *cera* (= horn), refers to the blunt anal horn of this species.

Remarks — This species can be readily recognized in the field by the immaculate pale-yellow wings held roof-like over the abdomen, and under a microscope by the slightly bifid blunt anal horn, thin widely-separated hypoalves, and two-branched, long, thin, bare ventral parameres of the male.

Neopanorpa is the predominant scorpionfly genus throughout Southeast Asia, with 86 percent of the described species. In contrast, *P. apscisacera*, **n. sp.** is only the second species of *Panorpa* described from Thailand. The males of this remarkable species resemble seven members of the Chinese *guttata*-group, with a blunt anal horn on the caudodorsal margin of segment 6 and a hump on the dorsum of segment 7, especially *Panorpa substricta* Wang & Gong, 2021, whose anal horn is slightly bifid.

The unexpected presence of *Panorpa* in northern Thailand is presumed to be due to the cooler temperatures of the late season at the elevation that the two were collected.

***Neopanorpa appendicema* Bicha & Suttiprapan, new species**
(Figs. 6–13)

urn:lsid:zoobank.org:act:3D863131-92C3-427B-86D0-99134A438E7D

Diagnosis — Male hypoalve apices curl mesad nearly forming complete circles somewhat resembling hypoalve apices of *Neopanorpa malaisei* Byers, 1999, but differing in hypoalves possessing large, basomesal lobe on hypoalve basomesal margins, which *N. malaisei* lacks. Male genital bulb entirely ochre, that of *N. malaisei* is glossy black. Wing pterostigma pronounced, while that of *N. malaisei* faint.

Description — 15 males, 7 females initially preserved in ethanol, 4 males and one female subsequently pinned and spread. Male body length approximately 11.3 mm. Female body length approximately 11.6 mm. Male fore wing length 11.2 mm; hind wing length 10.2 mm. Female fore wing length 11.5 mm; hind wing length 10.7 mm.

Rostrum pale yellow with smoky longitudinal stripe. Frons pale yellow. Ocellar triangle and vertex black. Ocelli amber; eyes plum to gray. Antennae nearly as long as wings with 42 flagellomeres; scape, pedicel, and flagellomeres brown.

Pronotum black, lacking long, black setae on the anterior margin. Scutellum smoky. Meso- and metanotum pale yellow with lateral margins and medial one-third black with infusate margins. Dorsum clothed with sparse, short, black, caudad setae. Episterna and epimera white with sparse apical black setae. Coxae and femora pale yellow. Tibiae pale orange. Tarsi brownish orange. Tarsal claws serrate with dark brown teeth.

Wing membranes slightly smoky brown. Male wings (Fig. 6) immaculate except for conspicuous ochre pterostigma and faintly smoky apical and pterostigmal bands. Female wings (Fig. 7) more heavily marked with anterior half of apical band complete; anterior portion of pterostigmal band triangular, posterior apical branch complete with basal branch reduced to a spot in forewing, posterior

pterostigmal band absent in hindwing; basal band reduced to anterior and posterior spot. Veins brown. Cross veins light brown except colorless in apical band. R_2 bifurcate. Thyridium present. Nygma brown. Two or four rows of macrotrichia in center of cells distal to pterostigmal band. One cross vein between 1A and 2A in forewings, and 1A terminating at wing posterior margin proximal to ORs, typical of *Neopanorpa*.

Male abdomen with terga 2–5 black. Tergum 3 posterior process (notal organ) broadly triangular, extending one-half length of tergum 4, somewhat hook-shaped ventrad against tergum 4 (Figs. 8 & 9). Tergum 4 with raised setose peg at midpoint. Sterna 2–5 and pleura sordid white. Anterior half of segment 6 black; posterior half yellowish orange. Segments 7 and 8 yellowish orange and equal length as segment 6. Genital bulb (Fig. 10) yellowish orange. Epandrium apical margin truncate. Hypandrium base width two-thirds length, apex width one-fourth length, bearing two hypovalves. Hypovalves (Fig. 11) yellowish orange, extending to base of gonostyles becoming dark near apex, narrowing and curling basomesad nearly completing circle. Gap between hypovalves (vertex) circular. Hypovalves with large, basomesal ear-shaped appendage. Gonocoxites fused basal one-third of length, elliptical with width nearly equal to length, yellowish orange, apical margins truncate bearing 2–6 long, black setae. Hypandrium, gonostyles, and epandrium covered with fine black caudad hairs. Aedeagus white. Ventral parameres present, straight, bare, length one-fifth length of hypovalves. Gonostyles with large basomesal lobe bearing black basad setae on basal finger; with slight median tooth; falcate, long, slender, with outer margins nearly straight.

Female abdomen with terga 2–6 brownish black; sterna 2–5 sordid white; terga 7–9 light ochre; sterna 6–9 light ochre; cerci black. Subgenital plate of sternum 8 brown with long setae; tapered apically (Fig. 12). Genital plate with axial portion thick; apodeme darkened; arms spatulate, twisting to become vertical posteriorly, equal in length to axial portion (Fig. 13).

Material examined — Holotype male, allotype female, and 7 male, 1 female paratypes, THAILAND, Chiang Mai Province, Doi Inthanon National Park, Mae Aum, 18°30'32.9"N, 98°30'19.2"E, 1628 m

elevation, sweep net, 5 September 2019, *leg.* W. Srisuka. Additional paratypes: 2 males, 2 females, same area but 18°31'39.5"N, 98°29'59.7"E, 1639 m elevation, malaise trap 2–29 May 2014, sample 2014-130; 1 male, 1 female, same locality, 29 May–1 June 2014, malaise trap, sample 2014-158; 1 male, Doi Inthanon National Park, Checkpoint 2, 18°31.559'N, 98°29.941'E, 1700 m elevation, 15 July 2006, malaise trap, sample T67; 1 male, 2 females, same locality, 3 September 2019; 1 male, same locality, 4 September 2019; 1 male, same area, 18°31'39.5"N, 98°29'59.7"E, 1639 m elevation, 29 September– November 2014, malaise trap, sample 2014-274.

Holotype, allotype, and most paratypes reside in the QSBG collection, Chiang Mai. Additional paratypes deposited in Illinois Natural History Survey (INHS) collection, Champaign, Illinois.

Etymology — The specific epithet, *appendicema* (feminine), is derived from the Latin *appendicem*, meaning appendage and refers to the ear-like appendage on the basomesal margin of each male hypovalve.

Remarks — This insect may be differentiated in the field from other scorpionflies with which it coexists by its nearly immaculate (male) to faintly marked (female) wings and ochre genital bulb. The wings of all other *Neopanorpa* in northwest Thailand except *N. malaisei* have dark brown bands. *Neopanorpa malaisei* has a glossy black genital bulb. The male genitalia, wings, and body coloration of this species superficially resembles *N. zhengyucheni* Wang & Gong, 2021 from China but differs by males having a shorter notal organ on the third tergum, lobes on the basomesal margin of the hypovalves, and more pronounced mesal curl of the apices of the hypovalves. This species may also be related to *N. lifashengi* Hua & Chou, 1999 and *N. nigritis* Carpenter, 1938 of China.

***Neopanorpa inchoata* Bicha & Schiff, new species**
(Figs. 14–20)

urn:lsid:zoobank.org:act:761289FA-E5EE-41EE-9128-E9978E141A63

Diagnosis — Male with overlapping elliptical hypovalves, similar to *N. siamensis* Byers, 1965, *N. thai* Byers, 1965, *N. tuberosa* Byers, 1965, but

N. inchoata n. sp. is noticeably larger, and wings have incomplete apical bands. Other species of Thai scorpionflies with overlapping hypovalves have complete apical bands.

Description — 8 males, 16 females initially preserved in ethanol.

Body length approximately 18.7 mm male, 11.0 mm female. Male fore wing length 14.8 mm, hind wing length 13.3 mm. Female fore wing length 11.5 mm, hind wing length 11.2 mm.

Dorsum of head dark brown. Ocelli amber; eyes plum to grey. Rostrum yellowish-brown; labrum and mouthparts yellowish-brown except apex of maxillary palps dark brown. Antennae long, extending to stigma of forewing, with 42 flagellomeres; scape ochre, pedicel brown, flagellomeres brownish black.

Pronotum dark brown. Mesonotum anterior half dark brown, remainder sordid white to yellowish-brown with broad dark brown medial stripe including scutellum. Metanotum with broad dark brown median stripe including scutellum, lateral portions sordid white to yellowish-brown. Pleural areas sordid white. Coxae, femora, tibiae, and tarsi sordid white to light brown with numerous fine black apical setae; tibiae with few sparse, longer, black setae; tarsal claws serrate with five dark brown teeth.

Wing membranes (Fig. 14) hyaline except for anterior half of area between apical and pterostigmal bands slightly frosted (whitish); markings brown; most veins brown. R_2 in forewings with three or sometimes four branches. Posterior portion of apical bands posterior to R_5 or M_1 generally incomplete. Pterostigmal band forked posteriorly with basal branch generally always present, anterior branch sometimes incomplete or faint. Marginal spots present. Thyridium present. Nygma brown. Two or four rows of macrotrichia in center of cells distal to pterostigmal band. Basal bands thin, often interrupted to form two spots. No humeral spots. Wing markings somewhat reduced in hind wing. One cross vein between 1A and 2A in forewings, and 1A reaching wing posterior margin proximal to ORs. Posterior base of forewings and anterior base of hindwings with 2–3 stout setae.

Abdomen of male: Terga 2–5 dark brown; corresponding sterna pale yellowish orange; pleural areas sordid white; posterior process of tergum 3 (notal organ) broadly triangular, extending one-

third to one-half length of tergum 4, twice thickness anteriorly as posteriorly (Fig. 15), to fit slightly raised, setose ridge on tergum 4 (Fig. 16). Segment 6 cylindrical with slight diameter reduction caudally; brown anteriorly sometimes grading to ochre posteriorly. Segments 7–8 subconical, expanding from anterior to posterior, ochre, covered with fine, black, caudad hairs. Epandrium apical margin truncate; apex extended slightly beyond segment 10; cerci brown. Hypandrium base width nearly equal to length, apex width two-thirds base width, bearing two hypovalves. Hypovalves dark brown, elliptical, overlapping, extending one-third length beyond base of gonostyles obscuring genital bulb interior, densely covered with fine black hairs. Gap between hypovalves (vertex) circular (Fig. 17). Gonocoxites fused basal four fifths of length, elliptical with width three-fourths length, ochre, apical margins truncate. Hypandrium, gonostyles, and epandrium covered with fine yellowish-brown to black caudad hairs. Aedeagus elongate (Fig. 18); ventral valves conspicuous, long, extending to base of gonostyles; dorsal valves approximately similar in size and shape as ventral valves, darkened; ventral parameres vestigial; lateral parameres pronounced, blade-like; dorsal parameres vestigial. Outer margins of gonostyles straight to slightly convex, apices brownish black, bases ochre; basal lobe notched, often obscured under aedeagus and hypovalves.

Abdomen of female: Terga 2–6 brownish black; sterna 2–5 pale yellowish orange; terga 7–10 reddish-brown; sterna 6–10 reddish-brown; cerci black. Subgenital plate of sternum 8 dark brown, oval, deeply incised apically; lobes and lateral edges with long setae, remainder with shorter setae (Fig. 19). Genital plate with axial portion one-third length of arms; arms broad at base, flat (Fig. 20).

Material examined — Holotype male, allotype female, and 3 male, 4 female paratypes, THAILAND, Nan Province, Na Noi District, Khun Sathan Unit, 18°16'40.4"N, 100°30'19.0"E, 1346 m elevation, 13 November 2018, leg. W. Srisuka. Additional paratypes: THAILAND, Chaipayum Province, Pa Hin Ngam National Park, car park at Tung Dok Grajeaw, 15°38.438'N, 101°23.576'E, 780 m, 6–7 July 2006, 2 females, pan trap sample T324, leg. K. Sa-nog & B. Adnafai; Chiang Mai Province, 18.85660°N, 99.36531°E, 1,426 m, 11

males, 4 females, leg. W. Bicha & W. Srisuka; same locality, 2 November 2018, 2 males, 2 females, leg. W. Bicha & W. Srisuka; Phetchabun Province, Nam Nao National Park, forest check point, 16°43.695'N, 101°33.797'E, 921 m, 26–27 October 2006, 1 female, pan trap sample T1006, leg. N. Hongyothi; Same locality, 29–30 October 2006, 1 female, pan trap sample T1009; same locality, 21 November 2006, 1 male and 1 female, pan trap sample T1318; same locality, 22–23 November 2006, 1 male and 1 female, pan trap sample T1319; same locality, 23–24 November 2006, 2 females, pan trap sample T1320; same locality, 20–27 November 2006, 1 male, pan trap sample T1325; Phitsanulok Province, Thung Salaeng Luang National Park, dry evergreen forest, 16°50.277'N, 100°52.917'E, 486 m, 11–18 September 2006, 1 female, malaise trap sample T926, leg. P. Pranee.

Holotype, allotype, and the majority of the paratypes reside in the QSBG collection with additional paratypes in the CAS and INHS collections.

Etymology — The specific epithet, *inchoata* means incomplete and refers to the distinguishing incomplete posterior portion of the apical wing band of this insect.

Remarks — This insect may be differentiated in the field from other scorpionflies that it coexists by its slightly larger size, wider wings, and incomplete posterior portion of the wing's apical bands. Unlike Panorpinidae, where species can readily be determined by the shapes and configurations of male ventral parameres, many Southeast Asian *Neopanorpa*, such as this species, have vestigial ventral parameres hidden under large, oval overlapping hypovalves so that male genitalia generally are of little diagnostic value. Fortunately, the wing patterns of many *Neopanorpa* (Figs. 6, 7, 14, 21, 26, and 33–49) are generally diagnostic as they are in this species.

Neopanorpa gestroi Navás, 1929 has similar male genitalia, but boldly marked basal, pterostigmal, and (complete) apical bands on the wings and uniquely darkened meta- and mesosterna.

Previously, we considered this a variant of *Neopanorpa panda* Byers, 1965 and erroneously reported it as occurring in Vietnam, Cambodia, and Thailand (Bicha 2010, 2019; Bicha et al. 2015, 2017). However, analysis and comparison of COI DNA

gene fragments revealed that the smaller specimens with the twisted hypovalves and complete apical bands (the true *N. panda*) are shown to be unrelated on a COI Neighbor-Joining tree (Fig. 70) and differ by an average 10.3% K2P distance from the larger form with the simple, overlapping hypovalves and incomplete apical bands (*N. inchoata* **n. sp.**) (Fig. 14). The average intraspecific K2P distance within *N. inchoata* **n. sp.** is 1.8% for specimens from Thailand and 8.2% for specimens from Cambodia, Thailand, and Vietnam contrasted with 2.8% intraspecific K2P distance within all species of Thai Panorpididae. It is possible that each of these three countries populations, may in time with further collecting and study, be proved to be unique species. *Neopanorpa pulchra* Carpenter, 1945 appears to be a somewhat similar-appearing Chinese species but has a COI DNA average interspecific K2P distance from *N. inchoata* **n. sp.** of 10.7%, is geographically isolated from *N. inchoata* by the Himalaya, and we consider it to be a unique, but possibly related species.

Neopanorpa inchoata **n. sp.** appears to be one of the most widespread species in mountainous areas throughout Southeast Asia, being found in the Vietnam Central Highlands and adjacent Cambodia to northwest Thailand. In northwest Thailand it was found to coexist in the spring and early autumn with *N. arcuata* Bicha, 2019, *N. byersi* Webb & Penny, 1979, *N. siamensis* Byers, 1965, *N. spatulata* Byers, 1965, and *P. auripennis* Bicha, 2019 on the upper surfaces of ground vegetation along forested trails. In the Vietnam Central Highlands, it was found to coexist with *N. cucullata* Bicha, 2017, and *N. dorsalis* Byers, 1965.

Neopanorpa setosiloba Bicha & Suttiaprapan new species

(Figs. 21–24)

urn:lsid:zoobank.org:act:EEBE3CAA-6BD0-4753-920D-5E5671334EB8

Diagnosis — Male gonostyle basomesal margins of this species possess large, bristly lobes, which other Thai *Neopanorpa* lack. Wing membranes slightly smoky brown, nearly immaculate except for conspicuous ochre pterostigma and faint apical and pterostigmal bands.

Description — Two males pinned and spread from ethanol. Male body length approximately 9.4 mm; fore wing length 12.0 mm; hind wing length 10.9 mm.

Rostrum pale brown. Frons blackish brown. Ocellar triangle and vertex blackish brown. Ocelli amber; eyes plum to grey. Antennae nearly as long as wings with 42 flagellomeres; scape pale yellow, pedicel and flagellomeres black.

Pronotum black, short black setae on the anterior margin. Scutellum blackish brown. Meso- and metanotum pale yellow with medial one-third blackish brown with infusate margins. Episterna and epimera white with sparse apical brown setae. Coxae and femora pale yellow. Tibiae pale orange. Tarsi brown. Tarsal claws serrate with dark brown teeth.

Wing membranes slightly smoky brown. Wings (Fig. 21) nearly immaculate except for conspicuous ochre pterostigma in fore and hind wings, and faint apical band and nearly indiscernible pterostigmal band in fore wings. Veins brown. Cross veins light brown except colorless between M_1 and M_2 and M_2 and M_3 . R_2 bifurcate. Thyridium present. Nygma brown. One cross vein between 1A and 2A in forewings, and 1A terminating at wing posterior margin proximal to ORs, typical of *Neopanorpa*.

Male terga 2–5 blackish brown. Tergum 3 (Fig. 22) posterior broadly triangular at base, graduating to rod-like caudally, extending one-third length of tergum 4. Tergum 4 (Fig. 23) with raised setose hook-like peg at mid point. Sterna 2–5 and pleura light brown. Segment 6 blackish brown. Segments 7 and 8 yellowish orange and equal length as segment 6. Genital bulb (Fig. 24) pilose, brown basally, blackish brown apically. Epandrium apical margin truncate. Hypandrium length slightly longer than base width, bearing two widely separated hypovalves. Hypovalves ochre, extending approximately halfway to base of gonostyles, narrowing and bending mesally. Gonocoxites fused basal one-third length, elliptical with width equal to length, ochre, apical margins truncate. Hypandrium, gonostyles, and epandrium covered with fine black caudad hairs. Aedeagus (Fig. 25) white basally, dorsal parameres blade-like, apically rounded, extending to base of gonostyles. Gonostyles blackish brown, falcate, long, and slender, with outer margins slightly

concave. Gonostyle bases with large bristly mesal lobes bearing long, black basad setae.

Type material examined — Holotype male, THAILAND, Chiang Mai Province, Ban Lek Nai Pa-yai village, 20.0752°N, 99.18196°E, 1559 m, 28 April 2022, leg. Srisuka. One paratype male, same locality, 6 October 2019, CBHR DNA sample #7779, leg. Srisuka & Bicha. Holotype in the QSBG collection.

Etymology — The specific epithet, *setosiloba*, a combination of, *setose* (= bristly) and *loba* (= lobe), refers to the bristly lobes on the basomesal margin of the male gonostyles of this species.

Remarks — This insect superficially resembles *Neopanorpa malaisei*, with the dark brown body and nearly immaculate wings, but the male genitalia details are significantly different.

***Neopanorpa mandangensis* Bicha & Schiff,
new species**
(Figs. 26–30)

urn:lsid:zoobank.org:act:35364472-1A3F-4770-9A07-5427258438C2

Diagnosis — Male hypovalve apices of this species curve mesad as those of *Neopanorpa arcuata* Bicha, 2019 however, notal organ of tergum 3 is narrow and extends to posterior margin of tergum 4, while the notal organ of *N. arcuata* is broad and short.

Description — 1 male pinned and spread from ethanol. Body length approximately 17.0 mm; fore wing length 12.3 mm; hind wing length 11.3 mm.

Rostrum light brown. Frons black. Ocellar triangle and vertex black. Ocelli amber; eyes plum to gray. Antennae nearly as long as wings with 44 flagellomeres; scape pale yellow, pedicel and flagellomeres black.

Pronotum black, short black setae on the anterior margin. Scutellum brown. Meso- and metanotum sordid white with brown inverted triangular area with infusate margins. Episterna, epimera, coxae, femora, and tibiae white with sparse apical brown setae. Tarsi brown. Tarsal claws serrate with dark brown teeth.

Wing membranes slightly smoky brown, markings brown (Fig. 26). Wings with apical band complete posteriorly to R_5 . Anterior portion of

pterostigmal band wide, triangular, proximal branch of posterior portion thin, distal branch reduced to spot in fore wing and absent in hind wing. Basal band reduced to two faint spots in fore wings and absent in hind wings. Marginal spot present in fore wings and absent in hind wings. Veins brown. Cross veins light brown. R_2 bifurcate. Thyridium present. Nygma brown. One cross vein between 1A and 2A in fore wings, and 1A terminating at wing posterior margin proximal to ORs, typical of *Neopanorpa*.

Male terga 2–5 brown. Tergum 3 (Fig. 27) posterior process (notal organ) broadly triangular at base, immediately narrowing to long rod-like appendage extending to tergum 4 posterior margin. Tergum 4 (Fig. 28) with anterior-leaning raised setose hook-like peg at midpoint. Sterna 2–5 and pleura sordid white. Segment 6 anterior two-thirds brown, posterior one-third ochre. Segment 7 ochre and equal in length as segment 6, narrow anteriorly, wider posteriorly. Genital bulb (Fig. 29) ochre. Epandrium apical margin truncate. Hypandrium length slightly longer than base width, bearing two hypovalves. Hypovalves ochre, extending to base of gonostyles, apices covered with fine setae bending mesally (Fig. 30). Gonocoxites fused basal one-half length, elliptical with width equal to length, ochre, apical margins truncate. Hypandrium, gonostyles, and epandrium covered with fine black caudad setae. Aedeagus (Fig. 30) white basally, dorsal parameres blade-like, extending to base of gonostyles, brown. Gonostyles ochre with basal cups, slight medial tooth; falcate, long, slender, with outer margins slightly concave.

Female unknown.

Type material examined — Holotype male, THAILAND, Phitsanulok Province, Phu Hin Rong Kla National Park, Man Dang, 18°30'32.0"N, 98°30'19.2"E, 1628 m, 18 June 2019, light trap sample PL1, CBHR DNA sample #8065, *leg.* Srisuka. Holotype in the QSBG collection.

Etymology — The specific epithet, *mandangensis*, refers to the specific location within Phu Hin Rong Kla National Park where this specimen was collected.

Remarks — The species is very similar to *N. arcuata*, from which it can be differentiated by its long, narrow tergum 3 notal organ that extends to posterior margin of tergum 4, vs the short, broad notal organ of *N. arcuata*. This lone specimen

was initially recognized as being different from *N. arcuata* and other Thai species by having an average COI interspecific K2P distance from *N. arcuata* of 13.1% and all Thai species of 14.1%. Interestingly, while the male genital details of this species are most similar to *N. arcuata*, the notal organ of this insect is most similar to *N. byersi* from which this species has an average interspecific K2P distance of 10.9%.

DNA Barcode Results and Discussion

We assembled DNA barcodes for 134 Mecoptera including 123 new sequences from Thailand representing 19 of the 22 Thai species and 11 sequences from China, Vietnam, Cambodia, and the United States that were either new or available from Genbank (see Fig. 70). The sequences were aligned using Clustal W and a neighbor-joining tree was generated using Megalign. The tree divided the specimens into 25 species clusters including 6 branches that consisted of a single specimen and 19 branches that included multiple representatives of an individual species. Three of the singletons represented the uncommonly collected species *N. apscisacera*, *N. mandangensis* and *Merope tuber* Newman, 1838 and were only represented by single specimens. The other 3 singleton branches were two specimens of *N. arcuata* and one specimen of *N. malaisei*. These latter species are well represented in the data set with 21 and 7 specimens respectively and the three specimens should have clustered with their congeners but didn't. Typically, when a specimen forms a unique branch on a tree, the specimen is investigated morphologically as a potential new species. We inspected these specimens but were unable to separate them morphologically from their congeners. Specimens that do not assign to their morphological species are well known from large barcode datasets and are considered dead ends (Hajibabaei et al 2006, Schmidt et al 2017). The three specimens here represent only 2.2 % of the data set and have been eliminated from further analysis.

Eight further specimens were "misplaced" in the barcode analysis. Four specimens of *N. spatulata* were placed in the *N. siamensis* cluster, two specimens of *N. siamensis* were placed in the *N. spatulata* cluster, one specimen of *N. malaisei* was placed in the *N. appendicema* cluster and the sole Thai representative

of *N. harmandi* was placed in the *N. spatulata* cluster. It is possible that these represent mistakes made in the laboratory, but the specimens were re-extracted and re-sequenced with the same results. As the sequences were not random but fit nicely into different species clusters, and mitochondrial DNA is maternally inherited in insects and not rearranged by crossing over, we suggest these misplaced individuals may represent old hybridization events. Species with individuals that belong to different barcode clusters is also well known (Hajibabaei et al 2006, Schmidt et al 2017). The clustering of the single Thai specimen of *N. harmandi* with *N. spatulata* suggests that we did not have the *N. harmandi* barcode from Thailand. We did have *N. harmandi* specimens from Cambodia and since they were morphologically identical to the Thai specimen we suspect the Cambodian barcodes are the true *N. harmandi* barcodes and that the sole Thai specimen was the result of a hybridization event between *N. harmandi* and *N. spatulata*. In contrast, even though the sole Thai specimen of *N. nielsenii* did not cluster with another species, we included two available sequences of Vietnamese *N. nielsenii* in the analysis and found that all three sequences clustered together such that we believe the Thai *N. nielsenii* barcode is legitimate.

The 131 specimens remaining after the 3 dead end singletons were removed were further analyzed by Maximum Likelihood using MEGA X (Kumar et al., 2018). The results were not phylogenetically informative at the generic level, the 2 species of *Panorpa*, *P. auripennis* and *P. apscisacera* were not on the same branch and the *Neopanorpa* species formed a comb, but they did cluster specimens into 22 species groups supported with high bootstrap values. As the resulting tree was too large for a journal page, we selected 2 individuals representing the diversity of the species and generated a representative neighbor-joining tree (Fig. 70). The tree lists significant bootstrap values for the representative tree followed by values in parentheses for the same branches from the full tree. The tree is rooted with *M. tuber* which is an archaic family of the Mecoptera (Byers 1973). We further generated a Kimura 2 parameter (K2P) distance table using Megalign on the abbreviated data set (data not shown) that allowed us to calculate average distances between species clusters based on DNA sequence data. *Merope tuber* was clearly the

most distant taxon with 17.7% distance between it and *N. arcuata*. Most of the other species were approximately 10–12% different from each other, for example distances between *N. nielsenii* and *N. infusca* 11.3%, *N. appendicema* and *N. arcuata* 12% and *N. panda* to *N. apscisacera* 10.85%. This applied to the genera *Panorpa* and *Bittacus* as well, *B. leptocaudus* to *N. arcuata* 12.45% and *B. leptocaudus* to *P. auripennis* 11.98%. The most closely related taxa were *N. siamensis* and *N. tuberosa* at 5.76% and *N. spatulata* to *N. harmandi* at 6.85%. These distances combined with the high bootstrap values support 22 separate taxa.

DNA Barcodes did not definitively identify individual specimens to species because they could not differentiate between the species itself and putative hybrids, but they did sort 131 out of 134 specimens into barcode clusters that represent individual species including hybrids. Barcodes were particularly useful identifying instances of cryptic diversity in this study. First, we did not initially recognize *N. inchoata* as a new species because it is similar in appearance to *N. panda* from Vietnam, but disparate barcodes forced us to examine the specimens more closely and we discovered that the hypovalves were twisted and the wing apical bands were complete in *N. panda* but not the case in *N. inchoata*. Second, based on their nearly identical genitalia we considered *N. mandangensis* to be just another specimen of *N. arcuata* but further examination prompted by a significantly different barcode revealed a much longer process on the third tergum in *N. mandangensis*. Finally, large barcode differences assure us that *N. pulchra* from China is not the same as *N. inchoata* or *N. panda* although this difficult complex would benefit from more extensive sampling and study. The results of this study support the use of morphology and barcodes to uncover new Mecoptera diversity in Southeast Asia.

***Bittacus leptocaudus* Field Observations**

Nothing has been reported about Thailand's one described hangingfly, *Bittacus leptocaudus* Byers, 1965, beyond the original description. Recently, the insect was observed in a dipterocarp forest with 1 m tall grass while hanging from the undersides of vegetation (Fig. 71) southeast of Lamphun,

18°32'14"N, 99°7'26"E, 430 m elevation, 29 October 2020, with one male and three females collected by Theerapan Dokjan. The females have darkened wing membranes and a distinct pterostigma (Fig. 33), compared to the holotype male which had pale, unmarked wings.

Key to Thai Species of Mecoptera

1. Tarsi with one claw (Figs.31). Wings as Fig. 33. Male terminalia as Figs. 50 & 51 (Bittacidae). *Bittacus leptocaudus* Byers, 1965. — Tarsi with two claws (Fig. 32) (Panorpidae) . . 2
2. Wings with 1A vein terminating at wing margin distal to ORs (Fig. 1); wings comparatively wide at base (*Panorpa*) 3 — Wings with 1A vein terminating at wing margin basal to ORs (Fig. 14); wings comparatively narrow at base (*Neopanorpa*) 4
3. Wings golden with thin, brown bands (Fig. 34). Male genital bulb as Fig. 52 *Panorpa auripennis* Bicha, 2019. — Wings pale yellow, nearly immaculate (Fig. 1). Male genital bulb as Fig. 5 *Panorpa apscisacera* **n. sp.**
4. Wings with wide black bands (Fig. 39). Male genital bulb as Fig. 57. Common species in disturbed areas *Neopanorpa harmandi* (Navás, 1908). — Wings with thin brown to dark brown markings or no markings 5
5. Male hypovalve apices curled (Figs. 11 & 60) 6 — Male hypovalve apices not curled (Fig. 17) . . 7
6. Male gonostyle bases bearing large, black, setose, ventromesal lobes (Fig. 24) *Neopanorpa setosiloba* **n.sp.** — Male gonostyles basomesal lobes digitate or small. 7
7. Male hypovalves lacking basomesal appendages (Fig. 60). Wings as Fig. 42; 7th and 8th segments white *Neopanorpa malaisei* Byers, 1999. — Male hypovalves with basomesal appendages (Fig. 11); 7th and 8th segments yellowish brown *Neopanorpa appendicema* **n. sp.**
8. Male 3rd tergum with elongated rod-like process (notal organ) extending to at least the 6th abdominal segment (Fig. 68). Wings as Fig.44. Male genital bulb as Fig. 62 *Neopanorpa normpennyi* Bicha, 2019. — Male 3rd tergum process not extending to 6th abdominal segment (Fig. 28). 9
9. Male 3rd tergum process slender, extending more than halfway across 4th tergum Fig. 28) 10 — Male 3rd tergum process wide, not extending more than halfway across 4th tergum (Fig. 15) 12
10. Relatively large species; male hypovalves overlapping (Fig. 61). Wings as Fig. 43. *Neopanorpa nielsenii* Byers, 1965. — Relatively small species; male hypovalves not overlapping (Figs. 29 & 55). 11
11. Male hypovalves apices darkened and conspicuously extending ventrally out of genital bulb (Fig. 55). Wings as Fig. 37 *Neopanorpa byersi* Webb & Penny, 1979. — Male hypovalves gently curving mesad (Fig. 30). Wings as Fig 26. *Neopanorpa mandangensis* **n. sp.**
12. Male hypovalves not overlapping (Figs. 53, 56, & 59) 13 — Male hypovalves overlapping (Fig. 17). 16
13. Male hypovalves widely separated; base between hypovalves subquadrate (Fig. 59). Wings as Fig. 41 *Neopanorpa latiseaparata* Bicha, 2010. — Male hypovalves slightly separated; base between hypovalves (vertex) circular. 14
14. Male hypovalves slender with acuminate apices (Fig. 56). Wings as Fig. 38 *Neopanorpa cuspidata* Byers, 1965. — Male hypovalves apices not acuminate (Fig. 17) 15

15. Male hypovalves base wide, mesal margins deeply emarginated near mid-length, apices twisted together and drawn to a point (Fig. 53). Wings as Fig. 35. Southern Thai species
.....*Neopanorpa angustipennis* (Westwood, 1841).
 - Male hypovalves apices laterally compressed and arched mesad (Fig. 54). Wings as Fig. 36. Northern Thai species
.....*Neopanorpa arcuata* Bicha, 2019.
 16. Male hypovalves short and wide, shield-like (Figs. 63 & 65). Wings with the basal band extending distally along the posterior margin (Fig. 45 & 47)..... 17
 - Male hypovalves long and narrow (Fig. 64). Wings with basal band not extending distally along posterior wing margin (Fig. 46)..... 18
 17. Male gonostyles with basomesal lobe divided into upper cup-like portion and large pendulous lower appendage (Fig. 63). Wings as Fig. 45 ..
.....*Neopanorpa pendulifera* Byers, 1965.
 - Male gonostyles with a basomesal lobe lacking large pendulous appendage (Fig. 65). Wings as Fig. 47 ... *Neopanorpa spatulata* Byers, 1965.
 18. Wings smoky brown without distinct bands, with long, dark brown stigma and circular pale area behind stigma (Fig. 40). Male genital bulb as Fig. 58.....
.....*Neopanorpa infuscata* Banks, 1931.
 - Wings with distinct bands (Fig. 14)..... 19
 19. Male gonostyles basomesal lobes spherical, knob-like (Figs. 67 & 69). Wings as Fig. 49. Southeastern species
.....*Neopanorpa tuberosa* Byers, 1965.
 - Male gonostyles basomesal lobes not knob-like (Fig. 18) 20
 20. Males gonostyles basally thickened with outer margins slightly convex bearing dense setae (Fig. 66). Wings as Fig. 48
.....*Neopanorpa thai* Byers, 1965.
 - Male gonostyles not basally thickened and outer margins straight and without long, dense setae (Fig. 17) 21
 21. Slightly larger species with male tergum 3 process (notal organ) length equal with width (Fig. 15); posterior one-third of apical band of wings often incomplete (Fig. 14). Male genital bulb as Fig. 17*Neopanorpa inchoata* n. sp.
 - Slightly smaller species with male tergum 3 process (notal organ) narrow (acute triangular). Wings apical bands entire (Fig. 46). Male genital bulb as Fig. 64.....
.....*Neopanorpa siamensis* Byers, 1965.
- กฎเกณฑ์ในการจัดจำแนกชนิดแมลงแมงป่อง (ตัวผู้) ในประเทศไทย
1. Tarsi มีเล็บ (claw) 1 อัน (ภาพที่ 31) ปีกมีลักษณะตามภาพที่ 33 อวัยวะสืบพันธุ์ (terminalia) มีลักษณะตามภาพที่ 50 และ 51 (วงศ์ Bittacidae)
.....*Bittacus leptocaudus* Byers, 1965.
 - Tarsi มีเล็บ (claw) 2 อัน (ภาพที่ 32) (วงศ์ Panorpidae) 2
 2. ปลายของเส้นปีก 1A เชื่อมติดกับขอบปีกในตำแหน่งหลังจุด ORs (ภาพที่ 1) โคนปีกกว้าง (สกุล *Panorpa*) 3
 - ปลายของเส้นปีก 1A เชื่อมติดกับขอบปีกในตำแหน่งก่อนจุด ORs (ภาพที่ 14) โคนปีกแคบ (สกุล *Neopanorpa*) 4
 3. ปีกสีเหลืองทอง มีแถบสีน้ำตาลแคบ (ภาพที่ 34) Genital bulb มีลักษณะตามภาพที่ 52.....
.....*Panorpa curipennis* Bicha, 2019.
 - ปีกมีสีเหลืองอ่อนเกือบทั่วทั้งปีก (ภาพที่ 1) Genital bulb มีลักษณะตามภาพที่ 5
.....*Panorpa apscisacera* n. sp.
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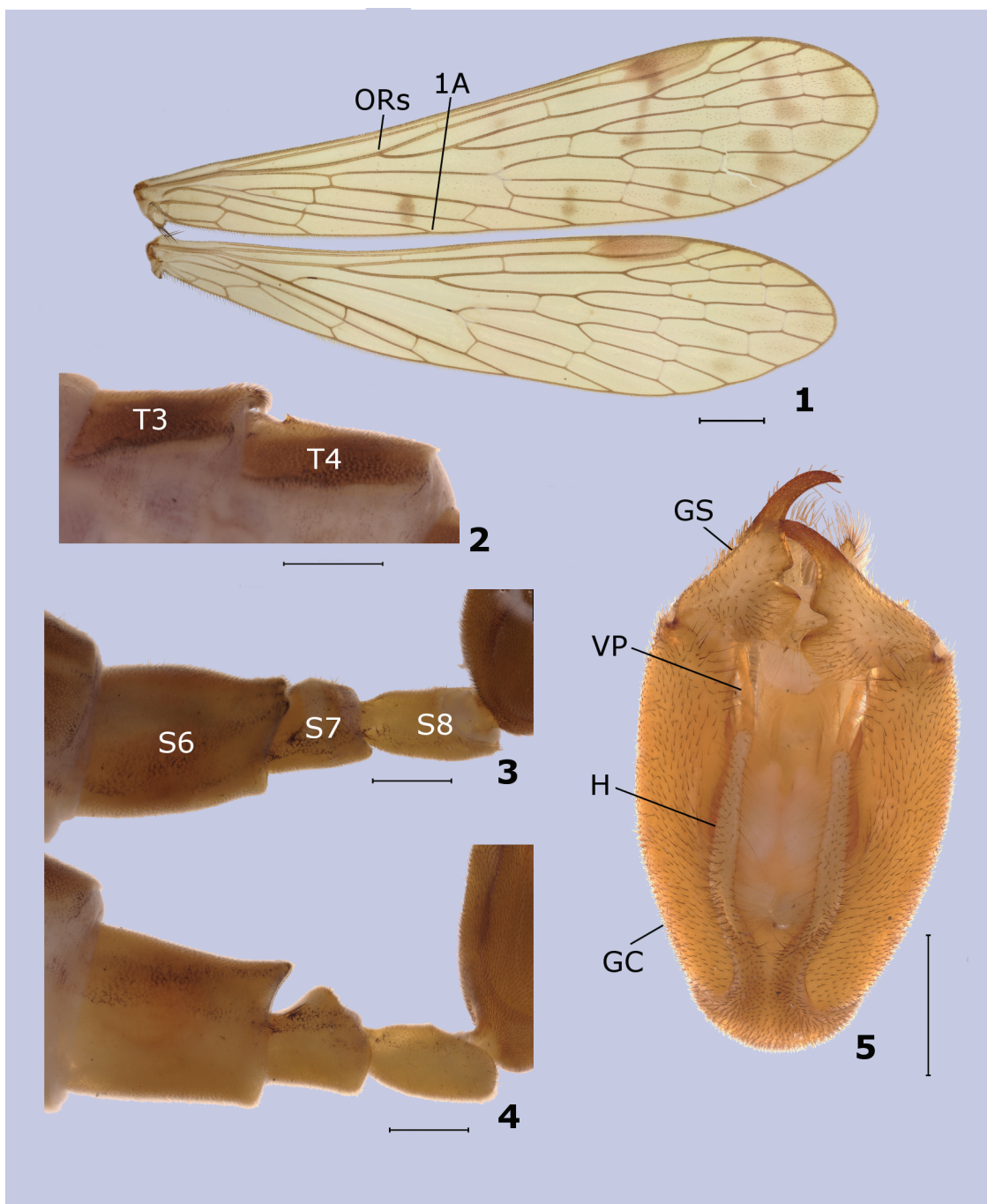
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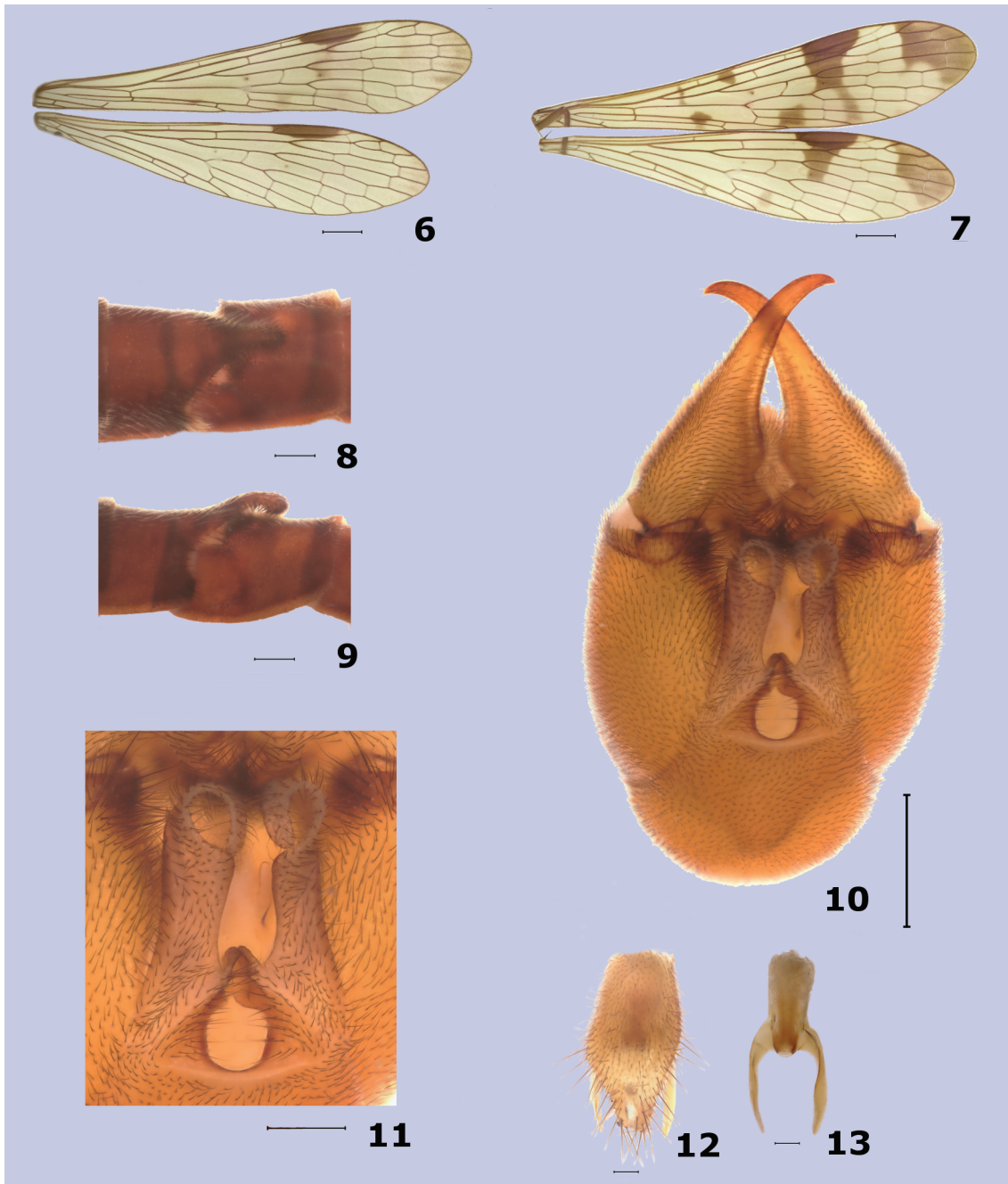
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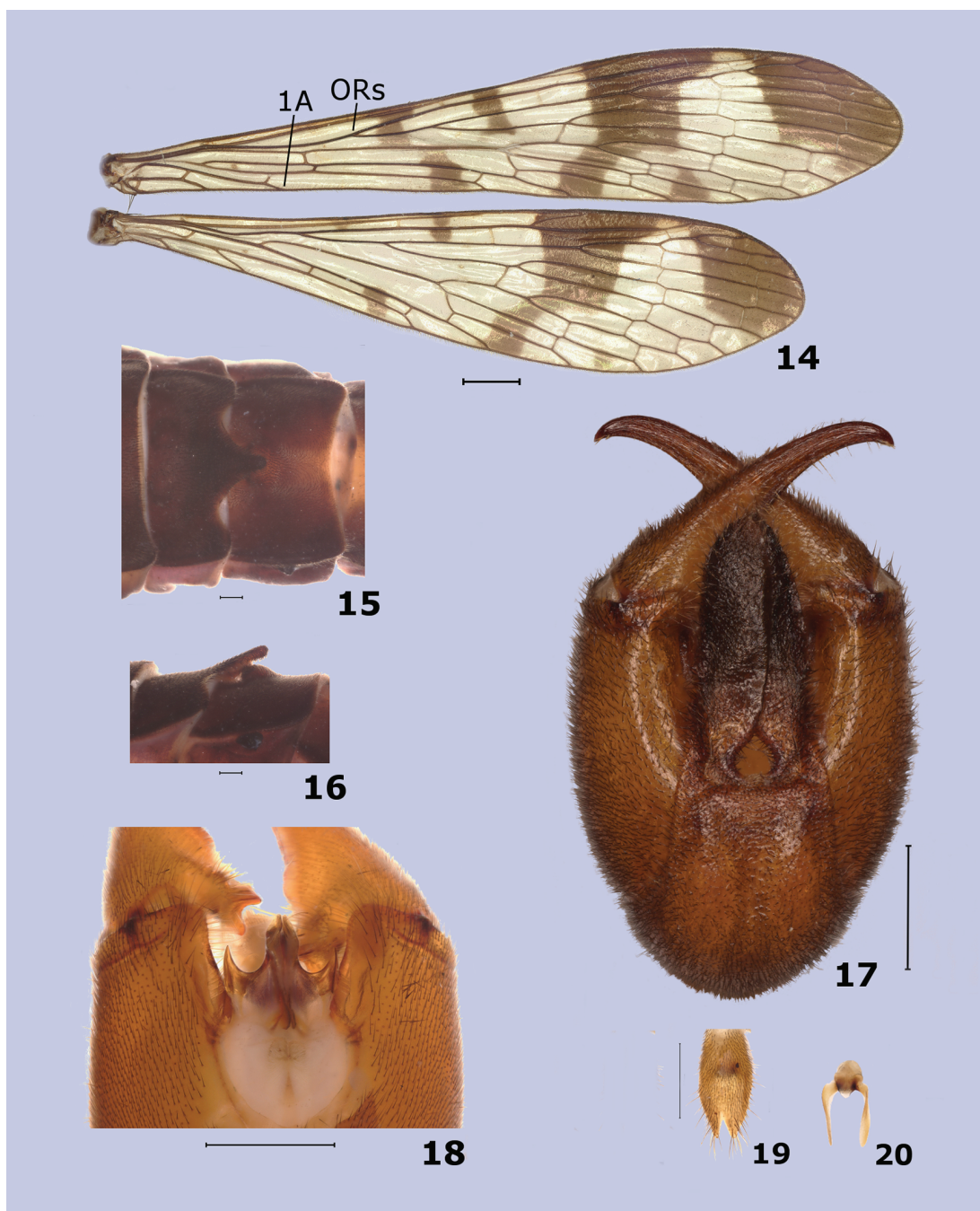
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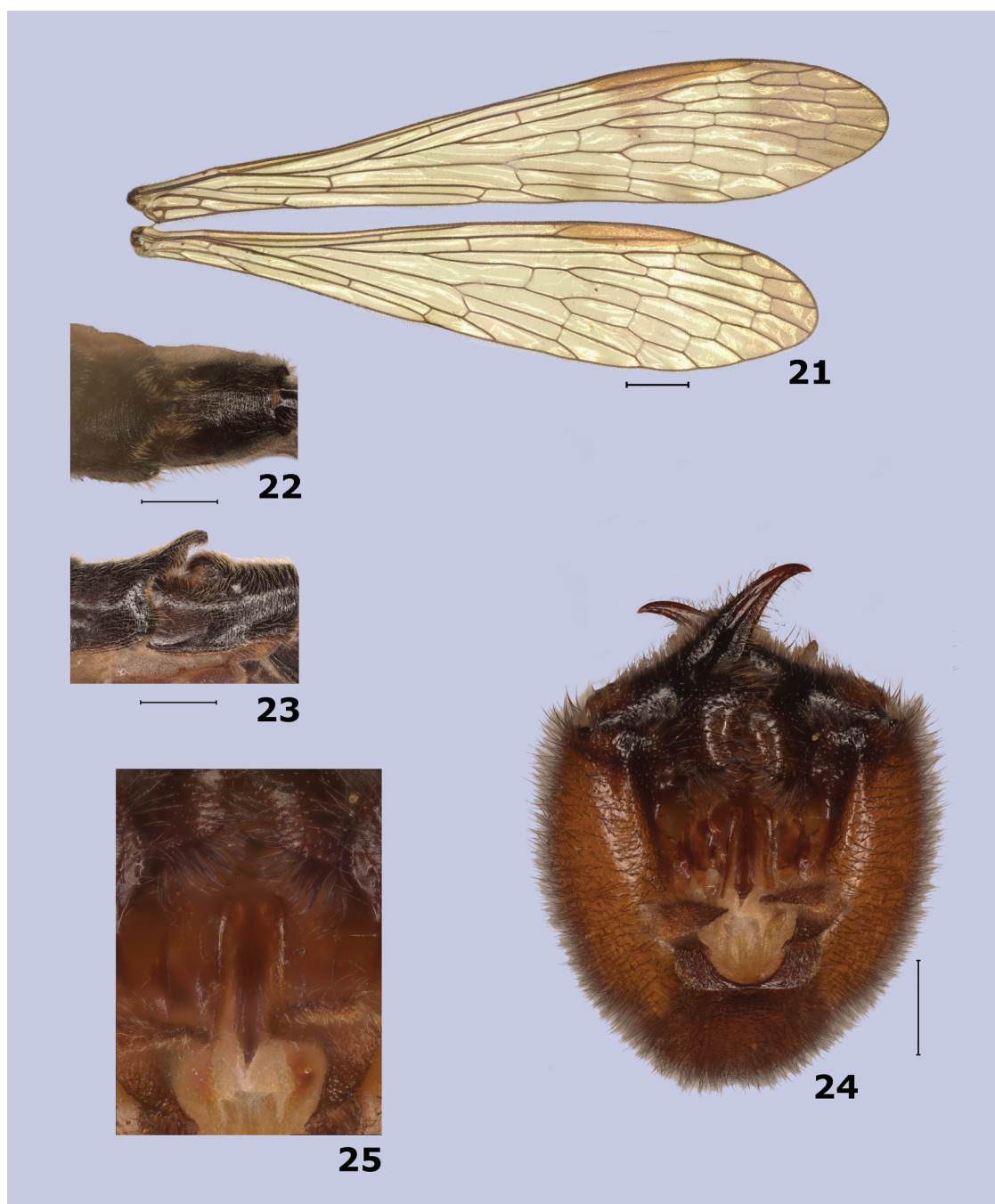
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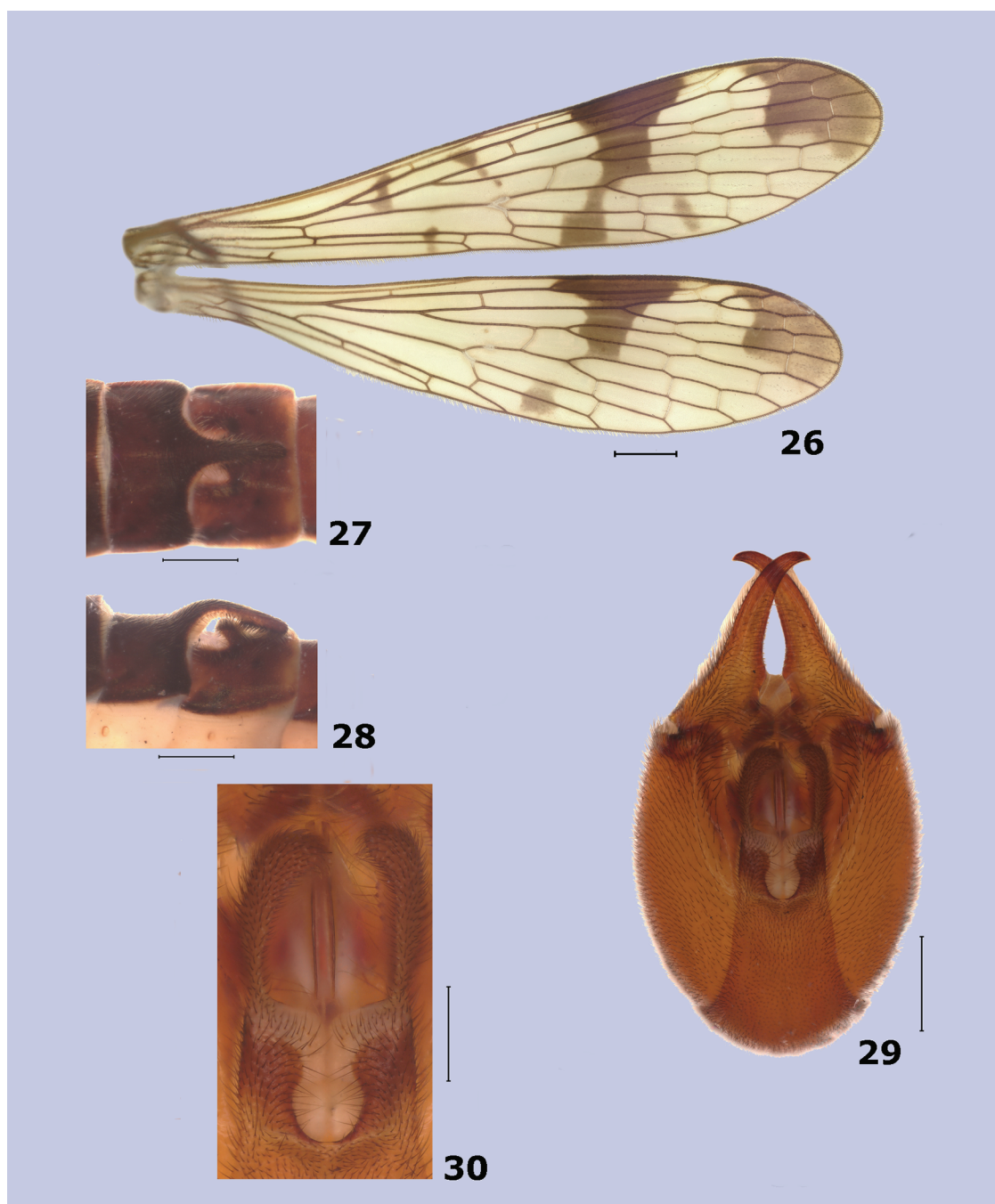
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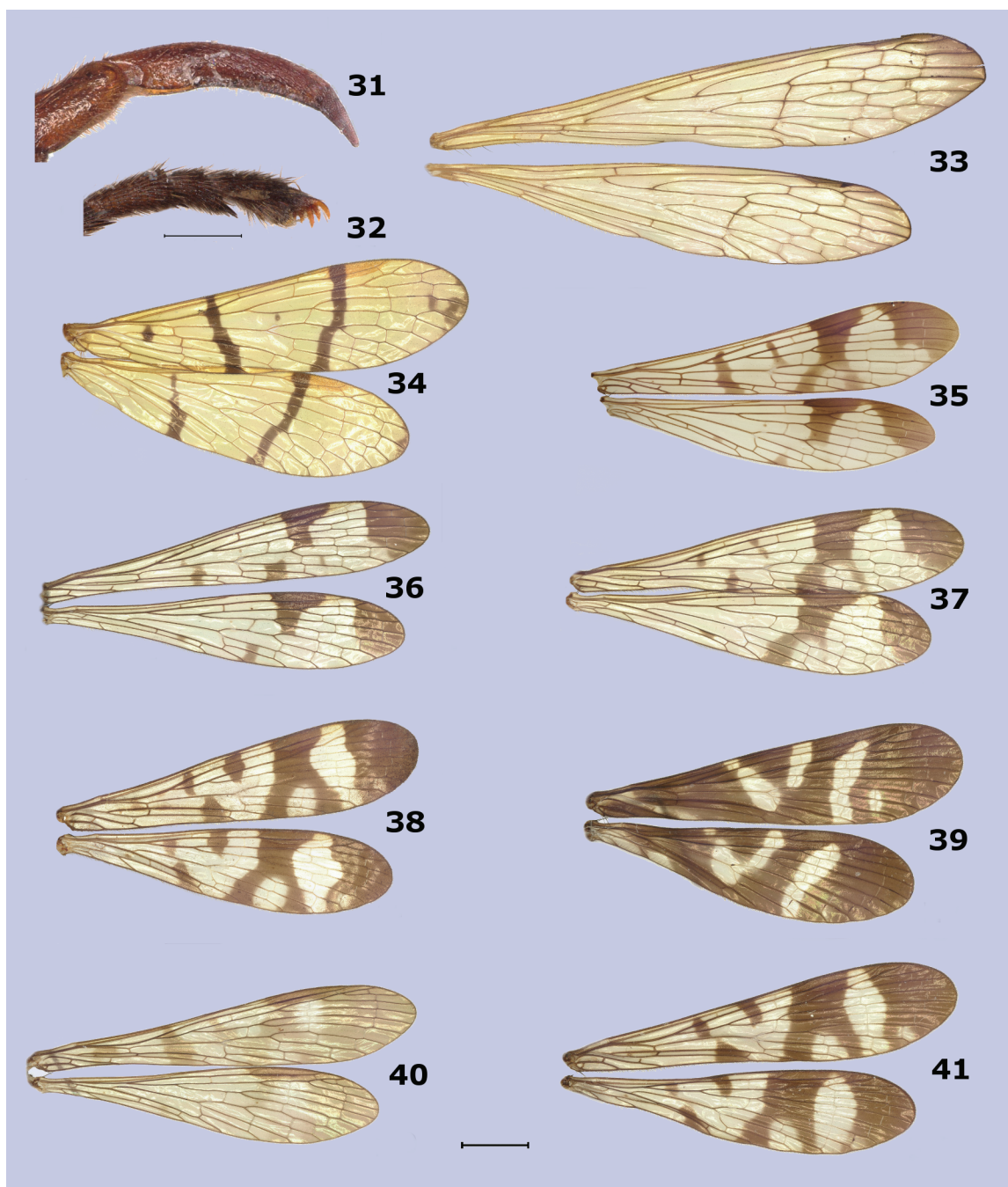
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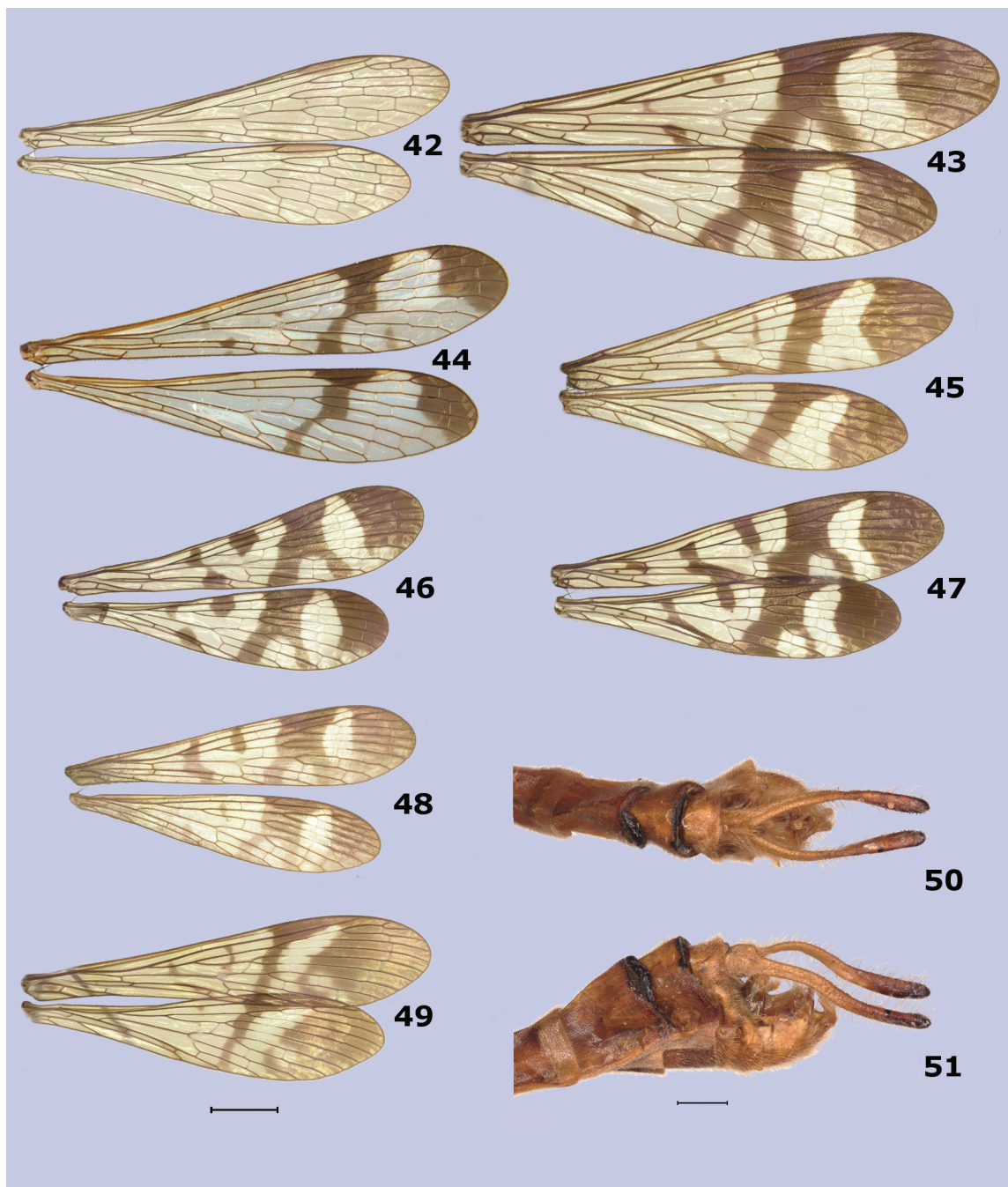
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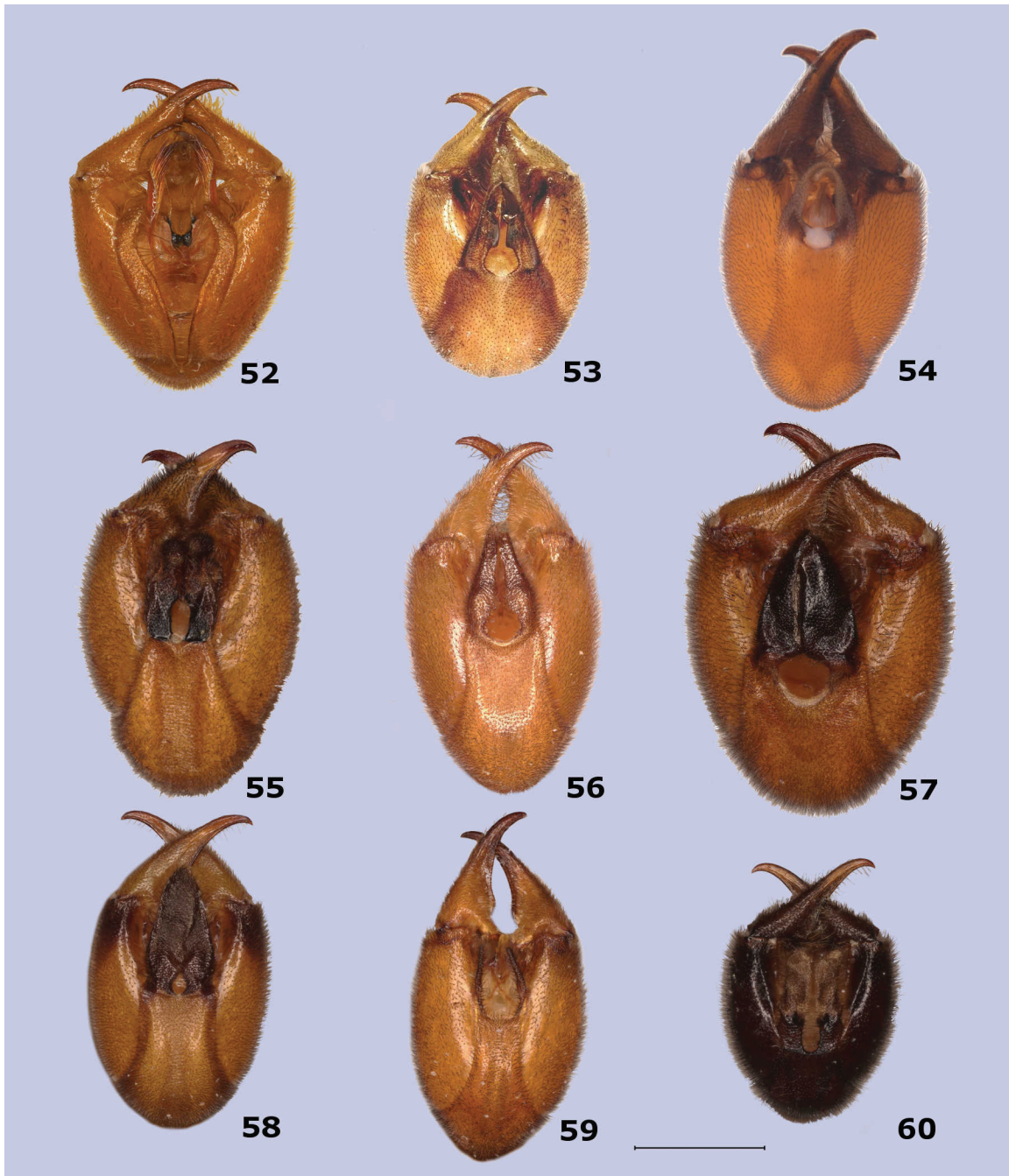
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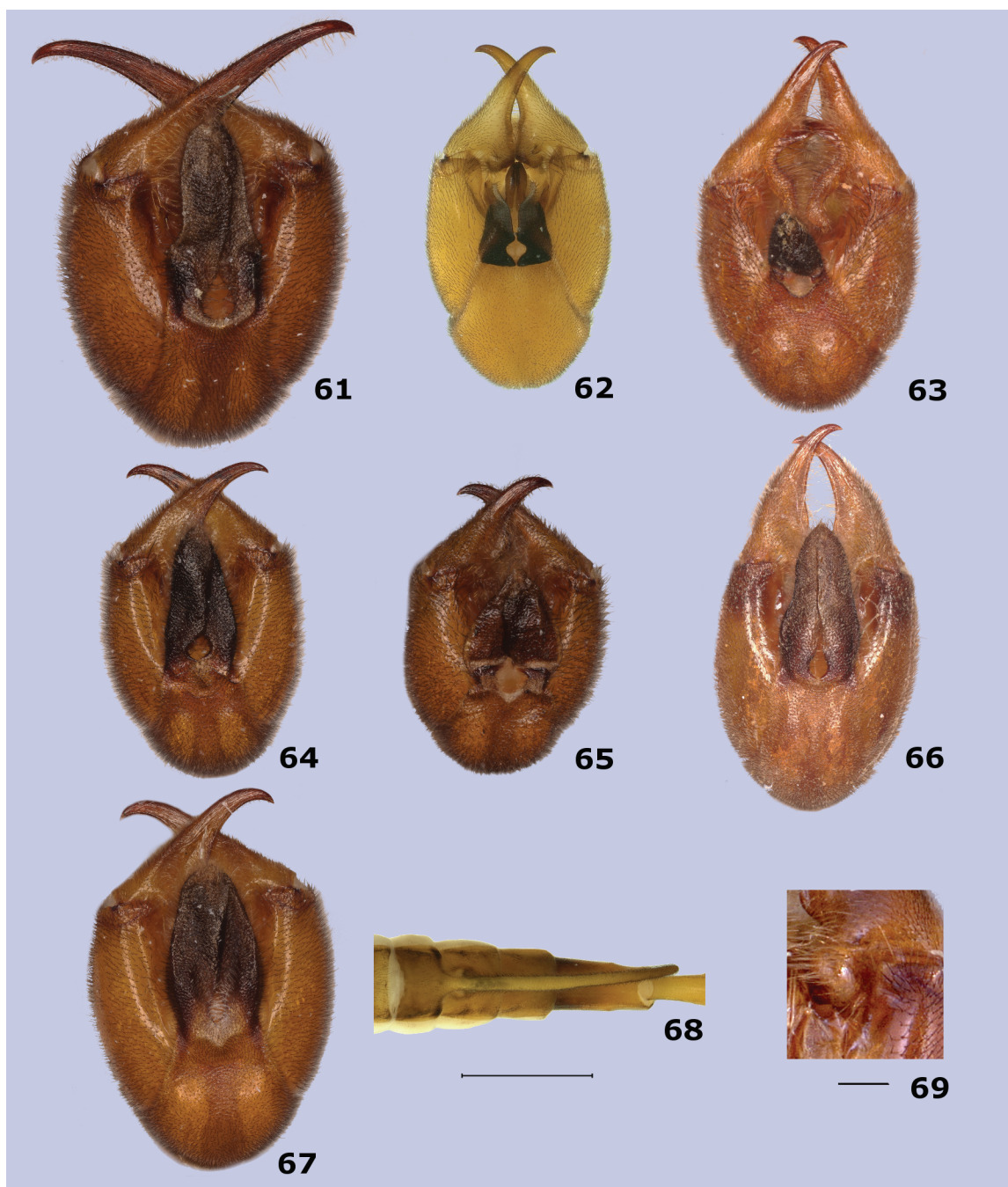
Figures 31–41: Terminal tarsi, scale bar = 0.25 mm: 31. *Bittacus leptocaudus*. 32. *Neopanorpa cuspidata*.
 Figures 33–41: Wings, dorsal aspect, scale bar = 2 mm: 33. *Bittacus leptocaudus*. 34. *Panorpa auripennis*.
 35. *Neopanorpa angustipennis*. 36. *Neopanorpa arcuata*. 37. *Neopanorpa byersi*. 38. *Neopanorpa*
cuspidata. 39. *Neopanorpa harmandi*. 40. *Neopanorpa infuscata*. 41. *Neopanorpa latiseparata*.



Figures 42–49: Wings, dorsal aspect, scale bar = 2 mm: 42. *Neopanorpa malaisei*. 43. *Neopanorpa nielseni*. 44. *Neopanorpa normpennyi*, 45. *Neopanorpa pendulifera*. 46. *Neopanorpa siamensis*. 47. *Neopanorpa spatulata*. 48. *Neopanorpa thai*. 49. *Neopanorpa tuberosa*. Figures 50–51: *Bittacus leptocaudus* terminalia, scale bar = 0.5 mm: 50. dorsal aspect. 51. lateral aspect.



Figures 52–60: Male genital bulbs, ventral aspect, scale bar = 1 mm: 52. *Panorpa auripennis*. 53. *Neopanorpa angustipennis*. 54. *Neopanorpa arcuata*. 55. *Neopanorpa byersi*. 56. *Neopanorpa cuspidata*. 57. *Neopanorpa harmandi*. 58. *Neopanorpa infuscata*. 59. *Neopanorpa latiseparata*. 60. *Neopanorpa malaisei*.



Figures 61–67: Male genital bulbs, ventral aspect, scale bar = 1 mm: 61. *Neopanorpa nielseni*. 62. *Neopanorpa normpennyi*, 63. *Neopanorpa pendulifera*. 64. *Neopanorpa siamensis*. 65. *Neopanorpa spatulata*. 66. *Neopanorpa thai*. 67. *Neopanorpa tuberosa*. Figure 68. *Neopanorpa normpennyi* tergum 3 notal organ, dorsal aspect. Figure 69. *Neopanorpa tuberosa* right male gonostyle basomesal lobe, ventral aspect, scale bar = 0.75 mm.



Figure 71. *Bittacus leptocaudus* hanging from the undersides of broadleaf ground vegetation growing in a dipterocarp forest southeast of Lamphun.

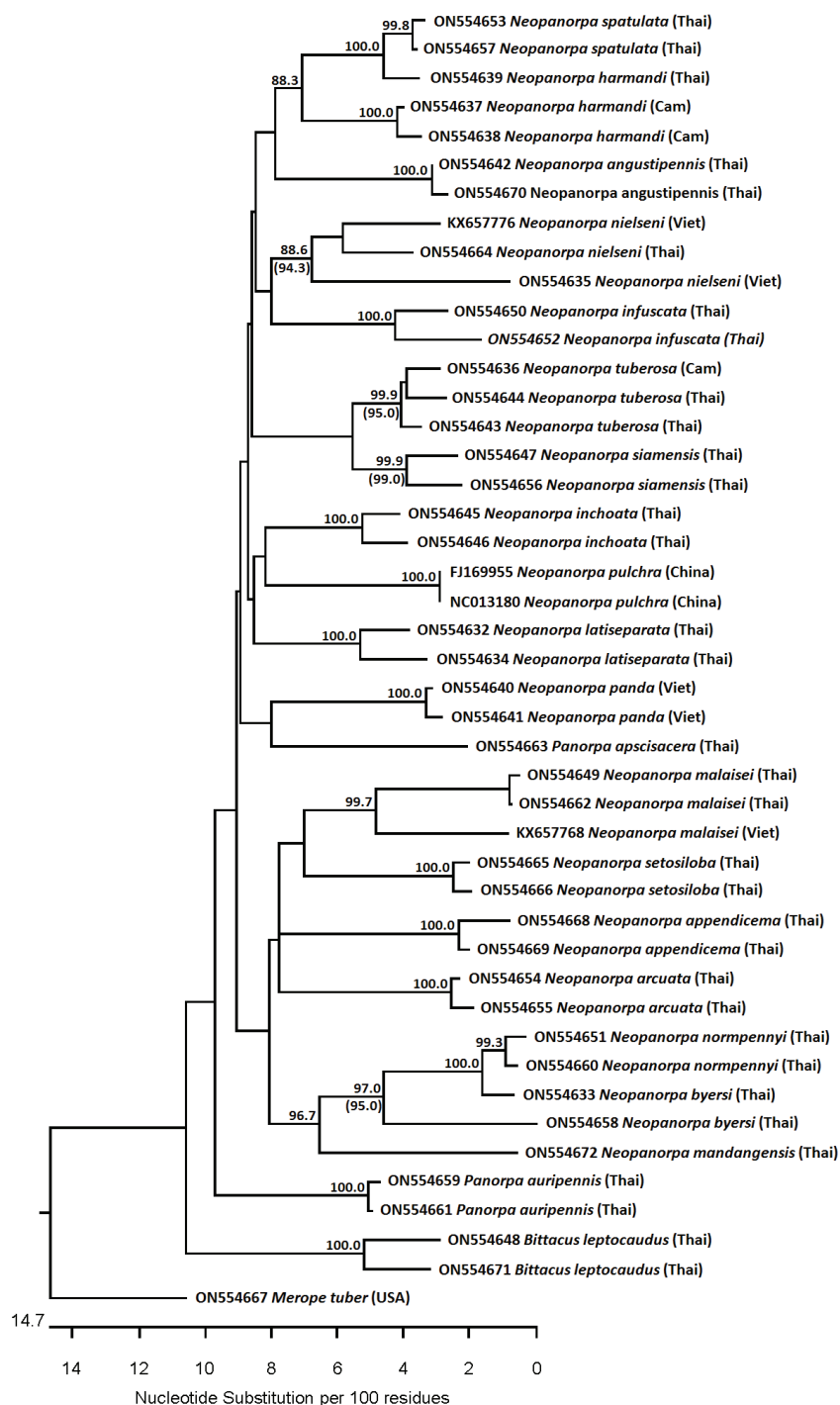


Figure 70. Thai Mecoptera mitochondrial cytochrome oxidase I relational tree.