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Research article

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A taxonomic study of millipede genera, *Orangutana* Golovatch, 1996 and *Gigantomorpha* Jeekel, 1963 (Diplopoda, Polydesmida, Paradoxosomatidae), with description of four new species from Sabah, Borneo, East Malaysia

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Abstract. This taxonomic study focuses on the millipede genera, *Gigantomorpha* Jeekel, 1963, and *Orangutana* Golovatch, 1996, both in the family Paradoxosomatidae. The present investigation focuses on specimens collected in Sabah, Malaysian Borneo, a region known for its remarkable biodiversity. Two new species are described from the Crocker Range Park: *Gigantomorpha alabensis* Ng & Likhitrakarn

sp. nov., and *Orangutana koropungoi* Ng & Likhitrakarn sp. nov. Another two new species come from the Kinabalu Park: *Gigantomorpha sayapensis* Ng & Likhitrakarn sp. nov. and *Gigantomorpha mesilauensis* Ng & Likhitrakarn sp. nov. Their descriptions highlight the neglected, yet vibrant millipede diversity in Sabah. The statuses of both *Gigantomorpha* and *Orangutana* are mentioned, their distribution map is presented, and an identification key to all species of *Gigantomorpha* is given.

Keywords. Taxonomy, key, Myriapoda, Borneo.

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Introduction

The millipede family Paradoxosomatidae Daday, 1889 has long been recognised for its dominance in the Southeast Asian (Oriental) millipede fauna. This family is the largest in the whole class Diplopoda de Blainville, 1844 presently encompassing about 200 genera and over 1000 described species, with a global distribution spanning all regions except Antarctica, which is self-evident, and the Nearctic, which is peculiar (Nguyen & Sierwald 2013). Southeast Asia is particularly rich in Paradoxosomatidae, especially endemic genera (Jeekel 1968). Only a few species of Paradoxosomatidae are known for their vast distributions, all through human introduction, e.g., *Asiomorpha coarctata* (De Sausure, 1860), *Oxidus gracilis* (C.L. Koch, 1847), *Helicorhynchomorpha holstii* (Pocock, 1895) (Nguyen & Sierwald 2013; Golovatch & Enghoff 2015).

Sabah, a territory of East Malaysia, located in the northern part of Borneo, is renowned for its rich biodiversity, encompassing a very wide range of habitats, from coastal areas to high mountains. The Kinabalu Park complex in northwestern Sabah, which includes both Mount Kinabalu, the highest mountain in Borneo and the entire Sundaland, and the adjacent Crocker Range, hosts ecologically significant habitats for a diverse invertebrate fauna, including a third of the known land snails of Sabah (Ito *et al.* 2002; Mohamed *et al.* 2004; Liew *et al.* 2010).

To date, the most significant contribution to our knowledge of Paradoxosomatidae in Sabah was by Golovatch (1996). He described six species from seven genera – *Borneochiropus spinitergus* Golovatch, 1996, *Orangutana setosa* Golovatch, 1996, *Dajakina longipes* Golovatch, 1996, *Kalimantanina crucifera* Golovatch, 1996, *Euphyodesmus reductus* Golovatch, 1996, *Magaritosoma borneorum* Golovatch, 1996 – and added a new regional record, *Gigantomorpha immanis* Jeekel, 1963. Currently, seven species of paradoxosomatid millipedes are known from Sabah. Four species were described from a lowland forest in Sandakan on the eastern coast (Locality 1 in Fig. 1B–C). Two species, namely *E. reductus* and *M. borneorum*, were described from the northwestern mountain ranges of Mount Kinabalu (Locality 2 in Fig. 1B) and the Crocker Range (Locality 3 in Fig. 1B–C), respectively. Additionally, *G. immanis* was recently recorded from the Crocker Range (Golovatch, 1996; Locality 4 in Fig. 1B–C).

In our present investigation, we had the opportunity to collect new millipede specimens from montane forests around the Mount Kinabalu and the Crocker Range, leading to the discovery of four new species belonging to two genera, *Orangutana* Golovatch, 1996 and *Gigantomorpha* Jeekel, 1963. This represents the first new millipede species ever to be described from Sabah in nearly three decades and also increases our knowledge of the taxonomy of the family Paradoxosomatidae in the region.

Material and methods

Millipedes were collected in montane forest regions of the Kinabalu Park complex and Gunung (Mount) Alab Substation of the Crocker Range Park, in the north and west of Sabah, respectively. Coordinates and elevations were recorded by Garmin GPSMAP 64s using the WGS84 datum and subsequently double-checked with Google Earth ver. 7.3.4. Live animals were photographed in their habitats using an Olympus TG-4 digital camera. The specimens were euthanised based on the guidelines for the euthanasia of animals established by the American Veterinary Medical Association (2020), kept in 75% (v/v) ethanol for morphological observations and taken to the laboratory. The specimens were examined, measured and photographed under a Nikon SMZ 745T trinocular stereo microscope equipped with a Canon EOS 5DSR digital SLR camera. Digital images obtained were processed and edited with Adobe Photoshop CS5. Line drawings of the gonopods were drawn from photographs captured using a stereo microscope. For scanning electron microscopy (SEM), the gonopods were coated with 8 nm gold layer using a CCU-010 high vacuum sputter and a carbon coater (Safematic), then imaged with a TESCAN VEGA3 scanning electron microscope operated at 5 keV of acceleration voltage and returned to alcohol after SEM examination. The holotypes are housed in the Sabah Parks Zoological Collection (SP) and the BORNEENSIS Zoological Collection, Institute for Tropical Biology and Conservation, Universiti Malaysia Sabah (BOR). Line drawings of comparative specimens examined herein were reproduced from their original descriptions, based on type material housed at the Muséum d'Histoire naturelle in Geneva (MHNG).

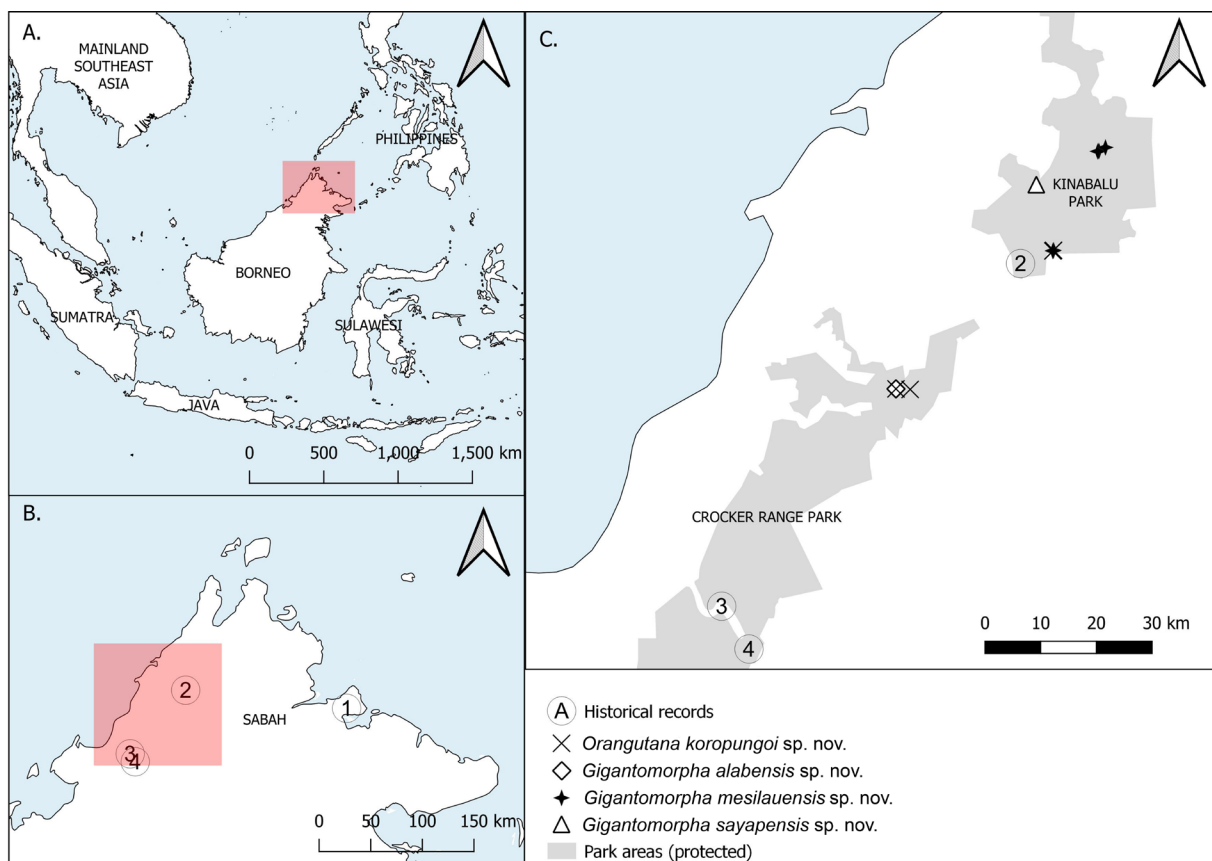


Fig. 1. A. Map of Southeast Asia, with the area of Sabah, East Malaysia, shaded. B. Historical collection localities of millipedes in Sabah, with the area of recent collections shaded: 1. Sepilok, Sandakan; 2. Bukit Ular trail, Kinabalu Park, Ranau. 3. 16 mile, Kimanis Road, Keningau. 4. 8.5 to 10 mile, Kimanis Road, Keningau. C. Historical and recent collecting localities of millipedes from the Kinabalu Park and the Crocker Range Park areas, Sabah. Recent localities marked with symbols.

In the synonymy sections, D stands for the original description and/or subsequent descriptive notes, K for the appearance in a key, L for the appearance in a species list, and M for a mere mention.

The terminology of the somatic and some gonopodal structures mostly follows Golovatch (1996) and Likhitrakarn *et al.* (2022). Abbreviations of certain gonopodal structures in the figures are explained both in the text and figure captions.

Results

Taxonomy

Class Diplopoda de Blainville in Gervais, 1844

Order Polydesmida Leach, 1815

Family Paradoxosomatidae Daday, 1889

Tribe Orthomorphini Brölemann, 1916

Genus *Gigantomorpha* Jeekel, 1963

Gigantomorpha Jeekel, 1963: 106 (D, K).

Gigantomorpha – Jeekel 1968: 116 (L); 1979: 164 (L). — Golovatch 1996: 169 (M, K). — Nguyen & Sierwald 2013: 1244 (L).

Type species

Gigantomorpha immanis Jeekel, 1963, by original designation.

Emended diagnosis

Body medium to large-sized (ca 20–55 mm long, ca 2.8–8.0 mm wide), with 20 rings. Paraterga from moderately to strongly developed. Transverse metatergal sulci distinct. Legs moderate in length to rather long, without modifications. Adenostyles absent. Sternal lamina present between male coxae 4, following sternites modified with a cone near coxa, or unmodified.

Gonopods slightly curved, relatively complex; coxa moderate in size, subcylindrical, sparsely setose distoventrally, without tubercles; prefemoral (= densely setose) part of telopodite relatively short, $\frac{1}{5}$ – $\frac{1}{3}$ as long as acropodite; femoral part long and slender, almost straight, without evidence of torsion (= seminal groove running only mesally), often slightly enlarged distally, with a clear-cut, oblique, distolateral sulcus demarcating a postfemoral part; solenophore moderately strongly curved mesad or caudomesad, consisting of well-developed laminae lateralis and medialis, yet with lamina medialis usually larger than lamina lateralis, lamina medialis developed only in distal part of postfemoral part, where it gives rise to a more or less complicated laminate process, tip of solenophore deeply bifid, each prong with either minute denticles or lappets, or completely reduced. Solenomere flagelliform, almost fully sheathed by solenophore.

Other species included

Gigantomorpha aterrima Jeekel, 1963, *G. cornalata* Jeekel, 1963, *G. fasciata* (Attems, 1898), *G. mutilata* Golovatch, 1996, *G. pallida* Jeekel, 1963, *G. socialis* (Carl, 1912), *G. spinescens* Jeekel, 1963, *G. transmontana* Jeekel, 1982, *G. trichopleura* Jeekel, 1963, as well as *G. alabensis* Ng & Likhitrakarn sp. nov., *G. mesilauensis* Ng & Likhitrakarn sp. nov. and *G. sayapensis* Ng & Likhitrakarn sp. nov.

Remarks

The genus *Gigantomorpha* was originally established by Jeekel (1963) with the designation of *G. immanis* as type species. That work included descriptions of seven new species from Borneo and the transfer of two previously described species, *Pratinus fasciatus* Attems, 1898 from Borneo and *Pratinus socialis* Carl, 1912 from Sulawesi, due to uncertainties regarding the taxonomic status of *Pratinus* Attems, 1937 (Jeekel 1963). Subsequently, Golovatch (1996) re-examined the type material of *G. immanis*, refining the variation range of the ambiguities in some morphological characters. His study provided the detailed redescription and illustrations of *G. immanis* and included the description of a new species from Bali (Golovatch 1996).

Gigantomorpha alabensis Ng & Likhitrakarn sp. nov.

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Figs 2–4

Diagnosis

This new species closely resembles *G. sayapensis* sp. nov., but differs in the pleurosternal carinae in males present until ring 7 (vs 4), shorter male legs, ca 1.3–1.5 times as long as midbody height (vs 1.5–1.7 times), and tarsal brushes in males present until ring 18 (vs ring 16), coupled with the gonopodal lamina medialis (lm) tip bifid, with a deep and evident incision (vs a single subtruncate tip).

Etymology

To emphasise the type locality, adjective in feminine gender.

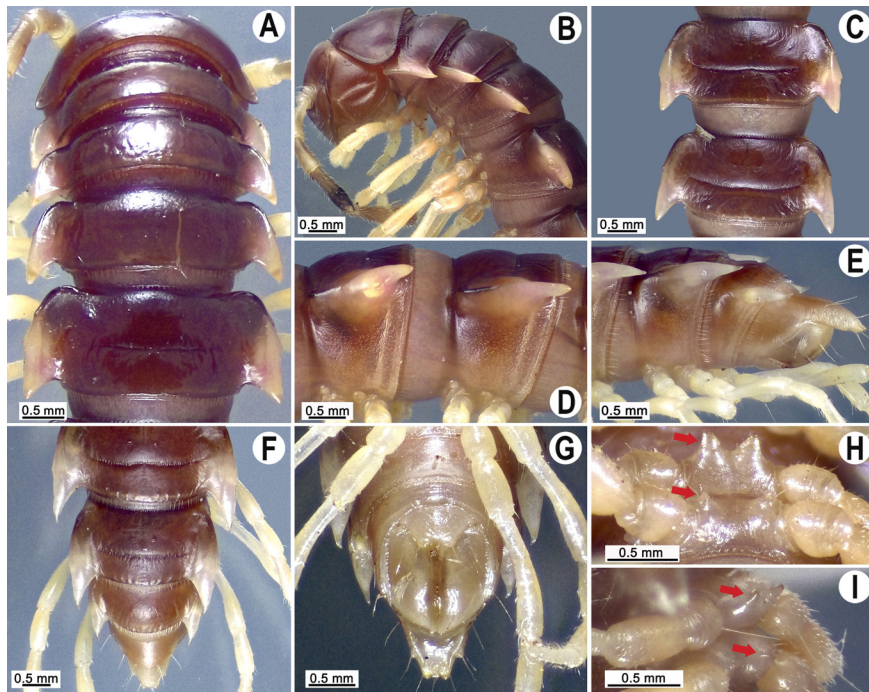


Fig. 2. *Gigantomorpha alabensis* Ng & Likhitrakarn sp. nov., holotype, ♂ (SP 14836). **A–B.** Anterior part of body, dorsal and lateral views, respectively **C–D.** Rings 10 and 11, dorsal and lateral views, respectively. **E–G.** Posterior part of body, lateral, dorsal, and ventral and views, respectively. **H–I.** Sternal cones between coxae 4 indicated by red arrows, caudal and sublateral views, respectively.

Material examined

Holotype

MALAYSIA • ♂; Borneo, Sabah, Tambunan, Crocker Range Park, Gunung Alab Substation; 5°49'17.6" N, 116°20'29.4" E; ca 1904 m a.s.l.; 19 Mar. 2023; T.H. Ng, T.S. Liew and F. Anthony leg.; SP 14836.

Description

Length of holotype 28.5 mm, width of midbody pro- and metazona of holotype, 2.2 and 4.8 mm, respectively.

Colouration of alcohol material after seven months of preservation castaneous with a pattern of contrasting pale pinkish to whitish paraterga and epiproct, antennae brown to light yellowish, venter brownish to light brown, and legs light brown to light yellowish (Fig. 2A–I).

Clypeolabral region and vertex densely setose, epicranial suture distinct. Antennae rather short (Fig. 2B), reaching body ring 4 when stretched dorsally. In width, head < ring 3 < collum < ring 4 < 2 < 5 < 6 < 7–16 (Fig. 2A), thereafter body gently and gradually tapering. Collum with three transverse rows of strong setae: 3+3 anterior, 2+2 intermediate, and 4+4 posterior; caudal corner very broadly rounded, paraterga declined ventrad, not produced past rear tergal margin (Fig. 2A–B).

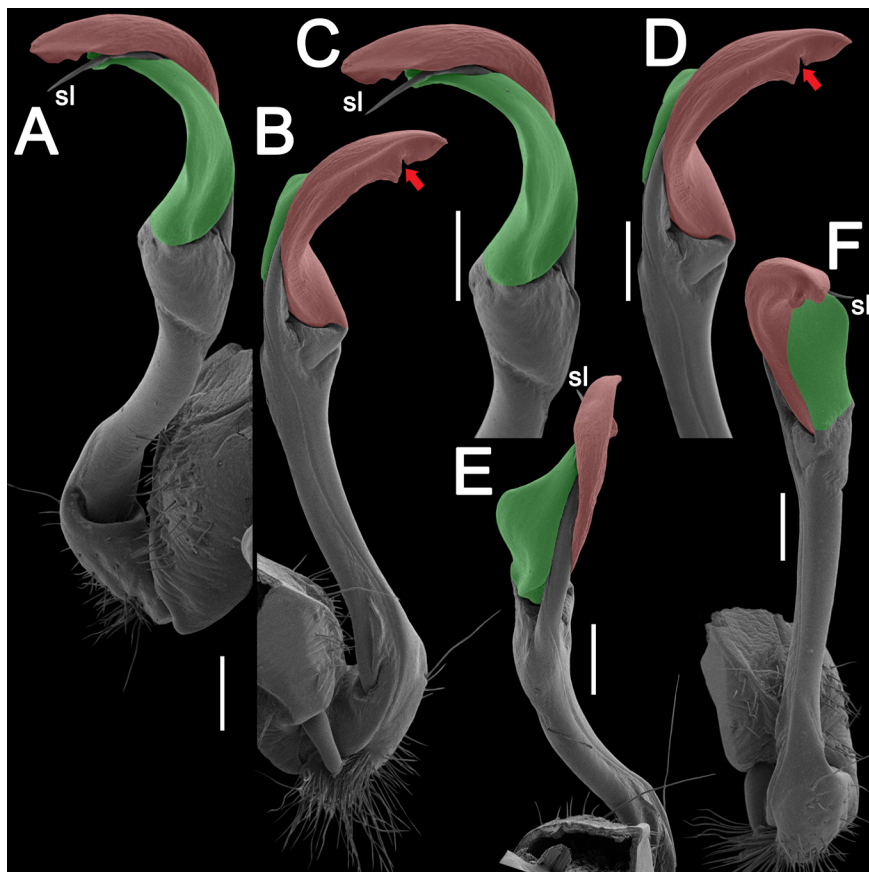


Fig. 3. *Gigantomorpha alabensis* Ng & Likhitrakarn sp. nov., holotype, ♂ (SP 14836), left gonopod. A–B. Sublatero and mesal views, respectively. C–F. Sublatero, mesal, subcaudal and suboral views, respectively. Colours: red = lamina medialis (lm); green = lamina lateralis (ll). Red arrows = evident incision. Abbreviation: sl = solenomere. Scale bars = 0.2 mm.

Tegument rather smooth and shining, prozona delicately shagreened, metaterga smooth and leathery, posterior halves faintly rugulose, surface below paraterga microgranulate (Fig. 2A–F). Postcollum metaterga each with two transverse rows of setae: 2+2 in anterior, 3(4)+3(4) in posterior row, setae in

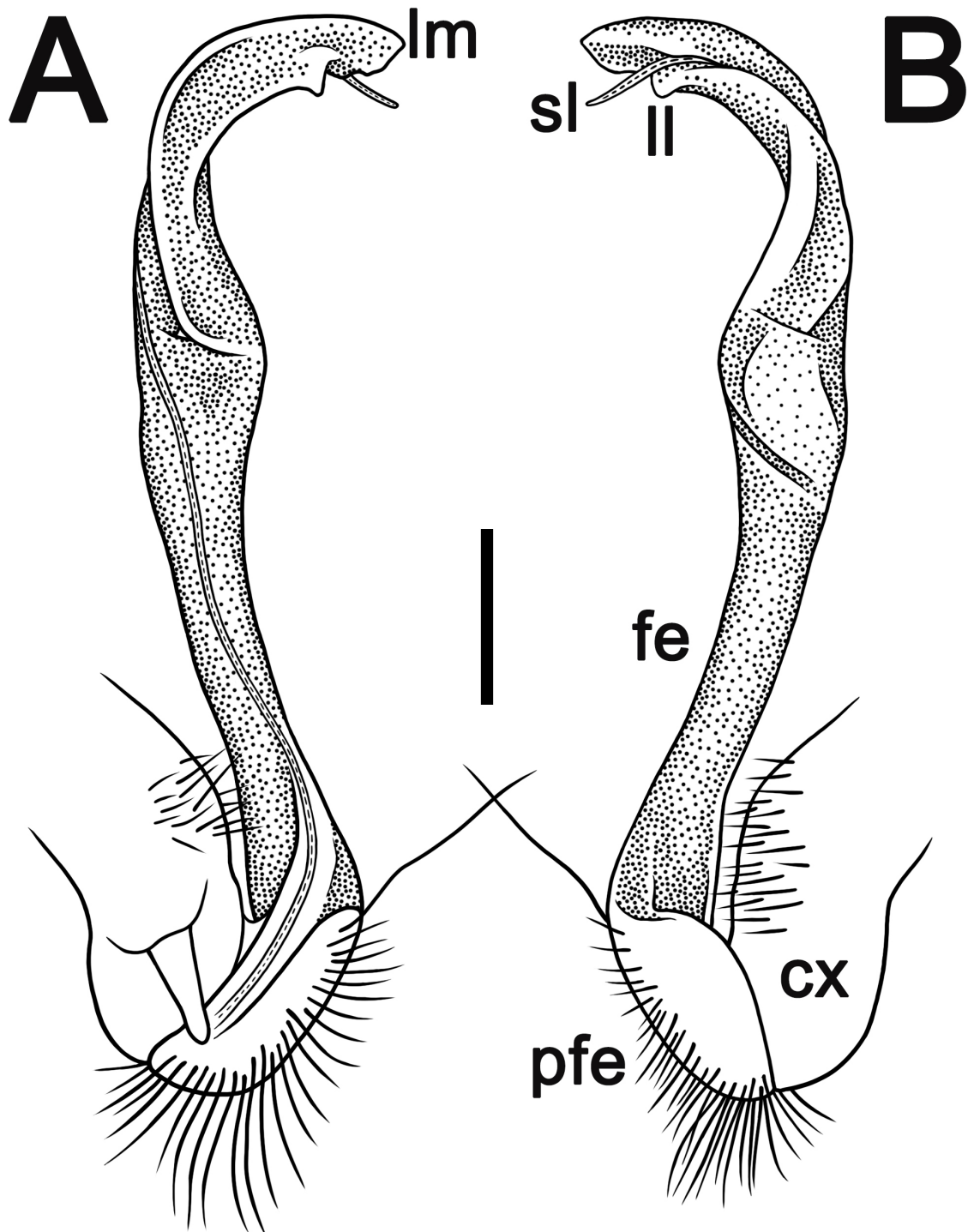


Fig. 4. *Gigantomorpha alabensis* Ng & Likhitrakarn sp. nov., holotype, ♂ (SP 14836), left gonopod. A–D. Mesal and lateral views, respectively. Abbreviations: cx = coxa; fe = femoral part; ll = lamina lateralis; lm = lamina medialis; pfe = prefemoral part; sl = solenomere. Scale bar = 0.2 mm.

posterior row mostly abraded and borne on minute knobs or oblong wrinkles. Tergal setae rather short, strong, slender, about $\frac{1}{4}$ metatergal length. Axial line traceable both on pro- and metazona. Paraterga strongly developed (Fig. 2A–G), subhorizontal, slightly upturned posteriorly, always lying high, at upper $\frac{1}{3}$ midbody height, but remaining below dorsum; anterior edge on rings 2–4 each broadly rounded and narrowly bordered, fused to callus; following rings slightly rounded and oblique laterally (Fig. 2A); caudal corner almost completely to fully pointed, always extending past rear tergal margin, bent posteriad on rings 16–19 (Fig. 2E–G); posterior edge oblique (Fig. 2A, C, F); paraterga thin blunt blades in lateral view, a little thicker only on pore-bearing rings (Fig. 2D). Calluses on paraterga delimited by a sulcus only dorsally, but on pore-bearing ring paraterga with sulci both dorsally and ventrally. Paraterga 2–4 broad, lateral edge of each with two small incisions at lateral edge (Fig. 2A), one in anterior $\frac{1}{3}$, the other in posterior $\frac{1}{3}$. Lateral edge of paraterga of following rings with two small incisions, one larger and one smaller, but evident incisions in anterior $\frac{1}{3}$ (Fig. 2A, C, F). Ozopores evident, lateral, lying in an ovoid groove at about $\frac{1}{3}$ of metatergal length in front of posterior edge of metaterga (Fig. 2B, D–E).

Transverse metatergal sulci usually distinct (Fig. 2A, C, F), slightly incomplete on ring 19, complete and clearly visible on metaterga 5–18, deep and narrow, reaching the bases of paraterga, line-shape, ribbed at bottom. Stricture between pro- and metazona narrow, deep, beaded at bottom down to base of paraterga (Fig. 2A, C, F). Pleurosternal carinae complete crests bulged anteriorly and with a sharp caudal tooth on ring 2, thereafter only a sharp caudal tooth on ring 3, a small denticle on ring 4, thereafter missing (Fig. 2B).

Epiproct (Fig. 2E–G) conical, flattened dorsoventrally, subtruncate, with two evident apical papillae directed caudally, both pointed; pre-apical papillae small, but evident, lying close to tip. Hypoproct subtrapeziform (Fig. 2G), small setigerous knobs at caudal edge well-separated and evident.

Sterna sparsely setose, without modifications; cross-impressions rather shallow; a sparsely setose, transverse lobe bearing a paramedian pair of evident, basally contiguous cones between male coxae 4 and a pair of small, separated cones near each coxa 5 (Fig. 2H–I). A paramedian pair of small, but evident tubercles in front of gonopod aperture. Legs long and slender, midbody ones ca 1.5–1.7 times as long as body height; prefemora without modifications; tarsal brushes present until legs of ring 16.

Gonopods (Figs 3–4) simple; coxa long and thick, subcylindrical, a little curved caudad, sparsely setose distoventrally (Figs 3A–B, E, 4A–B). Prefemoral part short, densely setose as usual, about $\frac{1}{4}$ as long as femoral part + postfemoral part (Fig. 3A–B). Femoral part long and slender, expanded distad, slightly curved, postfemoral part demarcated by an oblique lateral sulcus (Figs 3A–D, F, 4A–B); seminal groove running entirely mesally along the femoral part, solenomere (sl) flagelliform, fully sheathed by solenophore (sph). Lamina medialis (lm) well developed, elevated, prominent, stout, slightly expanded apically, tip bifid with a deep and evident incision (Figs 3A–D, 4A), terminal lobe with minute denticles at ventral margin (Fig. 3A, C, F). Lamina lateralis (ll) shorter than lamina medialis (lm), subtruncate at tip (Figs 3A, C, 4B).

Remarks

This species was found at the Gunung Alab Substation (Fig. 1C), inside a small building which houses the office and guesthouse, adjacent to forest trails, and together with *Orangutana koropungoi* Ng & Likhitrakarn sp. nov.

Gigantomorpha aterrima Jeekel, 1963

Gigantomorpha aterrima Jeekel, 1963: 249 (D, K).

Gigantomorpha aterrima – Golovatch 1996: 169 (M, K). — Nguyen & Sierwald 2013: 1244 (L).

Distribution

Indonesia, East Borneo, S Mentawir (Jeekel 1963).

Gigantomorpha cornalata Jeekel, 1963

Gigantomorpha cornalata Jeekel, 1963: 247 (D, K).

Gigantomorpha cornalata – Golovatch 1996: 169 (M, K). — Nguyen & Sierwald 2013: 1244 (L).

Distribution

Indonesia, East Borneo, Birang River (Jeekel 1963).

Gigantomorpha fasciata (Attems, 1898)

Prionopeltis fasciatus Attems, 1898: 353 (D).

Prionopeltis fasciatus – Carl 1912: 141 (M). — Attems 1914: 203 (L). — Weidner 1960: 89 (L). — Moritz & Fischer 1978: 103 (L).

Pratinus fasciatus – Attems 1937: 115 (D).

Gigantomorpha fasciata – Jeekel 1982: 226 (D, R). — Golovatch 1996: 169 (M, K).

not *Gigantomorpha fasciata* – Jeekel 1963: 253. — Wang 1967: 391.

Distribution

Indonesia, Borneo (Attems 1898); South Borneo, Pleihari near Bandjarmasin (Jeekel 1982).

Gigantomorpha immanis Jeekel, 1963

Gigantomorpha immanis Jeekel, 1963: 242 (D, K).

Gigantomorpha fasciata Wang, 1967: 391 (R), corrected by Golovatch 1996: 171 (M).

Gigantomorpha immanis – Golovatch 1996: 169 (D, R, K). — Nguyen & Sierwald 2013: 1244 (L).

Distribution

Indonesia, East Borneo: Mountain Tibang, 1400 m a.s.l.; Pajan River; Blu-u, Mahakkam River; Blu.u; Upper Manhakkam River; Mahakkam (Jeekel 1963). East Malaysia, Borneo, Sabah, Sandakan Residency Sepilok, “Kabili-Sepilok Forest Reserve”, forest near “Orang-Utan Rehabilitation Station”, lowland rain forest; Sepilok, forest near pond, degraded lowland rain forest; “Kabili-Sepilok Forest Reserve”, path toward mangrove, before “Ridge”, lowland rain forest; Interior Residency, Kimanis road, 8.5 mi from Keningau, path from “Checkpoint” to above village “Temperate Vegetation Project”; same locality, 8.5 mi from Keningau, Checkpoint, near barracks, 950 m a.s.l.; Borneo, Brunei, Temburong District, “Peradayan Forest Reserve” (= “Bukit Patoi”) 14.5 km from Bangar (= 2.5 km from Labu), primary mixed dipterocarp forest, 10–300 m a.s.l. (Golovatch 1996).

Gigantomorpha mesilauensis Ng & Likhitrakarn sp. nov.
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Figs 5–7

Diagnosis

This new species closely resembles *G. sayapensis* sp. nov., especially in that both species have the gonopod tip small bifid without distinct branching. However, it is distinguished by the less strongly

bordered paraterga (Fig. 5A, C, F) (vs strongly bordered; Fig. 8B, D, F), the sternal cones present only between male coxae 4 (vs between both male coxae 4 and 5), and the gonopodal lamina lateralis (ll) and lamina medialis (lm) subequal in length, long, and slender, slightly narrowed apically (Figs 6A, C, E, 7A–B) (vs lamina medialis (lm) larger and expanded apically, Figs 3A–D, 4A–B).

Etymology

To emphasise the type locality, adjective in feminine gender.

Material examined

Holotype

MALAYSIA • ♂; Borneo, Sabah, Ranau, Mesilau Nature Resort, Nepenthes Trail; 6°02'45.4" N, 116°35'49.1" E; 1926 m a.s.l.; 26 Sep. 2023; T.H. Ng, F. Anthony, E.S.H. Quah, J. Dulipat, F.J. Chong, A. Joseph and C.L. Soo leg.; BOR/MYR 90.

Paratypes

MALAYSIA • 1 ♂; same data as for holotype; SP 14837 • 1 ♂; same data as for holotype; BOR/MYR 85 • 1 ♂; Borneo, Sabah, Ranau, Mesilau Nature Resort, Tambang Gate; 6°02'41.7" N, 116°35'45.0" E; 1922 m a.s.l.; 27 Sep. 2023; T.H. Ng, F. Anthony and F.J. Chong leg.; BOR/MYR 111 • 1 ♀; same data as for preceding; SP 14838 • 1 ♀; same data as for preceding; BOR/MYR 108 • 1 ♂; Borneo, Sabah, Ranau, Kinabalu Park, Mount Tambuyokon; 6°12'24.5" N, 116°40'13.9" E; 2012 m a.s.l.; 11 May 2023; T.H. Ng, F. Anthony and T.S. Liew leg.; SP 14839 • 1 ♀; Borneo, Sabah, Ranau, Kinabalu Park, Mount Tambuyokon; 6°12'22.5" N, 116°40'06.7" E; 2052 m a.s.l.; 11 May 2023; T.H. Ng, F. Anthony and T.S. Liew leg.; BOR/MYR 78 • 1 ♀; Borneo, Sabah, Ranau, Kinabalu Park, Mount Tambuyokon;

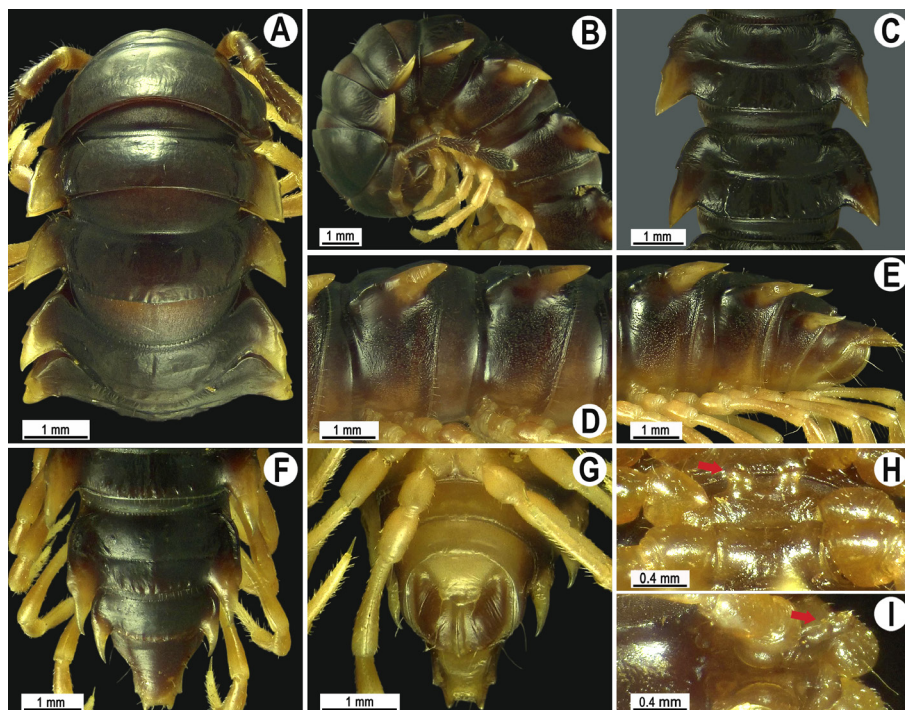


Fig. 5. *Gigantomorpha mesilauensis* Ng & Likhitrakarn sp. nov., holotype, ♂ (BOR/MYR 90). A–B. Anterior part of body, dorsal and lateral views, respectively. C–D. Rings 10 and 11, dorsal and lateral views, respectively. E–G. Posterior part of body, lateral, dorsal and ventral views, respectively. H–I. Sternal cones between coxae 4 indicated by red arrows, caudal and sublateral views, respectively.

6°12'45.5" N, 116°40'51.7" E; 1398 m a.s.l.; 11 May 2023; T.H. Ng, F. Anthony and T.S. Liew leg.; SP 14840.

Description

Length 35.4–41.3 mm (♂) or 33.5–39.5 mm (♀), width of midbody pro- and metazonae 2.4–2.8 and 3.6–4.2 mm (♂) or 2.3–3.3 and 3.9–4.4 mm (♀), respectively. Holotype 37.4 mm long, and 2.7 and 4.1 mm wide on midbody pro- and metaterga, respectively.

Colouration of alcohol material after one year of preservation dark brown or castaneous brown with a pattern of contrasting yellowish brown paraterga and epiproct (Fig. 5A–G); antennae brown to light brown (Fig. 5B); venter and legs light brown to light yellowish (Fig. 5B, E–I).

Clypeolabral region and vertex sparsely setose, epicranial suture distinct. Antennae rather short (Fig. 5B), reaching body ring 3 (♂, ♀) when stretched dorsally. In length, antennomere 3=2>5>4=6>>1=7. Interantennal isthmus ca 0.6 times diameter of antennal socket (Fig. 8B). In width, head<collum<ring 3<2<4<5<6<7–16 (Fig. 5A), thereafter body gently and gradually tapering. Collum with three transverse rows of strong setae: 3+3 anterior, 2+2 intermediate, and 4+4 posterior; caudal corner very broadly rounded, paraterga declined ventrad, not produced past rear tergal margin (Fig. 5A–B).

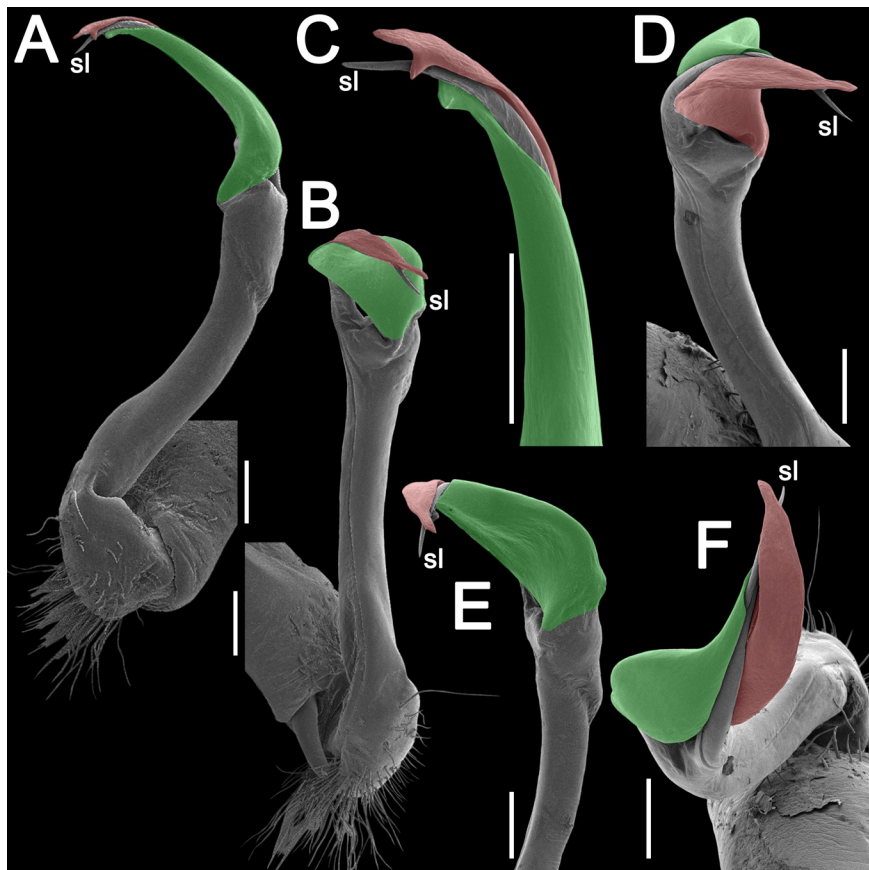


Fig. 6. *Gigantomorpha mesilauensis* Ng & Likhitrakarn sp. nov., holotype, ♂ (BOR/MYR 90), left gonopod. **A–B.** Sublateral and submesal views, respectively. **C–F.** Distal part, sublateral, submesal, suboral, and subcaudal views, respectively. Colours: red = lamina medialis (lm); green = lamina lateralis (ll). Abbreviation: sl = solenomere. Scale bars = 0.2 mm.

Tegument rather smooth and shining, prozona delicately shagreened, metaterga smooth and leathery, posterior halves faintly rugulose, surface below paraterga microgranulate (Fig. 5A–F).

Postcollum metaterga each with two transverse rows of setae: an anterior transverse row with 2+2, often abraded setae traceable at least as insertion points, and a posterior row with 4(5)+4(5) setae borne on low, oblong, rounded tubercles or minute knobs with insertion points of mostly abraded setae. Tergal

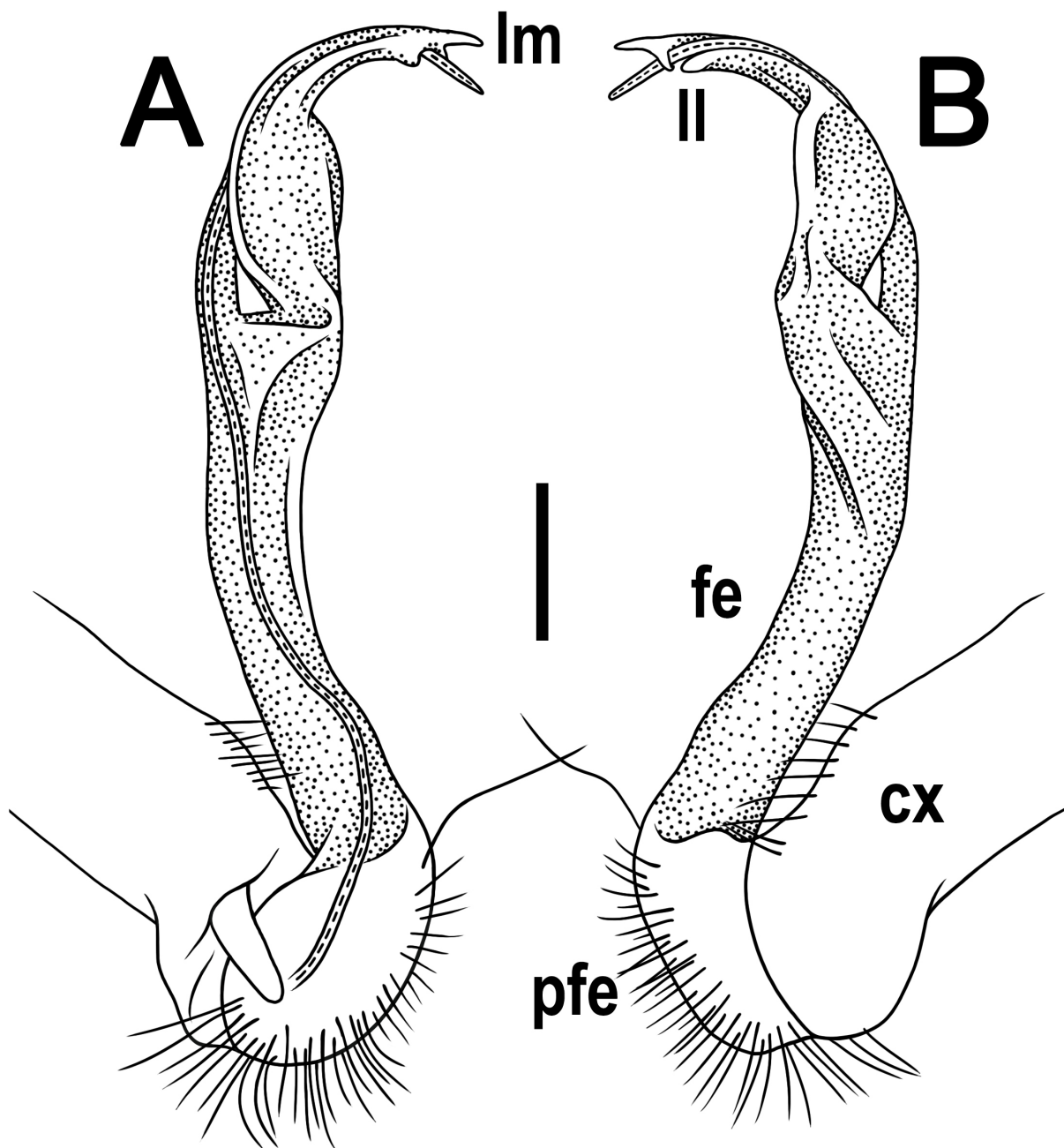


Fig. 7. *Gigantomorpha mesilauensis* Ng & Likhitrakarn sp. nov., holotype, ♂ (BOR/MYR 90), left gonopod. **A–B.** Mesal and lateral views, respectively. Abbreviations: cx = coxa; fe = femoral part; ll = lamina lateralis; lm = lamina medialis; pfe = prefemoral part. Scale bar = 0.2 mm.

setae rather short, strong, slender, about $\frac{1}{4}$ metatergal length. Axial line traceable both on pro- and metazona. Paraterga very strongly developed (Fig. 5A–G), especially well so in males, subhorizontal to mostly slightly upturned, lying above dorsum or slightly above dorsum, thin in lateral view, like blunt blades, a little thicker only on pore-bearing rings, on postcollum rings extending increasingly beyond dorsum, especially so in rings 17–19; anterior edge broadly rounded and narrowly bordered, fused to callus; caudal corner almost completely to fully pointed, always extending past rear tergal margin, bent posteriad on rings 17–19; posterior edge oblique (Fig. 5A, C, F). Calluses on poreless paraterga delimited by a sulcus only dorsally, but on pore-bearing rings paraterga both dorsally and ventrally. Paraterga 2 broad, lateral edge with three small acute denticles, one at midway, the other two each at posterior $\frac{1}{3}$ (Fig. 5A). Paraterga 3 and 4 each with two similar evident incisions, one at midway, the other in posterior $\frac{1}{3}$ (Fig. 5A). Following poreless rings with two evident incisions, one at midway, the other in posterior $\frac{1}{3}$, caudal incision in pore-bearing rings smaller or gradually reduced in posterior rings (Fig. 5D, F). Ozopores evident, lateral, each lying in an ovoid groove at about $\frac{1}{3}$ metatergal length in front of posterior edge of metaterga (Fig. 5C–E).

Transverse sulcus usually distinct (Fig. 5A, C, F), complete and visible on metaterga 5–18, rather deep and narrow, reaching the bases of paraterga, linear, ribbed at bottom. Stricture between pro- and metazona rather wide, deep, ribbed at bottom down to base of paraterga (Fig. 5A, C, F). Pleurosternal carinae complete crests only on rings 2 and 3 (Fig. 8B), each with an evident sharp denticle caudally, thereafter increasingly reduced until ring 8 (♂) or 7 (♀).

Epiproct (Fig. 5E–G) conical, flattened dorsoventrally, subtruncate, with two evident apical papillae directed caudally, both pointed at tip; pre-apical papillae evident, lying close to tip. Hypoproct subtrapeziform (Fig. 5G), small setigerous knobs at caudal edge well-separated and evident.

Sterna sparsely setose, without modifications; cross-impressions shallow; two large and long, fully separated, sparsely setose, sternal cones between male coxae 4 (Fig. 5H–I). A paramedian pair of small tubercles in front of gonopod aperture. Legs long and slender, midbody ones ca 1.3–1.5 (♂) or 1.1–1.3 (♀) times as long as body height; prefemora without modifications; tarsal brushes present until legs of ring 17.

Gonopods (Figs 6–7) simple; coxa long and thick, subcylindrical, a little curved caudad, sparsely setose distoventrally (Figs 6A–B, 7A–B). Prefemoral part short, densely setose as usual, about $\frac{1}{4}$ as long as femoral part + postfemoral part (Fig. 7A–B). Femoral part long and slender, slightly expanded distad, curved, postfemoral part demarcated by an oblique lateral sulcus (Figs 6A–B, D, F, 7A–B); seminal groove running entirely mesally along femorite, solenomere (sl) flagelliform, fully sheathed by solenophore (sph). Both lamina lateralis (ll) and lamina medialis (lm) well developed, subequal in length, long and slender (Figs 6A, C, E, 7B). Lamina medialis (lm) with tip clearly bifid (Fig. 7A).

Remarks

This species was collected on rocks and vegetation, under rotten branches or logs, in lower montane forest habitats in the Mesilau and Mount Tambuyokon areas in the eastern part of the Kinabalu Park complex (Fig. 1C).

Gigantomorpha mutilata Golovatch, 1996

Gigantomorpha mutilata Golovatch, 1996: 171 (D, K).

Gigantomorpha mutilata – Nguyen & Sierwald 2013: 1244 (L).

Distribution

Indonesia Bali: Bedugul, slope above Lake Bartan, 1130–1180 m a.s.l.; same locality, Botanical Gardens, forested part, 1230–1260 m a.s.l. (Golovatch 1996).

Gigantomorpha pallida Jeekel, 1963

Gigantomorpha pallida Jeekel, 1963: 251 (D, K).

Gigantomorpha pallida – Golovatch 1996: 169 (M, K). — Nguyen & Sierwald 2013: 1244 (L).

Distribution

Indonesia, East Borneo, S Mentawir (Jeekel 1963).

Gigantomorpha socialis (Carl, 1912)

Prionopeltis socialis Carl 1912: 139 (D).

Prionopeltis socialis – Attems 1914: 204 (L).

Pratinus socialis – Attems 1937: 116 (D).

Gigantomorpha socialis – Jeekel 1963: 261 (D). — Golovatch 1996: 169 (M, K). — Nguyen & Sierwald 2013: 1244 (L).

Distribution

Indonesia (South Sulawesi), Bontorio, south Celebes (Carl 1912).

Gigantomorpha spinescens Jeekel, 1963

Gigantomorpha spinescens Jeekel 1963: 259 (D, K).

Gigantomorpha spinescens – Golovatch 1996: 169 (M, K). — Nguyen & Sierwald 2013: 1244 (L).

Distribution

Indonesia, East Borneo, without a precise locality (Jeekel 1963).

Gigantomorpha transmontana Jeekel, 1982

Gigantomorpha fasciata Jeekel, 1963: 253 (D).

Gigantomorpha transmontana Jeekel, 1982: 228 (M).

Gigantomorpha transmontana – Golovatch 1996: 169 (M, K). — Nguyen & Sierwald 2013: 1244 (L).

Distribution

Indonesia, East Borneo, S Mentawir (Jeekel 1963).

Gigantomorpha trichopleura Jeekel, 1963

Gigantomorpha trichopleura Jeekel, 1963: 255 (D, K).

Gigantomorpha trichopleura – Golovatch 1996: 169 (M, K). — Nguyen & Sierwald 2013: 1244 (L).

Distribution

Indonesia, East Borneo, without a precise locality (Jeekel 1963).

Gigantomorpha sayapensis Ng & Likhitrakarn sp. nov.

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Figs 8–10

Diagnosis

Differs from all known congeners by the gonopod tip with a small bifid structure, lacking the distinct branching observed in other species. This characteristic appears to be particularly similar to both *G. mutilata* and *G. transmontana*. However, the new species differs in having a thicker, apically expanding solenophore (i.e., the solenophore becomes slightly wider towards the apex) (Figs 9B–C, 10A–C) (vs long, slender and tapering in all the other species).

Etymology

To emphasise the type locality, adjective in feminine gender.

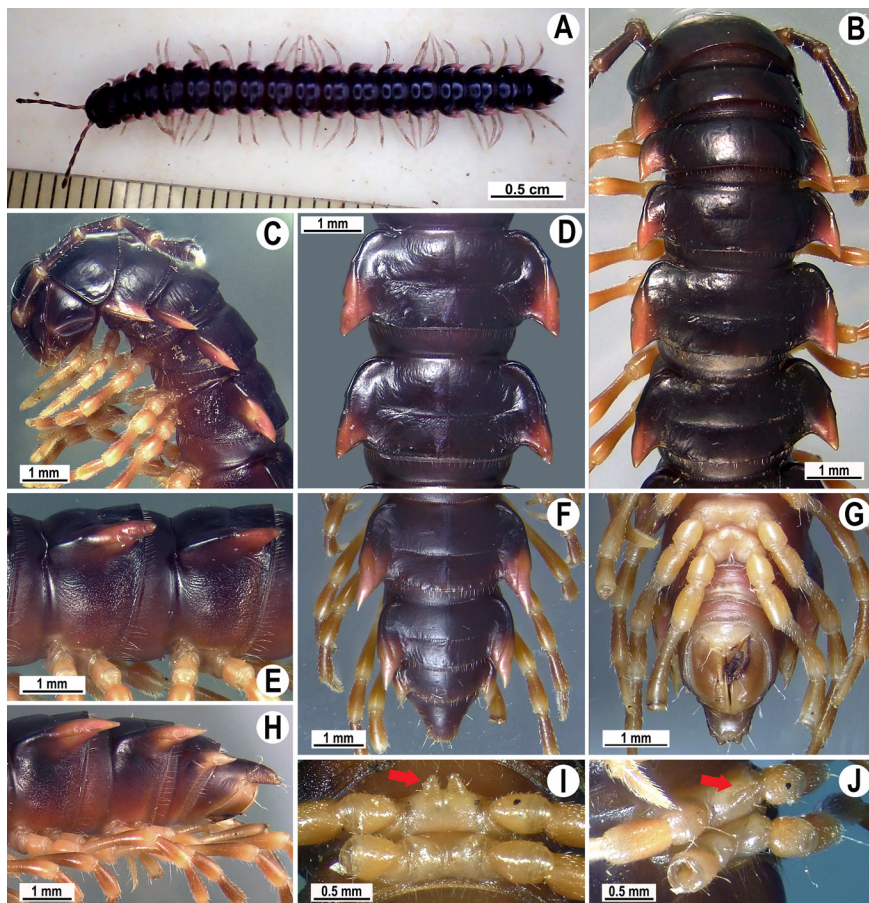


Fig. 8. *Gigantomorpha sayapensis* Ng & Likhitrakarn sp. nov., holotype, ♂ (SP 14835). **A.** Habitus, live colouration. **B–C.** Anterior part of body, dorsal and lateral views, respectively. **D–E.** Rings 10 and 11, dorsal and lateral views, respectively. **F–H.** Posterior part of body, dorsal, ventral and lateral views, respectively. **I–J.** Sternal cones between coxae 4 indicated by red arrows, caudal and sublateral views, respectively.

Material examined

Holotype

MALAYSIA • ♂; Borneo, Sabah, Kota Belud, Kinabalu Park, Sayap Substation; 6°09'8.9" N, 116°34'8.5" E; ca 1071 m a.s.l.; 10 Mar. 2023; T.H. Ng, F. Anthony and D. Bantason leg.; SP 14835.

Description

Length of holotype 35.3 mm, width of midbody pro- and metazona of holotype, 2.5 and 5.1 mm, respectively.

Colouration of living animal castaneous brown (Fig. 8A); with contrasting pale pinkish paraterga, antennae dark brown, venter and legs yellowish brown; colouration of alcohol material after seven months of preservation a little faded to red-brown castaneous; paraterga pale pinkish to pale red, antennae brown to light brown, venter and legs light brown to light yellowish (Fig. 8B–J).

Clypeolabral region and vertex sparsely setose, epicranial suture distinct. Antennae rather short (Fig. 8A–C), reaching body ring 4 when stretched dorsally. In length, antennomere $3 > 2 = 4 > 5 > 6 >> 1 = 7$. Interantennal isthmus ca 0.6 times diameter of antennal socket (Fig. 8B). In width, head $<$ ring $3 < 4 <$ collum $<$ ring $2 < 5 < 6 < 7$ –16 (Fig. 8B), thereafter body gently and gradually tapering. Collum

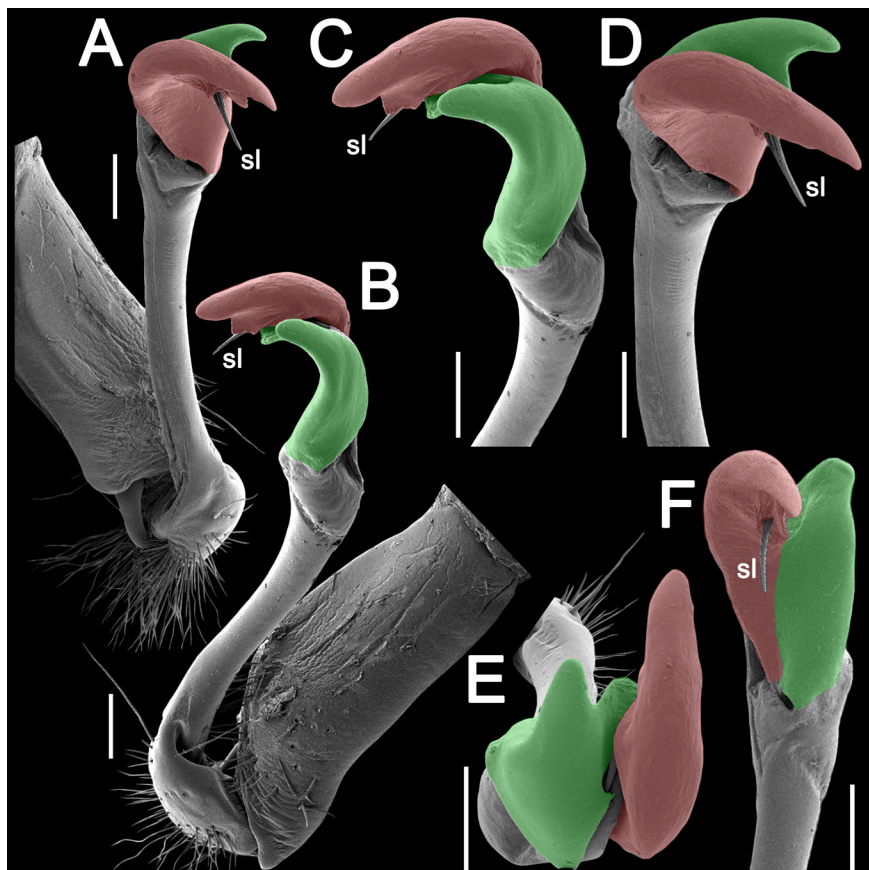


Fig. 9. *Gigantomorpha sayapensis* Ng & Likhitrakarn sp. nov., holotype, ♂ (SP 14835), left gonopod. A–B. Submesal and sublateral views, respectively. C–F. Distal part, sublateral, submesal, subcaudal and suboral views, respectively. Colours: red = lamina medialis (lm); green = lamina lateralis (ll). Abbreviation: sl = solenomere. Scale bars = 0.2 mm.

with three transverse rows of strong setae: 3+3 anterior, 2+2 intermediate, and 4+4 posterior; caudal corner very broadly rounded, paraterga declined ventrad, not produced past rear tergal margin (Fig. 8C).

Tegument rather smooth and shining, prozona delicately shagreened, metaterga smooth and leathery, posterior halves faintly rugulose, surface below paraterga microgranulate (Fig. 8A–F, H). Postcollum metaterga each with two transverse rows of setae: 2+2 in anterior and 3+3 in posterior row, setae in posterior row mostly abraded and borne on minute knobs or oblong wrinkles (Fig. 8B–F, H). Tergal setae rather short, strong, slender, about $\frac{1}{5}$ metatergal length. Axial line traceable both on pro- and metazona. Paraterga strongly developed (Fig. 8A–F, H), subhorizontal, slightly upturned posteriorly, always lying high, at upper $\frac{1}{3}$ midbody height, but remaining below dorsum; anterior edge broadly rounded and narrowly bordered, fused to callus; caudal corner almost completely to fully pointed, always extending past rear tergal margin, bent posteriad on rings 18 and 19; posterior edge oblique (Fig. 8B, D, F); paraterga thin blunt blades in lateral view, a little thicker only on pore-bearing rings (Fig. 8E). Calluses on paraterga delimited by a sulcus only dorsally, but on pore-bearing ring paraterga demarcated by sulci both dorsally and ventrally. Paraterga 2 broad, lateral edge with two small incisions at lateral edge (Fig. 8B), one in anterior $\frac{1}{3}$, the other at posterior $\frac{1}{3}$. Paraterga 3 and 4 each with an evident incision in anterior $\frac{1}{3}$ and a small knob in posterior $\frac{1}{3}$ (Fig. 8B). Lateral edge of paraterga of following rings

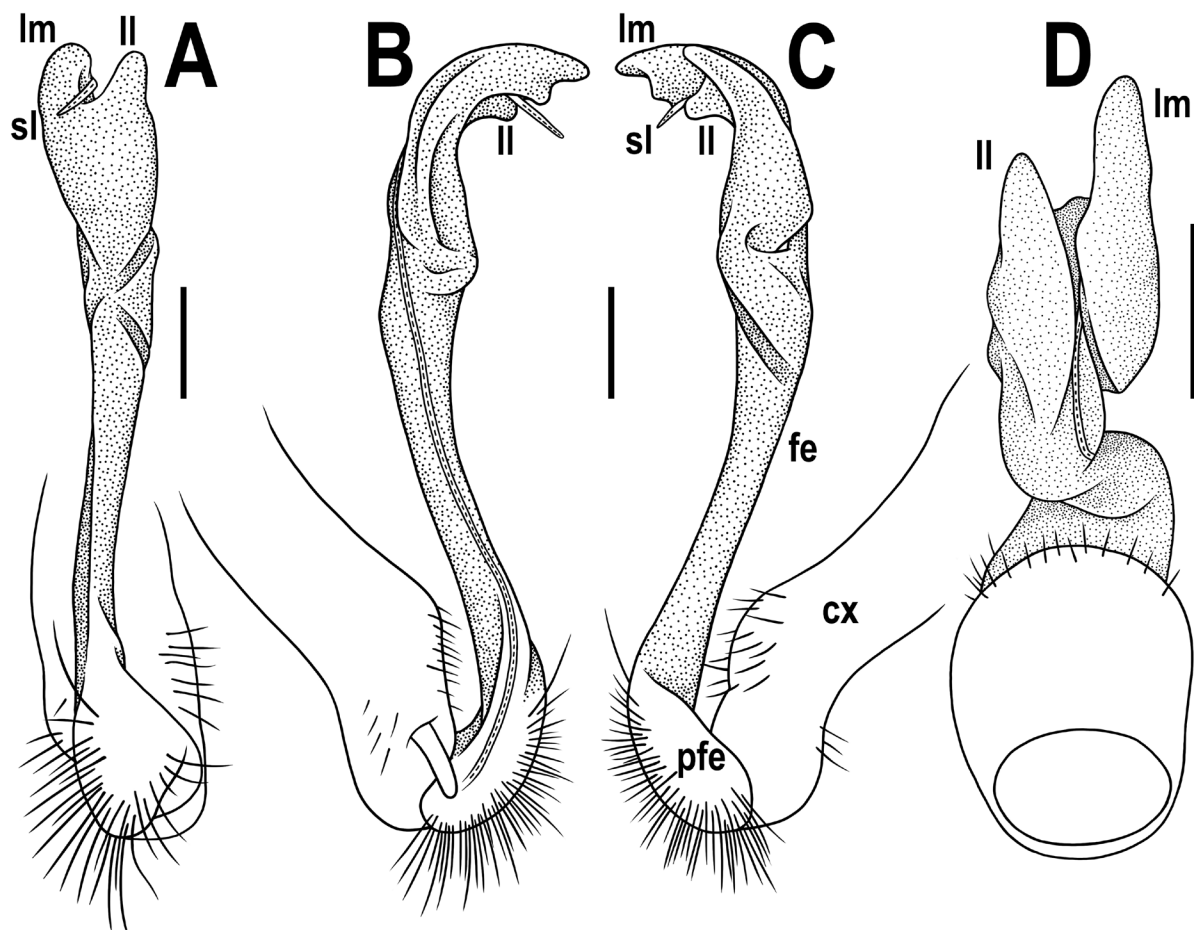


Fig. 10. *Gigantomorpha sayapensis* Ng & Likhitrakarn sp. nov., holotype, ♂ (SP 14835), left gonopod. A–D. Suboral, mesal, lateral and subcaudal views, respectively. Abbreviations: cx = coxa; fe = femoral part; ll = lamina lateralis; lm = lamina medialis; pfe = prefemoral part; sl = solenomere. Scale bars = 0.2 mm.

with two small incisions, one in anterior $\frac{1}{3}$, the other at midway, caudal incision in the pore-bearing rings smaller or gradually reduced in posterior rings (Fig. 8D, F). Ozopores evident, lateral, each lying in an ovoid groove at about $\frac{1}{3}$ metatergal length in front of posterior edge of metaterga (Fig. 8C, E, H).

Transverse metatergal sulci usually distinct (Fig. 8B, D, F), slightly incomplete on rings 4 and 19, complete and clearly visible on metaterga 5–18, rather deep and wide, reaching the bases of paraterga, arcuate, faintly beaded at bottom. Stricture between pro- and metazona narrow, deep, beaded at bottom down to base of paraterga (Fig. 8C–E). Pleurosternal carinae complete crests on ring 2, thereafter broken into an anterior bulge and a caudal tooth, both increasingly reduced until ring 7, thereafter missing (Fig. 8C, E, H).

Epiproct (Fig. 8F–H) conical, flattened dorsoventrally, subtruncate, with two evident apical papillae directed caudally, both pointed at tip; pre-apical papillae small, but evident, lying close to tip. Hypoproct subtrapeziform (Fig. 8G), small setigerous knobs at caudal edge well-separated and evident.

Sterna sparsely setose, without modifications (Fig. 8G); cross-impressions shallow; a sparsely setose and transverse lobe bearing a paramedian pair of evident, basally contiguous cones between male coxae 4 and a pair of small, separated cones near each coxa 5 (Fig. 8I–J). A paramedian pair of small, but evident tubercles in front of gonopod aperture. Legs long and slender, midbody legs ca 1.3–1.5 times as long as body height (Fig. 8A, C); prefemora without modifications; tarsal brushes present until legs of ring 18.

Gonopods (Figs 9–10) rather simple; coxa long and thick, subcylindrical, a little curved caudad, sparsely setose distoventrally (Figs 9A–B, 10A–C). Prefemoral part short, densely setose as usual, about $\frac{1}{4}$ as long as femoral part + postfemoral part (Fig. 10A–C). Femoral part long and slender, expanded distad, slightly curved, postfemoral part demarcated by an oblique lateral sulcus (Figs 9B–C, F, 10A, C); seminal groove running entirely mesally along the femoral part, solenomere (sl) flagelliform, fully sheathed by solenophore (sph). Lamina medialis (lm) well developed, prominent and unciform, terminal tip clearly bifid, terminal lobe a little larger than subterminal one (Figs 9A–D, E, 10B–C). Lamina lateralis (ll) unciform, shorter than lamina medialis (lm), bifid, with two subequal lobes (Figs 9, 10B–C).

Remarks

This species was collected from the ground, under a rotten branch, in a lower montane forest habitat on the western side of the Kinabalu Park complex (Fig. 1C).

Key to the presently known species of *Gigantomorpha* Jeekel, 1963 (modified after Golovatch 1996)

1. Gonopodal tip deeply and prominently bifid, with robust branches. Sternites modified, with a cone near each coxa 6
– Gonopodal tip very small, bi- to trifold, with reduced and less distinct branches (Figs 3–4, 6–7, 9–10). Sternites typical, generally without cones near coxae but with exceptions 2
2. Larger: midbody width 5.5–5.6 mm. Pleurosternal carinae present until ring 10. Sternites modified, with a cone near each coxa. Male tarsal brushes absent *G. transmontana* Jeekel, 1982
– Smaller: midbody width at most 5.1 mm. Pleurosternal carinae present (not extending beyond ring 8). Sternites typical, without cones near coxae. Male tarsal brushes present at least until legs of ring 4 3
3. Smaller: midbody width 2.8–3.2 mm (♂, ♀). Sternal cones between male coxae 4 fused basally into a single lamina. Male tarsal brushes present until legs of ring 4. Bali . *G. mutilata* Golovatch, 1996
– Larger: midbody width at least 3.6 mm (♂). Sternal cones between male coxae 4 isolated (Figs 2H–I, 5H–I, 8I–J). Male tarsal brushes present at least until legs of ring 16. Sabah, northern Borneo .. 4

4. Smaller: midbody width 3.6–4.4 mm (♂, ♀). Paraterga less strongly bordered (Fig. 5A, C, F). Sternal cones present only between male coxae 4. Gonopodal lamina lateralis (ll) and lamina medialis (lm) subequal in length, long and slender (Fig. 7A) *G. mesilauensis* Ng & Likhitrakarn sp. nov.
 – Larger: midbody width at least 4.8 mm. Paraterga especially strongly bordered (Figs 2A, C, F, 8B, D, F). Sternal cones present between both male coxae 4 and 5. Gonopodal lamina medialis (lm) larger than lamina lateralis (ll), expanded apically (Figs 3A–D, 4A–B, 9A–D, F, 10A–C) 5
5. Pleurosternal carinae present until ring 7. Male legs shorter, ca 1.3–1.5 times as long as midbody height. Male tarsal brushes present until legs of ring 18. Gonopodal lamina lateralis (ll) unciform, tip, with two subequal apical lobes (Figs 9, 10B–C) *G. sayapensis* Ng & Likhitrakarn sp. nov.
 – Pleurosternal carinae present until ring 4. Male legs longer, ca 1.5–1.7 times as long as midbody height. Male tarsal brushes present until legs of ring 16. Gonopodal lamina lateralis (ll) with a single subtruncate tip (Figs 3A, C, 4B) *G. alabensis* Ng & Likhitrakarn sp. nov.
6. Lateral edges of collum rounded caudally. Paraterga 2 directed somewhat ventrad, lying distinctly below level of paraterga 3. Male femora straight 7
 – Lateral edges of collum angular caudally. Paraterga 2 somewhat upturned, nearly level to paraterga 3. Male femora distinctly arched 8
7. Smaller: midbody width 5.0–5.4 mm (♂, ♀). A pattern of 4(5)+4(5) very small tubercles near caudal margin of metaterga. Paraterga set relatively low (at about mid-height on male ring 4), below them almost all rings with an irregular row of setae along caudal margin. Pleurosternal carinae present until ring 17 *G. trichopleura* Jeekel, 1963
 – Larger: midbody width 6.3–8.0 mm (♂, ♀). Usually 3+3 larger tubercles near caudal margin of metaterga. Paraterga clearly set higher (at about 1/3 height on male ring 4), without setae below them. Pleurosternal carinae present until ring 14 or 15 *G. spinescens* Jeekel, 1963
8. Body ring dark brown to blackish, with paraterga and a middorsal band pale brownish. Gonopodal femoral part rather strongly constricted about midlength *G. fasciata* (Attems, 1898)
 – Colouration rings in ethanol without continuous middorsal pale band. Gonopodal femoral part without constriction 9
9. Colouration in ethanol uniformly blackish, with only the caudal corners of the paraterga brown. Male proximal podomeres covered with short, curved setae, femora less strongly arched
 *G. aterrima* Jeekel, 1963
 – Colouration in ethanol not uniformly dark; dorsum may be somewhat paler, occasionally with a pale central spot on prozonites, or dark with contrasting yellow areas. Paratergal caudal corners always yellowish. Male legs with long, erect setae, and femora more strongly arched 10
10. Pleurosternal carinae present until ring 16 or 17 11
 – Pleurosternal carinae present until ring 14 or 15 12
11. Colouration of dorsum rather uniformly pale brownish gray. Paraterga distinctly projecting caudally past rear tergal margin from ring 11 or 12 onwards. East Borneo *G. pallida* Jeekel, 1963
 – Colouration black-brown with caudal corners of paraterga yellow. Paraterga extending caudally past rear tergal margin from ring 15 onwards. South Sulawesi *G. socialis* (Carl, 1912)
12. Paraterga largely strongly elevated above dorsum. Pleurosternal carinae present until ring 14 or 15. Male legs more slender, proximal podomeres without ventral brushes of setae
 *G. cornalata* Jeekel, 1963
 – Paraterga more or less level to dorsum. Pleurosternal carinae present until ring 9 or 10. Male legs more strongly incrassate, with ventral brushes on all podomeres *G. immanis* Jeekel, 1963

Genus *Orangutana* Golovatch, 1996

Orangutana Golovatch, 1996: 164 (D).

Orangutana – Shelley *et al.* 2000: 116 (L). —Nguyen & Sierwald 2013: 1246 (L).

Type species

Orangutana setosa Golovatch, 1996, by original designation.

Amended diagnosis

Body small to medium-sized (ca 11–35 mm long, ca 0.9–5.1 mm wide), with 20 rings. Paraterga from moderately to strongly developed. Transverse metatergal sulci distinct. Legs relatively long and slender, without modifications. Adenostyles absent. Sternal lamina present only between male coxae 4. Postcollum metaterga each with a dense row of uniform setae at posterior margin.

Gonopods simple to relatively complex; coxa long and subcylindrical, sparsely setose distoventrally, without tubercles; prefemoral part of telopodite densely setose, relatively short, $1/4$ – $1/5$ as long as acropodite; femoral part very long and slender, without evidence of torsion (= seminal groove running only mesally); solenophore hypertrophied due to both a well-developed lamina lateralis and a distally strongly notched lamina medialis, both laminae sheathing most of a relatively short and flagelliform solenomere; free solenomere branching off proximally, not extended to the same height as the sulcus demarcating the solenophore.

Other species included

Orangutana koropungoi Ng & Likhitrakarn sp. nov.

Orangutana koropungoi Ng & Likhitrakarn sp. nov.

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Figs 11–13

Diagnosis

This new species strongly resembles *Orangutana setosa*, with which it appears to share most of the gonopodal characteristics. However, the new species is distinguished from *O. setosa* by its considerably larger body measuring 35.3 mm in length (vs smaller, 11–12 mm), the colour pattern which is black to dark brown with contrasting lighter red-brown paraterga (Fig. 11A–H) (vs a uniformly pale yellowish brown to pale brown body), the longer antennae, in situ reaching body ring 4 (Fig. 11A, C) (vs only past body ring 2), as well as the pleurosternal carinae being with complete crests, each with an evident, sharp, caudal denticle produced past the rear tergal margin on rings 2–4, gradually decreasing in size until rings 7 (♂) or 4 (♀) (Fig. 11C, E, H) (vs completely absent), male sterna without modifications (vs male sterna show vestigial rounded knobs near the coxae starting with ring 8 onwards).

Etymology

“Koropungoi” is a vernacular name commonly used in the central Dusun language, which is spoken by people indigenous to the area around Gunung Alab and Mount Kinabalu, to denote a small millipede; noun in apposition.

Material examined

Holotype

MALAYSIA • ♂; Borneo, Sabah, Tambunan, Crocker Range Park, Gunung Alab Substation; 5°49'17.6"N, 116°20'29.4"E; 1904 m a.s.l.; 19 Mar. 2023; T.H. Ng, T.S. Liew and F. Anthony leg.; BOR/MYR 44.

Paratypes

MALAYSIA • 1 ♀; Borneo, Sabah, Tambunan, Crocker Range Park, Gunung Alab Substation, along Minduk Sirung Trail; 5°49'4.52" N, 116°21'52" E; 1918 m a.s.l.; 20 Mar. 2023; T.H. Ng, T.S. Liew and F. Anthony leg.; SP 14831 • 1 ♂; Borneo, Sabah, Ranau, Mesilau Nature Resort, Nepenthes Trail; 6°02'45.4" N, 116°35'49.1" E; 1926 m a.s.l.; 26 Sep. 2023; T.H. Ng, F. Anthony, E.S.H. Quah, J. Dulipat, F.J. Chong, A. Joseph and C.L. Soo leg.; BOR/MYR 891 • 1 ♂; same data as for preceding; SP 14833 • 2 ♀♀; same data as for preceding; BOR/MYR 86, 88 • 1 ♀; same data as for preceding; SP 14834 • 2 ♀♀; Borneo, Sabah, Ranau, Mesilau Nature Resort, Tambang Gate; 6°02'41.7" N, 116°35'45.0" E; 1922 m a.s.l.; 27 Sep. 2023; T.H. Ng, F. Anthony and F.J. Chong leg.; BOR/MYR 109, 110 • 1 ♀; Borneo, Sabah, Tambunan, Crocker Range Park, Gunung Alab Substation, Nepenthes Trail; 5°49'21.4" N, 116°20'30.5" E; ca 1900 m a.s.l.; 26 Mar. 2024; T.H. Ng and F. Anthony leg.; BOR/MYR 137 • 1 ♂; same data as for preceding; 27 Mar. 2024; BOR/MYR 138 • 1 ♂; Borneo, Sabah, Tambunan, Crocker Range Park, Gunung Alab Substation, along road up to substation; 5°49'14.52" N, 116°21'52" E; ca 1800 m a.s.l.; 27 Mar. 2024; T.H. Ng and F. Anthony leg.; BOR/MYR 144.

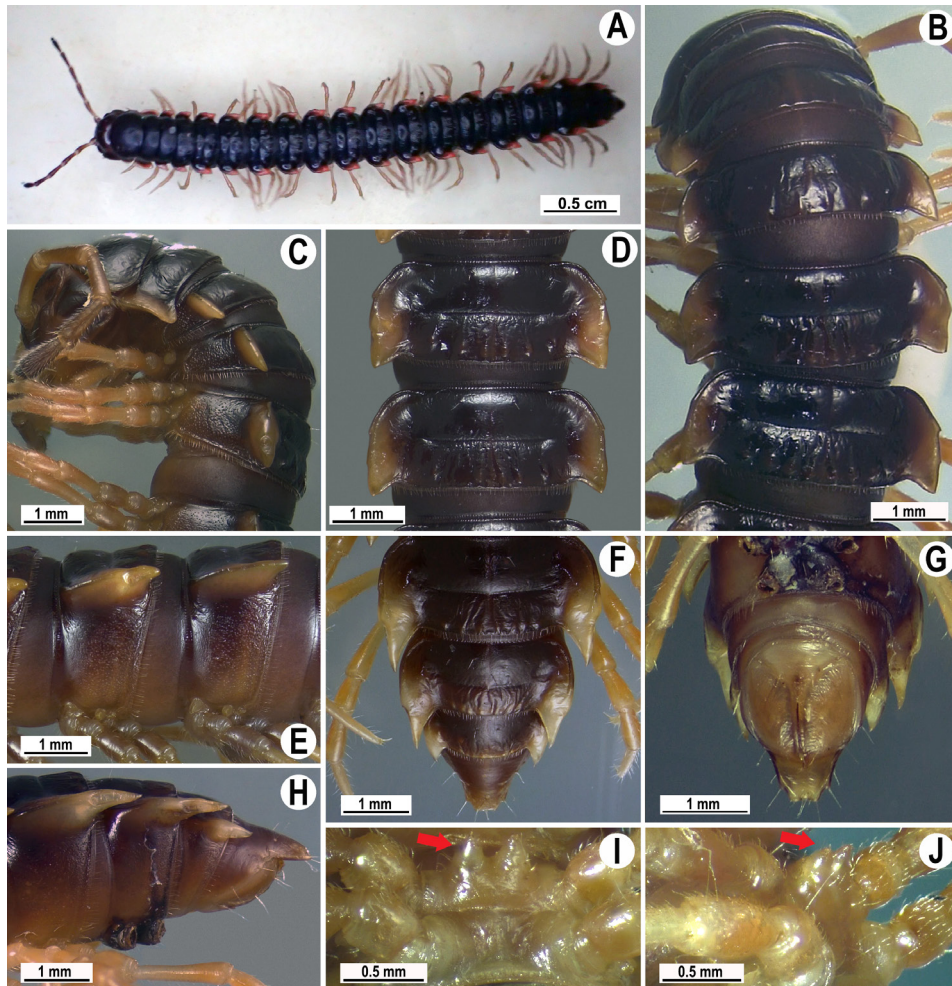


Fig. 11. *Orangutana koropungoi* Ng & Likhitrakarn sp. nov., holotype, ♂ (BOR/MYR 44). **A.** Habitus, live colouration. **B–C.** Anterior part of body, dorsal and lateral views, respectively. **D–E.** Rings 10 and 11, dorsal and lateral views, respectively. **F–H.** Posterior part of body, dorsal, ventral and lateral views, respectively. **I–J.** Sternal cones between coxae 4 indicated by red arrows, subcaudal and sublateral views, respectively.

Description

Length 30.6–32.5 mm (♂) or 26.8–34.8 mm (♀), width of midbody pro- and metazona 2.2–2.7 and 3.3–3.6 mm (♂) or 2.6–3.5 and 3.2–4.3 mm (♀), respectively.

Colouration of live animals blackish (Fig. 11A); with contrasting pale red paraterga, antennae brown, venter and legs yellowish brown; colouration of alcohol material after seven months of preservation faded to castaneous brown; paraterga yellowish brown to pallid, antennae light, venter and legs light brown to light yellowish (Fig. 11B–J).

Clypeolabral region and vertex sparsely setose, epicranial suture distinct. Antennae rather short (Fig. 11A), reaching body ring 4 (♂, ♀) when stretched dorsally. In length, antennomere $2 > 3 = 4 > 5 > 6 \gg 1 = 7$. Interantennal isthmus ca 0.6 times diameter of antennal socket (Fig. 12A). In width, head $<$ collum $<$ ring 3 $<$ 2 $<$ 4 $<$ 5 $<$ 6 $<$ 7–16 (Fig. 11A–B), thereafter body gently and gradually tapering (♂, ♀). Collum with three transverse rows of strong setae: 3+3 anterior, 2+2 intermediate, and 4+4 posterior; caudal corner very broadly rounded, paraterga declined ventrad, not produced past rear tergal margin (Fig. 11A, C).

Tegument rather smooth and shining, moderately rugulose only near transverse sulcus, prozona delicately shagreened, metaterga smooth and leathery, posterior halves often rugulose, surface below

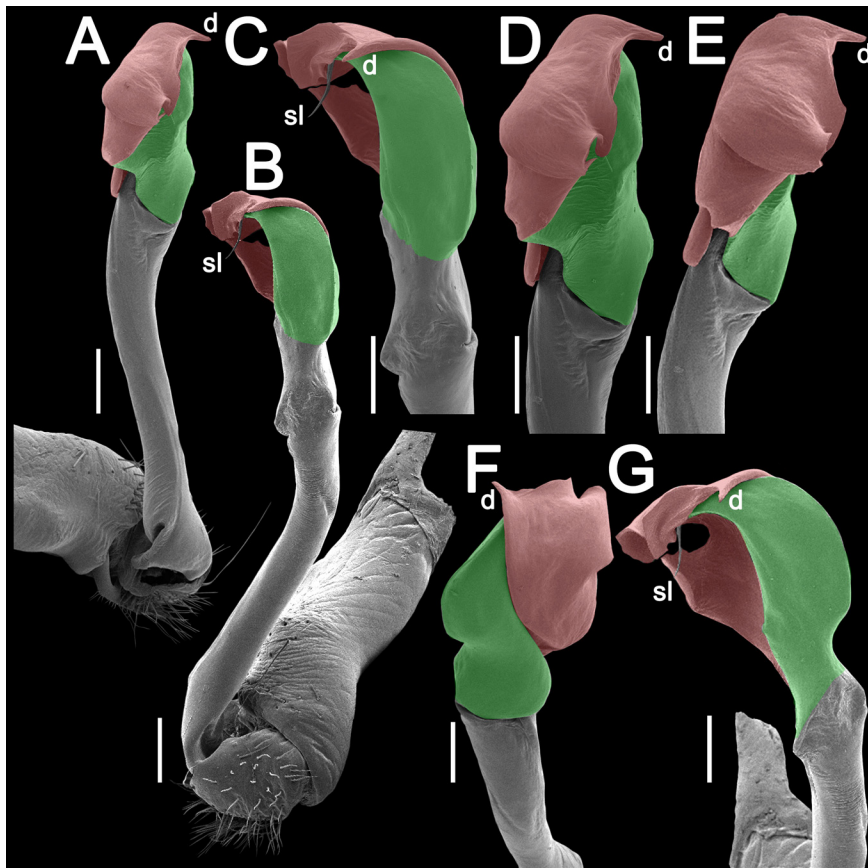


Fig. 12. *Orangutana koropungoi* Ng & Likhitrakarn sp. nov., holotype, ♂ (BOR/MYR 44), left gonopod. A–B. Submesal and sublateral views, respectively. C–G. Distal part, sublateral, sublateral, submesal, subcaudal and suboral views, respectively. Colours: red = lamina medialis (lm); green = lamina lateralis (ll). Abbreviations: d = denticulate process; sl = solenomere. Scale bars = 0.2 mm.

paraterga microgranulate (Fig. 11A–F, H). Postcollum metaterga each with two uniform and transverse rows of setae: 2+2 in anterior, 3+3 in posterior row (Fig. 11B–H); setae in posterior row borne on knobs, which become increasingly crestlike towards the telson, these reaching the transverse sulcus, but then gradually decreasing in size towards ring 19 (Fig. 11B, D, F).

Tergal setae short, strong, slender, about $\frac{1}{6}$ metatergal length. Axial line traceable both on pro- and metazona. Paraterga strongly developed (Fig. 11A–F, H), subhorizontal, slightly upturned posteriorly, always lying high, at upper $\frac{1}{3}$ midbody height, but remaining below dorsum; anterior edge well-developed, mostly nearly straight and narrowly bordered, fused to callus (Fig. 11B, D); caudal corner of most paraterga very narrowly rounded, extending increasingly posterior tergal margin, slightly curved mesad on rings 14–19 (Fig. 11F), posterior edge oblique (Fig. 11D, F); paraterga very thin blunt blades in lateral view, a little thicker only on pore-bearing rings (Fig. 11E). Calluses on paraterga delimited by a sulcus only dorsally. Paraterga 2 broad, anterior edge convex, lateral edge with four small acute denticles. Following poreless rings each with two small incisions at lateral edge (Fig. 11B), one larger in

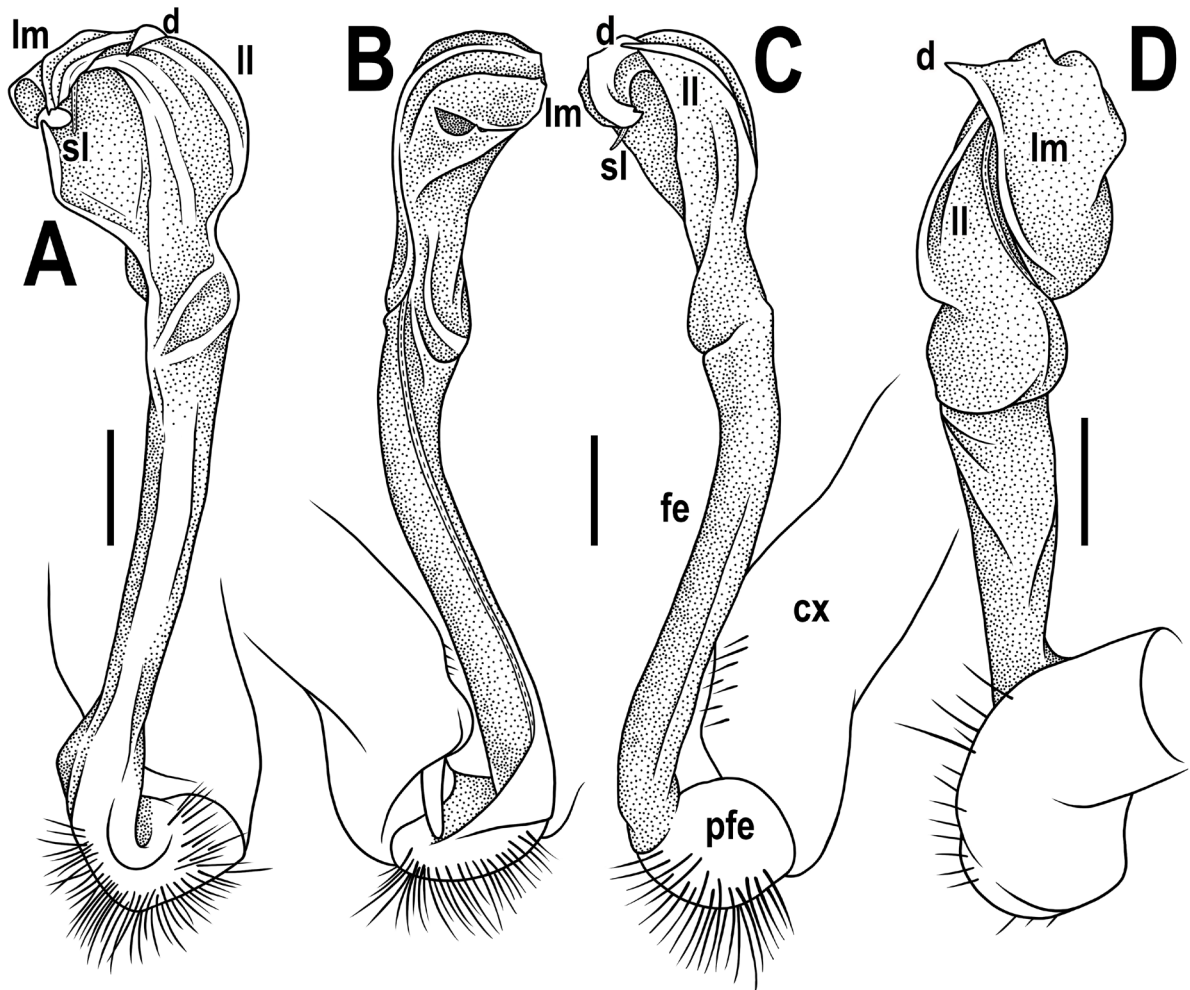


Fig. 13. *Orangutana koropungoi* Ng & Likhitrakarn sp. nov., holotype, ♂ (BOR/MYR 44), left gonopod. A–D. Suboral, mesal, lateral and subcaudal views, respectively. Abbreviations: cx = coxa; d = denticulate process; fe = femoral part; ll = lamina lateralis; lm = lamina medialis; pfe = prefemoral part; sl = solenomere. Scale bars = 0.2 mm.

anterior $\frac{1}{3}$, the other smaller at posterior $\frac{1}{3}$. Lateral edge of paraterga of following poreless rings with only one small incision near midway (Fig. 11D).

Ozopores evident, lateral, each lying in an ovoid groove at about $\frac{1}{3}$ metatergal length in front of posterior edge of metaterga (Fig. 11C, E). Transverse metatergal sulci usually distinct (Fig. 11B, D, F), slightly incomplete on rings 4 and 18, complete and clearly visible on metaterga 5–17, rather deep, reaching the bases of paraterga, ribbed at bottom. Stricture between pro- and metazona rather wide, deep, beaded at bottom down to base of paraterga (Fig. 11C–E). Pleurosternal carinae complete crests on rings 2–4, thereafter missing (♀) or broken into an anterior bulge and a caudal tooth, both increasingly reduced until ring 7, thereafter missing (♂) (Fig. 11C, E, H).

Epiproct (Fig. 11F–H) conical, flattened dorsoventrally, subtruncate, with two evident apical papillae directed caudally, both pointed at tip; pre-apical papillae small, but evident, lying close to tip. Hypoproct subtrapeziform (Fig. 11G), small setigerous knobs at caudal edge well-separated and evident.

Sterna sparsely setose, without modifications; cross-impressions shallow; a sparsely setose, transverse lobe bearing a paramedian pair of evident, basally contiguous cones between male coxae 4 (Fig. 11I–J). A paramedian pair of small, but evident tubercles in front of gonopod aperture. Legs long and slender, midbody legs ca 1.2–1.4 (♂) or 1.1–1.3 (♀) times as long as body height, prefemora without modifications, tarsal brushes present until legs 7.

Gonopods (Figs 12–13) rather complex; coxa long and thick, subcylindrical, a little curved caudad, sparsely setose distoventrally (Figs 12A–B, 14). Prefemoral part very short, densely setose about $\frac{1}{5}$ as long as femoral part + postfemoral part (Figs 12A–B, 14A–C). Femoral part long and slender, slightly curved distad, postfemoral– part demarcated by a very faint and oblique lateral sulcus (Figs 12B, E–F, 13C); seminal groove running entirely mesally along the femoral part, solenomere (sl) flagelliform, fully sheathed by solenophore (sph). Solenophore hypertrophied composed of both well-developed lamina lateralis and lamina medialis. Lamina medialis (lm) well developed, thick and large, unciform, expanded apically, terminal tip clearly bifid, subterminal lobe smaller than terminal one, triangular in shape and pointed at tip; with a strong, sharp and denticulate process (d) at caudal edge (Figs 12–13). Lamina lateralis (ll) thick and large, expanded apically, set lower than lamina medialis, both laminae supporting and sheathing most of solenomere (Figs 12, 13A, C–D).

Remarks

This species was found at the Gunung Alab Substation (Fig. 1C), which primarily consists of mossy, montane forest habitats and experiences limited periods of sunlight and extensive fog cover throughout the day (Majuakim & Anthony 2016). One individual was found inside a small building which houses the office and guesthouse, adjacent to forest trails, and together with *Gigantomorpha alabensis* sp. nov., while the others were revealed under rotten logs along forest trails or by the roadside. The species was also found in the eastern part of the Kinabalu Park complex, at Mesilau (Fig. 1C). *Orangutana setosa*, was reported from lowland areas in Sepilok, Sandakan, in eastern Sabah, approximately 180 km away from the type locality of the new species.

Orangutana setosa Golovatch, 1996

Fig. 14

Orangutana setosa Golovatch, 1996: 164 (D).

Orangutana setosa – Shelley *et al.* 2000: 116 (M). — Nguyen & Sierwald 2013: 1246 (L).

Remarks

This species was described from Sepilok, Sandakan, in eastern Sabah, ca 50 m a.s.l., 5°51'54" N, 117°56'55" E (Golovatch 1996). The type locality is located within the Sepilok Orang Utan Rehabilitation Centre, which was established in 1964 as the first official orang utan initiative to rescue and rehabilitate orphaned juvenile orang utan for eventually returning to the wild (Sabah Wildlife Department 2021).

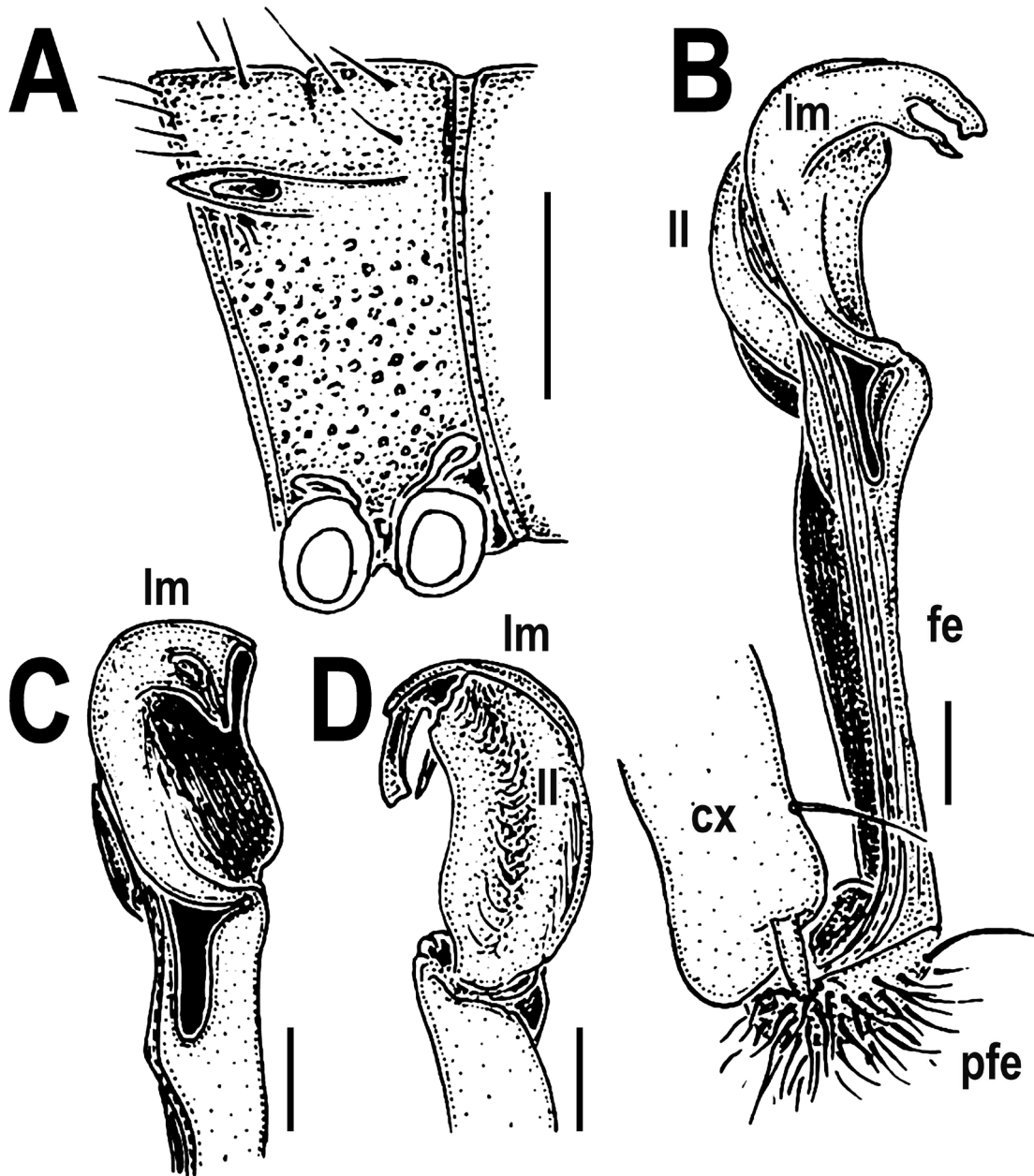


Fig. 14. *Orangutana setosa* Golovatch, 1996, paratype, ♂ (MNHG). **A.** Ring 10, lateral view. **B–D.** Left gonopod. **B.** Mesal view. **C–D.** Distal part, sublateral and subventral views, respectively. Abbreviations: cx = coxa; fe = femoral part; ll = lamina lateralis; lm = lamina medialis; pfe = prefemoral part. Scale bars = 0.2 mm (after Golovatch 1996, modified).

Discussion

This study significantly expands our knowledge of Paradoxosomatidae millipede diversity in Sabah, Malaysia, with the description of one new species of genus *Orangutana* and three new species of genus *Gigantomorpha*. These discoveries, all originating from the protected montane forests of Kinabalu Park and Crocker Range Park, represent the first new paradoxosomatid millipedes record from Sabah, and Borneo, in nearly three decades, highlighting the potential for continued taxonomic discoveries in the region.

Prior to this study, seven species of paradoxosomatids have been recorded from Sabah (Golovatch 1996). The only past record of *Gigantomorpha* from Sabah, *G. immanis*, was also collected from the Crocker Range, approximately 50 km west of the type locality of both *Orangutana koropungoi* sp. nov. and *Gigantomorpha alabensis* sp. nov. That type locality is located in the mossy, montane (cloud) forests of Mount Alab, a characteristic habitat above altitudes of 1200 m in the Crocker Range Park, which was first gazetted as a forest reserve in 1967 and later designated as a state park in 1984 (Mohamed *et al.* 2004; Majuakim & Anthony 2016; Sabah Parks 2023a). *Orangutana koropungoi* was also collected from the eastern part of Kinabalu Park at Mesilau, which may indicate a wider distribution between the central Crocker Range and the Kinabalu Park area. *Gigantomorpha sayapensis* sp. nov. was taken from the dipterocarp hill forests at the Sayap Substation, at the northwestern edge of Kinabalu Park, which was gazetted as a state park in 1964 (Sabah Parks 2023b). *Gigantomorpha mesilauensis* sp. nov. was collected from montane forests of the eastern Kinabalu Park from 1300 to more than 2000 m a.s.l. at Mesilau and the Mount Tambuyokon area, which is next to Mount Kinabalu. The areas around Mount Alab (Crocker Range) and Sayap are likely to have been uplifted in the Miocene (Breitfeld *et al.* 2023).

While our findings increase the total number of known Paradoxosomatidae species in Sabah to eleven, the limited number of documented locations (currently only nine, Fig. 1) suggests a high probability of further, yet undiscovered species or records, or both, particularly in the still unexplored mountainous regions. This emphasises the need for taxonomic research in Sabah to fully elucidate the diversity and distribution of this fascinating millipede family. The discovery of new species underscores the importance of these protected montane habitats for preserving the unique biodiversity and the ecological roles these millipedes play within their environments.

Future studies should focus on comprehensive surveys and molecular analyses to better understand the phylogenetic relationships and biogeographic patterns of Paradoxosomatidae millipedes in Southeast Asia. Such research can inform targeted conservation strategies, such as habitat preservation and management efforts, by identifying biodiversity hotspots and areas of endemism, as well as highlighting species that may be at higher risk of extinction.

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