



## Whip spiders of the genus *Sarax* Simon 1892 (Amblypygi: Charinidae) from Borneo Island

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### Abstract

Five species of the whip spider genus *Sarax* are recognized from Borneo, with the following four species newly described: *Sarax yayukae* **sp. nov.** from Sabah (Malaysia), West and Central Kalimantan (Indonesia), and three species from East Kalimantan, *S. cavernicola* **sp. nov.**, *S. sangkulirangensis* **sp. nov.**, and *S. mardua* **sp. nov.**. *Sarax mardua* and *S. cavernicola* have pale coloration, reduced eyes and elongate legs suggesting troglomorphic adaptations to cave environments. The characters diagnosing the family Charinidae and the genus *Sarax* are discussed and revised. The distribution patterns of *Sarax* species in Southeast Asia, especially in Borneo Island, are discussed in relation to their habitat preferences. The generic status of *Stygophrynus moultoni* Gravelly 1915 (Charontidae) is briefly discussed.

**Key words:** Caves, troglomorphic species, taxonomy, new species, *Stygophrynus*

### Introduction

Whip spiders (Amblypygi) are bizarre arachnids found in tropical and subtropical regions of the world that have a peculiar external appearance characterized by their dorso-ventrally flattened body, strong raptorial pedipalps armed with spines, and the first legs extremely elongate and antenniform (Weygoldt 2000). The whip spider fauna of Borneo Island is currently represented by only two species of different genera in different families: *Sarax sarawakensis* (Thorell 1888) (Charinidae) from Sarawak (Malaysia) and *Stygophrynus moultoni* Gravelly 1915 (Charontidae) from Klingkang Range (Indonesia) near the border of Sarawak and West Kalimantan.

Southeast Asian whip spiders have been poorly studied, and we expect that many further species are to be found in Borneo. The present study focuses on the species *Sarax* Simon 1892 collected from Borneo. *Sarax* is one of the three valid genera recognized in the family Charinidae (Harvey 2003). We have recognized five species of *Sarax* in Borneo Island, of which four are herewith described as new. The characters diagnosing the family Charinidae and the genus *Sarax* are discussed and revised. The generic status of *Stygophrynus moultoni* is also briefly discussed.

### Material and methods

The present study was based on the specimens mainly collected by the first author and deposited in the Museum Zoologicum Bogoriense, Bogor, Indonesia (abbreviated as MZB) and the Muséum National

d'Histoire Naturelle, Paris, France (MNHN) but also those loaned from the Field Museum of Natural History, Chicago, USA (FMNH) and California Academy of Sciences, San Francisco, USA (CAS). An important specimen in the Museo Civico di Storia "Giacomo Doria", Genova, Italy (MCSG) was also examined by CR during a visit to Genova in 2009.

The measurements and drawings were made using, respectively, an ocular micrometer and a drawing tube mounted on a stereoscopic dissecting microscope (Olympus SZX12). The structure of the genitalia was examined by lifting the genital operculum. General terminology and the pedipalpal spination follow Weygoldt (2000), and the pedipalpal terminology follows Harvey and West (1998). The following abbreviations are used to describe the trichobothria present on each segment (Weygoldt 1970): basitibia (*bt*, basitibial); distitibia (*bf*, basofrontal; *bc*, basocaudal; *sbf*, subbasofrontal; *sbc*, subbasocaudal; *stc*, subterminocaudal; *stf*, subterminofrontal; *sc*<sub>1-x</sub>, series caudal and trichobothria present; *sf*<sub>1-x</sub>, series frontal and trichobothria present).

*Comparative material:* *Sarax brachydactylus* Simon 1892: 1 female (FMNH), PHILIPPINES: *Palawan Province*: Palawan Island, Bacangan Puerto Princesa, first growth Casuarina forest in/under rotten logs near sea level, F. Werner, 22 March 1947, Philippines Zoological Expedition (1946–7) (*Sarax* sp., det. P. Weygoldt 1998), 1 specimen (MNHN-Am.13), CAMBODIA: labeled "Sré Umbell, Cambodge, Mars 1939, Mission C. Dawydoff, 1938/39, Indochine" (Fage det.), 1 juvenile (MNHN-Am.14), labeled "Poulo Dama, Nov. 1938, Golfe du Siam, Mission C. Dawydoff, Indochine 1938-39" (Fage det.); 6 males/females (MNHN-Am.15), labeled "Réam, Cambodge, Avril 1939, Mission Dawydoff, Indochine, 1938/39" (Fage det.).

## Taxonomy

### Family Charinidae Quintero 1986

#### History of higher taxon classification

Quintero (1986) proposed the family Charinidae to harbor the following seven genera: *Paracharon* Hansen, *Tricharinus* Quintero, *Catageus* Thorell, *Phrynichosarax* Gravely, *Charinides* Gravely, *Sarax* Simon and *Charinus* Simon. All these genera, except *Paracharon* and *Tricharinus*, had been previously placed in the family Charontidae (Pocock 1900, 1902, Mello-Leitão 1931). Weygoldt (1996) cladistically analyzed characters in the Amblypygi and presented relationships among whip spider genera. He proposed a new higher-level (at and above the family level) classification system, in which his phylogenetic hypothesis can be expressed as (Paracharontidae + (Charinidae + (Charontidae + (Phrynidae + Phrynichidae))). However, the family Charinidae was not supported by any apomorphic characters in Weygoldt's (1996) analysis. The Charinidae is defined by (1) the three major spines of the pedipalpal patella decreasing in length proximally, (2) the pedipalpal tarsus having one to three dorsal spines, (3) the tibia of the first leg with up to 23 segments, and (4) the anterior margin of the carapace rounded; all of which are plesiomorphic in the Amblypygi other than the family Paracharontidae which consists of only *Paracharon*. As discussed later, one of the new species described here removes the first character from the diagnostic characters for the family. The last character, gradually varying among Amblypygi genera, is also poorly defined. With this ambiguity of Charinidae as a taxon in mind, we summarize the current status of the genera in the family before we move to *Sarax* species in Borneo.

Weygoldt (1996) showed that *Charinus*, *Tricharinus* and *Charinides* share an apomorphic character, namely, the absence of the ventral sacs on the third abdominal sternite. Weygoldt (2000) synonymized *Tricharinus* under *Charinus*. This synonymy and Delle Cave's (1986) synonymy of *Charinides* with *Charinus*, though Baptista and Giupponi (2002) doubted these synonymies, have been widely accepted (Weygoldt *et al.* 2002; Harvey 2003; Weygoldt & Van Damme 2004; Weygoldt 2005). The genus *Catageus* is also characterized by the absence of ventral sacs on the third abdominal sternite (Weygoldt 1996) but Weygoldt (1996) questioned the placement of this genus in the Charinidae. With the transfer of *C. rimosus* Simon to *Sarax* [spelt as *Catageus rimosus*], only the type species *C. pusillus* Thorell from Myanmar

remains in *Catageus* (Harvey 2003). *Catageus pusillus* has the pedipalpal spines distinctly different from that of all other species and genera of Charinidae as follows: the second spine of the pedipalpal patella is the largest and the proximal spine of the antero-dorsal pedipalpal tibia is larger than the distal one (Gravely 1915, Weygoldt 2000).

Simon (1892) proposed two new genera, *Sarax* and *Charinus*, in his subfamily Charontinae Simon 1892 (currently treated as a family, see Harvey 2003) along with two other genera, *Charon* Karsch and *Catageus*. Weygoldt (1996, 2000, 2002) considered that *Phrynichosarax* is a junior synonym of *Sarax* and he (Weygoldt 2002) transferred *P. buxtoni* Gravely to *Sarax*. Harvey (2003) referred to Weygoldt's (2000) synonymy of *Phrynichosarax* with *Sarax*, but Harvey (2003) officially synonymized the two genera by transferring all of the remaining four species-group taxa previously placed in *Phrynichosarax* to *Sarax*.

With 11 species and one subspecies currently recognized, *Sarax* whip spiders are distributed in the Oriental and Papuan region (India to the Solomon Islands) (Harvey 2003; Rahmadi & Kojima in press). Harvey (2003) included *S. mediterraneus* Delle Cave 1986, from Greece in the genus, but Weygoldt (2005) considered the taxon to be a synonym of an Oriental species and doubted the locality data of the type specimen. Although further intensive studies are necessary to establish concepts of amblypygid taxa at supra-species level, the genus *Sarax* is diagnosed below.

### ***Sarax* Simon 1892**

*Sarax* Simon 1892: 43; Harvey 2003: 7; Rahmadi and Kojima in press.

**Type species:** *Sarax brachydactylus* Simon 1892, by original designation.

*Phrynichosarax* Gravely 1915: 437 (synonymised by Weygoldt 2000: 25).

**Type species:** *Phrynichosarax cochinchensis* Gravely 1915, by original designation.

**Diagnosis:** Small to medium-sized whip spiders, adult body length less than 10 mm, but sometimes longer than 15 mm in cave-dwelling species; pedipalpal patella with three large primary spines, of which the distal spine is largest and the subsequent spines become shorter proximally or all of which are about equal in size; pedipalpal tibia with two dorsal spines and one ventral spine; pedipalpal tarsus clearly divided into two parts; tibial segments of leg I with 23 segments; basitibia of leg IV consisting of three or four segments; the uppermost cheliceral tooth bicuspid, the upper cusp larger than the lower cusp; ventral sac covers on the third abdominal sternite present; and eyes situated close to the margin of the carapace.

### ***Sarax cavernicola* sp. nov.**

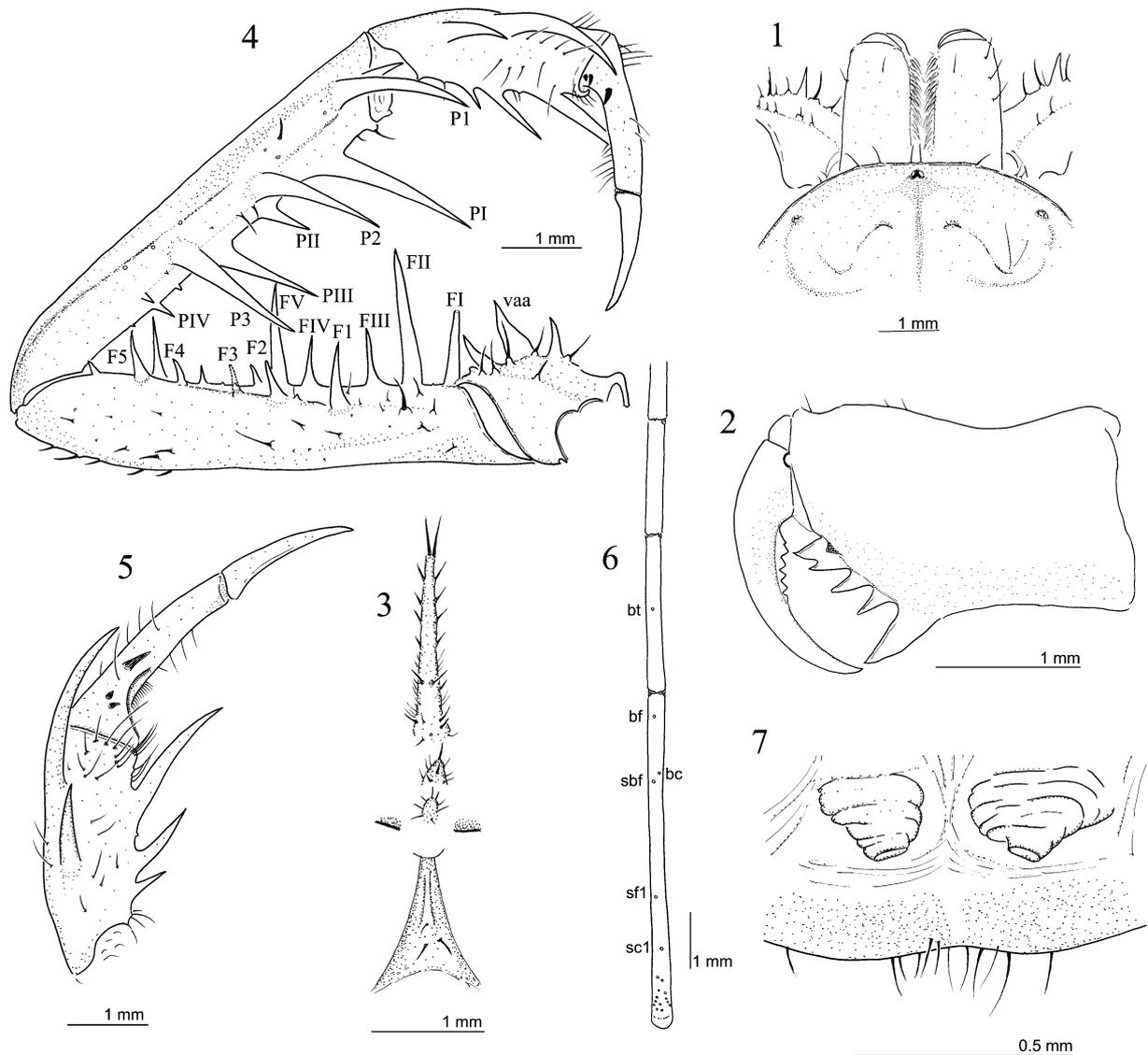
(Figs. 1–7, 33–34)

**Material examined:** Female holotype (MZB.Ambl.145), INDONESIA: *East Kalimantan*: Kutai Timur Regency, Sangkulirang District, Pengadan Village, Gua Ambulabung (Gua Baai) (KAL-110), GPS coordinates 1°9'11.00"N, 117°33'59.91"E, 16 August 2004, L. Deharveng. Paratypes: 2 females (MZB.Ambl.146, MNHN-Am.08), 1 male (MZB.Ambl.147), same data as holotype; 2 females (MZB.Ambl.072–073), INDONESIA: *East Kalimantan*: Kutai Timur Regency, Kelay District, Marang, Gua Sungai, 22 August 2004, Y.R. Suhardjono; 2 females (MZB.Ambl.091–092), INDONESIA: *East Kalimantan*: Kutai Timur Regency, Kelay District, Marang, Gua Sungai, GPS coordinates 1°05'38.78"N, 117°17'45.39"E, 23 August 2004, C. Rahmadi.

**Diagnosis:** *Sarax cavernicola* differs from other Bornean species by the rather large body (adult body length about 6.2–16.2 mm). Body yellowish-brown in color. Anterior margin of carapace broadly rounded, eyes slightly reduced in size. Pedipalpal femur with many spines both on antero-dorsal and antero-ventral margins; pedipalpal patella on antero-dorsal margin with three spines about equal in length; pedipalpal tibia on antero-dorsal margin with two spines (proximal spine less than half of distal one length) and on antero-ventral margin with three spines decreasing in size from distal to proximal to major spine proximally;

pedipalpal tarsus with three spines: proximal spine the shortest and the distal one the longest (medial spine close to the proximal one). Tibia of leg IV with 19 trichobothria: *bc* very close to *sbf*, *bt* close to proximal margin of fourth basitibial segment of leg IV.

**Description:** *Female:* Color in alcohol: Carapace yellowish-brown, centrally with brown marks; pedipalp yellowish-brown except for reddish-brown spines and tarsus. Legs II–IV yellowish-brown to light yellow, except patella dark brown. Abdomen yellow with a pair of spots on each tergite.



**FIGURES 1–7.** *Sarax cavernicola* sp. nov., female holotype: 1. Carapace; 2. Left chelicera, external view; 3. Sternal area of opisthosoma, ventral view; 4. Left pedipalp, antero-dorsal view; 5. Left pedipalpal tarsus; 6. Arrangement of trichobothria on fourth basitibial segment and distibiae of left leg IV; 7. Female gonopods, dorsal view.

Carapace (Fig. 1): Width about 1.3–1.5 times its length; surface finely granulate, without setiferous tubercles, with several short setae in frontal area. Flange wide and bent upwards. Anterior margin of carapace slightly rounded, with 6 frontal setae. Median sulcus deep in posterior one-third of the carapace; a line sulcus running from posterior of median eyes to central sulcus, two paired lateral sulci present running laterally, a pair of sulci on posterior of lateral eyes. Eyes small, median eye tubercle brown, without apical setae, reduced in size, triangular in shape; median eyes facing antero-laterally; lateral eyes close to lateral margin of

carapace, reduced in size, yellowish pale in color; frontal process not visible from above in holotype, and visible in paratypes.

Chelicera (Fig. 2): Dorsal surface smooth, without frontal setae and with several fine setae. Basal segment with 4 teeth: lower-most tooth largest, upper-most tooth bicuspid, with upper cusp larger than lower cusp; inner surface with several setae arranged in vertical row; outer surface with one small tooth opposite of bicuspid tooth, ventrally with several setae near proximal margin. Movable article with 6 teeth; second tooth the largest and subsequent teeth decreasing in size distally.

Sternum (Fig. 3): First sternite (= tritosternum) elongate, with paired apical setae and laterally many setae shorter than apical setae. Second and third sternites rounded and slightly elongate, respectively with 8 and 6 setae in addition to paired apical setae. Fourth sternite (= metasternum) with 3 setae.

Pedipalp (Figs. 4–5): Strong and slender. Trochanter with 10 setiferous tubercles and several setae along antero-dorsal margin, 1 spine medially and 7 setiferous tubercles on antero-ventral margin; ventro-anterior apophysis equipped with several setiferous tubercles present on distal margin of trochanter. Femur: antero-dorsal margin with 6 major spines (length  $F1 > F3 > F5 > F2 > F4$ ), several setiferous tubercles and small tubercles; antero-ventral margin with 7 major spines (length  $FII > FV > FI > FVIII > FIII > FIV > FVI > FVII$ ), several minor spines and small tubercles. Patella: antero-dorsal margin with 3 major spines (**P1**, **P2**, **P3**) about equal in size, several minor spines, several setiferous tubercles and small tubercles, the three major spines located on more than half of pedipalpal patella length distally, 1 minor spine present between **P1** and distal margin of patella, the length of minor spine less than half of **P1** length, 1 minor spine present between **P3** and proximal margin; antero-ventral margin with 4 major spines (length  $PI > PIII > PII > PIV$ ), several setiferous tubercles and small tubercles, 2 minor spines between **PIII**-**PIV** and 3 minor spines between **PIV** and proximal margin. Tibia with several setiferous tubercles, outer surface roughened and several setae on inner surface; antero-dorsal margin with two major spines, proximal spine less than half as long as distal one; antero-ventral margin with 3 major spines (Fig. 5), the distal-most spine longest, following spines decreasing in size proximally, other specimens (MZB.Ambl. 072–073, 091–092) have only one spine without 2 additional proximal spines. Tarsus completely divided (claw clearly demarcated by articulation), antero-dorsal margin with 3 spines: proximal and medial spines short, about equal in length and close to each other (space between them about basal diameter of medial spine), distal spine longer than proximal and medial spine, medial spine by about 3 basal diameter of medial spine, without basal row of seta on proximal end of cleaning organ; cleaning organ ventrally with about 30 modified hairs; apotele present.

Legs (Fig. 6): Femora of legs I–IV with small tubercles and setiferous tubercles. Tibia and tarsus of leg I with 23 and 41 segments, respectively; tibiae of legs II and III two-segmented; basitibiae of leg IV four-segmented, fourth segment with 1 trichobothrium (value in parentheses: ratio of the distance from the trichobothrium to the proximal margin of the segment against the length of the segment), *bt* (0.45); distitibiae of legs II–IV each with 18 trichobothria, *bf* (0.05), *sbf* (0.23), *bc* (0.26), *sf1* (0.60), *sc1* (0.75), *bt* close to proximal margin of fourth basitibial segment, *bc* very close to *sbf* (Fig. 6). Tarsi of legs II–IV four-segmented; first segment about as long as length of subsequent three segments combined; second segment with light-yellow transverse line; fourth segment without oblique slit; pulvilli present.

Genitalia (Fig. 7): Covered ventrally with genital operculum slightly concave apically, paired with 2 tubes projecting medially.

*Male* (Figs. 33–34): Similar to female, without distinct sexual dimorphism. Genitalia: Covered ventrally by genital operculum slightly concave on the posterior margin (Fig. 34); paired apically-pointed small projections on medial lobes; 2 brown marks present on lateral lobes. In dorsal view, paired, anteriorly rounded with 2 light brown bands running from anterior to mid-length of genitalia, 2 small brown marks present medially (Fig. 33).

Measurements (in mm): male (n=1) [female (n=3)]; values for segments of the appendages are their lengths. Body length (excluding chelicera) 8.64 [6.17–16.25]. Carapace: median length 3.20 [4.57–6.37]; width 4.17 [6.30–8.29]; median eyes to anterior margin of carapace 0.08 [0.11–0.15]; distance between lateral eyes 1.88 [3.00–4.54]; lateral eye to anterior margin of carapace 0.37 [0.64–0.69]; lateral eye to lateral margin of carapace 0.14 [0.24–0.35]. Pedipalps: trochanter 1.08 [1.97–2.62]; femur 2.92 [5.95–8.98]; patella 3.26

[6.15–9.08]; tibia 1.59 [2.81–3.82]; tarsus 1.87 [3.00–4.51]. Leg I: femur 17.08 [24.35–35.79]; patella 0.86 [1.00–1.18]. Leg II: femur 8.25 [11.32–17.29], patella 1.11 [1.57–1.79]; basitibia 7.23 [11.22–12.79]; distitibia 4.52 [6.92–10.40]; metatarsus + tarsus 2.95 [4.08–5.42]. Leg III: femur 9.38 [13.16–18.72]; patella 1.18 [1.25–1.97]; basitibia 7.69 [11.67–19.32]; distitibia 5.18 [6.95–11.46]; metatarsus + tarsus 3.59 [4.28–5.86]. Leg IV: femur 9.08 [12.92–18.28]; patella 1.18 [1.21–1.80]; basitibia 9.90 [13.14–23.28]; distitibia 4.81 [6.79–10.29]; metatarsus + tarsus 2.40 [4.21–6.13].

**Etymology:** The specific name is a Latin adjective meaning inhabiting caverns or caves.

**Distribution:** This species is only known from the Sangkulirang Karst, located in East Kalimantan (Indonesia) (Figs. 41, 42).

**Natural history:** The whip spiders of this species were collected in caves of Gua Ambulabung (Baai) and Gua Sungai (Marang). They were found to live with several cave arthropods to which most of them are new to science such as a giant cave cockroach *Miroblatta baai* Grandcolas & Deharveng 2007, and the cave millipeds *Plusioglyphiulus bedosae* Golovatch *et al.* 2009 and *P. pallidior* Golovatch *et al.* 2009. Lips (2002) reported a whip spider (identified as *Acarimens*) from other caves in Marang together with a figure of a specimen (N<sup>o</sup>. 1074) from Lubang Tendoyan (Marang) which depicts a whip spider which has three equal-sized spines on the pedipalpal patella which we interpret as a specimen of *S. cavernicola*.

**Remarks:** *Sarax cavernicola* has three major spines about equal in size on the antero-dorsal margin of the pedipalpal patella, the pedipalpal tarsus divided into two parts, and pulvilli present on legs II–IV. These features somewhat resemble the genus *Stygophrynus* which is a member of the family Charontidae. The pedipalpal patella spination is similar to *Stygophrynus moultoni* from Klingkang Range in western Borneo (Kalimantan Barat, Indonesia) and differs from that species by the length of the proximal spine of the dorsal pedipalpal tibia about equal to the distal one (see Gravely 1915, fig. 9).

The following characters demonstrate that the new species here is not a member of the genus *Stygophrynus*: the pedipalpal tibia without at least three spinelets that increase in size from proximal to distal on the distal of major spine (see Kraepelin 1895, fig. 32; 1899, fig. 92), the absence of a basal row of setae on the proximal end of the cleaning organ on the pedipalpal tarsus (see Quintero 1986, Weygoldt 1996, 2000, 2002), the cheliceral dentition with the upper cusp larger than the lower cusp, and the tibial and tarsal segments of the antenniform legs with 23 and 41 segments, respectively. Most of these characters clearly conform to the family Charinidae. We tentatively place the new species within the genus *Sarax* to which it most closely resembles. However, we believe that in future a new genus may be established when the taxonomic position of the charinid genera is fully resolved.

### ***Sarax yayukae* sp. nov.**

(Figs. 8–15, 35–36)

**Material examined:** Male holotype (MZB.Ambl.056), INDONESIA: *Central Kalimantan*: Murung Raya Regency, Tumbang Topus, Liang Puruk, GPS coordinates 0°27'45.0"N, 115°00'55.5"E, 9 June 2004, C. Rahmadi, Y.R. Suhardjono & D. Silam. Paratypes: 2 females and 1 juvenile (MZB.Ambl. 057-059), 1 female (MNHN-Am.09), Liang Puruk, GPS coordinates 0°27'45.0"N, 115°00'55.5"E, 9 June 2004, C. Rahmadi, Y.R. Suhardjono & D. Silam; 1 male (MZB.Ambl.093), Liang Hajuq, GPS coordinates 0°27'37.9"N, 115°00'47.6"E, 11 June 2004, C. Rahmadi; *West Kalimantan*: 1 male (MZB.Ambl.148), Gua Kelasi in buffer zone, Bukit Raya-Bukit Baka National Park, Menukung, Melawi, 7 August 2008, K.P.G. Himakova. 1 male, 3 females (CAS, CASENT 9036127), MALAYSIA: *Sabah*: Kota Kinabalu, Manukan Island, under logs in forest, 6 May 2006, T. Briggs; 1 juvenile (CAS, CASENT 9036126), Kota Kinabalu, Manukan Island, jogging track on leaf litter, under logs, 6 May 2006, H. Tu & T. Briggs.

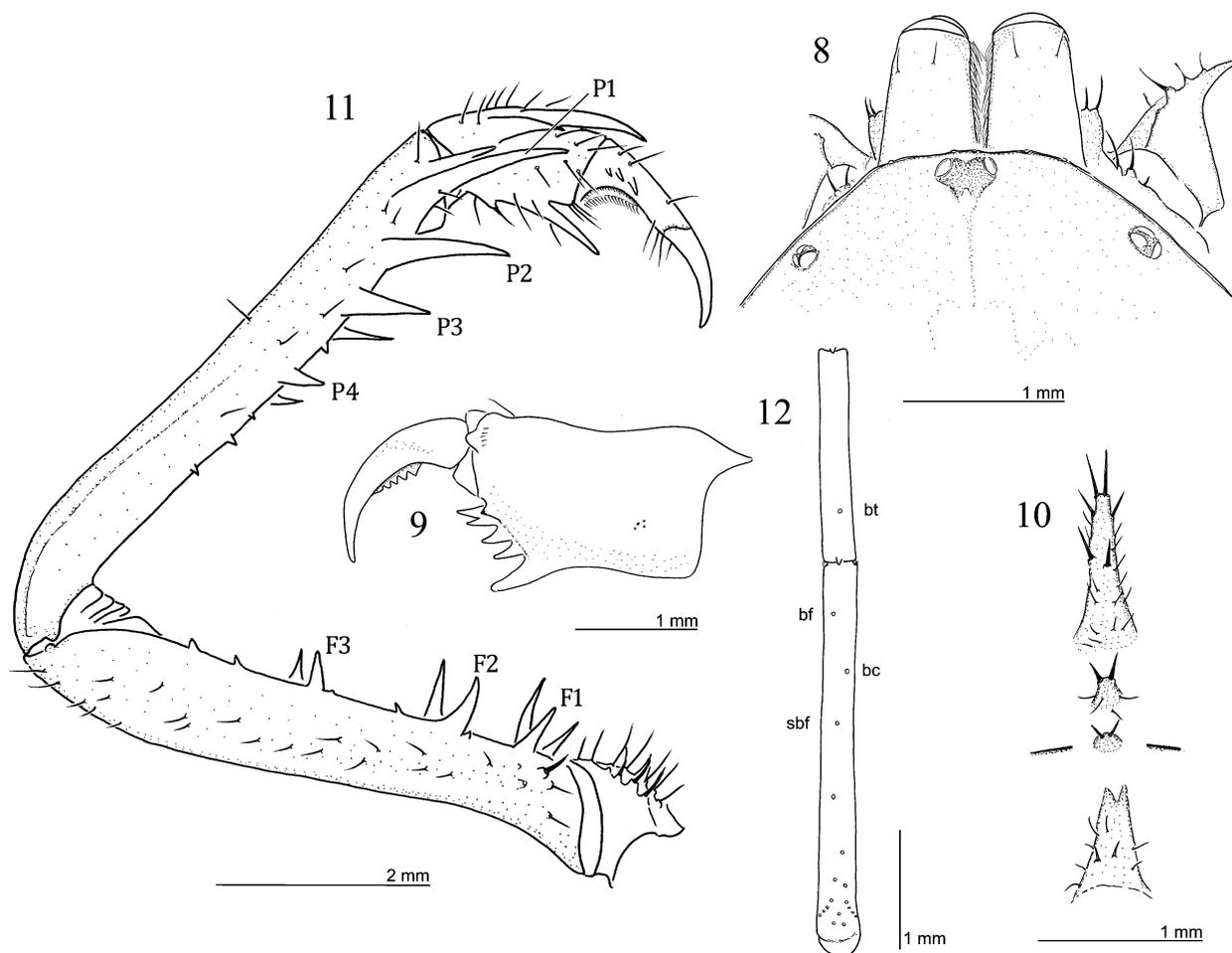
**Diagnosis:** *Sarax yayukae* has distinct sexual dimorphism, the male with strong and slender pedipalp whereas the female shorter and stouter. The species is medium-sized with an adult body length of about 8.8–11.8 mm. Pedipalpal femur with three major spines on antero-dorsal and antero-ventral margins; patella with four major spines on antero-dorsal margin; tarsus with three spines on antero-dorsal margin in adult

specimens; the juveniles of *S. yayukae* have two spines on the pedipalpal tarsus. Tibia leg IV with 19 trichobothria with *bc* much closer to *sbf* than to *bf*; *bt* on fourth basitibial segment of leg IV close to the distal margin of the segment.

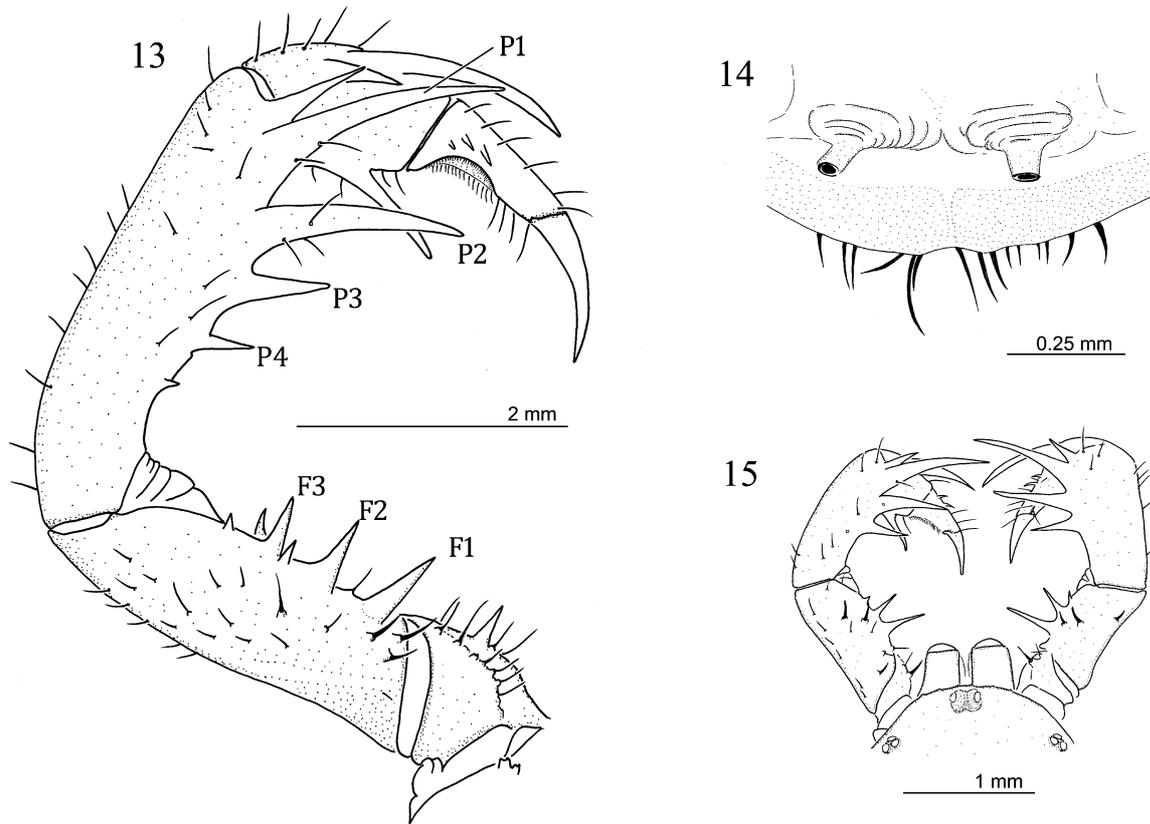
**Description: Male:** Color in alcohol: Carapace brown, centrally with darker marks; pedipalp brown except for tarsus reddish-brown; legs yellowish-brown, but patella dark brown; abdomen yellowish-brown. The paratype male from Sabah is similar to the holotype. The paratype male from West Kalimantan much darker than other specimens: carapace, pedipalps and legs dark brown.

Carapace (Fig. 8): Width about 1.4–1.5 times its length; surface finely granulate, without setiferous tubercles, with several short setae in frontal area; median sulcus deep in posterior one-third of the carapace; paired lateral sulci present. Flange wide and bent upward. Anterior margin of carapace rounded, with 5 (in holotype) or 6 (in paratypes) frontal setae and 11 fine setae. Median eye tubercle black, without apical setae, slightly emarginate antero-medially to form heart-shape; eyes facing antero-laterally. Lateral eyes close to lateral margin of carapace. Frontal process not visible from above.

Chelicera (Fig. 9): Dorsal surface smooth, with 2 fine frontal setae and 2 fine setae. Basal segment with 4 teeth: lower-most tooth largest, upper-most tooth bicuspid, with upper cusp larger than lower cusp; inner surface with several setae arranged in vertical row; outer surface with small tooth opposite bicuspid tooth, ventrally with several setae near proximal margin. Movable article with 5 (holotype) or 3 (paratype (MZB.Ambl.148)) teeth; basal-most tooth largest, subsequent teeth decreasing in size distally.



**FIGURES 8–12.** *Sarax yayukae* sp. nov., male holotype, unless stated otherwise: 8. Frontal area of carapace, male paratype from Liang Hajuq (MZB.Ambl.148); 9. Left chelicerae, external view; 10. Sternal area of opisthosoma, ventral view; 11. Left pedipalp, antero-dorsal view; 12. Arrangement of trichobothria of fourth basitibial segment and distibiae of left leg IV.



**FIGURES 13–15.** *Sarax yayukae* sp. nov.: 13. Left pedipalp, antero-dorsal view, female paratype (MZB.Ambl.057); 14. Female genitalia, paratype (MZB.Ambl.057); 15. Pedipalp and anterior margin of carapace, juvenile paratype (MZB.Ambl.059).

Sternum (Fig. 10): First sternite (= tritosternum) elongate, with paired apical and 17 other setae. Second and third sternites rounded and slightly elongate, with 5 and 2 setae, respectively, in addition to paired apical setae. Fourth sternite (= metasternum) with 5 setae.

Pedipalp (Fig. 11): Strong and slender. Trochanter: antero-dorsal margin with several setiferous tubercles and 2 setae, antero-ventral margin with one spine medially and seven setiferous tubercles; distal margin with ventro-anterior apophysis equipped with several setiferous tubercles. Femur: antero-dorsal margin with 3 major spines (length **F1**>**F2**>**F3**), several setiferous tubercles and small tubercles (Fig. 11); area without setiferous tubercles or small tubercles forming narrow band running length-wise; antero-ventral margin with 3 major spines (length **F1**>**FII**>**FIII**), several minor spines and small tubercles; 1 spine present dorsally of **F1** and as long as half length of **F1**, minor spine present between **F1** and **FII** and between **FII** and **FIII**, 3 minor spines between **FIII** and distal margin of femur. Patella: antero-dorsal margin with 4 major spines (length **P1**>**P2**>**P3**>**P4**) clumped distally, several minor spines, several setiferous tubercles and small tubercles; major spines located on distal half of patella, 1 minor spine between **P1** and distal margin of patella, and as long as half of **P1** length, 1 spine between **P3**-**P4**, three minor spines between **P4** and proximal margin (Fig. 11); antero-ventral margin with 3 major spines (length **PI**>**PII**>**PIII**), several setiferous tubercles and small tubercles present, 2 minor spines between **PIII** and proximal margin. Tibia with outer surface smooth and with spines as follows: 2 major spines on antero-dorsal margin, proximal spine less than half as long as distal spine; 1 major spine on antero-ventral margin close to distal margin of tibia. Tarsus completely divided (claw clearly demarcated by articulation), with 3 spines on antero-dorsal margin: proximal spine shortest, medial spine about half as long as distal one, proximal and medial spines separated from each other by about one basal diameter of median one, medial spine separated proximal spine by about 3 basal diameters of medial one; cleaning organ ventrally with about 29 modified hairs; apotele present (Fig. 11).

Legs (Fig. 12): Femora of legs I–IV with small tubercles bearing setae. Tibia and tarsus of leg I with 23 and 41 segments, respectively; tibiae of legs II and III 2-segmented; basitibia of leg IV 4-segmented, fourth segment with 1 trichobothrium (value in parentheses: ratio of the distance from the trichobothrium to the proximal margin of the segment against the length of the segment), *bt* (0.74); distitibiae of legs II–IV each with 18 trichobothria (Fig. 12), *bf* (0.14), *sbf* (0.43), *bc* (0.29), *bt* close to distal margin of fourth basitibial segment, *bc* closer to *sbf* than to *bf*. Tarsi of legs II–IV 4-segmented; first segment about as long as length of subsequent three segments combined; second segment with light-yellow transverse line; fourth segment without oblique slit; pulvilli present.

Genitalia (Figs. 35–36): Covered ventrally by genital operculum rounded apically and with several setae; paired with 2 small lobes apically, 2 brown sclerotized curves, the apical curve larger than the basal in the white weakly sclerotized area, brownish sclerotized area with two projected point medially (Fig. 36). In dorsal view, paired brown bands extend posteriorly, apical sclerotized area and small ventral lobes present (Fig. 35).

*Female* (Figs. 13–14): Color in alcohol much darker and distinctly different from male as follows: pedipalp distinctly shorter and stouter (Fig. 13) (see Fig. 11 for male); trochanter with 4 setiferous tubercles, 3 of them arranged in row along antero-dorsal margin; femur with single minor spine each between **F2-F3** and between **F3** and distal margin; antero-ventral margin with 4 minor spines. Patella with four major spines distributed across most of patella. Tarsus with 3 spines: proximal spine the shortest, distal spine the longest, and medial spine about half as long as distal spine, medial and distal spines separated from each other by about three basal diameters of medial spine. Gonopods with paired tube-like, apically-pointed projections (Fig. 14).

*Juvenile* (Fig. 15): Similar to adult, but color in alcohol much paler, and pedipalpal tarsus with two instead of three spines (Fig. 15).

Measurements (in mm): male (n = 3) [female (n = 5)]; values for segments of the appendages are their lengths. Body length (excluding chelicera) 9.80–10.60 [8.80–11.80]. Carapace: median length 3.19–4.20 [3.40–3.80]; width 5.40–5.80 [5.00–5.48]; median eyes to anterior margin of carapace 0.04 [0.04]; distance between lateral eyes 2.40–2.52 [2.40–2.60]; lateral eye to anterior margin of carapace 0.60 [0.52–0.60]; lateral eye to lateral margin of carapace 0.20 [0.12–0.20]. Pedipalps: trochanter 1.44–1.72 [1.40]; femur 5.60–6.80 [2.96–3.40]; patella 6.20–7.40 [3.60–3.80]; tibia 1.92–2.20 [1.40–2.00]; tarsus 1.60–2.00 [2.00–2.40]. Leg I: femur 14.80 [10.00–12.20]; patella 0.80 [0.80]. Leg II: femur 8.80 [6.20–7.20], patella 1.20 [1.20]; basitibia 6.40–8.00 [4.80–6.40]; distitibia 3.56–4.20 [3.04–3.40]; metatarsus + tarsus 3.00–3.60 [2.40–2.80]. Leg III: femur 8.00–11.20 [6.80–8.00]; patella 1.20–1.40 [1.20]; basitibia 8.80–10.00 [6.40–7.80]; distitibia 3.60–3.80 [3.20–3.80]; metatarsus + tarsus 3.60 [2.00–2.80]. Leg IV: femur 8.00–9.60 [7.00–8.00]; patella 1.20 [1.00]; basitibia 9.20–10.80 [7.00–8.00]; distitibia 3.40–3.60 [3.00–3.40]; metatarsus + tarsus 3.20 [2.00–3.00].

**Etymology:** This species is dedicated to Yayuk R. Suhardjono who collected the type material from caves in Central Kalimantan, and has contributed much to the knowledge on cave biology in Indonesia.

**Distribution:** *Sarax yayukae* is found in Central and West Kalimantan (Indonesia), and Manukan Island, Sabah (Malaysia) (Fig. 41).

**Natural history:** This species inhabits caves (Liang Puruk, Liang Hajuq and Gua Kelasi), as well as occurring under logs in forest (Manukan Island, Sabah). Detailed descriptions of the caves in Central Kalimantan were given in Rahmadi & Suhardjono (2006). The species was observed preying on cave crickets, *Diestramenna* sp., in Liang Puruk, Central Kalimantan.

**Remarks:** *Sarax yayukae* can be distinguished from other congeners by its distinct sexual dimorphism, the presence of three spines on the pedipalpal tarsus in adults (Fig. 11) and two in juveniles (Fig. 15), the tibia of leg IV having 19 trichobothria arranged with *bc* much closer to *sbf* than to *bf*, and *bt* on the fourth basitibial segment of leg IV being close to the distal margin of the segment (Fig. 12). The juvenile of *S. yayukae* is similar to *S. sarawakensis* in having two spines on the pedipalpal tarsus, but the spines in *S. yayukae* (both juvenile and adult) are long while those in *S. sarawakensis* are short and minute. *Sarax sarawakensis* has four spines on the antero-dorsal margin of the pedipalpal femur and three spines in the juvenile of *S. yayukae*. The pedipalpal patella of *S. sarawakensis* has four major spines on the antero-dorsal margin instead of three in juveniles of *S. yayukae*. The number and arrangement of the trichobothria on the tibia of leg IV also differ

between both species: *S. yayukae* (both juvenile and adult) has 19 trichobothria while *S. sarawakensis* has 17 trichobothria (Weygoldt 1996, 2000).

*Sarax davidovi* Fage 1946 from Indochina shows distinct sexual dimorphism and has three spines on the antero-dorsal margin of the pedipalpal tarsus as in *S. yayukae*. They differ in the number of spines on the antero-dorsal margin of the male pedipalpal patella (4 spines decreasing in size from distal to proximal in *S. yayukae*; 2 long spines in *S. davidovi* (see Fage 1946, fig. 4)) and the shape of the carapace (anterior margin rounded in *S. yayukae*, with broad flange on the antero-lateral corners in *S. davidovi* see Fage 1946, fig. 2). The number and arrangement of the trichobothria on tibia leg IV of *S. davidovi* is unknown.

### ***Sarax sarawakensis* (Thorell 1888)**

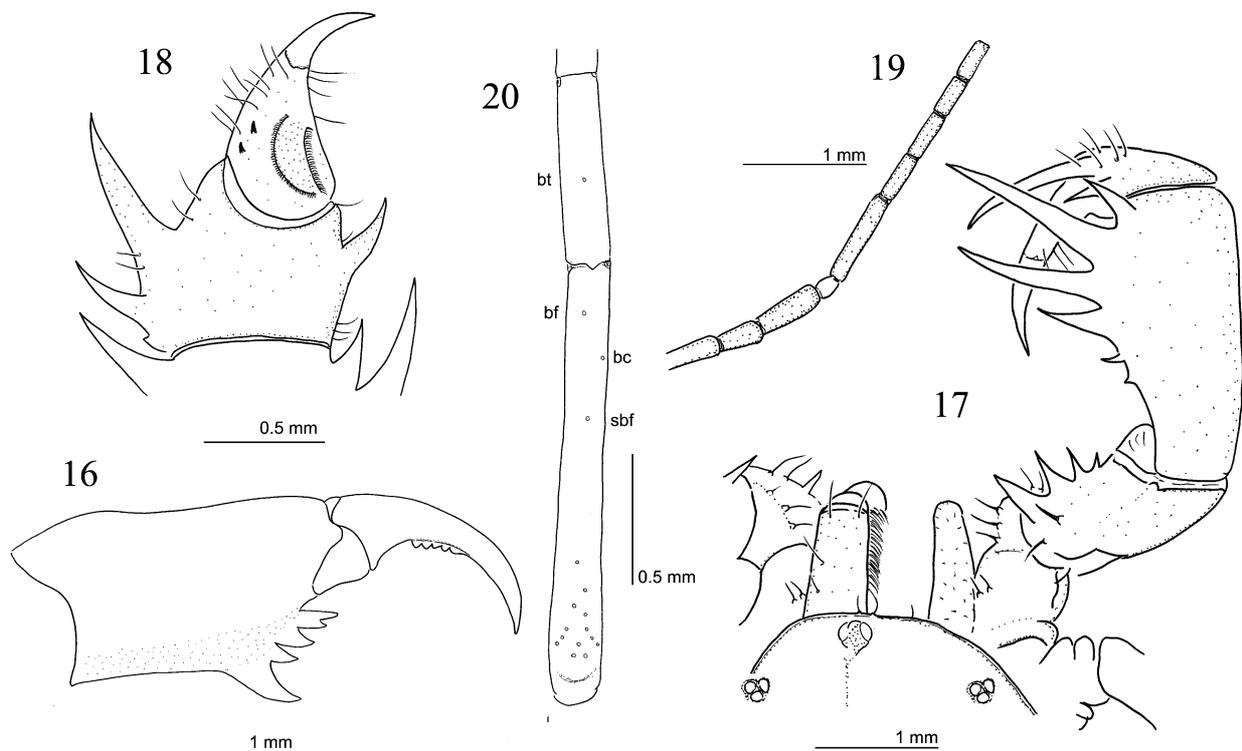
(Figs. 16–20)

*Charon sarawakensis* Thorell 1888: 354.

*Sarax sarawakensis* (Thorell): Simon 1892: 48; Harvey 2003: 8; Rahmadi and Kojima in press.

**Material examined:** Female holotype (MCSG), MALAYSIA: *Sarawak*: (labeled “*Sarax sarawakensis* Thor. Sarawak, Viag Doria and Beccari”). 1 female (MNHN.Am.17), INDONESIA: *Java*: labeled “*Sarax sarawakensis* Thor., Kraepelin det. 1900, Java, Raffray 1005.77, 1877”. 1 female (MZB.Ambl.149), INDONESIA: *Lampung*: Kalianda, Raja Basa, GPS coordinates 5°46.896’S, 105°37.687’E, altitude 1255 m. asl., 15 August 2004, A. Riedel.

**Distribution:** *Sarax sarawakensis* is known from Andaman Island, Peninsular Malaysia (Selangor), Java, Sumatra [new record] (Indonesia), and Borneo (Sarawak) (Fig. 41).



**FIGURES 16–20.** *Sarax sarawakensis* (Thorell 1888), female holotype from Borneo unless stated otherwise: 16. Frontal carapace and right pedipalp; 17. External view of right chelicerae; 18. Pedipalpal tarsus, internal view; 19. Tibial and tarsal segments of leg I showing three most distal tibial segments, and five most proximal tarsal segments; 20. Arrangement of trichobothria of fourth basitibial segment and distibiae of left leg IV, (MZB.Ambl.149).

**Remarks:** *Sarax sarawakensis* was first described by Thorell (1888) in the genus *Charon* based on a single female from Sarawak. The species was later transferred to *Sarax* by Simon (1892) when the genus was established. The type species, *Sarax brachydactylus* Simon 1892, was found in the Philippines from caves situated near Antipolo, San-Mateo and Calapnitan (Simon 1892).

Delle Cave (1986) provided additional information on the holotype of *S. sarawakensis*, which she compared with a *Sarax* specimen from Singapore in the collection of the British Museum. She noted differences between the holotype and specimen from Singapore, where the pedipalpal patella possessed only one spine between **P1** and the distal margin instead of two. Gravely (1911) reported this species from Singapore which he named *Sarax sarawakensis singapora* which was later elevated to species level and moved to the genus *Phrynichosarax* (Gravely 1915), forming the combination *P. singapora*. The genus *Phrynichosarax* was based on the presence of three basitibial segments of leg IV (Gravely 1915), but Weygoldt (2000) synonymised it with *Sarax*.

A single female specimen of *Sarax* sp. from Bacangan, Palawan Island, was found in the FMNH collection. It has small setiferous tubercles and one spine between spine **P1** and the distal margin of the pedipalpal patella, and 17 trichobothria on tibia of leg IV which conforms to *S. sarawakensis* (Fig. 20). Fage (1946) compared the pedipalp spination of three species, *S. davidovi* Fage, 1946, *S. brachydactylus* and *S. sarawakensis*. Among them, *S. brachydactylus* can be distinguished from other congeners by the presence of two spines between **P1** and the distal margin, five major spines on the pedipalpal patella and four major spines on the pedipalpal femur (see Fage 1946, fig. 3). *Sarax sarawakensis* has four major spines on the pedipalpal patella (Fig. 17) and three major spines on the pedipalpal femur with additional distal minor spines. The specimen from Raja Basa (southern Sumatra) shows similar pedipalp spination.

Although the number and arrangement of trichobothria on leg IV in the type of *S. brachydactylus* is unknown, the specimen of *Sarax* from Palawan is clearly similar to *S. brachydactylus* based on the spination of the pedipalpal patella and femur as specified in the identification key by Kraepelin (1899) and the figure by Fage (1949).

#### ***Sarax sangkulirangensis* sp. nov.**

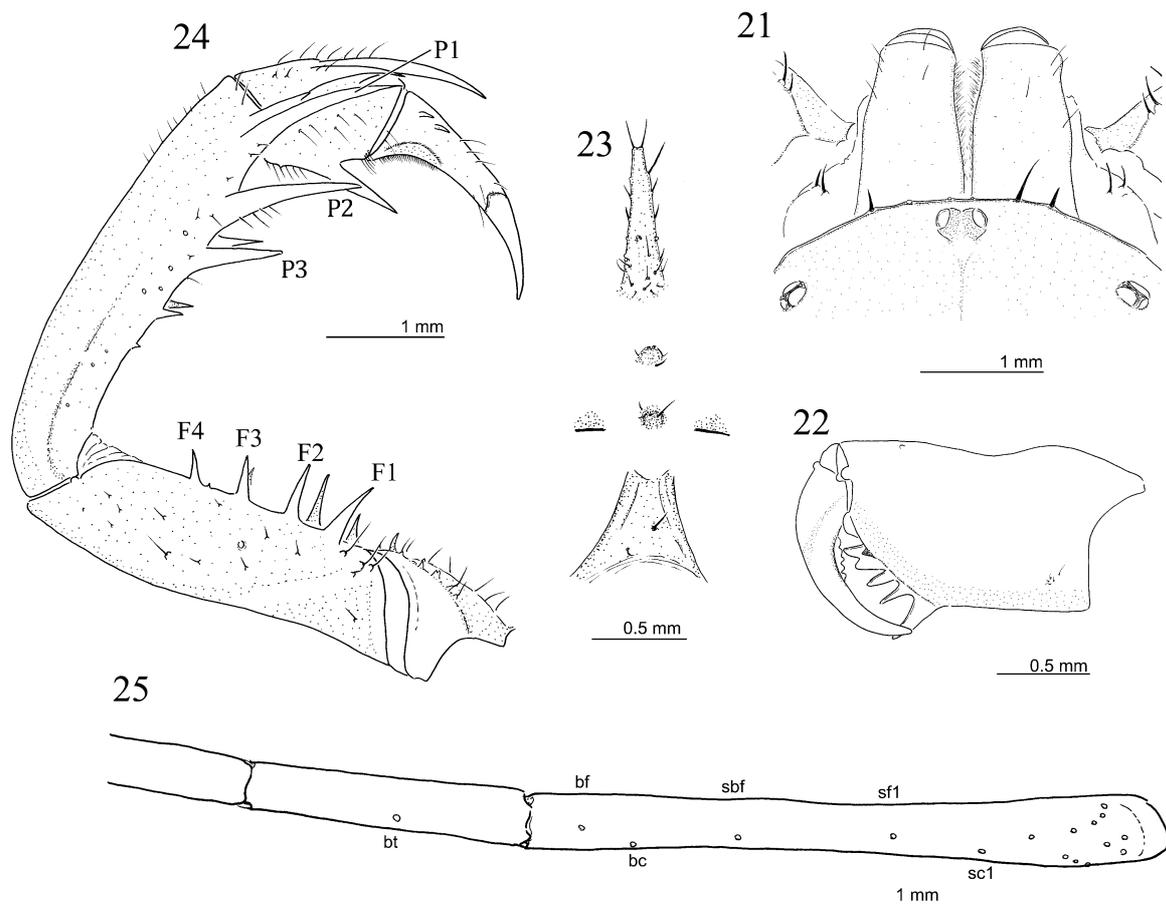
(Figs. 21–25, 37–38)

**Material examined:** Female holotype (MZB.Ambl.070), INDONESIA: *East Kalimantan*: Berau Regency, District Tabalar Ulu, Gua Ke 4, GPS coordinates 1°28'13.23"N, 117°39'28.14"E (approximate), 9 August 2004, C. Rahmadi, ovigerous. Paratypes: 1 male (MZB.Ambl.150), Berau Regency, Kelai District, Merapun Village, near Tebo Lake, Gua Danum Tengen, GPS coordinates 1°31'28.50"N, 117°22'4.90"E (approximate), 2 September 2004, Y.R. Suhardjono; 1 juvenile (MNHN-Am.10), Berau Regency, Tabalar District, Gua Louwading, Tabalar Ulu, 11 August 2004, L. Deharveng & A. Bedos (KAL-059); 1 male (MNHN-Am.11), Kutai Timur Regency, Sangkulirang District, Pengadan Village, Gua Ampanas, GPS coordinates 1°12'01.46"N, 117°44'03.58"E (approximate), 18 August 2004, L. Deharveng & A. Bedos (KAL-113).

**Diagnosis:** *Sarax sangkulirangensis* is relatively small sized (adult body length 5.9–9.8 mm), lacking sexual dimorphism, the pedipalpal tarsus has two spines with the proximal spine about half as long as distal spine, and tibia of leg IV has 19 trichobothria with *bt* on the middle of fourth basitibial segment, and *bc* closer to *bf* than to *sbf*.

**Description:** *Female*: Color in alcohol: Carapace brown, centrally with black marks, flange yellowish-brown; pedipalp yellowish-brown except for tarsus reddish-brown and spine yellow; legs yellowish-brown, but patella dark brown; abdomen greenish-brown.

Carapace (Fig. 21): Width about 1.4–1.7 times its length; surface granulate, without setiferous tubercles; median sulcus deep in posterior one-third of the carapace; 3 pairs lateral sulci present; flange wide and bent upward; anterior margin slightly rounded, with 6 frontal setae. Median eye tubercle black, well-developed and high, without apical setae, slightly emarginate antero-medially to form heart-shape and median eyes facing antero-laterally; lateral eyes close to lateral margin of carapace, well-developed with black tapetum.



**FIGURES 21–25.** *Sarax sangkulirangensis* sp. nov., female holotype unless stated otherwise: 21. Frontal area of carapace of male paratype (MZB.Ambl.150); 22. External view of left chelicerae; 23. Sternal area of opisthosoma, ventral view; 24. Antero-dorsal view of left pedipalp; 25. Fourth basitibial segment and distibiae of right leg IV, male paratype (MZB.Ambl.150).

Chelicera (Fig. 22): Dorsal surface smooth, with 1 fine frontal seta and several fine setae. Basal segment with 4 teeth: lower-most tooth largest, upper-most tooth bicuspid, with upper cusp larger than lower; inner surface with several setae arranged in vertical row; outer surface with small tooth opposite bicuspid tooth, ventrally with several setae near proximal margin. Movable article with 5 teeth almost equal in size.

Sternum (Fig. 23): First sternite (= tritosternum) elongate, with paired apical and several setae. Second and third sternites rounded and slightly rounded, respectively with 3 and 2 setae in addition to paired apical setae. Fourth sternite (= metasternum) with 5 setae.

Pedipalp (Fig. 24): Short and stout. Trochanter on antero-dorsal margin with 4 setiferous tubercles, without median spine; antero-ventral margin with ventro-anterior apophysis equipped with several setiferous tubercles on distal margin of trochanter. Femur: antero-dorsal margin with 4 major spines (length **F1**>**F2**>**F3**>**F4**), 1 minor spine, several setiferous tubercles and small tubercles; antero-ventral margin with 4 major spines (length **FI**>**FII**>**FIII**>**FIV**), 2 minor spines and small tubercles; 1 spine present dorsally of **FI** and as long as three-quarters length of **FI**, minor spine present between **FII**-**FIII**. Patella: antero-dorsal margin with 4 major spines (length **P1**>**P2**>**P3**>**P4**), clumped distally, 1 minor spine, several setiferous tubercles and small tubercles; 1 minor spine as long as half of **P1** presents between **P1** and distal margin of patella, 1 spine presents between **P4** and proximal margin; antero-ventral margin with 4 major spines (length **PII**>**PI**>**PIII**>**PIV**), several setiferous tubercles and small tubercles present. Tibia with outer surface smooth,

with spines as follows: 2 major spines on antero-dorsal margin, proximal spine about half as long as distal one; 1 major spine on antero-ventral margin close to distal margin of tibia. Tarsus completely divided (claw clearly demarcated by articulation), with 2 spines on antero-dorsal margin separated from each other by about three times basal diameter of proximal spine: proximal spine shortest, length of distal spine about twice as long as proximal one; cleaning organ ventrally with about 30 modified hairs; apotele present.

Legs (Fig. 25): Femora of legs I–IV with small tubercles bearing setae. Tibia and tarsus of leg I with 23 and 41 segments, respectively; tibiae of legs II and III 2-segmented; basitibia of leg IV 4-segmented, fourth segment with 1 trichobothrium (value in parentheses: ratio of the distance from the trichobothrium to the proximal margin of the segment against the length of the segment), *bt* (0.52); distitibiae of legs II–IV each with 18 trichobothria *bfl* (0.07), *sbf* (0.31), *bc* (0.16), *bt* close to distal margin of basitibial fourth segment, *bc* close to *sbf* than to *bf*. Tarsi of legs II–IV 4-segmented; first segment more than length of subsequent 3 segments combined; second segment with light-yellow transverse line; fourth segment without oblique slit; pulvilli present.

Genitalia: Gonopods covered ventrally with genital operculum, with posterior margin concave. Gonopods paired, soft, white and tube-like.

**Male:** Similar to female pedipalpal femur with 3 major spines (**F1>F2>F3**) on antero-dorsal margin. Genitalia: covered ventrally by genital operculum, slightly concave on posterior margin; paired pointed-projections posteriorly, lateral lobes with brown band on basal lobe (Fig. 38). In dorsal view, soft, paired brownish band running from anterior to posterior to median section (Fig. 37).

Measurements (in mm): male (n=2) [female (n=1)]; values for segments of the appendages are their lengths. Body length (excluding chelicera) 5.94–7.01 [9.85]. Carapace: median length 2.35–2.65 [3.63]; width 3.44–3.82 [5.28]; median eyes to anterior margin of carapace 0.03–0.07 [0.07]; distance between lateral eyes 1.65–1.87 [2.55]; lateral eye to anterior margin of carapace 0.32–0.45 [0.50]; lateral eye to lateral margin of carapace 0.14–0.15 [0.37]. Pedipalps: trochanter 0.97–1.01 [1.32]; femur 1.96–2.14 [3.44]; patella 2.32–2.45 [4.00]; tibia 1.11–1.50 [1.13]; tarsus 1.22–1.39 [2.01]. Leg I: femur 6.48–7.62 [12.13]; patella 0.49–0.55 [0.71]. Leg II: femur 3.38–4.53 [7.10], patella 0.62–0.72 [1.03]; basitibia 2.55–3.67 [6.17]; distitibia 1.67–2.30 [3.51]; metatarsus + tarsus 1.13–1.56 [2.74]. Leg III: femur 4.06–5.53 [8.35]; patella 0.65–0.79 [1.16]; basitibia 3.33–4.83 [7.65]; distitibia 1.87–2.48 [3.70]; metatarsus + tarsus 1.59–2.09 [2.89]. Leg IV: femur 3.60–4.81 [7.09]; patella 0.66–0.73 [0.58]; basitibia 3.42–5.38 [7.52]; distitibia 1.61–2.10 [3.33]; metatarsus + tarsus 1.80–1.92 [2.97].

**Etymology:** The species name is derived from the name of type locality.

**Distribution:** *Sarax sangkulirangensis* is only known from the Sangkulirang Karst, East Kalimantan (Indonesia) (Figs. 41, 42).

**Natural history:** This species was collected from caves situated in three different limestone hills on the northern part of the Sangkulirang Karst formation, including Tabalar Ulu which is a small limestone area with several horizontal underground rivers, the Tebo Area where an isolated karst lake is located, and Gua Ampanas. *Sarax sangkulirangensis* was collected from the same caves as *Plusioglyphiulus similis* Golovatch *et al.* 2009, a recently described millipede (Golovatch *et al.* 2009).

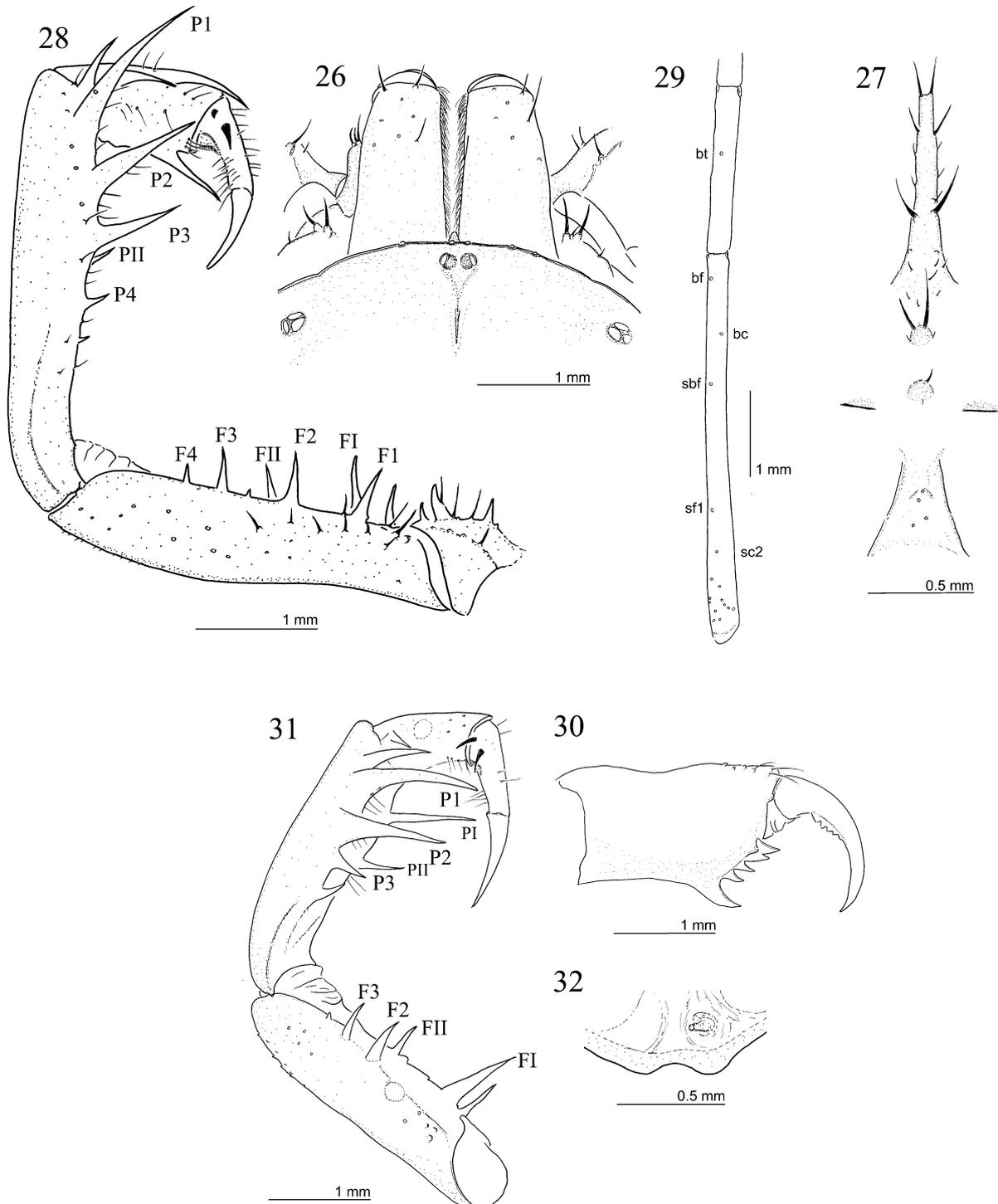
**Remarks:** *Sarax sangkulirangensis* differs from *S. sarawakensis* by the number of trichobothria and the size of the spines on the pedipalpal tarsus. It differs from *S. mardua* in having smaller spines on the pedipalpal tarsus, the lack of distinct sexual dimorphism and can be easily distinguished by the high and black median eye tubercle.

### ***Sarax mardua* sp. nov.**

(Fig. 26–32, 39–40)

**Material examined:** Male holotype (MZB.Ambl.151), INDONESIA: East Kalimantan: Kutai Timur Regency, Sangkulirang District, Pengadan Village, Gua Mardua, near Pengadan, GPS coordinates 1°13'55.13"N, 117°44'23.53"E (approximate), 19 August 2004, L. Deharveng & A. Bedos col., (KAL-119). Paratypes: 1 female and 2 juveniles (MNHN-Am.12), same locality data as holotype.

**Diagnosis:** *Sarax mardua* has a large body-size (adult body length 8.5–10.1 mm), distinct sexual dimorphism, with the pedipalp shorter in the female than the male, and color in alcohol pale yellow. The median eye tubercle is low and small, and is completely divided into two parts each with an eye, legs elongate, trichobothrium *bt* close to proximal margin of fourth basitibial segment, and trichobothrium *bc* about midway between *bf* and *sbf*.



**FIGURES 26–32.** *Sarax mardua* sp. nov., male holotype unless stated otherwise: 26. Frontal area of carapace; 27. Sternal area of opisthosoma, ventral view; 28. Antero-dorsal view of left pedipalp; 29. Fourth basitibial segment and distibiae of right leg IV; 30. Antero-dorsal view of left pedipalp, paratype female (MNHN-Am.12); 31. External view of left chelicerae; 32. Female gonopods, dorsal view, (MNHN-Am.12).

**Description:** *Male:* Color in alcohol: Carapace yellowish pale, centrally with brown marks, flange yellow; pedipalp yellowish-brown except for tarsus brown and spine yellow; legs yellowish-brown, but patella dark brown; abdomen pale yellow.

Carapace (Fig. 26): Width about 1.4–1.7 times its length; surface finely granulate, without setiferous tubercles; median sulcus deep in posterior one-third of carapace; 4 pairs of lateral sulci present; flange wide and bent upward; anterior margin rounded, with 5 frontal setae, anterior process visible from above. Median eye tubercle low and small, clearly divided into 2 parts each including eye, without apical setae; median eyes facing antero-laterally; lateral eyes close to lateral margin of carapace, small, with yellowish tapetum.

Chelicera (Fig. 30): Dorsal surface smooth, with 2 fine frontal setae and several fine setae. Basal segment with 4 teeth: lower-most tooth largest, upper-most tooth bicuspid, with upper cusp larger than lower cusp; inner surface with several setae arranged in vertical row; outer surface with small tooth opposite bicuspid tooth, ventrally with several setae near proximal margin. Movable article with 5 small teeth almost equal in size.

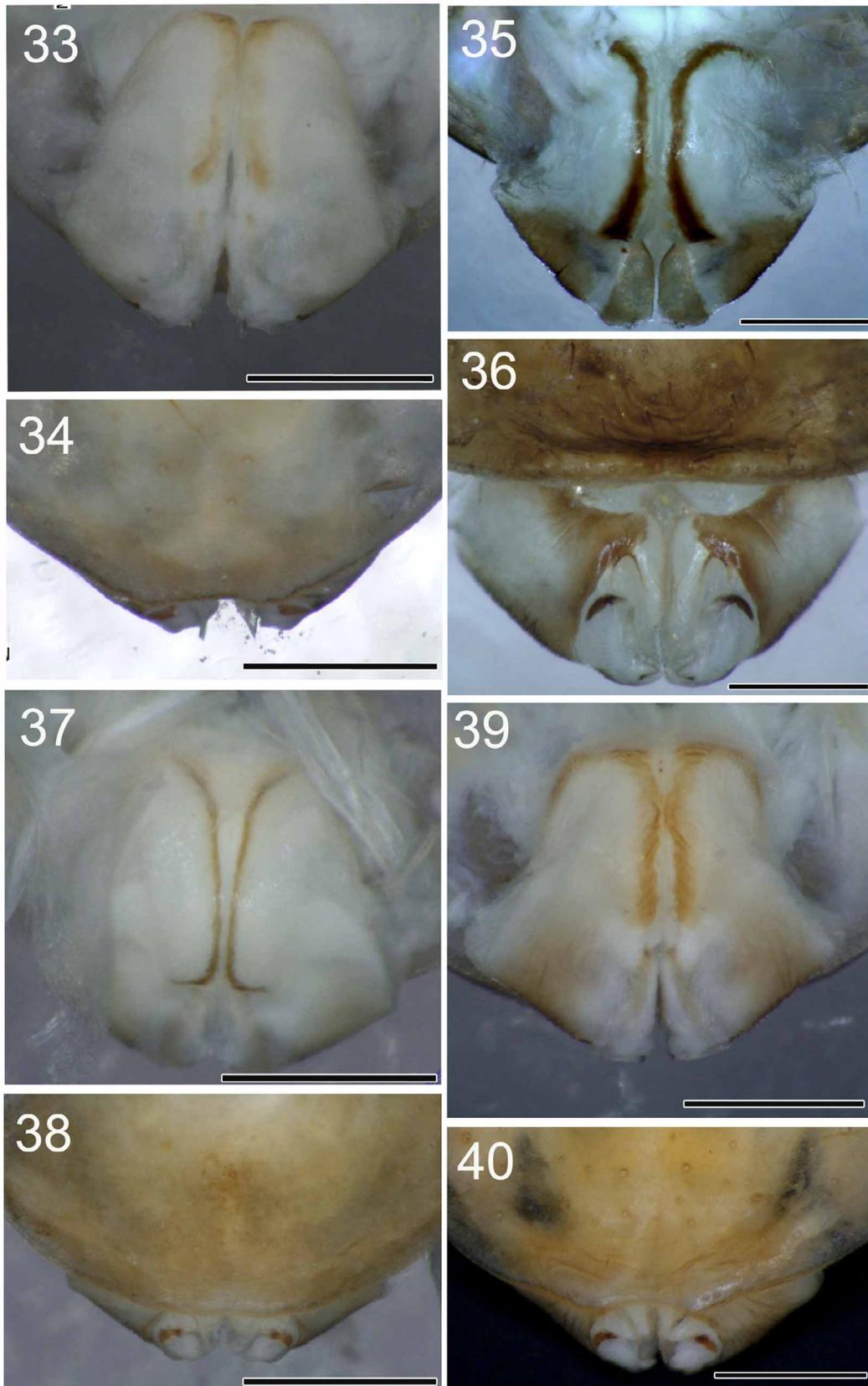
Sternum (Fig. 27): First sternite (= tritosternum) elongate, with paired apical and several other setae. Second and third sternites rounded and slightly domed, with 4 and 1 seta, respectively, in addition to paired apical setae. Fourth sternite (= metasternum) with 4 setae.

Pedipalp (Fig. 28): Strong and slender. Trochanter: antero-dorsal margin with 4 setiferous tubercles, and median spine; antero-ventral margin with ventro-anterior apophysis present on distal margin equipped with several setiferous tubercles. Femur: antero-dorsal margin with 4 major spines, 1 minor spine, several setiferous tubercles and small tubercles, length of spines: **F1>F2>F3>F4**; antero-ventral margin with 4 major spines (length **F1>FII>FIII>FIV**), 1 minor spine, several setiferous tubercle and small tubercles; 1 spine present dorsally of **F1** and as long as half of **F1**. Patella: antero-dorsal margin with 4 major spines (length **P1>P2>P3>P4**), distributed in distal half length of patella, 1 minor spine, several setiferous tubercles and small tubercles, 1 minor spine as long as 1/3 of **P1** length between **P1** and distal margin of patella and, 1 spine between **P4** and proximal margin; antero-ventral margin with 3 major spines (length **PI>PII>PIII**), several setiferous tubercles and small tubercles. Tibia: antero-dorsal margin with outer surface smooth and with 2 major spines, proximal spine about half as long as distal spine; antero-ventral margin with 1 major spine close to distal margin of tibia. Tarsus completely divided (claw clearly demarcated by articulation), with 2 spines on antero-dorsal margin: proximal spine short about 1/3 as long as distal spine, the spines separated each other by about two times basal diameter of proximal spine; cleaning organ ventrally with about 30 modified hairs; apotele present.

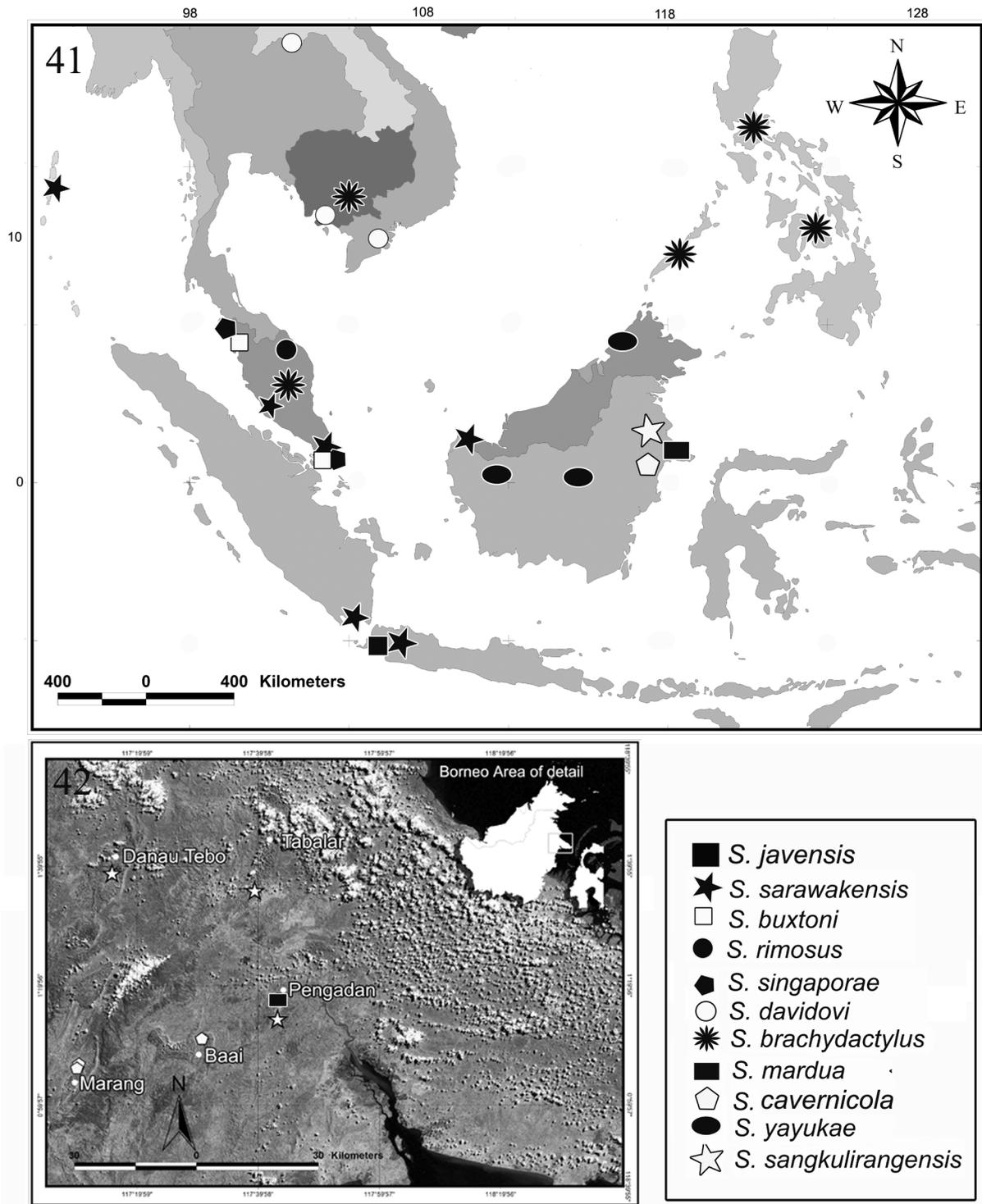
Legs (Fig. 29): Femora of legs I–IV with small tubercles bearing setae. Tibia and tarsus of leg I with 23 and 41 segments, respectively; tibiae of legs II and III 2-segmented; basitibia of leg IV 4-segmented, fourth segment with 1 trichobothrium (value in parentheses: ratio of the distance from the trichobothrium to the proximal margin of the segment against the length of the segment), *bt* (0.40); distitibiae of legs II–IV each with 18 trichobothria *bf* (0.06), *sbf* (0.33), *bc* (0.20), *bt* close to proximal margin of basitibial fourth segment, *bc* about midway between *sbf* and *bf* (Fig. 29). Tarsi of legs II–IV 4-segmented; first segment greater than length of subsequent three segments combined; second segment with light-yellow transverse line; fourth segment without oblique slit; pulvilli present.

Genitalia: Covered ventrally by genital operculum, proximal margin slightly concave; lateral margin yellowish-brown and median part white, medial lobes larger than lateral lobes separated with brown marks on basal lateral lobes (Fig. 40). In dorsal view, anterior margin of gonopods rounded with brown bands extending to mid-length (Fig. 39).

*Female:* Distinct sexual dimorphism. Pedipalps short and stout (Fig. 31), shorter than male. Pedipalpal femur on antero-dorsal margin with 3 major spines (length **F2>F1>F3**), antero-ventral margin with 3 spines (length **F1>FII>FIII**), between **F1** and proximal margin of femora with 1 spine about half of **F1** length. Pedipalpal patella on antero-dorsal margin with 4 major spines (length **P1>P2>P3>P4**), the spines located for most of patella length, the most distal spines between **P1** and distal margin about half of **P1** length; antero-ventral margin with 3 major spines (length **PI>PII>PIII**). Tibia: antero-dorsal margin with 2 spines, proximal spines less than half distal spine. Pedipalp tarsus with two long spines, the distal spine longer than proximal one. Genitalia: with paired gonopods, soft and small, tube-like (Fig. 32).



**FIGURES 33–40.** Male genitalia of *Sarax* species from Borneo: 33. *S. cavernicola*, dorsal view; 34. same, ventral view; 35. *S. yayukae* from West and Central Kalimantan, dorsal view; 36. same, ventral view; 37. *S. sangkulirangensis* new species, dorsal view; 38. ventral view; 39. *S. mardua* from Gua Mardua, East Kalimantan, dorsal view, 40. Ventral view. Scale bars: 0.5 mm.



**FIGURES 41–42.** Map showing the distribution of *Sarax* species: 41. The distribution in Southeast Asia, except for *Sarax* species from India and New Guinea. 42. A detailed map showing the distribution in the Sangkulirang Karst, East Kalimantan.

Measurements (in mm): male (n=1) [female (n=1)]; values for segments of the appendages are their lengths. Body length (excluding chelicera) 10.06 [8.47]. Carapace: median length 3.82 [3.35]; width 5.59 [4.47]; median eyes to anterior margin of carapace 0.08 [0.08]; distance between lateral eyes 2.71 [2.19]; lateral eye to anterior margin of carapace 0.54 [0.47]; lateral eye to lateral margin of carapace 0.16 [0.21]. Pedipalps: trochanter 1.43 [1.01]; femur 4.27 [3.31]; patella 5.18 [3.35]; tibia 1.87 [1.09]; tarsus 2.00 [1.49].

Leg I: femur 15.39 [11.39]; patella 0.79[0.70]. Leg II: femur 8.78 [6.79], patella 1.38 [0.86]; basitibia 9.45[5.63]; distitibia 5.08 [3.61]; metatarsus + tarsus 3.61 [3.07]. Leg III: femur 10.07 [7.37]; patella 1.41 [0.84]; basitibia 9.29 [7.10]; distitibia 4.81 [3.98]; metatarsus+ tarsus 3.56 [2.93]. Leg IV: femur 8.99 [6.87]; patella 1.07 [0.78]; basitibia 9.65 [7.74]; distitibia 4.38 [3.52]; metatarsus + tarsus 3.64 [3.02].

**Etymology:** The species name is derived from the name of the cave “Gua Mardua” where the type material was collected (Gua means “cave”).

**Distribution:** *Sarax mardua* has only been found in the Sangkulirang Karst, East Kalimantan (Indonesia) (Figs. 41, 42).

**Natural history:** The species is known only from Gua Mardua where it occurs with a mite harvestman, *Stylocellus* sp. (Opiliones, Stylocellidae).

**Remarks:** *Sarax mardua* can be distinguished from *S. sangkulirangensis* by the presence of distinct sexual dimorphism, and the reduced median eye tubercle which is completely divided into two parts (Fig. 26). The arrangement of the trichobothria differs from *S. sangkulirangensis* where trichobothrium *bc* is slightly closer to *sbf* than to *bf* (Fig. 29); in *S. sangkulirangensis*, *bc* is slightly closer to *bf* than to *sbf* (Fig. 25)

### Key to the species of *Sarax* species from Borneo

1. Anterior margin of carapace rounded; median eye tubercle well-developed or reduced in size; pedipalpal patella with 4 spines, **P1** the longest, and subsequent spines decreasing in size from distal to proximal; pedipalpal tarsus with 2 or 3 spines; tibia of leg IV with 17 or 19 trichobothria ..... 2
  - Anterior margin of carapace slightly rounded, nearly straight (Fig. 1); median eye tubercle reduced in size; pedipalpal patella with 3 spines, about equal in size (Fig. 4); pedipalpal tarsus with 3 spines (Fig. 5); tibia of leg IV with 19 trichobothria (Fig. 6) ..... *Sarax cavernicola* **sp. nov.**
2. Pedipalpal patella with 4 major spines on antero-dorsal and 4 or 3 major spines on pedipalpal femur; pedipalpal tarsus with 2 or 3 spines; tibia leg IV with 19 trichobothria ..... 3
  - Pedipalpal patella with 4 major spines on antero-dorsal and 3 major spines on pedipalpal femur (Fig. 16); pedipalpal tarsus with 2 minute spines (Fig. 18); tibia of leg IV with 17 trichobothria (Fig. 20)..... *Sarax sarawakensis* (Thorell 1888)
3. Pedipalpal tarsus with 2 spines; trichobothrium *bt* on the middle or close to distal fourth basitibial segment; trichobothrium *bc* closer to *bf* than to *sbf* or about midway between *bf* and *sbf*, with or without sexual dimorphism ..... 4
  - Pedipalpal tarsus with 3 spines (Figs. 11, 13); trichobothrium *bt* close to distal fourth basitibial segment, trichobothrium *bc* about midway between *bf* and *sbf* (Fig. 12); with distinct sexual dimorphism ..... *Sarax yayukae* **sp. nov.**
4. With distinct sexual dimorphism; median eye tubercle completely divided into two parts (Fig. 26); trichobothrium *bt* close to proximal fourth basitibial segment, trichobothrium *bc* about midway between *bf* and *sbf* (Fig. 29).....
  - ..... *Sarax mardua* **sp. nov.**
  - Without sexual dimorphism; median eye tubercle high, black and well-developed, not divided into two parts (Fig. 21); trichobothrium *bt* on the middle of fourth basitibial segment; trichobothrium *bc* closer to *bf* than to *sbf* (Fig. 25) ..... *Sarax sangkulirangensis* **sp. nov.**

### Discussion

**Distribution pattern of Southeast Asian *Sarax* species.** The whip spider genus *Sarax* has been recorded from India and Southeast Asia, and also in New Guinea, New Britain, Bismarck Islands and Solomon Islands (Harvey 2003). The present study adds Sumatra and Palawan as new locality records and has subsequently filled the previously existing gaps between the Malay Peninsula and Java, and between Borneo and Luzon. The genus, however, has never been recorded in Sulawesi, the Moluccas or the Lesser Sunda Islands. Such a disjunct distribution pattern may require a specific biogeographic event to explain it or would be simply attributed to the fact that those areas have been very poorly explored for whip spiders. The other charinid genus, the circum-tropical *Charinus*, occurs in southern New Guinea, northern Australia, Solomon Islands and further east amongst the Pacific islands (Dunn 1949, Harvey 2003, Weygoldt 2006), but has never been recorded in the Indonesian archipelago.

In Borneo Island, five *Sarax* species including the four new species described in this paper are recognized. This number in terms of Southeast Asian area-specific species number is the second largest after Malay Peninsula (six species), two species from Java, one species each from the Philippines and Sumatra (Simon 1892, Kraepelin 1895, Gravely 1915, Harvey 2003) (Fig. 41). Again, such a low number of species in Sumatra and Java, and possibly in the Philippines, could be due to the fact that whip spider faunas in these areas have been poorly studied.

Although information on *Sarax* species in Southeast Asia is still limited, the 11 species so far known from Southeast Asia fall into three groups in terms of their distribution patterns. The first group is rather widely distributed in Southeast Asia (Fig. 41), including *S. sarawakensis* distributed in Andaman Islands, Malay Peninsula, southern Sumatra, Java and Borneo, and *Sarax brachydactylus* so far recorded in Luzon, Cebu and Palawan in the Philippines, and Malay Peninsula, Malaysia and Cambodia (Simon 1892, Fage 1946, Delle Cave 1986, Weygoldt 2002, Harvey 2003). The second consists of only *Sarax davidovi*, which occurs in eastern part of Indochina (Cambodia, Laos and Vietnam) (Fage 1946). The third and last group includes remaining seven species that are endemic to a small area and/or an island or to the Malay Peninsula south of the Isthmus of Kra, all in the so-called Cenozoic Sundaland (Hall 1998). They are *S. buxtoni*, *S. rimosus* and *S. singaporeae* known only from the Malay Peninsula south of the Isthmus of Kra, *S. javensis* known only in Bogor, western Java (Gravely 1915), and the four species described herein from Borneo Island.

Our rudimentary knowledge about their phylogenetic relationships prevents us from making any discussion on a scenario of speciation and dispersal which may have led to the formation of the current distribution pattern of Southeast Asian *Sarax* species.

The distribution pattern of the species occurring in Borneo, on the other hand, is worth discussing in relation to their habitat preferences. *Sarax sarawakensis* is an epigeal whip spider, which should have higher dispersal ability than a cave dweller; this may explain the fact that the species is rather widely distributed in Southeast Asia (Fig. 41). *Sarax yayukae* is known from West and Central Kalimantan and also on Manukan Island in Sabah (Fig. 41). This whip spider was collected in both caves and epigeal habitats, which may suggest that the species has rather higher dispersal ability than strict cave dwellers, explaining the wide distribution in Borneo. All of the remaining three species, *S. cavernicola*, *S. mardua* and *S. sangkulirangensis*, seem to be strict cave dwellers, and their distribution ranges are very restricted (Fig. 42), showing that Sangkulirang caves have many unique species with high levels of endemism (Salas *et al.* 2005).

**Taxonomic notes on *Stygophrynus moultoni* Gravely 1915 (Charontidae).** The whip spider genus *Stygophrynus* is found in Myanmar, the Thai-Malay Peninsula, Sumatra, Java, Borneo and the Solomon Islands (Harvey 2003). The occurrence of the genus in the Solomon Islands is questionable, as *S. forsteri* Dunn 1949 may represent a species of *Charon* (Rahmadi 2009). In Borneo, the sole named species is *S. moultoni* from western Kalimantan (Gravely 1915). Rahmadi & Harvey (2008) presumed the species also occurs in Sangkulirang Karst, East Kalimantan, but this identification was incorrect and we here describe these specimens as *Sarax cavernicola*. Although Gravely (1915) placed *S. moultoni* in *Stygophrynus* he noted that a new genus might eventually be established for the species (see Gravely 1915, p. 436). *Stygophrynus moultoni* was included in the new subgenus *Neocharon* Dunn 1949, along with the type species *S. (N.) forsteri*. All these might allow us to question the generic and familial affiliation of *S. moultoni*.

The male holotype *S. moultoni* is not present in the Natural History Museum, London (J. Beccaloni, pers. comm.), where it was reported to be lodged (Gravely 1915) and is not currently available for study. The description and figure of *S. moultoni* by Gravely (1915) suggests that the generic position of *S. moultoni* may be incorrect, and the species might be better placed to the family Charinidae. However, a more robust decision on the taxonomic status of *Stygophrynus moultoni* can only be made after we obtain further material from the type locality that match the original description of *S. moultoni* and suitable revisionary work is undertaken.

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