

Three new species of the genus *Stephos* Scott, 1892 (Crustacea, Copepoda, Calanoida, Stephidae) from Jeju Island, Korea

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Abstract

During general field surveys carried out recently to collect benthopelagic copepods from near the substrate of the shallow waters off Jeju Island, Korea, a few specimens of three new species of *Stephos* Scott, 1892, were collected. The new species are placed in the genus *Stephos* because of the following combination of features: absence of seta on the basal exite of maxillule, and male right leg 5 ending in an unarmed claw-like and/or mitten-like segment. *Stephos jejuensis* **sp. nov.** can be distinguished from its congeners by body length 0.92 mm, left side of the female genital double-somite with protruding lobes, antennule that extends beyond the distal area of the genital double-somite, and the male leg 5 terminal complex. *Stephos concavus* **sp. nov.** can be distinguished from its congeners by the genital double-somite with protruding lobes on both sides, and the presence of larger spinules on the distomedial margin of leg 5. *Stephos fortipes* **sp. nov.** can be distinguished from its congeners by its longer body length, 1.12 mm long in the female, antennules that extend to the end of the genital double-somite, and the presence of a covered row of minute spinules on the ventral surface of the genital operculum in the female. Until now, 35 species of stephids were known worldwide.

Keywords

Stephos, new species, benthopelagic, near bottom, Jeju Island

Introduction

Benthopelagic copepods are of low abundance and high diversity in the benthic boundary layer (Bradford-Grieve 2004). However, they are difficult to sample on the continental slope or ocean-basin environments, which has contributed to the slow accumulation of knowledge about the benthopelagic fauna (Bradford-Grieve 2004). The benthopelagic calanoid family Stephidae Sars, 1902, consists of four valid genera by: *Stephos* Scott, 1892; *Parastephos* Sars, 1902; *Miostephos* Bowman, 1976 and *Parastephos* Sars, 1902; *Speleohvarella* Kršinić, 2005. Their species are generally smaller in body size, and include hyperbenthic forms living in anchialine and marine coastal habitats (Boxshall and Halsey 2004; Jaume et al. 2008; Kršinić 2012, 2015; Moon et al. 2015; Suárez-Morales et al. 2017). The genus *Stephos* is the most diverse, comprising 32 species (Bradford-Grieve 1999; Boxshall and Halsey 2004; Kršinić 2015; Moon et al. 2015; Suárez-Morales et al. 2017). Up to now, there have been a total of eleven species from the Australia-Western Pacific region, as follows: *S. pentacanthos* Chen & Zhang, 1965; *S. morii* Greenwood, 1978; *S. tropicus* Mori, 1942; *S. tsuyazakiensis* Tanaka, 1967; *S. pacificus* Ohtsuka & Hiromi, 1987; *S. angulatus* Bradford-Grieve, 1999; *S. robustus* Ohtsuka & Hiromi, 1987; *S. kurilensis* Kos, 1972; *S. hastatus* Bradford-Grieve, 1999; *S. geojinensis* Moon, Youn & Venmathi Maran, 2015; and *S. projectus* Moon, Youn & Venmathi Maran, 2015. Species of *Stephos* show many similarities to species of its confamilial genera but differs as follows: the male right fifth leg is 4-segmented (vs. 5-segmented in *Parastephos* and 3-segmented in *Miostephos* and *Speleohvarella*); and the male right fifth leg ends in an unarmed claw-like and/or mitten-like segment (vs. a claw being armed with spines along the concave margin in *Parastephos* and reduced in *Miostephos* and *Speleohvarella*) (Boxshall and Halsey 2004). The zoogeographical distribution of species of *Stephos* was established by Suárez-Morales et al. (2017).

During a survey of the copepod fauna of the southern coasts of Jeju Island, the largest island in Korea, a few specimens of staphids were collected from near-bottom shallow waters by vertical tows of 0.1-mm mesh conical nets at high tide in dusk hours. One of these samples contained representatives of several *Stephos* not known to the benthopelagic environment. This paper reports on three undescribed species of the genus *Stephos* that are herein described in full and compared with their known congeners around the world.

Materials and methods

Copepods were collected from the shallow waters of Jeju Island, Korea by vertical tows (0.1-mm mesh conical nets) at high tide in dusk hours (Fig. 1). For morphological examination, samples were fixed in a 5% natural formalin-seawater solution and cleared in 70% lactic acid for an hour before dissection in a drop of lactophenol on a wooden slide under the dissection microscope (Humes and Gooding 1964). Dissected body parts and appendages were examined under a compound microscope with magnification up to X1,000. Measurements were made with a stage micrometer from the head

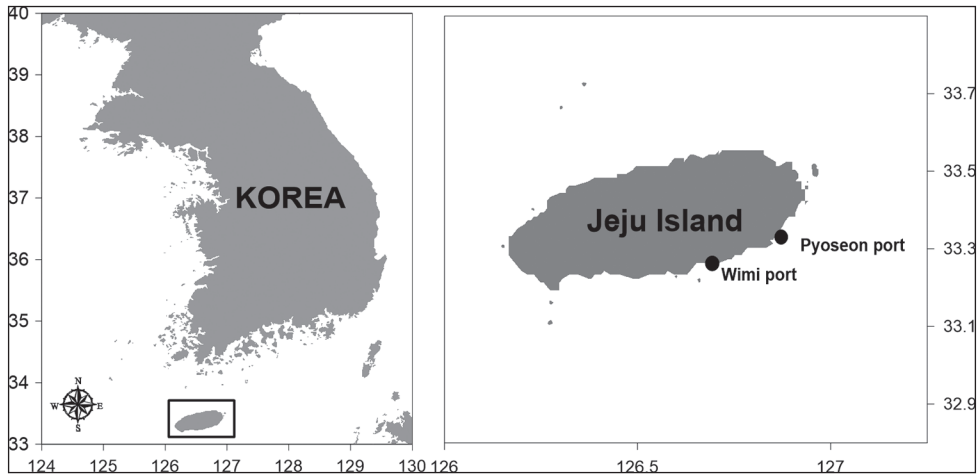


Figure 1. Map showing the sampling location (black circles) in Jeju Island, Korea.

to the tip of the caudal ramous, excluding the caudal setae. Drawings were made with the aid of a drawing tube equipped on the microscope. The morphological terminology follows Huys and Boxshall (1991) and Ferrari and Ivanenko (2008). An abbreviation used in the text and figures is ae, for aesthetasc. Specimens are deposited at the National Institute of Biological Resources (NIBR), Incheon, Korea.

Taxonomy

Order Calanoida Sars, 1901

Family Stephidae Sars, 1902

Genus *Stephos* Scott, 1892

***Stephos jejuensis* sp. nov.**

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Figures 2–5

Material examined. *Holotype* ♀ (NIBRIV0000840220), allotype ♂ (NIBRIV0000840219) undissected in 70% ethanol, 11 November 2012. Dissected *para-types* ♀ (NIBRIV0000840221), ♂ (NIBRIV0000840222) mounted on two glass slides, 11 November 2011. All specimens collected by D. H. Cho.

Type locality. Near the bottom (ca. 5 m depth), Pyoseon port, Jeju Island (33°19'32"N, 126°50'42"E), Korea.

Etymology. The specific name of the new species *jejuensis* refers to the type locality.

Description of female. Body (Fig. 2A, B) robust, length 0.92 mm (mean 0.91 ± 0.03 , $N = 3$). Prosome 5-segmented; cephalosome and first pedigerous somites completely separated; fourth and fifth pedigerous somites incompletely fused (Fig. 2A, B),

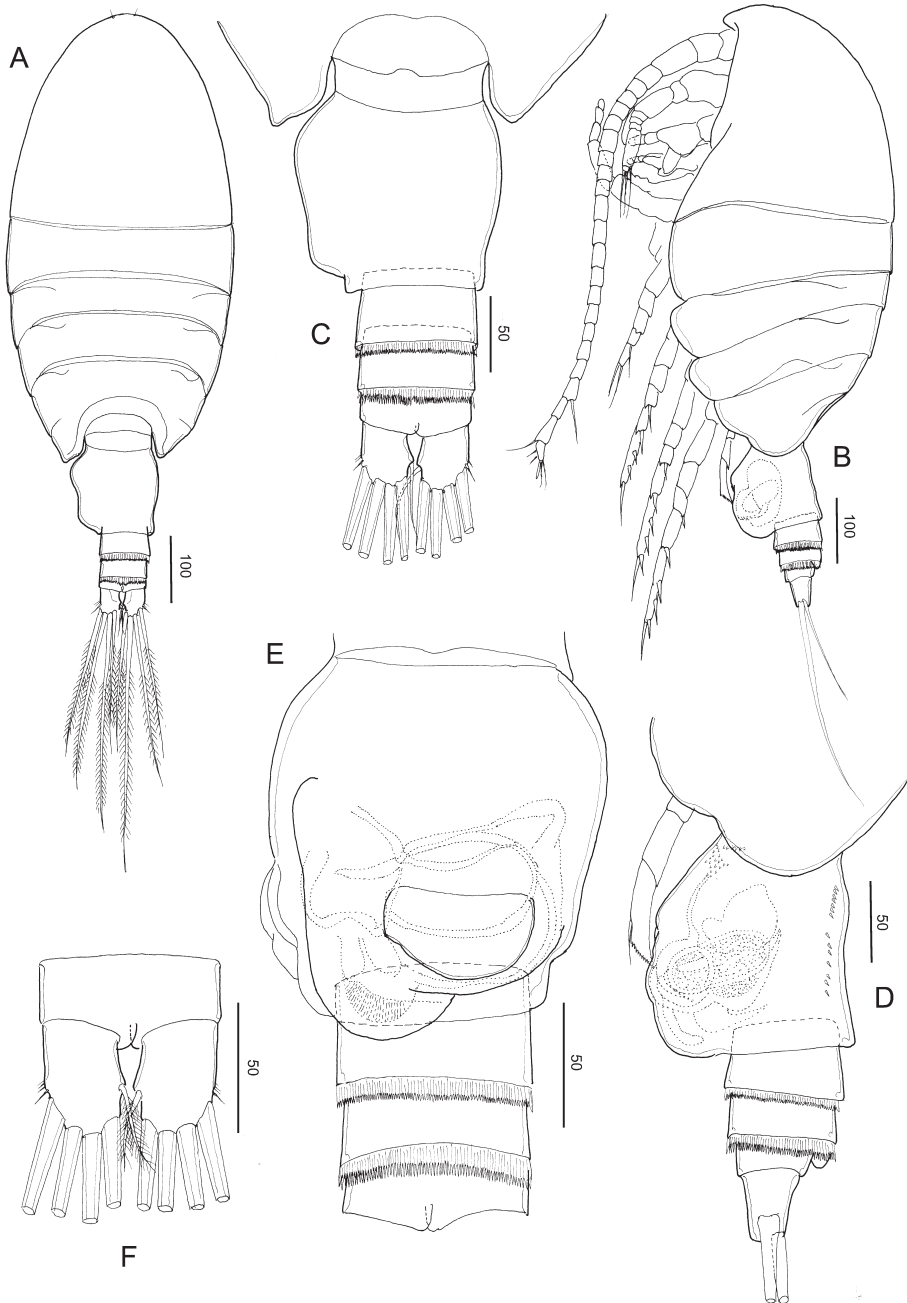


Figure 2. *Stephos jejuensis* sp. nov. Female paratype **A** habitus, dorsal view **B** habitus, lateral view **C** urosome, dorsal view **D** urosome, lateral view **E** urosome, ventral view **F** anal somite and caudal rami. Scale bars in μm .

posterior corners of fifth pedigerous somite slightly asymmetric. Rostrum represented by a rounded knob. Prosome-urosome ratio 2.61:1. Urosome 4-segmented, comprising genital double-somite, two free abdominal somites, and anal somite; length ratio of genital double-somite, first free abdominal somite, second free abdominal somite, and anal somite as 48.2: 14.2: 12.6:11.7:13.4 = 100. Genital double-somite (Fig. 2C, E) asymmetric, with protruding lobe on the anterior to posterior of the left side and a projecting lobe to distal margin, with minute spinules patched in lateral view (Fig. 2D); on the right anterior side is a swollen, common operculum bumpy-shaped ventromedially and with ear lobe on the ventrolateral margin. First and second abdominal somites with transverse hyaline frill dorsally and ventrally. Anal somite short. Caudal rami (Fig. 2F), with six setae, symmetric, 1.45 times longer than wide ($44 \times 31 \mu\text{m}$); caudal setae II–VII present (seta I lacking); seta II spiniform, seta III ca. half the length of seta V, seta V longer (right longer than left) than seta IV, both plumose; dorsal seta VII short, plumose.

Antennule (Fig. 3A) symmetric, extending beyond the distal area of genital double-somite; 24-segmented, apparently ancestral. Segments I–II, III–IV, X–XI, and XXVII–XXVIII are fused. Segmentation and setation pattern as follows (ancestral segment number-setae+aesthetasc): I–II-3+2ae, III–IV-4+3ae, V-2+ae, VI-2, VII-2+ae, VIII-2+ae, IX-2, X–XI-4+ae, XII-1, XIII-1, XIV-2+ae, XV-1, XVI-2+ae, XVII-1, XVIII-1, XIX-1, XX-1, XXI-1+ae, XXII-1, XXIII-1+ae, XXIV-1+1, XXV-1+1, XXVI-1+1, XXVII–XXVIII-5+ae. Ancestral segments I to XIV and XVI to XXV with a row of spinules on the posterior surface.

Antenna (Fig. 3B) biramous; coxa and basis separate, coxa with one and basis with two setae; endopod 2-segmented, proximal segment with two setae, compound distal segment bilobed with eight and seven plumose setae subterminally and terminally, respectively, outer margin ornamented with small serrated process subdistally on the medial margin; tiny spinule adjacent to serrated process; exopod 7-segmented, with intersegmental articulation between segments 2 and 3 not completely expressed, with setal formula of 1, 3, 1, 1, 1, 1, 3.

Mandible (Fig. 3C): well-developed coxal gnathobase, with a straight row of moderately incised teeth. Mandibular palp biramous; basis with four setae on the inner margin. Exopod 5-segmented, with setal formula of 1, 1, 1, 1, 2; endopod 2-segmented, proximal with four setae and distal segments with ten setae.

Maxillule (Fig. 3D): praecoxal arthrite bearing nine stout marginal spines and four elements on posterior surface, rows of tiny spinules on the posterior surface. Coxal epipodite with nine setae; coxal endite with three stiff setae. Basis with cluster of denticles on the anterior surface; proximal basal endite with four setae; distal basal endite indistinct, with five setae; no trace of basal exite. Exopod with eleven marginal setae and a row of setules along the distal portion of the medial margin. Endopod not articulated to basis, indistinctly 3-segmented, setal formula 4, 4, 7.

Maxilla (Fig. 3E): apparently 6-segmented, comprising coalesced praecoxa and coxa, allobasis and 3-segmented endopod. Armature of praecoxal and coxal endites

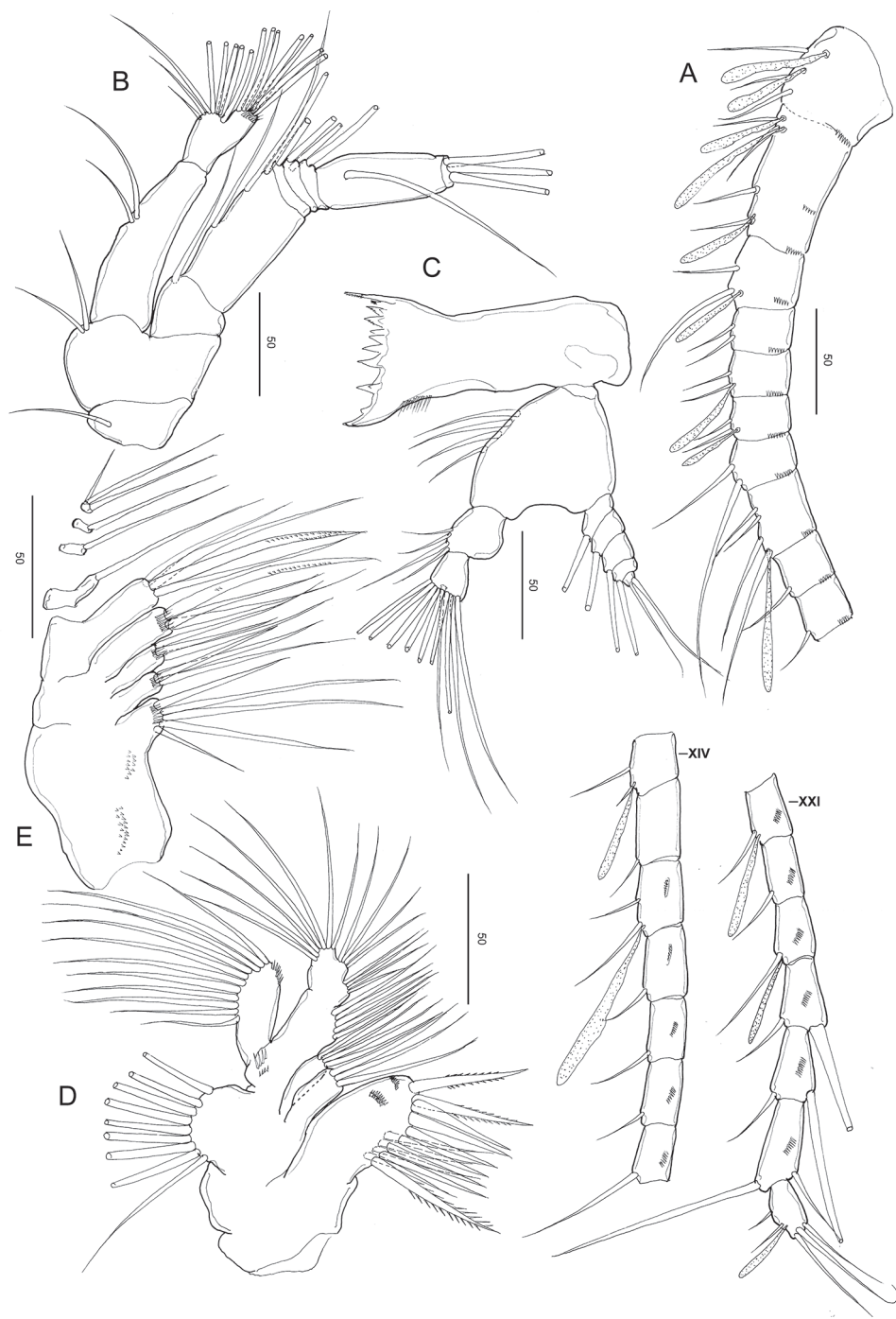


Figure 3. *Stephos jejuensis* sp. nov. Female paratype **A** antennule **B** antenna **C** mandible **D** maxillule **E** maxilla. Scale bars in μm .

5,3,3,3. Basal endite with four setae, one stouter than the rest; endopodal endite with one seta on tip. Free endopod setal formula 1, 1, 3 respectively. Integument of praecoxa ornamented with patch of spinules on the posterior margin. Praecoxal and coxal endites with cluster of long spinules subdistally on the lateral surface; distal coxal endite with additional row of spinules proximally on the medial surface.

Maxilliped (Fig. 4A): syncoxa robust, with setal formula 1, 2, 2, 3 and oblique row of tiny spinules on the posterior distal part; basis with three setae and a row of setules on the mediolateral margin; endopod 6-segmented, with setal formula 2, 4, 4, 3, 3+1, 4.

Legs 1–4 (Fig. 4B–E) progressively larger toward the posterior, each comprising coxa, basis, and 3-segmented exopod; endopod of leg 1 (Fig. 4B) 1-segmented, that of leg 2 (Fig. 4C) 2-segmented; endopods of P3 (Fig. 4D) and leg 4 (Fig. 4E) 3-segmented. Armature formula of legs 1–4 as follows (Roman numerals indicate spines, Arabic numeral indicates setae):

Legs	Coxa	Basis	Exopod	Endopod
Leg 1	0-0	0-1	0-0; I-1; I,1,3	0,2,3
Leg 2	0-1	0-0	I-1; I-1; III,1,4	0-1; 1,2,2
Legs 3 and 4	0-1	0-0	I-1; I-1; III,1,4	0-1; 1,2,2

Leg 1 (Fig. 4B) biramous, with long curved inner setae on the basis, and endopod with lobe on the outer margin, bearing a minute spinous process and a row of minute spinules on the anterior surface.

Leg 2 (Fig. 4C) biramous, endopod 2-segmented; coxa and basis unarmed; second endopodal segments with a row of spinules on the medial and distal edges, with a pointed process on the distolateral corner; exopod 3-segmented, with a row of spinules on the medio to distal margins of the distal exopodal segment.

Legs 3 (Fig. 4D) and 4 (Fig. 4E) biramous, with 3-segmented rami: coxa and basis unarmed; second and distal endopodal segments with a row of spinules on the distal edges, with a pointed process on each of the distolateral corners; exopod with a row of spinules on the medial to distal margins of the distal exopodal segment.

Leg 5 (Fig. 4F) symmetric, uniramous, 3-segmented with a proximal segment fused to intercoxal sclerite; basis separated, 2.27 times longer than wide ($41 \times 18 \mu\text{m}$), widening distally with minute spinules on the anterior corner and an acute inner process, and unarmed. Distal segment with a transverse row of spinules across near the middle part and an outer seta medially.

Description of male. **Body** (Fig. 5A, B) robust, length 0.93 mm. Prosome 5-segmented; cephalosome and first pedigerous somites completely separated; fourth and fifth pedigerous somites incompletely fused (Fig. 5A). Rostrum same as in female. Prosome-urosome ratio 2.18:1. Urosome 5-segmented, comprising genital somite, three free abdominal somites, and anal somite; length ratio of genital somite, first to fourth free abdominal somites, and anal somite as 27.5: 19.2: 16.3: 14.5: 10.9: 11.5 = 100. Genital somite with asymmetric and protruding lobe on the left side. First to third ab-

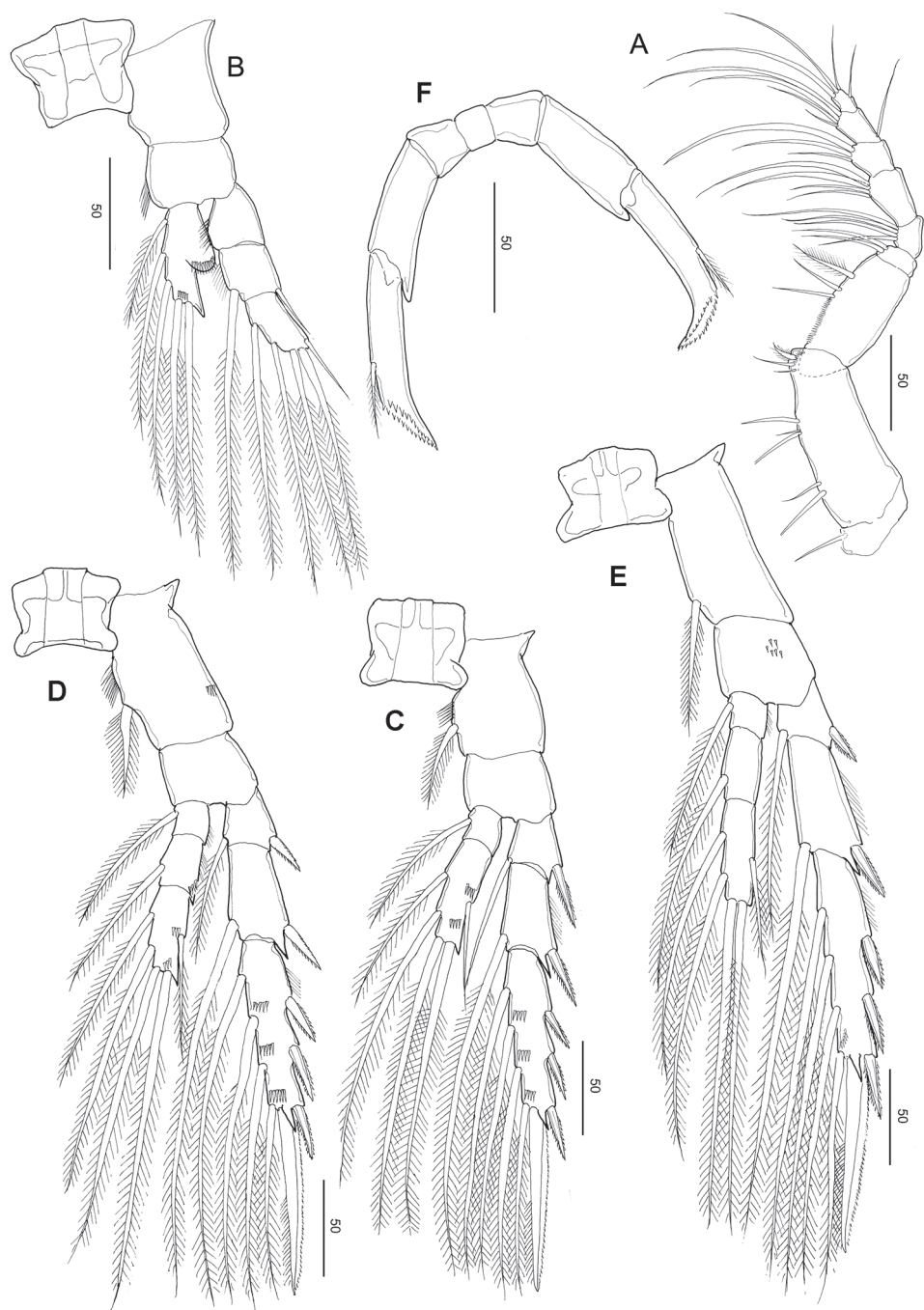


Figure 4. *Stephos jejuensis* sp. nov. Female paratype **A** maxilliped **B** leg 1 **C** leg 2 **D** leg 3 **E** Leg 4 **F** Leg 5. Scale bars in μm .

dominal somites with transverse hyaline frill dorsally and ventrally. Anal somite shortest. Caudal rami similar to those of the female.

Antennule (Fig. 5C) symmetric, extending beyond the distal area of the genital double-somite; 24-segmented, apparently ancestral; segments I–II, III–IV, X–XI, and XXVII–XXVIII are fused. Segmentation and setation pattern as follows (ancestral segment number-setae+aesthetasc): I–II-3+2ea, III–IV-4+3ae, V-2+ae, VI-2, VII-2+ae, VIII-2+ae, IX-2, X–XI-4+ae, XII-1, XIII-1, XIV-2+ae, XV-1, XVI-2+ae, XVII-1, XVI-II-1, XIX-1, XX-1, XXI-1+ae, XXII-1, XXIII-1+ae, XXIV-1+1, XXV-1+1, XXVI-1+1, XXVII–XXVIII-5+ae. Ancestral segments I–XIV and XVI–XXV with row of spinules on the posterior surface.

Antenna, mandible, maxillule, maxilla, maxilliped and legs 1–4 similar to those of the female.

Leg 5 (Fig. 5D–F), strongly asymmetric, slender on both sides, developed as a grasping organ on the left. Right leg 4-segmented; coxa and basis are short, unarmed, but thickened proximally; terminal segment comprising a single longer process (see arrowed in Fig. 5F), outwardly directed, curved medially, and acute at its tip. Left leg 5-segmented (see Fig. 5E); proximal segment ca. as long as right proximal segment; second segment with rounded outgrowth on medial margin; third segment elongated, unarmed; fourth segment narrow, shorter than third segment; terminal segment complex, with 5 terminal (long) and 5 subterminal (short) lamella spines.

Variations. Within this new species, there was a minor variation in the number of spinules on the genital double-somite and on the surfaces of legs 1–4 in both sexes.

Remarks. The genital double-somite in most species of *Stephos* has been found to be symmetric and/or slightly asymmetric in shape. The feature of an asymmetric genital somite in *S. jejuensis* sp. nov. is shared with five of its congeners, *S. lamellatus* Sars, 1902; *S. tsuyazakiensis* Tanaka, 1966; *S. exumensis* Fosshagen, 1970; *S. kurilensis* Kos, 1972; and *S. robustus* Ohtsuka & Hiromi, 1987. Of these, *S. jejuensis* has a projecting lobe on the distal margin in the lateral side of the genital double-somite; however, the other five species do not have this feature. *Stephos jejuensis* has been group IV.

In addition, *S. jejuensis* expresses by two diagnostic features: the fifth pedigerous somite is slightly asymmetric; and a projecting lobe in the lateral side of the genital double-somite. These features are shared by only one other species: *S. jejuensis* can be distinguished from *S. maculosus* (Bradford-Grieve 1999) by the following features in the female: the body length is 0.92 mm (vs. 0.62 mm in *S. maculosus*); dorsally the left side of the genital double-somite has anterior and posterior protruding lobes (vs. without protruding lobe in *S. maculosus*); the antennule extends beyond the distal area of the genital double-somite (vs. not beyond the distal area in *S. maculosus*); and the distal segment is less than four times longer than the second segment of leg 5 (vs. more than four times in *S. maculosus*). In the male: the body length is 0.93 mm (vs. 0.54 mm in *S. maculosus*); the antennule extends beyond the distal area of the genital double-somite (vs. beyond the anterior margin of the caudal rami in *S. maculosus*); on the leg 5 fourth

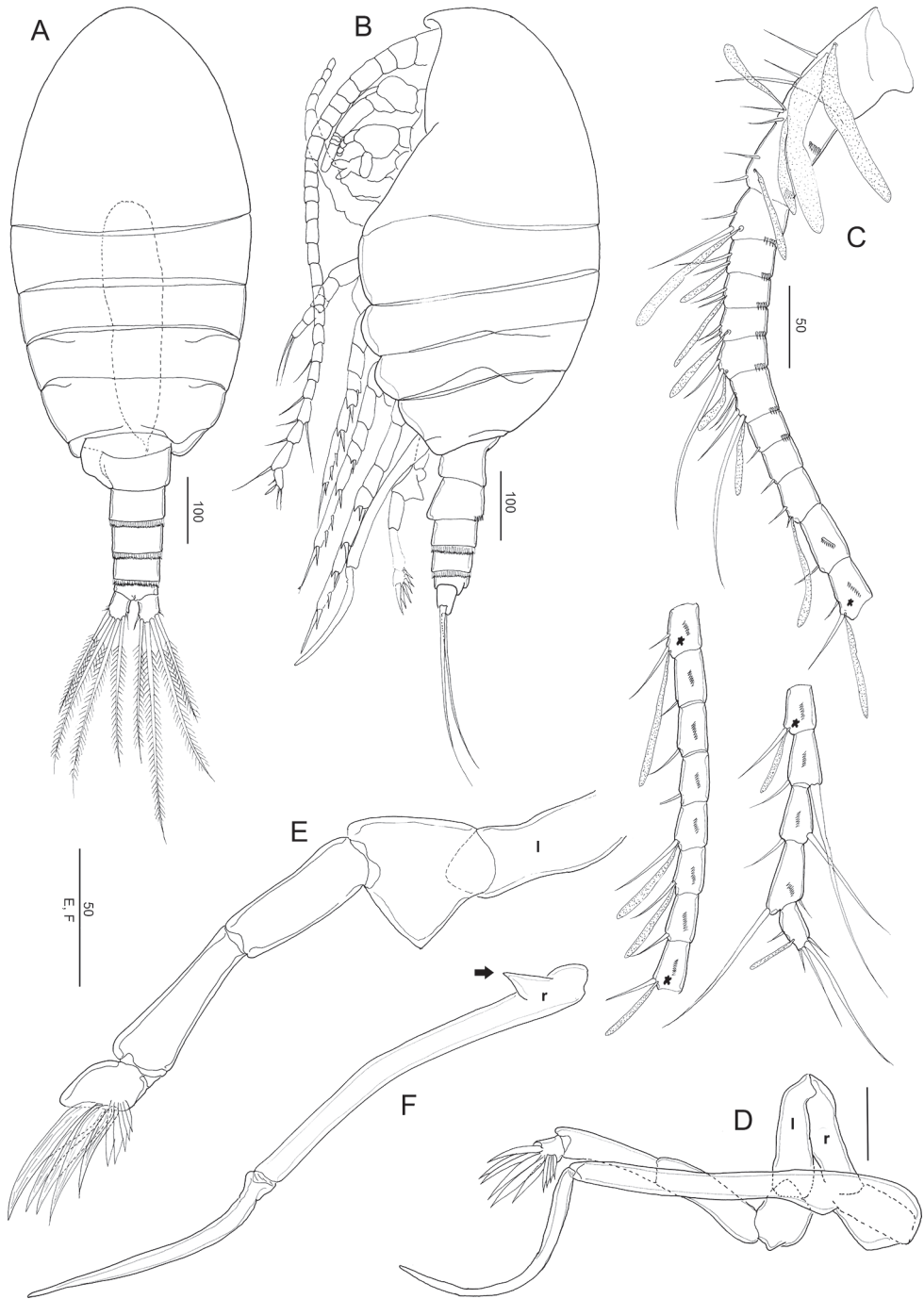


Figure 5. *Stephos jejuensis* sp. nov. Male paratype **A** habitus, dorsal view **B** habitus, lateral view **C** antennule **D–F** leg 5. Scale bars in µm.

segment of the male is narrow (vs. with an finger-like lobe on the medial expansion in *S. maculosus*); and the leg 5 terminal segment complex consists of five terminal (long) and five subterminal (short) lamella spines (vs. not complex, only with three lamella spines in *S. maculosus*).

***Stephos concavus* sp. nov.**

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Figures 6–8

Material examined. *Holotype* ♀ (NIBRIV0000293109) dissected on two glass slides collected by D. H. Cho, 9 May 2012.

Type locality. Near the bottom (ca. 4 m depth), Wimi port, Jeju Island (approximately 33°16'13"N, 126°39'43"E), Korea.

Description of female. *Body* (Fig. 6A, B) robust, length 0.93 mm. Prosome 5-segmented; cephalosome and first pedigerous somites completely separated; fourth and fifth pedigerous somites incompletely fused (Fig. 6A), posterior corners of prosome slightly asymmetric. Rostrum represented by a rounded knob. Prosome-urosome ratio 2.25:1. Urosome 4-segmented, comprising genital double-somite, two free abdominal somites, and anal somite; length ratio of genital double-somite, first free abdominal somite, second free abdominal somite, and anal somite as 43.0:18.9:18.1:9.4:10.7 = 100. Genital double-somite (Fig. 6C–E) slightly asymmetric, with protruding lobe on the anterior to medial part of both sides and with a row of spinules in lateral view (Fig. 6C, D); common operculum located ventromedially slightly round (Fig. 6E) and with spermatophore and coupler in dorsal view (Fig. 6C). First and second abdominal somites (Fig. 6C), with transverse hyaline frill dorsally and ventrally. Anal somite shortest. Caudal rami with six setae, symmetric, 1.75 times longer than wide ($49 \times 28 \mu\text{m}$); caudal setae II–VII present (seta I lacking); seta II spiniform, seta III ca. half the length of seta V, seta V longer (right longer than left) than seta IV, both plumose; dorsal seta VII short, plumose.

Antennule (Fig. 7A) symmetric, extending beyond distal area of genital double-somite; 24-segmented, apparently ancestral, segments I–II, III–IV, X–XI, and XX–VII–XXVIII are fused. Segmentation and setation pattern as follows (ancestral segment number-setae+aesthetasc): I–II-3+2ae, III–IV-4+3ae, V-2+ae, VI-2, VII-2+ae, VIII-2+ae, IX-2, X–XI-4+ae, XII-1, XIII-1, XIV-2+ae, XV-1, XVI-2+ae, XVII-1, XVI-II-1, XIX-1, XX-1, XXI-2+ae, XXII-1, XXIII-1+ae, XXIV-1+1+ae, XXV-1+1, XXVI-1+1, XXVII–XXVIII-5+ae. Ancestral segments I–XIV and XVI–XXV with row of spinules on posterior surface.

Antenna (Fig. 7B) biramous; coxa and basis separate, coxa with one and basis with two setae; endopod 2-segmented, proximal segment with two setae, compound distal segment bilobed with eight and seven plumose setae subterminally and terminally,

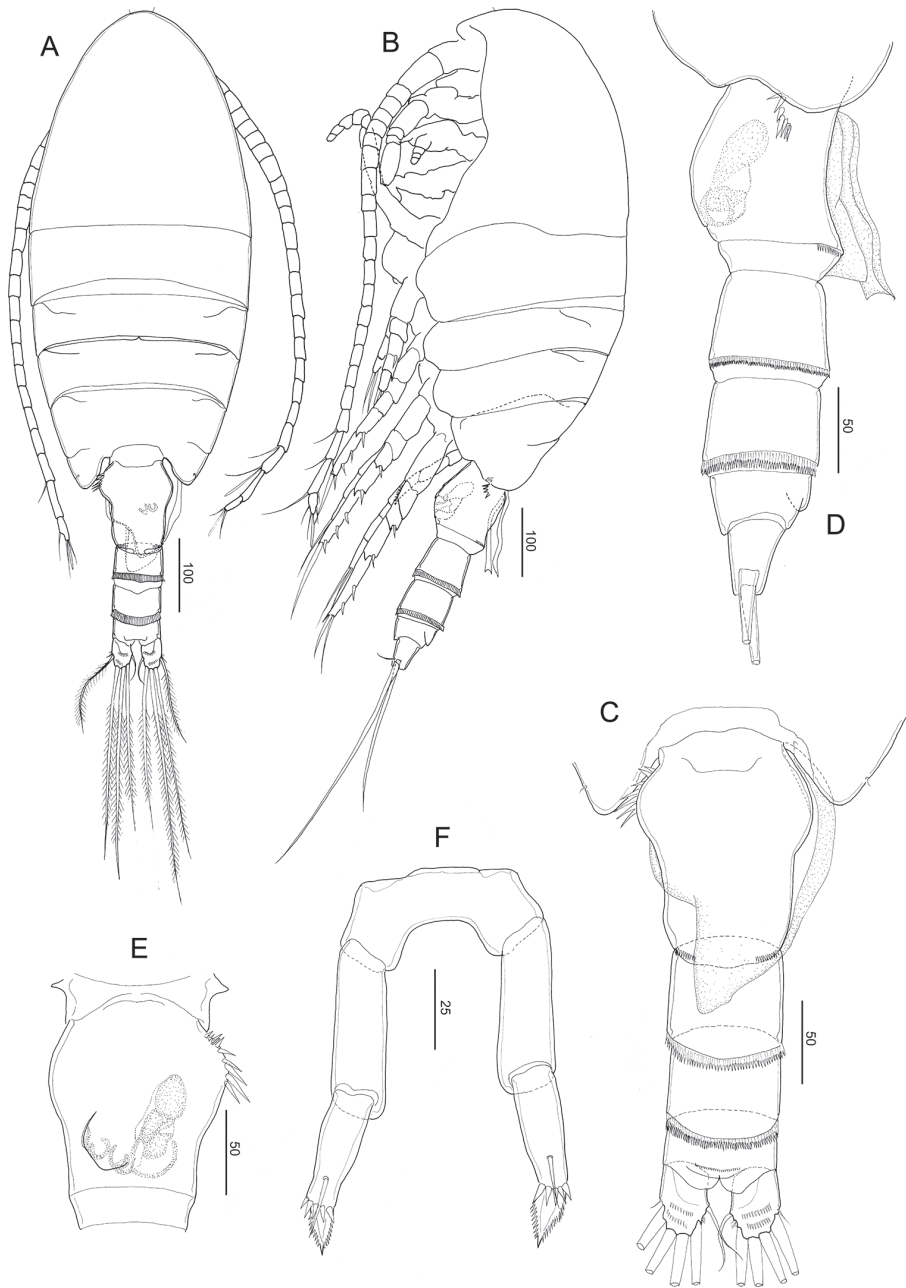


Figure 6. *Stephos concavus* sp. nov. Female holotype **A** habitus, dorsal view **B** habitus, lateral view **C** urosome, dorsal view **D** urosome, lateral view **E** genital double-somite, ventral **F** leg 5. Scale bars in μm .

respectively, outer margin ornamented with a small serrated process subdistally on medial margin; tiny spinule adjacent to serrated process; exopod 7-segmented, with intersegmental articulation between segments 2 and 3 not completely expressed, with setal formula of 1, 3, 1, 1, 1, 1, 3.

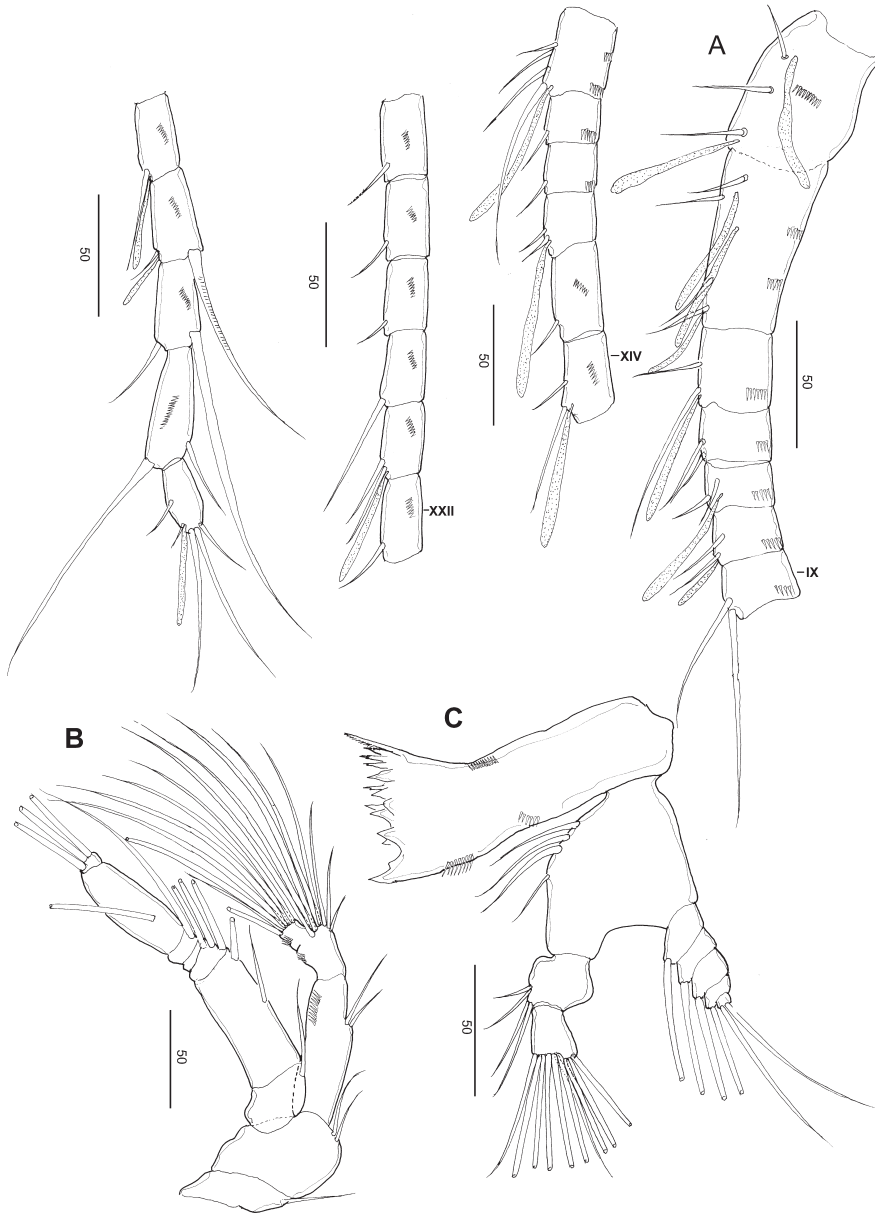


Figure 7. *Stephos concavus* sp. nov. Female holotype **A** antennule **B** antenna **C** mandible. Scale bars in μm .

Mandible (Fig. 7C): well-developed coxal gnathobase, with a straight row of moderately incised teeth and patched spinules on the anterior and posterior corners. Mandibular palp biramous; basis with four setae on inner margin. Exopod 5-segmented, with setal formula of 1, 1, 1, 1, 2; endopod 2-segmented, proximal with 4 setae and distal segments with 10 setae.

Maxillule (Fig. 8A): praecoxal arthrite bearing nine stout marginal spines and four elements on posterior surface, rows of tiny spinules on the posterior surface. Coxal epipodite with nine setae; coxal endite with three stiff setae. Basis with cluster of denticles on the anterior surface; proximal basal endite with four setae; distal basal endite indistinct, with five setae; no trace of basal exite. Exopod with eleven marginal setae; with row of setules along the distal portion of the medial margin. Endopod not articulated to basis, indistinctly 3-segmented, setal formula 4, 4, 7.

Maxilla (Fig. 8B): apparently 6-segmented, comprising coalesced praecoxa and coxa, allobasis, and 3-segmented endopod. Armature of praecoxal and coxal endites 5, 3, 3, 3, respectively. Basal endite with four setae, one stouter than the rest; endopodal endite with one seta on tip. Free endopod setal formula 1, 1, 3, respectively. Integument of praecoxa ornamented with a patch of spinules on the posterior margin. Praecoxal and coxal endites with a cluster of long spinules subdistally on the lateral surface; distal coxal endite with an additional row of spinules proximally on the medial surface.

Maxilliped (Fig. 8C): syncoxa robust, with setal formula 1, 2, 2, 3 and an oblique row of tiny spinules on the anterior distal part; basis with three setae and patched setules on the mediolateral margin; endopod 6-segmented, with setal formula 2, 4, 4, 3, 3+1, 4.

Legs 1–4 (Fig. 8D–G) progressively larger towards the posterior, each comprising coxa, basis, and 3-segmented exopod; endopod of leg 1 (Fig. 8D) 1-segmented, that of leg 2 (Fig. 8E) 2-segmented; endopods of leg 3 (Fig. 8F) and P4 (Fig. 8G) 3-segmented. Armature formula of legs 1–4 as follows in *S. jejuensis* sp. nov.

Leg 1 (Fig. 8D) biramous, with long curved inner setae on the basis, and endopod with lobe on the outer margin, bearing a minute spinous process and a row of minute spinules on the dorsal surface.

Leg 2 (Fig. 8E) biramous, endopod 2-segmented; coxa and basis unarmed; second endopodal segments with a row of spinules on medial and distal edges, with pointed process on the distolateral corner; exopod 3-segmented, with a row of spinules on the medio to distal margins of the distal exopodal segment.

Legs 3 (Fig. 8F) and 4 (Fig. 8G) biramous, with 3-segmented rami: coxa and basis unarmed; second and distal endopodal segments with a row of spinules on the distal edges, with a pointed process on each distolateral corner; exopod with row of spinules on the medio to distal margins of the distal exopodal segment, except for a row of spinules on the posterior surface of leg 4 basis.

Leg 5 (Fig. 6F) symmetric, uniramous, 3-segmented with a proximal segment fused to intercoxal sclerite; basis separated, 2.53 times longer than wide ($38 \times 15 \mu\text{m}$) and unarmed. Distal segment constricted slightly at ca. mid-length with five large spinules and a large seta medially and with two rows of teeth on both lateral each sides as figured.

Male. Not collected.

Remarks. The new species *Stephos concavus* sp. nov. is easily recognized by its four diagnostic features in the female: the genital double-somite with a protruding lobe on

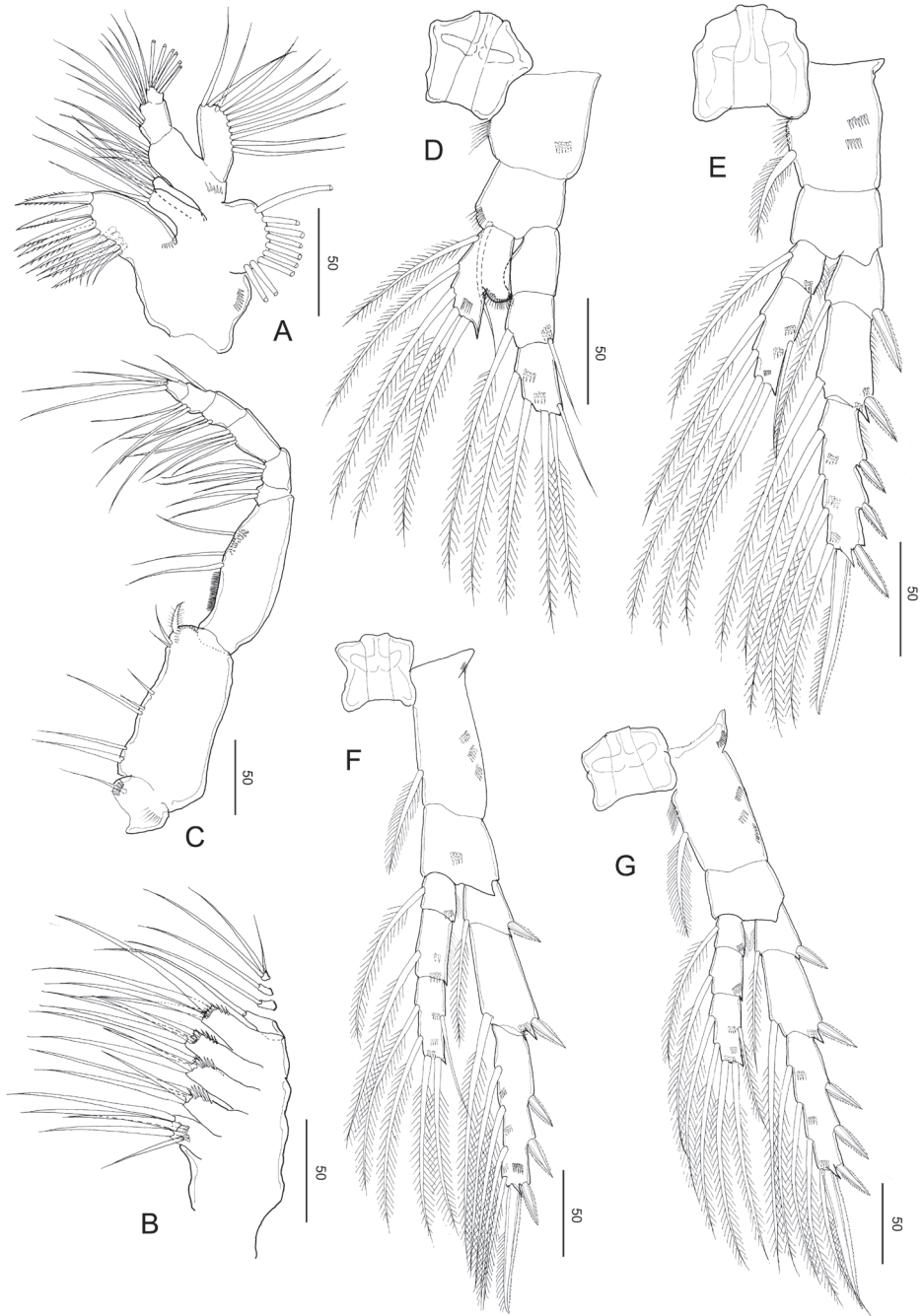


Figure 8. *Stephos concavus* sp. nov. Female holotype **A** maxillule **B** maxilla **C** maxilliped **D** leg 1 **E** leg 2 **F** leg 3 **G** leg 4. Scale bars in μm .

the anterior to medial part of both lateral sides; the presence of seven large rows of spinules on the left side of the genital double-somite; the basis of leg 5 is separated, 2.53 times longer than wide; and the presence of large spinules mediodistally on distal segment of leg 5.

The new species closely resembles *S. cryptospinosus* (Zagami et al. 2000), but it differs in the following features in the female: the body length is 0.93 mm (vs. 0.86 mm in *S. cryptospinosus*); the presence of seven spinules on the left side of the genital double-somite (vs. absence in *S. cryptospinosus*); the antennule extends beyond the distal end of the genital double-somite (vs. beyond the posterior margin of the prosome in *S. cryptospinosus*); the presence of large spinules on the mediodistal margin of leg 5 distal segment (vs. absence in *S. cryptospinosus*); and the terminal segment with teeth on both sides and large spinules mediodistally on both fifth legs (vs. absence in *S. cryptospinosus*).

Stephos concavus differs from another congener *S. longipes* (Giesbrecht, 1902) in the following features of the female: the genital double-somite with protruding lobe on the anterior to medial part of both sides (vs. triangular lobe on the medial part of both sides in *S. longipes*); the presence of a row of spinules on the left side of the genital double-somite (vs. absence in *S. longipes*); the absence of a row of minute spinules on the dorsodistal surface of the genital double-somite (vs. presence in *S. longipes*); the leg 5 distal segment is tapering and stout (vs. tapering and not stout in *S. longipes*); and the teeth on the outer margin of both sides (vs. finely serrated fringe on the outer margin in *S. longipes*).

***Stephos fortipes* sp. nov.**

<http://zoobank.org/C726634A-9A85-4966-B9B1-B63AA83DA929>

Figures 9–11

Material examined. *Holotype* ♀ (NIBRIV0000293110) dissected on a glass slide collected by D. H. Cho, 9 May 2012.

Type locality. Near the bottom (ca. 4 m depth), Wimi port, Jeju Island (approximately 33°16'13"N, 126°39'43"E), Korea.

Etymology. The specific name *fortipes* is the combination of Latin words *fortis* (strong) and *pes* (leg), alluding to the strong feature of the female fifth leg.

Description of female. *Body* (Fig. 9A, B) robust, length 1.12 mm. Prosome five-segmented; cephalosome and first pedigerous somites completely separated; fourth and fifth pedigerous somites incompletely fused (Fig. 9A), posterior corners of prosome slightly asymmetric. Rostrum represented by a rounded knob. Prosome-urosome ratio 2.45:1. Urosome 4-segmented, comprising a genital double-somite, two free abdominal somites, and anal somite; length ratio of genital double-somite, first free abdominal somite, second free abdominal somite, and anal somite as 39.1: 18.7: 17.1:15.1:10.0 = 100. Genital double-somite (Fig. 9C, E) slightly asymmetric with a differing groups

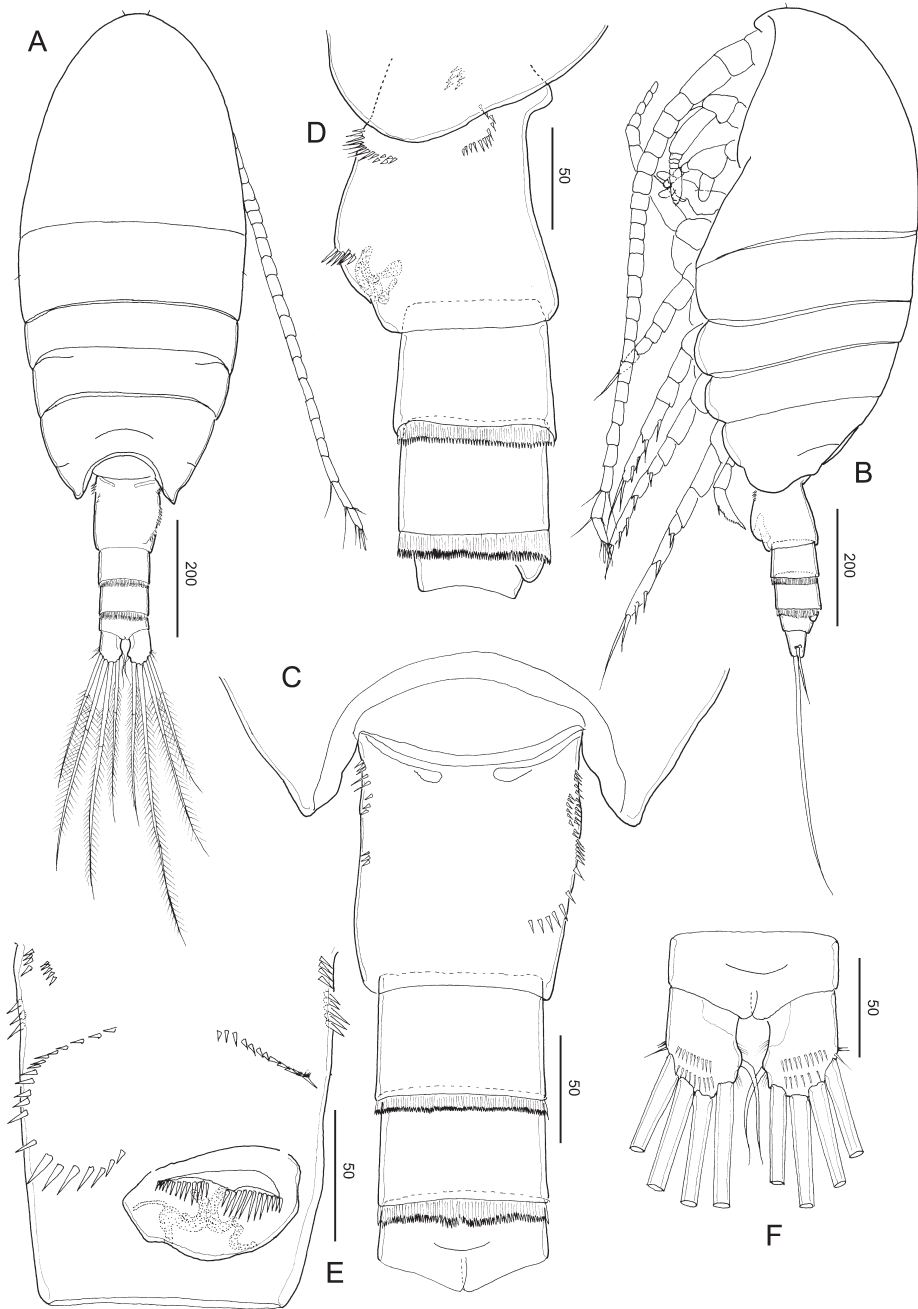


Figure 9. *Stephos fortipes* sp. nov. Female paratype **A** habitus, dorsal view **B** habitus, lateral view **C** urosome, dorsal view **D** urosome, lateral view **E** genital double-somite, ventral view **F** caudal rami, dorsal view. Scale bars in μm .

of minute spinules on each side, anterior to mid-length; on the left side is a group of minute spinules that tend to be obscured by detritus and difficult to observe, patches and rows of fine spinules on the right side; genital double-somite not produced ventrally, operculum slightly round, with rows of spinules on the ventral surface. First and second abdominal somites (Fig. 9C), with transverse hyaline frill dorsally and ventrally. Anal somite shortest. Caudal rami (Fig. 9F), with six setae, symmetric, 1.19 times longer than wide ($56 \times 47 \mu\text{m}$), with minute spinules on the dorsal surface; caudal setae II to VII present (seta I lacking); seta II spiniform, seta III ca. half the length of seta V, seta V longer (right longer than left) than seta IV, both plumose; dorsal seta VII short, plumose.

Antennule (Fig. 10A) symmetric, extending near to distal area of genital double-somite; 24-segmented, apparently ancestral, segments I–II, III–IV, X–XI, and XXVII–XXVIII are fused. Segmentation and setation pattern as follows (ancestral segment number-setae+aesthetasc): I–II-3+ae, III–IV-4+3ae, V-2+ae, VI-2, VII-2+ae, VIII-2+ae, IX-2, X–XI-4+ae, XII-1, XIII-1, XIV-2+ae, XV-1, XVI-2+ae, XVII-1, XVIII-1, XIX-1, XX-1, XXI-1+ae, XXII-1, XXIII-1, XXIV-1+1, XXV-1+1, XXVI-1+1, XXVII–XXVIII-5+ae. Ancestral segments I–XIV and XVI–XXV with a row of spinules on the posterior surface.

Antenna (Fig. 10B) biramous; coxa and basis separate, coxa with one and basis with two setae; endopod 2-segmented, proximal segment with two setae, compound distal segment bilobed with eight and seven plumose setae subterminally and terminally, respectively, outer margin ornamented with a small serrated process subdistally on the medial margin; tiny spinule adjacent to the serrated process; exopod 7-segmented, with intersegmental articulation between segments 2 and 3 not completely expressed, with setal formula of 1, 3, 1, 1, 1, 1, 3.

Mandible (Fig. 10C): well-developed coxal gnathobase, with a straight row of moderately incised teeth, ornamented with spinule rows on the medioventral part. Mandibular palp biramous; basis with four setae on inner margin. Exopod 5-segmented, with setal formula of 1, 1, 1, 1, 2; endopod 2-segmented, proximal with four setae and distal segments with ten setae.

Maxillule (Fig. 10D): praecoxa and coxa incompletely fused; praecoxal arthrite with ten marginal spines plus four stiff setae on posterior surface, rows of tiny spinules on posterior surface. Coxal epipodite with nine setae; coxal endite with three stiff setae. Basis with cluster of denticles on the anterior surface; proximal basal endite with four setae; distal basal endite indistinct, with five setae; no trace of basal exite. Exopod with eleven marginal setae. A row of setules along the distal portion of the medial margin. Endopod not articulated to basis, indistinctly 3-segmented, setal formula 4, 4, 7.

Maxilla (Fig. 10E): apparently 6-segmented, comprising coalesced praecoxa and coxa, allobasis, and 3-segmented endopod. Armature of praecoxal and coxal endites 5,3,3,3, respectively. Basal endite with four setae, one stouter than the rest; endopodal endite with one seta on tip. Free endopod setal formula 1, 1, 3, respectively. Integument of praecoxa ornamented with patch of spinules on the posterior margin. Prae-

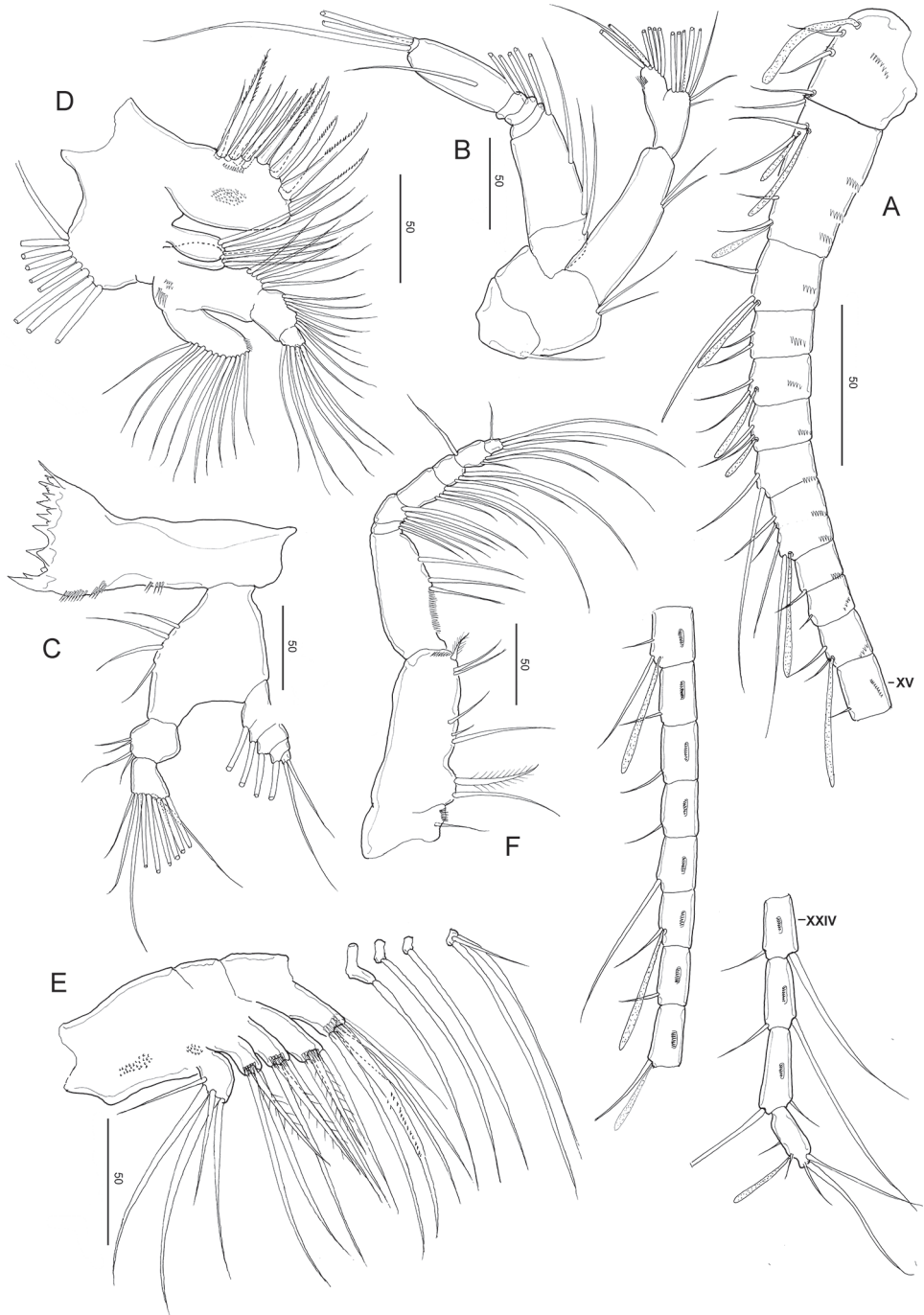


Figure 10. *Stephos fortipes* sp. nov. Female paratype **A** antennule **B** antenna **C** mandible **D** maxillule **E** maxilla **F** maxilliped. Scale bars in μm.

coxal and coxal endites with a cluster of long spinules subdistally on the lateral surface; distal coxal endite with an additional row of spinules proximally on the medial surface.

Maxilliped (Fig. 10F): syncoxa robust, with setal formula 1, 2, 2, 3 and an oblique row of tiny spinules on the posterior distal part; basis with three setae and a row of setules on the mediolateral margin; endopod six-segmented, with setal formula 2, 4, 4, 3, 3+1, 4.

Legs 1–4 (Fig. 11A–D), progressively larger towards posterior, each comprising coxa, basis, and 3-segmented exopod; endopod of leg 1 (Fig. 11A) 1-segmented, that of leg 2 (Fig. 11B) 2-segmented; endopods of leg 3 (Fig. 11C) and P4 (Fig. 11D) 3-segmented. Armature formula of legs 1–4 as in *S. jejuensis* sp. nov.

Leg 1 (Fig. 11A) biramous, coxa with hairs and spinules on the inner and posterior surfaces; basis with a row of spinules on the inner distal corner and long, curved inner setae, and endopod with a lobe on the outer margin, bearing a minute spinous process; second and distal exopodal segments with patched minute spinules; second and terminal exopodal segment with a row of spinules on the posterior margin.

Leg 2 (Fig. 11B) biramous, endopod 2-segmented; coxa with hairs on the inner margin, row of spinules on the posterior surface; basis unarmed; each first and second endopodal with row of spinules on the medial and distal edge, with pointed process on distolateral corner; exopod 3-segmented, with a row of spinules on the medio to distal margins of distal exopodal segment.

Legs 3 (Fig. 11C) and 4 (Fig. 11D) biramous, with 3-segmented rami: coxa with hairs on the inner margin and a row of spinules on the anterior surface; first to distal endopodal segments with a row of spinules on distal edges, with pointed process on each distolateral corner; exopod with a row of spinules on the medio to distal margins of distal exopodal segment.

Leg 5 (Fig. 11E) symmetric, uniramous, 3-segmented with proximal segment fused to intercoxal sclerite; basis separated from the single, tapering terminal segment. Second segment (basis) 1.38 times longer than wide ($44 \times 32 \mu\text{m}$), with an antero-medial patch of minute spinules on the anterior surface. Distal segment constricted slightly at ca. mid-length with seven large spinules and inner stout spine and with two rows of denticles along the tapering portion

Male. Not collected.

Variations. Within this new species, there was a minor variation in the number of spinules on the genital double-somite and on the surfaces of legs 1–4 in the female.

Remarks. The new species closely resembles its congeners *S. angulatus* Bradford-Grieve, 1999, *S. hastatus*, and *S. pacificus* Ohtsuka & Hiromi, 1987; however, it differs in the following characteristics in the female: the antennule extends to the end of the genital double-somite (vs. first abdominal segment end in *S. angulatus*, and fifth pedigerous end in *S. hastatus* and *S. pacificus*); the operculum is slightly round (vs. triangular in three species); and the stout and present large row of spinules on the terminal tapering part of leg 5 (vs. not stout and absent in three species).

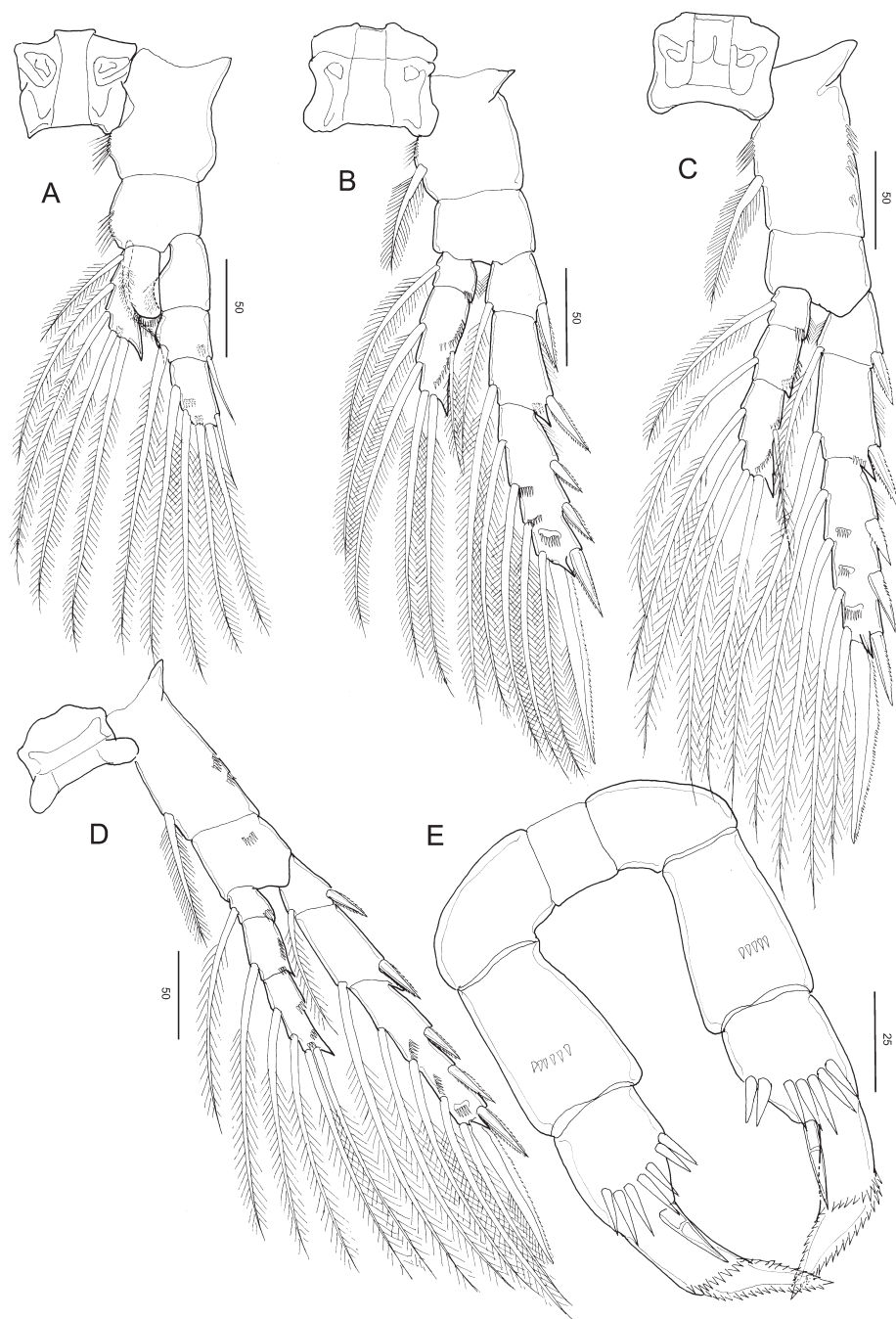


Figure 11. *Stepbos fortipes* sp. nov. Female paratype **A** leg 1 **B** leg 2 **C** leg 3 **D** leg 4 **E** leg 5, dorsal view. Scale bars in μm.

Discussion

The benthopelagic copepod fauna of the Korean peninsula was previously surveyed (Soh et al. 2013; Moon et al. 2014, 2015). They recorded five species: *Sarsarietellus orientalis*, Soh et al., 2013, offshore of Yogji and Maemul Island, southern Korea; *Stephos geojinensis* from the Geojin fishery port in eastern Korea; *S. pacificus* from the shallow waters of Jangdeong beach in southern Korea; *S. projectus* from the Naro Island in southern Korea; and *Boholina ganghwaensis*, Moon & Soh, 2014, from Ganghwa Island in western Korea. The morphological characteristics of the genus *Stephos*, and a key to identifying the species were provided by Boxshall and Halsey (2004). Taxonomic analysis of closely related species of *Stephos* is based on the subtle morphological characters by Bradford-Grieve (1999) and Suárez-Morales et al. (2017). Bradford-Grieve (1999) categorized the species of the genus by analyzing the fourth segments of the male left fifth leg into four types. In this study, seven species in the Australian-Western Pacific region belong to “group IV”, where the fourth segment of the male left fifth leg is narrow, as follows: *S. angulatus* Bradford-Grieve, 1999; *S. geojinensis* Moon, Youn, & Venmathi Maran, 2015; *S. jejuensis* sp. nov., *S. morii* Greenwood, 1977; *S. pacificus* Ohtsuka & Hiromi, 1987; *S. pentacanthos* Chen & Zhang, 1965; and *S. tsuyazakiensis* Tanaka, 1967 (Table 1). The zoogeographic analysis presented based on the structural patterns of the female fifth leg by Suárez-Morales et al. (2017), grouped the 29 species of *Stephos* together. The three new species described here belong to “group A”, where lateral setae are present and segments are apically elongate. This primitive “group A” is the most widespread, present in the most diverse regions (Suárez-Morales et al. 2017).

Most species of *Stephos* are frequently found in hyperbenthic and epibenthic habitats of tropical to polar regions (Boxshall and Halsey 2004; Jaume et al. 2008; Kršinić 2015; Moon et al. 2015; Suárez-Morales et al. 2017), and are occasionally recorded in anchialine caves (Boxshall et al. 1990; Riera et al. 1991; Carola and Razouls 1996; Jaume et al. 2008; Suárez-Morales et al. 2017). However, in this study, the three new species were collected at night using a plankton net in shallow waters. Other stephids have also occurred in plankton samples collected at night in coastal waters (Kos 1972; Ohtsuka and Hiromi 1987; Costanzo et al. 2000; Zagami et al. 2000; Moon et al. 2015). These facts suggest that benthopelagic calanoids could undertake daily vertical migrations (Zagami et al. 2000; Moon et al. 2015) and also diel feeding rhythm, reproduction, molting, dispersal, and niche diversification (Alldredge and King 1980).

The stephids comparisons of morphological features between the three new species of Korean fauna and the all species of genus *Stephos* are based on both sexes in the World. *Stephos* shares many of the characteristics of *Miostephos* Bowman, 1976, but differs in that the right fifth leg in female is 4-segmented and the male right fifth leg ends in an unarmed claw and/or mitten-like segment in *Stephos* (Boxshall and Halsey 2004; Kršinić 2015). According to Suárez-Morales et al. (2017), the structure of the female fifth leg is of great significance in the taxonomy of stephids. These characteristics were used in the keys to species of *Stephos* by Suárez-Morales et al. (2017). Here the following combination of features are used in order to separate

Table 1. Comparison of morphological characteristics of *Stephos* spp.

Character	<i>Stephos angulatus</i> Bradford-Grieve, 1999	<i>Stephos antarcticum</i> Wolfenden, 1908	<i>Stephos arcticus</i> Sars, 1909	<i>Stephos boettgerschnuckae</i> Krsinic, 2012	<i>Stephos canariensis</i> Boxshall, Stock & Sanchez, 1990	<i>Stephos concavus</i> sp. nov.	<i>Stephos cryptosinus</i> Zagami, Campolimi & Costanzo, 2000
Female							
Body length (mm)	0.82	1.85–2.0	1.20	0.89–0.93	0.64–0.69	0.93	0.86
Posterolateral corners	symmetrical	slightly asymmetrical	slightly asymmetrical	asymmetrical	asymmetrical	asymmetrical	symmetrical
Shape of genital double-somite	asymmetrical	symmetrical, lateral swelling on both side	asymmetrical, lateral swelling on left side	symmetrical	slightly asymmetrical	asymmetrical, convex on posterior corner	symmetrical
Operculum shape of genital double-somite	triangular	–	–	–	rounded	slightly rounded	slightly rounded
Ornamentation of genital double-somite	fringe of fine spinules on left side	long spines on both side	–	–	absent	left side with 7 row spinules	absent
Antennule extension	distal margin of first abdominal segment	distal margin of second abdominal segment	distal margin of fifth pedigerous somite	distal margin of caudal rami	distal margin of fifth pedigerous somite	distal margin of genital double-somite	distal margin of fifth pedigerous somite
Row of spinules on basis of fifth legs	absent	absent	absent	absent	present	absent	present
Shape of third segment of fifth legs	tapering	tapering	conical	tapering	tapering, short	tapering, short	tapering, short
Large spinules of third segment of fifth legs	absent	absent	absent	absent	present	present	absent
Outer seta on third segment of fifth legs	present	absent	present	present	present	present	present
Terminal distal part of the segment of fifth legs	curved, distal portion bordered by coarse teeth	curved, strongly serrate process apically	scarcely denticles on distal half of lateral margin	scattered denticles both side	scattered denticles both side	scattered denticles both side	finely serrated fringe on outer margin
Male							
Body length (mm)	0.703	1.75	1.05	0.82–0.9	0.59–0.64	–	0.78
Posterolateral corners	symmetrical	asymmetrical	–	asymmetrical	symmetrical	–	symmetrical
Shape of genital somite	asymmetrical, with genital aperture on the left	–	symmetrical	asymmetrical	symmetrical	–	symmetrical
Antennule extension	distal margin of fifth pedigerous end	second abdominal segment end	distal margin of fifth pedigerous end	end of caudal rami	about to posterior border of genital somite	–	approximately to posterior margin of genital somite
Type of left segment of P5	left segment 4 narrow	left segment 4 narrow, segment 5 bifurcate without leaf-like elements	left segment 4 swollen, segment 5 with leaf-like elements	left segment 4 swollen, segment 5 with leaf-like elements	left segment 4 swollen	–	left segment 4 swollen, segment 5 with leaf-like elements

Table 1. Continued.

Character	<i>Stephox deichmanniae</i> Fleminger, 1957	<i>Stephox exumenis</i> Fosshagen, 1970	<i>Stephox fernandoi</i> Suárez-Morales, Gutiérrez-Aguirre, Cervantes- Martínez & Illife, 2017	<i>Stephox fortipes</i> sp. nov.	<i>Stephox fulvoni</i> Scott T. & Scott A., 1898	<i>Stephox geojinensis</i> Moon et al., 2015	<i>Stephox grieneae</i> Kšinić, 2015
Female							
Body length (mm)	0.62–0.73	0.73	0.47	1.12	1.00	0.88	0.60–0.67
Posterolateral corners	asymmetrical	asymmetrical	symmetrical	symmetrical	symmetrical	symmetrical	slightly asymmetrical
Shape of genital double-somite	asymmetrical	asymmetrical, protruding lobe on left side	symmetrical	asymmetrical	symmetrical	asymmetrical, protruding lobe on both side	symmetrical
Operculum shape of genital double-somite	–	–	rounded	rounded	–	rounded	rounded
Ornamentation of genital double-somite	present	present	4 slender spiniform elements on ventral surface	row of minute spinules on ventral surface	absent	row of spinules on ventral surface	absent
Antennule extension	–	–	posterior margin of preanal sonite	distal margin of genital double-somite	distal half of genital double-somite	distal margin of second urosomite	distal margin of third urosomite
Row of spinules on basis of fifth legs	present	present	absent	present	absent	absent	absent
Shape of third segment of fifth legs	tapering	tapering	cylindrical	tapering, stout	asymmetrical, right leg longer than left	tapering, elongated	tapering, elongated
Large spinules of third segment of fifth legs	absent	present	absent	present	absent	absent	absent
Outer seta on third segment of fifth legs	absent	absent	absent	present (spine)	absent	present	present
Terminal distal part of the segment of fifth legs	row of spinules on distal half of lateral margin	finely serrated fringe on outer margin	spiniform bipinnated apical process	distal portion bordered by fringe teeth	broad knife-like shape of right leg	coarsely serrated spine incorporated distally	single small spine on anterior surface
Male							
Body length (mm)	0.61–0.66	–	0.49	–	1	0.819	0.55–0.62
Posterolateral corners	asymmetrical	–	symmetrical	–	symmetrical	symmetrical	symmetrical
Shape of genital somite	asymmetrical	–	symmetrical	–	symmetrical	asymmetrical, with lateral lobe at each side	slightly asymmetrical
Antennule extension	–	–	beyond distal margin of second urosomite	–	–	distal margin of second urosomite	distal margin of third urosomite
Type of left segment of P5	left segment 4 swollen	–	left segment 4 narrow, segment 5 bifurcate without leaf-like elements	–	left segment 4 swollen	left segment 4 narrow	left segment 4 narrow

Table 1. Continued.

Character	<i>Stephos gynus</i> (Giesbrecht, 1893)	<i>Stephos hastatus</i> Bradford- Grieve, 1999	<i>Stephos jejuensis</i> sp. nov.	<i>Stephos kurilensis</i> Kos, 1972	<i>Stephos lamellatus</i> Sars G.O., 1902	<i>Stephos longipes</i> Giesbrecht, 1902	<i>Stephos lucayensis</i> Fosshagen, 1970
Female							
Body length (mm)	0.9–1.0	1.06	0.92	1.32	1.00	0.75–0.80	0.63–0.71
Posterolateral corners	symmetrical	asymmetrical	asymmetrical	asymmetrical	asymmetrical	–	asymmetrical
Shape of genital double-somite	asymmetrical	asymmetrical	asymmetrical, protruding lobe	asymmetrical, swollen on the left side	asymmetrical	symmetrical, triangular swollen on both sides	Asymmetrical, slightly more swollen on the left than on the right side
Operculum shape of genital double-somite	–	triangular	bumpy	–	–	–	–
Ornamentation of genital double-somite	row of spinules anteriorly on ventral surface	weak spine on right anterior margin	–	absent	absent	present	present
Row of spinules/setules on the dorsal surface of caudal rami	absent	distal margin of fifth pedigerous somite	distal margin of genital double-somite	genital double-somite proximally	–	absent	–
Antennule extension	–	present	present	absent	distal margin of caudal rami	–	–
Row of spinules on basis of fifth legs	absent	tapering	tapering	tapering	absent	absent	present
Shape of third segment of fifth legs	tapering, curved	absent	absent	present	tapering	tapering, curved	tapering
Large spinules of third segment of fifth legs	present	present	absent	present	present	absent	present
Outer seta on third segment of fifth legs	absent	striated hyaline	row of spinules across near the middle part	strongly serrate process apically	present	present	absent
Terminal distal part of the segment of fifth legs	strongly serrate process apically				strongly serrate process apically	strongly serrate process apically	strongly serrate process apically
Male							
Body length (mm)	–	0.943	0.93	1.24			
Posterolateral corners	symmetrical	symmetrical, with genital aperture on the left	asymmetrical, with protruding lobe on the left side	asymmetrical, slightly asymmetrical	1.0mm	0.65–0.70	0.58–0.68
Shape of genital somite	–	distal margin of fifth pedigerous end	distal margin of genital double-somite	distal margin of fifth pedigerous end	symmetrical	asymmetrical	slightly asymmetrical
Antennule extension	distal margin of second urosomite	left segment 4 swollen	left segment 4 narrow	left segment 4 swollen	distal margin of caudal rami	–	asymmetrical
Type of left segment of p5	left leg 4 swollen, segment 5 with leaf-like elements	leg segment 4 swollen	left leg segment 4 narrow	left segment 4 swollen	left segment 4 swollen	left segment 4 narrow, segment 5 bifurcate without leaf-like elements	left segment 4 swollen

Table 1. Continued.

Character	<i>Stephos maculosus</i> Andronov, 1974	<i>Stephos margaleff</i> Riera, Vives & Gili, 1991	<i>Stephos marsalsensis</i> Costanzo, Campolmi & Zagani, 2000	<i>Stephos minor</i> Scott T., 1892	<i>Stephos mortii</i> Greenwood, 1978	<i>Stephos pacificus</i> Ohtsuka and Hiroini, 1987	<i>Stephos pentacanthos</i> Chen and Zhang, 1965
Female							
Body length (mm)	0.86	0.77–0.80	0.76	0.73	–	0.73	–
Posterolateral corners	slightly asymmetrical	symmetrical	Slightly asymmetrical	slightly asymmetrical	–	symmetrical	–
Shape of genital double-somite	symmetrical	symmetrical	symmetrical	symmetrical	–	symmetrical	–
Operculum shape of genital double-somite	–	–	–	–	–	–	–
Ornamentation of genital double-somite	absent	–	Row of minute spinules dorsolaterally	–	–	row of minute spinules on both side	–
Antennule extension	distal margin of caudal rami	distal margin of second urosomite	Posterior margin of first urosomite	beyond of genital double-somite	–	fifth pedigerous end	–
Row of spinules on basis of fifth legs	absent	absent	absent	absent	–	present	–
Shape of third segment of fifth legs	tapering, curved	tapering, stouted	asymmetrical	tapering, stouted	–	tapering	–
Large spinules of third segment of fifth legs	absent	absent	present	absent	–	absent	–
Outer seta on third segment of fifth legs	absent	present	absent	present	–	absent	–
Terminal distal part of the segment of fifth legs	strongly serrate process apically	strongly serrate process apically	right segment sickle-shaped with patch of spinules on proximal anterior surface	scarcely denticuls on distal half of lateral margin	–	striated hyaline	–
Male							
Body length (mm)	0.54	0.74	0.73	0.6	0.85	0.62	0.75
Posterolateral corners	slightly asymmetrical	asymmetrical	symmetrical	symmetrical	asymmetrical	slightly asymmetrical	asymmetrical, produced
Shape of genital somite	symmetrical	asymmetrical	symmetrical	symmetrical	asymmetrical, more rounded on left side than right	asymmetrical with protruding lone on left side	–
Antennule extension	distal margin of fourth urosomite	–	Posterior margin of second urosomite	end of last pedigerous somite	distal margin of third urosomite	distal margin of fifth pedigerous somite	distal margin of second urosomite
Type of left segment of P5	left leg segment 4 swollen	left segment 4 swollen	left segment 4 narrow	left segment 4 swollen	left segment 4 narrow	left segment 4 narrow	left segment 4 narrow

Table 1. Continued.

Character	<i>Stephos projectus</i> Moon et al., 2015	<i>Stephos robustus</i> Ohtsuka and Hiroimi, 1987	<i>Stephos rustadi</i> Strömgren, 1969	<i>Stephos scottii</i> Sars, 1902	<i>Stephos tropicus</i> Mori, 1942	<i>Stephos tsuyazakensis</i> Tanaka, 1967	<i>Stephos rivei</i> Jaume, Boxshall & Gracia, 2008
Female							
Body length (mm)	1.51	1.01	0.68	0.95	0.82	0.78	0.45
Posterolateral corners	asymmetrical	asymmetrical	symmetrical	symmetrical	symmetrical	asymmetrical	slightly asymmetrical
Shape of genital double-somite	asymmetrical, elongated	asymmetrical, lateral swelling on both sides	asymmetrical, lateral swelling on both sides	symmetrical	—	swollen on the left side	symmetrical
Operculum shape of genital double-somite	bumpy	fringed	—	—	—	—	paired genital opercular plates
Ornamentation of genital double-somite	patch spinules on dorsal surface	row of spinules on anterior margin	—	absent	—	left side with minute spinules	row of spinules on ventrolateral and dorsolateral margin
Antennule extension	distal margin of fifth pedigerous somite	distal margin of fifth pedigerous somite	beyond of fifth pedigerous somite	distal margin of second urosomite	—	distal margin of genital segment	beyond posterior margin of fifth pedigerous somite
Row of spinules on basis of fifth legs	absent	present	absent	absent	absent	—	absent
Shape of third segment of fifth legs	tapering, elongated	tapering	absent	tapering	tapering	tapering	tapering, stout
Large spinules of third segment of fifth legs	absent	present	absent	absent	absent	present	absent
Outer seta on third segment of fifth legs	present	present	present	present	absent	absent	present
Terminal tapering part of the segment of fifth legs	curved, distal portion furnished	curved, distal portion both sides	finely serrated fringe on outer margin	row of denticles on distal margin	finely serrated fringe on outer margin	row of spinules on distal margin	two rows of denticles on distal part
Male							
Body length (mm)	0.93	0.91	0.62	0.85	0.73	0.73	0.44–0.45
Posterolateral corners	asymmetrical, with lateral lobe on left margin	asymmetrical	symmetrical	—	—	asymmetrical, slightly produced on the left side	slightly asymmetrical
Shape of genital double-somite	asymmetrical with protruding lobe on left side	asymmetrical, spinules on lateral margin	symmetrical	—	—	asymmetrical, produced on the left side	asymmetrical, produced laterally on left side
Antennule extension	distal margin of fifth pedigerous somite	distal margin of fifth pedigerous somite	distal margin of third urosomite	distal margin of third urosomite	distal margin of second urosomite	distal margin of second urosomite	beyond posterior margin of fifth pedigerous somite
Type of left segment of fifth leg	left segment 4 swollen	left segment 4 swollen	left segment 4 narrow	left segment 4 swollen	left segment 4 swollen	left segment 4 narrow	left segment 4 narrow

species: (1) the body length in both sexes; (2) the shape of postero-lateral corners in both sexes; (3) the shape and ornamentations of the genital double-somite in females; (4) the presence and/or absence of spinules on the caudal rami in both sexes; (5) the antennule extension in both sexes; and (6) the ornamentation and shape of fifth legs in both sexes.

The principal differences between the three new species and their congeners are summarized in Table 1. Although some features occasionally overlap within the all species considered herein, the characteristic combinations proposed are different for each species, showing them to be essential diagnostic elements. These morphological characteristics were very useful and important criteria for identifying each species of stephids.

To date, the genus *Stephos* consists of 35 valid species, including those described herein (Boxshall and Halsey 2004; Jaume et al. 2008; Kršinić 2012, 2015; Moon et al. 2015; Suárez-Morales et al. 2017; this study). Additionally, most of the genus *Stephos* species were not described following modern standards, and most of them need to be redescribed. Thus, the taxonomy, morphological variability, and distribution of stephids are well understood (Bradford-Grieve 1999; Moon et al. 2015; Suárez-Morales et al. 2017). These facts suggest that more detailed research on its taxonomy, biodiversity, and molecular features is necessary for a better understanding of its evolutionary history.

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Description of two new species of *Tonsilla* Wang & Yin, 1992 with an updated key to species (Araneae, Agelenidae)

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Abstract

Two new species of *Tonsilla* Wang & Yin, 1992 are described from Jinggang Mountain National Nature Reserve, Jiangxi Province, China: *T. jinggangensis* K. Liu & X. Xu, **sp. nov.** (♀) and *T. subyanlingensis* K. Liu & X. Xu, **sp. nov.** (♂♀). The new species are illustrated, and their distributions are mapped. Detailed generic characters and an updated key to *Tonsilla* species are also given.

Keywords

Jiangxi, Coelotinae, identification key, Jinggang Mountain, spider, taxonomy

Introduction

At present, the Coelotinae, with approximately 770 species belonging to 33 genera, is the largest subfamily of Agelenidae. The number of species in this subfamily has increased in the last five years greatly due to more than 20 publications, so that now the Agelenidae is the tenth largest spider family (WSC 2020). More than half of the species of Coelotinae belong to 24 genera and are known from China (WSC 2020);

therefore, China has most species- and genus-rich fauna in the world. However actual species richness in the region remains unrevealed.

Tonsilla Wang & Yin, 1992 is relatively small genus with 11 named species which are known exclusively from China. It is a relatively well-studied genus due to numerous publications (see WSC 2020), although half of the species are known by a single sex only (five by females and one by a male). Only one species was described from Jiangxi Province (Zhu et al. 2017).

While studying the Agelindae from the Jinggang Mountain National Nature Reserve, Jiangxi Province, we found two new species belonging to *Tonsilla*, and the main goals of this paper are, therefore, to describe these new species, to provide a key to all species of the genus, and to discuss the affinities of *Tonsillia*.

Materials and methods

Specimens were examined using a Zeiss Stereo Discovery V12 stereomicroscope with a Zoom Microscope System. Both the male palps and female copulatory organs were detached and examined in 75–80% ethanol under a Zeiss Axio Scope A1 compound microscope with a KUY NICE CCD. For SEM photographs, the specimens were dried on filter paper and photographed with the ZEISS EVO LS15 scanning electron microscopes under a low vacuum. The specimens were subsequently stored in 75% ethanol after SEM.

All measurements were made by using ImageView CM2000 software and in millimetres. Leg measurements are given as total length (femur, patella, tibia, metatarsus, tarsus). All the specimens are deposited in the Animal Specimen Museum, Life Science of College, Jinggangshan University (ASM-JGSU).

Terminology of the male and female copulatory organs follows Wang (2003) and Wang et al. (2010). Leg spines are documented by dividing each leg segment into three aspects, dorsal and ventral, the latter being divided into prolateral and retrolateral, e.g., I femur 0 (dorsal) 2 (prolateral ventral) 2 (retrolateral ventral); I tibia 1 (dorsal) 4 (prolateral ventral) 4 (retrolateral ventral). An asterisk (*) indicates a slender spine. The abbreviations used in the text and figures are:

Eyes

ALE anterior lateral eye;
AME anterior median eye;
PLE posterior lateral eye;
PME posterior median eye;

Male palp

BLC basal lamella of conductor;
CF cymbial furrow;

Con conductor;
DAC dorsal apophysis of conductor;
Em embolus;
MA median apophysis;
PA patellar apophysis;
RTA retrolateral tibial apophysis;
VTA ventrolateral tibial apophysis;

Epygine

At atrium;

CD copulatory duct;
CO copulatory opening;
EH epigynal hood;
ET epigynal teeth;
FD fertilization duct;
SH spermathecal head;
Spe spermatheca;

Legs
fe femur;
mt metatarsus;
pa patella;
ta tarsus;
ti tibia.

Taxonomy

Family Agelenidae C.L. Koch, 1837

Subfamily Coelotinae F.O. Pickard-Cambridge, 1893

Genus *Tonsilla* Wang & Yin, 1992

Tonsilla Wang and Yin 1992: 263.

Tonsilla: Wang 2003: 569.

Tonsilla: Yin et al. 2012: 1029.

Tonsilla: Zhu et al. 2017: 547.

Type species. *Tonsilla truculenta* Wang & Yin, 1992.

Diagnosis. Males of this genus can be easily distinguished from these of other genera of Coelotinae by the male palpal patella with a large strong apophysis, which is more than half of the patella length (Figs 5D, E, 7F) (vs small, less than half length of palpal patella in other genera) and conductor with dorsal apophysis (Figs 5C–E, 7A–C, E) (vs without dorsal apophysis). Females of *Tonsilla* are most similar to those of *Pireneitega* in having the large epigynal atrium and large copulatory ducts, and easily differentiated from them by the sub-spherical spermathecae (Figs 1D, 2B, 6D, 7I) (vs strongly convoluted) and from other genera by epigynal teeth located on the anterior atrial margin close to each other (Figs 1C, D, 2A, B, 6C, D, 7H, I) (vs widely separated epigynal teeth located bilaterally in other genera).

Description. **Body size** 7.0–17.0 mm. The morphological appearance of this genus is similar to that of other coelotines. Carapace anteriorly narrowed to between 0.6 and 0.9 times its maximum width. PLE–PLE covered half width of anterior carapace. Chelicerae (Figs 1B, 6B) robust, as wide as half of carapace, with long fang, usually with 3 promarginal and 2 or 3 retromarginal teeth. Endites (Figs 1B, 6B): bean-shaped, longer than wide, with a relatively narrow base, ectal margins distinctly convex; ectal edge concave. Labium: longer than wide, posteriorly narrowed. Sternum (Figs 1B, 6B): longer than wide, shield-shaped, almost straight anteriorly, with slightly convex sides, and pointed posteriorly.

Male palp (Figs 5C–E, 7A–G): patella with large apophysis, more than half of the patella length, strongly sclerotized, extending to dorsal part of patella; tibia with 2 apophyses, ventroretrolateral and retrolateral, the former broad, arising basally, extending

along the retrolateral margin, anteriorly with slightly protruding beyond the distal or subdistal part of tibia, with widely truncated tip, the later from small to large, arising latero-medially; cymbium length/width ratio varies 1.8–2.4 in dorsal view, cymbial furrow less than half of cymbial length, in *T. defossa* and *T. subyanlingensis* sp. nov. from half to more than half of cymbial length; conductor long, anterior part with a distinct furrow or without, with a bifurcated tip or not, with a fine dorsal apophysis of conductor arising from its base; embolus flat and thin, arising at 6 o'clock position, with broad basally, roundly bent and coiled; tegular apophysis spoon-like.

Epigyne: atrium from large to small, heart-shaped, posteromedially located, broad and anteriorly located in *T. defossa*, with an arch-shaped or triangular septum arising antero-medially in *T. truculenta* Wang & Yin, 1992; copulatory openings located postero-laterally in the atrium; epigynal teeth tube-shaped or horn-like, flattened in *T. subyanlingensis* sp. nov., located antero-medially, separated by its length or less, or slightly fused basally; copulatory ducts sac-shaped, mostly rounded, tube-shaped in *T. jinggangensis* sp. nov., *T. subyanlingensis* sp. nov., and *T. yanlingensis*; spermathecae spherical or ovoid, duct-shaped in *T. defossa*, widely separated or close to each other; spermathecal heads arising anteriorly or posteriorly, from short or long; fertilization ducts arising from the posterior part of spermathecae.

Distribution and habitat. The genus is known from subtropics in south China (Sichuan, Anhui, Guizhou, and Jiangxi provinces). Habitats of these spiders are not very diverse, usually found in woody debris, among tree roots on the ground, in humus, and under stones or tree bark.

Composition. *T. defossa* Xu & Li, 2006 (♂♀; Sichuan), *T. distalis* Zhang, Zhu & Wang, 2017 (♀; Guizhou), *T. eburniformis* Wang & Yin, 1992 (♀; Hubei), *T. jinggangensis* K. Liu & X. Xu, sp. nov. (♀; Jiangxi), *T. lyrata* (Wang, Yin, Peng & Xie, 1990) (♀; Hunan), *T. makros* Wang, 2003 (♂; Guizhou), *T. mopanensis* Zhang, Zhu & Wang, 2017 (♂♀; Guizhou), *T. rostrum* Jiang, Chen & Zhang, 2018 (♂♀; Guizhou), *T. subyanlingensis* K. Liu & X. Xu, sp. nov. (♂♀; Jiangxi), *T. tautispina* (Wang, Yin, Peng & Xie, 1990) (♀; Jiangxi), *T. truculenta* Wang & Yin, 1992 (♂♀; Hunan, Hubei, Guizhou, Sichuan), *T. variegata* (Wang, Yin, Peng & Xie, 1990) (♂♀; Anhui), and *T. yanlingensis* (♀; Hunan).

Key to species of *Tonsilla*

Males (males of *T. distalis*, *T. eburniformis*, *T. jinggangensis* sp. nov., *T. lyrata*, *T. tautispina* and *T. yanlingensis* are unknown)

- 1 Cymbial furrow less than half of cymbial length (see Jiang et al. 2018: fig. 24C)2
- Cymbial furrow more than half of the cymbial length (Fig. 5E)4
- 2 Patellar apophysis shorter than patella (see Zhu et al. 2017: fig. 359E).....3
- Patellar apophysis as long or longer than patella (see Zhu et al. 2017: fig. 358C)6
- 3 Ventrolateral tibial apophysis not extending beyond the distal end of tibia (see Zhu et al. 2017: fig. 353C–E)..... *T. defossa*
- Ventrolateral tibial apophysis extending beyond the distal end of tibia (Fig. 5D, E) 4

- 4 Retrolateral tibial apophysis large and strong, longer than half of tibia (Figs 5D, E, 7B, E, F) *T. subyanlingensis* sp. nov.
- Retrolateral tibial apophysis small, less than half length of tibia (see Zhu et al. 2017: fig. 362D) 5
- 5 Retrolateral tibial apophysis arising from the base of tibia (see Zhu et al. 2017: fig. 358C) *T. makros*
- Retrolateral tibial apophysis arising from the middle part of tibia (see Zhu et al. 2017: fig. 362D) 6
- 6 Conductor with posterior lobe (see Zhu et al. 2017: figs 361E, 362D) *T. truculenta*
- Conductor without lobe (see Zhu et al. 2017: fig. 363D, E) 7
- 7 Tip of conductor bifurcated (see Jiang et al. 2018: 89, fig. 24A–C *T. rostrum*
- Tip of conductor not bifurcated (see Zhu et al. 2017: figs 359D, E, 363D, E) .. 7
- 8 Tip of dorsal apophysis of conductor close to median apophysis of tegulum (see Zhu et al. 2017: fig. 363D, E) *T. variegata*
- Tip of dorsal apophysis of conductor separated with median apophysis of tegulum (see Zhu et al. 2017: fig. 359C–E) *T. mopanensis*

Females (female of *T. makros* is unknown)

- 1 Atrium located anteriorly *T. defossa*
- Atrium located posteriorly or medially 2
- 2 Epigynal teeth basally fused *T. truculenta*
- Epigynal teeth slightly separated 3
- 3 Spermathecal heads located antero-laterally *T. lyrata*
- Spermathecal heads located medially or posteriorly 4
- 4 Spermathecae coiled *T. mopanensis*
- Spermathecae sac-shaped, round or tube-shaped 5
- 5 Spermathecae separated by their width *T. distalis*
- Spermathecae, separated by less than radius 6
- 6 Spermathecal heads extending from median to anterior vulva *T. eburniformis*
- Spermathecal heads not extending median to anterior vulva 7
- 7 Copulatory ducts strongly expanded anteriorly 8
- Copulatory ducts not anteriorly expanded 9
- 8 Spermathecal heads arising from median part of spermatheca *T. variegata*
- Spermathecal heads arising from postero-lateral part of spermathecae *T. tautispina*
- 9 Spermathecae kidney-shaped, with a light constriction *T. rostrum*
- Spermathecae oval or tube-shaped with strong constriction 10
- 10 Spermathecal heads very long, tapering anteriorly *T. jinggangensis* sp. nov.
- Spermathecal heads relatively short, not tapering anteriorly 11
- 11 Copulatory ducts extending along the lateral part of spermathecae; spermathecae close to each other *T. yanlingensis*
- Copulatory ducts not extending along the lateral part of spermathecae; spermathecae, separated by less than each half width *T. subyanlingensis* sp. nov.

***Tonsilla jinggangensis* K. Liu & X. Xu, sp. nov.**

<http://zoobank.org/8400223E-E24F-44FC-84D7-DA546F661BFC>

Figures 1–3

Type material. *Holotype* ♀; China: Jiangxi Province, Ji'an City, Jinggangshan County Level City, Luofu Town, Pingtuo Village, Jinggang Mountain National Nature Reserve, Changguling Forest Farm; 26°38'28"N, 114°14'6"E, 583 m; 5.X.2014; Ke-ke Liu et al. leg.

Etymology. The specific name refers to the type locality; adjective.

Diagnosis. The female of this species is similar to that of *T. yanlingensis* but differs by the long horn-shaped epigynal teeth (vs short, bell-shaped in *T. yanlingensis*), the widened posterior part of atrium (vs narrowed in *T. yanlingensis*) and the slender spermathecal heads (vs relatively short and curved in *T. yanlingensis*) (Figs 1C, D, 2, 3).

Description. Female. Habitus as in Figure 1A, B. Total length 11.03. **Carapace** (Fig. 1A, B) 6.84 long, 3.70 wide, anteriorly narrowed to between 0.8- and 0.9-time maximum width of carapace. **Eye** (Fig. 1A) sizes and interdistances: AME 0.18; ALE 0.30; PME 0.20; PLE 0.24; AME–AME 0.18; AME–ALE 0.25; PME–PME 0.20; ALE–ALE 0.94; PME–PLE 0.38; PLE–PLE 1.38; ALE–PLE 0.18, AME–PME 0.21; AME–PLE 0.52. MOA: 0.62 long; 0.56 anterior width, 0.62 posterior width. **Chelicerae** (Fig. 1A, B) with 3 promarginal teeth (median largest) and 3 retromarginal teeth (median largest). **Leg** measurements (Fig. 1A, B): I 13.81 (3.82, 1.80, 2.91, 3.30, 1.98); II 12.24 (3.52, 1.76, 2.33, 2.88, 1.75); III 10.91 (3.23, 1.62, 1.83, 2.78, 1.45); IV 14.84 (4.22, 1.85, 3.11, 3.95, 1.71). **Spination:** I fe 211, ti 022, mt 055; II fe 211, ti 033, mt 055; III fe 122, pa *111, ti 055, mt 855, ta 021; IV fe 101, pa *101, ti 055, mt 855, ta 022. Pedicel 0.40. **Abdomen** (Fig. 1A, B) 5.40 long, 3.26 wide.

Carapace brown. Chelicerae red brown. Endites, labium, and sternum yellow-brown. Legs yellow-brown. Abdomen dark brown, dorsally with 2 pairs of yellow-brown spots from antero-median to middle and 4 yellow-brown chevron-like stripes in posterior half.

Epigyne (Figs 1C, D, 2, 3). Atrium deep, transverse, more than 2 times wider than long. Copulatory openings located at postero-lateral part of the atrium. Epigynal teeth long, horn-shaped, separated by its length, apex slightly convergent. Copulatory ducts slightly longer than spermathecae, originating posteriorly, extending forward along spermathecae and connected to anterior part of spermathecae. Spermathecae arched, with many constrictions, separated by less than radius of spermatheca. Spermathecal heads slender tube-shaped, posteriorly located, bent laterally. Fertilization ducts located at the posterior part of spermathecae.

Distribution. Known only from the type locality in Jiangxi Province, China (Fig. 9).

Comments. Although we have only the female of this species, we are convinced that it is not conspecific with *T. makros* a species known from Guizhou. The male of *T. makros* (6.20) is slightly larger than half of the female of *T. jinggangensis* sp. nov. (11.03). *Tonsilla* species seem to have a narrow distribution, except for *T. truculenta*

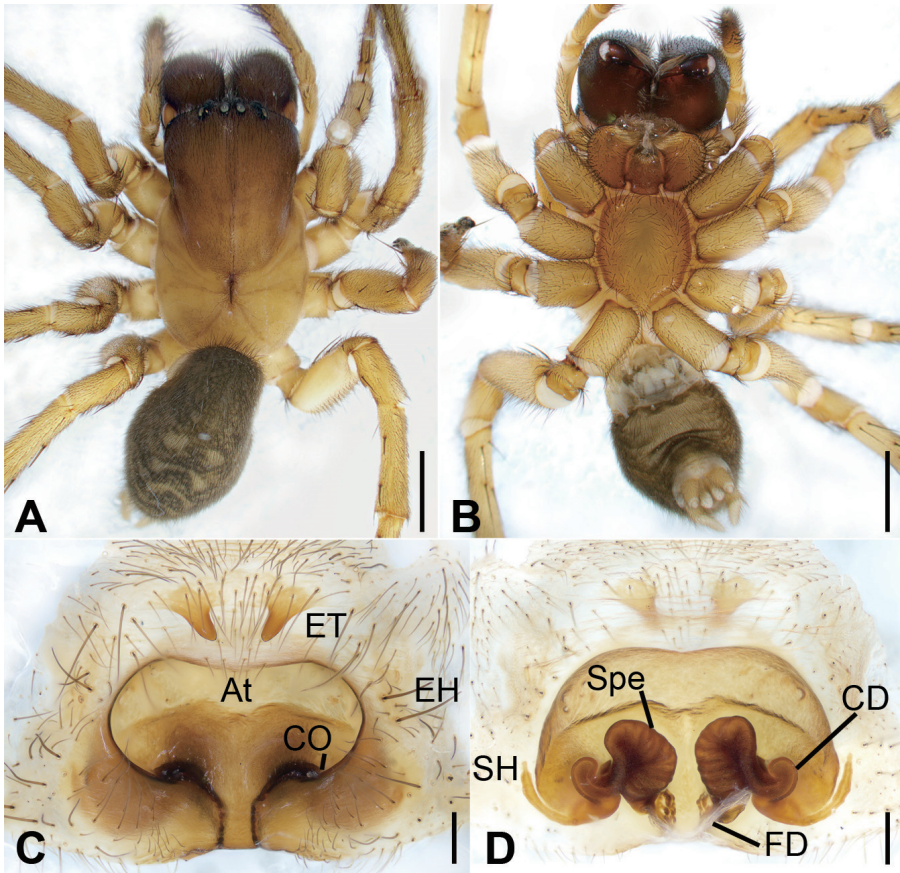


Figure 1. *Tonsilla jinggangensis* sp. nov., female holotype **A** habitus, dorsal view **B** same, ventral view **C** epigyne, ventral view **D** vulva, dorsal view. Scale bars: 2 mm (**A**, **B**), 0.2 mm (**C**, **D**). Abbreviations: At – atrium, CD – copulatory duct, CO – copulatory opening, EH – epigynal hood, ET – epigynal teeth, FD – fertilization ducts, SH – spermathecal heads, Spe – spermathecae.

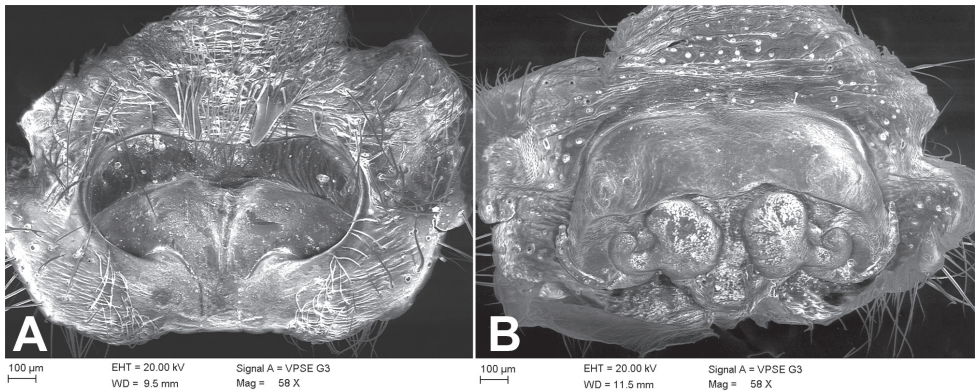


Figure 2. SEM images of *Tonsilla jinggangensis* sp. nov., female holotype **A** epigyne, dorsal view **B** vulva, ventral view.

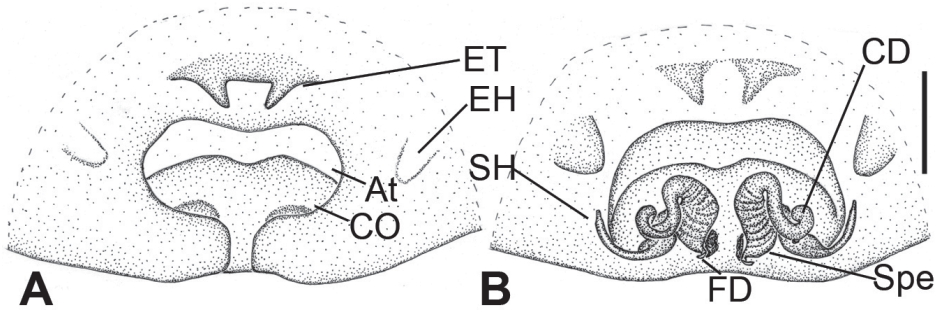


Figure 3. *Tonsilla jinggangensis* sp. nov., female holotype **A** epigyne, ventral view **B** vulva, dorsal view. Scale bars: 0.5 mm. Abbreviations: At – atrium, CD – copulatory duct, CO – copulatory opening, EH – epigynal hood, ET – epigynal teeth, FD – fertilization ducts, SH – spermathecal heads, Spe – spermathecae.

from south China. *Tonsilla jinggangensis* sp. nov. and *T. tautispina* from Jiangxi are more similar to species from Hunan, such as *T. lyrata* and *T. yanlingensis*, than species from Guizhou (*T. makros*, *T. mopanensis*). Hence, the male palp of this species may have a stout patellar apophysis.

***Tonsilla subyanlingensis* K. Liu & X. Xu, sp. nov.**

<http://zoobank.org/64760314-489A-4A5C-AFA3-3D857B92ED14>

Figures 4–8

Type material. *Holotype* ♂; China: Jiangxi Province, Ji'an City, Jinggangshan County Level City, Ciping Town, Wuzhi Peak Scenic Spot; 26°31'59.07"N, 114°08'28.47"E, 735 m; 2.X.2018; Ke-ke Liu et al. leg. *Paratypes*: 2 ♀; same data as holotype; 1 ♀; same locality, Dajing Village; 26°33'50.4"N, 114°07'26.4"E, 930 m; 19.X.2014; Ke-ke Liu et al. leg.; 1 ♀; same locality; 26°34'12.89"N, 114°07'41.87"E, 950 m; 30.IX.2018; Ke-ke Liu et al. leg.; 1 ♀; same locality, Jingzhushan Scenic Spot; 26°31'33.37"N, 114°06'30.34"E, 786 m; 1.X.2018; Ke-ke Liu et al. leg.

Etymology. The specific name refers to its similarity to *T. yanlingensis* (Zhang, Yin & Kim, 2000); adjective.

Diagnosis. Females of the new species closely resemble *T. yanlingensis* by the heart-shaped, large atrium and wide epigynal teeth, but can be distinguished by the spermathecae separated by less than 1/5 of their width (vs touching each other in *T. yanlingensis*), long and broad copulatory ducts along with the spermathecae (vs very short in *T. yanlingensis*), the slightly procurved spermathecal heads located at posterior part of spermatheca (Figs 5C, D, 7H, I) (vs strong procurved spermathecal heads located at mid part of spermatheca in vulva), and the spermathecae slightly separated by less than 1/5 of their width (vs touching each other) (Wang and Yin 1992; Zhu et al. 2017). The male of this species is similar to that of *T. mopanensis* and *T. truculenta* in having a long, broad, and furrowed basal lamella of conductor, but can be separated by the patellar

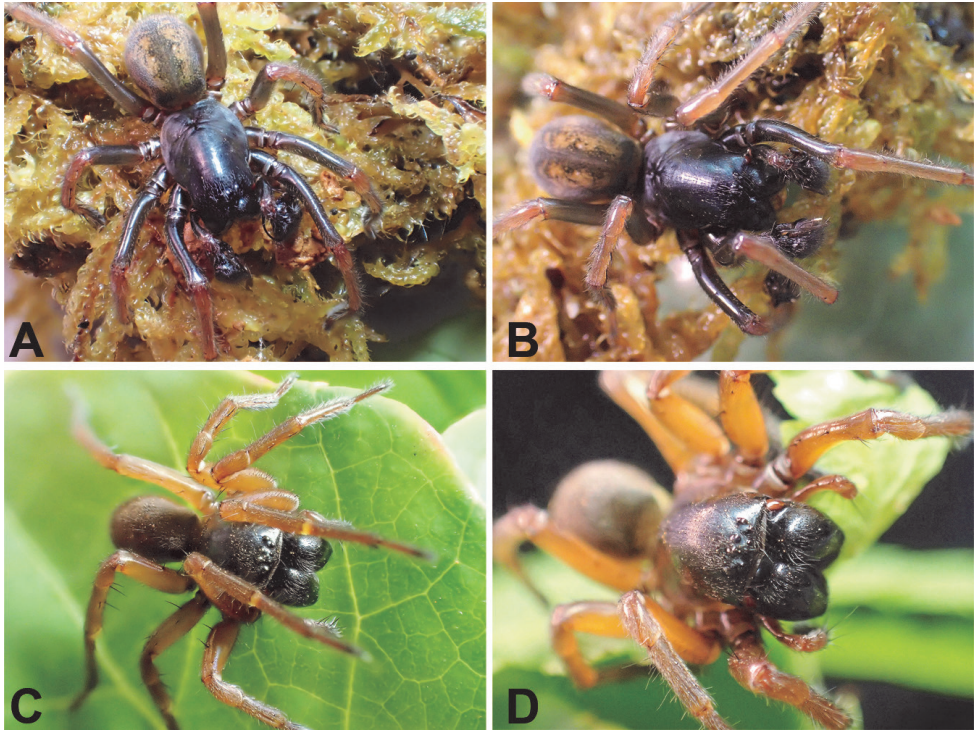


Figure 4. Photographs of living specimens of *Tonsilla subyanlingensis* sp. nov. from Jinggang Mountain. **A, B** male **C, D** female.

apophysis which is relatively shorter than patellar (vs as long as patellar apophysis in *T. mopanensis* or longer in *T. truculenta*) and the conductor with a long, broad curved dorsal apophysis (Figs 5A–C, 7A–G, 8A–C) (vs long, narrowed in *T. mopanensis*; short, strong in *T. truculenta*).

Description. Male (Holotype). Habitus as in Figures 4A, B, 5A, B. Total length 11.25. **Carapace** (Fig. 5A) 6.01 long, 4.44 wide, anteriorly narrowed to between 0.6 and 0.7 its maximum width. **Eye** sizes and interdistances: AME 0.20; ALE 0.25; PME 0.24; PLE 0.25; AME–AME 0.10; AME–ALE 0.18; PME–PME 0.08; ALE–ALE 0.81; PME–PLE 0.36; PLE–PLE 1.16; ALE–PLE 0.10, AME–PME 0.16; AME–PLE 0.45. MOA: 0.60 long; 0.49 front width, 0.50 back width. **Chelicerae** (Fig. 5B) with 2 promarginal teeth (proximal smaller) and 2 retromarginal teeth (proximal larger). **Leg** (Fig. 5A, B) measurements: I 17.84 (4.88, 1.95, 4.46, 4.30, 2.25); II 15.78 (4.25, 1.90, 3.74, 3.74, 2.15); III 13.36 (3.62, 1.81, 2.82, 3.40, 1.71); IV 17.27 (4.87, 1.92, 3.69, 4.77, 2.02). **Spination**: I fe 120, pa 001, ti 055, mt 033, II fe 000, ti 044, mt 033. Femur I with 6 ventral cusps. Leg measurements (Fig. 5A, B): I 13.15 (4.17, 1.85, 3.26, 2.54, 1.33); II 12.90 (3.62, 1.18, 2.90, 2.83, 1.71); III 11.00 (3.01, 1.72, 2.14, 2.75, 1.38); IV 14.12 (3.84, 1.87, 3.45, 3.70, 1.32). Spina-

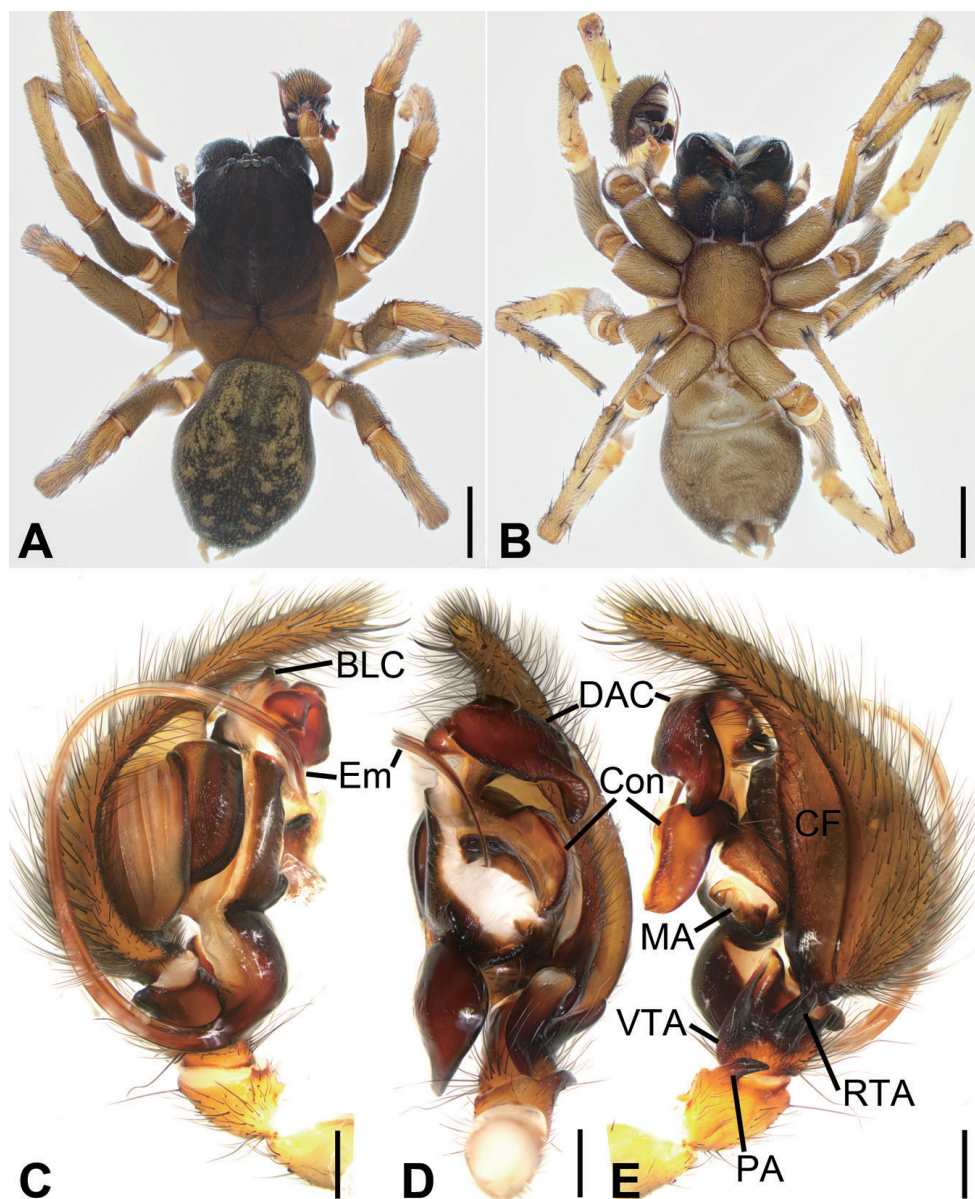


Figure 5. *Tonsilla subyanlingensis* sp. nov., male holotype **A** habitus, dorsal view **B** same, ventral view **C** palp, prolateral view **D** same, ventral view **E** same, retrolateral view. Scale bars: 2 mm (**A**, **B**), 1 mm (**C–E**). Abbreviations: BLC – basal lamella of conductor, CF – cymbial furrow, Con – conductor, DAC – dorsal apophysis of conductor, Em – embolus, ET – epigynal teeth, MA – median apophysis, RTA – retrolateral tibial apophysis, PA – patellar apophysis, VTA – ventrolateral tibial apophysis.

tion: I fe 210, ti 043, mt 055; II fe 210, ti 043, mt 065; III fe 121, pa 011, ti 433, mt 655, ta 011; IV fe 100, ti 342, mt 753, ta 012. Pedicel 0.32. **Abdomen** (Fig. 5A, B) 5.24 long, 3.68 wide.

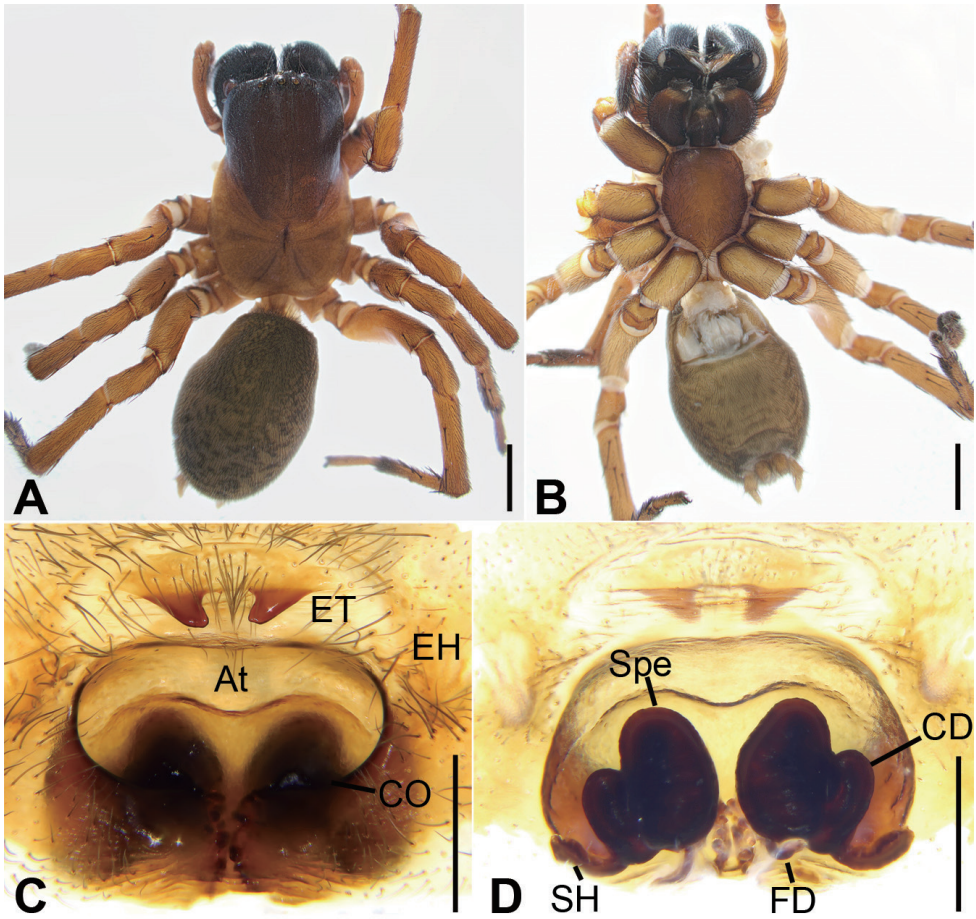


Figure 6. *Tonsilla subyanlingensis* sp. nov., female paratype **A** habitus, dorsal view **B** same, ventral view **C** epigyne, ventral view **D** vulva, dorsal view. Scale bars: 2 mm (**A**, **B**), 0.5 mm (**C**, **D**). Abbreviations: At – atrium, CD – copulatory duct, CO – copulatory opening, EH – epigynal hood, ET – epigynal teeth, FD – fertilization ducts, SH – spermathecal heads, Spe – spermathecae.

Carapace dark brown. Chelicerae dark brown. Endites and labium dark yellow-brown. Sternum and legs yellow-brown. Abdomen dark brown with 5 pairs of yellow-brown spots on posterior half.

Palp (Figs 5C–E, 7A–G, 8A–C). Femur more than 2 times longer than patella. Patellar apophysis slightly shorter than patella, thumb shaped. Tibia with wide ventrolateral apophysis and long retrolateral apophysis, the former extending beyond tibia, strongly sclerotized; the later slightly shorter than ventrolateral, and twice thinner, apex bent ventrally to the tip of ventrolateral apophysis, forming a right angle with its axis. Cymbium, approximately 3 times longer than wide, cymbial furrow less than $2/3$ of the cymbial length, approximately $1/3$ of cymbial width in retrolateral view. Median apophysis spoon-shaped, located near the base of embolus; conductor, slightly curved, with a long, broad and furrowed basal lamella and a large, twisted, sclerotized dorsal

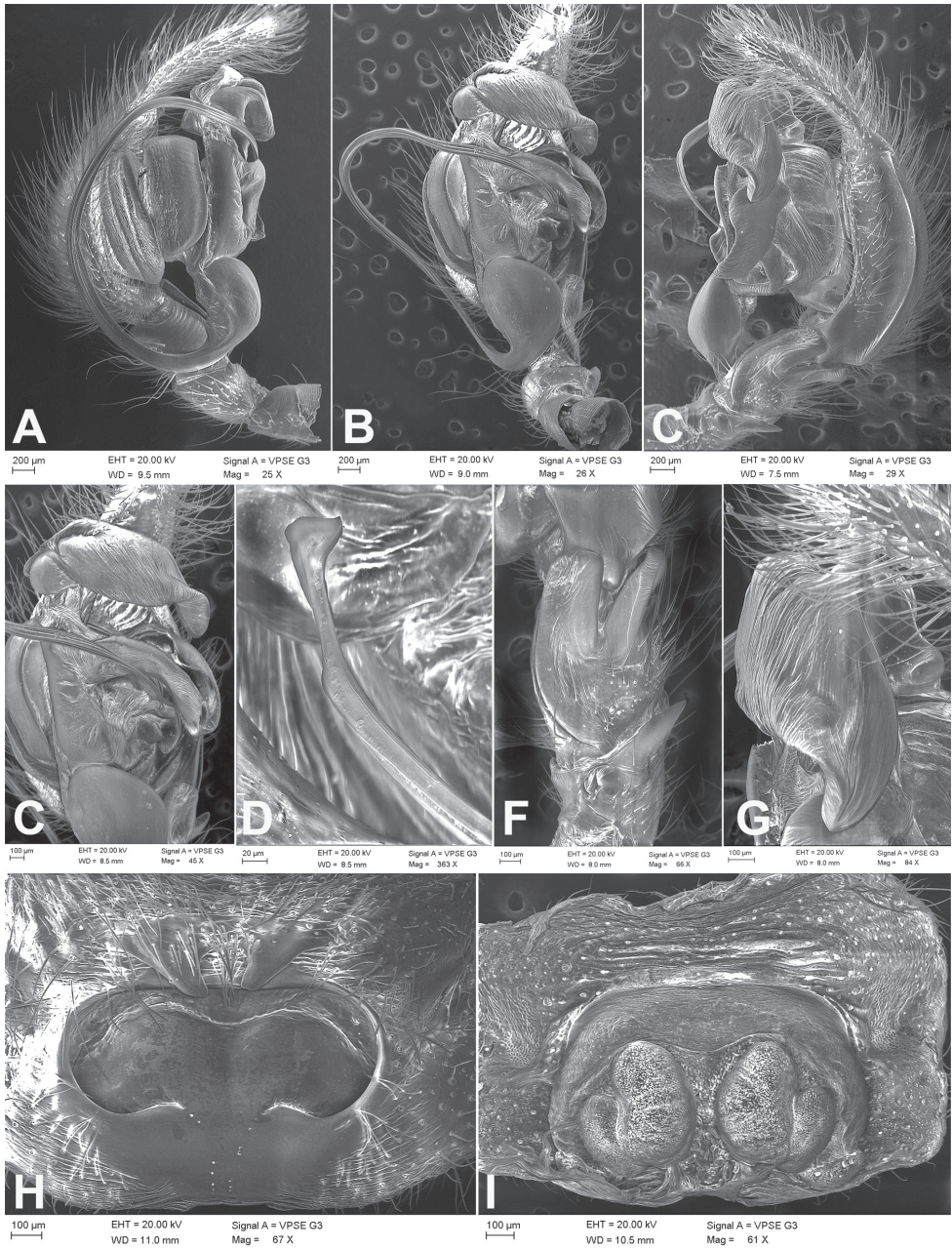


Figure 7. SEM images of *Tonsilla subyanlingensis* sp. nov., male holotype and female paratype **A** palp, prolateral view **B** same, ventral view **C** same, detail of conductors, ventral view **D** same, detail of embolus, ventral view **E** same, retrolateral view **F** same, detail of patellar apophysis, retrolateral tibial apophysis and lateral tibial apophysis, retrolateral view **G** same, detail of conductor dorsal apophysis, retrolateral view **H** epigyne, dorsal view **I** vulva, ventral view.

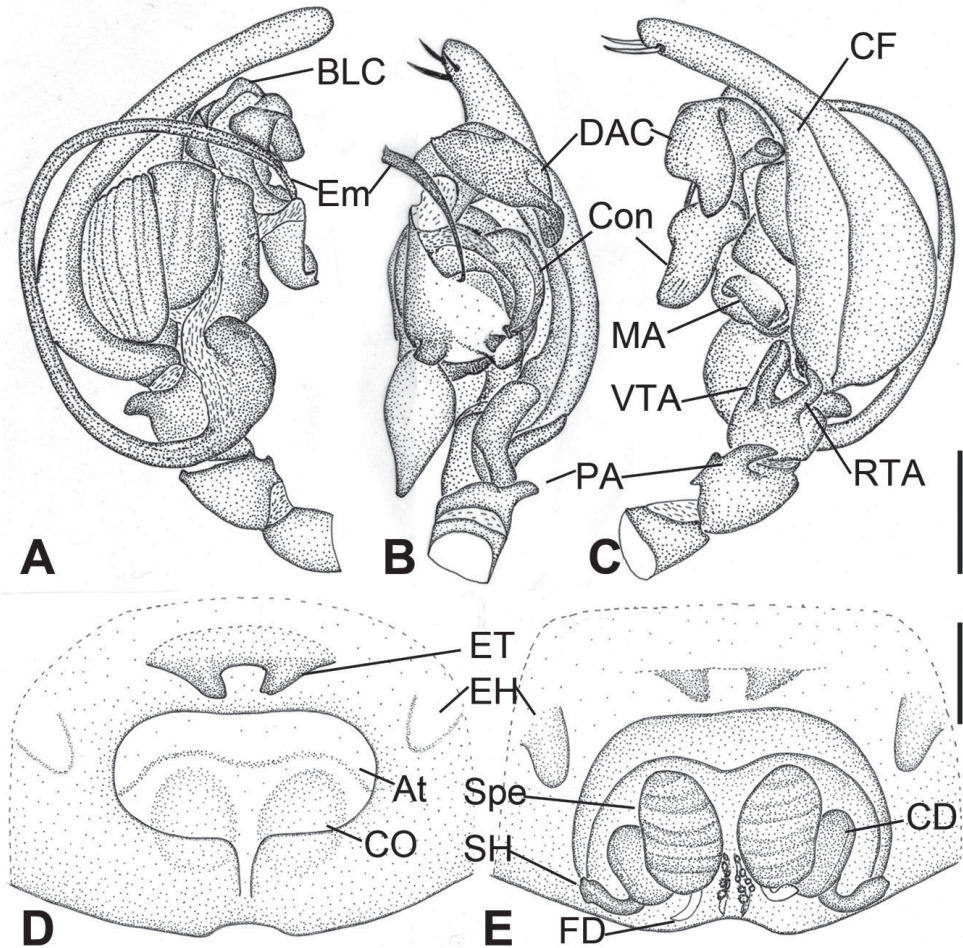


Figure 8. *Tonsilla subyanlingensis* sp. nov., male holotype and female paratype **A** male palp, prolateral view **B** same, ventral view **C** same, retrolateral view **D** epigyne, ventral view **E** vulva, dorsal view. Scale bars: 1 mm. Abbreviations: At – atrium, BLC – basal lamella of conductor, CD – copulatory duct, CF – cymbial furrow, CO – copulatory opening, Con – conductor, DAC – dorsal apophysis of conductor, EH – epigynal hood, Em – embolus, ET – epigynal teeth, FD – fertilization ducts, MA – median apophysis, PA – patellar apophysis, RTA – retrolateral tibial apophysis, SH – spermathecal heads, Spe – spermathecae, VTA – ventrolateral tibial apophysis.

apophysis; embolus long and broad, originates at 6 o'clock position, coiled around the margin of cymbium and posteriorly embedded in the furrow of conductor.

Female (Paratype). Habitus as in Figures 4C, D, 6A, B. Total length 13.21. **Carpapace** (Fig. 6A) 6.66 long, 4.33 wide, anteriorly narrowed to between 0.7 and 0.8 its maximum width. **Eye** sizes and interdistances: AME 0.20; ALE 0.24; PME 0.22;

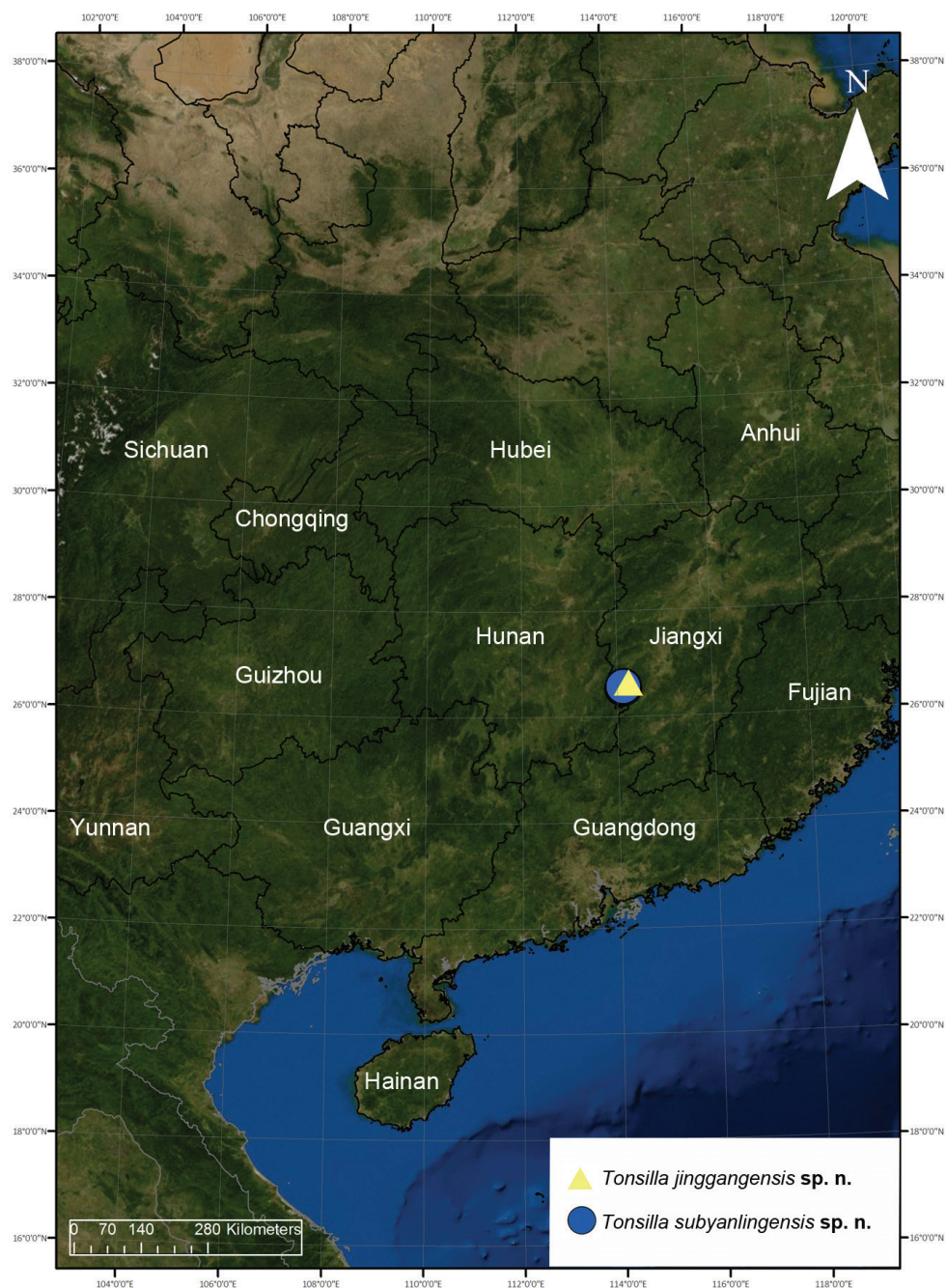


Figure 9. Type localities of *Tonsilla jinggangensis* sp. nov. and *T. subyanlingensis* sp. nov.

PLE 0.24; AME–AME 0.10; AME–ALE 0.18; PME–PME 0.20; ALE–ALE 0.92; PME–PLE 0.41; PLE–PLE 1.46; ALE–PLE 0.14, AME–PME 0.16; AME–PLE 0.45. MOA: 0.68 long; 0.60 front width, 0.70 back width. **Chelicerae** (Fig. 6A, B) with 3

promarginal teeth (proximal smallest, median largest) and 3 retromarginal teeth (proximal largest). **Leg** measurements (Fig. 6A, B): I 13.15 (4.17, 1.85, 3.26, 2.54, 1.33); II 12.90 (3.62, 1.18, 2.90, 2.83, 1.71); III 11.00 (3.01, 1.72, 2.14, 2.75, 1.38); IV 14.12 (3.84, 1.87, 3.45, 3.70, 1.32). **Spination**: I fe 402, ti 004, mt 044; II fe 122, pa 011, ti 035, mt 065; III fe 122, pa 111, ti 055, mt 622, ta 011; IV fe 122, pa 011, ti 055, mt 866, ta 011. Pedicel 0.46. **Abdomen** (Fig. 6B, C) 6.10 long, 4.01 wide.

Lighter than male. Abdomen, dorsally with four indistinct yellow-brown chevron-like stripes on posterior half.

Epigyne (Figs 6C, D, 7H, I, 8D, E). Atrium with a transverse depression, broad, more than 2 times longer than its length, heart-shaped, anterior margin near the apex of teeth, posterior part relatively broad. Copulatory openings located at postero-lateral of the atrium. Epigynal teeth flat, separated by less than their length, apex slightly converging. Copulatory ducts, originating laterally, extending forward along spermathecae, then back, but located at lateral part of spermathecae. Spermathecae egg-shaped, clearly separated by less than 1/5 their width. Spermathecal heads relatively broad, short, posteriorly located, curved laterally. Fertilization ducts located at the posterior part of the spermathecae.

Distribution. Known only from the type locality in Jiangxi Province, China (Fig. 9).

Acknowledgements

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A revision of *Pachyballus* Simon, 1900 and *Peplometus* Simon, 1900 (Araneae, Salticidae, Ballini) with descriptions of new species

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Abstract

Two genera from the tribe Ballini (Araneae, Salticidae), *Pachyballus* Simon, 1900 and *Peplometus* Simon, 1900, are remarkable for their resemblance to beetles. Their biology is, however, poorly known and taxonomy has hitherto been rarely analysed. Thirteen species are included in this taxonomic revision of the two genera. Six of them are new to the science: *Pachyballus caelestis* **sp. nov.** (♂♀, Congo D.R.), *Pachyballus miniscutulus* **sp. nov.** (♂♀, South Africa), *Pachyballus mombasensis* **sp. nov.** (♂♀, Kenya), *Pachyballus ornatus* **sp. nov.** (♂♀, Congo D.R. and Tanzania), *Peplometus congoensis* **sp. nov.** (♂♀, Congo and Congo D.R.), and *Peplometus nimba* **sp. nov.** (♂, Guinea). One species (*Pachyballus cordiformis* Berland et Millot, 1941) and a subspecies (*P. flavipes aurantius* Caporiacco, 1949) are recognised as synonyms of *Pachyballus flavipes* Simon, 1910. One new combination is proposed: *Peplometus oyo* (Wesołowska et Russell-Smith, 2011) **comb. nov.** (ex *Pachyballus*). The previously unknown females of *Pachyballus transversus* Simon, 1900 and *Peplometus chlorophthalmus* Simon, 1900, along with the males of *Pachyballus castaneus* Simon, 1900 and *Peplometus biscutellatus* (Simon, 1887) are newly diagnosed and described. Neotypes for *Pachyballus castaneus* and *P. flavipes* are designated. Numerous new data on the distribution are provided here and a key to *Pachyballus* females and to the males of *Peplometus* is presented. Identity of one species remains doubtful, *Pachyballus gambei* (Simon, 1880).

Keywords

Africa, jumping spiders, mimicry, new combination, redescription, synonyms, taxonomy

Introduction

Simon (1900) established two African genera, *Pachyballus* and *Peplometus*, for some species that mimic beetles and assigned them to the Balleae group (Simon 1901). Subsequently Petrunkevitch (1928) included them in the subfamily Magoninae. Benjamin (2004) did not study these two genera in his revision of Ballinae. According to the most up to date systematics of the jumping spiders (Maddison 2015), *Pachyballus* and *Peplometus* belong to the tribe Ballini Banks, 1892 in the subfamily Salticinae Blackwall, 1841. Only a few species have been described within these genera up to now, seven as *Pachyballus* (with one subspecies) and two as *Peplometus* (WSC 2019). After our review the species number within the two genera is nine and five respectively.

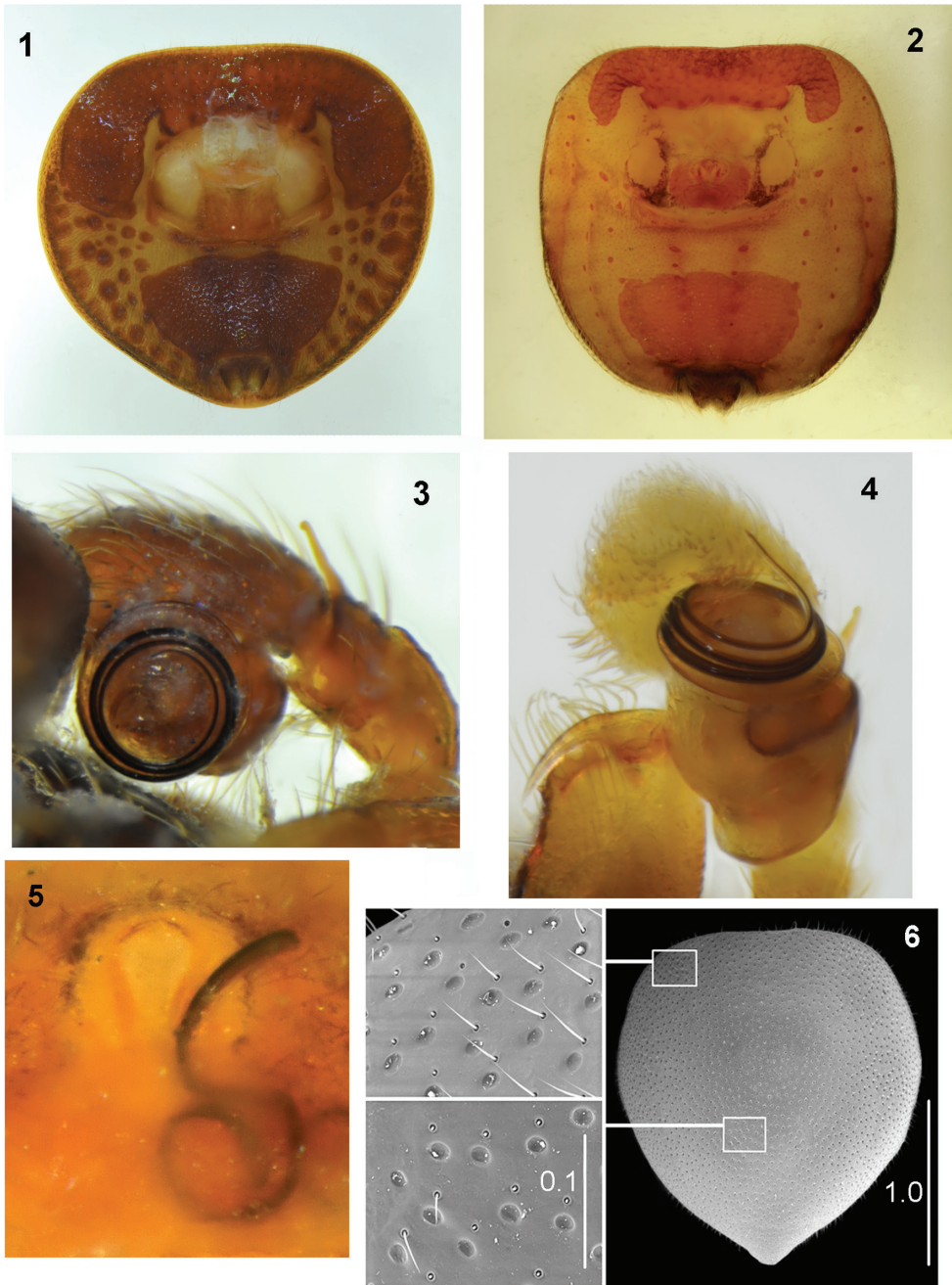
Pachyballus and *Peplometus* are closely related and share most morphological characters. They are small but robust spiders, with a strongly flattened body (Figs 31, 35, 137), covered with a very hard, sclerotised exoskeleton. The dorsum of their body has a characteristic pitted microsculpture (Fig. 6). The anterior part of the abdomen is covered by posterior edge of the carapace, so that the pedicel is invisible (Figs 99, 172). A putative morphological synapomorphy for these two genera is the presence of characteristic scuta on the ventral surface of their abdomen. This ventral “armament” consists of the two scuta: a narrow one along the anterior margin of the abdomen, which laterally extends backwards, and a posterior trapezoid scutum (Figs 1, 2). There are also numerous minute sclerotised bumps on the ventral side of the abdomen (Fig. 1). These structures, in combination with dorsal strong sclerotisation, make members of these genera among the most heavily armour-plated spiders. Legs are short, and the first pair of male legs is clearly larger than others (Figs 19, 154) and has thickened femora and the tibiae ventrally covered with dense setae.

The conformation of genitalia in both sexes is very similar in all species. Tibial apophysis of the male palp is thin and straight, bulb oval, tegulum has a large posterior lobe, spiralled embolus with more than three coils on the bulb tip (Figs 3, 4). The epigyne has anterior semi-circular depression divided by a median septum (Figs 38, 107), very long copulatory ducts with initial short spiral followed by several loops (Fig. 150), and more or less oval spermathecae (Figs 96, 171). On the sides of the epigynal depression two crevices of unknown role can sometimes be seen (Figs 95, 153). We observed once a broken embolus, which was blocking the copulatory opening (Fig. 5), however we did not notice any other mating plugs.

Material and methods

Specimens examined in this study are deposited in the following institutions:

BMNH	British Museum (Natural History) London, United Kingdom
CAS	California Academy of Sciences, San Francisco, USA
HNHM	Hungarian Natural History Museum, Budapest, Hungary
MCZ	Museum of Comparative Zoology, Harvard University, Cambridge, USA
MEU	Museum of Evolution, Uppsala University, Sweden



Figures 1–6. Some morphological characters of *Pachyballus* and *Peplometus* **1** *Pach. flavipes* (specimen from Gabon), male, ventral abdominal scuta **2** *Pach. ornatus* (specimen from Tanzania), female, ventral abdominal scuta **3** *Pach. flavipes* (specimen from Congo), embolus **4** *Pepl. biscutellatus* (specimen from Ivory Coast), palpal organ in ventral view **5** *Pach. flavipes* (specimen from Zimbabwe), epigyne with broken embolus in copulatory opening **6** *Pach. castaneus*, pitted integument of abdomen.

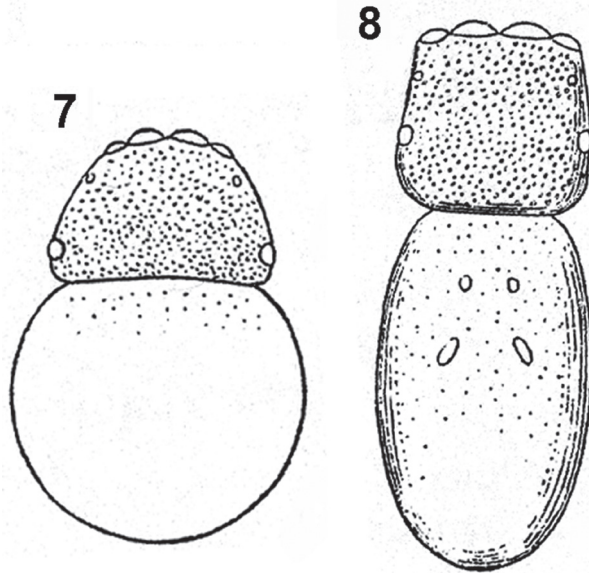
MNHN	National Museum of Natural History, Paris, France
MRAC	Royal Museum for Central Africa, Tervuren, Belgium
NCA	National Collection of Arachnida, Pretoria, South Africa
NMBA	National Museum, Bloemfontein, South Africa
NHRS	Naturhistoriska Riksmuseet, Stockholm, Sweden
NMZ	Natural History Museum, Bulawayo, Zimbabwe
SMF	Senckenberg Natural History Museum, Frankfurt, Germany
UCZM	Zoological Museum, University of Copenhagen, Denmark

The specimens were examined in 70% ethanol. The epigynes were macerated in cold 5% KOH for 24 hours, dehydrated with absolute ethanol, cleared in xylene and put in clove oil in a temporary microscope slides. A reticular eyepiece attached to a stereomicroscope was used for drawing. After examination and reverting the above described sequence, the female genitalia were placed to microvials and stored with specimens. Specimens were measured as in Metzner (1999); all dimensions are given in millimetres. A Nikon Coolpix 8400 or Canon EOS 550D mounted on the stereomicroscope was used to take digital photos, which were stacked using Helicon Focus image stacking software. Male-female matching was based both on the co-occurrence of specimens and morphological similarities between the sexes (e.g., shape and colouration of body). SEM microphotographs were taken with SEM Hitachi TM–1000. The photographed parts were dried, and then mounted on an adhesive specimen stub. The maps were prepared using DIVA-GIS.

Distinguishing genera

Due to numerous similarities of *Pachyballus* and *Peplometus*, many collectors have failed to distinguish the two genera and labelled the specimens simply as *Pachyballus*. All previously undetermined specimens analysed in this work had been assigned to *Pachyballus* before and mostly determined only to the genus level. *Peplometus* after the work by Simon (1901) was only found by Berland and Millot (1941) and mentioned by Bodner and Maddison (2012; for specimen from Ghana used in molecular phylogenetic analysis).

Simon (1901) differentiated the two genera by the shape of their carapace – significantly wider than long in *Pachyballus* and elongate in *Peplometus* (Figs 7, 8). However, Simon depicted this feature on *Pachyballus transversus*, which has the widest carapace among its congeners. In most species that can be assigned to this genus the ratio of carapace width and length is approximately 1:1 and it may overlap with the proportions seen in *Peplometus*. A better character allowing the separation of these genera is the shape of abdomen. It is clearly elongated in *Peplometes*, whereas in *Pachyballus* the length of abdomen is equal to its width. The other reliable feature for telling apart the two genera, which may be applied only to males though, is the form of the tibia I. These tibiae in *Pachyballus* are not modified (Fig. 129), but in *Peplometus* are always



Figures 7, 8. Simon's drawings of body shape. **7** *Pachyballus* **8** *Peplometus* (from Simon 1901).

conspicuously altered. They are strongly thickened and often flattened (Figs 130–133), or considerably elongated, but in this case the metatarsus has a basal process (Figs 134, 135). Tibia I in *Pachyballus* bears dense and long hairs on ventral surface (Fig. 129), whereas in *Peplometus* it has a “brush” of long leaf-like setae (Figs 132–135). The structure of tibia I of males may even be used in distinguishing *Peplometus* species. Identifying females in this genus is very difficult in general and the results may be doubtful. Conversely, species recognition by *Pachyballus* is relatively straightforward in females, where a combination of morphological characters and genitalia conformation is used. Determination of the males is sometimes impossible, because the structure of their palpal organs is extremely similar and there often lack reliable distinguishing morphological features. As a consequence of this, we were able to construct the key only for *Pachyballus* females and males of *Peplometus*. Most probably, many taxonomic intricacies will be possible to solve only using molecular methods. Fresh material for analysis of the two genera will, however, be difficult to obtain.

Table 1. Features for distinguishing *Pachyballus* and *Peplometus*.

Genus	shape of the abdomen	structure of leg I in male
<i>Pachyballus</i>	rounded or heart-shaped (width-length ratio = ca. 1:1)	tibia not modified, with long setae ventrally
<i>Peplometus</i>	clearly elongated (width-length ratio ≤ 0.8)	tibia very robust with dense feather-like setae ventrally, or elongated with same setae and metatarsus with a dorsal hump

Taxonomic account

Pachyballus Simon, 1900

Pachyballus Simon 1900: 399; 1901: 486.

Type species. *Pachyballus transversus* Simon, 1900.

Diagnosis. *Pachyballus* is closely related to *Peplometus*. From the latter genus it can easily be separated by the rounded abdomen (elongated in *Peplometus*), by the form of leg I in males (not modified) and by the absence of the leaf-like setae on tibia I.

Description. Small to medium-sized spiders (ca. 3.0–5.0 mm length), with very flat body, covered with tough highly sclerotised integument. Body colouration in the majority of species dark brown or black with metallic lustre, only legs (especially in females) lighter. Carapace rounded, its width usually slightly larger than the length, eye field clearly trapezoid. Posterior part of carapace covered with abdomen. Chelicerae with three (exceptionally two) teeth on promargin and two to four teeth on retromargin, basally fused together. Abdomen short and wide, heart-shaped or rounded, its length to width ratio is 0.8–1.1, clearly wider than carapace, with straight anterior border. Abdominal dorsum totally covered with strongly sclerotised scutum, its edges sloping so that the abdomen has shape of a shallow bowl. Venter with a narrow scutum along anterior margin, its lobes extending laterally as lobes. A second, trapezoid scutum in posterior part, numerous very small sclerotised bumps on both sides of abdomen (Fig. 1). Legs short, first pair slightly bigger in males, with enlarged femora. Tibia I not modified, setae on its ventral side not so dense as in *Peplometus*. Tarsus of the female palp usually black. Male palp with oval bulb, embolus spirally coiled around its tip (Fig. 3). Tibial apophysis thin and straight. Epigyne with large semi-circular depression (atrium), usually divided by epigynal septum, copulatory ducts usually long, forming a spiral in their initial parts and with several complex loops distally.

Key to *Pachyballus* (females only)

- | | | |
|---|---|------------------------|
| 1 | Ventral scutum in posterior half of the abdomen present (Fig. 2)..... | 2 |
| – | Ventral scutum in posterior half of the abdomen absent..... | <i>P. variegatus</i> |
| 2 | Ventral posterior scutum trapezoid, large, its width about half of abdomen width..... | 3 |
| – | Ventral scutum small, its width not more than third of abdomen width (Fig. 61)..... | <i>P. miniscutulus</i> |
| 3 | Carapace clothed in white hairs, epigynal depression wide and short (Fig. 16)..... | <i>P. caelestis</i> |
| – | White hairs absent from carapace, epigynal depression long | 4 |
| 4 | Copulatory ducts relatively short, forming no more than a single loop..... | 5 |
| – | Copulatory ducts very long, forming several loose loops | 6 |

- 5 Loop of the copulatory ducts tight (Fig. 28) *P. castaneus*
- Loop of the copulatory ducts loose (Fig. 73) *P. mombasensis*
- 6 Abdomen with a clear, contrasting pattern (Fig. 81) *P. ornatus*
- Abdomen uniformly coloured 7
- 7 Palps dark, abdomen rounded (Fig. 104) *P. transversus*
- Palps yellow, abdomen ovoid (Fig. 33) *P. flavipes*

***Pachyballus caelestis* sp. nov.**

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Figures 9–17, 193

Holotype. CONGO D.R. • ♀; Mayombe, Bas Congo, Luki Forest Reserve; 5°37'S, 13°05'E; 23.IX.2007; D. De Bakker and J.P. Michiels leg.; canopy fogging, old secondary rainforest; MRAC 226 102.

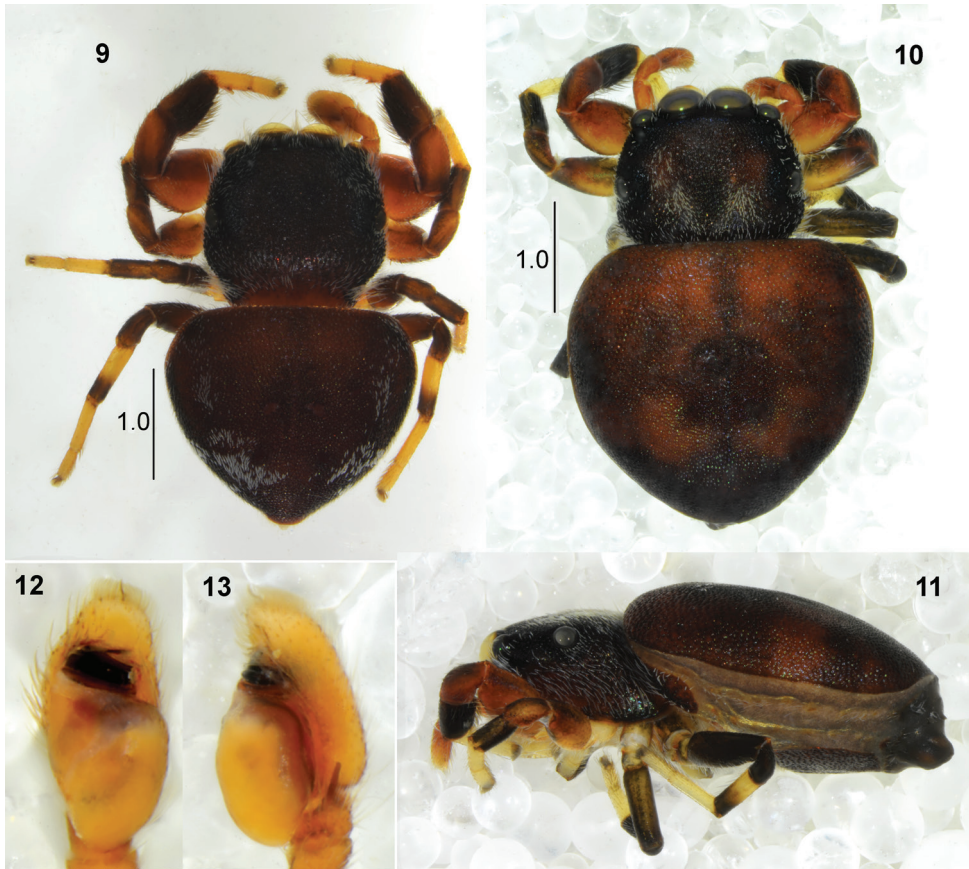
Paratypes. CONGO D.R. • 1♀; same locality as the holotype; 25.IX.2007; canopy fogging, old secondary rainforest; MRAC 226 107 • 1♀; the same locality; 1.X.2007; canopy fogging, primary rainforest; MRAC 226 114 • 1♂; the same locality; 13.XI.2006; canopy fogging, primary rainforest; MRAC 226 113.

Diagnosis. This species is covered very densely with short hairs, which is the best feature to distinguish it from congeners. Male palpal organ has a characteristic embolus that forms a considerably high and narrow coil similar to that of *P. castaneus*. The coil comprises four loops (two and a half in the latter species). The female is distinctive in having the epigyne with broad, short ridge on posterior edge of the epigynal depression; the copulatory ducts are relatively straight (they do not form any loops).

Etymology. The specific name is from Latin, meaning “soaring” and refers to this species living high in a forest canopy.

Description. Male. Measurements. Cephalothorax: length 1.4, width 1.5, height 0.5. Eye field: length 0.7, anterior width 1.2, posterior width 1.5. Abdomen: length 1.8, width 2.0.

General appearance as in Fig. 9. Small, very flat spider with strongly sclerotised, pitted integument. Carapace black, clothed in dense short light hairs. Eye field trapezoid, distance between anterior lateral eyes shorter than between posterior laterals. Eyes encircled by white scales. Clypeus low, with a few white hairs. Chelicera with two teeth on promarginal edge and four retromarginal teeth. Endites and labium light brown with whitish tips. Abdomen heart-shaped, wider than long, blackish with white scales on sides and posterior part. Anterior margin of abdomen covers posterior part of carapace. Venter brown, with typical scuta. Spinnerets black. Legs I the stoutest, femur and patella brown, tibia slightly thickened, black with long dark setae ventrally, metatarsus and tarsus yellowish. Tibia with one short ventral spine distally, metatarsus with two pairs of ventral spines. Legs II the same in colour as the first pair. Legs III and IV brown with yellow distal segments. Pedipalp yellowish, its structure similar to that in other species, embolus forms a considerably high and narrow coil that comprises four loops as in Figs 12–15.



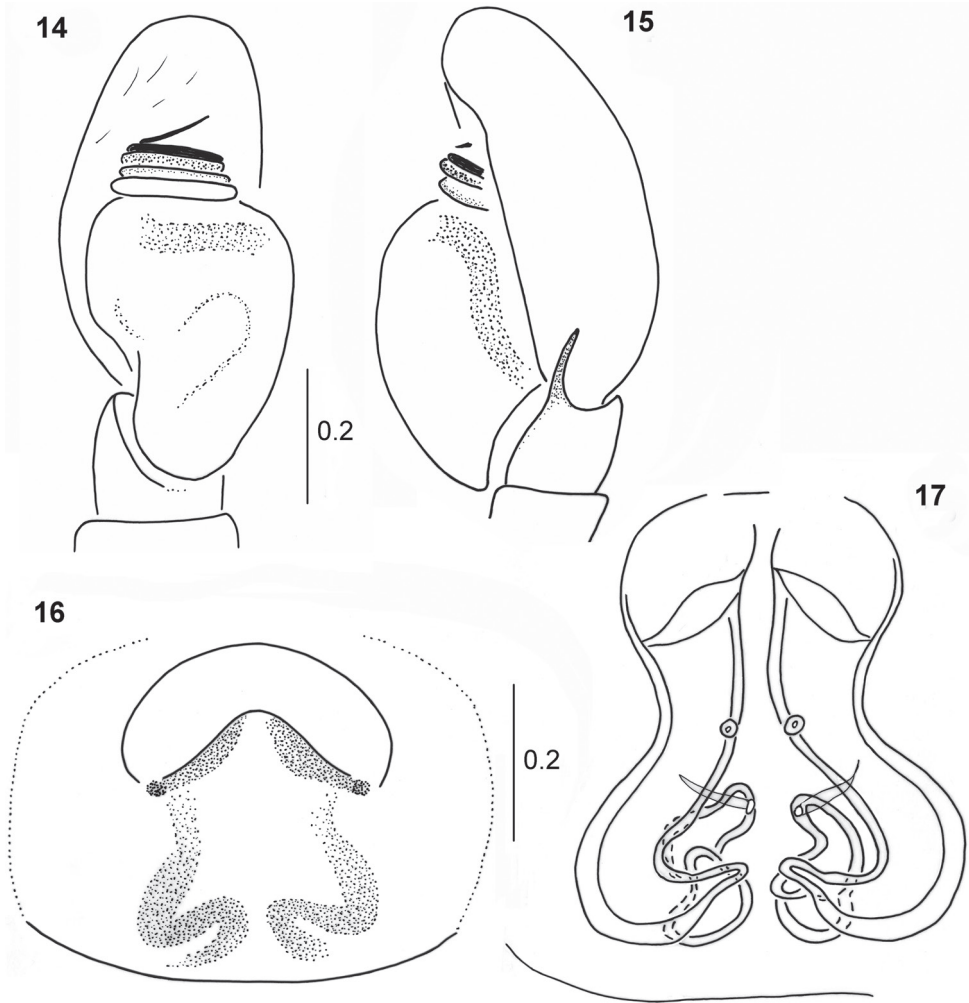
Figures 9–13. *Pachyballus caelestis* sp. nov. **9** male, habitus, dorsal view **10** female, habitus, dorsal view **11** female, habitus, lateral view **12** palpal organ, ventral view **13** palpal organ, lateral view.

Female. Measurements. Cephalothorax: length 1.1–1.2, width 1.3–1.4, height 0.5. Eye field: length 0.6–0.7, anterior width 1.0–1.1, posterior width 1.2–1.3. Abdomen: length 2.0–2.2, width 2.2–2.4.

General appearance as in Figs 10, 11. Slightly larger than male, shape of body similar. Carapace covered with white hairs. Colouration of abdomen a little lighter than in male, brown, blackish in the mid part and along edge. Palps light brown. Epigyne oval, central depression divided posteriorly by short, wide ridge (Fig. 16). Copulatory ducts wide, spermathecae slightly smaller than in other species, small accessory glands opening into copulatory ducts (Fig. 17).

Distribution. Known only from the type locality (Fig. 193).

Remarks. All specimens were collected by fogging. Probably, this species lives high in the forest canopy.



Figures 14–17. *Pachyballus caelestis* sp. nov. **14** palpal organ, ventral view **15** palpal organ, lateral view **16** epigyne **17** internal structure of epigyne.

***Pachyballus castaneus* Simon, 1900**

Figures 6, 18–28, 129, 193

Pachyballus castaneus Simon 1900: 400 (♀).

Neotype. SOUTH AFRICA • ♀; KwaZulu-Natal, Ulundi, Ophathe Game Reserve; 28°23'S, 31°24'E; 3.X.2008; C. Haddad leg.; overgrazed savanna, beating shrubs; NCA 2008/4147.

Paraneotypes. SOUTH AFRICA • 1♀; together with neotype • 1♂ 1♀; the same locality as neotype; 3.X.2008; C. Haddad leg.; overgrazed savanna, beating, shrubs; NCA 2008/4140.

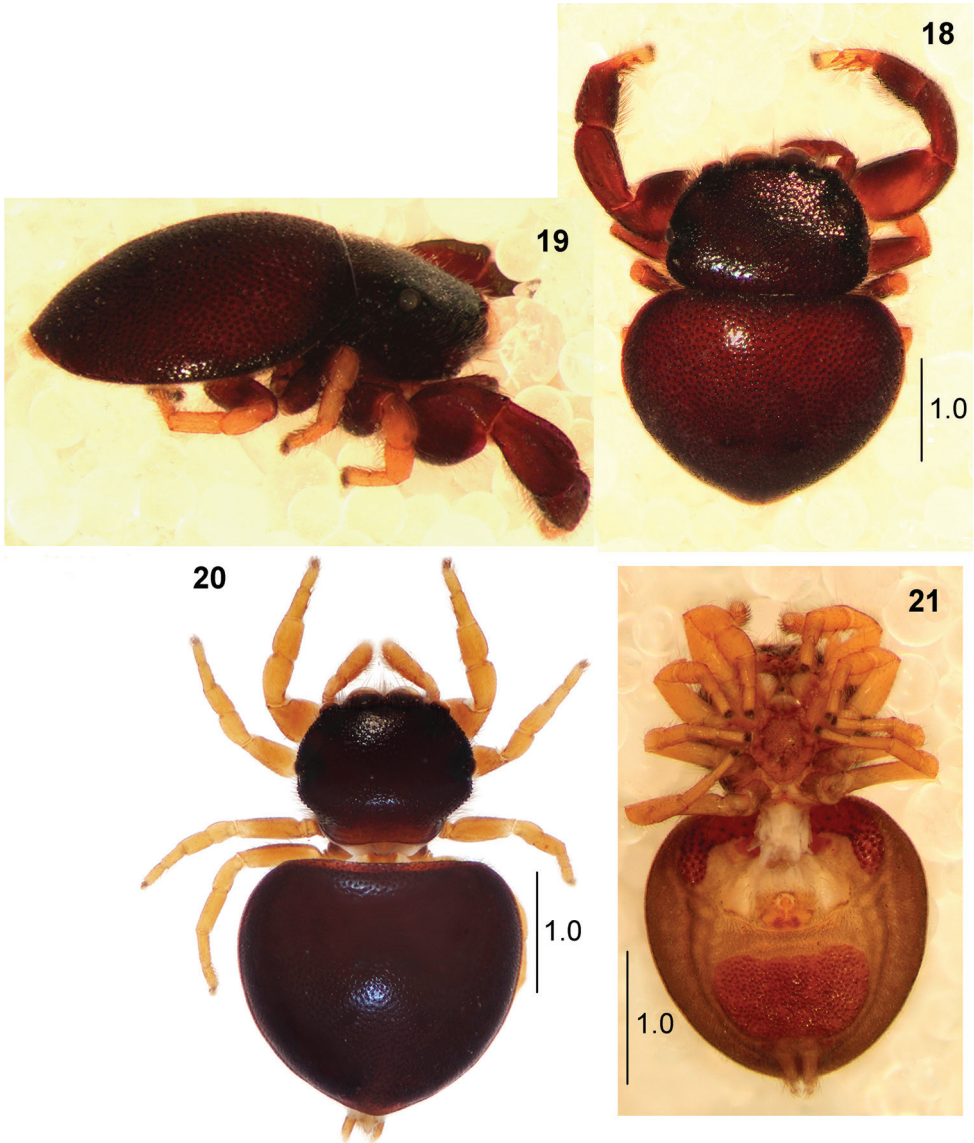
Other material examined. SOUTH AFRICA • 1♂; the same locality as neotype; 2.X.2008; NCA 2008/4167 • 1♂ 2♀ 8 imm.; the same locality; 500 m a.s.l.; rocky mountainside; NCA 2008/4154 • 3♂ 6 imm.; the same locality; 1.X.2008; NCA 2008/3993 • 1♂ 3 imm.; the same data; NCA 2008/3971 • 1♂; KwaZulu-Natal, iSimangaliso Wetland Park, Crocodile Centre; 28°21'S, 32°25'E; 14.V.2012; J.A. Neetling and C. Luwes leg.; canopy fogging, wetland, *Breonadia salicina*; NCA 2012/5736 • 2♀; the same locality, St. Lucia; 28°23'S, 32°25'E; 13.V.2012; J.A. Neetling and C. Luwes leg.; canopy fogging, coastal forest, *Trichilia dregeana*; NCA 2012/4019 and NCA 2012/5737 • 1♀; Lake St. Lucia, Fanies Island; 28°06'S, 32°27'E; 1.VII.1993; F.J. van der Lingen leg.; 200 m from lake campsite, W shore, in dense bush thicker; NMBA 08069 • 1♀; Mkuze, Banghoek Lodge; 27°45'S, 32°08'E; 17.V.2012; J.A. Neetling and C. Luwes leg.; canopy fogging, Bushveld, *Acacia karroo*; NCA 2012/3965 • 1♂; Ndumo Game Reserve; 26°55'S, 32°19'E; 30.VI.2009; R. Lyle leg.; sand forest, beating foliage; NCA 2009/3660 • 1♀; Sihangwane, Tembe Elephant Park, 40 km from Kosi Bay; 27°02'S, 32°25'E; 18.XI.1988, R. Harris leg.; NCA 94/828 • 1♀; the same locality; 6.II.2008; R. Lyle and R. Fourie leg.; beating, afro-montane forest; NCA 2008/505 • 1♂ 1♀; Hellsgate; 28°00'S, 32°48'E; 23.VIII.2004; J. Esterhuizen leg.; NCA 2010/155 and NCA 2010/156 • 1♀; Mpumalanga Prov., Nelspruit, Agricultural College; 25°27'S, 30°59'E; 12.XI.1999; P. Stephen leg.; beating, citrus; NCA 2000/223 • 1♀; Wildlife College, 10 km from Orpen Gate of Kruger National Park; 24°28'S, 31°23'E; 11.X.2000; W. Breytenbach leg.; beating *Euclea divinorum*; NCA 2003/626 • 1♂; Limpopo Prov., Little Leigh; 22°56'S, 29°22'E; 22.XI.2005; B. van der Waal leg.; branch beating, gallery forest; NCA 2009/2232. ZIMBABWE • 3♂; Mashonaland; Workman coll.; MCZ • 1♂; Harare; 17°50'S, 31°10'E; 2.III.2012; M. Cumming leg.; suburban garden, dropped from tree; NMZ.

Diagnosis. The male is indistinguishable from the males of *P. flavipes* and *P. mombasensis* by body shape and colouration, but its bulb is slightly narrower than in these species and the embolic spiral is tightly convoluted; width of the basal embolic loop equals only a half of tegulum width, whereas in both other species it is as wide as tegulum. The female can be separated from congeners in having copulatory ducts compactly arranged and not forming loose loops (see Fig. 28).

Redescription. Male. Measurements. Cephalothorax: length 0.9–1.3, width 1.3–1.9, height 0.5–0.6. Eye field: length 0.6–0.7, anterior width 1.1–1.4, posterior width 1.3–1.9. Abdomen: length 1.7–2.2, width 1.8–2.6.

General appearance as in Figs 18, 19. Small spider with flattened body covered with strongly sclerotised and pitted integument (Fig. 6). Carapace dark brown, eye field on more or less half of carapace, vicinity of eyes black. A few long bristles at anterior eyes. Posterior edge of carapace covered by abdomen. Chelicerae with three teeth on both margins (Fig. 22). Mouth parts brown, sternum oval, brown, clypeus extremely low. Abdomen dark brown, heart-shaped, as wide as long, dorsal scutum turned back via margins to venter (Fig. 19), ventral scuta typical; the anterior one narrow with lateral

extensions, posterior trapezoid. Numerous small bumps on sides. Colouration dark brown to black, iridescent, integument clearly pitted, short hairs on edges of carapace, dense bristles near eyes. Spinnerets brown. Legs I the thickest (Fig. 19), brown (except yellow tarsi and metatarsi), femur, patella and tibia slightly thickened, tibia slightly flattened dorsally, covered with dense setae ventrally. Tibiae and metatarsi with two pairs of short stout spines ventrally. Other legs yellow, with brownish femora. Pedipalp



Figures 18–21. *Pachyballus castaneus* **18** male (specimen from South Africa), habitus, dorsal view **19** male habitus, lateral view **20** female, habitus, dorsal view **21** female, neotype, habitus, ventral view.

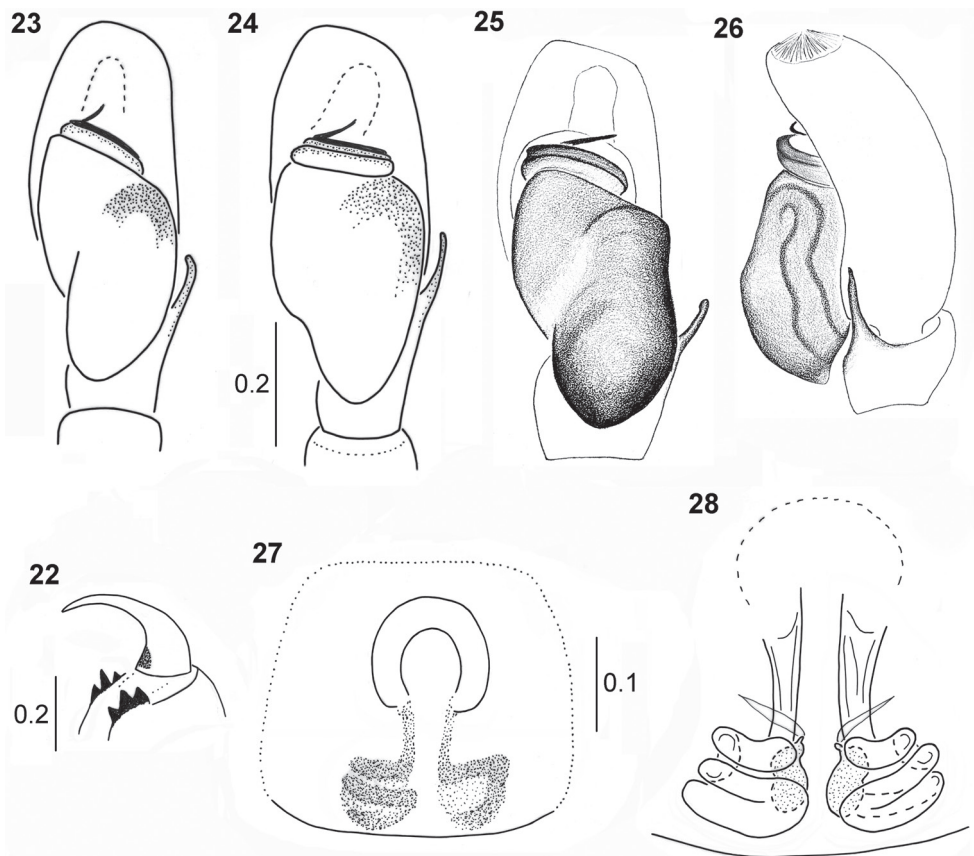
brown, its structure as in Figs 23–26, slightly narrower than in congeners. Palpal tibia short with single thin straight apophysis, bulb oval, embolus thin, long, spirally coiled on bulb tip.

Female. Cephalothorax: length 0.9–1.4, width 1.2–1.4, height 0.5–0.6. Eye field: length 0.5–0.7, anterior width 0.9–1.1, posterior width 1.2–1.4. Abdomen: length 1.7–2.0, width 1.8–2.1.

General appearance as in Figs 20, 21. Similar to male, abdomen almost round or oval, but its anterior margin almost straight. Abdominal venter with two scuta as in male (Fig. 21). All legs and palps dark yellow. Epigyne typical, with horseshoe-shaped anterior depression (Fig. 27). Internal structures relatively simple, copulatory ducts shorter than in congeners, compactly arranged, spermathecae strongly sclerotised (Fig. 28).

Immature specimens. Similar to adults, abdomen covered dorsally with one large scutum.

Distribution. Known from South Africa and Zimbabwe (Fig. 193).



Figures 22–28. *Pachyballus castaneus* 22 cheliceral dentition 23–25 palpal organ, ventral view (24 specimen from Zimbabwe) 26 palpal organ, lateral view 27 epigyne 28 internal structure of epigyne.

Designation of neotype. *Pachyballus castaneus* was originally described from Natal (South Africa) on the basis of a single female. The type specimen was lost (the collection manager informed us that the type could not be found in Simon's collection in MNHN). The original description is very superficial (only body size and colouration of legs are mentioned) and insufficient for identification of the species. Colouration of legs varies within different *Pachyballus* species (see Figs 32, 33, 104–106), so it cannot be used as a taxonomic character. The neotype, a female that originates from the same province as the type, is herein designated to stabilise the nomenclature.

Remarks. The male of this species is described here for the first time.

Pachyballus flavipes Simon, 1910

Figures 1, 3, 5, 29–57, 194

Pachyballus flavipes Simon 1910: 414 (♀); Lessert 1925: 434, f. 7–9 (♀); Wanless and Clark 1975: 290, f. 27–28 (♀); Dawidowicz and Wesołowska 2016: 449.

P. flavipes aurantius Caporiacco 1949: 464 (♀), syn. nov.

Pachyballus cordiforme Berland and Millot 1941: 396, f. 90 (♂), syn. nov.

Pachyballus cordiformis Wesołowska and Cumming 2011: 87, f. 40–45 (♂).

Neotype. CAMEROON • ♀; Biniiba, Bétaré-Oya; 5°36'N, 14°05'E; 20.VII.1949; B. Malkin leg.; CAS.

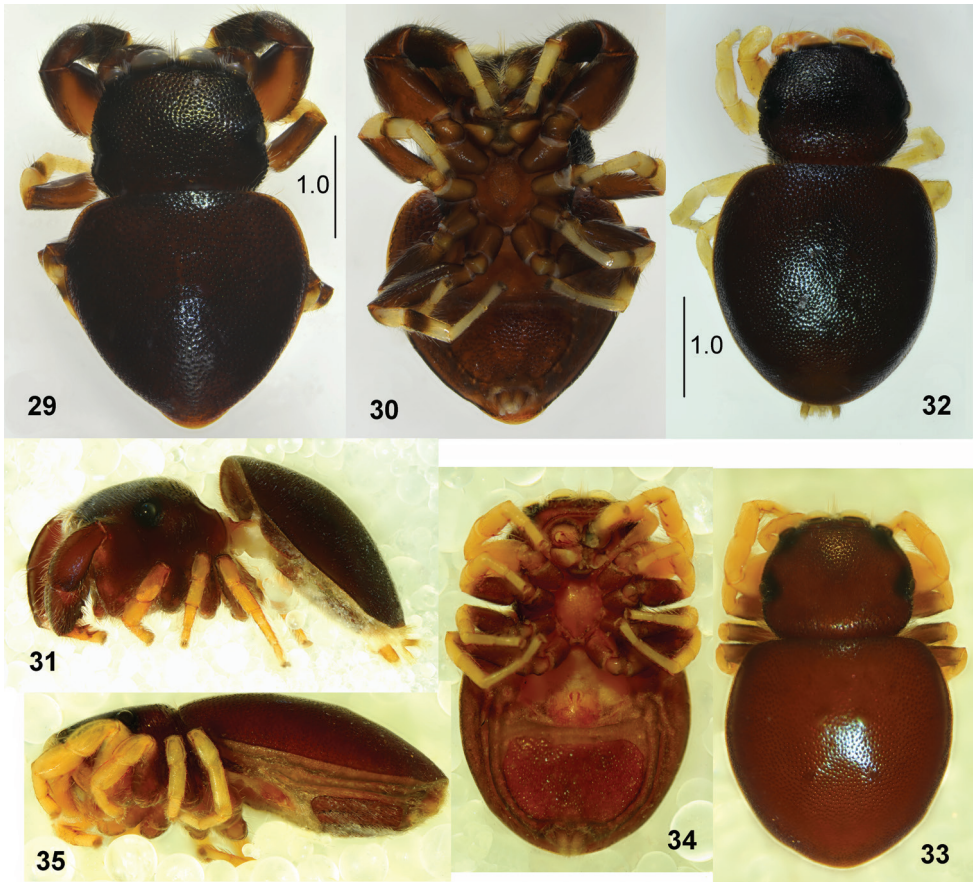
Other material examined. ANGOLA • 1♀; Hulla prov., Caconda; 13°46'S, 15°05'E; 30.IX.1949; B. Malkin leg. CAS. BOTSWANA • 1♀; Okavango Delta, Pom-Pom Camp; 19°18'S, 22°54'E; VII.2001; E. Kassimatis leg.; sweeping; NCA 2009/5688. CAMEROON • 1♀; Faro Game Reserve; 8°30'N, 12°30'E; 25.IV.2007; R. Jocqué, K. Loosveldt, L. Baert and M. Alderweireldt leg.; gallery forest, sieving; MRAC 221 442. CONGO D.R. • 1♀; South Kivu prov., Itombwe; 3°15'S, 28°50'E; 3200 m a.s.l.; XII.1958; N. Leleup leg.; forest with *Hagenia* and bamboo; MRAC 113 229 • 1♀; Semliki river valley; 9.VIII.1968; R.P.M. Lejeune leg.; MRAC 135 557 • 2♂; Mayombe, Bas Congo, Luki Forest Reserve; 5°37'S, 13°05'E; 17.IX.2007; D. De Bakker and J.P. Michiels leg.; old secondary rainforest, fogging; MRAC 226 092 • 1♂; the same data; 18.IX.2007; MRAC 226 097 • 1♂; the same data; 20.IX.2007; MRAC 226 095 • 1♀; the same data; 23.IX.2007; MRAC 226 103 • 2♀; the same data; 18.IX.2007; MRAC 226 096 • 1♀; the same data; 20.IX.2007; MRAC 226 094 • 2♀; the same data; 21.IX.2007; MRAC 226 093 • 1♂ 2♀ 2 subad. ♂; the same data; 17.IX.2007; MRAC 226 101 • 2♂; the same locality; 28.IX.2007; primary rainforest, fogging; MRAC 226 109 • 1♀; the same data; 1.X.2007; MRAC 226 116 • 1♂ 1♀; the same data; 1.X.2007; MRAC 226 120 • 3♀; the same data; 7.XI.2006; MRAC 220 945 • 3♀; the same data; 13.XI.2006; MRAC 220 971 • 1♀; the same locality; 14.IX.2007; secondary rainforest, beating; MRAC 223 432 • 2♂; Kivu prov., Ngoma; 4°24'S, 26°05'E; L. Burgeon leg.; MRAC 15 552/15 553 • 1♀; Kivu prov., Rutshuru, Kako; 1°11'S, 29°27'E; IX.1932; L. Burgeon leg.; MRAC 31 267 • 1♀; Kivu prov., Sanga plateau; 4°50'S 14°58'E; N. Leleup leg.;

MRAC 119 189. GABON • 1♂; Bisso-Binam [Bisso stream?]; 0°52'N, 11°39'E; 3.XI.1985; A. Pauly leg.; on *Borreria verticillata*; MRAC 172 765. GUINEA • 1♂; Nimba Mts, “Mare d’hivernage” (in UNESCO Biosphere reserve); 7°38'N, 8°27'W; 1650 m a.s.l.; 1.X.2008; D. van den Spiegel leg.; wet grassland with dispersal shrubs; MRAC 225 978. IVORY COAST • 1♂; Man; 7°24'N, 7°33'W; VIII.1937; J. Millot leg.; type of *P. cordiformis*: only two, left palps and legs left; MNHN • 1♀; Bingerville; 5°21'N, 3°54'W; VIII.1962; J. Decelle leg.; MRAC 122.004. KENYA • 1♂; Kwale prov., 30 km S to Mombasa; 4°10'S, 39°40'E; 12.XI.1992; V. Roth leg.; CAS • 1♀; Kitale; 1°01'N, 35°00'E; 2000 m a.s.l.; 23.I.1938; MEU • 1♀; Nairobi; 1°17'S, 36°49'E; 12.I.1970; on bamboo; SMF • 1♂; Mt Elgon, E slope; 1°07'N, 34°31'E; 2130 m a.s.l.; 6.I.1938; NHRS • 1♀; Mt Elgon, Salt lake estate; 2100 m a.s.l.; 17.XII.1937; *Acacia* steppe; MEU. TANZANIA • 1♀; Kilimanjaro, Kibonoto; 3°11'S, 37°06'E; Sjöstedt leg.; NHRS. UGANDA • 1♀; Victoria Lake, Gaya Bay, Island Buvuma; 0°13'N, 33°16'E; III.1968; E. Verriest leg.; MRAC 134 737. SOUTH AFRICA • 1♂; Free State, Weltevreden Nature Reserve; 28°57'S, 26°23'E; 15.VIII.2006; H. Killion leg.; NCA 2007/3429 • 1♀; Mpumalanga Prov., Nelspruit, Agricultural College; 25°27'S, 30°59'E; 22.XII.1998; P. Stephen leg.; on grapefruit; NCA 99/160 • 1♀; Limpopo Prov., Nylsvley Nature Reserve; 24°39'S, 28°41'E; 7.III.1998; sweeping, grass; A.S. Dippenaar leg.; NCA 98/586. ZAMBIA • 1♂; 30km SW of Mkushi; 13°43'S, 29°15'E; 1390 m a.s.l.; 22.IX.2009; J. Lenz leg.; NMZ. ZIMBABWE • 1♂ 2 imm.; Batoka Gore; 17°57'S, 26°04'E; 30–31.X.1990; V. Roth leg.; CAS • 1♂ 2♀; Matabeleland, Doddieburn Dam; 21°24'S, 29°21'E; 12.XII.1985; J. Minshull leg.; NMZ A4202 • 5♀ 2 subad. ♂ 8 imm.; Matetsi safari Area, Tshowe river rapids; 18°31'S, 25°52'E; 5.XII.1988; J. Minshull leg.; NMZ A6873 • 2♂; Matetsi safari Area, Kasetsheti Weirs; 18°01'S, 25°49'E; 11.X.1988; F. Nyati leg.; NMZ A6759.

Diagnosis. The male is almost indistinguishable from that of *P. mombasensis*, though it differs a little by having a protruding tibial apophysis while in the latter species tibial apophysis is adpressed to cymbium. The female resembles females of *P. castaneus* and *P. mombasensis*, but has very long copulatory ducts, forming several loops, whereas in two other species these ducts are relatively short (cf. Fig. 51 with Fig. 73 and Fig. 28).

Redescription. Male. Measurements. Cephalothorax: length 1.2–1.6, width 1.4–1.7, height 0.5–0.6. Eye field: length 0.6–0.8, anterior width 1.1–1.4, posterior width 1.4–1.7. Abdomen: length 1.9–2.5, width 1.8–2.3.

General appearance as in Figs 29–31. Shape of body typical for *Pachyballus*; small, flat, with heart-shaped abdomen. Body covered with strongly sclerotised and clearly pitted integument. Colouration of body brown to black dorsally and dark brown ventrally, dorsum iridescent, almost hairless. Some light hairs near anterior eyes and below anterior median eyes. Anterior margin of abdomen covers distal part of carapace. Venter with typical scuta and small sclerotised bumps (Fig. 1). Cheliceral dentition variable, with three teeth on promargin and two, three or (exceptionally) four on retromargin (Figs 41–43). Tips of mouth parts whitish. First pair of legs the stoutest, femora and patellae dark brown, tibiae black with dense long dark setae ventrally and two pairs of very short thick spines (Fig. 31), dorsal part of tibia slightly flattened, metatarsi and tarsi creamy. Other legs with clear contrasts: brown femora, other segments light, only



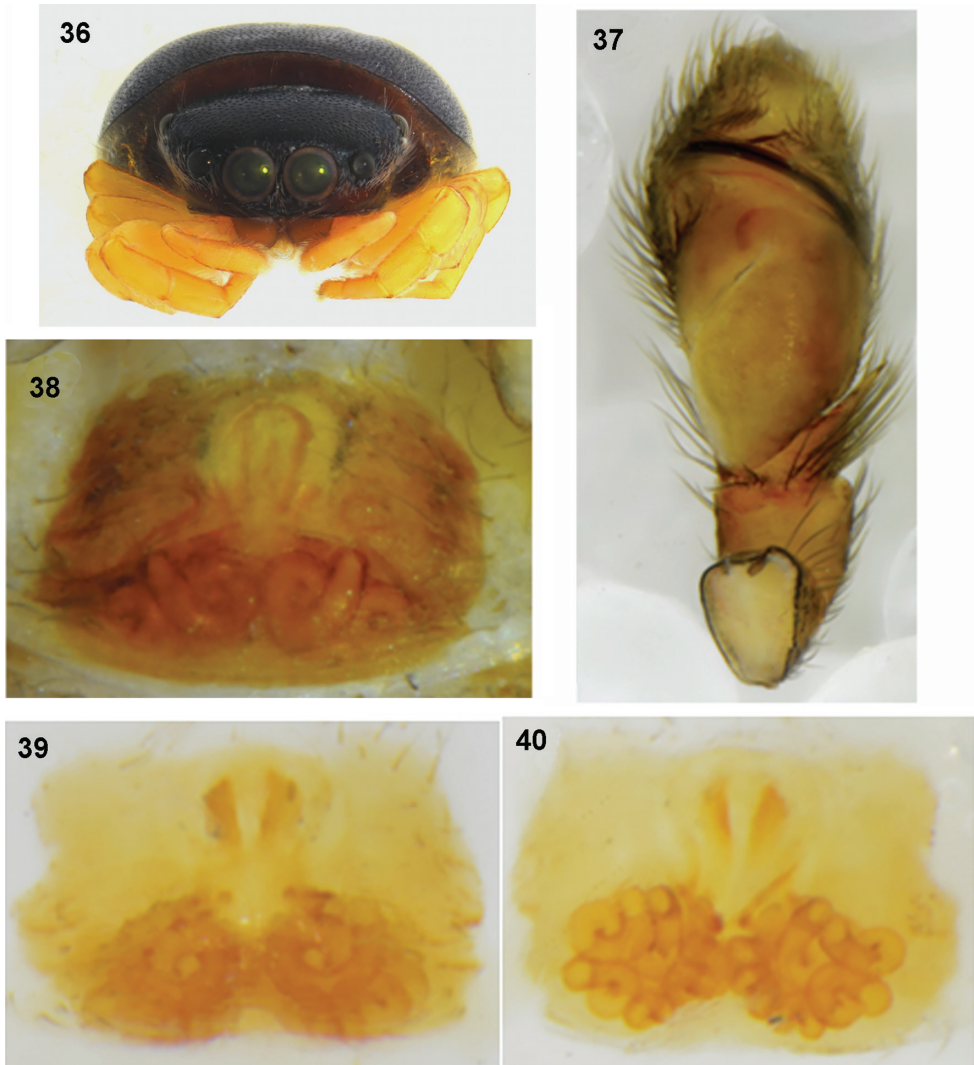
Figures 29–35. *Pachyballus flavipes* **29** male, habitus, dorsal view **30** male, habitus, ventral view **31** male, habitus, lateral view **32, 33** female, habitus, dorsal view **34** female, habitus, ventral view **35** female, habitus, lateral view (**29, 30, 32** specimen from Congo **31** specimen from Kenya **33–35** specimen from Cameroon).

sometimes dark ring on tibiae proximally (Fig. 30). Palps dark, tip of cymbium light. Structure of palpal organ as in Figs 3, 37, 44–46.

Female. Measurements. Cephalothorax: length 1.2–1.3, width 1.3–1.4, height 0.5. Eye field: length 0.6–0.8, anterior width 1.1–1.3, posterior width 1.3–1.4. Abdomen: length 1.9–3.1, width 1.7–2.9.

General appearance as in Figs 32–36. Similar to male, abdomen more oval. Anterior median eyes surrounded by short light hairs. All legs yellowish (Fig. 35), only femora brownish (or yellow with darker streak). Palps yellow (Figs 32, 36). Epigyne as in Figs 5, 38, 47–50, with horseshoe-shaped anterior depression. Internal structure of epigyne as in Figs 39, 40, 51–57, inlet part of copulatory ducts wide.

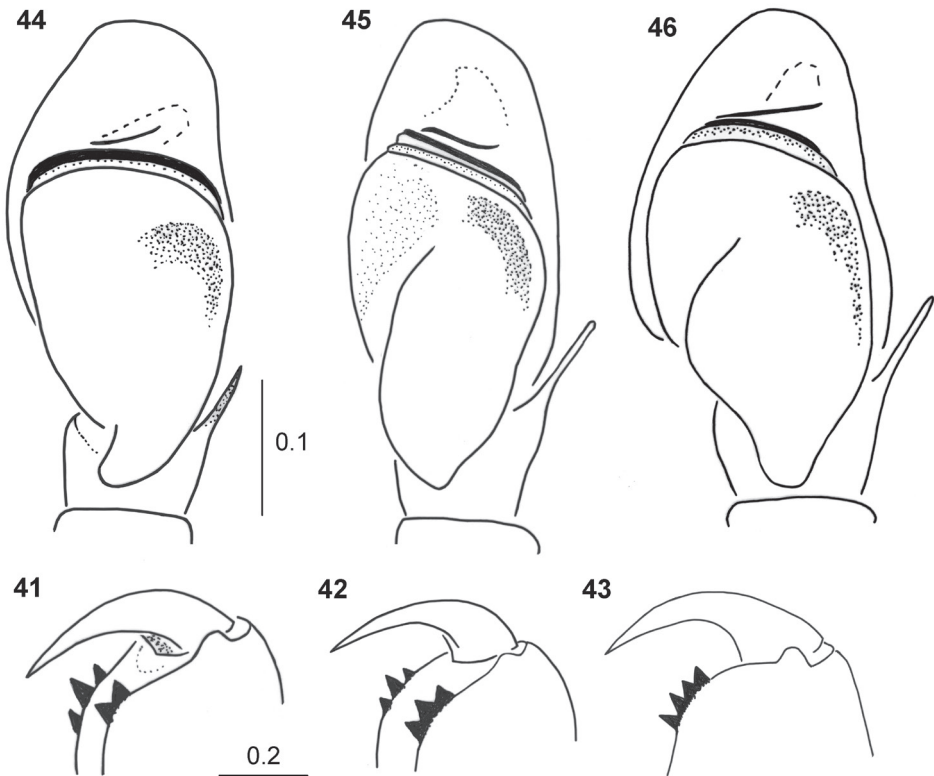
Immature specimens. Similar to adults, abdomen dorsally covered with one large scutum.



Figures 36–40. *Pachyballus flavipes* (specimen from Congo) **36** female, habitus, frontal view **37** palpal organ, ventral view **38** epigyne **39** internal structure of epigyne, ventral view **40** internal structure of epigyne, dorsal view.

Distribution. Species widely distributed in Africa (Fig. 194). Some of the records from Kenya were already mentioned in Dawidowicz and Wesołowska (2016).

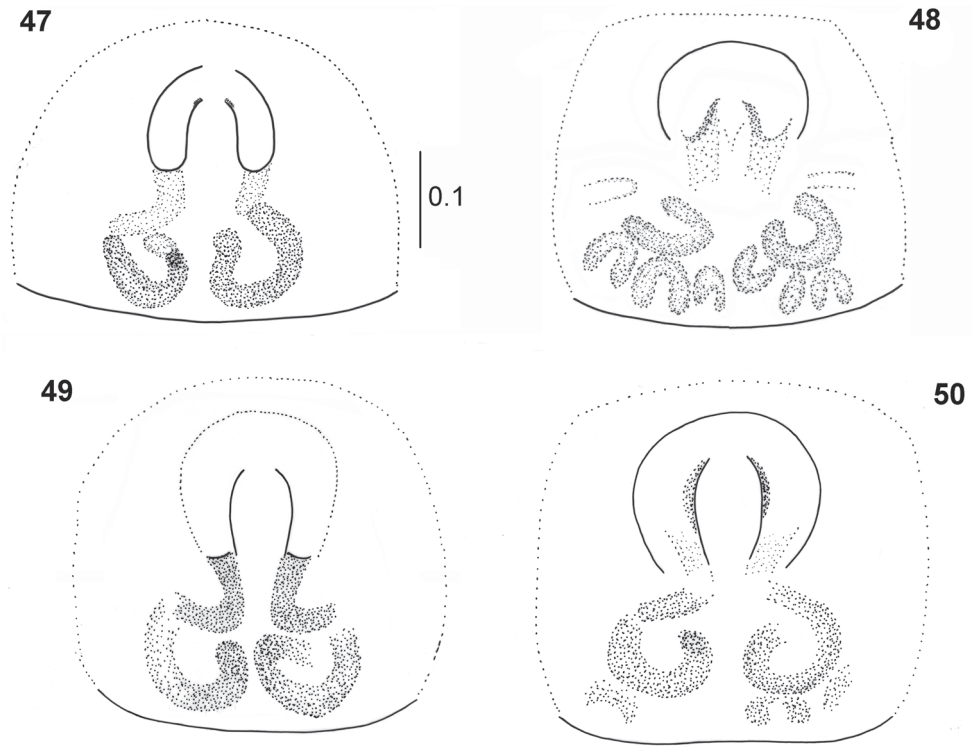
Synonymisation. Caporiacco (1949) described *P. flavipes aurantiacus* from Kenya on the basis of a single female. According to him, the epigyne of this subspecies was the same as in *P. flavipes* and the only difference consisted of colouration. However, this feature is variable. Moreover, according to Berdondini and Whitman (2003) type specimen of *P. flavipes aurantiacus* kept in the Natural History Museum of Florence collection is juvenile. Thus, we recognise *P. f. aurantiacus* as a synonym of the name *P. flavipes*.



Figures 41–46. *Pachyballus flavipes*, male **41–43** variation of cheliceral dentition **44–46** palpal organ, ventral view (**44** specimens from Congo **45** specimen from Gabon **46** type of *P. cordiformis*).

Type of *P. cordiformis* was destroyed and only two palps and three legs persisted in the vial. Although Berland and Millot (1941) reported that they had collected only a single male by the city Man, the two palps in the sample are left palps, so they must have been taken from two males. Structure of palpal organ and the figure in Berland and Millot (1941) suggest that this species is identical with *P. flavipes*. Therefore, we recognise the name *P. cordiformis* as the synonym of *P. flavipes*.

Designation of neotype. Simon (1910) described this species from Bioko (Fernando Po) on the basis of a single female. Wanless and Clark (1975) compared a female from Ivory Coast with the type and concluded their conspecificity. Unfortunately, the type specimen was lost (we were informed that the type could not be found in Simon's collection in MNHN) and the female collected by the latter authors lacked epigyne. Original description was insufficient to recognise the species; only the shape of body and colouration of legs were given. Taking this under consideration it is justified to propose the neotype to stabilise the nomenclature. The neotype, a female collected in Cameroon, the nearest continental country to Bioko (ca. 40 km), is herein designated.



Figures 47–50. *Pachyballus flavipes*, female, epigyne (**47, 48** specimens from Congo **49** specimen from Kilimanjaro **50** specimen from Cameroon).

Remarks. This species probably lives both in the forest canopy and in the understorey. Given this fact, i.e. the variety of preferred microhabitats, the large geographical range and high variation of cheliceral dentition, it is possible that it consists of several cryptic species. The sole morphology may be insufficient to solve this taxonomic problem and there is a need to support further analysis with molecular methods.

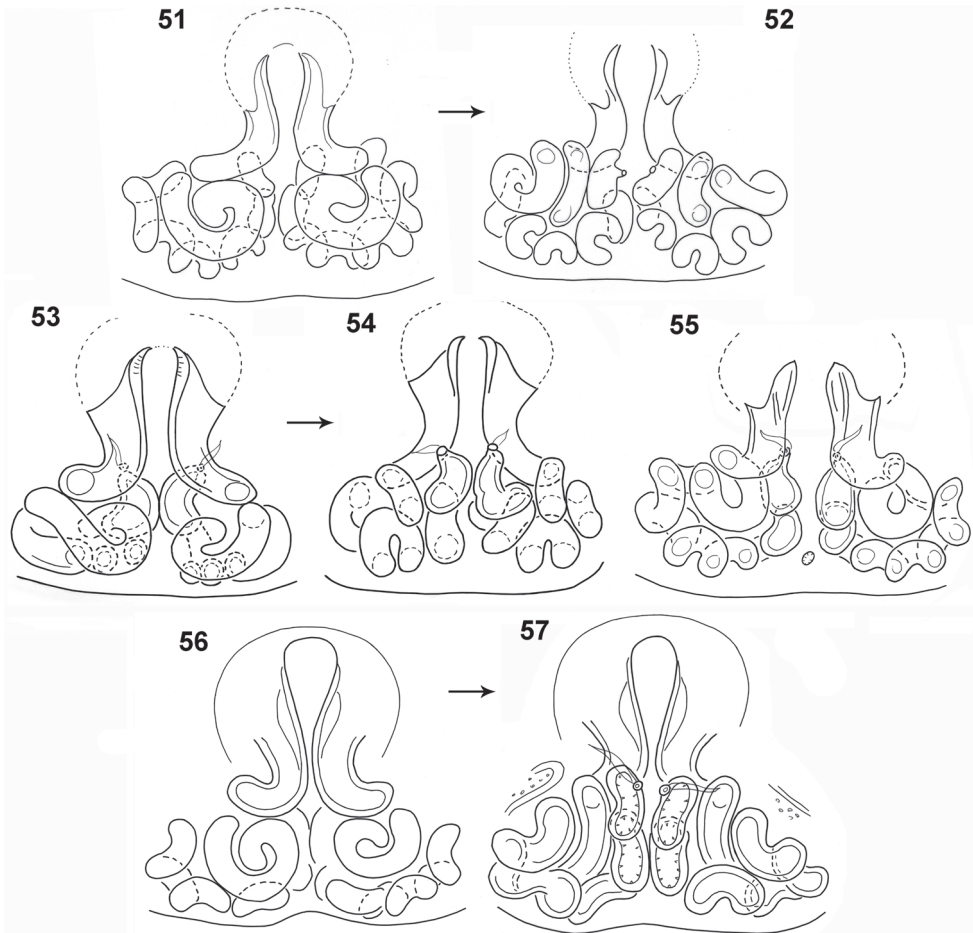
Pachyballus gambeyi (Simon, 1880)

Homalattus gambeyi Simon 1880: 166 (♂).

Pachyballus gambeyi Simon 1901: 485; Prószyński 1987: fig. on p. 73 (♂).

Holotype. NEW CALEDONIA • 1♂; [leg.] Bougier; MNHN 3646; not examined.

Remarks. The holotype was examined by Prószyński (1987). His drawings show that this specimen has palpal organ typical for *Pachyballus*, but morphological characters do not allow any specific identification. Simon described this species from Canala (21°32'S, 165°57'E), central New Caledonia. All species of *Pachyballus* are restricted to Africa, which is thousands kilometers from New Caledonia. This distribution pattern



Figures 51–57. *Pachyballus flavipes*, female, internal structure of epigyne **51, 53, 55, 56** ventral view **52, 54, 57** dorsal view (**51, 52** specimens from Cameroon **53–55** specimen from Congo **56, 57** specimen from Zimbabwe).

is highly improbable, and the situation might have resulted simply by mislabelling the sample, which is not an uncommon problem in collections. As the provenience of the specimen is doubtful we conclude that the status of *P. gambeyi* remains unclear.

***Pachyballus miniscutulus* sp. nov.**

<http://zoobank.org/3DC50D0E-AC8C-4810-827C-CD04B0674B80>

Figures 58–67, 195

Holotype. SOUTH AFRICA • ♂; Free State, Bloemfontein, National Botanical Gardens; 29°02'S, 26°12'E; 12.X.2012; C. Haddad leg.; sweeping, vegetation along stream; NCA 2019/1444.

Paratypes. SOUTH AFRICA • 3♀; together with holotype • 1♀; Free State, Bloemfontein, National Botanical Gardens; VII.2012; L. de Jager and J. van der Merwe leg.; karree litter (*Searsia lancea*), streamside; NCA 2019/1446 • 1♀; the same locality; 19.XII.2012; C. Haddad grassland leg.; pitfall traps; NCA 2013/1635 • 2♀; the same locality; 19.XI.2012; C. Haddad leg.; sweeping, open grassland; NCA 2013/1604 • 4♀; the same locality; 12.X.2012; C. Haddad leg.; sweeping, vegetation along stream; NCA 2012/5707 • 2♀; KwaZulu-Natal, Ithala Game Reserve, picnic site; 27°33'S, 31°19'E; 29.I.2014; C. Haddad leg.; base of grass tussocks; NCA 2013/5098.

Diagnosis. This species is distinctive in having a unique size of ventral posterior scutum (Figs 59, 61) that is clearly smaller than in other species. Its width is equal to spinnerets area (2–3 times larger in the congeners). The female has the epigyne similar to that in *Pachyballus mombasensis*, but the copulatory ducts are longer (cf. Fig. 74 with Figs 66, 67).

Etymology. The specific name is derived from the Latin words “mini-” and “scutum”, meaning “small” and “shield” correspondingly, and refers to the small size of ventral posterior scutum.

Description. Male. Measurements. Cephalothorax: length 1.3, width 1.25, height 0.6. Eye field: length 0.7, anterior width 1.0, posterior width 1.2. Abdomen: length 1.7, width 1.7.

General appearance as in Figs 58, 59. Colouration of carapace dark brown, with black rings around eyes, some long bristles at first row of eyes. Chelicerae dark brown. Clypeus and cheeks dark brown, covered with sparse white hairs. Labium and endites yellowish brown, paler apically. Sternum yellowish brown. Abdomen heart-shaped, dark brown dorsally. Venter brownish grey, with a small posterior scutum, ranging at one fifth of abdomen length (Fig. 59). Book-lung covers yellow. Spinnerets yellowish brown. First pair of legs brown with yellow tarsi. Legs II–IV light brown. Leg hairs brown. Structure of palpal organ as in Figs 62, 63, embolic coil wide, comprises 2.5 loops, palpal tibia with protruding apophysis.

Female. Measurements. Cephalothorax: length 1.0–1.1, width 1.1–1.2, height 0.5–0.6. Eye field: length 0.5–0.6, anterior width 0.9–1.0, posterior width 1.1–1.2. Abdomen: length 1.8–1.9, width 1.5–1.8.

General appearance as in Figs 60, 61. Similar to male. Posterior ventral scutum small, as in male. All legs and palps yellow. Epigyne as in Figs 64, 65, with spade-like or round central part in semi-circular depression. Internal structure of epigyne as in Figs 66, 67.

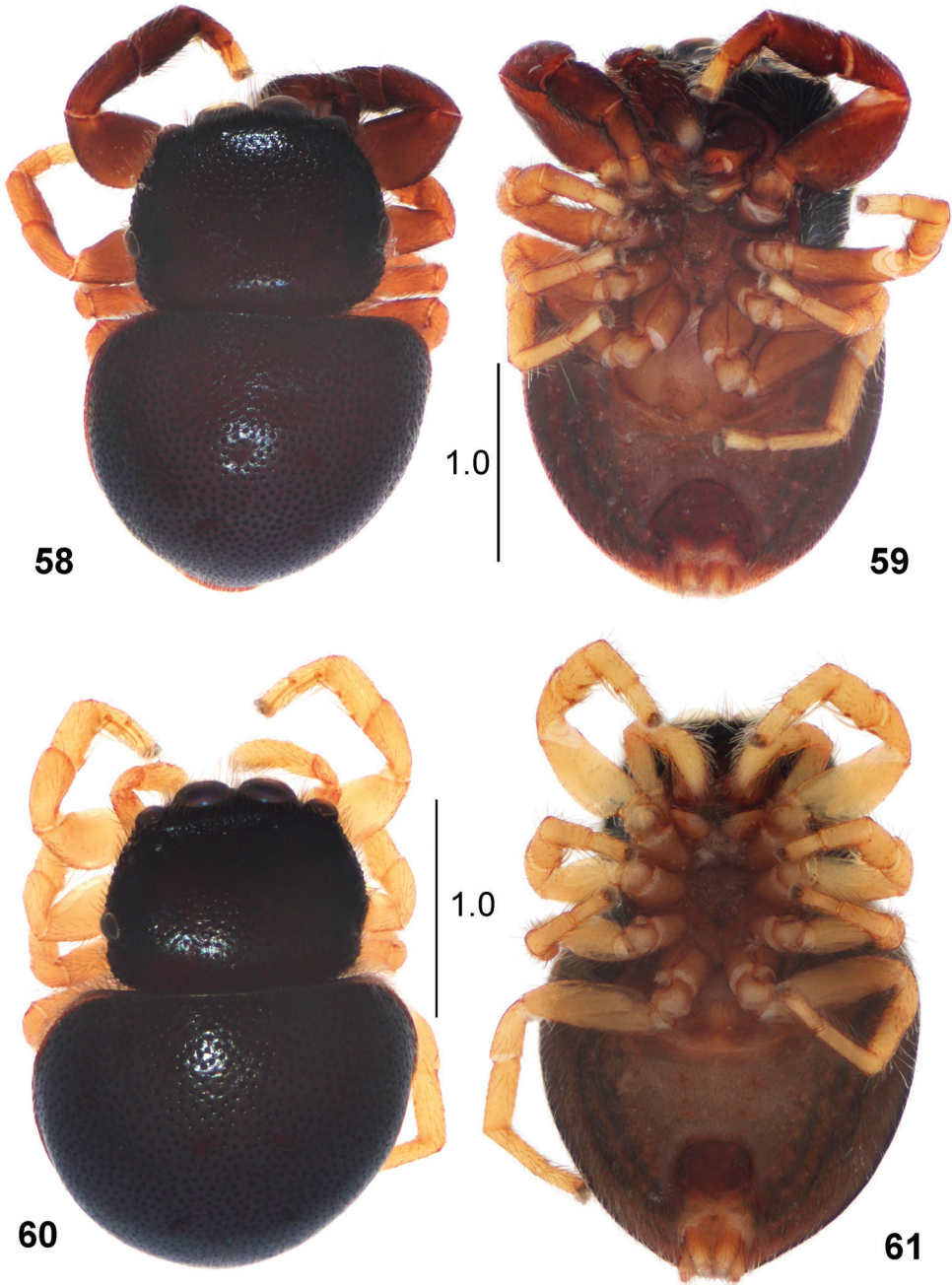
Distribution. Known from South Africa only (Fig. 195).

***Pachyballus mombasensis* sp. nov.**

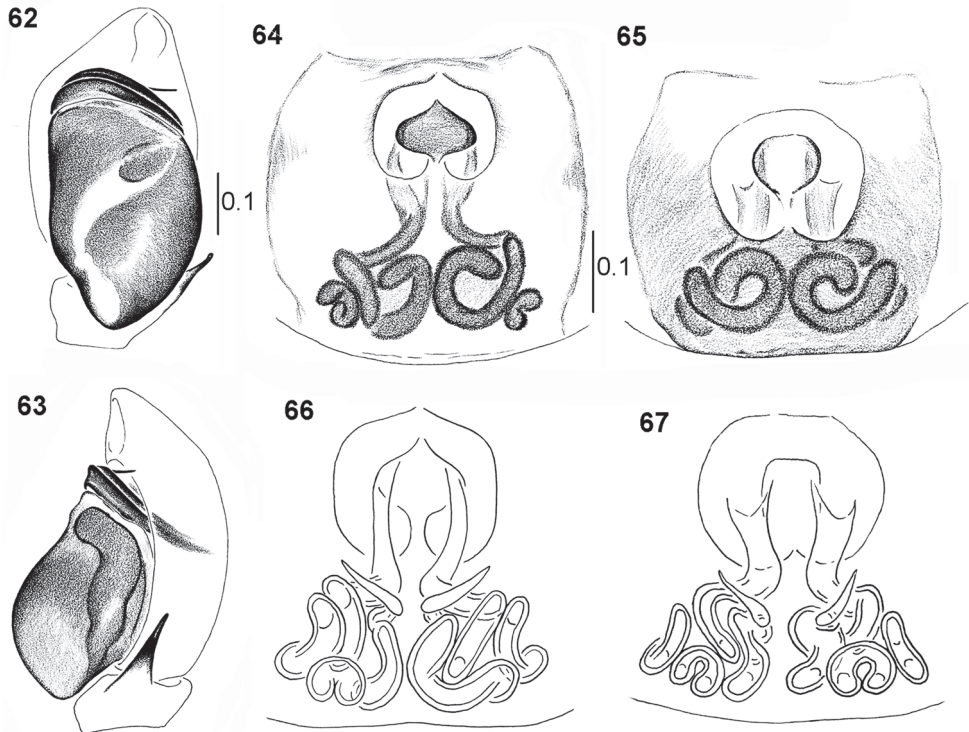
<http://zoobank.org/1A041DD3-803F-49E4-AA4B-F279265DC748>

Figures 68–74, 195

Holotype. KENYA • ♀; Diani Beach, 30 km S to Mombasa; 4°19'S, 39°34'E; 5–19. III.1970; T. Palm leg.; MEU.



Figures 58–61. *Pachyballus miniscutulus* sp. nov. **58** male, holotype, habitus, dorsal view **59** male, habitus, ventral view **60** female, habitus, dorsal view **61** female, habitus, ventral view.



Figures 62–67. *Pachyballus miniscutulus* sp. nov. **62** holotype, palpal organ, ventral view **63** palpal organ, lateral view **64, 65** epigyne **66, 67** internal structure of epigyne, dorsal view.

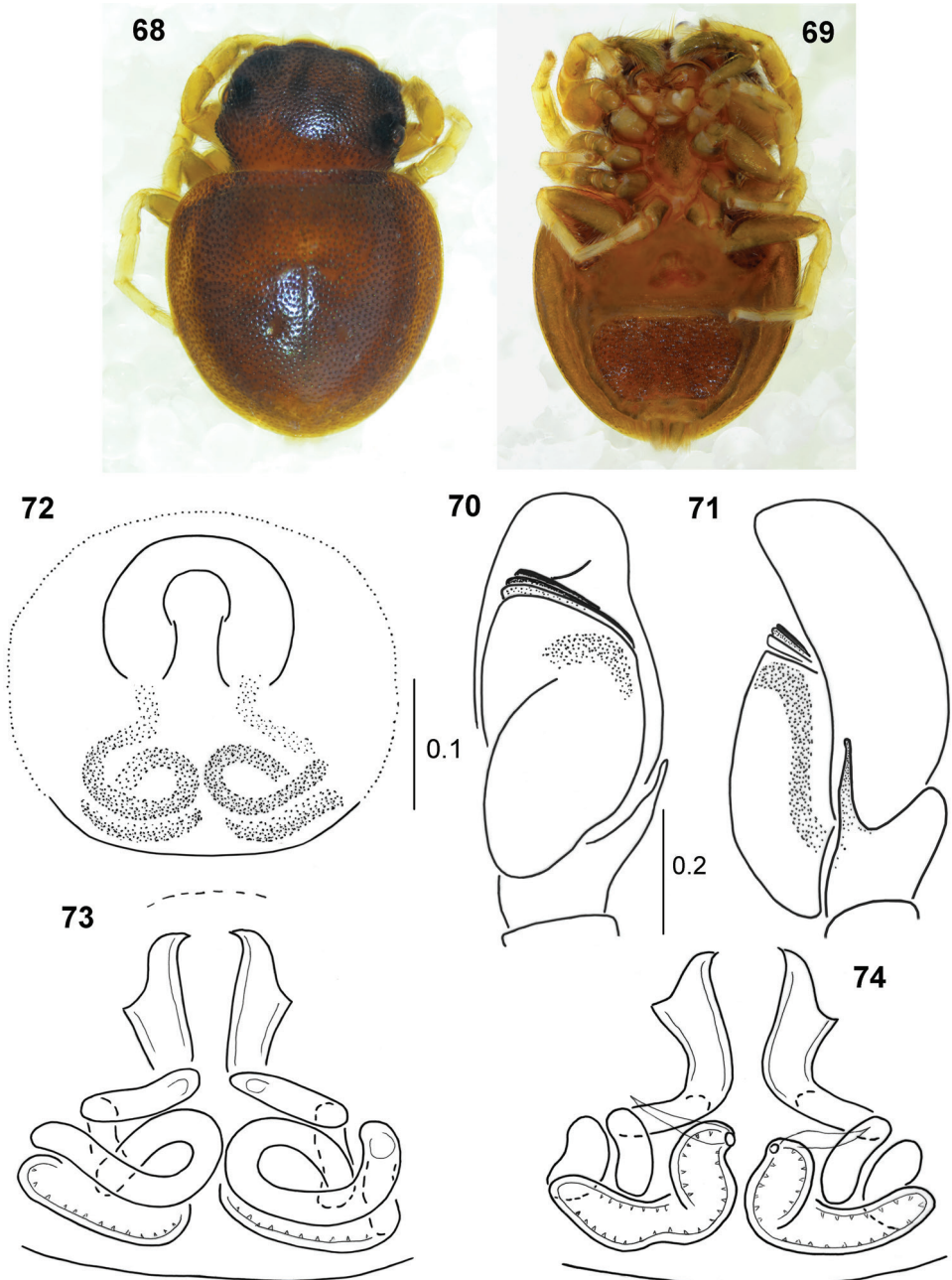
Paratype. KENYA • 1♂; together with the holotype; +3 imm.

Diagnosis. The male is indistinguishable from the males of *P. flavipes* and *P. castaneus* by body colouration; it differs from *P. castaneus* in having a wider bulb and wide and low embolic coil (cf. Fig. 70 with Fig. 25); from *P. flavipes* it can be distinguished by the palpal tibial apophysis adpressed to cymbium, (protruding in *P. flavipes*). The latter character requires verification though, as only single male of *P. mombasensis* is known. The female has relatively short copulatory ducts, forming only a single loop (Fig. 73).

Etymology. The specific name is derived from the type locality.

Description. Male. Measurements. Cephalothorax: length 1.1, width 1.5, height 0.5. Eye field: length 0.6, anterior width 1.1, posterior width 1.5. Abdomen: length 2.1, width 2.1.

Body flattened, integument strongly sclerotised, clearly pitted. Colouration of carapace dark brown, some bristles by the first row of eyes. Mouth parts brownish with lighter tips. Chelicera with three retromarginal teeth. Abdomen very flat, heart-shaped, dark brown, venter with typical scuta. First pair of legs brown, tibia short, slightly thickened, its dorsal part a little flattened, two pairs of ventral spines and dense dark setae. Other legs yellowish, only femora brownish. Palpal organ as in Figs 70, 71, embolic coil wide and low, tibial apophysis adpressed to cymbium.



Figures 68–74. *Pachyballus mombasensis* sp. nov. **68** female, holotype, habitus, dorsal view **69** female, habitus, ventral view **70** palpal organ, ventral view **71** palpal organ, lateral view **72** holotype, epigyne **73** internal structure of epigyne, ventral view **74** internal structure of epigyne, dorsal view.

Female. Measurements. Cephalothorax: length 1.3, width 1.5, height 0.5. Eye field: length 0.7, anterior width 1.1, posterior width 1.5. Abdomen: length 2.1, width 2.1.

General appearance as in Figs 68, 69. Similar to male, first pair of legs not stouter than others, palps dark. Posterior ventral scutum large. Epigyne with semicircular depression (Fig. 72). Internal structure as in Figs 73, 74, copulatory ducts clearly shorter than in congeners, spermathecae comparatively large, strongly sclerotised.

Immature specimens. As adults, dorsum of abdomen covered with one large scutum.

Distribution. Known only from the type locality (Fig. 195).

***Pachyballus ornatus* sp. nov.**

<http://zoobank.org/862AF941-D594-45CC-BBD5-7A38EA629BE7>

Figures 2, 75–97, 195

Holotype. TANZANIA • ♂; Tanga region, Usambara Mts, Amani Nature Reserve, Mbomole Hill; 5°05'S, 38°37'E; 1000 m a.s.l.; 5–8.XI.1995; C. Griswold, N. Scharff, D. Ubick leg.; CAS.

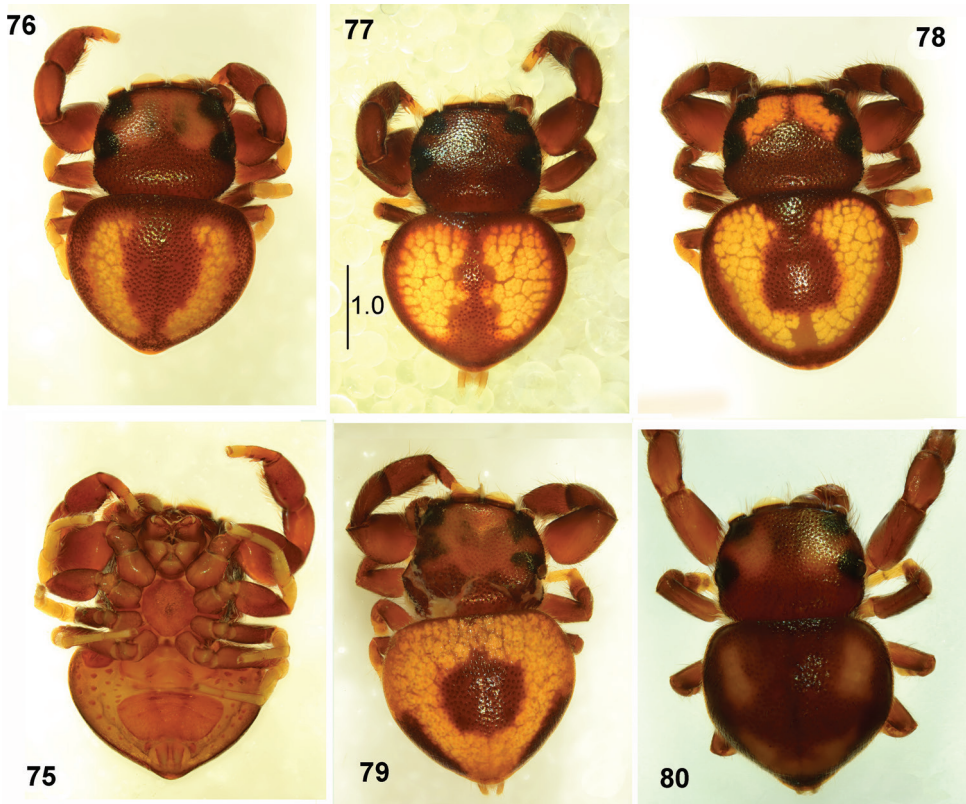
Paratypes. CONGO D.R. • 1♂; Equateur, Bokuma; 0°06'S, 18°42'E; in 1952; R.P. Lootens leg.; MRAC 85 126 • 1♂; Mayombe, Bas Congo, Luki Forest Reserve; 5°37'S, 13°05'E; 7.XI.2006; D. De Bakker and J.P. Michiels leg.; primary rainforest, fogging; MRAC 226 115 • 1♂; Kivu, Ibanda [Bukavu]; 2°29'S, 28°50'E; SMF. TANZANIA • 2♂ 2♀ (1 of females – black form); together with the holotype; CAS • 1♂; Mufindi distr., Iringa region, Uzungwa Scarp Forest Reserve; 8°32'S, 35°54'E; 750 m a.s.l.; 8.III.1996; McKamey leg.; canopy fogging; UCZM • 1♂; the same locality, by Chita village; 1300–1400 m a.s.l.; 26.X–14.XI.1984; N. Scharff leg.; montane rain forest; UCZM • 3♂ 4♀ (2 of females – black form); 11 km SE Masisiwe Kihanga Stream; 8°32'S, 35°58'E; 1800 m a.s.l.; 17–27.V.1997; canopy; UCZM • 1♂; Uluguru Mts, Kimboza Forest Reserve; 7°20'S, 37°47'E; 250 m a.s.l.; 18.VII.1981; M. Stoltze and N. Scharff leg.; UCZM.

Diagnosis. A characteristic body pattern allows an easy recognition of this species; the abdomen is light with dark margins and a dark streak or central patch (Figs 78, 81). Some specimens, probably young adult females (soon after moulting), can be uniformly black and resemble females of *P. flavipes*, but they are distinguishable in having dark palps (that are yellow in the latter species).

Etymology. The specific name is Latin and means *decorated*, which refers to the characteristic colour pattern.

Description. Male. Measurements. Cephalothorax: length 1.2–1.7, width 1.5–1.8, height 0.5–0.6. Eye field: length 0.8–1.0, anterior width 1.1–1.4, posterior width 1.5–1.8. Abdomen: length 1.7–2.3, width 1.8–2.4.

General appearance as in Figs 75–80. Body flat, integument strongly sclerotised, clearly pitted. Carapace wider than long, eye field trapezoid (distance between anterior lateral eyes shorter than between posterior laterals), occupies about half of carapace.

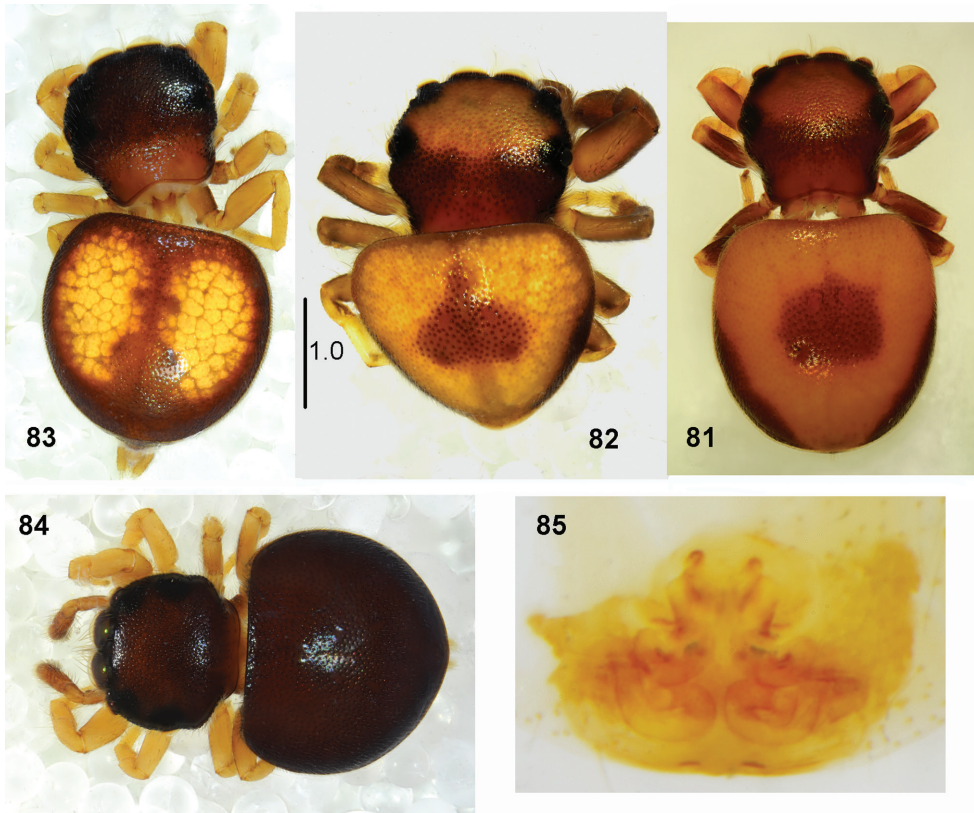


Figures 75–80. *Pachyballus ornatus* sp. nov., male, habitus **75** ventral view **76–80** dorsal view (all specimens from Tanzania).

Colouration of carapace brown, black around eyes, in some specimens with two large yellowish patches in eye field (Figs 76, 78, 80). Dense bristles at eyes of first row and at lateral edges of carapace. Chelicera with three short teeth on promargin and saw-shaped tooth with four tips on retromargin. Labium and endites brownish with lighter tips, sternum rounded, brown. Abdomen very flat, triangular to heart-shaped, wider than long, its anterior margin almost straight. Colouration of abdomen yellow, brown on the edges, with brown longitudinal median streak (Fig. 77), which is reduced to round patch positioned centrally in some specimens (Fig. 79). Variation of pattern as presented in Figs 76–80. Abdomen with typical ventral scuta (Figs 2, 75). Spinnerets yellow. First pair of legs slightly stouter than other legs, femora enlarged, tibiae slightly thickened, brown, only tarsi light. Other legs yellowish to light brown, femora darker. Palps as in Figs 86, 87, embolic coil low, but basal loop high.

Female. Measurements. Cephalothorax: length 1.3–1.5, width 1.4–1.8, height 0.5–0.6. Eye field: length 0.6–0.8, anterior width 1.1–1.2, posterior width 1.4–1.5. Abdomen: length 1.9–2.1, width 2.0–2.2.

General appearance as in Figs 81–84. Body shape and colouration similar to that in male. First legs not enlarged. Palps dark. Epigyne with anterior semi-circular de-



Figures 81–85. *Pachyballus ornatus* sp. nov., female, **81–84** habitus, dorsal view **85** epigyne (all specimens from Tanzania).

pression divided by a median septum (Figs 88–91). Copulatory ducts very long, form several loose loops, spermathecae oval (Figs 92–97).

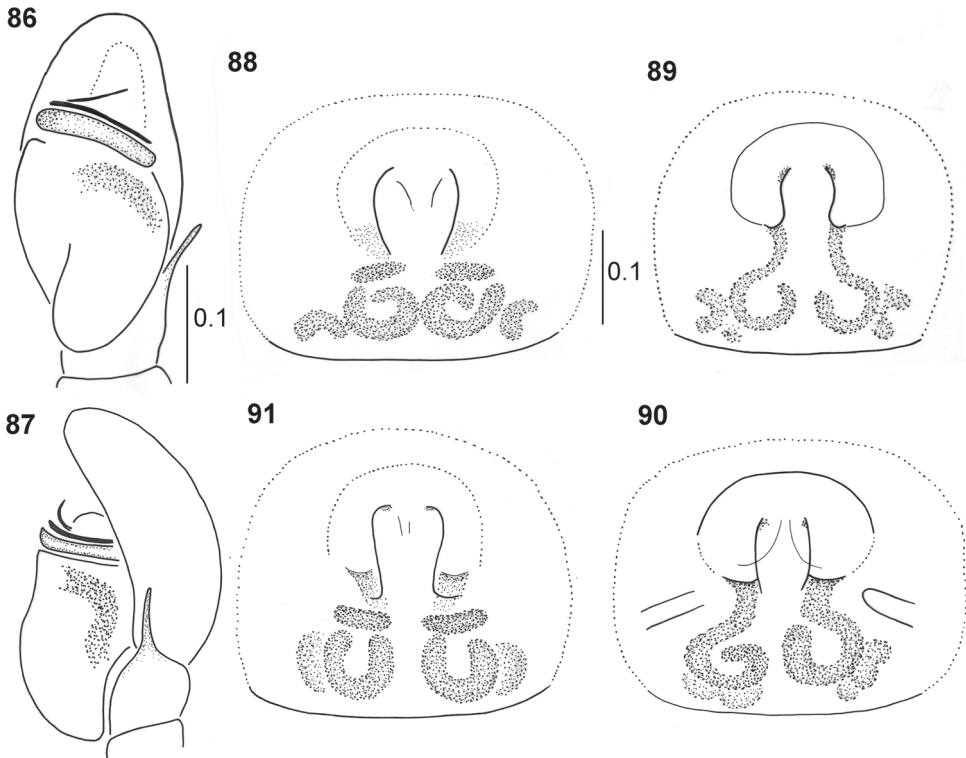
Distribution. Tanzania and Congo D.R. (Fig. 195).

Remarks. Some specimens, probably young females (soon after the moulting), were dark, almost black (Fig. 84). They appear to become brighter with age due to guanine accumulation (light spots are formed by guanine crystals stored under integument). Black females were collected together with light specimens. Internal structure of epigynes similar in light, Figs 92–94, and black, Figs 85, 95–97 specimens. Colouration seems to turn brighter in the course of life also in males.

Pachyballus transversus Simon, 1900

Figures 98–122, 191, 192, 196

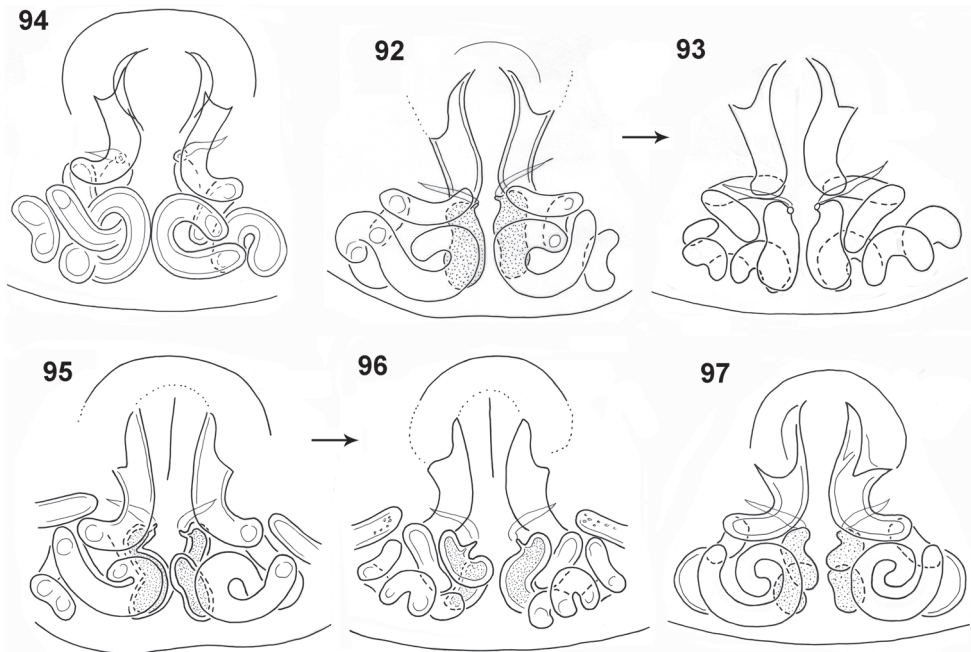
Pachyballus transversus Simon 1900: 399 (♂); 1901: 482, f. 570–571; 1910: 414; Berland and Millot 1941: 397.



Figures 86–91. *Pachyballus ornatus* sp. nov., copulatory organs **86** palpal organ, ventral view **87** palpal organ, lateral view **88–91** epigyne (**89, 91** black form **89, 90** specimens from Usambara Mts).

Syntypes. CONGO • 2♂; Mayombe; E. Simon coll.; MNHN 7545; examined.

Other material examined. CAMEROON • 1♀; Maroua; 10°36'N, 14°19'E; col. C.F. Roewer (nr 12 678); SMF • 1♀; without precise locality; in 1950; J. Birket-Smith leg.; UCZM. CONGO D.R. • 1♀; Mayombe, Bas Congo, Luki Forest Reserve; 5°37'S, 13°05'E; 28.IX.2007; D. De Bakker and J.P. Michiels leg.; primary rainforest, fogging; MRAC 226.109A • 3♂ 2 imm; Kivu N prov., Kaisola, Ruindi plain; 0°47'S, 29°17'E; 1100 m a.s.l.; 3.VII.1972; M. Lejune leg.; MRAC 144 487 • 1♂ 2♀ 1 imm.; Ruindi plain, Ndimu Hill; 1100 m a.s.l.; 28.VI.1972; P.M. Lejune leg.; MRAC 144 670 • 1♂; Kivu N prov., Rutshuru; 1°11'S, 29°27'E; III.1937; J. Ghesquière leg.; MRAC 30 583 • 1♂; Goma; 0°34'S, 28°42'E; 10.II.1952; E. Bertrand leg.; MRAC 78 975. ETHIOPIA • 3♂ 2 imm.; Gorgora; 12°14'N, 37°18'E; in 1961; F. Hartman leg.; MRAC 131 203 • 1♂; Yayu coffe forest plantation; 8°10'N, 36°00'E; in 2004; N. Aklilu leg.; MRAC 231 209 • 1♀; the same locality; beating; MRAC 230 736 • 1 imm.; the same locality; secondary forest, beating; MRAC 229 396. IVORY COAST • 1♀; Bingerville; 5°21'N, 3°54'W; VIII.1962; J. Decelle leg.; MRAC 122 004. MOZAMBIQUE • 1♀; 'N Mozambique'; col. C.F. Roewer (nr 9715); SMF. SOMALIA • 1♀; Sinandogo; in 1946; R. Accigliaro leg.; MRAC 131 175 • 1♀; Giumbo; 0°14'S, 42°37'E; in 1946;



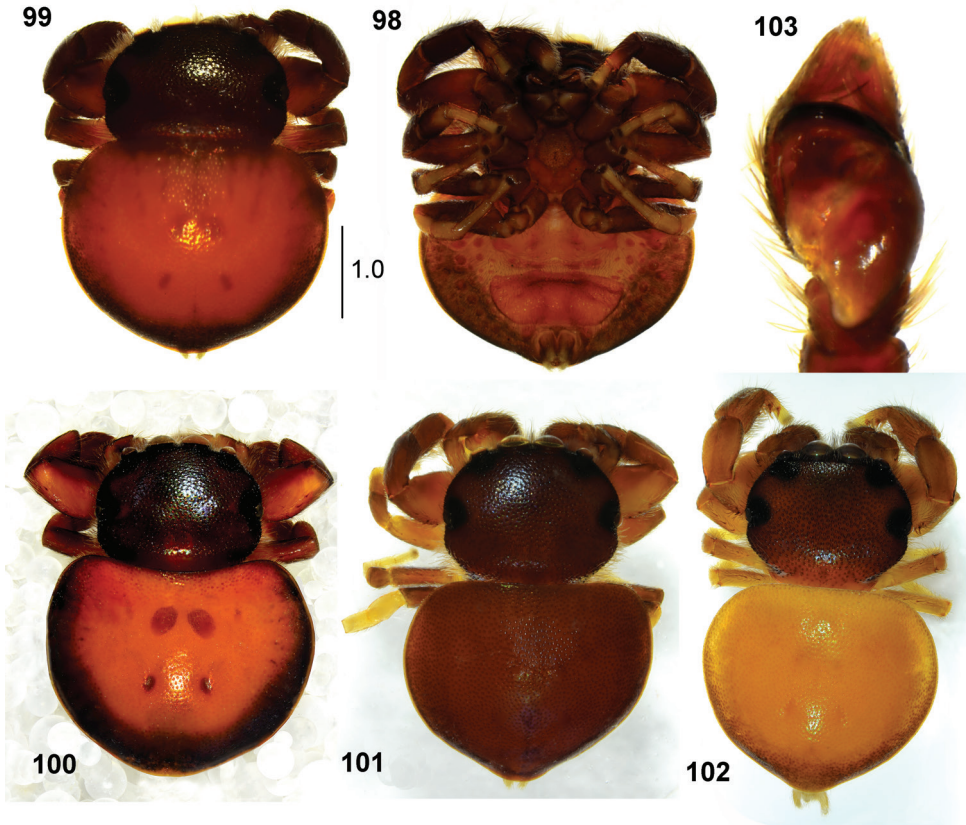
Figures 92–97. *Pachyballus ornatus* sp. nov., internal structure of epigyne **92, 94, 95, 97** ventral view, **93, 96** dorsal view (specimens **94–96** from Usambara Mts, lower row – black form).

R. Accigliaro leg.; MRAC 131 223. TANZANIA • 2♂; ‘Zanguebar’ (=eastern coast of tropical Africa, probably Zanzibar); E Simon coll.; MNHN 7021. SOUTH AFRICA • 1♂; KwaZulu-Natal, Ulundi, Ophathe Game Reserve; 28°23'S, 31°24'E; 3.X.2008; C. Haddad leg.; beating, shrubs, overgrazed savanna; NCA 2008/4154 • 1♂; the same locality; 1.X.2008; NCA 2008/3971 • 9♂; the same locality; NCA 2019/1448 • 1♀; Mpumalanga Prov., Nelspruit, Agricultural College; 25°27'S, 30°59'E; 12.XI.1999; P. Stephen leg.; beating, citrus; NCA 2000/223.

Diagnosis. The body proportions of this species are different than in other *Pachyballus* spp., namely width of carapace and width of abdomen are clearly greater than their length. Sigilla are strongly marked. Shape of the eye field is more trapezoid than in congeners, its width at posterior eye row is a quarter larger than anterior width.

Redescription. Male. Measurements. Cephalothorax: length 1.5–1.7, width 1.9–2.0, height 0.6. Eye field: length 0.8–1.0, anterior width 1.3–1.5, posterior width 1.9–2.0. Abdomen: length 2.4–2.9, width 2.8–3.2.

General appearance as in Figs 98–102. Slightly larger than *P. flavipes*, body flattened, covered with hard integument, pitted. Carapace wide, dark brown to blackish, vicinity of eyes black. Eye field strongly trapezoid, more than in other *Pachyballus* spp. Its width at last row of eyes is a quarter larger than its anterior width. A few hairs and long bristles at anterior eyes. Clypeus low. Chelicerae with short fang, three small teeth on promargin and four teeth with fused base on retromargin (Fig. 110). Mouth parts brown, sternum



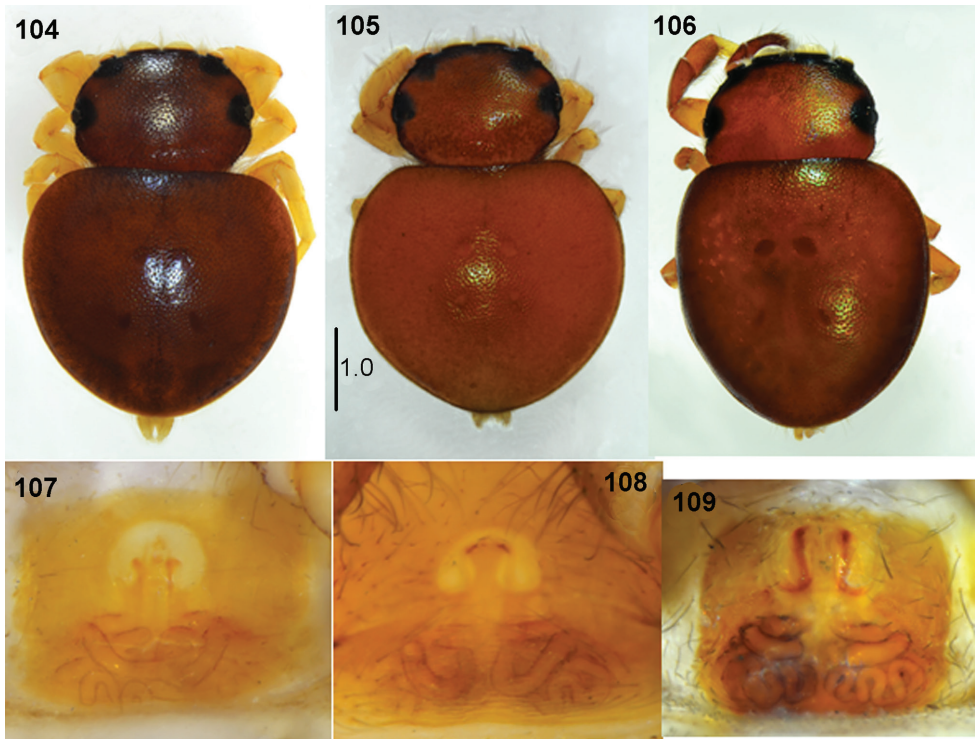
Figures 98–103. *Pachyballus transversus*, male **98** habitus, ventral view **99–102** habitus, dorsal view, **103** palpal organ, ventral view (all specimens from Congo).

oval, dark. Abdomen heart-shaped, wide, clearly wider than long. Colouration of abdomen usually light, orange brownish with blackish edge, sometimes yellowish or brown. Sigilla clearly visible. Venter brown, with typical scuta (Fig. 98). First pair of legs brown, slightly larger than other pairs, with femora and tibiae thickened, tibiae slightly flattened dorsally. All legs brownish with lighter tarsi. Palps dark, structure as in Figs 103, 111, 112.

Female. Measurements. Cephalothorax: length 1.4–1.6, width 1.6–2.0, height 0.7. Eye field: length 0.7–0.8, anterior width 1.2–1.5, posterior width 1.8–2.0. Abdomen: length 2.4–2.9, width 2.8–3.2.

General appearance as in Figs 104–106. Similar to male, eye field strongly trapezoid. Abdomen wide, rounded, with visible sigilla. All legs yellow, sometimes femora, patellae and tibiae brownish. Palps dark. Epigyne typical, with horseshoe-shaped anterior depression (Figs 107–109, 113–116). Copulatory ducts long, forming several loops, spermathecae strongly sclerotised (Figs 118–122).

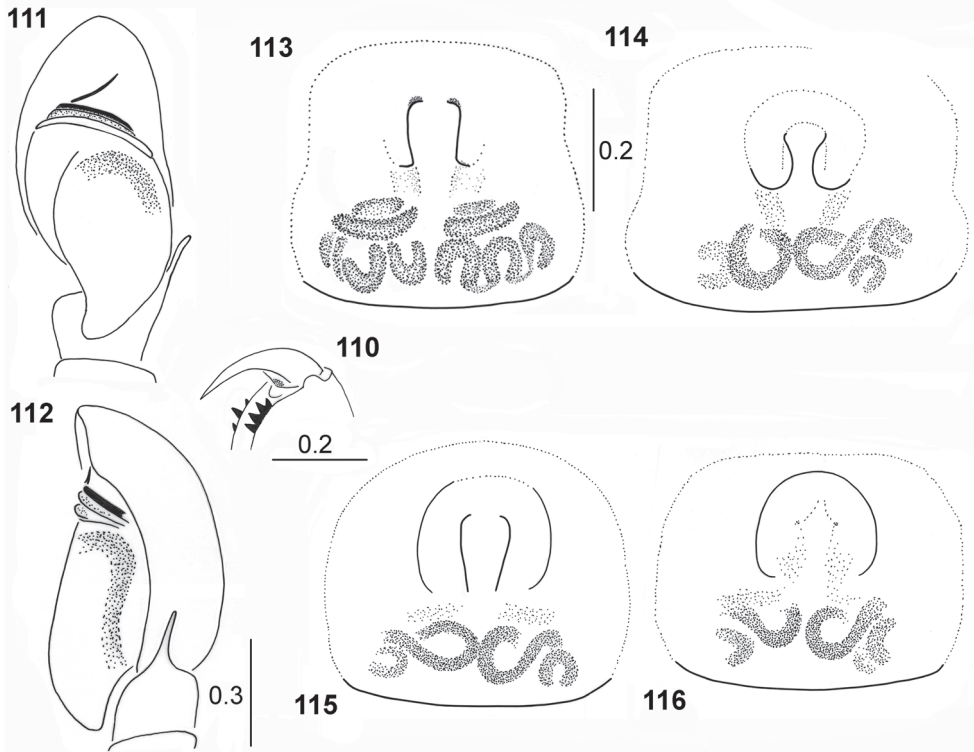
Immature specimens. Shape of body as in adults, abdomen with two oval scuta, close to each other on dorsum (Figs 191, 192). Ventral scuta absent.



Figures 104–109. *Pachyballus transversus*, female **104–106** habitus, dorsal view **107–109** epigyne (dissected from specimens visible above) (**104, 106** specimens from Congo **105** specimen from Ethiopia).

Distribution. Widely distributed in Africa (Fig. 196).

Remarks. Simon (1900) described only the female of *P. transversus*. He recorded this species from Congo, Transvaal (South Africa) and Zanzibar (Simon 1900, 1901). He found it also (Simon 1910) later in Guinea Bissau and noted in this publication that this species had been described from Congo. This suggests that the Congolese specimens constitute the “type material”. However, the two specimens from Congo, personally labelled by Simon and kept in the MNHN collection, are males. The fact was also mentioned by Berland and Millot (1941). Simon most probably described these specimens and apparently published the wrong data on sex of specimens. This description is very superficial and the structure of copulatory organs is not depicted. There are also some other males from Zanzibar in Simon’s collection in MNHN (but no female). Simon’s specimens from Natal, kept in MZC (examined) are immature and probably misidentified. Thus, it should be concluded that Simon’s description concerned the male and the female of this species is described here for the first time. The figure in Simon (1901) shows characteristic body proportions of *P. transversus* (width of carapace greatly exceeds its length, eye field is clearly trapezoid with long distance between eyes in the posterior row, and abdomen is rounded), which allows the proper species recognition.



Figures 110–116. *Pachyballus transversus* **110** cheliceral dentition **111** palpal organ, ventral view **112** palpal organ, lateral view **113–116** epigyne (**114** specimen from Ethiopia **115** specimen from Somalia **113, 116** specimens from Congo).

***Pachyballus variegatus* Lessert, 1925**

Figures 123–128, 193

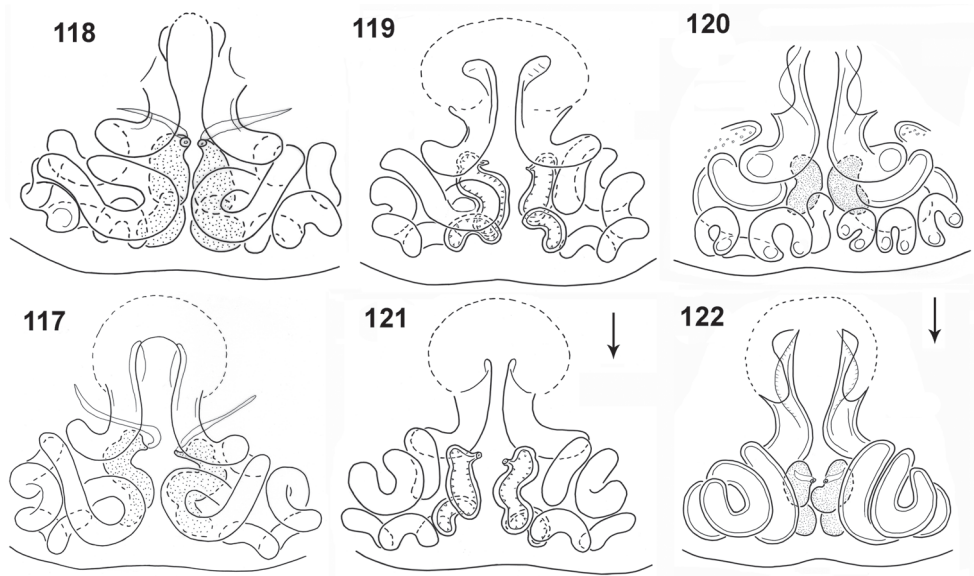
Pachyballus variegatus Lessert 1925: 437, f. 10–14 (♂♀).

Syntypes. TANZANIA • 1♂ 1♀; Kilimanjaro, Kibonoto; 3°11'S, 37°06'E; Sjöstedt leg.; NHRS; examined.

Diagnosis. This species is the only one in the genus that does not have the posterior ventral scutum on abdomen. Its other diagnostic feature is the pattern on abdomen; the anterior one-fourth of the abdomen is bright, the posterior part dark with a wide, light median patch (Figs 123, 127).

Redescription. Male. Measurements: Cephalothorax: length 1.4, width 1.3, height 0.4. Eye field: length 0.7, anterior width 1.1, posterior width 1.3. Abdomen: length 1.8, width 1.7.

General appearance as in Fig. 123. Body flattened, integument strongly sclerotised, clearly pitted. Eye field light, yellowish orange, blackish rings around eyes, thoracic



Figures 117–122. *Pachyballus transversus*, internal structure of epigyne **117–120** ventral view **121, 122** dorsal view (**117** specimen from Ethiopia **118** specimen from Somalia, other specimens from Congo).

part light brown anteriorly, posterior slope yellowish. A few delicate hairs at anterior eyes. Chelicerae brown, with three teeth on promargin and a tooth with two tips on retromargin (Fig. 124). Labium and endites basally brownish, with light tips. Sternum light brown. Abdomen heart-shaped, widest anteriorly and tapering, anteriorly orange, sides brown with wide orange area in the middle (Fig. 123). Venter yellowish, without scutum. Spinnerets short, yellow. Legs relatively short, dark yellow (first pair absent in the syntype, only coxae extant, brown). Pedipalp (only right present) brown. Palpal organ as in Figs 125, 126, embolic coil wide, with three loops.

Female. Measurements: Cephalothorax: length 1.5, width 1.4, height 0.5. Eye field: length 0.8, anterior width 1.2, posterior width 1.4. Abdomen: length 2.2, width 2.1.

Colouration as in male (Fig. 127). Abdomen rounded. Palp light, with brown apical part. Epigyne weakly sclerotised with shallow central depression (Fig. 128). Internal structure not studied, spermathecae probably large (visible through integument).

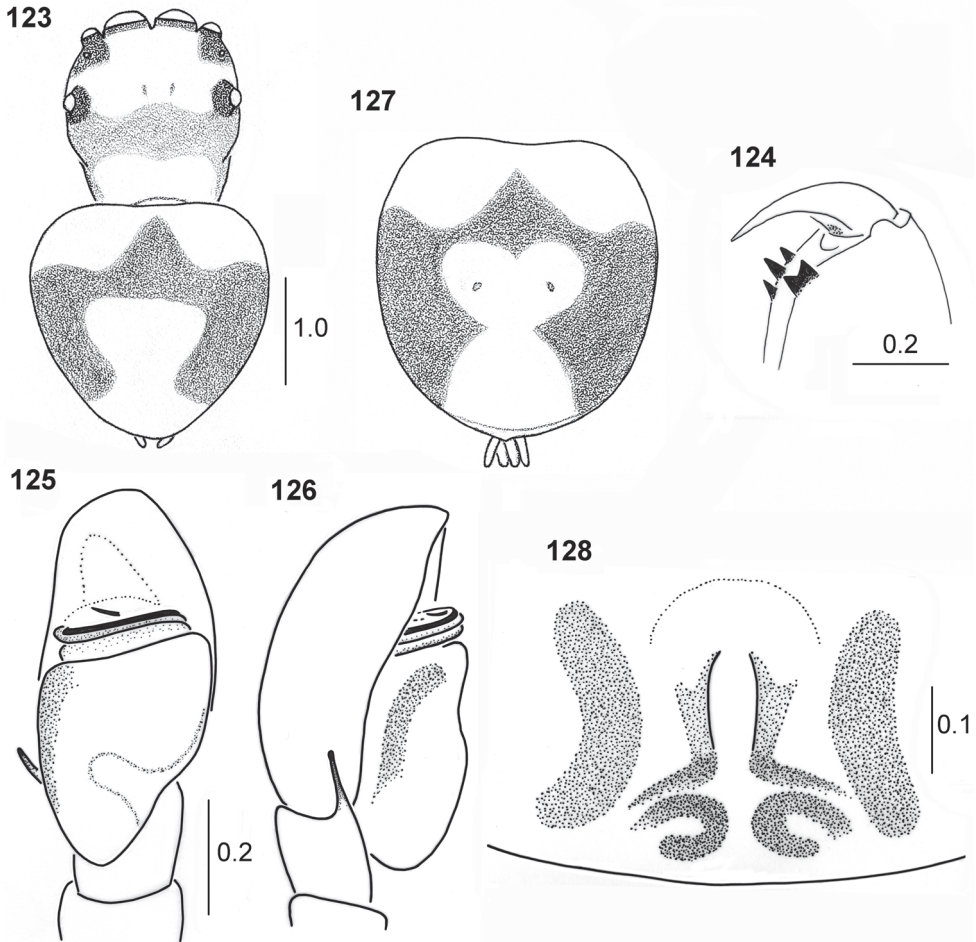
Remarks. Lessert (1925) wrote in the original description that the basic colour of body was black. The specimens must have bleached heavily, however the outline of lighter patches has been preserved.

Distribution. Known only from the type locality (Fig. 193).

Peplometus Simon, 1900

Peplometus Simon 1900: 399; 1901: 486.

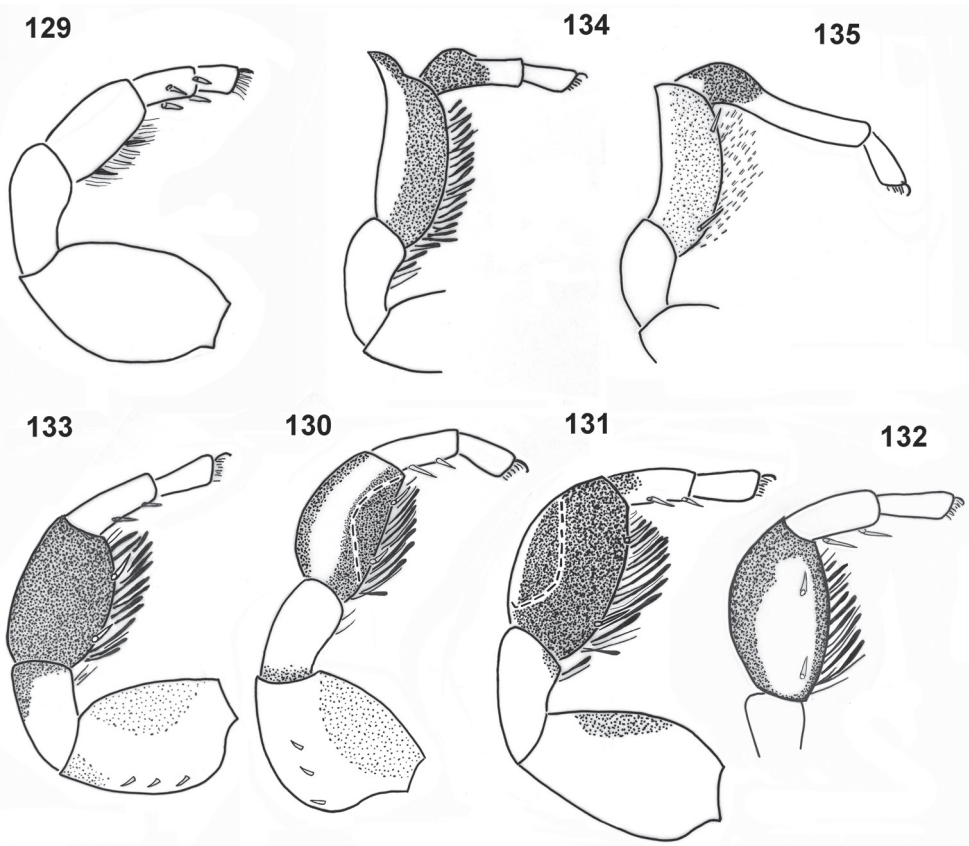
Type species. *Homalattus biscutellatus* Simon, 1887.



Figures 123–128. *Pachyballus variegatus*, syntypes **123** male, habitus **124** cheliceral dentition **125** palpal organ, ventral view **126** palpal organ, lateral view **127** female, colouration of abdomen **128** epigyne.

Diagnosis. *Peplometus* is closely related to *Pachyballus*. From the latter genus it can easily be separated by the elongated abdomen (rounded in *Pachyballus*). It differs also in the form of leg I in males having the leaf-like setae on tibia I (absent in the other genus).

Description. Small spiders (ca. 3.0–4.0 mm length), with very flat body, covered with hard strongly sclerotised integument. Carapace almost square-shaped, pitted dorsally, its length only slightly exceeds its width. Chelicerae with two (exceptionally three) small teeth on promargin and on retromargin a saw-shaped tooth with four to five denticles. Abdomen slightly elongated, ratio of its length to width 1.3–1.5 (only in female of *P. biscutellatus* 1.2). In males, width of abdomen almost equal to width of carapace, abdomen of females wider and rather oval. Anterior margin of abdomen straight. Hard scutum covers dorsum of abdomen, venter also strongly armoured, with scuta as in *Pachyballus*, namely the narrow scutum with backwards extending “horns” at anterior edge, and a large trapezoid scutum in posterior half of abdomen. Males



Figures 129–135. First leg of male **129** *Pachyballus castaneus* **130** *Peplometus biscutellatus* **131**, **132** *P. chlorophthalmus* **133** *P. congoensis* **134** *P. oyo* **135** *P. nimba* **132** retrolateral view, others prolateral view.

with a thinner sclerotised plate in front of epigastric furrow, its thick posterior margin forms narrow wedge-shaped bar (Figs 138, 185). Numerous sclerotised bumps on sides of the abdominal venter (Fig. 138). Legs short, in males the first pair slightly thicker, with enlarged femora and modified tibiae. In some species conspicuously thickened, usually flattened, in other species elongated (in this case the metatarsus I with a dorsal process). Tibiae I black, with ventral brush of long dense flattened setae, contrasting with other segments. Copulatory organs similar to those in *Pachyballus*.

Key to *Peplometus* males

- 1 Metatarsus I with a dorsal process, tibia not thickened.....2
- Metatarsus I without a process, tibia strongly thickened.....3
- 2 Tibia I with a distal process, metatarsus shorter than tibia (Fig. 134) ...*P. oyo*
- Tibia I without process, length of metatarsus equal to length of tibia (Fig. 135) *P. nimba*

3	Tibia I not flattened (Fig. 133)	<i>P. congoensis</i>
–	Tibia I flattened	4
4	Tibia I flattened dorsally (Fig. 131).....	<i>P. chlorophthalmus</i>
–	Tibia I flattened prolaterally (Fig. 130)	<i>P. biscutellatus</i>

***Peplometus biscutellatus* (Simon, 1887)**

Figures 4, 130, 136–153, 189, 190, 197

Homalattus biscutellatus Simon 1887: 263 (♀).

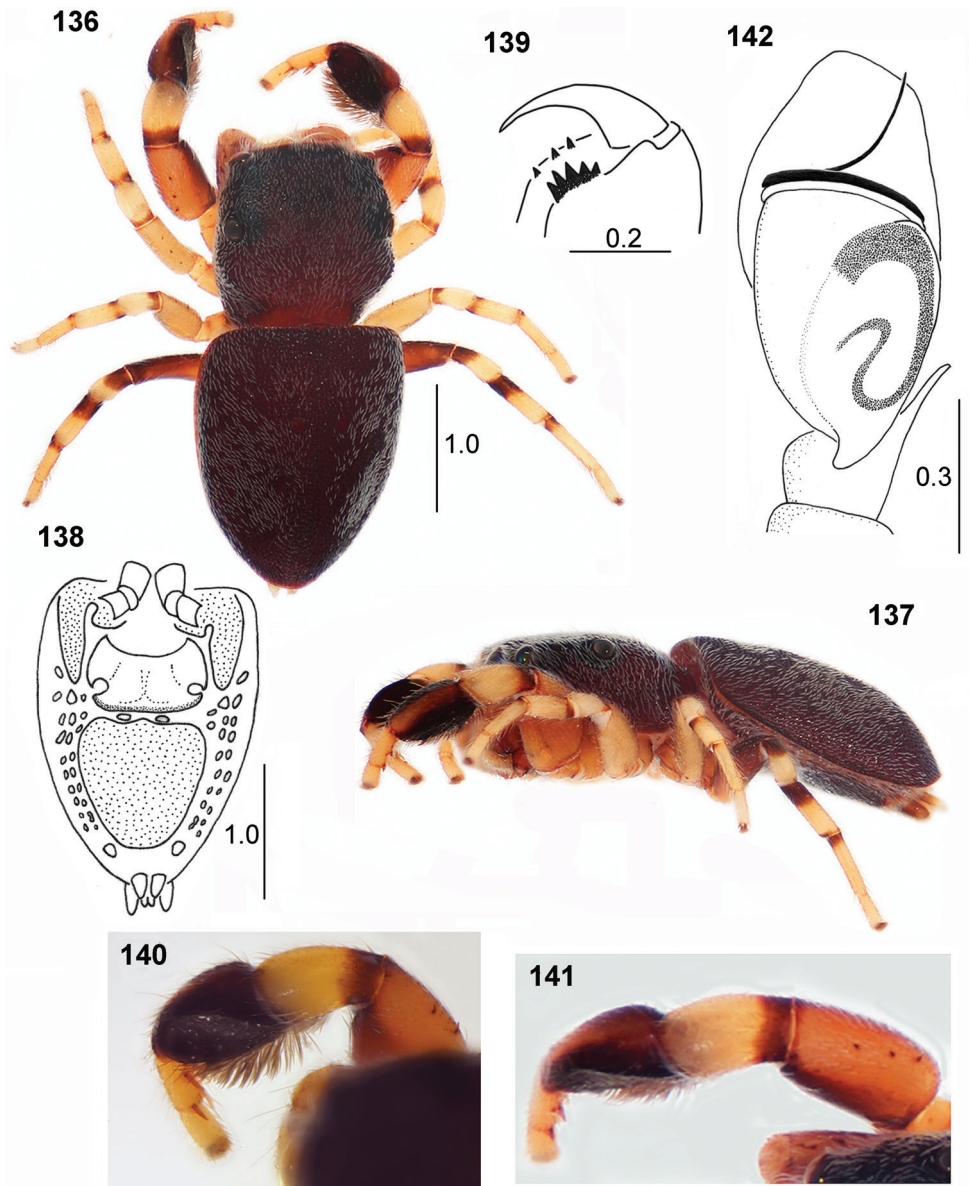
Peplometus biscutellatus Simon 1901: 486; Berland and Millot 1941: 398.

Holotype. IVORY COAST • ♀; Assinie; 5°08'N, 3°16'W; Alluau [C.] leg.; MNHN 9072; examined.

Other material examined. CAMEROON • 2♀; Matube, Tiko plantation; 4°04'N, 9°21'E; 24.IV-6.V.1949; B. Malkin leg.; CAS • 1♀; Mabete Victoria [Limbe]; 4°01'N, 9°13'E; 24.V-7.VI.1949; B. Malkin leg.; CAS • 1♀; Reserve Forestiere Nyong, S to Makak; 3°25'N, 12°47'E; 17.II.1950; J. Dahl and J. Birket-Smith leg.; UCZM. GHANA • 2♂; Kakum forest; 5°25'N, 1°19'W; 18.XI.2005; primary forest, R. Jockué, D. De Bakker and L. Baert leg.; fogging; MRAC 217 897 • 1♀; the same data; 16.XI.2005; MRAC 217 875 • 2♀; the same data; 25.XI.2005; MRAC 217 945 • 7♂ 4♀; the same locality; 15.XI.2005; secondary forest; MRAC 217 865 • 2♂; the same data; 17.XI.2005; MRAC 217 881 • 1♂; the same data; 12.XI.2005; MRAC 217 857. GUINEA • 1♀; Dalaba; 10°42'N, 12°15'W; VII.1937; J. Millot leg.; MNHN • 1♂; Nimba Mts, Zougoué Valley, near Gbakoré mine camp; 7°34'N, 8°28'W; 5.X.2011; 780 m a.s.l.; young secondary gallery forest, fogging canopy; D. van den Spiegel leg.; MRAC 238 187 • 1♂; same locality, Seringbara road; 8.II.2012; beating; A. Henrard, C. Allard, P. Bimou, M. Sidibé leg.; MRAC 239 050 • 2♂, 1♀; same locality; gallery forest of Zié; 3.X.2011; 1250 m a.s.l.; fogging, canopy forest, understory shrub layer; D. van den Spiegel, A. Hernard leg.; MRAC 238 066. IVORY COAST • 1 imm.; together with the holotype • 1♂; Bouaké, Foro Foro; 7°49'N, 5°01'W; 5–7.VIII.1974; pitfall; G. Couturier leg.; MRAC 216 442 • 1♂; the same data; MRAC 216 380. NIGERIA • 1♂; Kabba; 7°50'N, 6°04'E; 18–23.II.1949; B. Malkin leg.; CAS. SENEGAL • 1♂; Dakar; 8°19'N, 0°13'W; IX.1947; L. Berland leg.; MNHN. SIERRA LEONE • 2♂ 3♀ 2 imm.; Free Town; 8°30'N, 13°15'W; col. E. Simon, MNHN 19 988. TOGO • 1♀ 1 imm.; without precise locality; col. C.F. Roewer (nr 10861); SMF.

Diagnosis. The male of this species may be distinguished by a flat area on prolateral side of the tibia I (Figs 130, 140, 141). The female has a cordiform abdomen, while other congeners have oval abdomen; the width/length ratio of abdomen in *P. biscutellatus* female is 0.8, whereas it is 0.75 in other species.

Redescription. Male. Measurements. Cephalothorax: length 1.1–1.7, width 1.2–1.8, height 0.5–0.6. Eye field: length 0.7–0.9, anterior width 1.0–1.3, posterior width 1.2–1.6. Abdomen: length 1.9–2.9, width 1.3–2.1.



Figures 136–142. *Peplometes biscutellatus*, male **136** habitus, dorsal view **137** habitus, lateral view **138** venter of abdomen **139** cheliceral dentition **140** first leg, dorsoprolateral view **141** first leg, dorsal view **142** palpal organ, ventral view (photos – specimen from Ghana, drawings – specimen from Sierra Leone).

General appearance as in Figs 136, 137. Body flattened, completely covered with strongly sclerotised and pitted integument. Dorsum of body dark brown, clothed in dense short white hairs (lost in some of the studied specimens). Eye field on more than half of carapace length, black rings around eyes, the first row of eyes encircled with white hairs. Long white bristles between anterior eyes. Clypeus extremely low, brown with a few white hairs. Chelicerae with three diminutive teeth on promargin and five retromarginal

teeth fused basally (Fig. 139). Mouthparts brown. Sternum oval, brown. Abdomen elongated, widest anteriorly and tapering rearward, anterior edge almost straight. Dorsum of abdomen totally covered by very strongly sclerotised and pitted scutum, laterally slightly turned back to venter. Venter with typical scuta; anterior scutum narrow, extending backwards laterally, posterior ventral scutum largest, cordiform. In front of epigastric furrow a thin sclerotised plate with thick posterior margin forms narrow wedge-shaped bar. Numerous bumps on sides ventrally; armour-plate pattern is shown in Fig. 138. Spinnerets brown, obscured by dorsal scutum. Legs I the biggest, femora enlarged, brownish with darker prolateral side, three short spines on dorsum. Tibia thickened, clearly flattened prolaterally, blackish with pale dorsal streak, ventrally black brash of dense long feather-shaped setae (Figs 130, 140), metatarsi and tarsi short, yellowish, two pairs of ventral spines on metatarsi. Other legs pale yellowish with dark marks at bases of segments, only femora IV brown (or yellow with brown streak on prolateral side). Palps light, their structure as in Fig. 142. Palpal tibia short with single thin straight apophysis, bulb oval, embolus thin, long, spirally coiled, forming three loops on bulb tip.

Female. Measurements: Cephalothorax: length 1.0–1.4, width 1.2–1.4, height 0.5–0.6. Eye field: length 0.6–0.8, anterior width 1.0–1.2, posterior width 1.2–1.3. Abdomen: length 2.1–2.3, width 1.7–1.9.

General appearance as in Figs 143–145. Similar to male, but abdomen wider, heart-shaped. Scarce white hairs on body. Carapace dark brown, black near eyes. Legs I as in males, not so thick, tibia slightly thickened, retrolateral flattening hardly visible. Palps dark, blackish. Epigyne large, rectangular, weakly sclerotised, with small semi-circle shallow depression divided by median septum (Figs 146–149). In some females horizontal crevices laterally, formed by microsculpture of integument, not part of epigyne (Fig. 146). Copulatory ducts very long, spirally coiled behind openings, form several loops distally, spermathecae bean-shaped (Figs 150–153).

Immature specimens. Abdomen not elongated, heart-shaped, with two oval dorsal scuta on abdomen, close to each other (Figs 189, 190).

Remarks. The first description of the male is given here. Simon described *P. biscutellatus* based on a female from Ivory Coast, however in his samples from Sierra Leone the two sexes were present (labelled by Simon himself). This fact has already been mentioned by Berland and Millot (1941), but they have not described the missing male. Material collected by Simon is in a very poor condition. Numerous specimens have lately been collected by fogging, this species typically inhabits canopy.

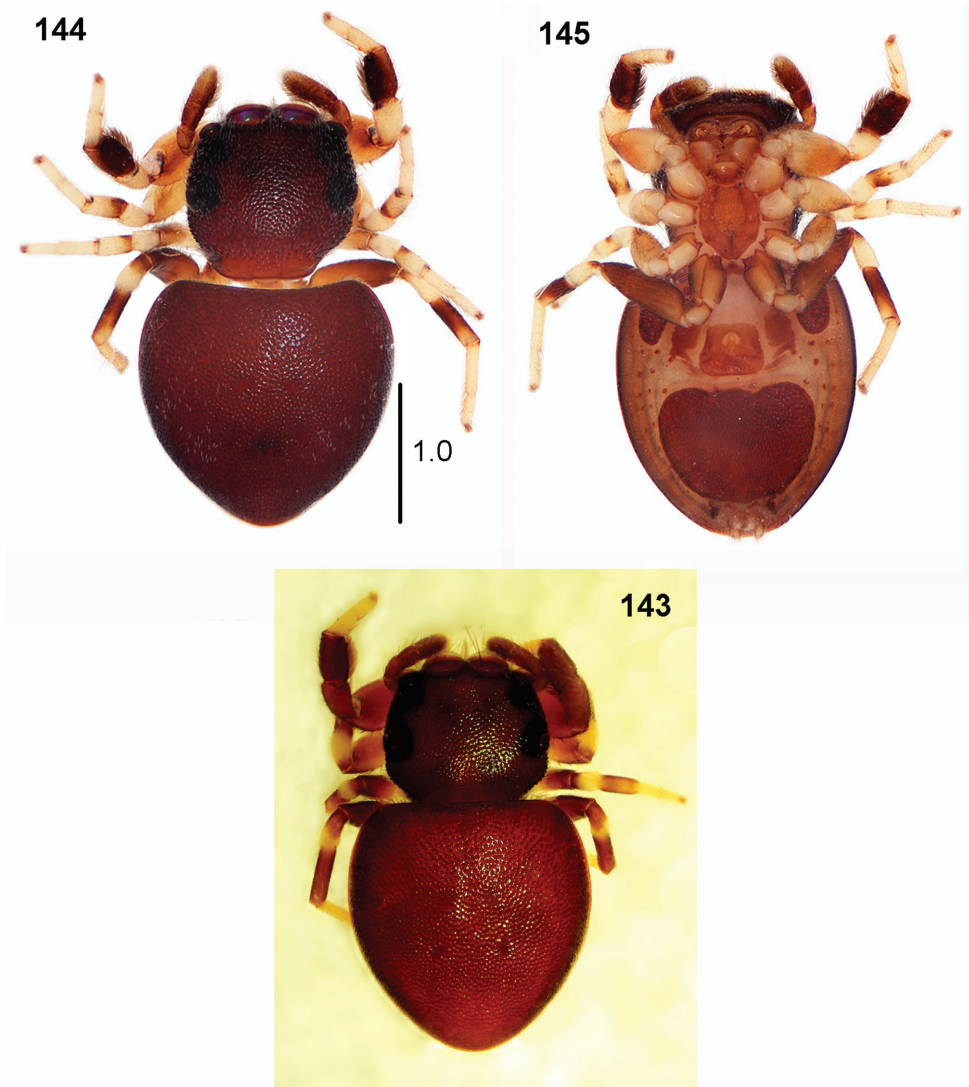
Distribution. West equatorial Africa (Fig. 197).

Peplometus chlorophthalmus Simon, 1900

Figures 131, 132, 154–171, 197

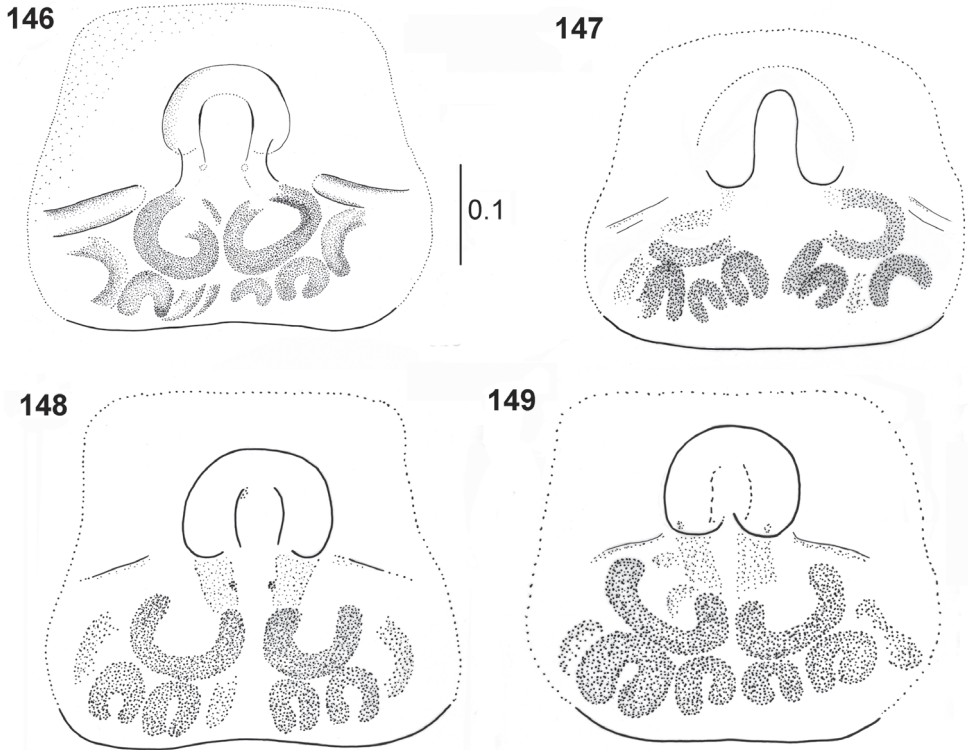
Peplometus chlorophthalmus Simon 1900: 399 (♂); 1901: 482, f. 566–569.

Holotype. SOUTH AFRICA • ♂; Natal (eastern SA); C. M[artin] [leg.]; MNHN 17 385; examined.



Figures 143–145. *Peplometes biscutellatus*, female **143, 144** habitus, dorsal view **145** habitus, ventral view (**143** specimen from Cameroon **144, 145** specimen from Ghana).

Other material examined. SOUTH AFRICA • 1♀ 5 imm.; together with the holotype. CONGO D.R. • 1♂ 1♀ 1 subad. ♂; Bas Congo, Mayombe, Luki Forest Biosphere Reserve; 5°40'S, 13°10'E; 7.XI.2006; D. De Bakker and J.P. Michiels leg.; beating; MRAC 221 505 • 1♀; the same data; 14.XI.2006; MRAC 219 997 • 1♀; the same data; 8.XI.2006; MRAC 219 944 • 2♀; the same data; 14.XI.2006 and 19.IX.2007; MRAC 226 100 • 1♂ 1♀; the same locality; 24.IX.2007; old secondary rainforest, fogging; MRAC 226 104 • 1♀; the same locality; 29.IX.2007; primary rainforest, fogging; MRAC 226 110 • 2♀; the same data; 5.XI.2006; MRAC 226 118 • 1♀; the same data; 11.XI.2006; MRAC 221 583 • 1♀; the same data; 12.XI.2006; MRAC 220 954.

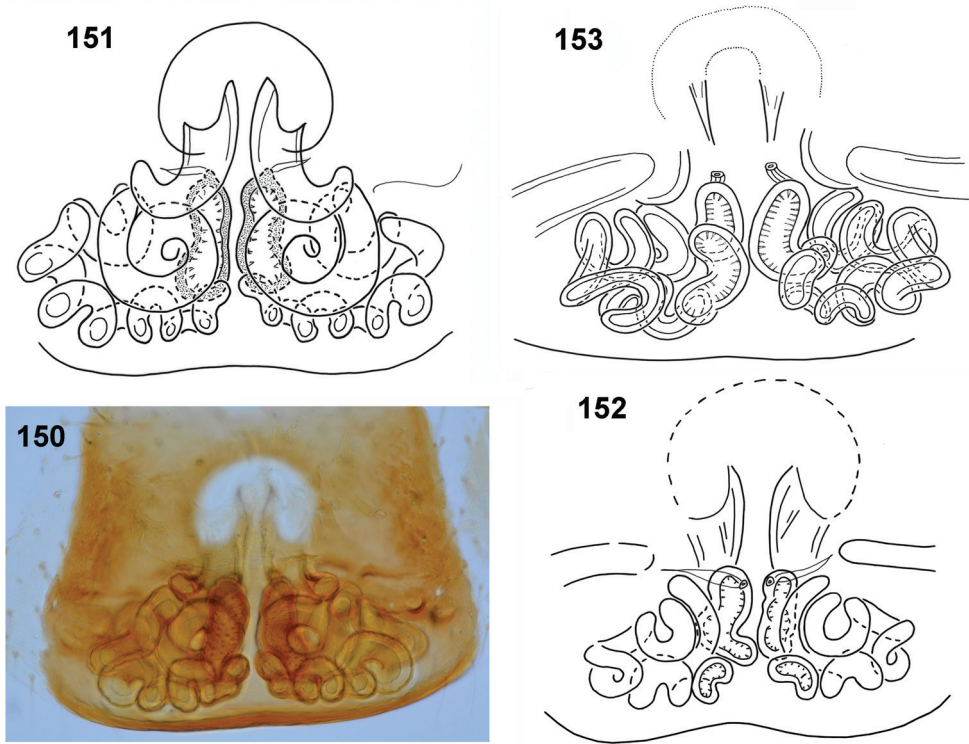


Figures 146–149. *Peplometus biscutellatus*, female, epigyne (upper row specimens from Sierra Leone, lower row specimens from Ghana).

Diagnosis. The tibia of the leg I in male is strongly flattened dorsally (Figs 131, 158). The female is difficult to distinguish from *P. biscutellatus*, but it has a narrower abdomen (see Diagnosis of the latter species).

Redescription. Male. Measurements. Cephalothorax: length 1.0–1.5, width 1.1–1.3, height 0.5–0.6. Eye field: length 0.6–0.8, anterior width 1.0–1.2, posterior width 1.2–1.3. Abdomen: length 2.2–2.3, width 1.4–1.5.

General appearance as in Figs 154–156. Small spider with flattened body. Carapace dark brown to blackish, pitted. White bristles around anterior median eyes and between all eyes of first row. Clypeus low, black, with a few white hairs. Fang of chelicerae short, two small teeth on promargin, retromarginal tooth with four tips (Fig. 160). Sternum oval, dark brown. Abdomen narrow, covered with strongly sclerotised, pitted, dark integument. Venter with typical scuta (same as by *P. biscutellatus*). Legs yellowish with dark lines along femora and tibiae III and IV on prolateral surface. Legs I the stoutest, tip of prolateral side of femur with small patch, tibia strongly thickened, black with yellow line along dorsum and large light patch on retrolateral side, long flattened black setae ventrally (Figs 157, 159). Tibia I characteristic for having a large flattened part on dorsal side (Figs 131, 158). Pedipalp light, its structure as in Figs 161–164, embolic coil wide.



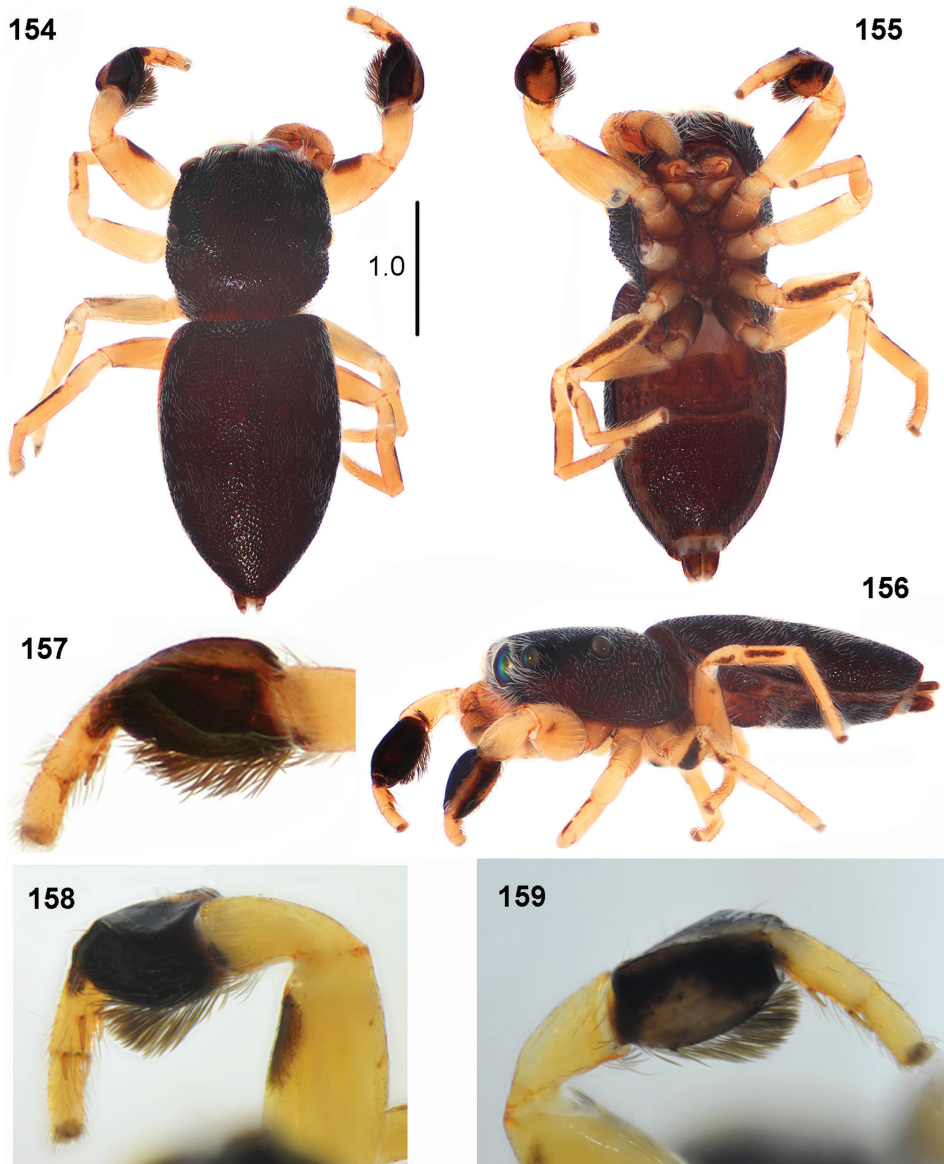
Figures 150–153. *Peplometus biscutellatus*, female, internal structure of epigyne **150, 151** ventral view **152, 153** dorsal view (**150, 151** specimen from Ghana **152** specimen from Cameroon **153** specimen from Sierra Leone).

Female. Measurements. Cephalothorax: length 1.0–1.4, width 1.1–1.3, height 0.5–0.6. Eye field: length 0.6–0.7, anterior width 1.0–1.2, posterior width 1.2–1.3. Abdomen: length 2.0–2.4, width 1.5–1.8.

Similar to male, general appearance as in Figs 166, 167. White hairs at anterior eyes and on posterior carapace slope. Abdomen wider than in male, but relatively narrow, narrower than in *P. biscutellatus*. Legs darker than in male. Femora of I–III legs brown with yellow ventral surface, femora IV completely brown. Patellae IV with pro- and retrolateral brown stripes. First leg not larger, its tibia black with black long setae ventrally, in some specimens with narrow light streak along dorsum. Tibiae II with prolateral brown stripe, tibiae IV brown with thin yellow longitudinal stripes dorsally and ventrally. Other leg segments light yellow. Palps blackish. Epigyne as in Figs 168, 169, rectangular with shallow depression. Ventral structure of epigyne similar to other species, copulatory ducts long, weakly sclerotised in initial part, forming several loops (Figs 170, 171).

Immature specimens. Abdomen not elongated, heart-shaped, with two oval scuta on dorsum, close to each other, not covering whole dorsum of abdomen (Fig. 165).

Remarks. The first description of the female is given here. Simon described only the male of *P. chlorophthalmus*, although the vial with a type specimen contains also an



Figures 154–159. *Peplometus chlorophthalmus*, male **154** habitus, dorsal view **155** habitus, ventral view **156** habitus, lateral view **157** first leg, dorsal view **158** first leg, prolateral view **159** first leg, retrolateral view (specimen from Congo).

undescribed female and a few immature specimens. This material is however in a very poor condition.

Length of the apical part of embolus varies. It is very long in South African specimen, extending beyond the retrolateral edge of apical part of cymbium (Figs 161, 162), and short in specimen from Congo D. R. (Figs 163, 164).

Distribution. Known from Congo and South Africa (Fig. 197).

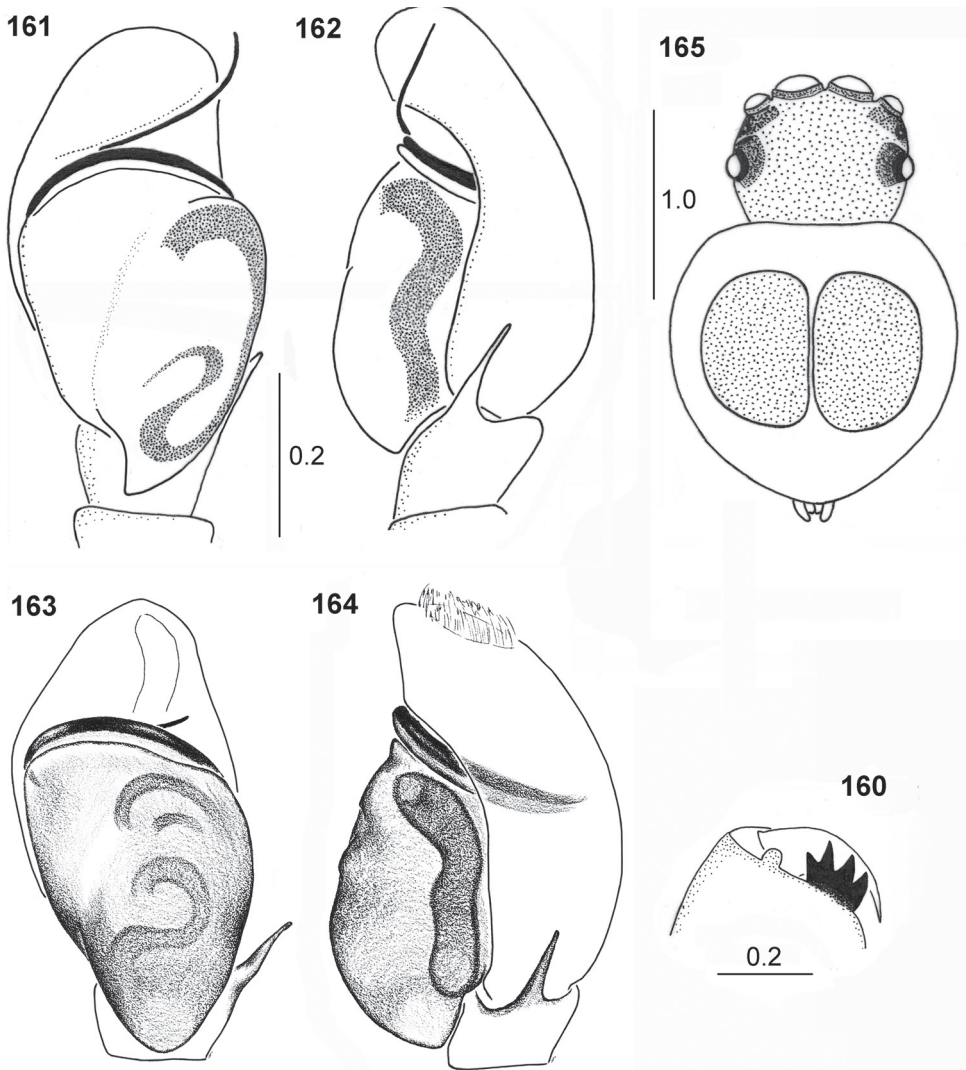
***Peplometus congoensis* sp. nov.**

<http://zoobank.org/41E2658D-9A97-49CA-923F-E8A3935F9795>

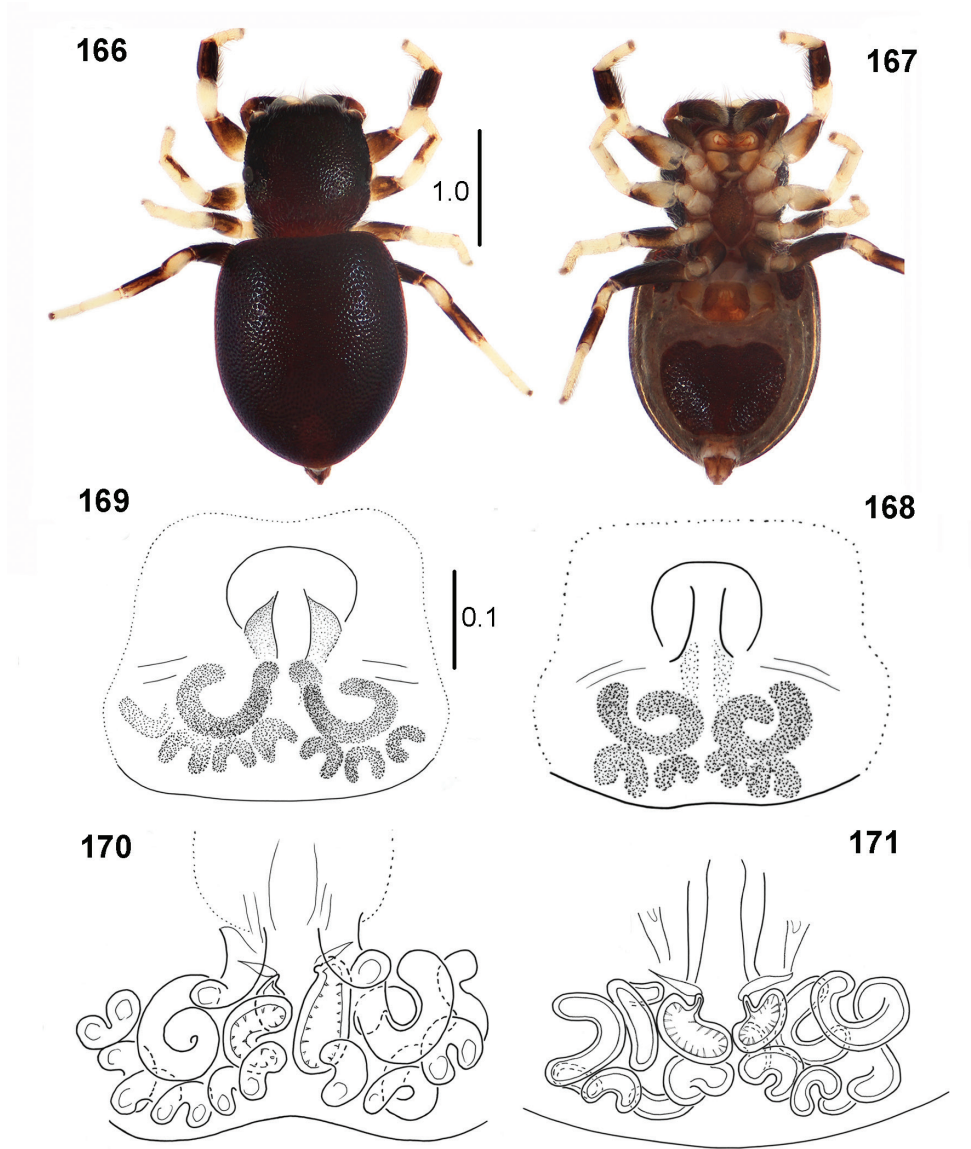
Figures 133, 172–183, 198

Holotype. CONGO • ♂; Brazzaville, ORSTOM Park; 4°16'S, 15°17'E; 19.X.1963; J. Balogh and A. Zicsi leg.; HNHM.

Paratypes. CONGO • 1♀; together with the holotype. CONGO D.R. • 1♀; Mayombe, Bas Congo, Luki Forest Reserve; 5°37'S, 13°05'E; 28.IX.2007; D. De Bakker and J.P. Michiel leg.; primary rainforest, canopy fogging; MRAC 226 108.



Figures 160–165. *Peplometus chlorophthalmus* 160 cheliceral dentition 161, 163 palpal organ, ventral view 162, 164 palpal organ, lateral view 165 immature specimen (160–162 holotype 163, 164 specimen from Congo).



Figures 166–171. *Peplometus chlorophthalmus*, female **166** habitus, dorsal view **167** habitus, ventral view **168, 169** epigyne **170** internal structure of epigyne, ventral view **171** internal structure of epigyne, dorsal view (**171** specimen from Natal, other specimens from Congo).

Diagnosis. The most characteristic feature of this species is colouration and shape of the first pair of legs. Tibia I in male is totally black, it is not flattened (Fig. 172), whereas in congeners tibia is flattened dorsally or laterally and has a light streak or patch. Tibia I of the female is light retrolaterally, with large dark patch at its basis (Figs 179, 180). The abdomen of female is narrow, similar as in male, while females of other species have abdomen wider than males.

Etymology. The species is named after its *terra typica* (Congo).

Description. Male. Measurements. Cephalothorax: length 1.7, width 1.8, height 0.6. Eye field: length 0.9, anterior width 1.3, posterior width 1.7. Abdomen: length 3.0, width 2.2.

General appearance as in Figs 172, 173. Body flattened, integument strongly sclerotised and clearly pitted. Carapace trapezoid, widest posteriorly, dark brown, black around eyes, a few bristles at eyes of first row. Chelicera with two small teeth on promargin and four-tip retromarginal tooth. Mouth parts and sternum light brown. Abdomen elongated, only slightly wider than carapace, venter also covered by scuta, posterior scutum large (Fig. 173). Legs I stout, brown, lateral side of femur slightly darker, tip of patella dark, tibia strongly thickened, black, with long dense black feather-shaped setae ventrally (Figs 133, 172). Other legs yellowish brown, with distal small dark brown patches on patellae and tibiae II–III and proximal brown rings on patellae, tibiae and metatarsi IV, femora IV brown. Palpal organ as in Figs 177, 178, apical part of embolus long.

Female. Measurements. Cephalothorax: length 1.2–1.3, width 1.1–1.3, height 0.4–0.5. Eye field: length 0.7, anterior width 1.0–1.1, posterior width 1.1–1.3. Abdomen: length 2.6–3.0, width 1.8–1.9.

General appearance as in Figs 174–176. Carapace rounded, brown to black, strongly sclerotised and clearly pitted, eye field on half of its length. Some dark bristles at eyes of first row. Chelicerae yellowish brown, with short fang, two small teeth on promargin and three-tip tooth on retromargin. Mouth parts creamy. Sternum oval, blackish. Abdomen relatively narrow, elongated, widest anteriorly, anterior edge almost straight. Dorsum of abdomen totally covered by very strongly sclerotised, pitted, black scutum, turned back on its margin. Abdomen ventrally with hard scuta; anterior scutum narrow along anterior margin of abdomen, extending backwards, posterior scutum large, trapezoid. Numerous bumps on sides of abdomen venter (Fig. 175). Spinnerets dark. Legs generally light, creamy with blackish stains. Legs I the biggest (not so markedly as in males); femora with black patch distally on prolateral side, tibia thickened, prolaterally black, basal half of retrolateral part black (Figs 179, 180). Dense long black setae on ventral side of tibia, two pairs of ventral spines. Dark line along dorsum of femora IV. Palps blackish. Epigyne large, rectangular, with small depression divided by median ridge, hardly visible horizontal crevices laterally (Fig. 181). Internal structure as in Figs 182, 183.

Distribution. Known only from Congo and DR Congo (Fig. 198).

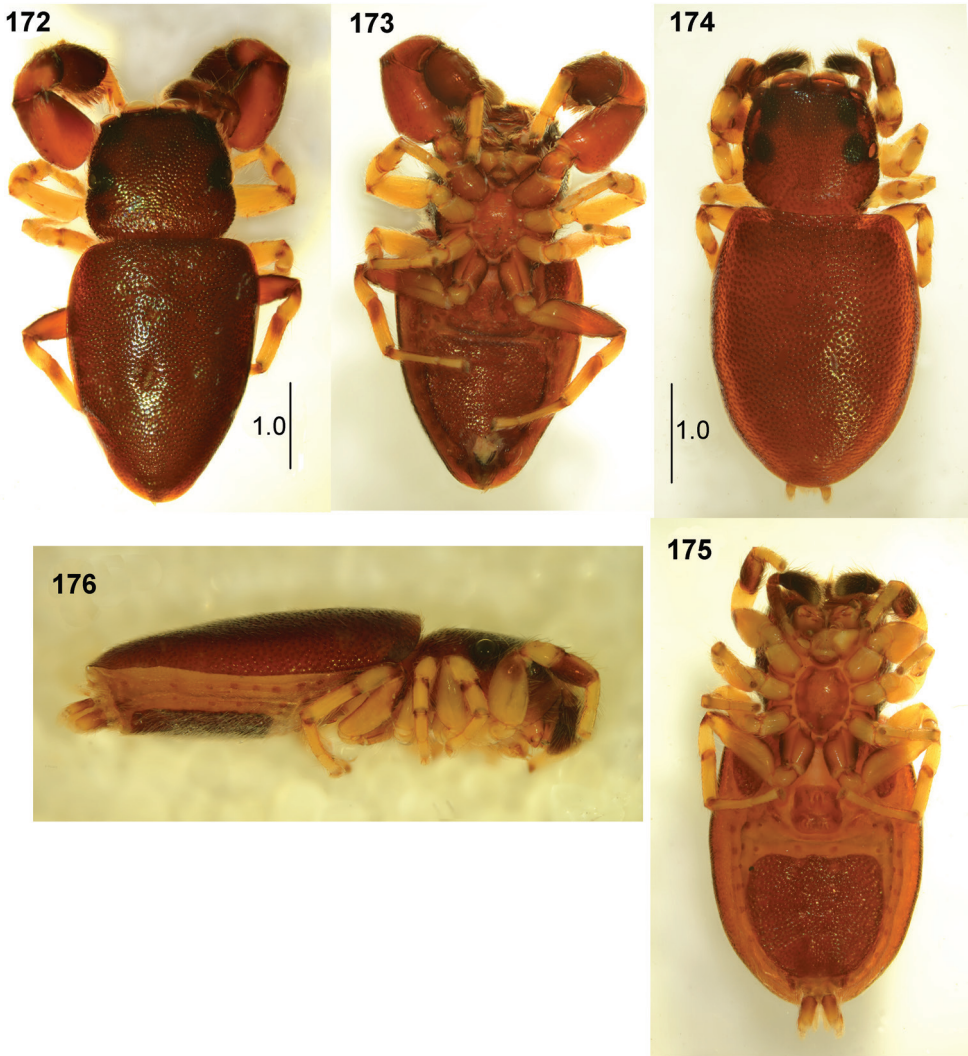
***Peplometus nimba* sp. nov.**

<http://zoobank.org/30CA27D6-8CC9-4960-B63C-9517D696F20A>

Figures 135, 184–188, 198

Holotype. GUINEA • ♂; Nimba Mts, Nion; 7°36'N, 8°28'W; 16.VI.1942; M. Lamotte leg.; BMNH.

Diagnosis. Male of this species is very similar to that of *Pachyballus oyo*, it can be distinguished by the lack of a conspicuous, sharp process on tibia I, which is very characteristic for the latter species (compare Fig. 135 with Fig. 134). In *P. nimba* metatarsus



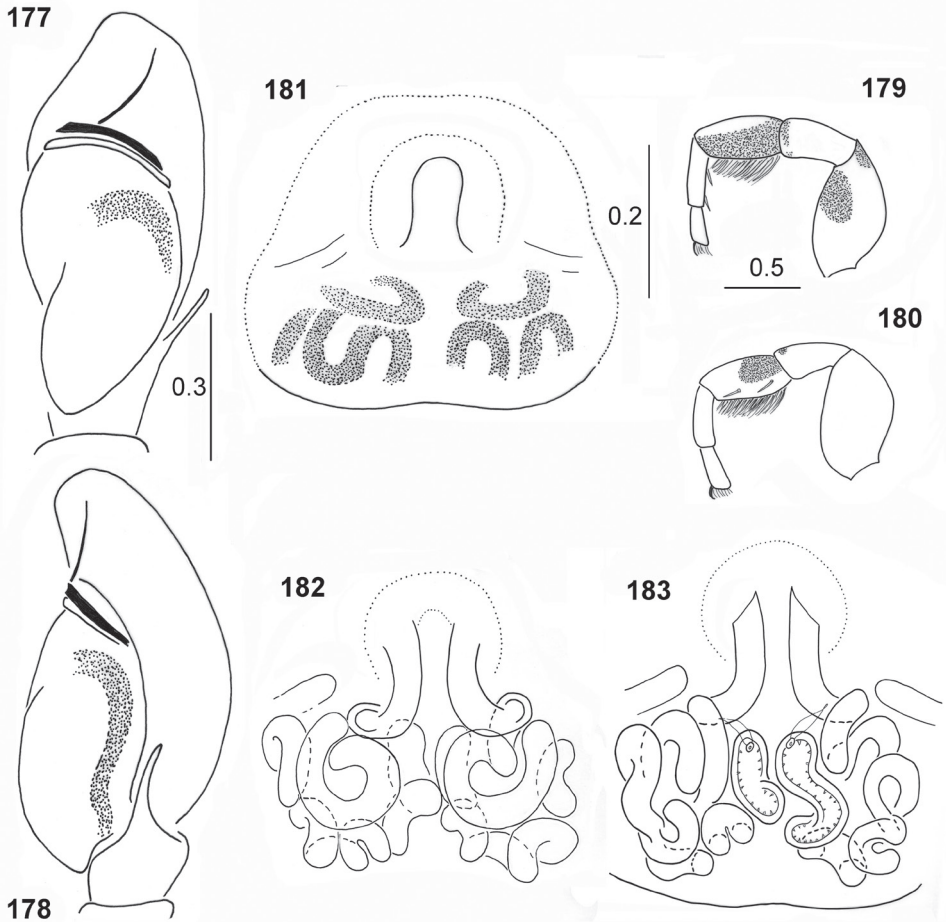
Figures 172–176. *Peplometus congoensis* sp. nov. **172** male, holotype, habitus, dorsal view **173** male, habitus, ventral view **174** female, habitus, dorsal view **175** female, habitus, ventral view **176** female, habitus, lateral view.

and tibia of leg I are of equal length, while in *P. oyo* metatarsus I is clearly shorter, about half of tibia I length.

Etymology. The specific name is a noun in apposition referring to the Nimba Mts, type locality of this species.

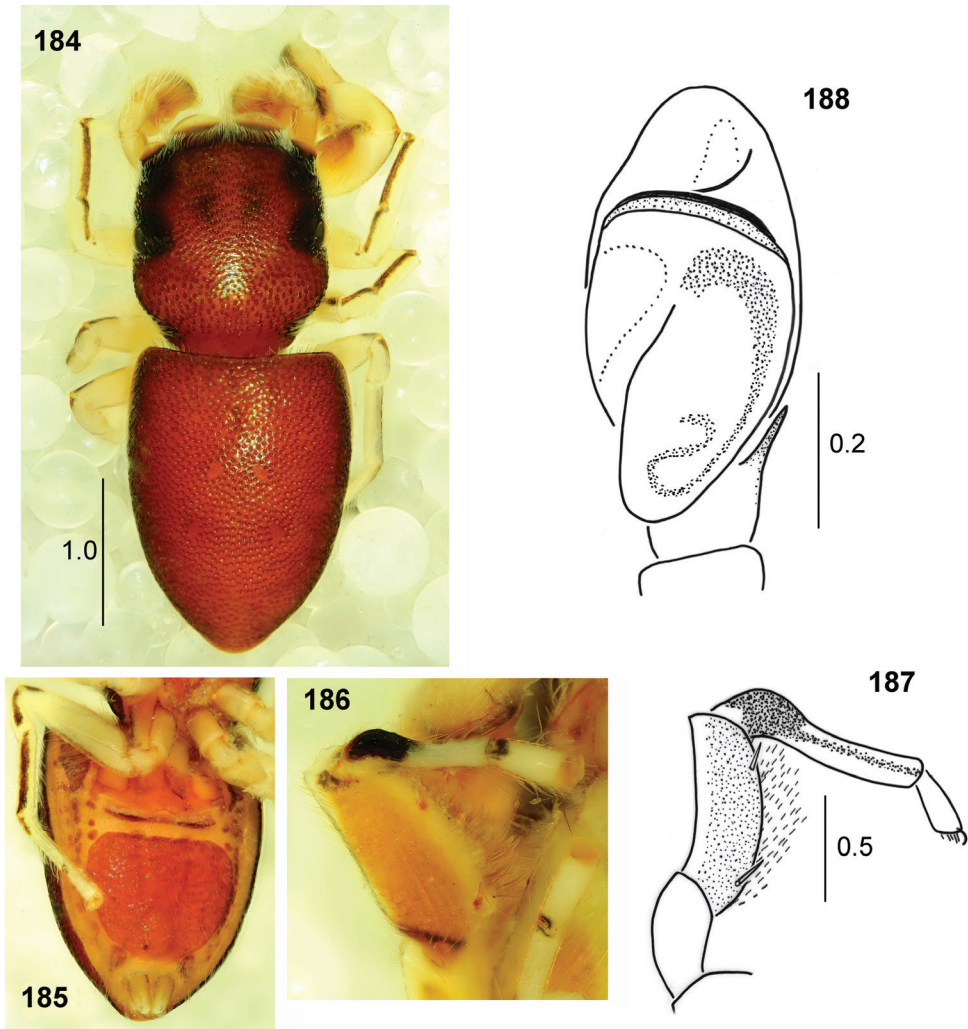
Description. Male. Measurements. Cephalothorax: length 1.4, width 1.2, height 0.5. Eye field: length 0.7, anterior width 1.1, posterior width 1.2. Abdomen: length 2.0, width 1.4.

General appearance as in Fig. 184. Body very flat, covered with strongly sclerotised integument, clearly pitted, brown with blackish area around eyes. Carapace slightly trap-



Figures 177–183. *Peplometes congoensis* sp. nov. **177** palpal organ, ventral view **178** palpal organ, lateral view **179** first leg of female, prolateral view **180** first leg of female, retrolateral view **181** epigyne **182** internal structure of epigyne, ventral view **183** internal structure of epigyne, dorsal view.

ezoid, white bristles near eyes of first row. Clypeus very low. Chelicerae with two teeth on promargin and five on retromargin (apical tooth very small), fang short. Endites, labium and sternum yellow. Abdomen elongated, shield shaped (its anterior margin almost straight), dorsum covered with large strongly sclerotised scutum. Ventrally abdomen with typical large scuta (Fig. 185), as in other species. In front of epigastric furrow clearly visible narrow wedge-shaped sclerotised swelling. Spinnerets yellow. First pair the stoutest, femora basically yellow, slightly darker on sides; patella light yellow, tibia slightly thickened, brown (prolateral surface darker), with light streak dorsally, dense long whitish (probably bleached) setae ventrally; metatarsus long, creamy with black dorsal hump and black line along prolateral side (Fig. 187). Legs II–IV yellow, with thin dark line along prolateral sides of patellae and tibiae. Legs without spines, except two short ventral spines on metatarsus I. Palps yellow, tibial apophysis very thin, bulb triangular, embolus spirally coiled on bulb tip (Fig. 188).



Figures 184–188. *Peplometus nimba* **184** male, holotype, habitus, dorsal view **185** venter of abdomen **186** first leg, retrolateral view **187** first leg, prolateral view **188** palpal organ, ventral view.

Female unknown.

Distribution. Known only from the type locality, Nimba Mts in western Africa (Fig. 198).

Peplometus oyo (Wesołowska & Russell-Smith, 2011), comb. nov.

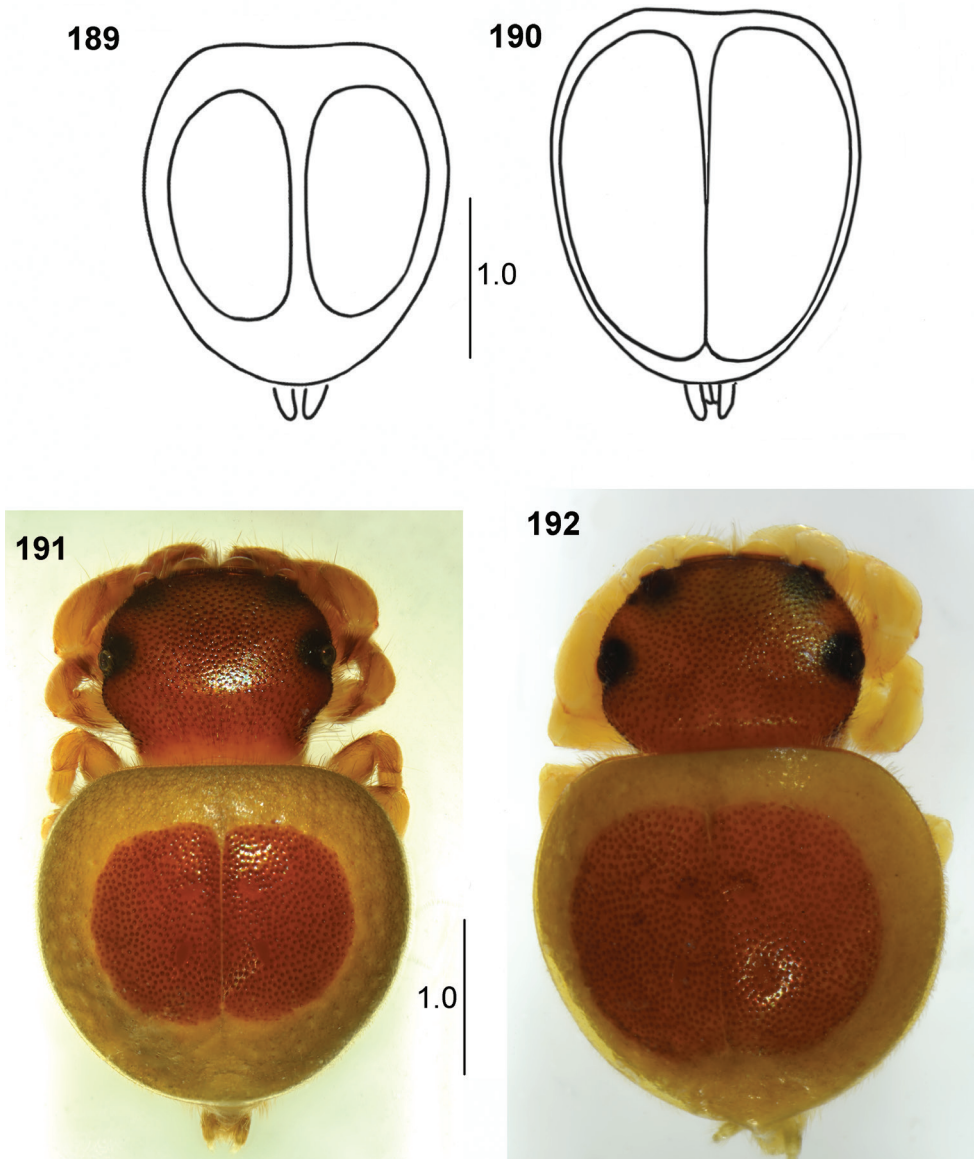
Figures 134, 198

Pachyballus oyo Wesołowska and Russell-Smith 2011: 588, f. 126–135, 232–234 (♂♀).

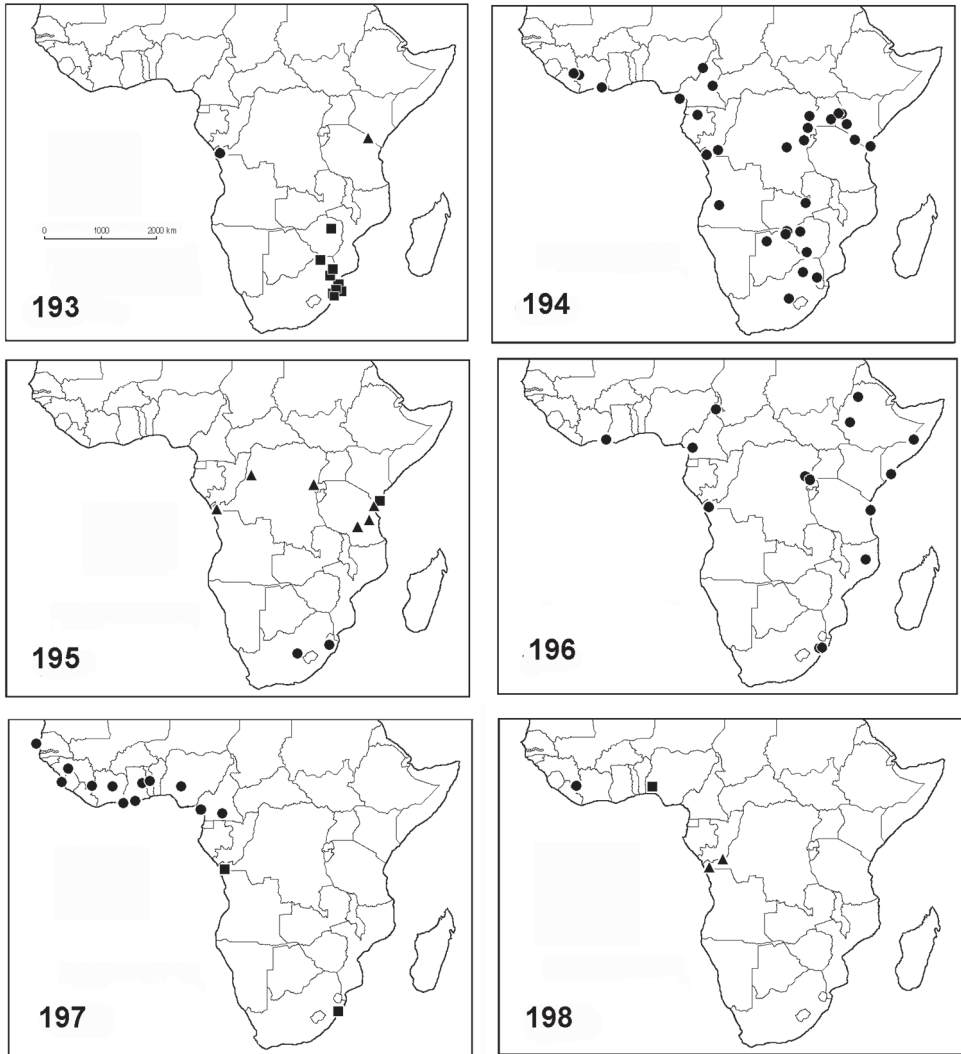
Diagnosis. The male of this species is similar to that of *Peplometus nimba*, but it can be identified by the presence of a big apical process on the first pair of legs and the metatarsus of this pair shorter than tibia (Fig. 134).

Description. For description of both sexes see: Wesółowska and Russell-Smith (2011).

Distribution. Southern Nigeria (Fig. 198).



Figures 189–192. Dorsal scuta of abdomen, immature specimens. **189, 190** *Peplometus biscutellatus* **191, 192** *Pachyballus transversus* **189, 191** younger instar **190, 192** subadult.



Figures 193–198. Distribution maps of *Pachyballus* and *Peplometus* species. **193** circle – *Pachyballus caelestis*, square – *P. castaneus*, triangle – *P. variegatus* **194** *P. flavipes* **195** circle – *P. miniscutulus*, square – *P. mombasensis*, triangle – *P. ornatus* **196** *P. transversus* **197** circle – *Peplometus biscutellatus*, square – *P. chlorophthalmus* **198** circle – *P. nimba*, square – *P. oyo*, triangle – *P. congoensis*.

Mimicry

The mimicry is a common phenomenon among spiders (Pocock 1909). Jumping spiders imitate various models, mainly ants (overview in Cushing 1997, 2012), but also pseudoscorpions (Platnick 1984), flies (Morrison 1981), wasps (Reiskind 1976, Žabka 1992), velvet wasps (Edwards 1984, Wesołowska 2009) or caterpillars (Logunov and Obenauer 2019). Some salticid genera resemble beetles (Cloudsley-

Thompson 1995) e.g. *Cylistella* Simon, 1901, *Coccorchestes* Thorell, 1881, *Planiemen* Wesolowska and van Harten, 2007. The Ballini genera *Pachyballus* Simon, 1901 and *Peplometus* Simon, 1901 also resemble beetles, most probably from the family Chrysomelidae, which is expressed in their body shape and a very strongly sclerotised integument. The microsculpture of the integument and bright or iridescent colouring emphasise this resemblance. In juveniles of all *Peplometus* species and *Pachyballus transversus* the two dorsal scuta on the abdomen are arranged in a pattern similar to elytra of beetles (Figs 165, 189–192), it is the unique feature among spiders. This type of resemblance in spiders usually suggests a Batesian type of mimicry. On the other hand, the two presented genera live in the canopy and their body type (small, flattened, colours often matching their preferred habitats) may suggest that it is a type of camouflage. The resemblance to other tree-living arthropods could be just a result of a shared cryptic body pattern.

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***Trioxys liui* Chou & Chou, 1993 (Hymenoptera, Braconidae, Aphidiinae): an invasive aphid parasitoid attacking invasive *Takecallis* species (Hemiptera, Aphididae) in the Iberian Peninsula**

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Abstract

Biological invasion of aphids and other insects has been increased due to long distance commercial transportation of plant material. The bamboo-aphid-parasitoid association is strictly specific and even though it does not develop interactions with the local environment it should be listed as part of the fauna of southwestern Europe. On-going research regarding aphids and their aphidiine parasitoids in Spain has yielded a new association of *Trioxys liui* Chou & Chou, 1993 with an undescribed species of *Takecallis* aphids on bamboo, *Phyllostachys* spp. Here we present the first association of *T. liui* with aphids of the genus *Takecallis* that attack bamboos. *Trioxys liui* is known as a parasitoid of *Cranaphis formosana* (Takahashi, 1924) and *Phyllaphoides bambusicola* Takahashi, 1921 on bamboos in China and Russia. The accidental introduction of this parasitoid species to southwestern Europe has been probably realized through transportation of contaminated bamboo plant material. In the current study, a new host association is recorded for *T. liui*. Its potential to invade other bamboo-associated aphids and the significance of the tritrophic bamboo-aphid-parasitoid interactions in the new environments are also discussed.

Keywords

Bamboo, invasive species, new association, parasitoid

Introduction

Bamboo is a common name that encompasses at least 1250 species and 75 plant genera (Scurlock et al. 2000) within the family Poaceae (subfamily Bambusoideae). Although bamboos are distributed mostly in the tropics, they also naturally occur in the subtropical and temperate zones of all continents except Europe (Ohrnberger 2002). China (Qiu et al. 1992) and India (Shanmughavel and Francis 1996) are regions where the highest number of bamboo species are growing, mainly as natural stands. On the other hand, species of the genera *Phyllostachys* and *Pleioblastus* are ornamental plants that have been introduced into Europe for commercial purposes (Schilberszky 1911). Furthermore, there is an increasing interest in the use of bamboos as energy plants (Scurlock et al. 2000; Wright 2006; Potters et al. 2009) and for other industrial applications (van der Lugt et al. 2006; Lipp-Symonowicz et al. 2011). The well known group of aphids that belongs to genus *Takecallis* Mastumura is associated with bamboos. These aphids have been considered as invasive organisms in different parts of the world where bamboos are purposefully or accidentally introduced (Stroyan 1964; Cofelt and Schultz 1990; Limonta 1990; Lazzari et al. 1999; Trejo-Loyo et al. 2004; Valenzuela et al. 2010). Three invasive *Takecallis* species, i.e., *Takecallis arundinariae* (Esisig, 1917), *Takecallis taiwanus* (Takahashi, 1926) and *Takecallis arundicolens* (Clarke, 1903) (Calaphidinae, Panaphidini) have already been recorded in several European countries (see Rakhshani et al. 2017). It should be noted that the three aforementioned aphid species occur in Spain (Nieto Nafría and Mier Durante 1998; Suay-Cano and González-Funes 1998; Pons and Lumbierres 2004).

A new parasitoid species, *Trioxys remaudierei* Starý & Rakhshani, 2017 (Hymenoptera, Braconidae, Aphidiinae), has been recently described and associated with two bamboo aphids, *T. arundinariae* and *T. taiwanus* in France and Spain (Rakhshani et al. 2017). This evidence led to an exhaustive investigation for parasitoids of bamboo aphids in southwestern Europe that resulted in detection of a *Trioxys* species emerging from *Takecallis* aphids, which infest bamboo groves in Spain. Surprisingly, this parasitoid species was not conspecific with *T. remaudierei*. Here we determine and illustrate a new aphid parasitoid association from bamboos in Spain. An annotated world-review of *Takecallis* aphids attacking bamboos is also provided.

Material and methods

Research on bamboo aphids was carried out in the east and northeast of the Iberian Peninsula: Valencia, Barcelona and Lleida (Fig. 1). In Valencia, samples were collected



Figure 1. General scheme of the sampling localities in the Iberian Peninsula **A** patch of *Phyllostachys aurea* in the Arboretum of Lleida **B** street garden with rows of bamboo (*Phyllostachys* sp.) in Barcelona.

from the Botanical Garden of the University of Valencia during spring 2017 (March to June). All species of bamboos that are growing in the Botanical Garden were sampled: *Bambusa ventricosa*, *Dendrocalamus giganteus*, *Phyllostachys nigra*, *Phyllostachys viridis*, *Phyllostachys aurea*, *Pleioblastus linearis*, *Pleioblastus pumilus*, *Pleioblastus pygmaeus* and *Shibataea kumasasa*. The aphid colonies were inspected in the field and the laboratory so as to be checked for any occurrence of parasitoids. At the beginning of April (10.iv.2017), several mummies of *Takecallis* spp. were recorded on mixed colonies of the three species of *Takecallis* present in the Iberian Peninsula (*T. arundicolens*, *T. arundinariae* and *T. taiwanus*). Samples from Barcelona originated from two locations: 1) a street garden (41°24'24.15"N, 2°11'49.78"E, 5 m a.s.l.), where a 100 m × 2 m row of bamboo (*Phyllostachys* nr. *aurea*) are planted; 2) the gardens of the Royal Palace of Pedralbes, where different irregular size patches of bamboo (mainly *Phyllostachys* nr. *aurea*), of a whole area of about 300 m² are planted (41°23'16.05"N, 2°07'03.53"E, 99 m a.s.l.). Both locations are separated by a 7 km straight line. Visual inspection determined the presence of some common aphid species on bamboo (*Melanaphis bambusae* (Fullaway, 1910) (Aphidinae, Aphidini); *T. taiwanus* and *T. arundinariae*), but the plants from the first location were mostly infested by *Takecallis* species. Mummies and live aphids within isolated or mixed colonies of *T. taiwanus* and *T. arundinariae* were collected in May and June 2018. In Lleida, samples from *Indocalamus tessellatus* and *P. aurea* were collected from the Arboretum and Botanical Garden Pius Font i Quer (41°37'29.96"N, 0°36'11.70"E, 182 m a.s.l.). *Phyllostachys aurea* was the dominant bamboo species there, occupying most of the bamboo plantation area (700 m²), but there were also small patches of other bamboos species such as *Phyllostachys aureosulcata*, *P. nigra*, *Pleioblastus fortunei*, *Pseudosasa usawae*, *S. kumasasa*, *I. tessellatus* and *Fargesia scabrida*. Aphids from the genus *Takecallis* were found on *P. aurea* and *I. tessellatus*.

Aphid colonies, containing both alive individuals and mummies, were sampled with small pieces of bamboo plants that were gently cut with scissors. Samples were transferred to the laboratory, where they were maintained at room temperature. Some adult aphids were preserved in a solution containing two parts of 90% ethanol to one

part of 75% lactic acid (Eastop and van Emden 1972) for identification. Then, they were compared with the keyed material according to Nieto Nafria and Mier Durante (1998) and Blackman and Eastop (2019). Aphid nomenclature and classification follows Favret (2019). The emerged parasitoids were captured with an aspirator and directly dropped into 70% ethanol. The external morphology of parasitoids was studied using a Nikon Eclips E200 stereomicroscope (Nikon Corp., Japan). The parasitoid specimens were identified according to Chen and Shi (2001) and Davidian (2005). Illustrations were traced on the digital photographs captured from the slides with a Canon EOS 700D (Canon Inc., Japan) in Adobe Illustrator CS5 and were processed in Photoshop CS5 (Adobe systems Inc., San Jose, USA).

A series of voucher specimens of the emerged aphid parasitoids was sorted and preserved in absolute ethanol, kept in a refrigerator for DNA extraction. Total DNA was extracted separately from two individuals (a male and a female) following the HotSHOT method (Truett et al. 2000) using 60 µl of both alkaline lysis and neutralizing reagents. A 710 bp fragment of the 5' region of the mitochondrial gene coding the cytochrome c oxidase subunit 1 (COI) was sequenced, using the primer pair LCO1490 and HCO2198 as described by Folmer et al. (1994). PCR and sequencing procedures are outlined in Pérez Hidalgo et al. (2012). After removing sequences corresponding to primers used in the PCR reaction, the sequences obtained from each sample consisted of 658 nucleotides. DNA sequences of both male (a) and female (b) parasitoids were deposited in the GenBank database under the accession numbers MT324250 and MT324249, respectively. The existing mtCOI sequences in NCBI for *Trioxys* and *Binodoxys* spp. were retrieved and aligned in MEGA X (Kumar et al. 2018) with the integrated ClustalW using default parameters. The evolutionary history was inferred using the Neighbor-Joining method (Saitou and Nei 1987) with pairwise deletion of missing sites and Kimura-2-Parameter (K2P) distances (Kimura 1980). The optimal tree with the sum of branch length = 1.48087269 is shown. The percentage of replicate trees in which the associated taxa clustered together in the bootstrap test (1000 replicates) are shown next to the branches. *Ephedrus persicae* Froggatt, 1904 (Hymenoptera, Braconidae, Aphidiinae – KY213710.1) and *Praon volucre* (Haliday, 1833) (Hymenoptera, Braconidae, Aphidiinae – KJ698515.1) were used as outgroups for the molecular analysis. The tree is drawn to scale, with branch lengths in the same units as those of the evolutionary distances used to infer the phylogenetic tree. The analysis involved 34 nucleotide sequences. Codon positions included were 1st+2nd+3rd+Noncoding. All ambiguous positions were removed for each sequence pair (pairwise deletion option). There were a total of 519 positions in the final dataset.

The material is deposited in the Entomology Collection of the University of Valencia of the Cavanilles Institute of Biodiversity and Evolutionary Biology, in the Laboratory of Entomology of the Department of Crop and Forest Sciences of the University of Lleida, in the collection of P. Stary (Academy of Sciences of the Czech Republic), in the Laboratory of Agricultural Zoology and Entomology of the Agricultural University of Athens and in the collection of Department of Plant Protection, University of Zabol.

Results

Four aphid species are present in the Botanical Garden of the University of Valencia living in mixed colonies only on *P. viridis*, *P. aurea*, and *P. linearis*. Three of them, which are not attended by ants, belong to the genus *Takecallis* (*T. arundicolens*, *T. arundinariae*, *Takecallis* sp. (probably a new species)). However, the fourth of these species, *M. bambusae*, was strongly attended by the ant *Lasius grandis* Forel, 1909 (Hymenoptera, Formicidae). Out of all parasitoid individuals emerged from 20 mummies of *Takecallis* sp. collected from Valencia we obtained six males and six females of an aphidiine whose morphological characters clearly matched those of *T. liui*. Samples collected from Barcelona and Lleida led to the emergence of additional 11 female and 13 male specimens of *Trioxys liui* Chou & Chou (Hymenoptera, Braconidae, Aphidiinae) originating from *T. taiwanus* and *T. arundinariae* which are reported below. Although *T. liui* has been originally figured (Chou and Chou 1993) and later keyed by Chen and Shi (2001) and Davidian (2005, 2007), additional illustrations (Figs 2, 3) are provided to increase the taxonomical evidence for comparison with other parasitoid species of bamboo aphids.

Trioxys liui Chou & Chou, 1993

Figures 2, 3

Material examined. 6♀ 6♂, SPAIN: Valencia, Botanical Garden, 39°28'36.6"N, 0°23'09.1"W, 17 m a.s.l., collected from 15.iv.2018 to 6.vi.2018, ex *Takecallis* sp. on *Phyllostachys aurea*, J.M. Michelena leg.; 2♀, Barcelona, public garden, 41°24'24.25"N, 2°11'49.78"E, 2 m a.s.l., 06.v.2018, ex *Takecallis taiwana* (Takahashi) on *Phyllostachys* sp., X. Pons leg. [Sample B-1052]; 2♀ 4♂, Barcelona, public garden, 41°24'24.15"N, 2°11'49.78"E, 2 m a.s.l., 18.v.2018, ex *Takecallis taiwana* (Takahashi) on *Phyllostachys* sp., X. Pons leg. [Sample B-1054]; 2♀ 4♂, same collecting data as for preceding, 06.vi.2018, ex *Takecallis arundinariae* (Essig) on *Phyllostachys* sp., X. Pons leg. [Sample B-1064]; 3♀, same collecting data as for preceding, ex *Takecallis taiwana* (Takahashi) on *Phyllostachys* sp., X. Pons leg. [Sample B-1065]; 2♀ 1♂, same collecting data as for preceding, captured on *Phyllostachys* sp., X. Pons leg. [Samples B-1064 + B-1065]; 1♂, Barcelona, public park, 41°23'16.05"N, 2°07'03.53"E, 71 m a.s.l., 15.vi.2018, captured on *Phyllostachys* sp., X. Pons leg. [Sample B-1070]; 1♂, Lleida Arboretum, 41°37'29.96"N, 0°36'11.70"E, 181 m a.s.l., 24.v.2018, captured on *Indocalamus tessellatus*, X. Pons leg. [Sample L-1059].

Morphological diagnosis. Female – Body length: 1.4–1.6 mm, forewing length 1.5–1.6 mm. **Chypeus** (Fig. 2A) narrow with 6 long setae on dorsal surface. Maxillary palp with 4 palpomeres, labial palp with 2 palpomeres (Fig. 2B). **Antenna** (Fig. 2C) filiform, with 11 antennomeres, covered mainly with semierect setae, slightly shorter than the diameter of segments. Flagellomere 1 (F1) 1.15–1.22× as long as F2 and 3.60–3.75× as long as maximally wide. F1 and F2 with 1–2 and 1–3 longitudinal

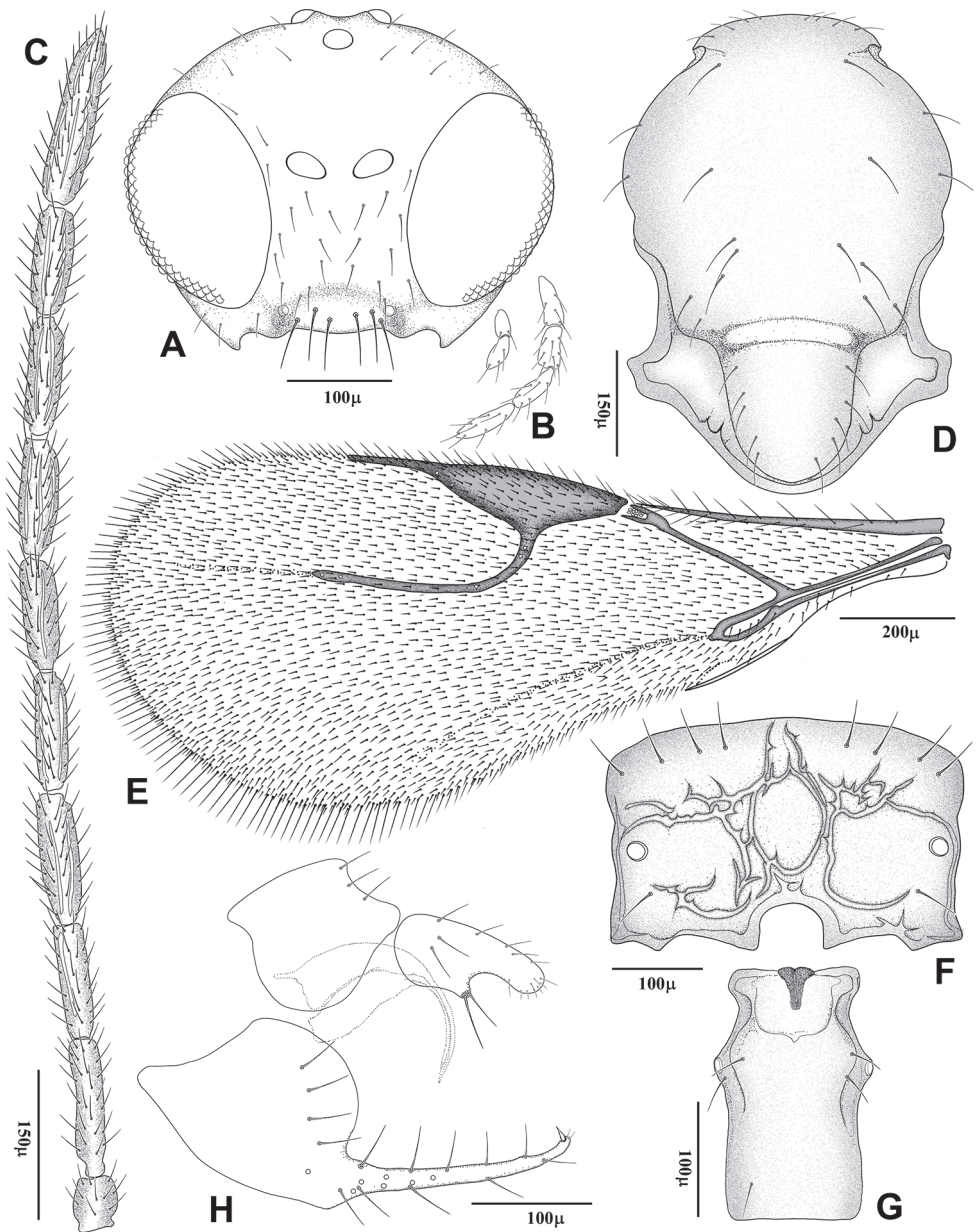


Figure 2. *Trioxys liui* – female **A** head, frontal view **B** maxillary and labial palps **C** antenna **D** mesonotum and scutellum, dorsal view **E** forewing **F** propodeum **G** petiole, dorsal view **H** genitalia, lateral aspect.

placodes, respectively. **Mesonotum** (Fig. 2D) smooth with notaulices hardly visible at anterior part, sparsely setose. **Forewing** (Fig. 2E) stigma elongate, triangular with slightly convex outline, $2.90\text{--}3.10\times$ as long as wide and $3.00\text{--}3.20\times$ as long as R1. Vein r&RS extended beyond R1. Wing margin with very long fringes. **Propodeum** (Fig. 2F) with well developed carinae, irregularly branched at anterior and lateral parts. Central



Figure 3. *Trioxys liui* – general habitus **A** female **B** male.

areola partially divided by irregular internal carinae. Upper and lower parts of propodeum with 8 and 2 long erected setae, respectively. **Petiole** (Fig. 2G) short, 1.55–1.80× as long as wide at spiracles with a pair of long setae near each prominent spiracular tubercle and a single seta at postero-dorsal area. **Ovipositor sheath** (Fig. 2H) stout, with smooth dorsal outline, deeply concaved ventrally in anterior edge, sharply expanded into a ventral projection bearing a pair of long setae. Prongs distinctly separated at base, almost stright, progressively constricted and upcurved at apex. Ventral side of prongs bear 4–5 prependicular setae, with single claw-shape seta and pair of short setae at apex.

Color (Fig. 3A). Head and mesosoma dark brown to black, gaster brown. Antenna brown, mouth parts, pedicel, F1, legs and petiole yellowish brown. Wings infumated. Apex of ovipositor sheath dark brown.

Male (Fig. 3B) – Antennae with 13 antennomeres, body length 1.4–1.5 mm.

Molecular data. The DNA sequences of the mtCOI gene were obtained from a single specimen of both male and female of *T. liui*, with no intraspecific genetic distance (0.0%). The interspecific genetic distances of mtCOI within *Trioxys* species ranged from 10.9% to 14.7%. The uncorrected pairwise genetic distances (p-distance) of mtCOI, separated *T. liui* from all other *Trioxys* species, with at least 10% of the sequence divergence (Table 1). After the reconstruction of the Neighbor-Joining tree, *T. liui* stands basal to the branch that includes *Trioxys pallidus* (Haliday, 1833) and *Trioxys complanatus* Quilis, 1931 (Fig. 4). No further analysis was possible because almost all deposited sequences originated from specimens that were identified only at generic level.

Discussion

Trioxys liui is an aphidiine parasitoid of two bamboo aphids in China: *Cranaphis formosana* (Takahashi, 1924) (Liu 1975) and *Phyllaphoides bambusicola* Takahashi, 1921 (Calaphidinae, Panaphidini) on *Phyllostachys makinoi* (Chou and Chou 1993). So far, *T. arundinariae* in Spain and *T. taiwanus* in France, both attacking *Phyllostachys* spp.,

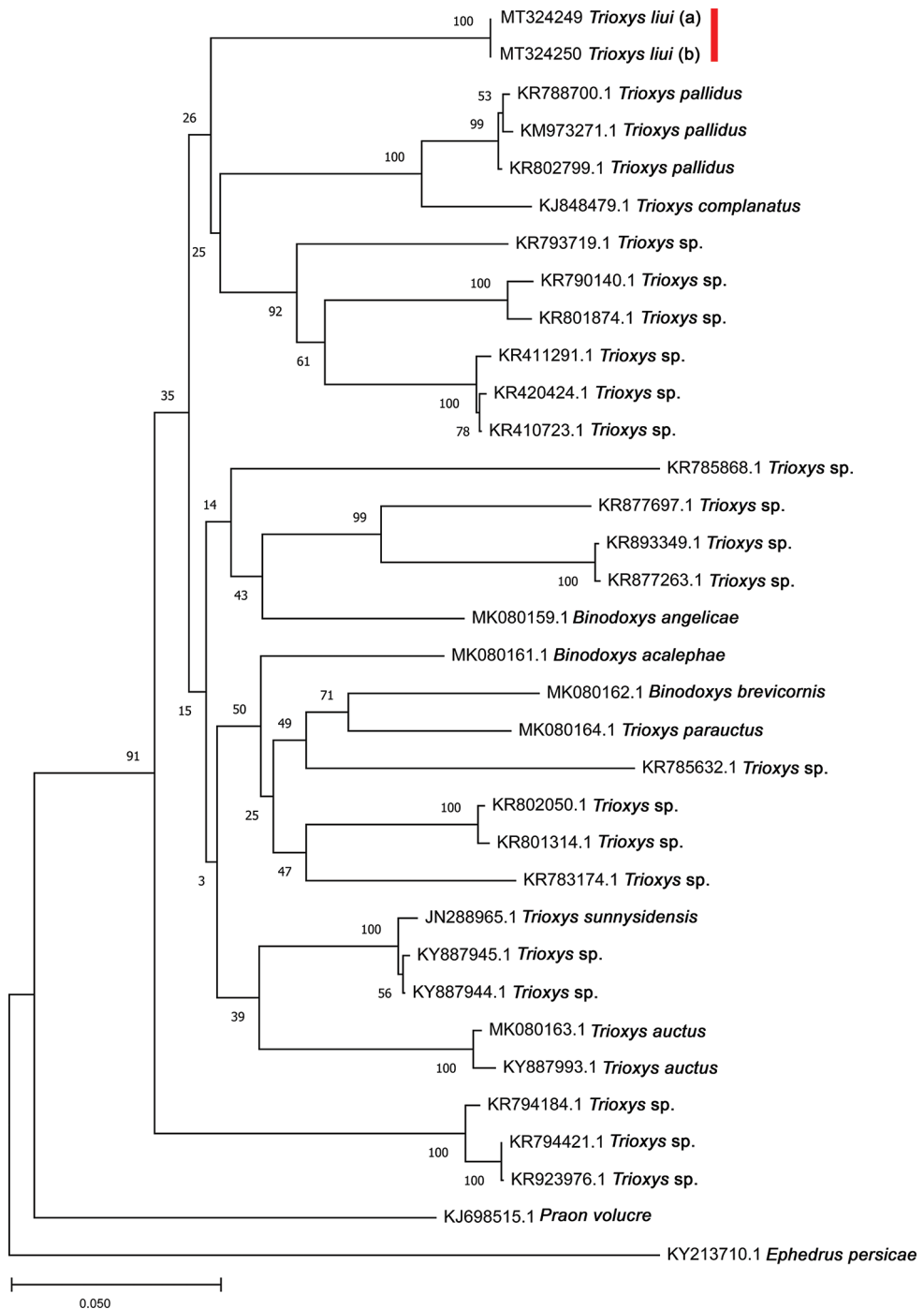


Figure 4. Neighbor-Joining tree based on the partial mtCOI sequences from *Trioxys* and *Binodoxys* spp., including *Trioxys liui*, with *Praon volucre* and *Ephedrus persicae* as outgroups (NCBI accession no). Numbers next to nodes are the bootstrap values.

Table 1. Uncorrected pairwise genetic distances between *Trioxys liui* and other *Trioxys*/*Binodoxys* species based on mtCOI sequences resulted from MEGA X.

Species	Accession No.	1	2	3	4	5	6	7	8	9	10
1 <i>T. liui</i>	MT324249										
2 <i>T. pallidus</i>	KM973271.1	0.139									
3 <i>T. complanatus</i>	KJ848479.1	0.147	0.052								
4 <i>Trioxys</i> sp.	KR411291.1	0.112	0.137	0.134							
5 <i>Trioxys</i> sp.	KR420424.1	0.109	0.134	0.134	0.005						
6 <i>T. auctus</i>	KY887993.1	0.133	0.145	0.136	0.141	0.138					
7 <i>T. parauctus</i>	MK080164.1	0.163	0.128	0.153	0.136	0.136	0.125				
8 <i>T. sunnysidensis</i>	JN288965.1	0.125	0.137	0.136	0.128	0.128	0.083	0.086			
9 <i>B. brevicornis</i>	MK080162.1	0.144	0.153	0.158	0.133	0.133	0.135	0.133	0.122		
10 <i>B. aculephae</i>	MK080161.1	0.122	0.128	0.128	0.131	0.128	0.104	0.104	0.101	0.101	
11 <i>B. angelicae</i>	MK080159.1	0.128	0.143	0.151	0.137	0.134	0.127	0.130	0.081	0.112	0.109

have been reported as the only hosts of the newly described aphidiine parasitoid, *T. remaudierei* in Western Europe (Rakhshani et al. 2017). Our findings add *T. liui* as a new member of the parasitoid fauna of Spain that parasitizes even a new species of *Takecallis* (Valencia). This evidence contributes both to the increase in the number of exotic parasitoid species on bamboo aphids and the potential of interspecific relations of parasitoids. The new association, *T. liui*/*Takecallis* spp. (Valencia, Barcelona and Lleida) is also a new assemblage apart from *T. remaudierei*/*Takecallis* spp. (Paris-France and Lleida-Spain). Therefore, our results clearly document the invasion and/or subsequent adaptation of the southeastern Asian endemic species into Western Europe. The lack of information on *T. liui*, with the exception of the knowledge about its original region, China, has indicated a direct interaction of southeastern Asia with Spain through bamboo plant material, that accidentally included aphid and parasitoid contamination. Furthermore, secondary exchanges of shipments between the gardeners are also considered possible. However, similar evidence from insects in other areas has not been documented yet. It is noteworthy to emphasize the obvious morphological differences between the two parasitoids of *Takecallis* in Europe, which might reveal new bamboo-aphid-parasitoid associations. *Trioxys remaudierei* has long ventral prongs fused over two-thirds of their length. However, prongs of *T. liui* are short and completely separated. Among European species, *Trioxys betulae* Marshall, 1896 has also partially fused prongs. However, this parasitoid has a different host range since it includes aphid species that do not belong to genus *Takecallis* (Rakhshani et al. 2017). Despite the complexity of the taxonomy of the genus *Trioxys*, little attention has been devoted to using molecular data for identification and resolving questions on their classification (mainly unpublished). None of these efforts include the parasitoids of *Takecallis* aphids.

Generally, bamboos grow and spread fast (Cao et al. 2011), a trait that can crowd out native plant species. The allelopathic secretions of various bamboo species can also prohibit the growth of the nearby plant species (Chou and Yang 1982; Chou 1999; Rawat et al. 2017). However, ornamental bamboos should be protected against invasive herbivorous insects that could be distributed along with their host plant material in botanical gardens in Europe. With few exceptions (Potenza 2005), there is no record

Table 2. *Takecallis* species associated with various bamboos and their distribution.

Aphid species	Distribution	Host plant	References
<i>Takecallis affinis</i> Ghosh, 1986	India	<i>Bambusa</i> sp. <i>Chimonobambusa jaunsarensis</i>	Ghosh 1986
<i>Takecallis alba</i> Lee, 2018	South Korea	<i>Pseudosasa</i> sp. <i>Sasa</i> spp.	Lee and Lee 2018
<i>Takecallis arundicola</i> (Clarke, 1903)	China, Eastern Russia, Europe (Spain, France, Netherlands, Serbia), Japan, Korea, North America, Taiwan	<i>Arundinaria japonica</i> <i>Bambusa</i> sp. <i>Phyllostachys</i> sp. <i>Pleioblastus chino</i> <i>Pseudosasa japonica</i> <i>Sasa nipponica</i> <i>Sasa palmate</i> <i>Sasa paniculata</i> <i>Sasa senanensis</i> <i>Sasaella ramosa</i>	Leclant 1966; Higuchi 1972; Lampel and Meier 2003; Qiao and Zhang 2004; Pons and Lumbierres 2004; Blackman and Eastop 2019; Piron 2009; Lee and Lee 2018; Petrović-Obradović et al. 2018
<i>Takecallis arundinariae</i> (Essig, 1917)	Australia, Central America (Mexico), China, Eastern Russia, Europe (Greece, Hungary, Italy, Netherlands, Portugal, Spain, Switzerland, United Kingdom), India, Japan, Korea, North America, South America (Brazil), Taiwan	<i>Arundinaria graminea</i> <i>Arundinaria japonica</i> <i>Bambusa bambos</i> <i>Bambusa rigida</i> <i>Bambusa stenostach</i> <i>Bambusa textilis</i> <i>Dendrocalamus asper</i> <i>Phyllostachys aurea</i> <i>Phyllostachys bambusoides</i> <i>Phyllostachys castillonis</i> <i>Phyllostachys dulcis</i> <i>Phyllostachys edulis</i> <i>Phyllostachys iridescens</i> <i>Phyllostachys mannii</i> <i>Phyllostachys puberula</i> <i>Phyllostachys viridiglaucescens</i> <i>Pseudosasa japonica</i> <i>Sasa nipponica</i> <i>Sasa palmate</i> <i>Sasa senanensis</i> <i>Sinoarundinaria niitakayamensis</i> <i>Sinobambusa tootsik</i>	Higuchi 1968; Higuchi 1972; Raychaudhuri 1973; Ghosh 1980; Ghosh and Quednau 1990; Coffelt and Schultz 1990; Giacalone and Lampel 1996; Aguiar and Ilharco 1997; Nieto Nafria and Mier Durante 1998; Suay-Cano and González-Funes 1998; Lazzari et al. 1999; Qiao and Zhang 2004 Trejo-Loyo et al. 2004; Pons and Lumbierres 2004; Cœur d'acier et al. 2010; Blackman and Eastop 2019; Barbagallo and Ortu 2009; Piron 2009; Valenzuela et al. 2010; Basky and Neményi 2014; Lee and Lee 2018
<i>Takecallis assumentus</i> Qiao & Zhang, 2004	China	<i>Bambusa</i> sp.	Qiao and Zhang 2004
<i>Takecallis himalayensis</i> Chakrabarti, 1988	India	<i>Arundinaria jounsarensis</i> <i>Bambusa</i> sp.	Chakrabarti 1988; Ghosh and Quednau 1990
<i>Takecallis sasae</i> (Matsumura, 1917)	Japan	<i>Phyllostachys</i> sp. <i>Pleioblastus</i> sp. <i>Sasa nipponica</i> <i>Sasa paniculata</i>	Higuchi 1968, 1972
<i>Takecallis taiwanus</i> (Takahashi, 1926)	Central America (Mexico), China, Europe (Hungary, Croatia, Netherlands, Spain, United Kingdom, Russia), Georgia, Japan, Korea, New Zealand, North America, South Africa, South America (Argentina, Brazil, Chile), Taiwan	<i>Arundinaria anceps</i> <i>Arundinaria gigantea</i> <i>Bambusa stenostach</i> <i>Dendrocalamus asper</i> <i>Phyllostachys arcana</i> <i>Phyllostachys aurea</i> <i>Phyllostachys bambusoides</i> <i>Phyllostachys castukkinis</i> <i>Phyllostachys dulcis</i> <i>Phyllostachys nigra</i> <i>Phyllostachys sulphurea</i> <i>Phyllostachys viridiglaucescens</i> <i>Pleioblastus amarus</i> <i>Pleioblastus variegatus</i> <i>Sasa</i> spp. <i>Shibataea kumasasa</i>	Stroyan 1964; Higuchi 1968; Higuchi 1972; Giacalone and Lampel 1996; Nieto Nafria and Mier Durante 1998; Suay-Cano and González-Funes 1998; Foureaux and Kato 1999; Lazzari et al. 1999; Gonzales et al. 2000; Peronti and Sousa-Silva 2002; Qiao and Zhang 2004; Pons and Lumbierres 2004; Trejo-Loyo et al. 2004; Ortego et al. 2004; Blakman and Eastop 2019; Ripka 2008; Simala et al. 2008; Maslyakov and Izhevsky 2011; Lee and Lee 2018

of aphid contamination hazards on bamboos, but their associations should be considered and listed in the Iberian Peninsula. The above mentioned case was the infestation of bamboo hedges by *T. taiwanus*, which were successfully controlled by the application of chemical pesticides.

Aphids of the genus *Takecallis* and their parasitoids are strictly associated with bamboo while any other interactions with the environmental local fauna have not been determined yet (Rakhshani et al. 2017). Therefore, in terms of the specific associations of *Takecallis* spp. and their parasitoids on bamboos, no hazardous effects are expected on the environment that is reserved for their plantation (i.e., arboretums, parks, public and private gardens). Although genus *Takecallis* is represented by seven valid species worldwide (Table 2), a vast number of aphid genera are recorded in association with bamboos and other plant species (e.g., Anacardiaceae, Cyperaceae, Poaceae, Rosaceae, Styracaceae) (Blackman and Eastop 1994, 2006). Apart from aphids, a rich fauna of insects is also associated with bamboos in their area of origin (Revathi and Remadevi 2011).

Conclusion

The increasing attention of bamboos from both ornamental and industrial aspects will evidently lead to the invasion of more alien species into Europe and other parts of the world. A concrete knowledge on the status of those insects in southeastern Asia needs to be elaborated, which is the current bamboo source to Europe. Phytosanitary authorities should very carefully examine all imported bamboo material at any entry point of Europe to intercept alien insect species that could be a potential threat to the local plantations and entomofauna.

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Application of DNA barcoding confirms the host of *Gonatopus viet* Olmi, 1986 (Hymenoptera, Dryinidae)

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Abstract

Gonatopus viet Olmi, 1986 was originally described from Vietnam based on a single female. No further distribution records or hosts have been documented since its original discovery. In the present study, this species is newly recorded from China and its host is confirmed as *Stirellus capitatus* (Distant, 1918) using DNA barcoding techniques. The utility of DNA barcoding to discover host-Dryinidae associations is discussed.

Keywords

Chrysidoidea, host association, leafhopper, molecular identification, *Stirellus capitatus*

Introduction

Species of Dryinidae (Hymenoptera: Chrysidoidea) are parasitoids and predators of Auchenorrhyncha (Hemiptera), many of which are important insect pests in agriculture and forestry (Olmi 1994). These wasps are considered to be important biological control agents against Auchenorrhyncha pests and a number of them have been deployed for that purpose (Guglielmino and Olmi 1997; He and Xu 2002; Guglielmino et al. 2013; Vétek et al. 2019). Further development of their potential use as biological control agents depends upon a better understanding of the biology and hosts of these

wasps (Guglielmino et al. 2013). However, our knowledge on host-Dryinidae interactions usually requires the rearing of the wasps from their hosts, which is difficult, if not impossible, for many dryinid species due to the rarity of the wasps themselves or difficulties in keeping the parasitized host alive until the emergence of the wasps.

On the other hand, most species of Dryinidae are ectoparasitoids of the nymphs or adults of their hosts, that is, the larvae of the wasps strongly protrude from the host's body and feed on the internal structures of the host from outside (Olmi 1994). These parasitized hosts as well as the adults of Dryinidae wasps and hosts are often captured by Malaise and yellow pan traps, rendering a rich resource for exploring the host associations of Dryinidae. While it is difficult to identify the host in the nymphal stage and the wasp species based on its larval morphology, DNA barcoding techniques may have a great potential to close this gap. The barcode region of the mitochondrial cytochrome oxidase subunit 1 (COI) could be used to identify all life states of animals (Hebert et al. 2003).

During an expedition to the Xisha Islands of South China Sea organized by Sun Yat-sen University in 2019, the first author collected a *Gonatopus* adult, a parasitized leafhopper nymph (Figure 1A, B) and many adults of the leafhopper species in yellow pan traps on the small Dong Island. In this study, we use DNA barcoding to confirm that the leafhopper, *Stirellus capitatus* (Distant, 1918) (Hemiptera: Cicadellidae), is the host of *Gonatopus viet* Olmi, 1986, on Dong Island.

Materials and methods

This work is based upon specimens of Dryinidae wasps and leafhoppers collected by yellow pan traps (YPT) on Dong Island (16°39.875'N, 112°43.813'E) of South China Sea. The adult dryinid wasp was identified using the keys of Xu et al. (2013). The adult leafhoppers were identified using the descriptions of Duan et al. (2016). The Dryinidae larva was extracted from the host body and analyzed. All the studied specimens are deposited in the Museum of Biology at Sun Yat-sen University, Guangzhou, China (SYSBM). Images and measurements were made using Nikon SMZ25 microscope with a Nikon DS-Ri 2 digital camera system. Images were post-processed with Adobe Photoshop CS6 Extended.

Genomic DNA was extracted from the adult wasp, the wasp larva, the parasitized leafhopper nymph, and a female leafhopper adult. A nondestructive DNA extraction protocol was used for the adult wasp and leafhopper, as described in Taekul et al. (2014), to enable preservation of a voucher specimen. For the wasp larva and the leafhopper nymph, only the skin and a single leg were used, respectively. DNA was extracted using a DNeasy Blood & Tissue Kit (QIAGEN, Inc.) and LCO1490 and HCO2198 primers (Folmer et al. 1994) were used to amplify the COI sequences. Amplicons were sequenced on an Applied Biosystems (ABI) 3730XL by Sangon Biotech (Shanghai, China). Chromatograms were assembled with Geneious 11.0.3. All the amplified sequences were deposited into GenBank (Table 1). Sequences were aligned and compared in Geneious 11.0.3 using the MAFFT alignment algorithm.



Figure 1. **A, B** *Stirellus capitatus* (Distant, 1918) nymph parasitized by *Gonatopus viet* Olmi, 1986 (SCAU 3040955) **A** habitus, dorsal view **B** habitus, ventral view **C, D** *Stirellus capitatus* (Distant, 1918) **C** habitus, female (SCAU 3040956), dorsal view **D** habitus, male (SCAU 3049598), dorsal view.

Table 1. Details of taxon sampling, codes, and accession numbers.

Taxon	Code	Accession number
<i>Gonatopus viet</i> female adult	SCAU 3040953	MT311154
Dryinidae larva	SCAU 3040954	MT311155
<i>Stirellus capitatus</i> nymph	SCAU 3040955	MT311156
<i>Stirellus capitatus</i> female adult	SCAU 3040956	MT311157

Results

The Dryinidae female adult is identified as *G. viet* based on morphology. It matches well with the original descriptions of *G. viet* except the body length is 2.86 mm (the holotype is 2.4 mm). This species can be recognized by the following characters (Figure 2): apterous; head excavated, unsculptured; frontal line complete; palpal formula 4:2; pronotum shiny, setose, unsculptured, crossed by strong transverse impression; metanotum not hollow behind mesoscutellum; metathorax and metapectal-propodeal complex shiny, completely smooth, with propodeal declivity transversely striate only near distal apex; mesopleuron and metapleuron not transversely striate; enlarged claw with one small subapical tooth and seven peg-like hairs; protarsomere 5 with inner margin proximally not serrated, with one row of 15 lamellae; distal apex with about

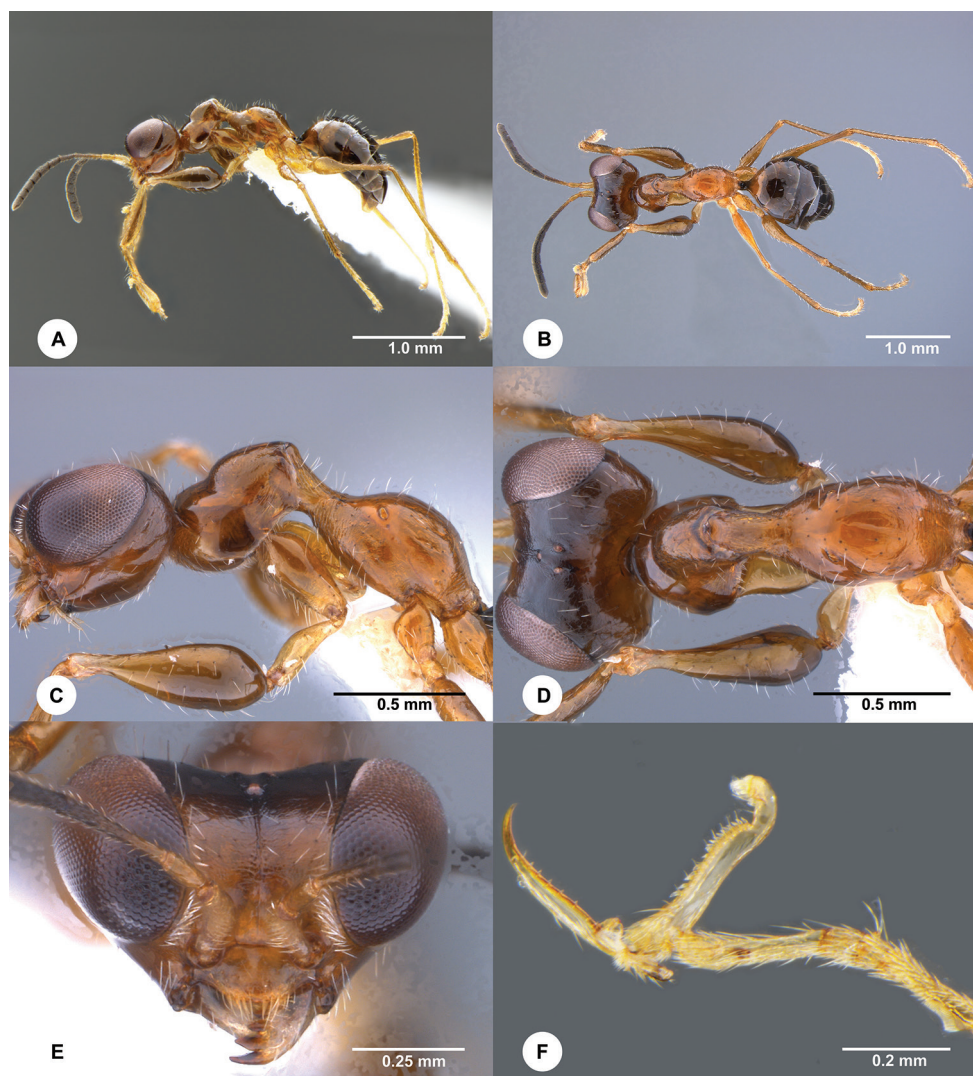


Figure 2. *Gonatopus viet* Olmi, female (SCAU 3040953) **A** habitus, lateral view **B** habitus, dorsal view **C** head and mesosoma, lateral view **D** head and mesosoma, dorsal view **E** head, anterior view **F** chela.

ten lamellae; tibial spurs 1/0/1. The COI sequences are over 99% identical between the adult wasp and the larva feeding on the leafhopper nymph, indicating that the wasp larva is conspecific with the adult wasp, i.e., *G. viet*.

The COI sequences are also over 99% identical between the parasitized leafhopper nymph and a female leafhopper adult, indicating that they are conspecific. This female leafhopper adult, along with the males from the same sample, is morphologically identified as *Stirellus capitatus* (Figure 1C, D), which has been previously recorded from South China, including Hainan Island.

Discussion

Dryinidae is a diverse group of parasitic wasps, with approximately 1900 species described worldwide (Xu et al. 2013; Olmi and Xu 2015; Olmi et al. 2019). Guglielmino et al. (2013) compiled the most recent host-parasite catalogue of the world Dryinidae and recognized 1014 relationships between dryinids and their hosts. However, considering the species diversity of Dryinidae, this number is far from the actual interactions between these wasps and their hosts. Besides, dryinids are not monophagous; in contrast, they may parasitize different groups of hosts. The many current monophagous parasitism records may due to the insufficient investigation of host-parasitoid interactions. In this study, we successfully use DNA barcoding to identify the host of a dryinid wasp species, *G. viet*, and to match the nymphal and adult stages of the host, *S. capitatus*. The present study illustrates the great potential that DNA barcoding has for accelerating the discovery of host-Dryinidae associations. It is worth noting that in some cases dryinid larvae protruding from the host's bodies contain hyperparasitoid larvae (Vétek et al. 2019) and may result in extracting mixture DNA from the wasp larvae. In such cases, taxon-specific primers (Mita et al. 2013) should be used or the Next Generation Sequencing approach should be applied.

Many species of Dryinidae display extreme sexual dimorphism, especially in the subfamilies Dryinae and Gonatopodinae (Mita and Matsumoto 2012; Tribull 2015). DNA markers have been shown to be powerful tools for the correct association of the female and male of Dryinidae species with sexual dimorphism (Mita and Matsumoto 2012), exploring intraspecific genetic variation (Mita et al. 2013), and molecular phylogeny (Tribull 2015). As the DNA barcode library of Dryinidae is populated with both sexes of additional species, we should be able to accelerate the discovery of host-Dryinidae associations using the approach present in this study.

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First description of the male *Quelaestrygon puetzi* Smetana, 1999 (Coleoptera, Staphylinidae, Staphylinini) from China

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Abstract

A male of the very rare and phylogenetically puzzling species, *Quelaestrygon puetzi* Smetana, 1999, is described for the first time based on a single specimen from Sichuan Province, China. High quality color images and line drawings of the male external and genitalic traits are provided.

Keywords

Morphology, rove beetle, taxonomy

Introduction

The monotypic genus *Quelaestrygon* Smetana, 1999 (Staphylinidae, Staphylininae, Staphylinini) was established based on two female specimens of *Quelaestrygon puetzi* Smetana, 1999 collected from the mountain areas in Sichuan, China.

Initially, this distinctive genus was assigned to the subtribe Quediina mostly due to its overall similarity to the other members of the subtribe. Later, a series of phyloge-

netic studies of Staphylinini were successively conducted by various authors (e.g., Solodovnikov 2006; Solodovnikov and Schomann 2009; Chatzimanolis et al. 2010; Brunke and Solodovnikov 2013; Brunke et al. 2016; Żyła and Solodovnikov 2019; Tihelka et al. 2020). As a result, the subtribe Quediina was confirmed to be highly polyphyletic and redefined as a more restricted group, while many genera were moved out from Quediina sensu Brunke et al. (2016). The systematic position of some of them, including *Quelaestrygon* Smetana, unfortunately, is still unclear (Brunke et al. 2016).

This peculiar genus is mainly characterized by its large size and the long appendages (Fig. 2A), the simultaneous presence of the postmandibular and infraorbital ridges on the head (Fig. 1D), the distinct basolateral mandibular ridge, removed from the lateral mandibular margin and bordered by a deep and very wide depression (Fig. 1A), the first four antennal segments devoid of dense appressed pubescence (Fig. 1E), the absence of dorsal rows of punctures on the pronotum (Fig. 1B), and the surface sculpture of the elytra with fine leather-like rugulae and scratch-like short lines, lacking the usual punctation and pubescence (Fig. 1C) (Smetana 1999).

Examination of rove beetle specimens collected from Sichuan Province, China revealed a male of this rare species. The aim of this study was to describe the male of *Q. puetzi* Smetana, in the hope that the new information provided could help with future resolution of this taxonomically uncertain genus.

Material and methods

The male specimen was relaxed in warm water (60 °C) for 5–8 hours for dissection of the abdominal segments VIII–X and the genitalia. After examination, the dissected body parts were glued back to the mounting card for future study. Observation, dissection and measurements were performed using a stereo microscope (Zeiss SteREO Discovery V20). Images of the adult and genitalia were captured with an AxioCam MRC 5 camera attached to a Zeiss Axio ZoomV16 Fluorescence Stereo Zoom Microscope, and photomontage was performed in Zen 2012 (blue edition) imaging software. Inkscape V0.91 was used to make the line drawings. The abdominal tergites and sternites were entirely flattened for the line drawings to make the illustrations more comparable among species.

The specimen examined was deposited in the Institute of Zoology, Chinese Academy of Sciences (IZ-CAS).

Morphological terminology followed Smetana (1999), Smetana and Davies (2000).

The following abbreviations are used in the text:

- BL body length (from apex of clypeus to apex of abdominal tergite VIII);
- BW body width (maximal body width, usually equal to EW);
- HL head length (from base of clypeus to neck constriction);
- HW head width (maximal head width, including eyes);
- PL pronotal length (along midline of pronotum);

PW	pronotal width (maximal pronotal width);
EL	elytral length (maximal elytral length);
EW	elytral width (maximal elytral width);
ESL	elytral suture length (from apex of scutellum to apex of elytral suture);
AW	abdominal width (maximal width of abdomen);
HEL	(head) eye length;
HTL	(head) temporal length.

Taxonomy

Quelaestrygon Smetana, 1999: 241.

Type species. *Quelaestrygon puetzi* Smetana, 1999, by monotypy.

Quelaestrygon puetzi Smetana, 1999

Figs 1–3

Quelaestrygon puetzi Smetana, 1999: 246 (type locality: China: Sichuan, Daxue Shan Gongga Shan, Mt. Hailuoguo Glacier Park, 2620–1940 m).

Material examined. 1 ♂; China, Sichuan Province, Mt. Emei, Leidongping; 8. VI. 2014; Chengbin Wang leg.

Measurements. BL = 18.3 mm, BW = 4.1 mm, HL/PL/EL = 1.00: 0.96: 1.28, HW/PW/EW/AW = 1.00: 1.13: 1.28: 1.32, HW/HL = 0.94, HEL/HTL = 0.39, PW/PL = 1.11, EW/EL = 0.95, ESL/EL = 0.59.

Description of female. See Smetana (1999: 246–247).

Description of male. Male with first four segments of foretarsus strongly dilated, sub-bilobed, each heavily covered with tenent setae ventrally, segment II slightly wider than apex of tibia; tergite VIII (Fig. 3A) with basal ridge complete, nearly straight, with one long seta on each side, apical margin with shallow and narrow medioapical emargination; sternite VIII (Fig. 3B) with basal ridge complete, slightly sinuate, with one long seta on each side, apical margin with shallow and wide medioapical emargination, a very small triangular area in front of the emargination impunctate; sternite IX (Fig. 3C) with basal portion short and wide, apex almost truncate, apical margin forming indistinct M-shaped indentation; tergite X (Fig. 3D) with basal side broadly and shallowly concave, apical margin complete, forming a right angle; aedeagus robust and strongly sclerotized, in lateral view (Fig. 3E) with apex of paramere distinctly not reaching that of median lobe, apical 1/4 of median lobe strongly bent toward parameral side, without any process at apex; aedeagus in parameral view (Fig. 3F) with paramere distinctly narrower than median lobe, wide at base, then gradually narrowed into obtuse apex, forming a near triangle shape, median lobe parallel-sided laterally,

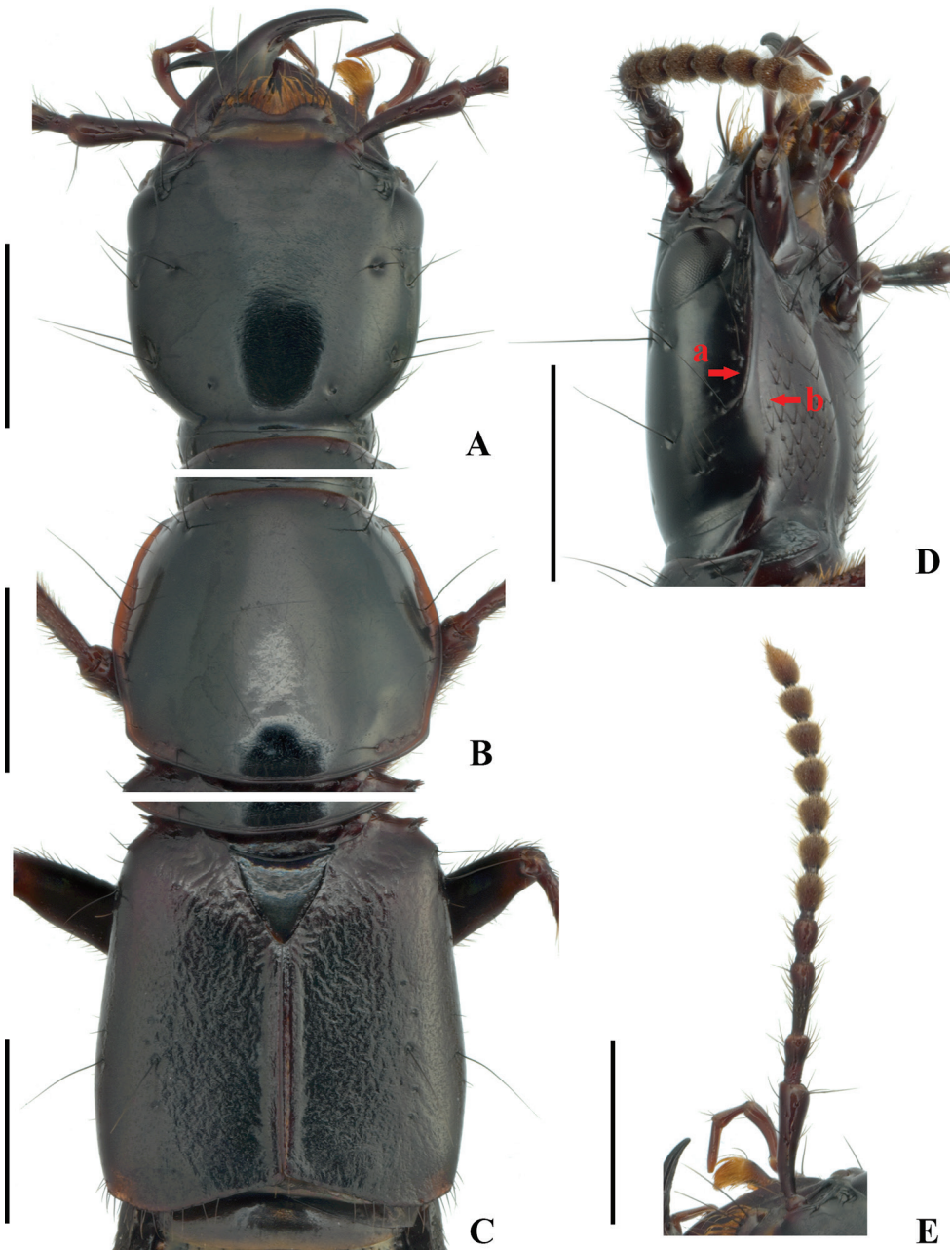


Figure 1. Male of *Quelaestrygon puetzi* Smetana **A** head in dorsal view **B** pronotum in dorsal view **C** elytra in dorsal view, showing sculpture **D** head in lateral view, showing postmandibular ridge (a) and infraorbital ridge (b) **E** antenna, detail. Scale bars: 2.00 mm.

distinctly constricted at apex, apex somewhat pointed (Figs 2C, 3F); apical portion of paramere with four moderately long apical setae, and two similar subapical setae on each lateral side below apex, underside with seven small tooth-shaped processes along

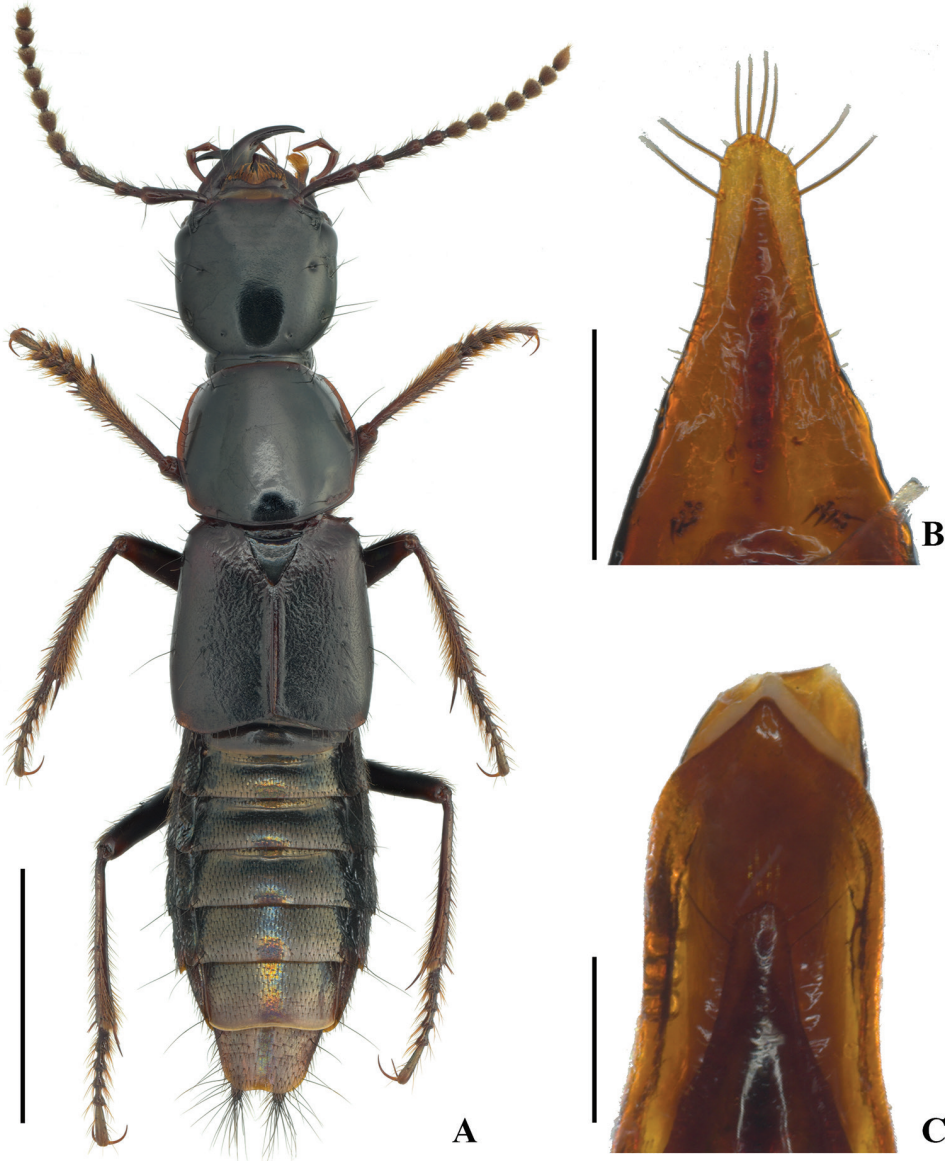


Figure 2. Male of *Quelaestrygon puetzi* Smetana, morphology **A** body in dorsal view **B** aedeagus, underside of paramere **C** aedeagus, apical portion of median lobe, parameral view. Scale bars: 5.00 mm (**A**), 0.50 mm (**B, C**).

the more strongly sclerotized and pigmented midline, and 6–7 spike-like sensory peg setae arranged in cluster far below apex on each side (Figs 2B, 3G).

Distribution. *Quelaestrygon puetzi* Smetana is at present known only from several mountain areas in Sichuan Province of China: Mt. Gongga, Mt. Jinping and Mt. Emei. The examined male specimen was hand-collected at a parking lot after landing on the collector's clothes.

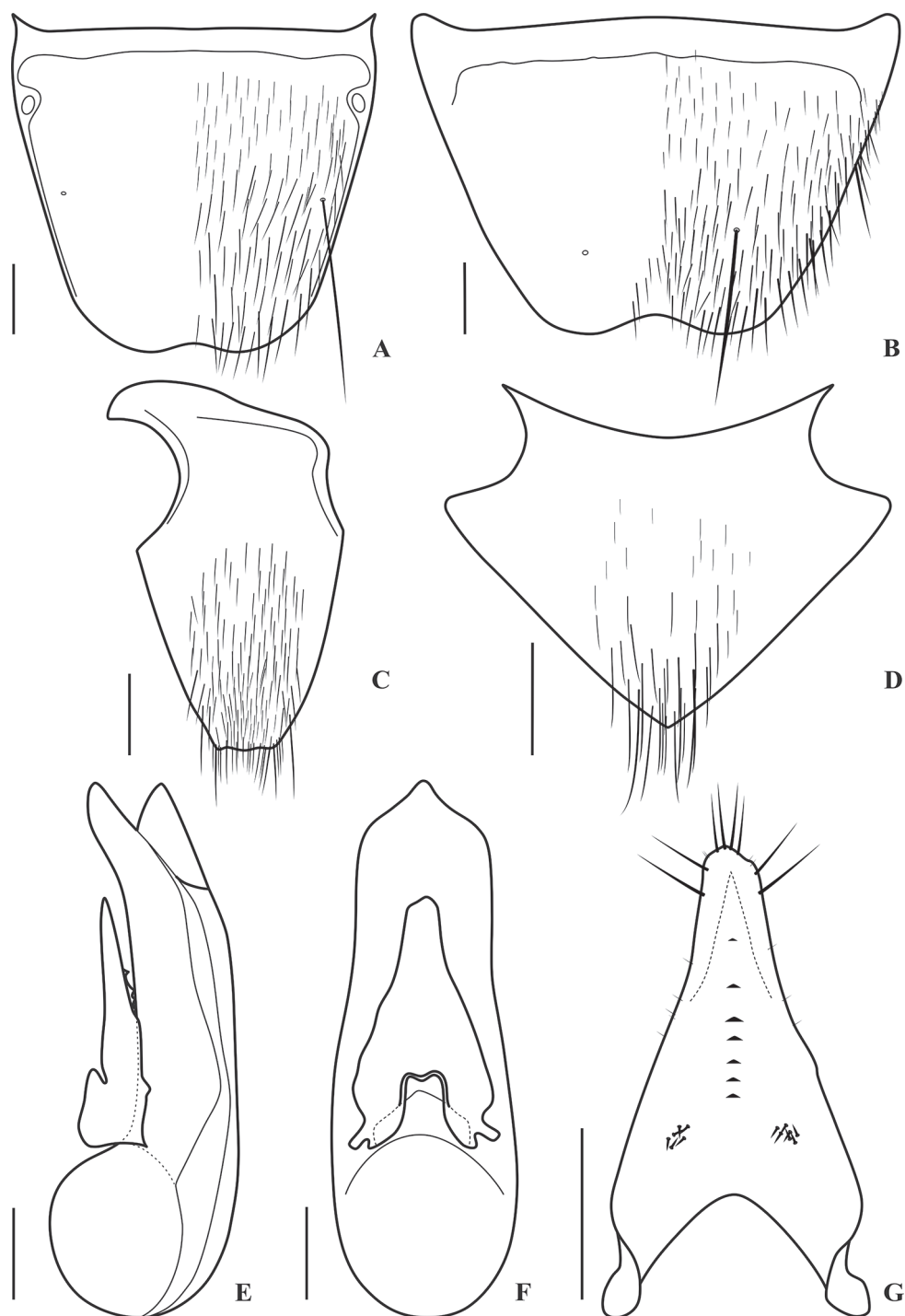


Figure 3. Male terminalia and genitalia of *Quelaestrygon puetzi* Smetana **A** male tergite VIII **B** male sternite VIII **C** male sternite IX **D** male tergite X **E** aedeagus, lateral view **F** aedeagus, parameral view **G** aedeagus, underside of paramere. Scale bars: 0.50 mm.

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Taiwanoshaira Lee & Beenen, a new genus and first record of moss-inhabiting Galerucinae *sensu stricto* (Coleoptera, Chrysomelidae) from Taiwan

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Abstract

Taiwanoshaira Lee & Beenen **gen. nov.** is described. It represents the first genus of Galerucinae (s. str.) in Taiwan documented to inhabit moss cushions. *Shaira chujoi* Kimoto, 1982 is transferred to *Taiwanoshaira*, as follows: *T. chujoi* (Kimoto), **comb. nov.** Two new species, *T. taipingshanensis* **sp. nov.** and *T. tsoui* **sp. nov.**, are described. Adults of *T. taipingshanensis* **sp. nov.** were observed feeding on the moss species *Plagiomnium vesicatum* (Besch.) T.J. Kop. (Mniaceae). Microhabitats and distribution of *Taiwanoshaira* species are discussed.

Keywords

cloud forest, leaf beetle, Malaise trap, moss, nocturnal, taxonomy

Introduction

Moss cushions constitute a special environment inhabited by a limited diversity of leaf beetles. Members of more than 50,000 known species of leaf beetles live mainly on the leaf surface of various flowering plants on which they feed. Konstantinov et al. (2013) reported that 27 leaf beetle species from 14 genera live within moss cushions. All known moss-inhabiting leaf beetles belong to the tribe Alticini, known as flea bee-

tles. Eighteen species and four genera were added to the diversity of moss-inhabiting flea beetles by Konstantinov et al. (2019). But only eight species from four genera were documented actually feeding on mosses (Konstantinov et al. 2019).

The Taiwan Chrysomelid Research Team (TCRT) started their inventory of all species of Chrysomelidae during 2005. We found only adults of *Ivalia* Jacoby inhabited moss cushions early in the project. A TCRT colleague, Sin-Syue Li, found several galerucines (*sensu stricto*) inhabiting moss cushions at Yuanyang Lake (= Yuanyanghu, 鴛鴦湖) (Fig. 1A) on August 19, 2010. During the following year, the first author and several members of TCRT went to the same locality to confirm Li's observation. We found that adults were nocturnal and active on moss cushions, and observed feeding (Fig. 1C) and mating (Fig.

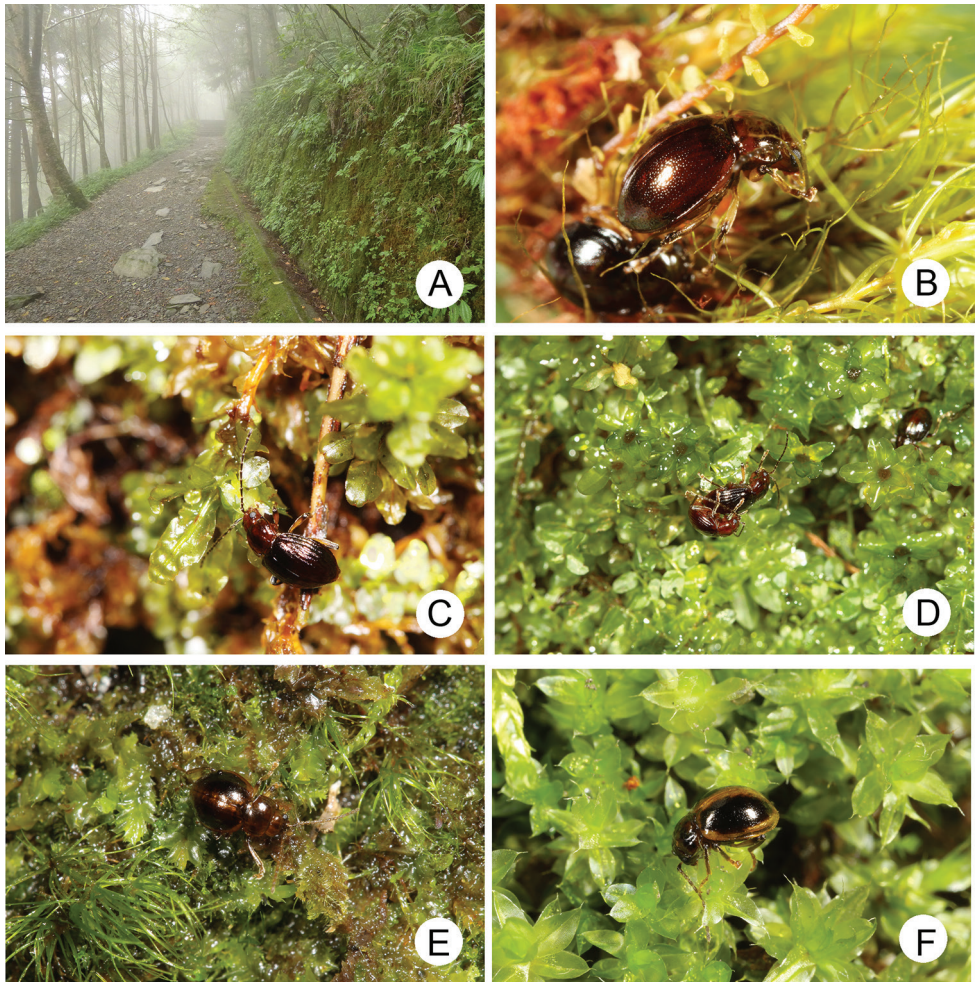


Figure 1. Habitat photographs. **A** microhabitat for *Taiwanoshaira taipingshanensis* sp. nov. and *T. tsoui* sp. nov. at Yuanyang Lake (鴛鴦湖) **B** active adults of *T. chujoi* comb. nov. inside moss cushions at Pilu (畢祿) **C** adult of *T. taipingshanensis* sp. nov. feeding on leaves of *Plagiomnium vesicatum* at Yuanyang Lake (鴛鴦湖) **D** adults of *T. taipingshanensis* sp. nov. mating at Yuanyang Lake (鴛鴦湖) **E** adult of *T. tsoui* sp. nov. at Hsiaofengkou (小風口) **F** adult of *T. tsoui* sp. nov. at Meifeng (梅峰).

1D). Catching them by hand-collecting was easy, and more than 30 adults were collected at that time. Collecting proved difficult at other localities even though their behavior was known. They were eventually found on host mosses at only three additional localities, Taipingshan (太平山), Tahsuehshan (大雪山), and Peitungyanshan (北東眼山).

These same moss-inhabiting galerucines were collected using Malaise traps by colleagues at the National Museum of Natural Science at Meifeng (梅峰), Yuanfeng (鳶峰), Hsiaofengkou (小風口), and Bilu Divine Tree (碧綠神木). Malaise traps are mostly used to collect flying insects and the base of the canvas (tent cloth) does normally not touch the ground. When the canvas touches the ground, then beetles that lack flying capacities can crawl upward. Adults of Taiwanese *Paraplotes* species are good examples of flightless insects collected with Malaise traps (Lee 2015). During visits to these localities, more than 150 specimens were captured with hand-collecting at the night.

These galerucines were initially identified as *Shaira chuioi* Kimoto, 1982 and allied undescribed species. However, they were clearly different in diagnostic characters from the type species of the genus, *S. maculata* Maulik, 1936. Thus, generic placement of these species was re-evaluated, species diversity was analyzed, and the results are presented here.

Material and methods

The abdomens of adults were separated from the bodies and boiled in 10% KOH solution, followed by washing in distilled water to clear and soften genitalia. The genitalia were then dissected from the abdomen, mounted on slides in glycerin, and studied and drawn using a Leica M165 stereomicroscope. For detailed examination a Nikon ECLIPSE 50i microscope was used.

At least two pairs from each species were examined to delimit variability of diagnostic characters. For species collected from more than one locality, at least one pair from each locality was examined. Length was measured from the anterior margin of the eye to the elytral apex, and width at the greatest width of the elytra.

Specimens were available for study and deposited in the following institutions:

- KMNH** Kitakyushu Museum of Natural History and Human History, Kitakyushu, Japan [Yûsuke Minoshima];
- KUEC** Faculty of Agriculture, Kyushu University, Fukuoka, Japan [Osamu Tadauchi];
- NMNS** National Museum of Natural Science, Taichung, Taiwan [Jing-Fu Tsai];
- RBCN** Ron Beenen collection, Nieuwegein, The Netherlands;
- TARI** Applied Zoology Division, Taiwan Agricultural Research Institute, Taichung, Taiwan [Chi-Feng Lee].

Exact label data are cited for all type specimens of previously described species; a double slash (//) divides the data on different labels and a single slash (/) divides the data in different rows. Other comments and remarks are in square brackets: [p] – preceding data are printed, [h] – preceding data are handwritten, [w] – white label, [y] – yellow label, [r] – red label, [b] – blue label.

Taxonomy

Chrysomelidae

Galerucinae s. str.

Taiwanoshaira Lee & Beenen, gen. nov.

<http://zoobank.org/E2A13741-632C-4DB4-B304-C90BC5318FC8>

Type species. *Taiwanoshaira tsoui* Lee & Beenen, sp. nov.

Description. Coloration (Figs 3, 6): dark brown or blackish-brown; margins of pronotum and elytra, including suture, yellowish-brown in *T. tsoui* sp. nov.; legs yellowish-brown, but apices of femora and bases of tibiae blackish-brown in *T. chujoi* comb.nov. and *T. tsoui* sp. nov. Body length 4.0–5.7 mm.

Head. Labrum trapezoidal, transverse, with about ten pairs of pores in a transverse row bearing pale, short or long setae, anterior margin medially depressed. Anterior part of head short, almost impunctate and glabrous, lined with setae along anterofrontal ridge. Compound eyes small, interantennal space 3.1–3.6× as wide as diameter of antennal insertion. Frontal tubercles transverse, subtriangular, slightly elevated, glabrous. Vertex smooth and glabrous. Antennae filiform, covered with dense setae, antennomere II subequal or a slightly shorter than III; similar in both sexes.

Pronotum 1.61–1.68 times as broad as long, lateral margins slightly rounded, basally narrowed. Disc smooth, with dense, fine punctures bearing tiny setae in *T. taipingshanensis* sp. nov. and *T. chujoi* comb. nov.; setae reduced in *T. tsoui* sp. nov. Anterior, lateral and posterior margins with marginal bead, without setae along margin. Anterior and posterior angles moderately swollen, rectangular; all angles with setigerous pores bearing long pale setae. Two pairs of longitudinal furrows starting from base, one pair deeper and shorter near middle, the other pair longer but shallow near sides. Scutellum subtriangular, impunctate, glabrous, with rounded apex.

Elytra ca 1.10–1.26 times as long as wide, almost glabrous, lateral margins rounded, apically tapering in males of *T. chujoi* comb. nov. and *T. tsoui* sp. nov., or both sexes of *T. taipingshanensis* sp. nov. Humeral calli reduced. Epipleura broad at base (Fig. 2D), gradually narrowed from base to basal 1/3, strongly narrowed at basal 1/3, abbreviated at apical 1/3. Disc with dense, confused punctures in *T. chujoi* comb. nov. (Fig. 3A, C–D, F) and *T. tsoui* sp. nov. (Fig. 6D, F), or with longitudinal impunctate ridges in *T. taipingshanensis* sp. nov. (Fig. 6A, C). Wingless, hindwings absent.

Ventral surface glabrous except abdomen, which is covered with pale setae. Anterior coxal cavities widely open (Fig. 2B) in *T. chujoi* comb. nov. and *T. tsoui* sp. nov., or almost closed (Fig. 2A) in *T. taipingshanensis* sp. nov. Prosternal process wide between procoxae. Abdomen simple, posterior margin of last ventrite (V) with median lobe in males (Fig. 2C); base extending anteriorly and almost reaching base of ventrite IV, median ridges present from base to apex of ventrite IV.

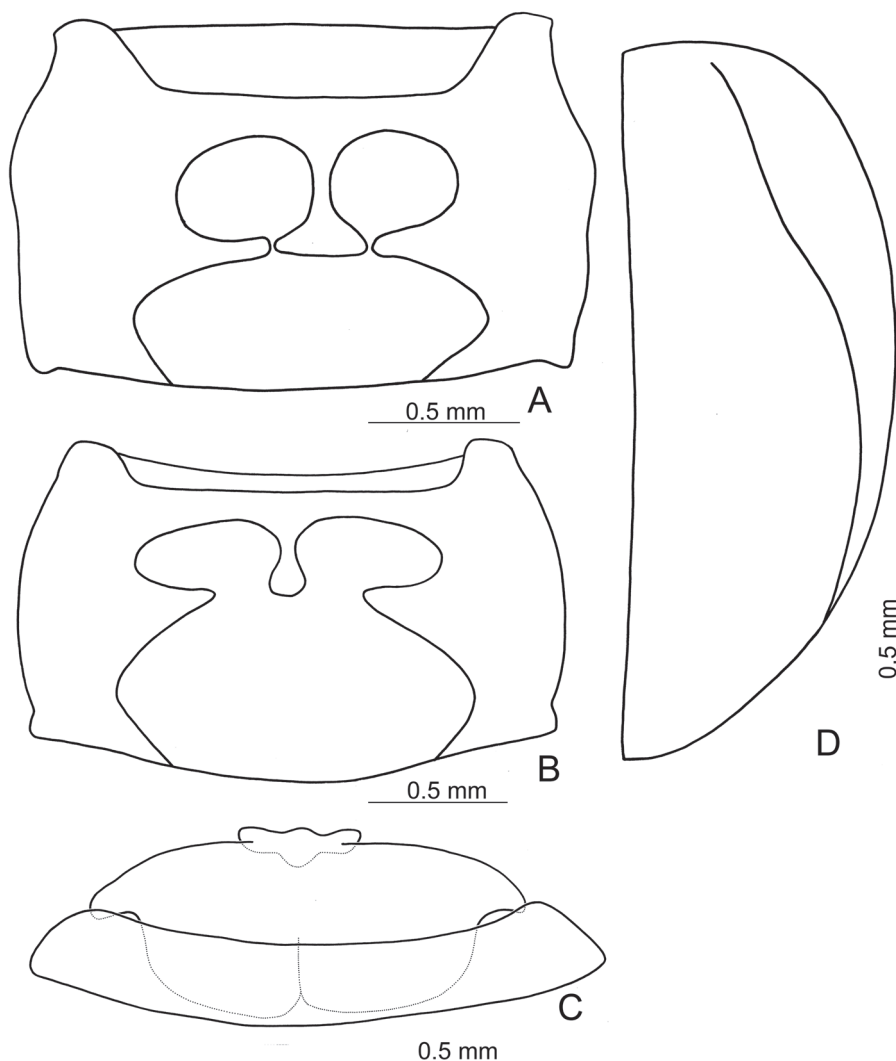


Figure 2. Generic characters for *Taiwanoshaira*. **A** prothorax, ventral view, *T. taipingshanensis* sp. nov. **B** prothorax, ventral view, *T. tsoui* sp. nov. **C** last two abdominal ventrites, dorsal view, male, *T. tsoui* sp. nov. **D** elytron, ventral view, *T. tsoui* sp. nov.

Legs slender. Tibiae lacking apical spines. Protarsomeres I slightly swollen in males of *T. taipingshanensis* sp. nov., but unmodified in either sex of *T. chujoi* sp. nov. and *T. tsoui* sp. nov. Metatarsomeres I a little longer than pro- and mesotarsomeres I, subequal to II and III combined. Claws appendiculate.

Penis (Figs 4C–D, 7C–G, 8C–L) slender, apex rounded; tectum broad, apical margin truncate; strongly curved in lateral view; internal sac with one longitudinal sclerite and one pair of small sclerites at sides near base of longitudinal sclerite.

Gonocoxae (Figs 4E–F, 7H–I, 8M–N) wide, tightly conjunct from base to middle; each gonocoxa wide, with four to 13 setae from near apex to apical 1/6, apex truncate or widely rounded; base irregular in *T. taipingshanensis* sp. nov. or narrowed in basal 1/3 in *T. chujoi* comb. nov. and *T. tsoui* sp. nov. Ventrite VIII (Figs 4G, 7J–K, 8O–P) well sclerotized, with several short setae at apex, spiculum elongate. Spermathecal receptaculum (Figs 4H, 7L, 8Q) strongly swollen; pump slender and curved; sclerotized spermathecal duct short.

Diagnosis. Adults of *Taiwanoshaira* gen. nov. lack metathoracic wings, but elytra present, which completely cover the abdomen. Furthermore, the morphology of the elytra differs from that of *Shaira*. In *Shaira* the elytra possess an elongate ridge from the humeral area to the apex, dividing the elytra into a horizontal part and a lateral inclined part. The narrow epipleura are situated below this vertically inclined part of the elytra. In *Taiwanoshaira* gen. nov. the elytra possess a margin that separates the horizontal elytral surface from the epipleura, which are inclined.

Remarks. The genus *Shaira* was proposed by Maulik (1936) for brachelytrous Gallerucinae with appendiculate claws and slender antennae. Beenen (2013) argued that *Shaira* should be classified in Luperini. Kimoto (1982) described *S. chujoi* from Taiwan and compared it with *S. maculata* Maulik, 1936 from Manipur (India). *Shaira chujoi* somewhat resembles this species, but differs in having the body shorter and more oval, pronotum transverse and with different coloration. In fact, *S. chujoi* should not have been included in the *Shaira*, because it differs in possessing entire elytra but the ridge is absent. We transfer it to the new genus *Taiwanoshaira*.

Taiwanoshaira gen. nov. is likely not closely related to *Shaira*, although also included in Luperini. It is unique and, although apterous, likely to be more closely related to the genus *Sikkimia* Duvivier, 1891 with all bordered pronotal margins, two pairs of longitudinal furrows starting from base, one pair deeper and shorter near middle, the other pair longer but shallow near sides. This new genus is easily separated from *Sikkimia* with the open procoxal cavities and uniform antennae in both sexes (the closed procoxal cavities and modified antennomeres X and XI in males of *Sikkimia*).

Etymology. The new genus name combines “Taiwan” and “*Shaira*” to indicate that this is a new genus endemic to Taiwan that is similar to *Shaira*. The gender is feminine.

Included species. *Taiwanoshaira chujoi* (Kimoto), comb. nov., *T. taipingshanensis* sp. nov., and *T. tsoui* sp. nov.

***Taiwanoshaira chujoi* (Kimoto) comb. nov.**

Figures 3, 4

Shaira chujoi Kimoto, 1982

Types. **Holotype** ♂ (KUEC): “TAPAN [達邦] / TAIWAN / 16. V. 1974 / S. TAKEDA [p, y] // *Shaira chujoi* / Kimoto, n. sp. [h, w] // HOLOTYPE [p, r] // PHOTO [p, r] // 九大 [h, w, abbreviation for Kyushu University]”. **Paratypes:** 1♂ (KMNH) (Fig. 3A, B): “(Taiwan) / Alishan (阿里山), 2300m / Chiayi Hsien [p, w] // 6.VI.1965 / T.

Nakane [p, w] // Shaira / chujoi / Kimoto, n. sp. [h, w] // PARATYPE [p, b] // Japan-U. S. / Co-op. Sci. / Programme [p, y]"; 1♀ (KMNH) (Fig. 3C): "TAPAN [達邦] / TAIWAN / 16. V. 1974 / S. TAKEDA [p, y] // Shaira / chujoi / Kimoto, n. sp. [h, w] // PARATOPOTYPE [p, b]".

Other material (N = 68). **Hualien:** 1♀ (TARI), Bilu Divine Tree (碧綠神木), 10–11.X.2013, leg. K. Takahashi; 5♂♂, 4♀♀ (NMNS), same locality, 1.VI.–28.VII.2011; 2♂♂ (TARI), same locality (= Pilu), 13.VI.2014, leg. C.-F. Lee; 1♀ (TARI), same but with "leg T.-H. Lee"; 6♂♂, 12♀♀ (TARI), same locality, 30.VII.2014, leg. C.-F. Lee; 1♂ (TARI), same but with "leg. T.-H. Lee"; 8♂♂, 9♀♀ (TARI), same locality, 7.VII.2015, leg. C.-F. Lee; 4♂♂, 3♀♀ (TARI), Chian (吉安), 18.VI.2015, leg. T.-H. Lee; 1♂ (TARI), Kalapao (卡拉寶), 15–17.VII.2019, leg. B.-H. Ho; 4♂♂, 3♀♀ (3♂♂, 1♀TARI; 1♂, 2♀♀: RBCN), Kuanyuan (關原), 25.VIII.2014, leg. F.-S. Huang; 2♂♂, 1♀ (1♂, 1♀: TARI; 1♂: RBCN), Pilu (畢祿), 8.VIII.2014, leg. M.-H. Tsou; **Nantou:** 1♂ (NMNS), Meifeng (梅峰), 8.VII.–5.VIII.2003, leg. C. S. Lin & W. T. Yang; 1♂ (NMNS), Yuanfeng (鸞峰), 13.VIII.–10.IX.2002, leg. C. S. Lin & W. T. Yang; 1♂ **Taitung:** 1♂ (TARI), Liyuan (栗園), 5.X.2010, leg. T.-H. Lee.

Redescription. Length 4.1–5.0 mm, width 2.5–3.3 mm. General color dark brown or blackish-brown (Fig. 3); each antennomere paler at base; legs yellowish-brown, but apices of femora and bases of tibiae blackish-brown. Antennae (Fig. 4A) filiform in males, ratios of lengths of antennomeres I to XI 1.0 : 0.5 : 0.6 : 0.6 : 0.6 : 0.6 : 0.6 : 0.6 : 0.6 : 0.7 : 0.9; ratios of length to width from antennomeres I to XI 3.3 : 2.3 : 2.5 : 2.7 : 2.7 : 2.9 : 3.0 : 2.9 : 3.1 : 3.6; similar in females, ratios of lengths of antennomeres I to XI (Fig. 4B) 1.0 : 0.5 : 0.6 : 0.7 : 0.6 : 0.6 : 0.6 : 0.6 : 0.6 : 0.8; ratios of length to width from antennomeres I to XI 3.2 : 2.2 : 2.7 : 2.9 : 3.2 : 3.1 : 3.0 : 2.8 : 3.0 : 3.0 : 3.6. Procoxal cavities widely open. Elytra 1.10–1.20 times longer than wide; disc with dense, confused, coarse punctures and longitudinal smooth patches; apices tapering in males but widely rounded in females. Tarsomeres I of front legs not modified in either sex. Penis (Fig. 4C, D) wide, about 6.3 times longer than wide; parallel sided but slightly curved in lateral view, apex narrowly rounded, base slightly sinuate; tectum broad from apical 1/10 to middle, apex truncate; ventral surface with large opening. Endophallic spiculae complex with median endophallic spiculae slender, apically bifurcate, and straight in lateral view, with one pair of small sclerites near basal third. Gonocoxae (Fig. 4E, F) short; apex of each gonocoxa widely rounded, with five to 13 long setae along apical margin, strongly narrowed in basal 1/3, with extreme wide base. Ventricle VIII (Fig. 4G) short and well sclerotized, with several short setae along apical margin, spiculum short. Spermathecal receptaculum (Fig. 4H) slightly swollen; pump extremely slender and curved; sclerotized spermathecal duct short.

Diagnosis. Adults of *Taiwanoshaira chujoi* (Kimoto) comb. nov. are similar to those of *T. tsoui* sp. nov. based on the following shared characters: elytra smooth and lacking longitudinal ridges (Figs 3A, C–D, 6D, F) (presence of the longitudinal ridges on elytra in *T. taipingshanensis* sp. nov. (Fig. 6A, C)), widely open procoxal cavities (Fig. 2B) (almost closed procoxal cavities (Fig. 2A) in *T. taipingshanensis* sp. nov.),

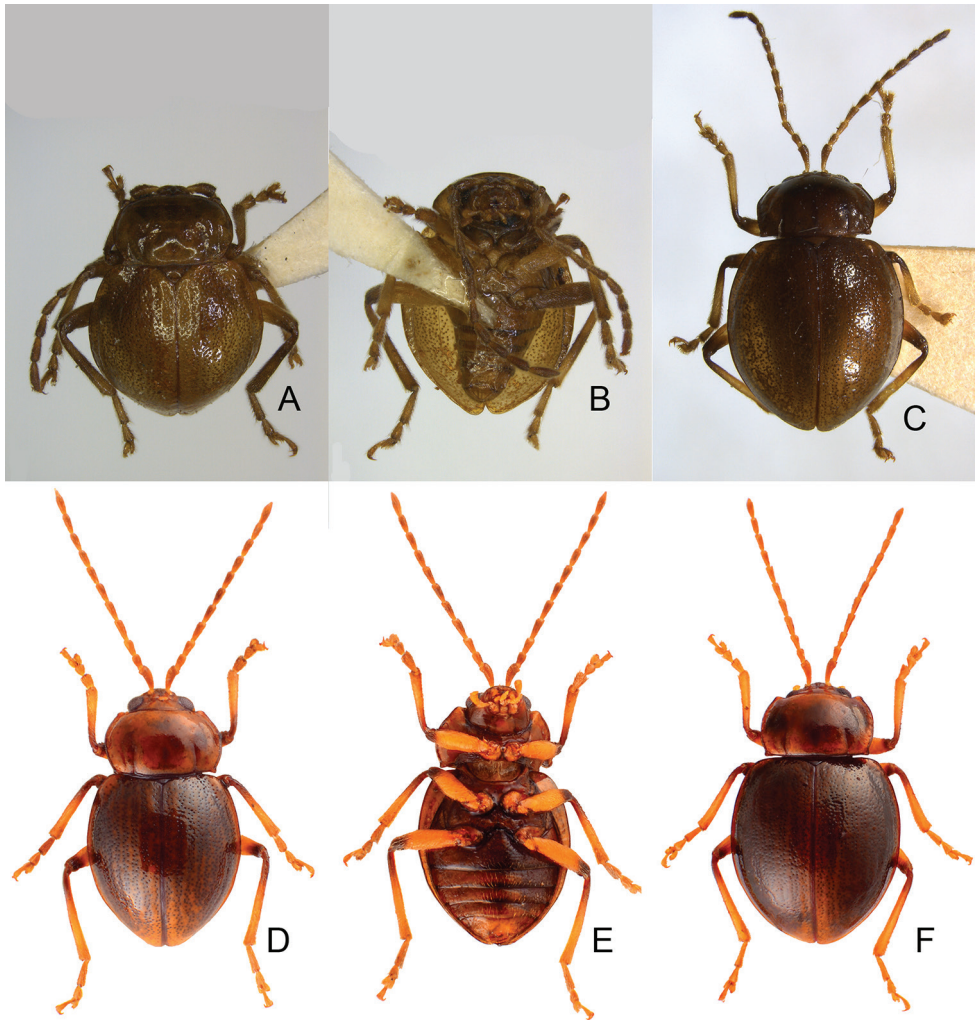


Figure 3. Habitus of *Taiwanoshaira chujoi* comb. nov. **A** male, paratype, from Alishan (阿里山), dorsal view **B** same, ventral view **C** female, paratype, from Tapan (達邦), dorsal view **D** male, from Bilu Divine Tree (碧綠神木), dorsal view **E** same, ventral view **F** female, from Bilu Divine Tree (碧綠神木), dorsal view.

yellowish-brown legs with dark apices of femora and bases of tibiae (Figs 3, 6D–F) (entirely black legs in *T. taipingshanensis* sp. nov. (Fig. 6A–C)), uniform protarsi I in both sexes (sexually dimorphic protarsi I in *T. taipingshanensis* sp. nov.), tapering elytral apices in only males (Fig. 3) (tapering elytral apices of both sexes (Fig. 6A–C) in *T. taipingshanensis* sp. nov.). *Taiwanoshaira chujoi* comb. nov. differs from *T. tsoui* sp. nov. in possessing black or blackish elytra (Fig. 3) with denser punctures in contrast to the black or blackish-brown elytra with yellowish-brown suture and margin (Fig. 6D–F) and sparser punctures of *T. tsoui* sp. nov. In addition, most genitalic characters of this

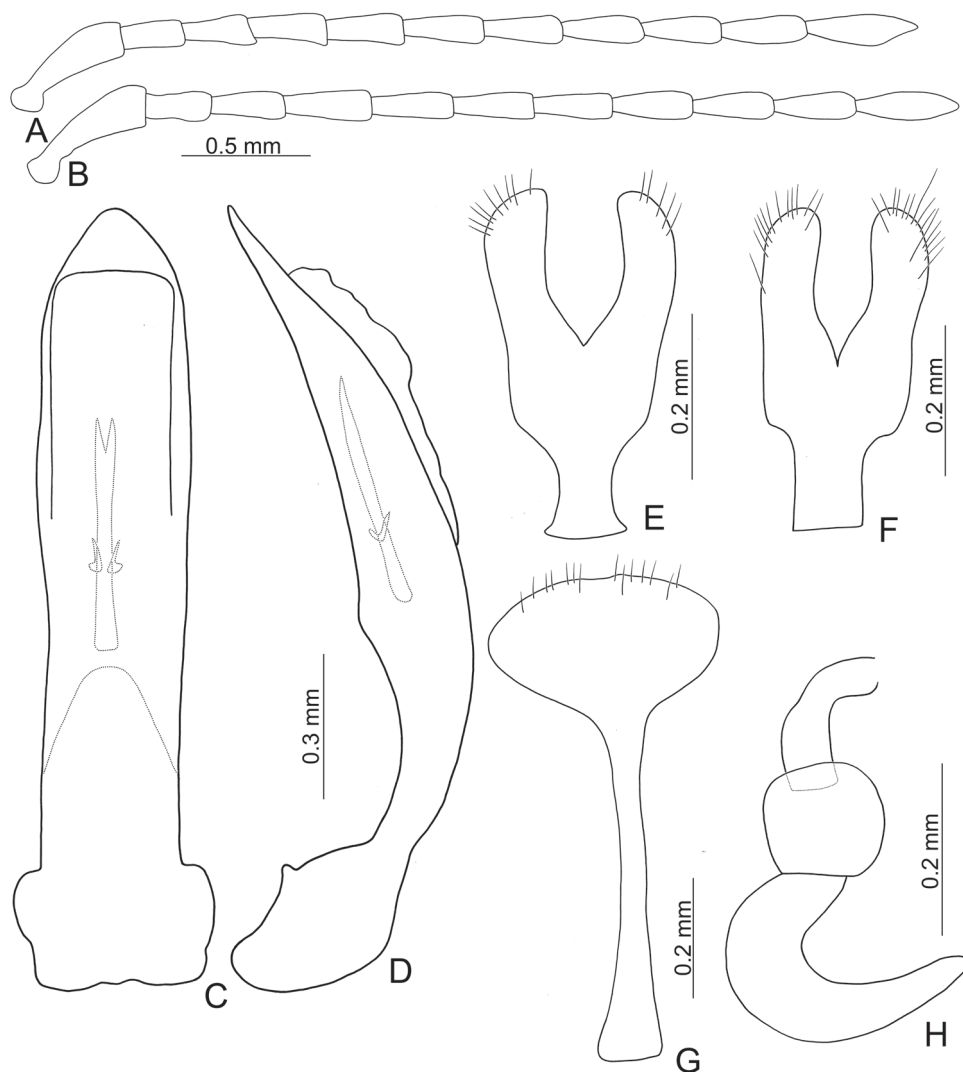


Figure 4. Diagnostic characters of *Taiwanoshaira chujoi* comb. nov. **A** antenna, male **B** antenna, female **C** penis, dorsal view **D** penis, lateral view **E** gonocoxae, from Tapan (達邦) **F** gonocoxae, from Pilu (碧綠) **G** abdominal ventrite VIII **H** spermatheca.

species are diagnostic, including the slightly curved penis (Fig. 4C, D) (moderately curved (Fig. 8C, D) in *T. tsoui* sp. nov.), wider base of gonocoxae (Fig. 4E–F) (narrower base of gonocoxae (Fig. 8M, N) in *T. tsoui* sp. nov.), and longer, slender spermathecal pump (Fig. 4H) (shorter, wider spermathecal pump (Fig. 8Q) in *T. tsoui* sp. nov.).

Host plants. Probably some species of moss, currently unknown (Fig. 1B).

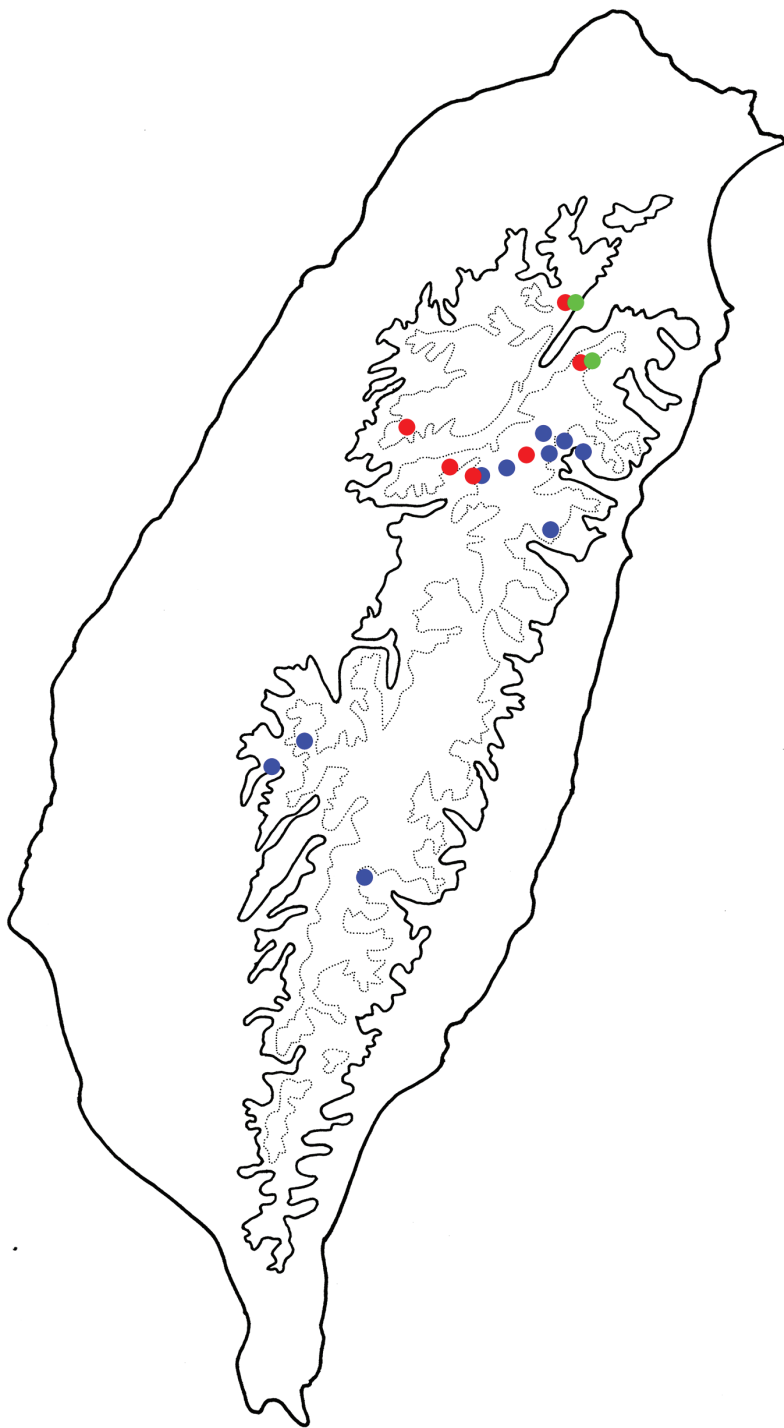


Figure 5. Distribution map of *Taiwanoshaira* species, solid line: 1000 m, broken line: 2000 m. **Blue Dots** *T. chuioi* comb. nov. **Red Dots** *T. tsoui* sp. nov. **Green Dots** *T. taipingshanensis* sp. nov.

Distribution. South and central Taiwan (Fig. 5). This species is sympatric with *T. tsoui* sp. nov. at Meifeng (梅峰).

***Taiwanoshaira taipingshanensis* sp. nov.**

<http://zoobank.org/1AE3EA77-43D4-420C-A3F3-E92F3CA65A9B>

Figures 6A–C, 7

Types ($N=77$). **Holotype** ♂ (TARI): TAIWAN. Ilan: Taipingshan (太平山), 5.VIII.2015, leg. Y.-T. Chung. **Paratypes.** 5♂♂, 15♀♀ (TARI), same as holotype; 10♂♂, 16♀♀ (TARI), Yuanyanhu (鴛鴦湖), 19.VIII.2010, leg. S.-S. Li; 4♂♂, 5♀♀ (TARI), same locality, 22.VIII.2011, leg. C.-F. Lee; 2♂♂, 8♀♀ (2♀♀: TARI; 2♂♂, 2♀♀: RBCN), same but with “leg. M.-H. Tsou”; 5♂♂, 6♀♀ (TARI), same but with “leg. H. Lee”.

Description. Length 4.0–5.7 mm, width 2.6–3.4 mm. General color dark brown or blackish-brown (Fig. 6A–C). Antenna (Fig. 7A) filiform in males, ratios of lengths of antennomeres I to XI 1.0 : 0.5 : 0.6 : 0.7 : 0.7 : 0.7 : 0.7 : 0.7 : 0.6 : 0.7 : 0.8; ratios of lengths to widths from antennomeres I to XI 3.0 : 2.0 : 2.2 : 3.0 : 3.2 : 3.2 : 3.3 : 3.5 : 3.0 : 3.1 : 3.4; similar in females, ratio of lengths of antennomeres I to XI (Fig. 7B) 1.0 : 0.4 : 0.5 : 0.8 : 0.7 : 0.7 : 0.7 : 0.7 : 0.7 : 0.7 : 0.8; ratios of lengths to widths from antennomeres I to XI 3.4 : 2.3 : 2.3 : 3.9 : 3.7 : 3.7 : 4.0 : 3.7 : 3.4 : 3.5 : 4.2. Pronotum 1.61–1.63 times wider than long; lateral margins slightly rounded; disc with fine punctures bearing tiny setae. Procoxal cavities almost closed. Elytra 1.11–1.20 times longer than wide; disc with dense, coarse punctures and longitudinal ridges not covered with punctures; apices tapering in both sexes. Tarsomeres I of front legs slightly swollen in males, not modified in females. Penis (Fig. 7C–E) wide, about 5.5 times longer than wide; parallel sided and strongly curved in lateral view, apex narrowly rounded, base with shallow median notch; tectum broad from apical 1/6 to middle, apex truncate; ventral surface with large opening. Endophallic spiculae complex (Fig. 7F, G) with median endophallic spiculae slender, apically bifurcate, and straight in lateral view; with one pair of small sclerites near base. Gonocoxae (Fig. 7H, I) short; apex of each gonocoxa widely rounded, with eight to ten long setae along apical margin, basal margin irregular. Ventricle VIII (Fig. 7J, K) short and well sclerotized, with several short setae along apical margin, spiculum long. Spermathecal receptaculum (Fig. 7L) strongly swollen; pump extremely slender and curved; sclerotized spermathecal duct long.

Variation. Female genitalic characters are variable among different localities. The apices of the gonocoxae are widely rounded in specimens from Taipingshan (太平山) (Fig. 7I) but tapering in those from Yuanyanhu (鴛鴦湖) (Fig. 7H). The apex of abdominal ventrite VIII is shorter in specimens from Taipingshan (Fig. 7K) than those from Yuanyanhu (Fig. 7J).

Diagnosis. *Taiwanoshaira taipingshanensis* sp. nov. is easily separated from other congeners by the presence of longitudinal ridges on the elytra (Fig. 6A, C) (lacking longitudinal ridges in others (Figs 3A, C–D, F; 6D, F)), almost closed procoxal cavities (Fig. 2A) (widely open procoxal cavities (Fig. 2B) in others), entirely black legs (Fig.



Figure 6. Habitus of *Taiwanoshaira taipingshanensis* sp. nov. and *T. tsoui* sp. nov. **A** *T. taipingshanensis* sp. nov., male, dorsal view **B** same, ventral view **C** same, female, dorsal view **D** *T. tsoui* sp. nov., male, dorsal view **E** same, ventral view **F** same, female, dorsal view.

6A–C) (yellowish-brown legs with dark apices of femora and bases of tibiae in others (Figs 3, 6D–F)), sexually dimorphic protarsi I (uniform protarsi I in both sexes of others), tapering elytral apices of both sexes (Fig. 6A–C) (tapering elytra apices in only males of others (Figs 3, 6D–F)). In addition, most genitalic characters of this new species are diagnostic, including the extremely strongly curved penis (Fig. 7C–E) (moderately

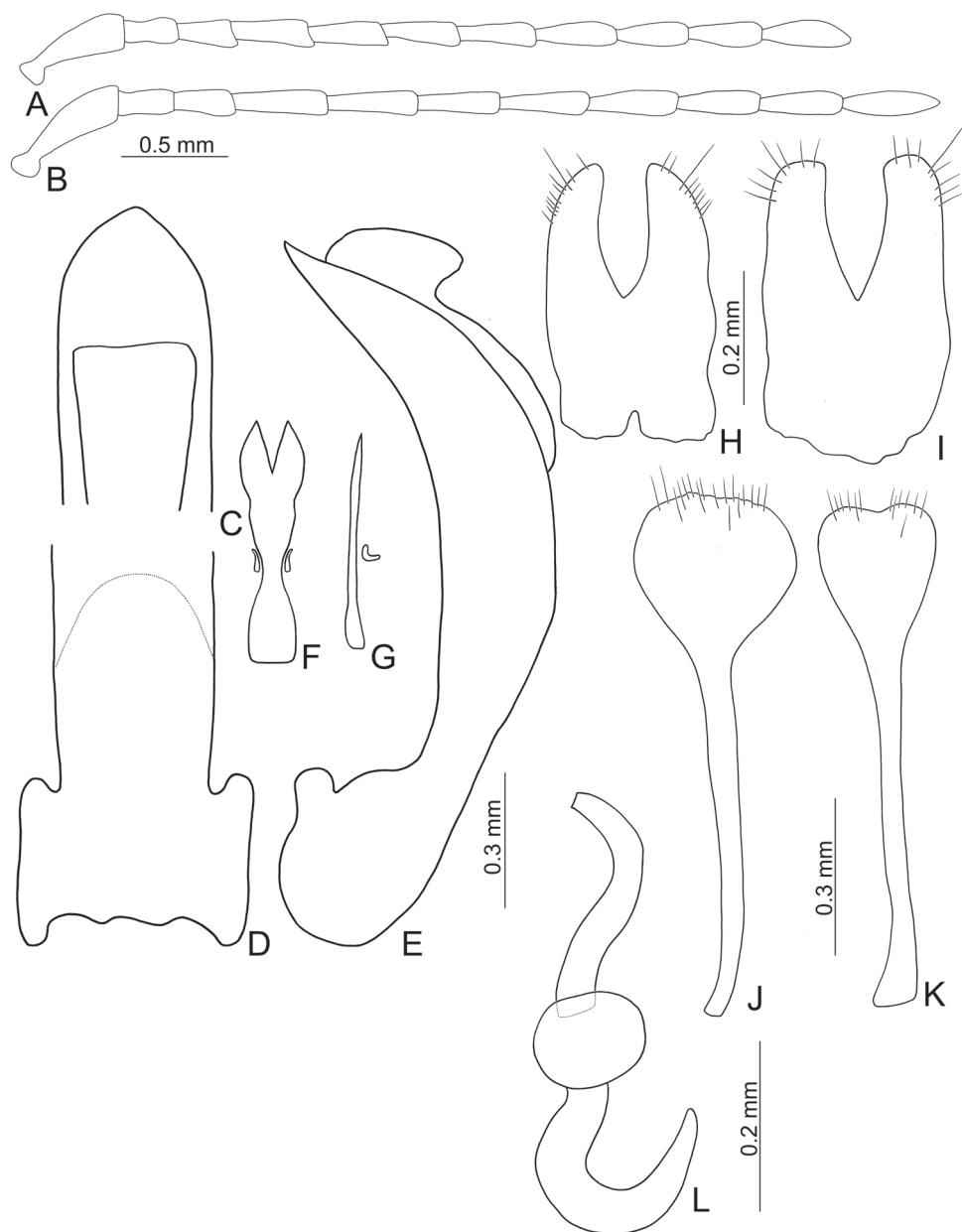


Figure 7. Diagnostic characters of *Taiwanoshaira taipingshanensis* sp. nov. **A** antenna, male **B** antenna, female **C** penis, apex, dorsal view **D** penis, base, dorsal view **E** penis, lateral view **F** endophallic sclerites, dorsal view **G** ditto, lateral view **H** gonocoxae, from Yuanyanghu (鸞鸞湖) **I** same, from Taipingshan (太平山) **J** abdominal ventrite VIII, from Yuanyanghu (鸞鸞湖) **K** same, from Taipingshan (太平山) **L** spermatheca.

or slightly curved in others (Figs 4C, D; 8C, D), irregular base of gonocoxae (Fig. 7H, I) (narrowed base of gonocoxae in others (Figs 4E, F; 8M, N)), and long sclerotized spermathecal duct (Fig. 7L) (short sclerotized spermathecal duct in others (Figs 4H, 8Q)).

Host plants. Mniaceae: *Plagiomnium vesicatum* (Besch.) T.J. Kop. We observed that adults fed on leaves of host plants (Fig. 1C, D).

Etymology. This new species is named for its type locality.

Distribution. Known from two localities in northern Taiwan (Fig. 5). This new species is sympatric with *T. tsoui* sp. nov.

***Taiwanoshaira tsoui* sp. nov.**

<http://zoobank.org/8B744065-FF3A-41D4-ADD4-9952A41D0D7F>

Figures 6D–F, 8

Types ($N = 54$). **Holotype** ♂ (TARI): TAIWAN. Nantou: Hsiaofengkou (小風口), 9.VIII.2012, leg. C.-F. Lee. **Paratypes.** 14♂♂, 21♀♀ (12♂♂, 19♀♀ TARI; 2♂♂, 2♀♀ RBCN), same data as holotype; 7♂♂, 6♀♀ (TARI), same but with “leg. T.-H. Lee”; 2♂♂, 2♀♀ (TARI), same locality, 29.VII.2014, leg. C.-F. Lee; 1♀ (NMNS), same locality, 23.VI.–24.VIII.2009, leg. W. T. Yang & K. W. Huang; 1♂, 3♀♀ (NMNS), same locality, 24.VIII.–24.IX.2009, leg. W. T. Yang & K. W. Huang; Ilan: 2♂♂, 1♀ (TARI), Taipingshan (太平山), 5.VIII.2015, leg. Y.-T. Chung; 1♀ (TARI), Yuanyanghu (鴛鴦湖), 19.VIII.2010, leg. S.-S. Li; Nantou: 1♀ (TARI), Meifeng (梅峰), 11.VI.2014, leg. C.-F. Lee; 1♂ (TARI), same locality, 29.VII.2014, leg. C.-F. Lee; 9♂♂, 2♀♀ (TARI), Peitungyanshan (北東眼山), 3.VII.2014, leg. C.-F. Lee; Taichung: 8♂♂, 4♀♀ (TARI), Tahsuehshan (大雪山), 2.VIII.2019, leg. B.-X. Guo.

Description. Length 4.1–4.8 mm, width 2.5–2.9 mm. General color dark brown or blackish-brown (Fig. 6D–F); each antennomere basally paler; margins of pronotum and elytra, including suture yellowish-brown; legs yellowish-brown but apices of femora and bases of tibiae dark brown. Antennae (Fig. 8A) filiform in males, ratio of lengths of antennomeres I to XI 1.0 : 0.5 : 0.5 : 0.5 : 0.5 : 0.6 : 0.7 : 0.6 : 0.6 : 0.6 : 0.7; ratios of lengths to widths from antennomeres I to XI 3.3 : 2.2 : 2.3 : 2.2 : 2.5 : 2.7 : 3.1 : 2.8 : 2.8 : 2.7 : 3.2; similar in females, ratio of lengths of antennomeres I to XI (Fig. 8B) 1.0 : 0.5 : 0.5 : 0.5 : 0.5 : 0.5 : 0.5 : 0.5 : 0.5 : 0.5 : 0.7; ratios of lengths to widths from antennomeres I to XI 3.2 : 2.1 : 2.0 : 2.4 : 2.5 : 2.7 : 2.6 : 2.4 : 2.4 : 2.4 : 2.7. Pronotum 1.63–1.68 times wider than long; lateral margins moderately rounded; disc with fine punctures bearing tiny setae. Procoxal cavities widely open. Elytra 1.17–1.26 times longer than wide; disc with sparse, confused, fine punctures; apices tapering in males, but widely rounded in females. Protarsomeres I not sexually dimorphic. Penis (Fig. 8C, D) wide, about 5.6 times longer than wide; parallel sided and moderately curved in lateral view, apex narrowly rounded, base with shallow median notch; tectum broad from apical 1/6 to middle, apex truncate; ventral surface with large opening. Endophallic spiculae complex with median endophallic spiculae extremely slender, apically curved in lateral view; with one pair of small sclerites near base. Gonocoxae (Fig. 8M, N) short; apex of each gonocoxa widely rounded, with eight to 11 long setae along apical margin, basally narrowed. Ventrite VIII (Fig. 8O, P) short and well sclerotized, with several short setae along apical margin, spiculum short. Spermathecal receptaculum (Fig. 8Q) swollen; pump slender and curved; sclerotized spermathecal duct short.

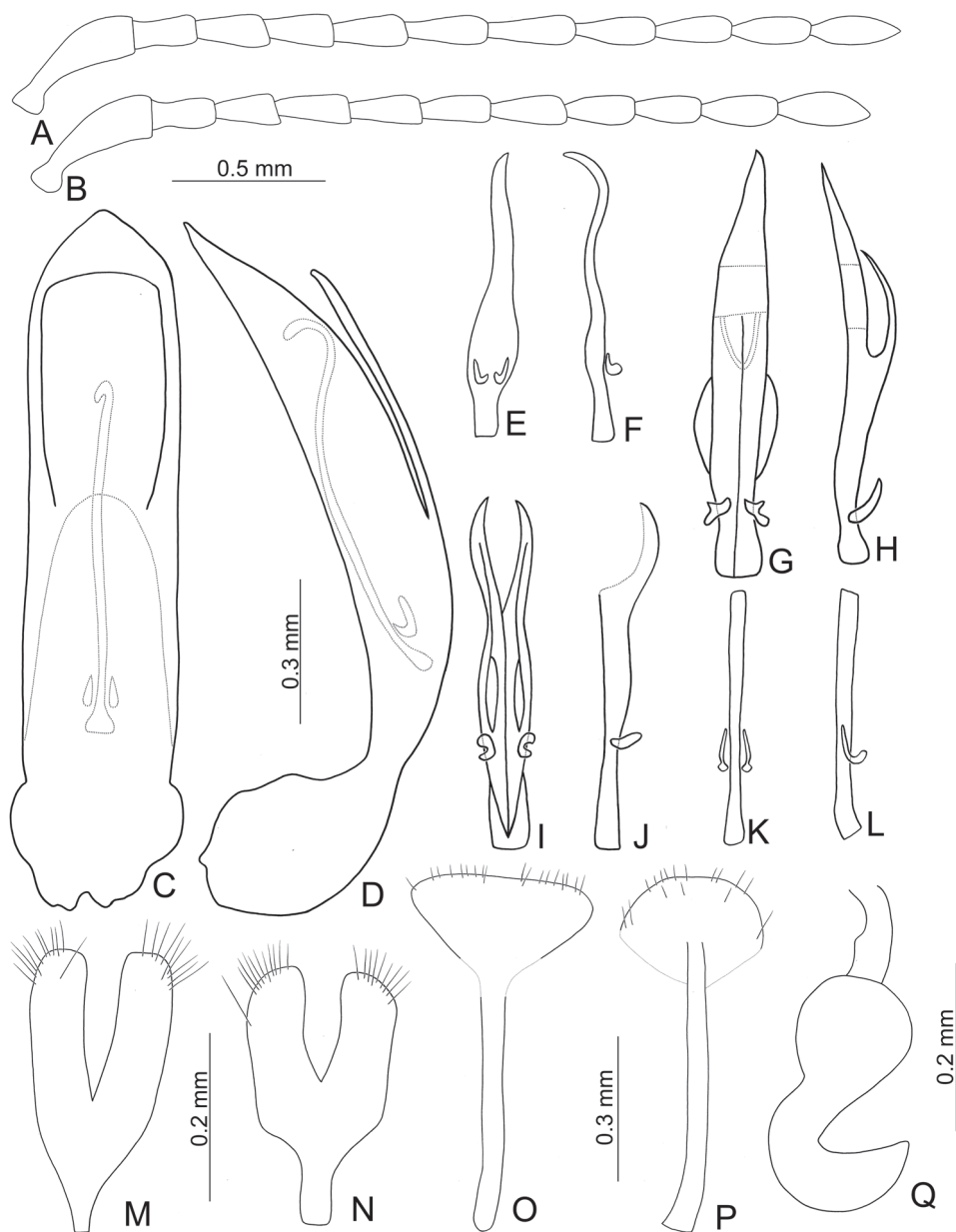


Figure 8. Diagnostic characters of *Taiwanoshaira tsoui* sp. nov. **A** antenna, male **B** antenna, female **C** penis, dorsal view **D** penis, lateral view **E** endophallic sclerites, from Meifeng (梅峰), dorsal view **F** ditto, lateral view **G** same, from Peitungyanshan (北東眼山), dorsal **H** ditto, lateral view **I** samel, from Tahsuehshan (大雪山), **J** ditto, lateral view **K** same, from Taipingshan (太平山), dorsal **L** ditto, lateral view **M** gonocoxae, from Hsiaofengkou (小風口) **N** same, from Taipingshan (太平山) **O** abdominal ventrite VIII, from Peitungyanshan (北東眼山) **P** same, from Taipingshan (太平山) **Q** spermatheca.

Variation. Specimens from Hsiaofengkou (小風口) have paler bodies and shorter antenna than others. The endophallic spiculae complexes are variable among localities:

subbases of endophallic spiculae are shorter and wider in specimens from Meifeng (梅峰) (Fig. 8E, F); similar to those from Meifeng but with a median membranous area and straight apex in specimens from Peitungyanshan (北東眼山) (Fig. 8G, H); similar to those in Peitungyangshan, but with bifurcate apices in specimens from Tahsuehshan (大雪山) (Fig. 8I, J); specimens from Taipingshan (太平山) (Fig. 8K, L) possess more slender median endophallic spiculae than those from Hsiaoengkou and shorter more truncate apices. Females from Hsiaoengkou have gradually narrowed bases of the gonocoxae (Fig. 8M) that differ from those with strongly narrowed bases in others (Fig. 8N). Females from Taipingshan have narrower apices of abdominal ventrites VIII (Fig. 8P) than others (Fig. 8O). It raises the question whether such variations of endophallic spiculae complexes at different localities indicate interspecific differentiation since endophallic sclerites are usually very consistent within a species. The problem needs further study by collecting more material from additional localities and combined with molecular study.

Diagnosis. Adults of *T. tsoui* sp. nov. are similar to those of *T. chujoi* (Kimoto) comb. nov. in sharing the following characters: elytra smooth and lacking longitudinal ridges (Figs 3A, C, D, F; 6D, F) (presence of the longitudinal ridges on elytra (Fig. 6A, C) in *T. taipingshanensis* sp. nov.), widely open procoxal cavities (Fig. 2B) (almost closed procoxal cavities (Fig. 2A) in *T. taipingshanensis* sp. nov.), yellowish-brown legs with dark apices of femora and bases of tibiae (Figs 3, 6D–F) (entirely black legs (Fig. 6A–C) in *T. taipingshanensis* sp. nov.), uniform protarsi I in both sexes (sexually dimorphic protarsi I in *T. taipingshanensis* sp. nov.), tapering elytra apices only in males (Figs 3, 6D–F) (tapering elytral apices of both sexes (Fig. 6A–C) in *T. taipingshanensis* sp. nov.). Adults of *T. tsoui* sp. nov. differ from those of *T. chujoi* comb. nov. by possessing yellowish-brown sutures and margins with black or blackish-brown elytra having punctures more sparse (Fig. 6D, F), in contrast to black or blackish elytra (Fig. 3A, C) with denser punctures in *T. chujoi* comb. nov. In addition, most genitalic characters of this species are diagnostic, including moderately curved penis (Fig. 8C, D) (slightly curved (Fig. 4C, D) in *T. chujoi* comb. nov.), narrower base of gonocoxae (Fig. 8M, N) (wider base of gonocoxae (Fig. 4E, F) in *T. chujoi* comb. nov.), and shorter spermathecal pump (Fig. 8Q) (much longer pump (Fig. 4H) in *T. chujoi* comb. nov.).

Food plants. Probably some species of moss, currently unknown (Fig. 1E, F).

Etymology. This new species is dedicated to Mei-Hua Tsou, a member of TCRT and the first to collect this new species.

Distribution. Northern and central Taiwan (Fig. 5). It is sympatric with *T. taipingshanensis* sp. nov. at Yuanyanahu (鴛鴦湖) and Taipingshan (太平山), and with *T. chujoi* comb. nov. at Meifeng (梅峰).

Key to species of the new genus *Taiwanoshaira*

- 1 Elytra with longitudinal ridges, apically narrowed in both sexes (Fig. 6A, C); procoxal cavities almost closed (Fig. 2A); legs entirely black or blackish (Fig. 6A–C), protarsi I swollen in males.....*T. taipingshanensis* sp. nov.
- Elytra smooth, without longitudinal ridges, apically narrowed in males but widely rounded in females (Figs 3, 6D, F); procoxal cavities widely open

- (Fig. 2B); legs yellowish-brown but apices of femora and bases of tibiae darker (Figs 3, 6D–F), protarsi I not modified in either sex **2**
- 2 Elytra entirely black (Fig. 3A, C, D, F), punctures on disc denser ***T. chujoi* (Kimoto) comb. nov.**
- Elytra with yellowish-brown sides and suture (Fig. 6D, F), punctures on disc sparser ***T. tsoui* sp. nov.**

Discussion

Mosses are common all over Taiwan since it is a country with high humidity. They are most dominant in cloud forests. The montane cloud forest of Taiwan was mapped using 12-year MODIS-derived ground fog frequency data (Schulz et al. 2017). It covers most montane areas above 1000 m altitude. However, species of *Taiwanoshaira* are restricted to limited areas based on TCRT's collecting experience. Moreover, they were absent at some localities where they were recorded 40 years ago, such as Tapan (達邦) and Alishan (阿里山) for *T. chujoi* comb. nov. They are currently common at only a few places, including Yuanyang Lake (鴛鴦湖), Hsiao Fengkou (小風口), and Bilu Divine Tree (碧綠神木). Of these localities, the climatic characters of the cloud forest at Yuanyang Lake (鴛鴦湖) was studied from 1994 to 2004 (Lai et al. 2006). This site (24°N, 121°24'E) is situated in Chi-Lan Mountain at an elevation of 1650 to 2420 m above sea level. The annual mean air temperature was 12.7 °C. The lowest mean monthly temperature was during February (monthly mean 5.9 °C), and the highest during July (month mean 18.1 °C). Winter featured light rain with a prolonged occurrence of fog, resulting in a large reduction of solar radiation. In summer, fog typically occurred during early morning and again from afternoon to evening. The latter was associated with wind direction changes and was usually accompanied by short moderate to heavy convective rain. The relative humidity was usually higher than 90%. The annual precipitation varied between 2109 mm (in 1995) and 4727 mm (in 2001), with an average of 3396 mm. On average, there were 239 rainy days per year. These climatic characteristics indicate that *Taiwanoshaira* species occur in microhabitats with high humidity year round. Adults of *Taiwanoshaira* were almost absent in south Taiwan except that one specimen was collected at Liyuan (栗園), Taitung county. This implies that the species might not survive in places where the climate has changed greatly, even though mosses persist and grow well.

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A note on the larva of *Chalcophora japonica chinensis* (Coleoptera, Buprestidae) based on morphological characters and molecular data

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Abstract

Larvae of *Chalcophora japonica chinensis* Schauffuss, 1879 were collected from within dead trunks in Hubei Province, China, in February 2019. These specimens created an opportunity to provide the first description of the larval stage of this subspecies; The larva is described and illustrated based on morphological characters and DNA barcoding.

Keywords

Chalcophora, China, DNA marker, jewel beetles, larval morphology

Introduction

To date, nine species and 24 subspecies of the genus *Chalcophora* Dejean, 1833 have been distributed from Palearctic region. Of these, two species and seven subspecies have been recorded from China (Kubáň 2016). The larva of *Chalcophora virginienensis* (Drury, 1770), a North American species (Maier and Ivie 2013), was simply illustrated by Böving and Craighead (1931), who provided only three simple drawings, without a detailed description. Subsequently, the larvae of three *Chalcophora* species were de-

scribed from the Palaearctic region and the interspecific differences of larval morphology were summarized by Bílý (1984). The taxonomic characters of larvae of known chalcophine genera were summarized by Bílý and Volkovitsh (2003).

Larvae of *Chalcophora* differ from known chalcophorine larvae by the following characters, as summarized by Bílý and Volkovitsh (2002, 2003): (1) anterior margin of labium with narrow microsetal area; (2) isolated sclerite of maxillary cardo with two short setae and five campaniform sensilla; (3) anterior sclerotized area of pronotal groove umbrella-shaped, transverse, with broadly rounded anterior margin.

Recently, DNA barcodes and markers have been used as an alternative approach for identification of arthropod stages, such as the identification of immature terrestrial (Caterino and Tishechkin 2006; Ekrem et al. 2007; Andrić et al. 2014) and aquatic arthropods (Miller et al. 2005). The complete mitochondrial genome of *Chrysochroa fulgidissima* has been determined by Hong et al. (2009).

Herein, we provide a morphological description and DNA barcoding of the larva of *Chalcophora japonica chinensis* Schauffuss, 1879.

Materials and methods

The specimens were examined using a Nikon SMZ800 stereomicroscope. The habitus images were taken using a Canon EOS 5D camera combined with a Canon MP-E65 mm macro lens.

The total genomic DNA was extracted from larval and adult tissues using EZNA Insect DNA Kit (Omega Bio-tek, USA). One fragment of the mitochondrial protein-coding gene (COI) was amplified from both larva and adult. The DNA barcode region (Hebert et al. 2003) was amplified using primers LCO1490 and HCO2198 (Folmer et al. 1994). The dataset used contained *Chrysochroa fulgidissima* (GenBank 7944365) as the outgroup. Sequences were aligned using the ClustalW algorithm (Thompson et al. 1994), as implemented in BioEdit v. 7.0.9.0. (Hall 1999). The maximum likelihood tree was constructed using the GTR+R model in Mega v. 6.06. The examined specimens are deposited in the China West Normal University (CWNU). Three adult specimens of *Chalcophora yunnana yunnana* were collected from Yingjiang of Yunnan province. The morphological terminology follows that used in the papers of Volkovitsh and Bílý (1997, 2001) and Bílý and Volkovitsh (2002, 2003).

Taxonomy

Key to known larvae of *Chalcophora* from Asia

- 1 Pronotal and prosternal asperate area consisting of transverse, short asperities and wrinkles 2

- Pronotal and prosternal asperate area consisting of transverse, long or elongate asperities and lines **3**
- 2 Y-shaped pronotal grooves with shorter branches, angle between branches about 30°, branches 1.3 times as long as common part; anterior margin of labrum slightly emarginate (Fig. 3C) ***C. intermedia***
- Y-shaped pronotal grooves with longer branches, angle between branches about 30°, branches 2.5 times as long as common part; anterior margin of labrum slightly arcuate (Fig. 3B) ***C. mariana***
- 3 Y-shaped pronotal grooves slightly bent at middle, angle between branches about 25°, branches 2.3 times as long as common part (Fig. 3A) ***C. detrita***
- Y-shaped pronotal grooves straight, angle between branches about 23°, branches 2.5 times as long as common part (Fig. 3D) ***C. japonica chinensis***

***Chalcophora japonica chinensis* Schaufuss, 1879**

Figures 1B, C, 2A–K, 3D

Chalcophora chinensis Schaufuss, 1879: 480; Fairmaire 1888: 25; Kurosawa 1974: 174.
Buprestis sinica Jakobson, 1913: 780.

Distribution. China (Anhui, Fujian, Guangdong, Guangxi, Henan, Hong Kong, Hubei, Hunan, Jiangsu, Jiangxi, Sichuan, Zhejiang provinces).

Larval description. The description is based on what is probably two later-instar larvae. Body length 42.0–52.1 mm; width of prothorax 10.3–11.6 mm. Larval body shape of buprestid type. Body elongate (Fig. 1B, C); prothorax widest, distinctly wider than meso- and metathorax; abdomen nearly parallel-sided. Mouthparts brown; mandibles black; dorsal and ventral prothoracic plates yellow-brown; abdomen light brown (white when alive). Body with sparse, short, brownish setae. Thoracic legs absent.

Head. Head prognathous (Fig. 2A, G), with mouthparts directed anteriorly, head capsule deeply retracted into prothorax. Stemmata absent.

Labrum (Fig. 2A, G) distinctly transverse, 2.1 times as wide as long; anterior margin and isolated patches on lateral lobes bearing dense microsetae, middle parts slightly arched, anterolateral lobes well developed; lateral sides slightly arched; posterior margin (covered by nearly pellucid membranous anteclypeus) slightly narrower than anterior margin; dorsal surface glabrous; medial group of sensilla consists of one apical seta and two lateral campaniform sensilla; apical seta not reaching anterior margin; anterolateral sensilla consists of two trichoid sensillae.

Anteclypeus (Fig. 2A, G) trapezoid, short, strongly transverse, 5.6 times as wide as long, membranous, glabrous; anterior margin nearly straight, weakly emarginate at middle; lateral sides distinctly arched.

Epistome (Fig. 2A, G) strongly transverse, approximately 3.3 as wide as long; anterior parts dark brown, well sclerotized, posterior part brown, moderately sclerotized; lateral parts of anterior margin distinctly protruded anteriorly, middle parts distinctly

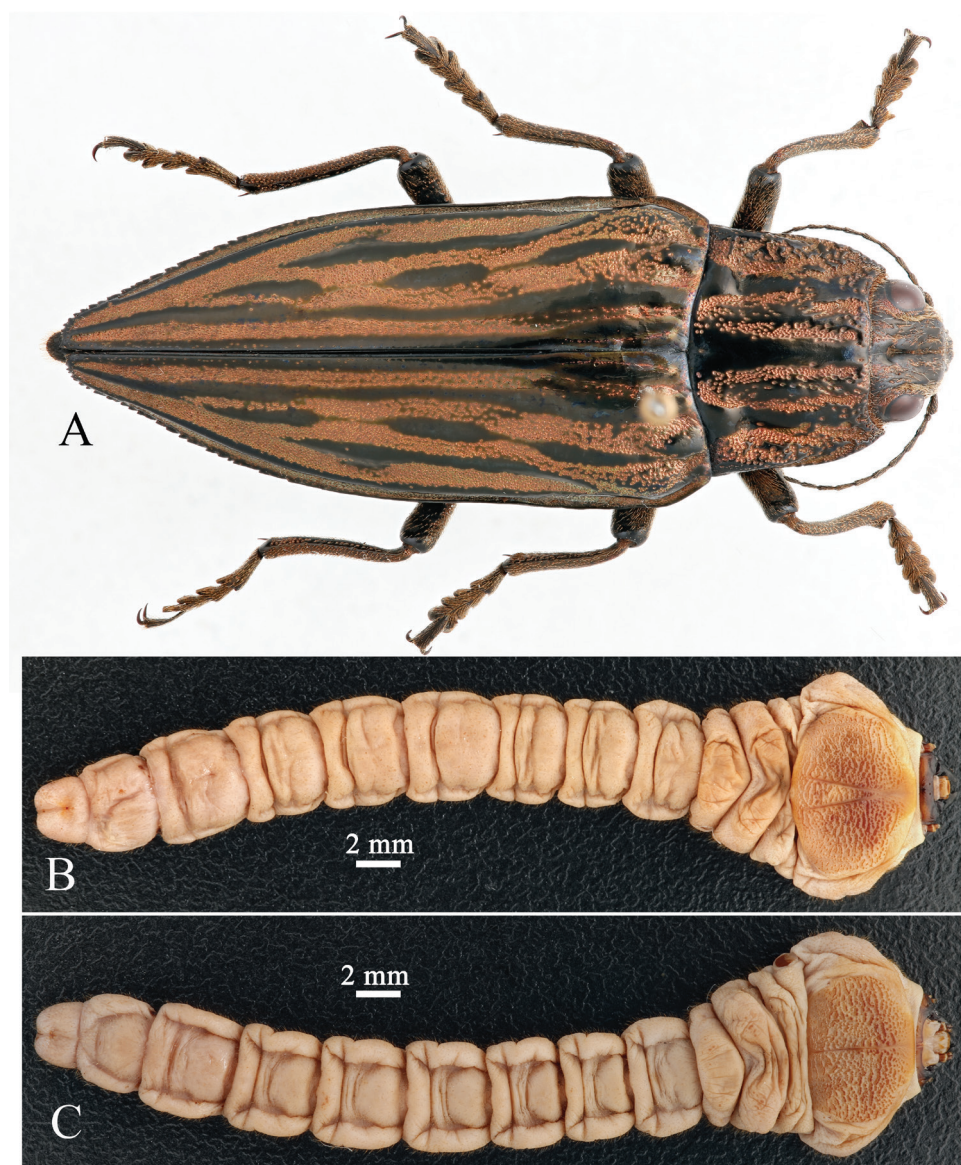


Figure 1. Habitus of *Chalcophora japonica chinensis* (Schaufuss, 1879) **A** adult, in dorsal view **B** larva, in dorsal view **C** larva in ventral view.

emarginate; lateral sides bent; surface with two groups of short trichosensillae situated in shallow depressions in middle parts.

Antennae (Fig. 2C, J) two-segmented, situated in deep incision, first antennomere approximately 1.8 times as long as second, approximately 1.2 times as long as wide, barrel-shaped, glabrous except anterior margin with dense microsetae; second antennomere distinctly shorter and narrower, nearly as long as wide, distinctly expanded an-

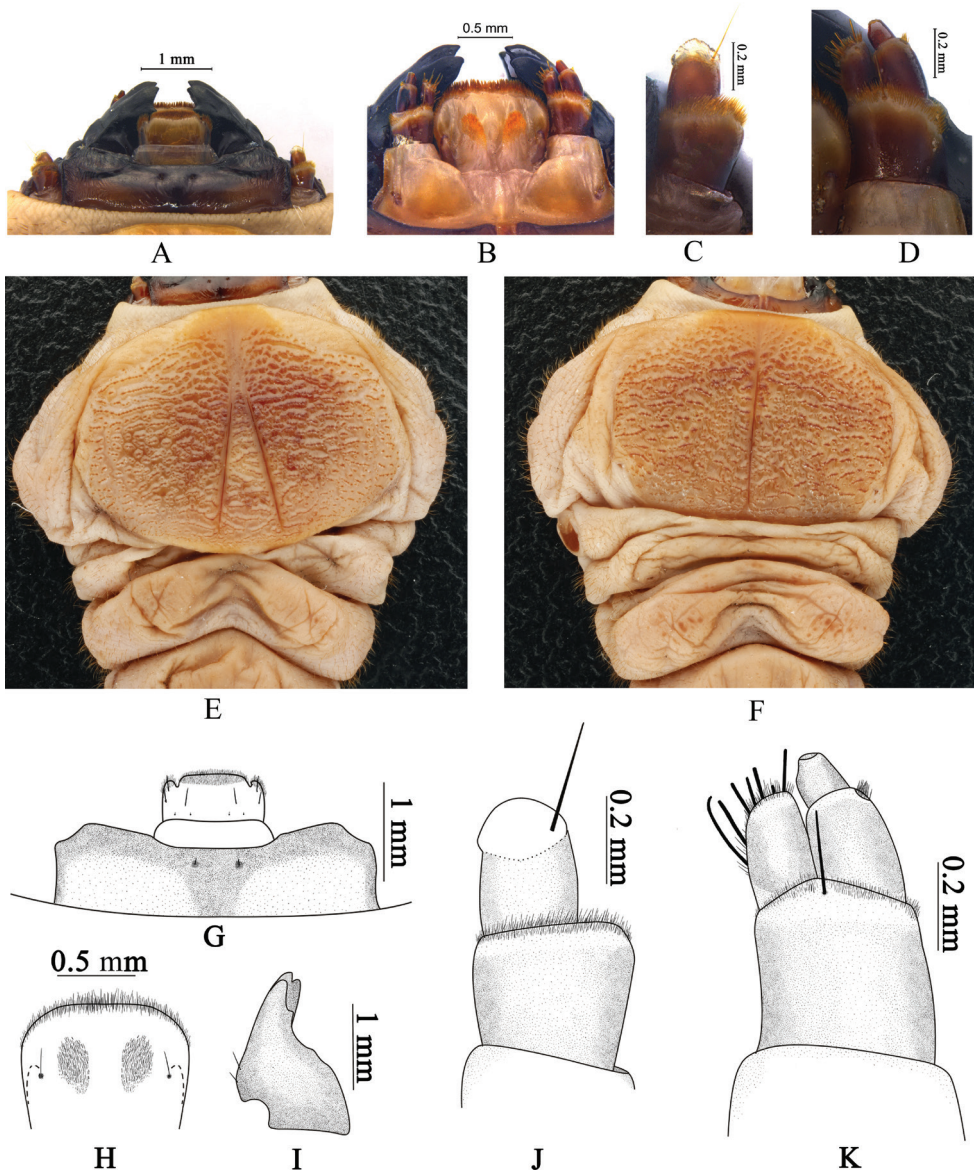
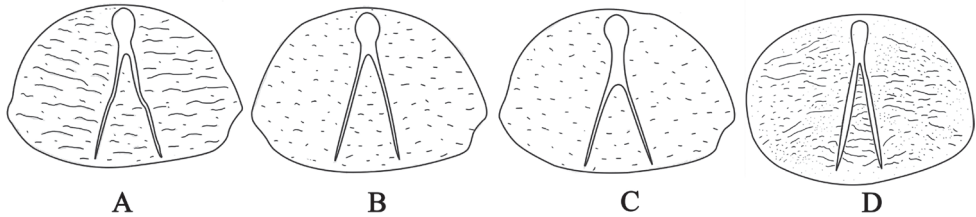


Figure 2. Larval morphology of *Chalcophora japonica chinensis* Schaufuss, 1879 **A, G** epistome and mouth parts, in dorsal view **B** mouth parts, in ventral view **C, J** antenna **D, K** maxilla, in ventral view **E, F** thorax, in dorsal and ventral views **H** prementum **I** left mandible.

teriorly, anterior parts transparent membranous, glabrous; apical cavity deep, bearing a long erect trichosensillum, slightly longer than second antennomere.

Mandibles (Fig. 2A, I) triangular, strongly sclerotized, black, approximately 1.1 times as long as wide; middle of incisor edge with an additional tooth; outer margin with one short erected seta above condyle.

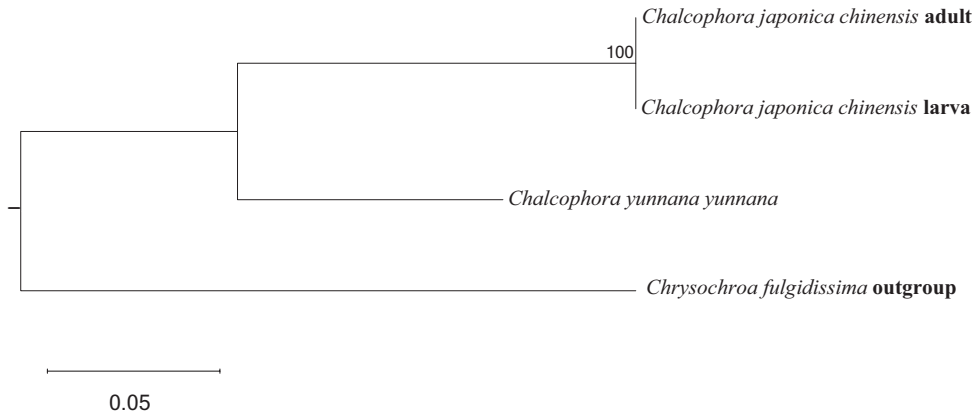


Figures 3. Larval pronotal plate of *Chalcophora* species (**A–C** from Bílý 1984) **A** *C. detrita* **B** *C. mariana* **C** *C. intermedia* **D** *C. japonica chinensis*.

Maxillae (Fig. 2B, D, K). Cardio transverse, subquadrate, widest at base, approximately 2.8 times as wide as long, glabrous; latero-basal sclerite of cardo sclerotized, with five campaniform sensillae bearing two short, erect, brown setae. Stipes subquadrate, distinctly wider than long. First palpomere of palpus maxillaris approximately 1.8 times as long as second palpomere, barrel-shaped, distinctly longitudinal, glabrous, outer parts of apical margin with a few microsetae; second palpomere distinctly narrower, glabrous, subcylindrical, approximately 1.4 times as long as wide. Mala elongate, approximately 1.8 times as long as wide, external sensilla of apex composed of one campaniform sensillum, one short, peg-like seta, five long, robust setae, and a few microsetae; internally with three short, robust setae and a few microsetae along inner side. Prementum (Fig. 2H) trapezoidal, anterior margin arcuate and wider than base, with surface bearing two microsetal zones in middle parts and two long setae near sides of middle parts.

Thorax (Figs 2E, F, 3D). Prothorax strongly expanded, widest at middle, approximately 1.7 times as long as total length of meso- and metathorax, approximately 1.7 times as wide as long; dorsal and ventral plates moderately sclerotized, strongly flattened, with transversely prolonged asperities and short winks; dorsal plate with inverted Y-shaped groove with long, straight branches; angle between branches about 23°; branches 2.5 times as long as common part; anterior sclerotized part nearly umbrella-shaped, with rounded anterior margin; ventral plate with uniramous groove; lateral parts bearing short, brownish setae. Mesothorax nearly an inverted trapezoid, widest at anterior margin, approximately 4.5 times as wide as long; surface bearing short, brownish setae; spiracles cribriform, reniform, strongly transverse, much larger than those of abdomen, approximate 2.2 times as wide as long, situated on sides of anterior parts; surface with dense, longitudinal, straight lines. Metathorax nearly an inverted trapezoid, widest at middle, approximately 2.2 times as wide as long; middle part of anterior margin distinctly protruded anteriorly; posterior margins distinctly emarginate; surface bearing sparse, short, brownish setae.

Abdomen. All segments transverse, slightly wider than long; surfaces of all segments with sparse, short, brownish setae; all dorsal parts of segments distinctly convex; dorsal parts of segments II–VIII each with distinctly transverse, deep groove on posterior parts; dorsal parts of segment IX with transverse, shallow groove before the base. Segment I nearly subtriangular, widest behind middle, approximately 2.3 times as wide as long; anterior margin distinctly protruded anteriorly; surface of dorsal parts with a few longitudinal



Figures 4. Maximum Likelihood tree of *Chalcophora* from China based on COI.

wrinkles. Segments II–IX subquadrate, approximately 1.2–2.3 times as wide as long; segment X well developed and posteriorly oriented, with paired, oval lobes divided by longitudinal, shallow anal cleft. Segments I–VIII with large spiracles, gradually becoming smaller posteriorly, spiracles of segment VIII smallest; segments IX and X without spiracles.

Specimens examined. Larvae: 2 ex., China, Hubei, Xiangyang, Baokang, Chengdong, Mingjiachang, 15-II-2019, Jie Deng leg., CWNU, taken from the stems of dead tree. **Adults:** 5♂ 5♀, China, Guannxi, Guilin, Ziyuanzhongfeng, 26-VII-2018, Yulong Huang leg., CWNU; 1♂ 1♀, Guangdong, Wengyuan, Nanpu, 5-X-2019, Hua Zhang leg., CWNU; 1♂, China, Jiangsu, Nangjiang, Zhongshanling, 18-IV-2019, Zhixin Chou, CWNU.

Results and discussion

There are two species and seven subspecies of *Chalcophora* recorded from China, accounting for 29% of the species known in the Palaearctic Region. Recently, some buprestids, including chalcophorine larvae, were described by Bílý and Volkovitsh (2002, 2003, 2005), Volkovitsh and Bílý (2001, 2015), and Bílý et al. (2013). In this study, data supporting the utility of COI sequences analysis is provided for identifying species at developmental larval stages. The larval COI sequence clustered together with the adult *C. japonica chinensis* sequences with high bootstrap support (Fig. 4), enabling us to identify the larvae as *C. japonica chinensis*.

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Supplementary material I

Detailed results of COI sequences dataset

Authors: Zhonghua Wei, Liumei Zhang, Aimin Shi

Data type: molecular data

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