ZooKeys 734: 1–12 (2018)
doi: 10.3897/zookeys.734.21153
http://zookeys.pensoft.net

RESEARCH ARTICLE

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# *Streptocephalus* diversity in Myanmar, with description of a new species (Branchiopoda, Anostraca)

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Academic editor: *P. Stoev* | Received 22 September 2017 | Accepted 24 November 2017 | Published 5 February 2018

*http://zoobank.org/89FDDEC0-A2E7-47E3-89BB-08C01E7CBCC6*

**Citation:** Shu S-S, Rogers CD, Chen X-Y, Sanoamuang L (2018) *Streptocephalus* diversity in Myanmar, with description of a new species (Branchiopoda, Anostraca). ZooKeys 734: 1–12. https://doi.org/10.3897/zookeys.734.21153

## Abstract

The diversity of anostracans in Myanmar is poorly known. A series of biodiversity surveys had been conducted in Myanmar, and two species of *Streptocephalus* were collected in the central dry zone. *Streptocephalus sirindhornae* Sanoamuang et al., 2000 is reported in Myanmar for the first time, and *Streptocephalus shinsawbuae* **sp. n.** is described as new. *Streptocephalus shinsawbuae* **sp. n.** belongs to the *S. dichotomus* group and is similar to *S. simplex* Bond, 1934 and *S. sahyadriensis* Rogers & Padhye, 2014, but can be distinguished by the form of the male antennal posterior primary ramus and anterior primary ramus apex and egg ornamentation. *Streptocephalus dichotomus* has been reported from Myanmar in the past but was not found in this survey.

## Keywords

Diversity, new record, Southeast Asia, *Streptocephalus shinsawbuae* sp. n.

## Introduction

The monogeneric Streptocephalidae Daday, 1910 is the largest anostracan family, composed of 65 species (Rogers 2013; Rogers and Padhye 2014), distributed across Africa, Eurasia, Australia, and North America (Daniels et al. 2004). *Streptocephalus* diversity in Asia has been examined in detail, with eleven species were reported from the Middle East to Taiwan (Rogers et al. 2013; Rogers and Padhye 2014, 2015; Shu et al. 2015). Six species are regarded as valid in India (Rogers and Padhye 2014; 2015). Four species have been reported from Southeast Asia, although this region as a whole is poorly studied (Rogers et al. 2013). *Streptocephalus javanus* Brehm, 1955 has been found and described from the island of Java (Vaas 1952; Brehm 1955), *Streptocephalus sirindhornae* and *S. siamensis* have been described from Thailand by Sanoamuang et al. (2000) and Sanoamuang and Saengphan (2006), respectively. Only *Streptocephalus dichotomus* has been reported from Myanmar previously (Belk and Brtek 1995; Sanoamuang et al. 2000).

The Southeast Asia Biodiversity Research Institute (Chinese Academy of Sciences) and the Forest Research Institute, Myanmar, conducted a series of biodiversity surveys in Myanmar from 2015 to 2017. Two *Streptocephalus* species were collected during these efforts: the first records of *S. sirindhornae* Sanoamuang et al., 2000 from Myanmar and a species new to science.

## Materials and methods

Specimens were collected by a hand held dip net and preserved in 95% alcohol in the field. Specimens were examined under a stereo microscope (Zeiss Stemi 508) and a compound microscope (Olympus CX31) in the laboratory. All drawings were made using a camera lucida and images were taken by ToupCam microscope digital camera inside the compound microscope, the egg image (Fig. 4D) was taken at different focal planes and combined automatically by Toupview to increase the depth of focus. The distribution map was produced by ArcGIS based on the GPS information which was collected in the field using a Garmin eTrex 309. Terminology follows Rogers et al. (2013), but to prevent confusion, parallel morphological terminology from Maeda-Martínez et al. (1995) and Sanoamuang et al. (2000) is marked in brackets. All specimens examined were deposited in the Kunming Natural History Museum of Zoology, Kunming Institute of Zoology, Chinese Academy of Sciences.

## Results

**Order: ANOSTRACA Sars, 1867**
**Family: Streptocephalidae Daday, 1910**
**Genus: *Streptocephalus* Baird, 1852**

***Streptocephalus* (*Streptocephalus*) *shinsawbuae* sp. n.**
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Figures 1–4

**Holotype.** KIZ–CR 2016001, male, collected from type locality on 29 December 2016: SS Shu, XY Chen, T Qin, KM Myint and TS Tin. Type deposited in the Kunming

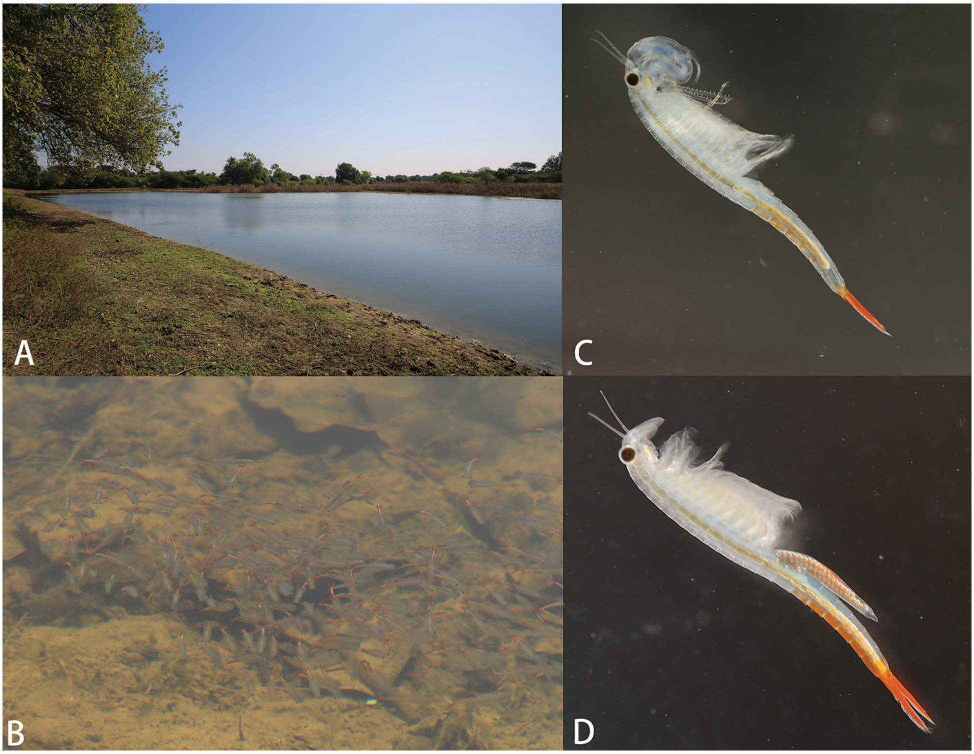

**Figure 1.** *Streptocephalus shinsawbuae* sp. n. **A** type locality **B** aggregation **C** adult male **D** adult female.

Natural History Museum of Zoology, Kunming Institute of Zoology (KIZ), Chinese Academy of Sciences (CAS).

**Allotype.** KIZ–CR 2016002, female, same data as holotype.

**Paratypes.** One male (SEABRI–CR 2016001) and one female (SEABRI–CR 2016002) deposited in Freshwater Biodiversity Laboratory, Southeast Asia Biodiversity Research Institute, Chinese Academy of Sciences, Myanmar, same data as holotype.

**Type locality.** (Fig. 1A, B) Myanmar: Mandalay Region: Pyawbwe Township: near Yanaung Village: a pond in the southern side of the road from Pyawbwe to No. 1 Highway, 20°33’46.9”N, 95°58’53.70”E, altitude 242 m.

**Material examined. MYANMAR**: MANDALAY REGION: Pyawbwe Township: near Yanaung Village: a pond in the southern side of the road from Pyawbwe to NO. 1 Highway, 20°33'46.9"N, 95°58'53.70"E, altitude 242 m, 25 males and 18 females. Zayetkon Township: a pond near the road from Kyaukpadaung to Nay Pyi Taw, 20°48'51.63"N, 95°26'58.88"E, altitude 430 m, 11 males and 24 females. SAGAING REGION: Monywa and Chaung-U Townships: a pond near Bawditataung Nature Reserve (Laykyun Sekkya Buddha), 22°5'26.47"N, 95°16'30.85"E, altitude 141 m, 6 males and 22 females. Myo Thar Township: a pond near the road from Gway Kone to Myo Thar, 21°43'37.31"N, 95°46'40.34"E, altitude 172 m, 15 males and 8 females. MAGWAY REGION: Yesagyo Township: a pond near the road from

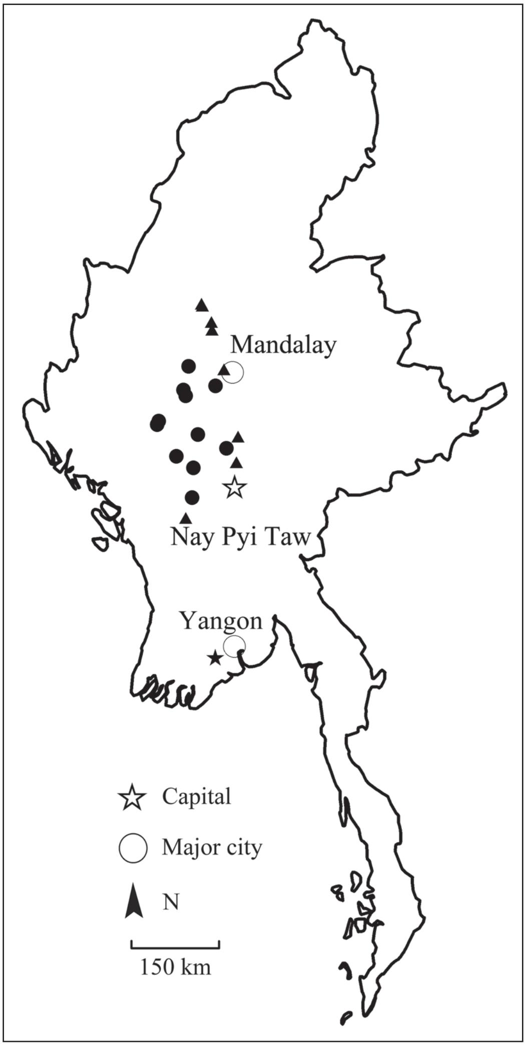

**Figure 2.** The distribution of *Streptocephalus shinsawbuae* sp. n. (black circles), *S. sirindhornae* (black triangles), and *S. dichotomus* (black star) in Myanmar.

Yesagyo to Lingadaw, 21°38'46.22"N, 95°10'56.00"E, altitude 90 m, 10 males and 8 females. Htammakauk Township: a pond near the road from East Kan Dwinn to Ohnbin, 21°4'13.33"N, 94°43'21.61"E, altitude 105 m, 4 males and 3 females. Kyuntaw Township: a pond near the road from Ywathitkyi to Htanpinchaung, 21°0'16.17"N, 94°41'18.05"E, altitude 128 m, 15 males and 22 females. Chaung Kauk Township: a pond near the road from Koebin to Egayit, 19°38'22.09"N, 95°20'25.40"E, altitude 153 m, 6 males and 12 females. Lelu Township: a pond near the road from Taungdwingyi to Magway, 20°11'55.78"N, 95°22'0.62"E, altitude 145 m, 15 males and 13 females. Yenangyaung City, Gyae Gone Township: a pond near the road from Gyae Gone to Wetchok, 20°24'31.38"N, 95°2'57.32"E, altitude 200 m, 5 males and 17 females. All specimens except the type series were collected by SS Shu, XY Chen, T Qin, P Zaw in June and July, 2017, and the locations are marked in Fig. 2.

**Diagnosis.** *Streptocephalus shinsawbuae* sp. n. is a member of the "*S. dichotomus*" species group, and can be distinguished from its congeners by the following characters: base of second antenna distal antennomere expanded, subquadrate, basal projection absent; antennal appendage with long peduncle, with one (rarely two) fleshy papilla(e), distal geniculations with 5–7 spines; anterior primary ramus with a digitiform basoposterior spine, ending distally as a triangular, lamellar projection, anterior ramus posterior branch with a subdistal and shallow notch; posterior ramus biramous, posteriolateral branch with two groups of crenulations, posterior primary ramus with two longitudinal rows of spines, distal tenth slightly curved anteriorly; egg with large, basically pentagonal polygons, separated by vertical ridges.

**Description.** ***Male.*** (Fig. 1C) *Body* length (from anterior margin of head to posterior margin of telson, not including cercopods) from 14.5 mm to 20.5 mm, average 17.7 mm.

*Head* round, subcylindrical. Cephalic appendage (Fig. 3D) short, triangular, unbranched, length ~30 % of second antenna proximal antennomere. First antenna filiform, extending beyond second antenna distal antennomere base, apex blunt, bearing three subequal long setae and two short setae. Second antenna (Fig. 3B) extending posteriorly to eighth thoracic segment. Proximal antennomere subcylindrical, length nearly four times width, medial surface smooth, without setae or pulvinus. Distal antennomere 0.9 times as long as proximal antennomere, laterally directed, smooth, curving medially in distal half; apex expanded and rounded to truncate; base expanded, subquadrate (Fig. 4B), basal projection absent.

Antennal appendage (Fig. 3A) with long peduncle (*sensu* Maeda-Martinez et al. 1995), length 1.6 times second antenna proximal antennomere, subcylindrical, without pulvinus. Peduncle anteromedial surface proximally with one fleshy papilla, half as long as peduncle, bearing a ventrolateral, longitudinal row of 12-14 subequal spines. Length of middle peduncle pseudosegment (between geniculations) more than half peduncle. Antennal appendage peduncle distal geniculations with a lateral longitudinal row of 5–7 spines; spines smooth, acute, with length approx. half of peduncle width. Antennal appendage apical cheliform structure ("hand" in Maeda-Martínez et al. 1995) strongly developed, with anterior ramus ("thumb") and posterior ramus ("finger").

Anterior primary ramus (Figure 4A) (the so called "thumb" see Maeda-Martínez et al. 1995) with an anterior, longitudinal, chitinized carina, ending distally as a triangular, lamellar projection, directed distally. Anterior ramus ("thumb") posterior branch ("spur") smooth, arcuate, recurving posteriorly approx. 80°, with a subdistal, ventral, shallow notch. "Spur" distoventral margin broadly curving into triangular gap. Triangular gap, becoming a narrow, deep cleft between "spur" and anterior ramus ("thumb"), at least as long as opening width. Anterior ramus ("thumb") gently arcuate, curving anteriorly approximately 30°, apex acuminate.

Posterior ramus ("finger") biramous and longer than anterior ramus. Posterior margin in lateral view near rami confluence with a shallow emargination. Posterio-

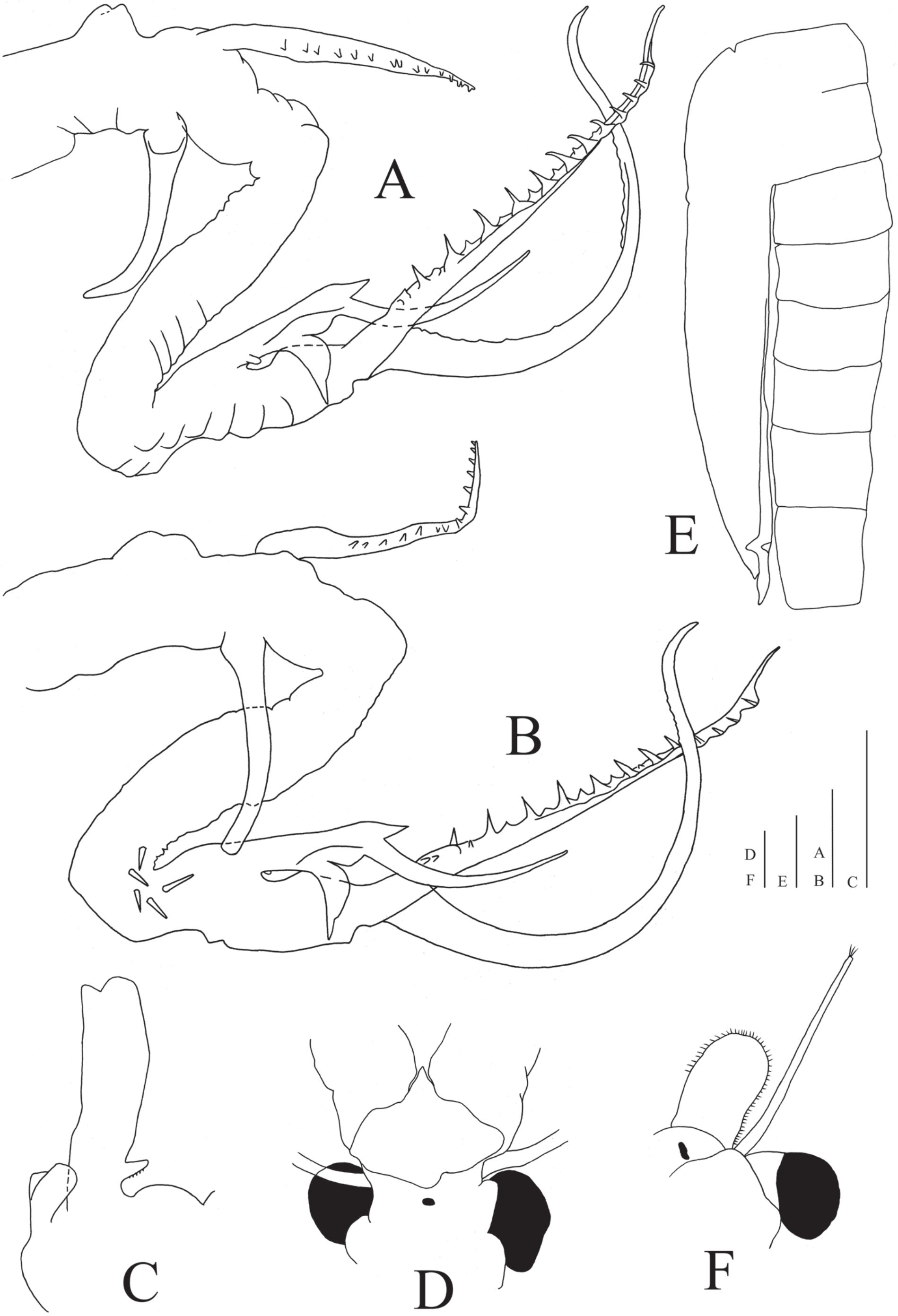

**Figure 3.** *Streptocephalus shinsawbuae* sp. n. **A** medial view of male second antenna **B** lateral view of male second antenna **C** gonopod, ventral view **D** male head, anterior view **E** brood pouch, left lateral view **F** female head and antennae, right side, anterior view. Scale bars 1 mm.

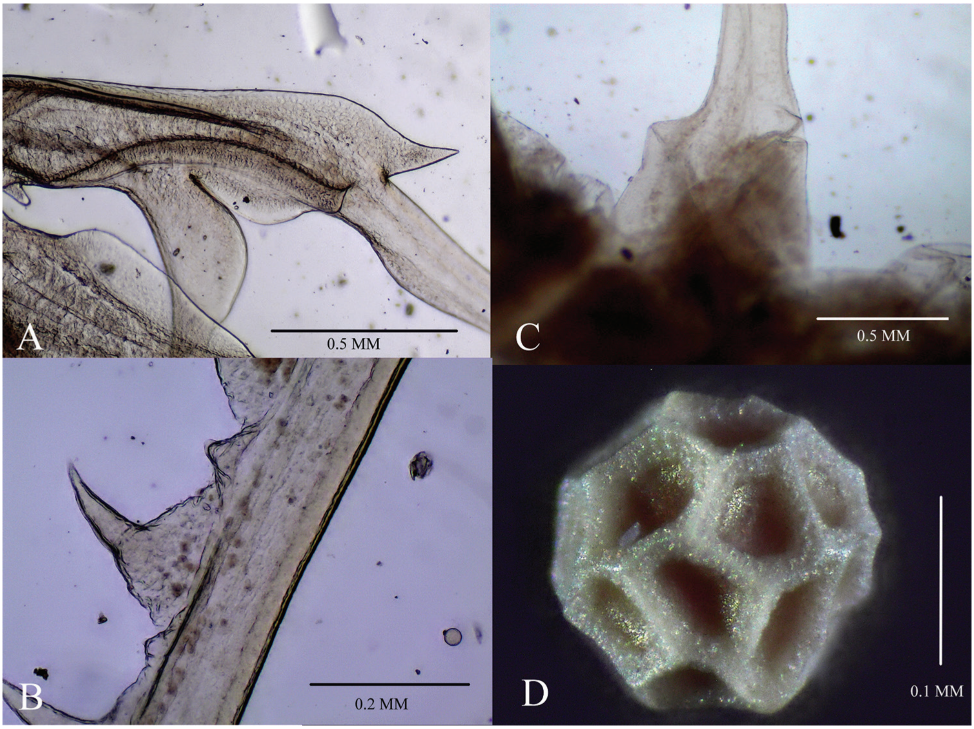

**Figure 4.** *Streptocephalus shinsawbuae* sp. n. **A** male anterior ramus (thumb) **B** male distal antennomere base **C** male posterior primary ramus (upper finger) primary small spines and hyaline large spines **D** egg.

lateral branch ("lower finger" in Sanoamuang et al. 2000) arcuate, broadly curved to ~160°, with apex bent nearly 90° distally, nearly attaining primary ramus ("upper finger") apex. Posteriolateral branch anterior margin subcrenulate in basal third, crenulate proximally in distal third. Posterior primary ramus ("upper finger") straight, directed distally, subequal in length to peduncle, with distal tenth slightly curved anteriorly. Anterior surface with two longitudinal rows of spines (Fig. 4C). The lateral spine row bears small, wide based spines, from branch confluence to three fourths the length of the ramus. The medial row bears hyaline spines in a series of medial hyaline lamellae, larger than the lateral spines, with tumid bases and aciculate apices. Medial spines increase in size gradually along proximal three fourths, and become more slender and arcuate in distal fourth. Most lamellae developed and connected, with apical half rotating to the medial side of the branch. The medial spine row distal apex ends subdistally on branch.

Labrum large, triangular, middle compress, apex directed posteriorly. Mandible, first and second maxillae as typical for the genus.

Eleven pairs *thoracopods*, increasing in size from the first pair to the fifth pair, then decreasing posteriorly. The structures of praeepipodites and epipodites typical for genus. Fifth thoracopod endite I and II with closely set, long plumose marginal setae. Endite I submargin with three widely spaced spines, the distal two are single, the proximal one with a basal spinule. Endite II submargin with two closely spaced spines, distal spine short, proximal spine long. Endite III–V with 3, 2, 2 long plumose setae and 2, 2, 1 spine(s), respectively, with small setae in proximal half. Endopodite broad, margin distal half with sparse plumose setae, each with 1–6 basal spinulae. Exopodite linguiform, margins with closely set plumose setae, longest distally, most setae with basal spinule. Epipod oval, without setae and spines, prae-epipod broadly oval, margins with small hooks.

*Genital segments* smooth, with lateral linguiform outgrowths. Gonopod (Fig. 3C) cylindrical, with a basomedial spiniform outgrowth, bearing four denticles medially. Everted gonopod elongate, distal end expanded, extending to the distal margin of abdominal segment IV, with a lateral, longitudinal row of spines from base to apex.

*Abdomen* and *cercopods* as typical for the genus.

***Female.*** Body smaller than male, body length from 14.0 to 17.5 mm, average 15.4 mm (Fig. 1D).

First antennae 2.2 times length of eye plus peduncle and 1.6 times length of second antennae, apex blunt, with three subequal long setae. Second antennae (Fig. 3F) broad, oval, smooth, apex round, margins bearing short sparse setae. Thorax smooth. Thoracopods as in male.

Brood pouch (Fig. 3E) elongate, fusiform, extending to the middle or apex of abdominal segment V in most specimens, less frequently extending to segment IV or segment VI.

Egg (Fig. 4D) subspherical, approx. 200 µm in diameter, with large, basically pentagonal polygons, separated by vertical ridges, polygons approx. 40 µm in diameter, and with broad floors.

**Etymology.** The specific epithet *shinsawbuae* refers to Queen Shin Sawbu (1453–1460) who facilitated more than 50 years of peace in Myanmar.

**Ecology.** During the sampling at the type location in June, 2017, the pond had a water temperature of 37.6 °C, a pH of 8.3, conductivity of 117µS/cm, and the dissolved oxygen was 5.9 mg/L. One species of clam shrimp, *Cyzicus pilosus* Rogers, Thaimuangphol, Saengphan, and Sanoamuang, 2013 was also collected.

**Remarks.** *Streptocephalus shinsawbuae* sp. n. is a member of the "*S. dichotomus*" species group, which includes *S. dichotomus* Baird, 1860, *S. echinus* Bond, 1934, *S. longimanus* Bond, 1934, *S. sahyadriensis* Rogers & Padhye, 2014, *S. simplex* Gurney, 1906, and *S. sirindhornae* Sanoamuang et al., 2000. This group is separated from all other *Streptocephalus* in that the posterior ramus (finger) is biramal. Of the six species in this group, *S. shinsawbuae* sp. n. is readily separated from other congers by the single papilla on the antennal appendage peduncle. Of approximately 120 male specimens of *S. shinsawbuae* sp. n., only one male from Magway (20°11'55.78"N, 95°22'0.62"E) had two papillae. This papilla in all other species of group is absent, or numbers three or more.

*Streptocephalus shinsawbuae* sp. n. is most similar to *S. sahyadriensis*. Both species have two longitudinal rows of spines on the antennal appendage posterior ramus (finger), and the anterior primary ramus (thumb) bears a small basoposterior spine. However, they can be separated by: (1) the shape of the posterior primary ramus (upper finger), which is straight in the proximal nine tenths, with the apex arcing anteriorly in *S. shinsawbuae* sp. n. vs. arcing distolaterally in the distal third 90° in *S. sahyadriensis*; (2) the posterior ramus posteriolateral branch (lower finger) has two groups of crenulations along the anterior margin in *S. shinsawbuae* sp. n. vs. only one group subdistally in *S. sahyadriensis*; (3) the anterior primary ramus apex shoulder is triangularly acute in *S. shinsawbuae* sp. n. vs. rounded in *S. sahyadriensis*; (4) the anterior primary ramus (thumb) basoposterior spine is digitiform in *S. shinsawbuae* sp. n. vs. triangular in *S. sahyadriensis*.

*Streptocephalus shinsawbuae* sp. n. is similar to *S. simplex* in having unbranched posterior primary ramus (upper finger), and acute anterior primary ramus (shoulder) apex, but they can be separated by: (1) the posterior ramus posteriolateral branch (lower finger) having two crenulated areas along anterior margin in *S. shinsawbuae* sp. n. vs. smooth in *S. simplex*; (2) the anterior primary ramus (shoulder) apex is triangular in *S. shinsawbuae* sp. n. vs. parallel sided in S. *simplex*; (3) anterior primary ramus (thumb) bearing a basal digitiform spine in *S. shinsawbuae* sp. n. vs. absent in *S. simplex*.

The eggs of *S. shinsawbuae* sp. n. have pentagonal polygons, which are very similar to those of both *S. echinus* and *S. longimanus*. From *S. simplex* it can be readily distinguished by the triangle polygons. In addition, the egg ridges are broad and deep in *S. shinsawbuae* sp. n. vs. narrow and shallow in S. *sahyadriensis*.

## ***Streptocephalus* (*Streptocephalus*) *sirindhornae* Sanoamuang, Murugan, Weekers, & Dumont, 2000**

**Remarks.** *Streptocephalus sirindhornae* is the most widely distributed member of the genus in Southeast Asia, with previous records from: Thailand, Laos, Cambodia, and China (Sanoamuang et al. 2000; Rogers et al. 2013; Shu et al. 2015). Some characters vary in different populations (Shu et al. 2013), and the materials collected from Myanmar is more similar to the Thai populations, with a deep depression on the posterior ramus ventral margin and unequal apical subrami on the posterior ramus.

Our materials were collected from the central dry zone of Myanmar including Mandalay, Magway, and Sagaing regions (Fig. 2). These are the most western records for this species. The distributional range of *S. sirindhornae* in Myanmar overlaps with that of *S. shinsawbuae* sp. n. (Fig. 2); however, the two species were not found co-occurring in the same pool.

**Material examined.** MYANMAR: MANDALAY REGION: Nyaung Lunt Township: rice field near the road from Nyaung Lunt to Yamethin, 20°18'9.26"N, 96°9'51.08"E, altitude 189 m, 12 males and 22 females. Hlaingdet Township: a pond near the road from Meiktila to Yin Mar Bin, 20°46'53.80"N, 96°11'30.24"E, altitude 162 m, 8 males and 15 females. SAGAING REGION: Kanbalu Township: Kaing Taw Village: rice field near the road from Kanbalu to Chatthin Wildlife Sanctuary, 23°15'22.53"N, 95°30'54.45"E, altitude 169 m, 5 males and 3 females. Kanbulu Township, Bugon Township and Ywa Zin Township: a pond near the road from Kanbulu to Shwebo, respectively, 23°13'21.22"N, 95°31'55.57"E, altitude 181 m, 3 males and 5 females; 22°55'1.54"N, 95°41'56.33"E, altitude 160 m, 9 males and 15 females; 22°46'30.75"N, 95°42'39.15"E, altitude 152 m, 14 males and 8 females. Saye Township: rice field near Saye Lake, 22°2'14.29"N, 95°55'46.90"E, altitude 86 m, 14 males and 11 females. MAGWAY REGION: Aunglan Township: a pond near the road from Pyay (Prome) to Taungdwinggyi. All specimens were collected by S.S. Shu, X.Y. Chen, T. Qin, P. Zaw in June and July, 2017, and the locations are marked in Fig. 2.

### ***Streptocephalus* (*Streptocephalus*) *dichotomus* Baird, 1860 (*sensu* Velu and Munuswamy 2005)**

= *Branchipus bengalensis* Alcock, 1896, *fide* Gurney, 1906.

**Remarks.** *Streptocephalus dichotomus* is widely distributed in the Indian subcontinent, Sri Lanka, and Pakistan (Selvarajah and Costa 1979; Belk and Esparza 1995; Velu and Munuswamy 2005; Rogers and Padhye 2014, 2015). Belk and Brtek (1995) reported this species from Yangon, Myanmar (Burma), and later, it was regarded as introduced (Sanoamuang et al. 2000). This species was not collected during our surveys.

## Discussion

*Streptocephalus shinsawbuae* sp. n. is the seventh species described from the *S. dichotomus* species group. The number of antennal peduncle papillae was used to separate some Indian species of *Streptocephalus* (Belk and Esparza 1995). Velu and Munuswamy (2005) suggested that this character is important in *Streptocephalus* taxonomy. All of our material bears a single papilla, except one specimen from Magway which has two, the larger papilla as described, with the smaller thin, short, and bare. This one aberrant specimen aside, we think that the single peduncle papilla character is stable, and this character readily allows it to be distinguished from all subgeneric species. This arrangement of papillae appears to fill a gap in the *S. dichotomus* group where the number of papillae is either none (*S. echinus*) or three or more.

Rogers and Padhye (2014) provided the keys for species of Asian *Streptocephalus* species. *Streptocephalus shinsawbuae* sp. n. would key out to couplet 8, which terminates with *S. simplex* and *S. longimanus*. We propose the following amendment to that key at couplet 6 to accommodate the new species:

6(5) Antennal peduncle papillae three or more; antennal appendage posterior ramus (“finger”) with lateral sickle shaped lateral subramus inerm on proximal half, crenulate on distal half ........................................ 7

6’ Antennal peduncle papillae absent; antennal appendage posterior ramus with lateral sickle shaped lateral subramus with a longitudinal row of spines, at least proximally with crenulations (immatures); India........................................................................................ ***Streptocephalus echinus* Bond, 1934**

6” Antennal peduncle papillae one (rarely two); antennal appendage posterior ramus (“finger”) with lateral sickle shaped lateral subramus inerm on proximal half, crenulate on distal half; Myanmar............................................................................................... ***Streptocephalus shinsawbuae* sp. n.**

Rogers et al. (2013) predicted that six species of *Streptocephalus* may occur in Southeast Asia. Our survey found two *Streptocephalus* species in Myanmar, bringing the total known number for this nation to three. The diversity of large branchiopods is poorly known in most of Southeast Asia, but it is probably fairly rich, especially since five species (Rogers et al. 2016a, b) have been reported or described since the last comprehensive review of the region (Rogers et al. 2013).

## Acknowledgements

We are grateful to Mr. Paing Zaw for assistance in collecting and for checking the spelling of the local names. We thank to Mr. Tao Qin, Mrs. Khin Mar Myint, and Ms. Thinn Su Tin for helping in collecting the material. This study was supported by the Southeast Asia Biodiversity Research Institute, the Chinese Academy of Sciences (Y4ZK111B01), the National Natural Science Foundation of China (31702011) and the Yunnan Provincial Science and Technology Program (2014FB178).

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ZooKeys 734: 13–42 (2018)
doi: 10.3897/zookeys.734.15061
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# Seven new species of *Pinelema* from Vietnam (Araneae, Telemidae)

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Academic editor: *Y. Marusik* | Received 14 June 2017 | Accepted 30 November 2017 | Published 5 February 2018

*http://zoobank.org/8727E9D5-DB45-4C93-A021-0031809DA1A9*

**Citation:** Zhao H, Dinh-Sac P, Song Y, Do T-D, Li S (2018) Seven new species of *Pinelema* from Vietnam (Araneae, Telemidae). ZooKeys 734: 13–42. https://doi.org/10.3897/zookeys.734.15061

## Abstract

Seven new species of the spider genus *Pinelema* Wang & Li, 2012, from Vietnam are reported: *P. damtaoensis* Zhao & Li, **sp. n.** (♂♀), *P. nuocnutensis* Zhao & Li, **sp. n.** (♂♀), *P. laensis* Zhao & Li, **sp. n.** (♂♀), *P. pacchanensis* Zhao & Li, **sp. n.** (♂♀), *P. spirulata* Zhao & Li, **sp. n.** (♂♀), *P. xiezi* Zhao & Li, **sp. n.** (♂♀), and *P. zhenzhuang* Zhao & Li, **sp. n.** (♂♀). Prior to the current study, this genus contained eight species and was known only from southwestern China. The diagnosis of the genus is updated, accounting for characters found in the new species.

## Keywords

haplogynae, karst, Southeast Asia, taxonomy

## Introduction

The spider family Telemidae Fage, 1913 contains nine genera and 69 species (World Spider Catalog 2017). *Pinelema* Wang & Li, 2012 is the second-most species rich genus of the family, comprising eight species from the Yunnan-Guizhou Plateau of

China. Here, seven new species of *Pinelema* are described from Vietnam. The diagnosis and description of the genus are extended. Prior to this study, only two species of the spider family Telemidae were known from Vietnam: *Telema cucphongensis* Lin, Pham & Li, 2009 and *T. exiloculata* Lin, Pham & Li, 2009 (Lin et al. 2009).

## Materials and methods

All specimens were examined and measured using a LEICA M205 C stereomicroscope. The bodies, male palps, and receptacles were photographed using an Olympus C7070 digital camera. Images were combined using Helicon Focus version 6.7.1 image stacking software (http://www.heliconsoft.com). Endogynes were removed and treated in lactic acid before photographing. All measurements are given in millimeters. Leg measurements are shown as: total length (femur, patella, tibia, metatarsus, tarsus). The left palpi of males were photographed using an FEI Quanta 450 Environmental Scanning Electron Microscope. The following abbreviations are used in the text and figures:

| | |
|---|---|
| **CA** | cymbial apophysis; |
| **Em** | embolus; |
| **Re** | receptacle; |
| **REC** | the ratio of embolus length (green line in Fig. 1D) and cymbium length (blue line in Fig. 1D); |
| **SR** | spiral ridge of embolus. |

All specimens treated here are deposited in the Institute of Zoology, Chinese Academy of Sciences (IZCAS), Beijing, China.

## Taxonomy

### Family Telemidae Fage, 1913

### Genus *Pinelema* Wang & Li, 2012

**Type species.** *Pinelema bailongensis* Wang & Li, 2012 from Guangxi, China.

**Diagnosis.** *Pinelema* is similar to *Telema* Simon, 1882 and can be distinguished from *Telema* by the presence of a distinct cymbial apophysis that is lacking in *Telema* (Wang et al. 2012, figs 2C, 4A).

**Comments.** *Pinelema* species are small (0.97–1.80). Carapace 0.48–0.75 long, yellow, with long thin legs relative to body length; tibia I 0.94–2.08 long. Six eyes are normally developed, vestigial, or in some species are completely absent. If eyes are present, they are encircled by black rings. Male palps are large relative to their body, with a distinct cymbial apophysis; embolus is long, medium or short in comparison to the cymbium; the REC varies from 0.28 to 0.90. The receptacle is unpaired as in other telemids and has spiral ducts inside.

**Distribution.** China, Vietnam.

**Natural history.** *Pinelema* species inhabit karst caves or leaf litter of tropical rainforests.

### *Pinelema damtaoensis* Zhao & Li, sp. n.

http://zoobank.org/DBBB5FB5-90DB-43C6-9839-92C0031B75D7

Figs 1–3, 22

**Type material.** ***Holotype*** ♂: Vietnam: Vinh Phuc Province: Dam Tao National Park: N21°27.62', E105°38.91', 999 m, leaf litter, 1.XI.2012, H.F. Zhao & Z.G. Chen leg. ***Paratypes*** 3♂ and 5♀, same data as holotype.

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

**Diagnosis.** The new species is similar to *P. huobaensis* and *P. yaosaensis* by having a short, triangular embolus, but can be distinguished from them by a distinct brown spiral ridge (Figs 1B, 1D, 2C–D) and droplet-shaped bulb (Figs 1C–D, 2A–B) vs. an indistinct spiral ridge of the embolus and an egg-shaped bulb in *P. huobaensis* and *P. yaosaensis*, as well as by a beak-shaped embolus (Figs 1B, 1D, 2D) vs. an equilateral triangular embolus in related species.

**Description.** ***Male*** **(holotype).** Total length 1.28. Carapace 0.53 long, 0.48 wide. Abdomen 0.68 long, 0.53 wide. Carapace light brown with a black spot and radial stripes (Fig. 2A). Sternum dark brown. Six eyes encircled by black rings, well-developed, clypeus 0.08 long, ocular quadrangle 0.18 wide. Leg measurements: I 3.55 (1.01, 0.19, 1.05, 0.74, 0.56); II 2.97 (0.86, 0.19, 0.85, 0.59, 0.48); III 2.12 (0.64, 0.16, 0.56, 0.37, 0.39); IV 2.61 (0.81, 0.18, 0.71, 0.51, 0.40). Abdomen blue-green, with sparse long hairs.

Palp: femur 2.7 times longer than patella, tibia 2.5 times longer than patella, cymbial apophysis brown and spine-like (Figs 1C, 2A); REC 0.40; bulb droplet-shaped; embolus beak-shaped (Figs 1C–D, 2A–D), spiral ridge dark brown, continuing approximately 180° around embolus (Figs 1B–D, 2B–D), opening of embolus slit-like, extending from the base to the tip (Fig. 2D).

***Female.*** Total length 1.39. Carapace 0.59 long, 0.55 wide. Abdomen 0.71 long, 0.59 wide. Coloration same as in male (Figs 3A–B). Six eyes, well-developed, clypeus 0.14 long, ocular quadrangle 0.21 wide. Leg measurements: I 3.77 (1.13, 0.19, 1.14, 0.75, 0.56); II 3.00 (0.92, 0.17, 0.90, 0.56, 0.45); III 2.28 (0.73, 0.16, 0.63, 0.40, 0.36); IV 2.92 (0.96, 0.16, 0.82, 0.57, 0.41). Receptacle globular, with long insemination duct, almost 2 times longer than receptacle diameter, and 5 times thinner than receptacle, receptacle diameter 0.14 wide (Fig. 3C).

**Distribution.** Known only from the type locality (Fig. 22).

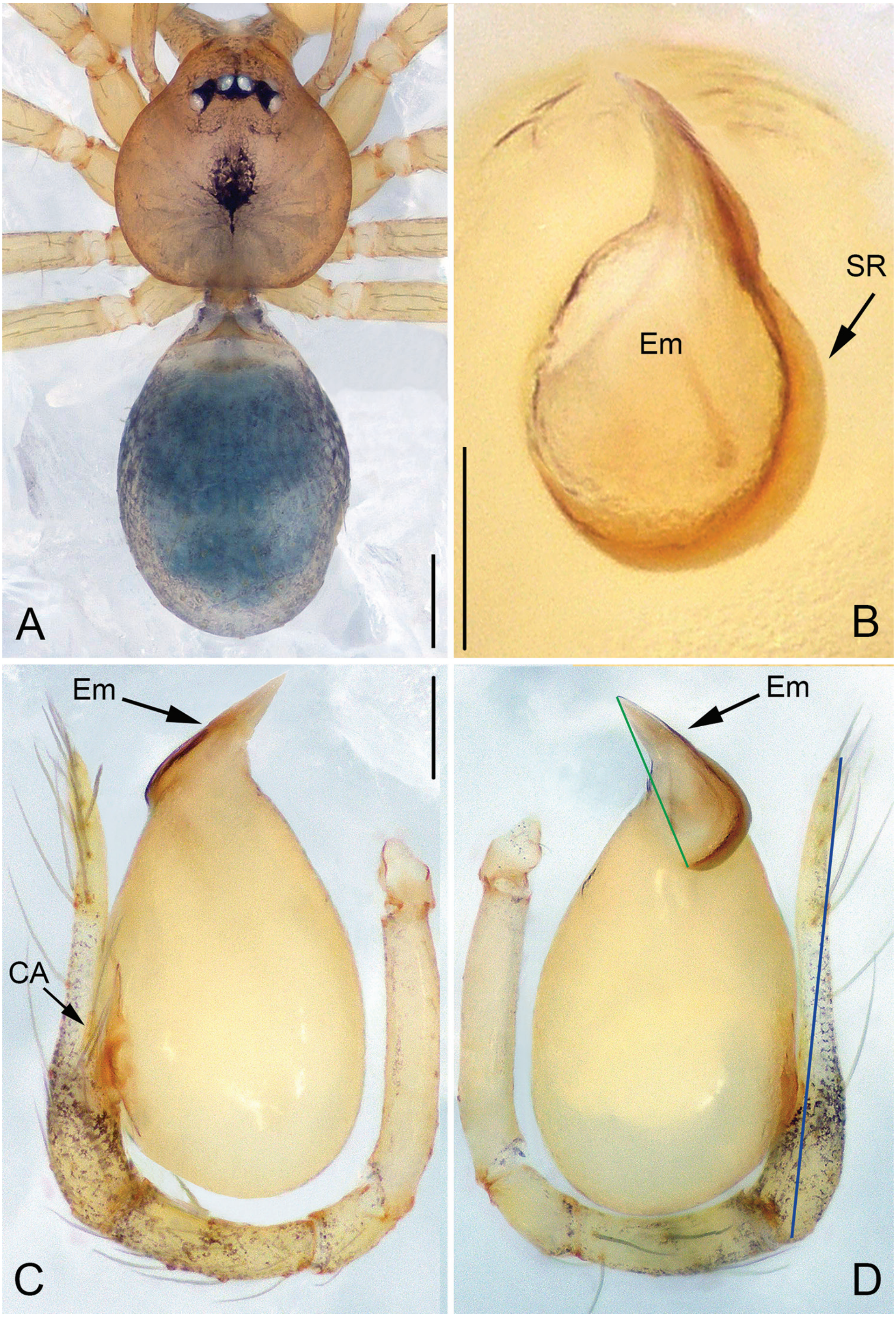

**Figure 1.** *Pinelema damtaoensis* sp. n., male holotype. **A** Habitus, dorsal view **B** Embolus, apical view **C** Palp, prolateral view **D** Palp, retrolateral view. Scale bars: 0.2 mm (**A**), 0.01 mm (**B**), 0.1 mm (**C–D**). Green line indicates the length of embolus; blue line indicates the length of cymbium.

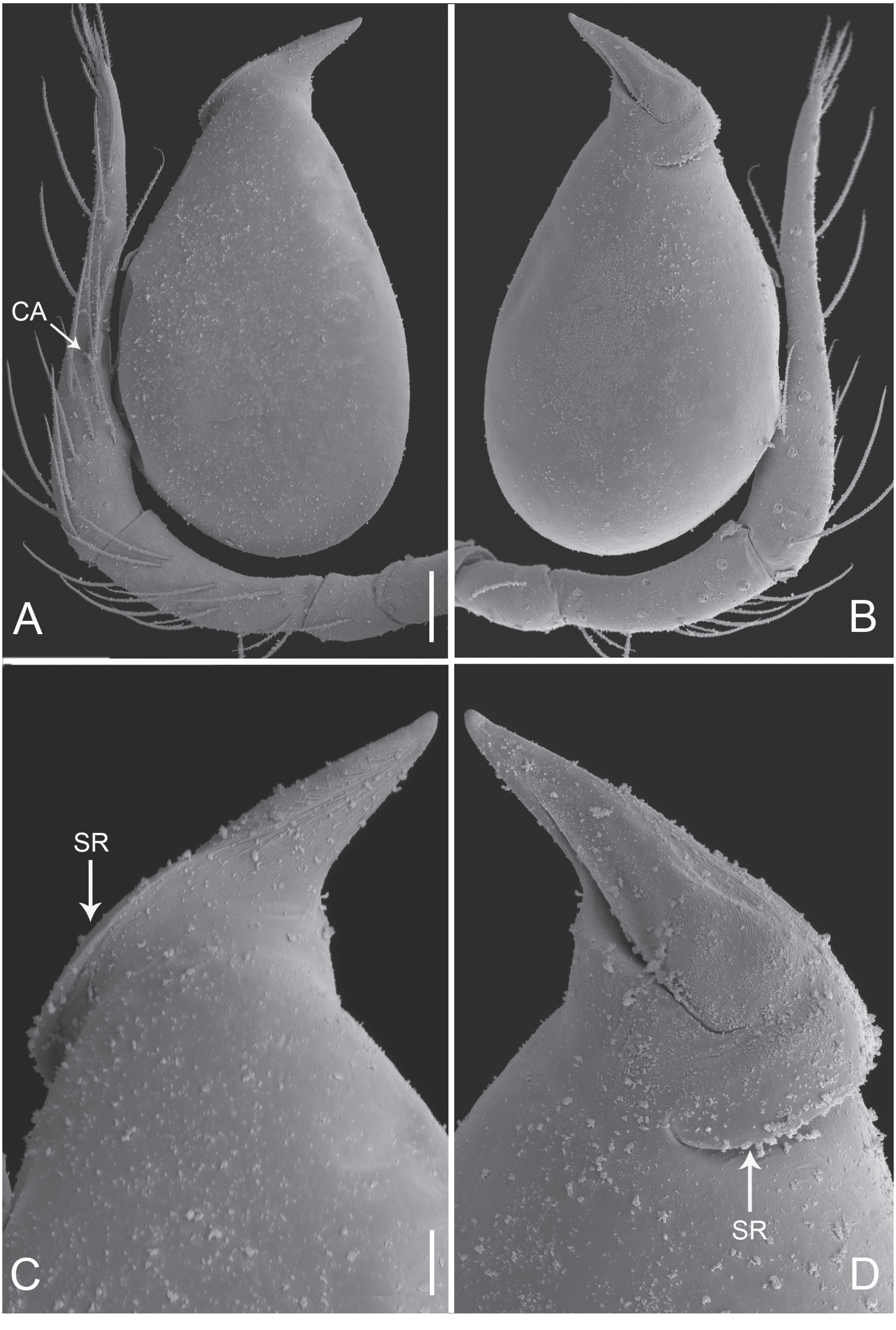

**Figure 2.** *Pinelema damtaoensis* sp. n., male. **A** Palp, prolateral view **B** Palp, retrolateral view **C** Embolus, prolateral view **D** Embolus, retrolateral view. Scale bars: 0.06 mm (**A–B**), 0.02 mm (**C–D**).

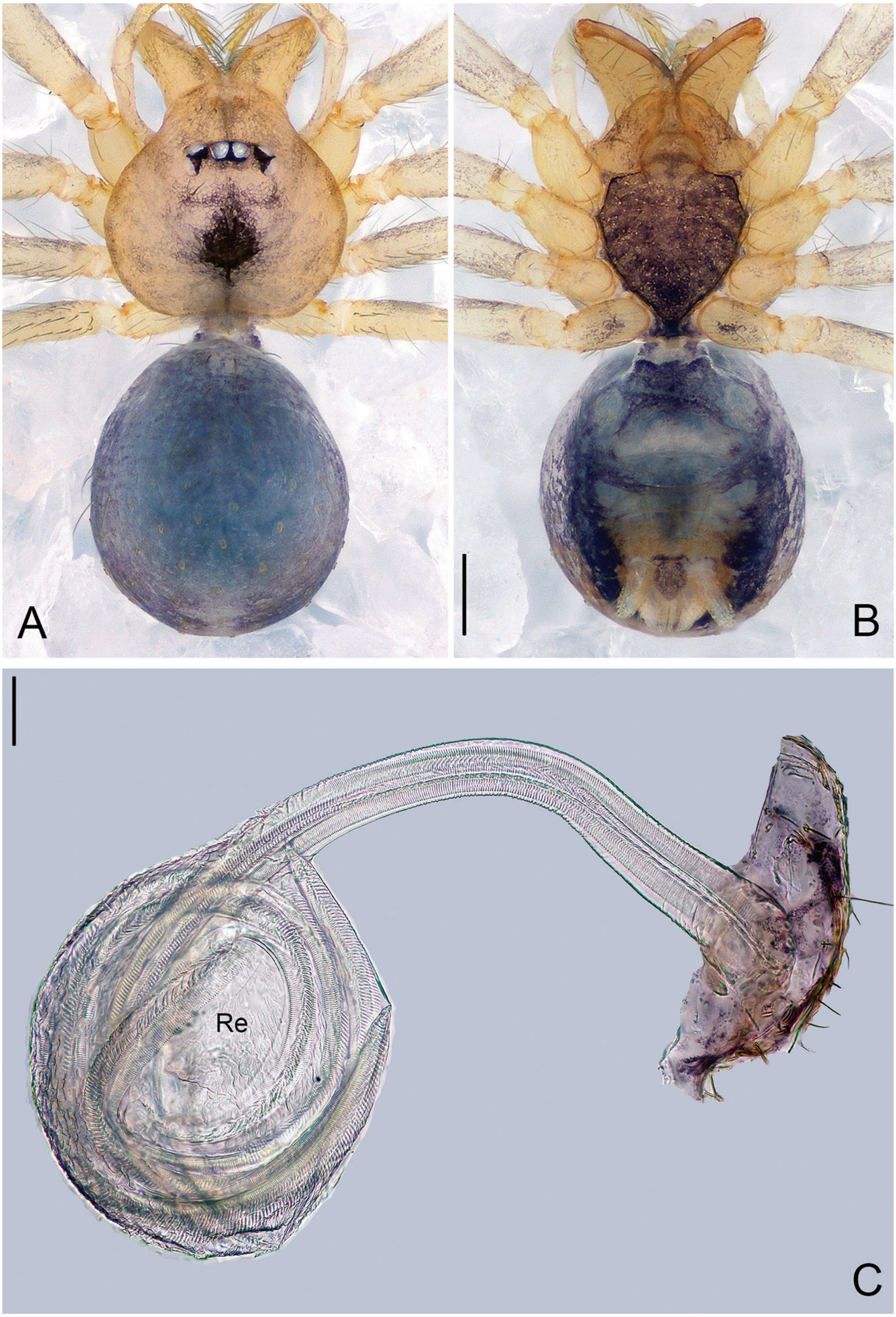

**Figure 3.** *Pinelema damtaoensis* sp. n., female paratype. **A** Habitus, dorsal view **B** Habitus, ventral view **C** Endogyne, lateral view. Scale bars: 0.2 mm (**A–B**), 0.05 mm (**C**).

## ***Pinelema nuocnutensis* Zhao & Li, sp. n.**

http://zoobank.org/86C258F1-260D-4009-83D9-4EC186BB7E08

Figs 4–6, 22

**Type material.** ***Holotype*** ♂: Vietnam: Quang Binh Province: Phong Nha-Ke Bang National Park: Nuoc Nut Cave, N17°29.62', E106°17.65', 143 m, 25.V.2016, Z.G. Chen & Q.Y. Zhao leg. ***Paratypes*** 2♂ and 5♀, same data as holotype.

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

**Diagnosis.** This new species is similar to *P. pacchanensis* sp. n., but can be distinguished by the vestigial eyes (Figs 4A, 6A) (eyes completely reduced in *P. pacchanensis* sp. n.), beak-shaped embolus (Figs 4B–D, 5A–D) (boomerang-shaped in *P. pacchanensis* sp. n.), and the U-shaped receptacle (Fig. 6C) (globular in *P. pacchanensis* sp. n.).

**Description.** ***Male*** **(holotype).** Total length 1.20. Carapace 0.53 long, 0.49 wide. Abdomen 0.63 long, 0.53 wide. Carapace, chelicerae, labium, and legs yellow, without any pattern (Fig. 4A). Four vestigial eyes. Leg measurements: I 4.42 (1.30, 0.20, 1.38, 0.90, 0.64); II 3.82 (1.13, 0.20, 1.18, 0.75, 0.56); III 2.73 (0.84, 0.18, 0.77, 0.51, 0.43); IV 3.24 (1.03, 0.18, 0.94, 0.63, 0.46). Abdomen light yellow, with a few long hairs.

Palp: femur 1.8 times longer than patella, tibia 1.5 times longer than patella, cymbial apophysis brown and spine-like (Figs 4C, 5A); REC 0.55; bulb kidney-shaped (Figs 4C–D, 5A–B); embolus beak-shaped, its outer margin forming a brown, spiral ridge (Fig. 4C–D, and arrows on Fig. 5C–D), opening two times shorter than embolus (Fig. 5B, D).

***Female.*** Total length 1.31. Carapace 0.54 long, 0.46 wide. Abdomen 0.81 long, 0.71 wide. Coloration and pattern as in male (Figs 6A–B). Eyes reduced to four vestigial spots. Leg measurements: I 4.18 (1.25, 0.19, 1.31, 0.80, 0.63); II 3.57 (1.06, 0.19, 1.08, 0.68, 0.56); III 2.68 (0.86, 0.16, 0.76, 0.48, 0.42); IV 3.14 (1.01, 0.17, 0.91, 0.59, 0.46). Endogyne J-shaped, with short and broad insemination duct and U-shaped receptacle, insemination duct as wide as receptacle. (Fig. 6C).

**Distribution.** Known only from the type locality (Fig. 22).

## ***Pinelema laensis* Zhao & Li, sp. n.**

http://zoobank.org/284193C9-50F3-4836-A3AC-B1C9790D49A9

Figs 7–9, 22

**Type material.** ***Holotype*** ♂: Vietnam: Phu Tho Province: Xuan Son National Park: La Cave, N21°08.27', E104°56.35', 424 m, 27.X.2012, H.F. Zhao & Z.G. Chen leg. ***Paratypes*** 1♂ and 4♀, same data as holotype.

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

**Diagnosis.** This new species is similar to *P. xiezi* sp. n. by having a trapezoidal embolus but can be distinguished by the marginally sclerotized, hollow embolus (Figs 7B, 8C–D). *Pinelema laensis* sp. n. is also similar to *P. huobaensis* and *P. yaosaensis* but can be distinguished from them by having distinct eyes and a trapezoidal embolus; *P. huobaensis* and *P. yaosaensis* have no eyes and their emboli are shaped like equilateral

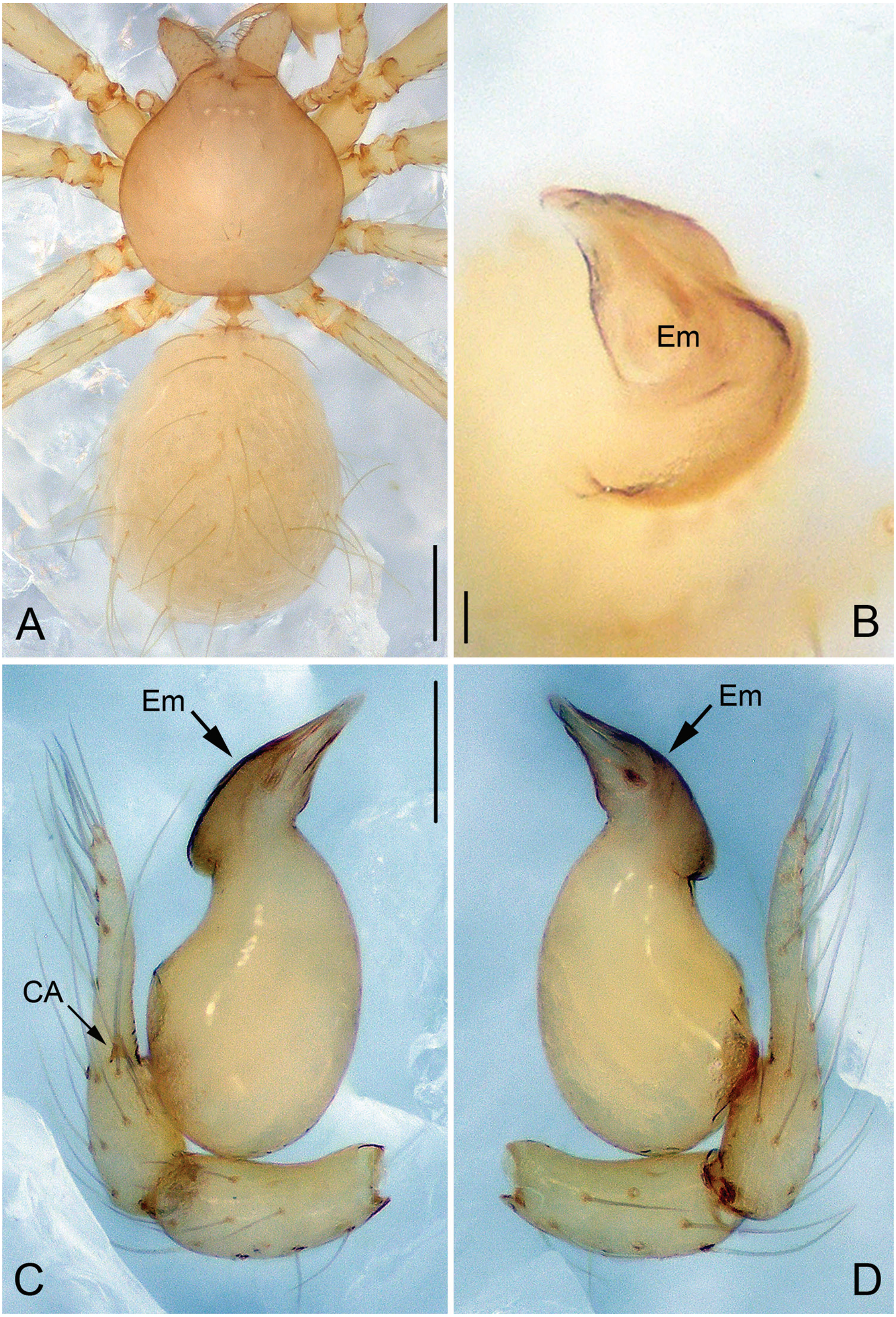

**Figure 4.** *Pinelema nuocnutensis* sp. n., male holotype. **A** Habitus, dorsal view **B** Embolus, apical view **C** Palp, prolateral view **D** Palp, retrolateral view. Scale bars: 0.2 mm (**A**), 0.02 mm (**B**), 0.1 mm (**C–D**).

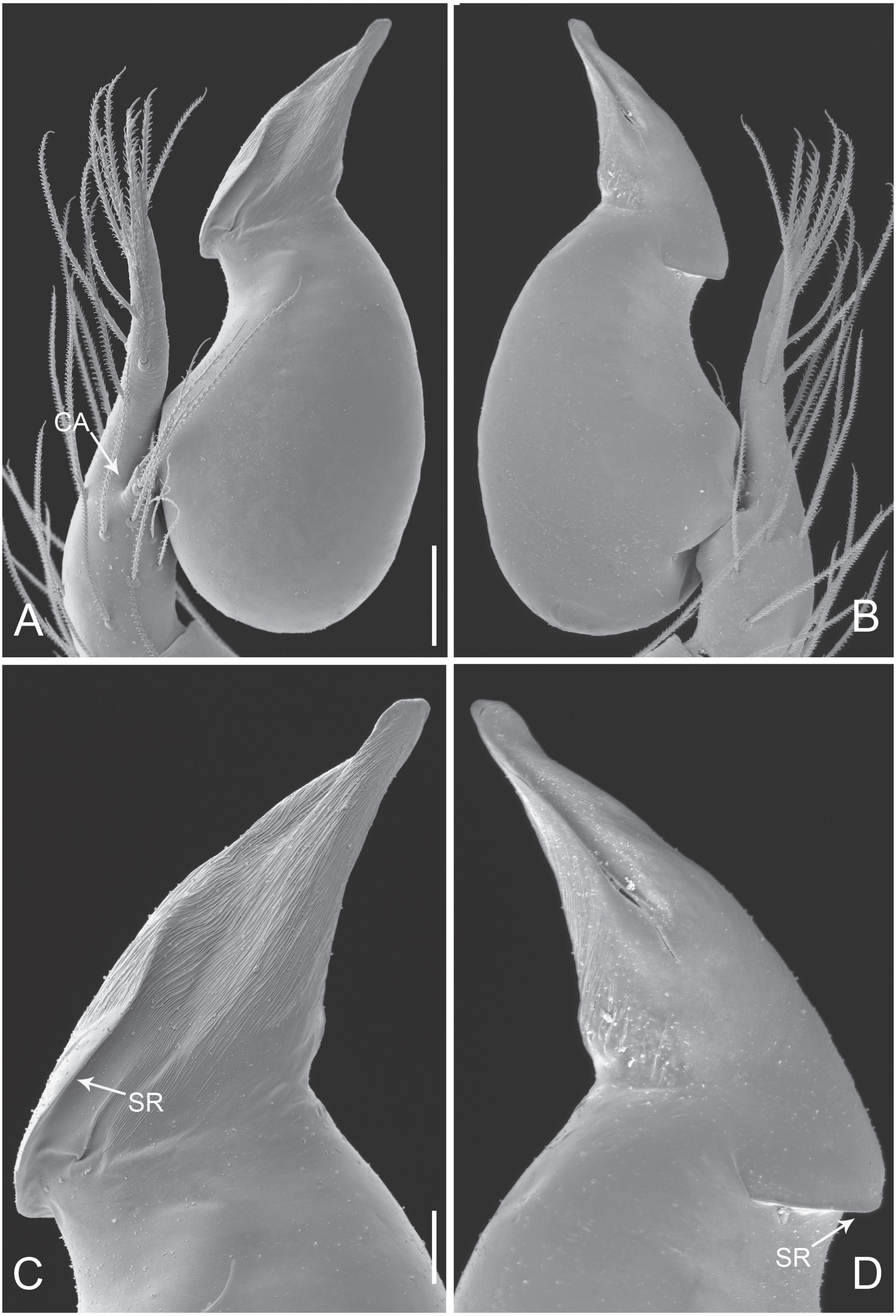

**Figure 5.** *Pinelema nuocnutensis* sp. n., male. **A** Palp, prolateral view **B** Palp, retrolateral view **C** Embolus, prolateral view **D** Embolus, retrolateral view. Scale bars: 0.06 mm (**A–B**), 0.02 mm (**C–D**).

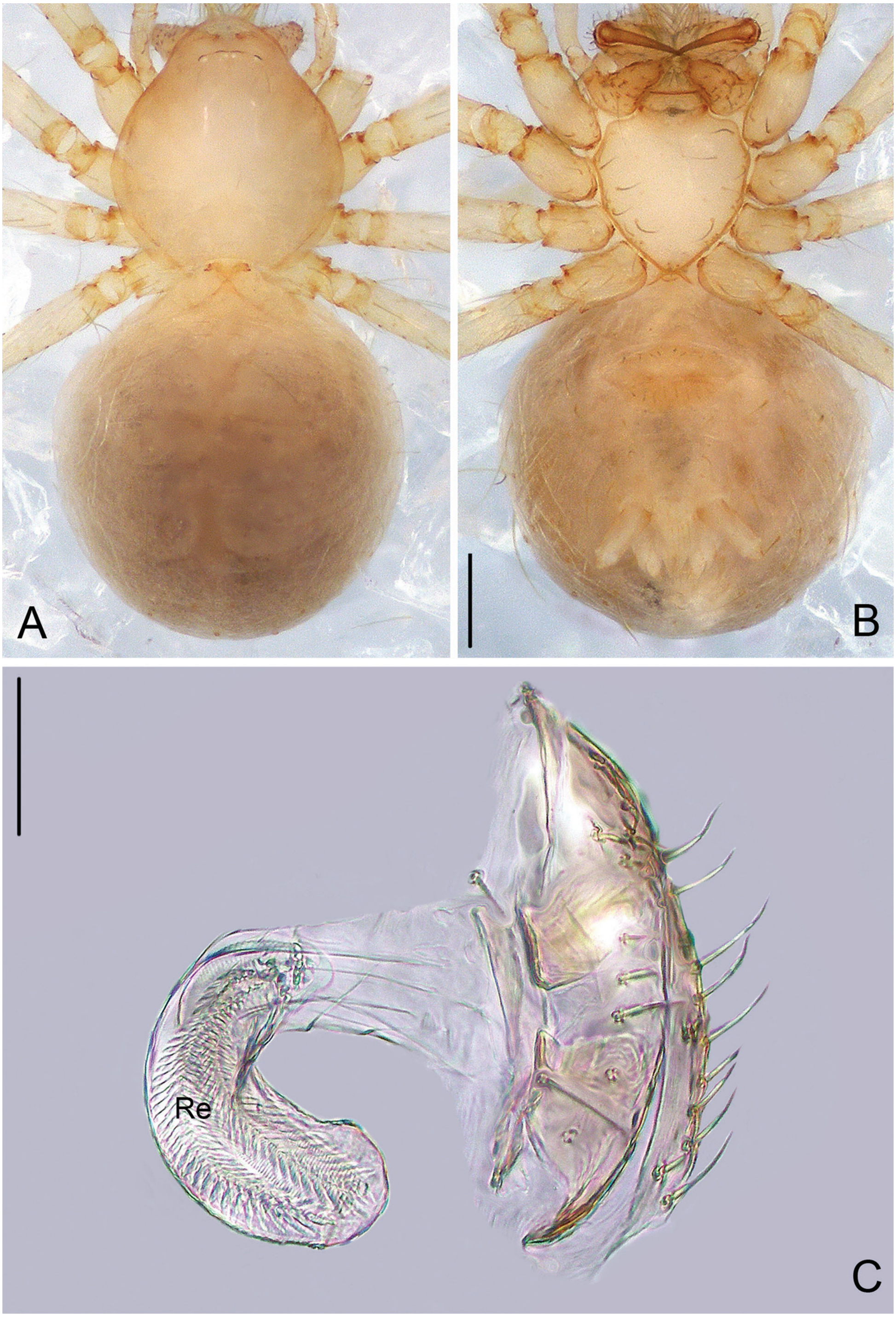

**Figure 6.** *Pinelema nuocnutensis* sp. n., female paratype. **A** Habitus, dorsal view **B** Habitus, ventral view **C** Endogyne, lateral view. Scale bars: 0.2 mm (**A–B**), 0.05 mm (**C**).

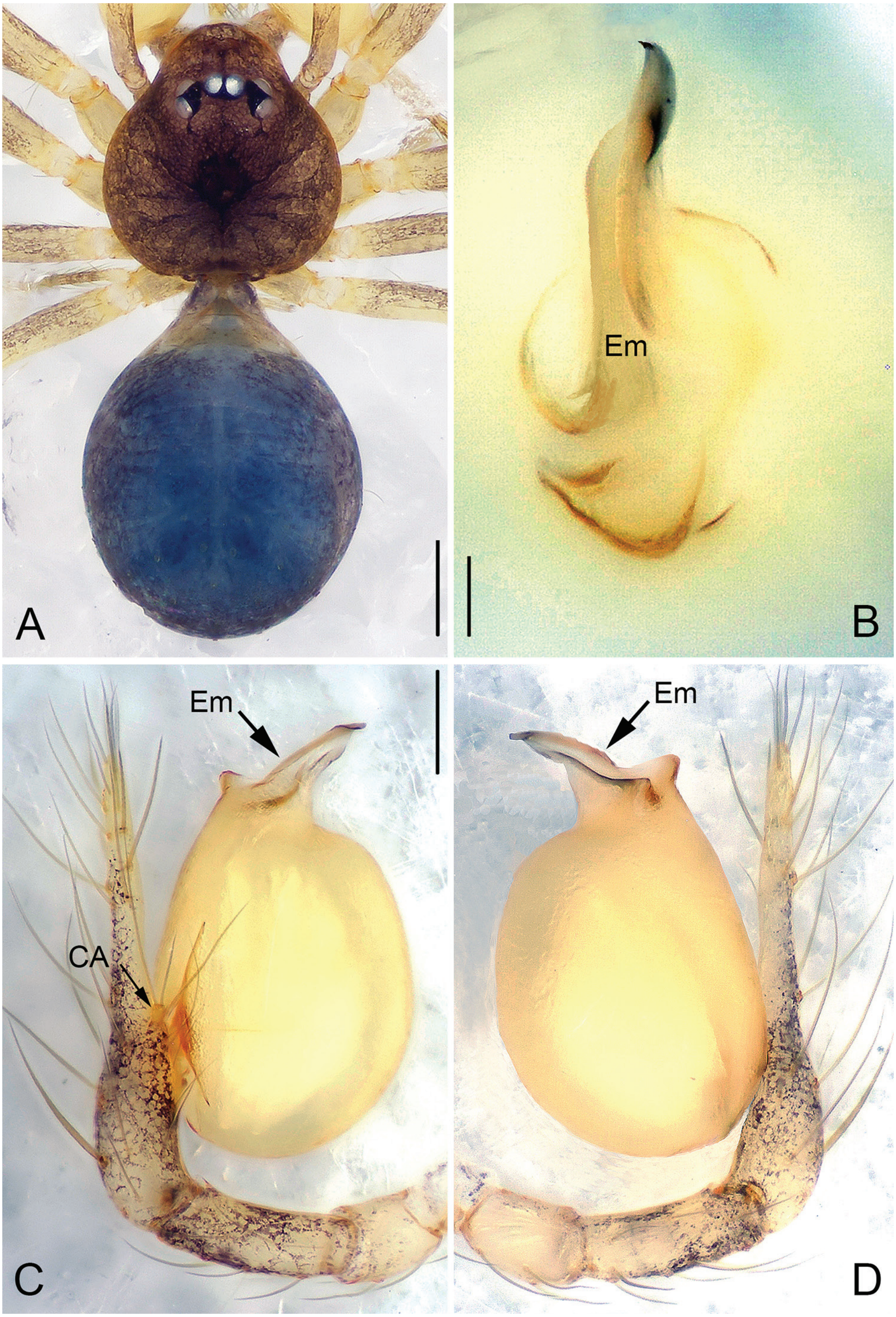

**Figure 7.** *Pinelema laensis* sp. n., male holotype. **A** Habitus, dorsal view **B** Embolus, apical view **C** Palp, prolateral view **D** Palp, retrolateral view. Scale bars: 0.2 mm (**A**), 0.02 mm (**B**), 0.1 mm (**C–D**).

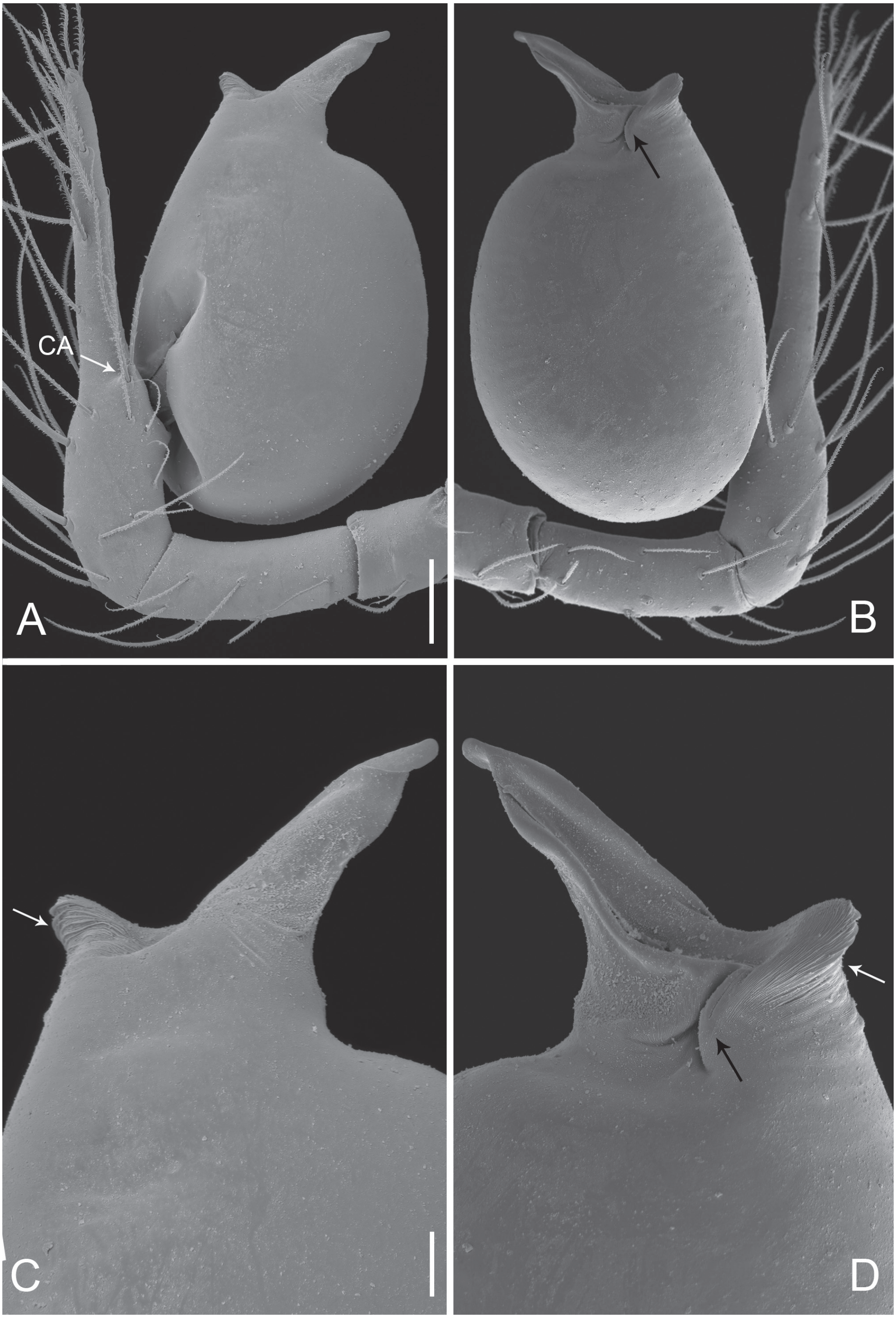

**Figure 8.** *Pinelema laensis* sp. n., male. **A** Palp, prolateral view **B** Palp, retrolateral view **C** Embolus, prolateral view **D** Embolus, retrolateral view. Scale bars: 0.06 mm (**A–B**), 0.02 mm (**C–D**). White arrows indicate tiny wrinkles and black ones indicate the groove of embolus.

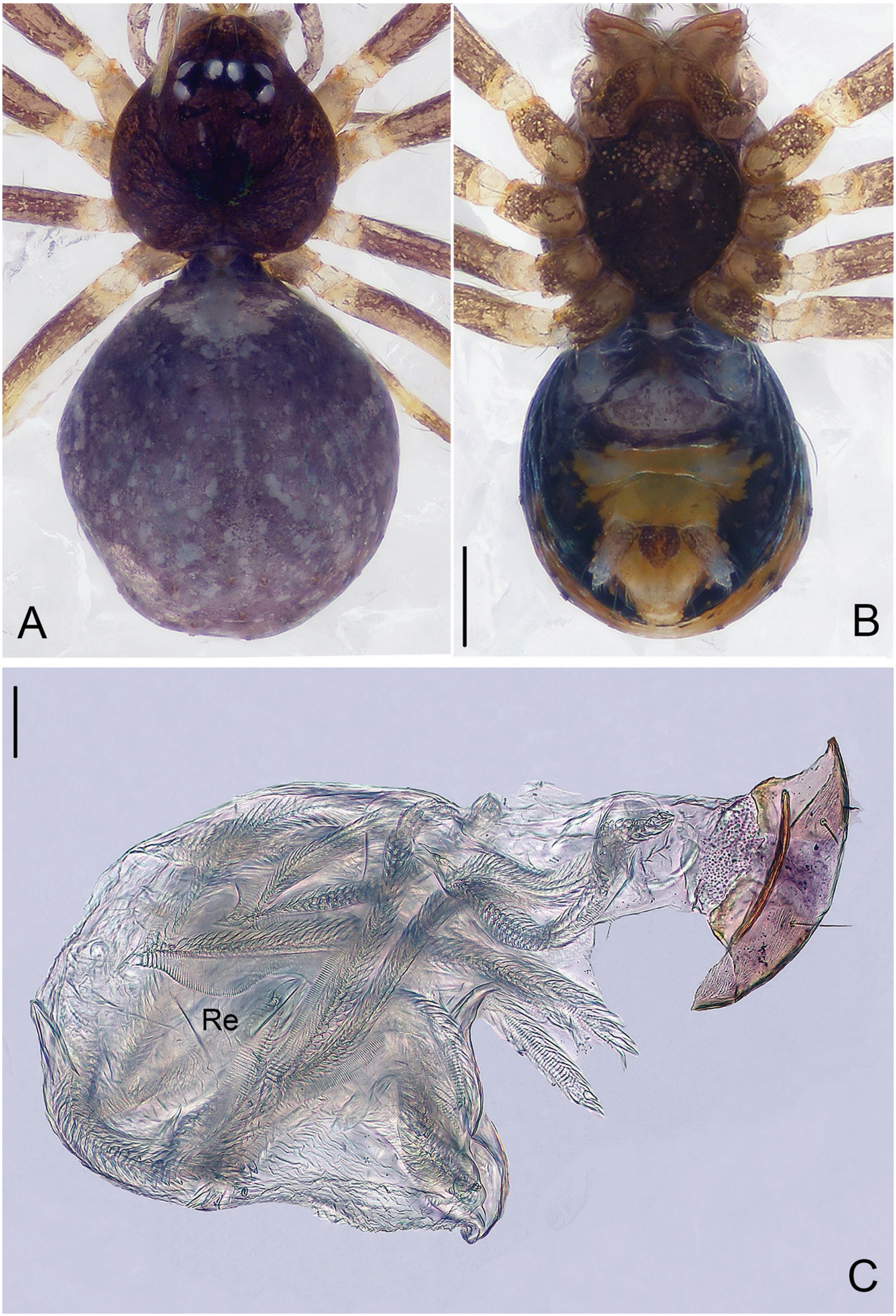

**Figure 9.** *Pinelema laensis* sp. n., female paratype. **A** Habitus, dorsal view **B** Habitus, ventral view **C** Endogyne, lateral view. Scale bars: 0.2 mm (**A–B**), 0.05 mm (**C**).

triangles. The new species can be distinguished from other congeners by the short embolus and axe-shaped endogyne (Fig. 9C).

**Description.** ***Male*** **(holotype).** Total length 1.20. Carapace 0.51 long, 0.47 wide. Abdomen 0.67 long, 0.55 wide. Carapace brown with a black spot. Six eyes encircled by black rings, clypeus 0.12 long, ocular quadrangle 0.19 wide. Chelicerae, labium and sternum dark brown. Legs yellow with brown dots and hairs (Fig. 7A), leg measurements: I 3.07 (0.87, 0.19, 0.94, 0.59, 0.48); II 2.66 (0.82, 0.15, 0.75, 0.48, 0.46); III 1.90 (0.56, 0.14, 0.52, 0.34, 0.34); IV 2.32 (0.71, 0.16, 0.64, 0.43, 0.38). Abdomen dark blue.

Palp: femur 2.5 times longer than patella, tibia approximately two times longer than patella, cymbial apophysis brown and thumb-like (Figs 7C, 8A); REC 0.56; bulb egg-shaped; embolus trapezoidal, sclerotized marginally, hollow inside (Figs 7C–D, 8C–D), slit of embolus obscure (Fig. 8D); embolus with vertical groove located retrolaterally (black arrows on Fig. 8B, D), with a pit prolaterally (Figs 7C, 8A, C) and wrinkles at the tip (white arrows on Fig. 8C–D).

***Female.*** Total length 1.19 (Figs 9A–B). Carapace 0.46 long, 0.45 wide. Abdomen 0.72 long, 0.69 wide. Coloration darker than male. Six eyes encircled by black rings, clypeus 0.09 long, ocular quadrangle 0.18 wide. Leg measurements: I 2.75 (0.82, 0.17, 0.81, 0.50, 0.45); II 2.41 (0.69, 0.17, 0.69, 0.43, 0.43); III 1.81 (0.54, 0.14, 0.50, 0.31, 0.32); IV 2.25 (0.71, 0.14, 0.64, 0.40, 0.36). Abdomen purple, with black and yellow pattern ventrally. Endogyne axe-shaped; insemination duct broad, its diameter 0.07; receptacle bag-like, 4 times wider than insemination duct (Fig. 9C).

**Distribution.** Known only from the type locality (Fig. 22).

### ***Pinelema pacchanensis*** **Zhao & Li, sp. n.**

http://zoobank.org/DA3352BD-B1B9-4215-A449-2D2A39BE4A3F
Figs 10–12, 22

**Type material.** ***Holotype*** ♂: Vietnam: Bac Kan Province: Cho Don District: Pac Chan Cave, N22°22.78', E105°36.79', 225 m, 18.X.2012, H.F. Zhao & Z.G. Chen leg. ***Paratypes*** 2♂ and 5♀, same data as holotype.

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

**Diagnosis.** This new species is similar to *P. nuocnutensis* sp. n. and *P. podiensis*, and can be distinguished from them by boomerang-shaped embolus (the embolus of *P. nuocnutensis* sp. n. is beak-shaped, embolus in *P. podiensis* is shaped like an isosceles triangle). The new species can be distinguished from other congeners by the medium length embolus (Figs 10C–D, 11A–B) (REC is 0.60) vs. REC of other *Pinelema* species 0.90 or less than 0.35.

**Description.** ***Male*** **(holotype).** Total length 1.41. Carapace 0.61 long, 0.55 wide. Abdomen 0.85 long, 0.71 wide. Carapace yellow with no markings. Eyes absent. Chelicerae, endites, labium, sternum, and legs the same color as carapace. Leg measurements: I 4.52 (1.34, 0.21, 1.41, 0.95, 0.61); II 4.13 (1.23, 0.21, 1.30, 0.83, 0.56); III 3.03 (0.95, 0.18, 0.85, 0.60, 0.45); IV 3.26 (1.18, 0.18, 1.08, 0.36, 0.46). Abdomen yellow with sparse long hairs.

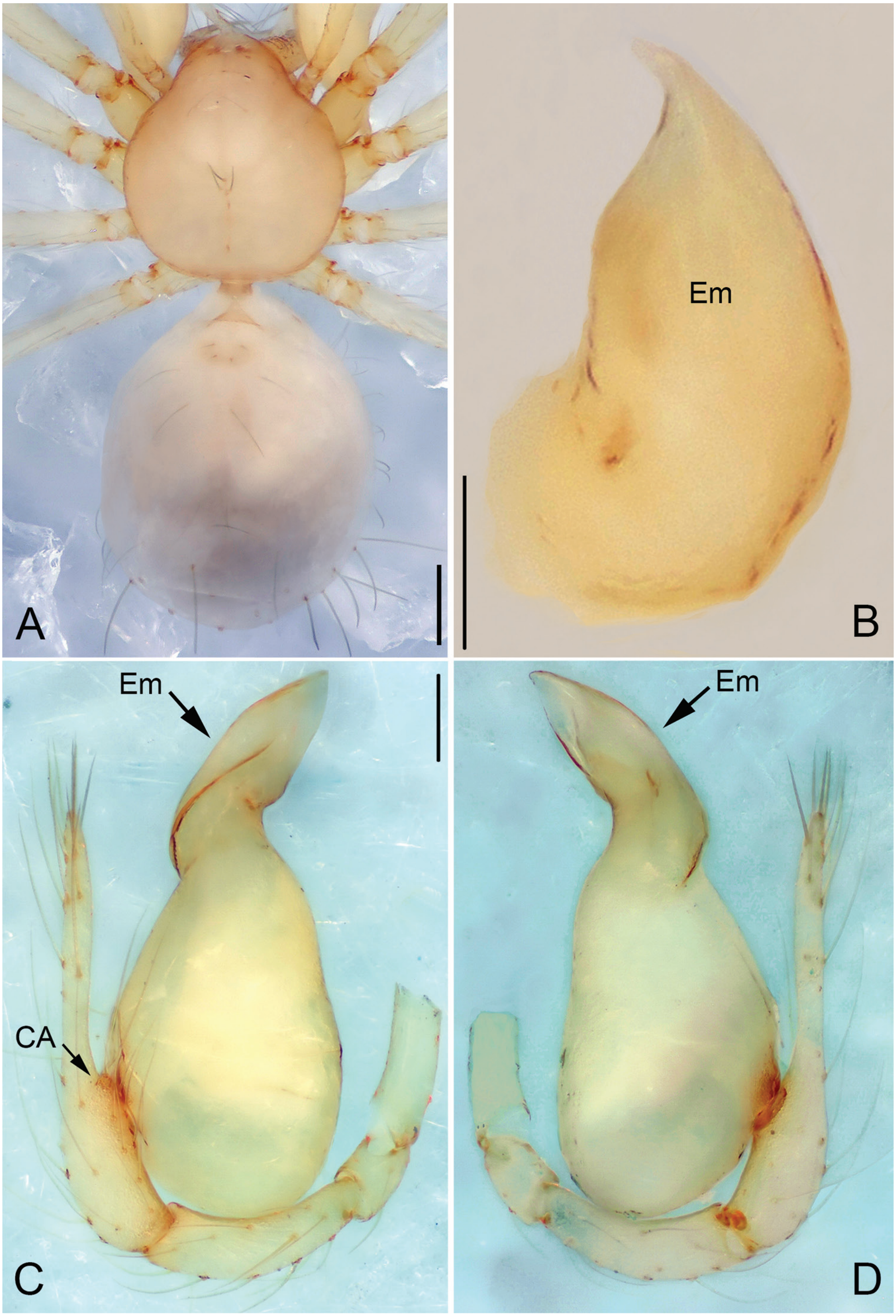

**Figure 10.** *Pinelema pacchanensis* sp. n., male holotype. **A** Habitus, dorsal view **B** Embolus, apical view **C** Palp, prolateral view **D** Palp, retrolateral view. Scale bars: 0.2 mm (**A**), 0.05 mm (**B**), 0.1 mm (**C–D**).

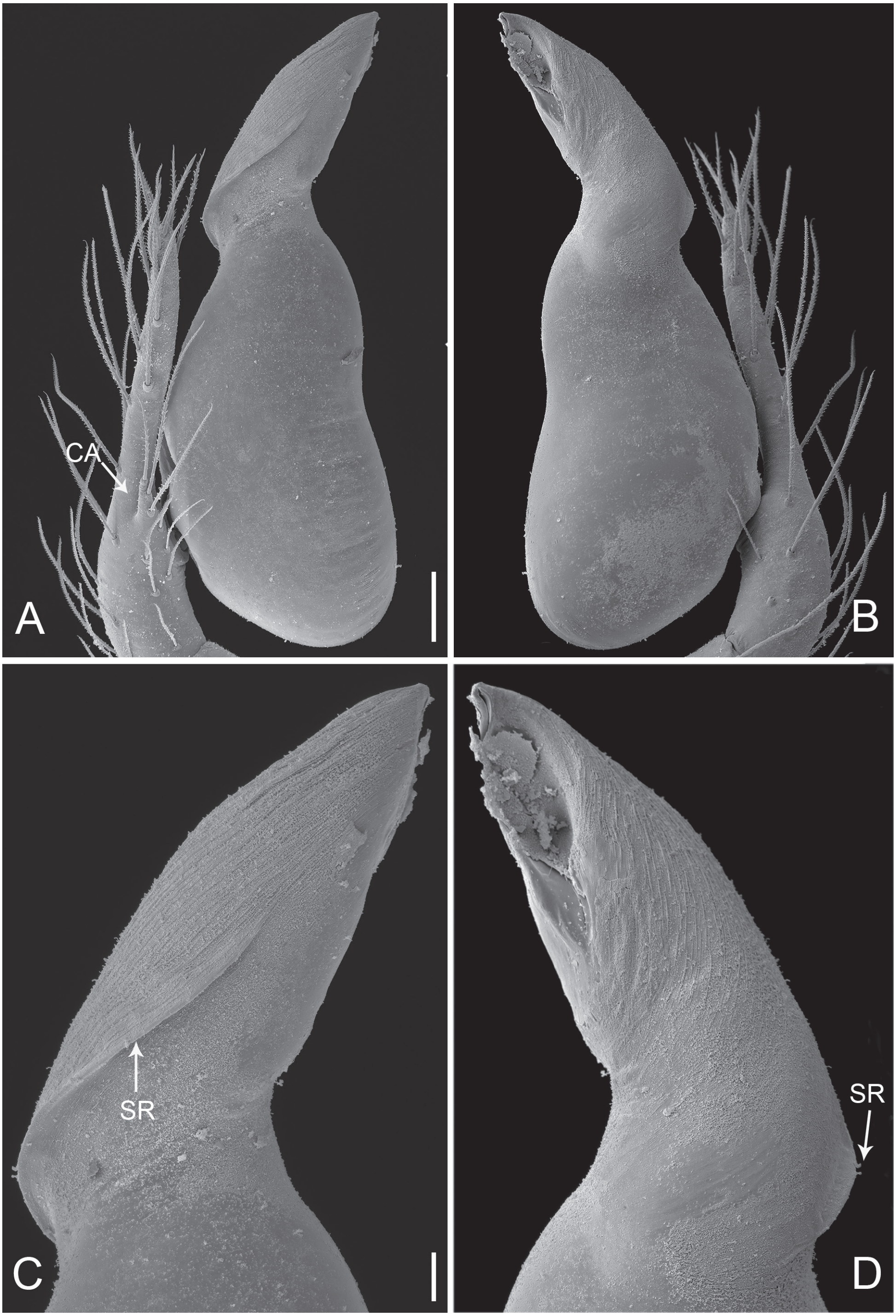

**Figure 11.** *Pinelema pacchanensis* sp. n., male. **A** Palp, prolateral view **B** Palp, retrolateral view **C** Embolus, prolateral view **D** Embolus, retrolateral view. Scale bars: 0.06 mm (**A–B**), 0.02 mm (**C–D**).

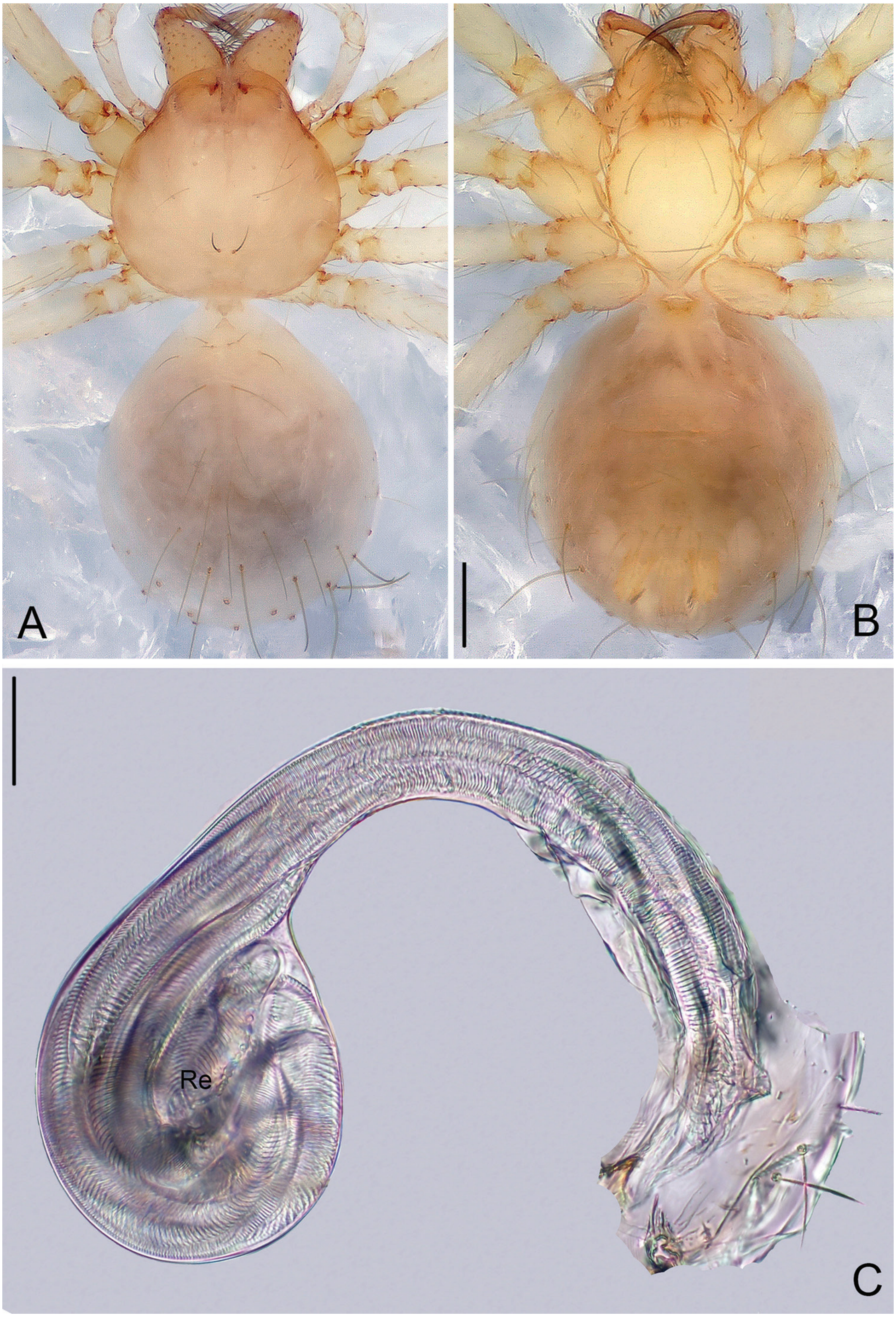

**Figure 12.** *Pinelema pacchanensis* sp. n., female paratype. **A** Habitus, dorsal view **B** Habitus, ventral view **C** Endogyne, lateral view. Scale bars: 0.5 mm (**A–B**), 0.05 mm (**C**).

Palp: femur approximately two times longer than patella, tibia nearly three times longer than patella, cymbium two times longer than tibia, cymbial apophysis brown and finger-shaped (Fig. 11A); REC 0.60; bulb kidney-shaped (Figs 10C–D, 11A–B); embolus boomerang-shaped (Figs 10D, 11D), spiral ridge brown (Figs 10B, 11C–D).

***Female.*** Total length 1.33 (Fig. 12A–B). Carapace 0.56 long, 0.55 wide. Abdomen 0.73 long, 0.67 wide. Coloration as in male. Leg measurements: I 4.26 (1.28, 0.22, 1.33, 0.86, 0.57); II 3.88 (1.18, 0.22, 1.19, 0.75, 0.54); III 2.89 (0.92, 0.16, 0.81, 0.54, 0.46); IV 3.56 (1.13, 0.17, 1.03, 0.75, 0.48). Endogyne comma-shaped, insemination duct long (2 times longer than diameter of receptacle) and its diameter twice as thin as receptacle. Receptacle globular (Fig. 12C).

**Distribution.** Known only from the type locality (Fig. 22).

## *Pinelema spirulata* Zhao & Li, sp. n.

http://zoobank.org/CAAA36BB-1471-4946-B8BF-657A483EA6BD
Figs 13–15, 22

**Type material.** ***Holotype*** ♂: Vietnam: Phu Tho Province: Xuan Son National Park: Lap Cave, N21°08.43', E104°56.57', 403 m, 2.X.2012, H.F. Zhao & Z.G. Chen leg. ***Paratypes*** 3♂ and 5♀, same data as holotype.

**Etymology.** The specific name is derived from the Latin word "*spirulatus*", meaning "screw-shaped", and refers to the spiral embolus; adjective.

**Diagnosis.** This new species can be distinguished from other congeners by the screw-shaped embolus (Figs 13B–D, 14A–D), emboli of other *Pinelema* species are either tube-shaped, triangular, or trapezoidal.

**Description.** ***Male*** **(holotype).** Total length 0.97. Carapace 0.51 long, 0.50 wide. Abdomen 0.50 long, 0.57 wide. Carapace yellow. Six eyes encircled by black rings, clypeus 0.08 long, ocular quadrangle 0.15 wide. Chelicerae, sternum, labium, and legs yellow. Leg measurements: I 3.71 (1.06, 0.19, 1.14, 0.76, 0.56); II 3.06 (0.90, 0.17, 0.91, 0.60, 0.48); III 2.25 (0.67, 0.16, 0.61, 0.42, 0.39); IV 2.58 (0.86, 0.16, 0.80, 0.39, 0.37). Abdomen dark blue with dense white hairs.

Palp: femur 2.5 times longer than patella, tibia approx. two times longer than patella, cymbium nearly two times longer than tibia, cymbial apophysis brown and spine like (Figs 13C, 14A); REC 0.28; bulb egg-shaped (Figs 13C–D, 14A–B); embolus spiral with brown ridge and tiny circular wrinkles (Figs 13B, 14C–D); the opening of embolus distinct (Fig. 14B, D).

***Female.*** Total length 1.30 (Fig. 15A–B). Carapace 0.52 long, 0.46 wide. Abdomen 0.74 long, 0.57 wide. Coloration as in male. Six eyes, clypeus 0.09 long, ocular quadrangle 0.17 wide. Leg measurements: I 3.50 (1.05, 0.14, 1.14, 0.65, 0.52); II 2.94 (0.87, 0.18, 0.90, 0.52, 0.47); III 2.23 (0.69, 0.16, 0.63, 0.39, 0.36); IV 2.77 (0.90, 0.16, 0.82, 0.49, 0.40). Endogyne as in Fig. 15C; insemination duct short, its diameter approx. 1/5 of receptacle diameter; receptacle with multiple membranous tubes inside.

**Distribution.** Known only from the type locality (Fig. 22).

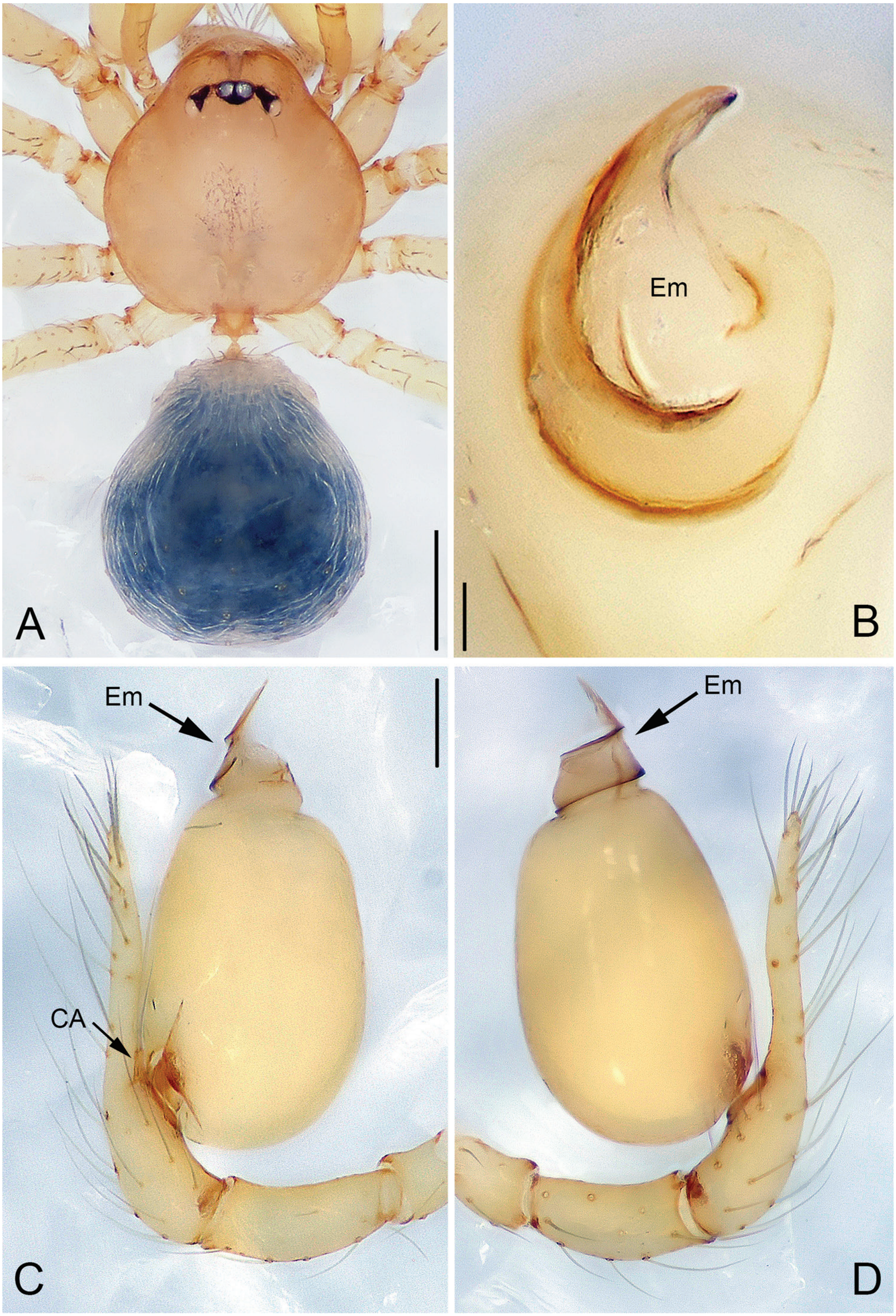

**Figure 13.** *Pinelema spirulata* sp. n., male holotype. **A** Habitus, dorsal view **B** Embolus, apical view **C** Palp, prolateral view **D** Palp, retrolateral view. Scale bars: 0.2 mm (**A**), 0.02 mm (**B**), 0.1 mm (**C–D**).

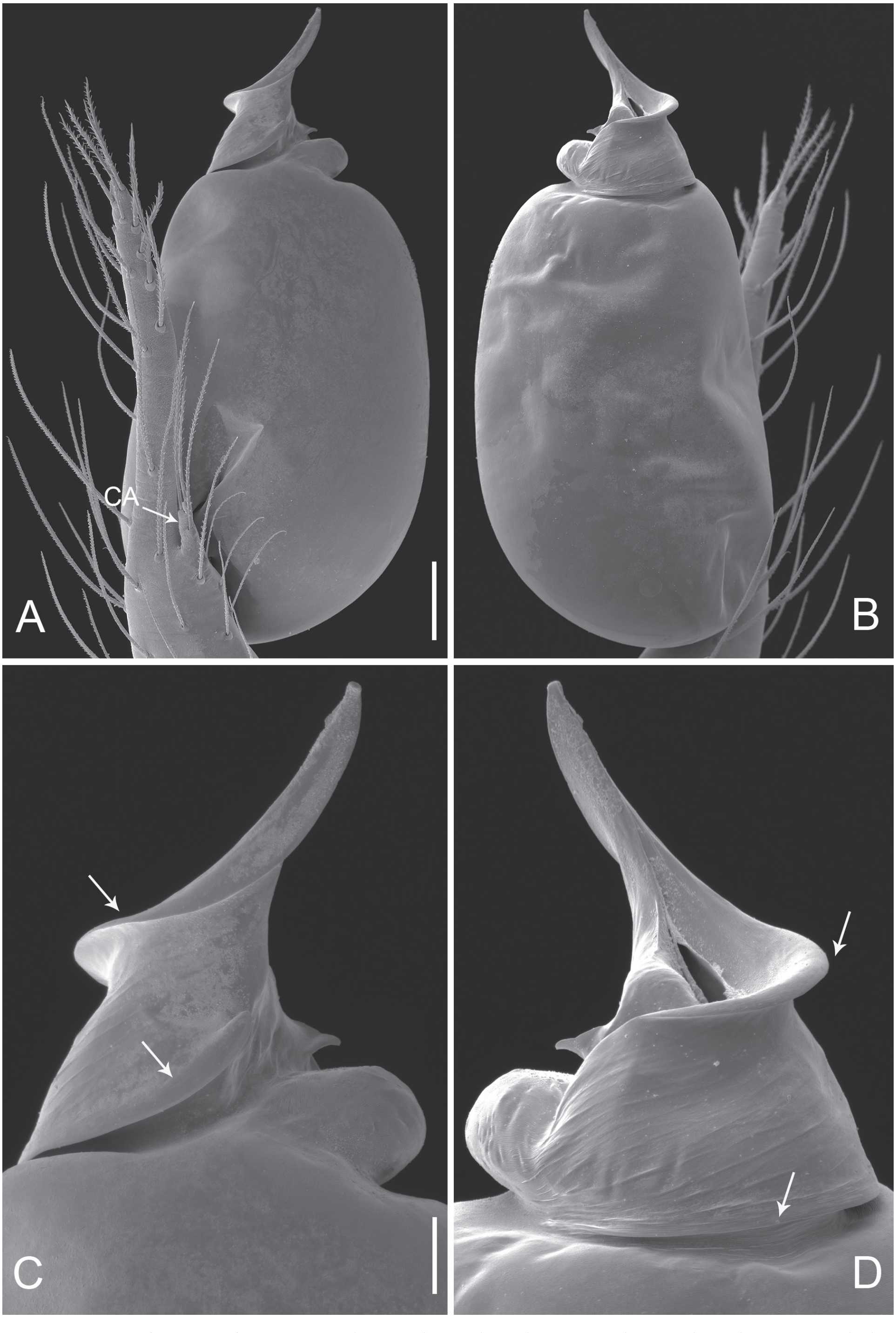

**Figure 14.** *Pinelema spirulata* sp. n., male. **A** Palp, prolateral view **B** Palp, retrolateral view **C** Embolus, prolateral view **D** Embolus, retrolateral view. Scale bars: 0.06 mm (**A–B**), 0.02 mm (**C–D**). Arrows indicate spiral ridge of embolus.

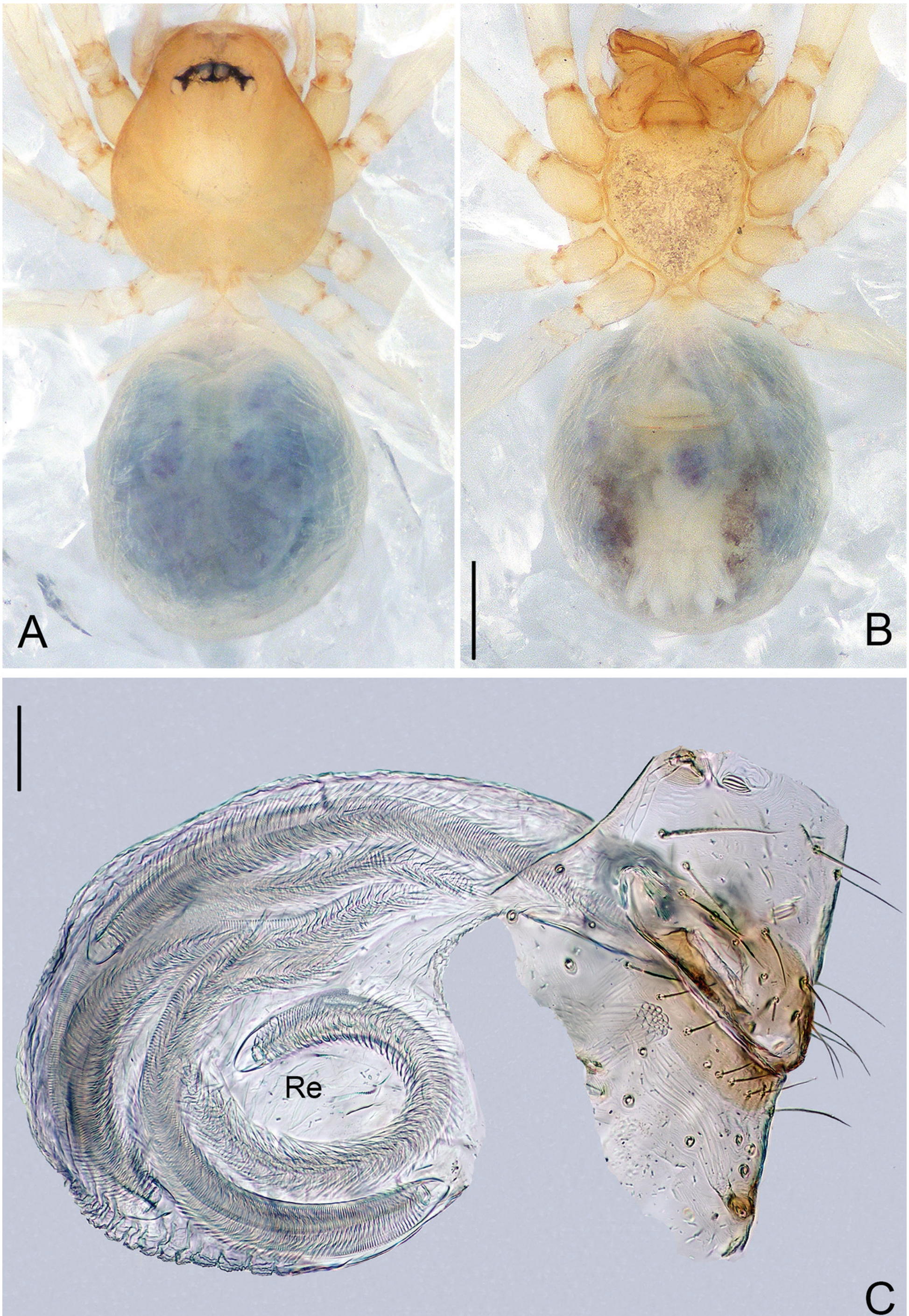

**Figure 15.** *Pinelema spirulata* sp. n., female paratype. **A** Habitus, dorsal view **B** Habitus, ventral view **C** Endogyne, lateral view. Scale bars: 0.2 mm (**A–B**), 0.1 mm (**C**).

### *Pinelema xiezi* Zhao & Li, sp. n.

http://zoobank.org/A6F02EFC-EFE5-47BF-B19F-07A517800007
Figs 16–18, 22

**Type material.** ***Holotype*** ♂: Vietnam: Quang Binh Province: Phong Nha-Ke Bang National Park: Tien Son Cave, N17°34.80', E106°16.92', 102 m, 17.V.2016, Z.G. Chen & Q.Y. Zhao leg. ***Paratypes*** 3♂ and 5♀, same data as holotype.

**Etymology.** This specific name is derived from the Chinese Pinyin 'xié zǐ', meaning 'shoe', in reference to the shoe-shaped embolus; noun.

**Diagnosis.** This new species is similar to *P. huobaensis* and *P. yaosaensis* by a having short embolus. It can be distinguished from related species by the shoe-shaped embolus (Figs 16B, 17C–D) (vs. triangular embolus in related species). It is also similar to *P. laensis* sp. n. but can be distinguished by the unsclerotized margin of the embolus (the embolus of *P. laensis* sp. n. is sclerotized marginally and hollow). This new species can be distinguished from other congeners by the short embolus.

**Description.** ***Male*** **(holotype).** Total length 1.52. Carapace 0.63 long, 0.54 wide. Abdomen 0.75 long, 0.53 wide. Carapace, labium, sternum, and legs yellow. Six eyes encircled by black rings, clypeus 0.15 long, ocular quadrangle 0.19 wide. Leg measurements: I 4.63 (1.39, 0.22, 1.50, 0.92, 0.60); II 3.70 (0.95, 0.21, 1.25, 0.75, 0.54); III 2.86 (0.87, 0.21, 0.85, 0.53, 0.40); IV 3.45 (1.13, 0.19, 1.01, 0.67, 0.45). Abdomen long, elliptic, light blue with sparse long hairs.

Palp: femur 2.5 times longer than patella, tibia 2.2 times longer than patella, cymbial apophysis light yellow and finger-shaped (Figs 16C, 17A); REC 0.48; bulb yellow and egg-shaped; embolus shoe-shaped (Figs 16C–D, 17C–D), with a distinct groove at the tip (Fig. 17B, D) and tiny wrinkles (Fig. 17A–D).

***Female.*** Total length 1.38 (Fig. 18A–B). Carapace 0.57 long, 0.52 wide. Abdomen 0.79 long, 0.66 wide. Coloration same as in male. Six eyes, clypeus 0.12 long, ocular quadrangle 0.18 wide. Leg measurements: I 4.27 (1.33, 0.19, 1.36, 0.81, 0.58); II 3.60 (1.11, 0.21, 1.13, 0.65, 0.50); III 2.53 (0.79, 0.17, 0.72, 0.46, 0.39); IV 3.22 (1.06, 0.18, 0.92, 0.63, 0.43). Insemination duct thinner than receptacle, receptacle hockey stick-shaped (Fig. 18C).

**Distribution.** Known only from the type locality (Fig. 22).

### *Pinelema zhenzhuang* Zhao & Li, sp. n.

http://zoobank.org/BC2C4389-A40D-43C4-933D-8E035EC791B0
Figs 19–21, 22

**Type material.** ***Holotype*** ♂: Vietnam: Quang Binh Province: Phong Nha-Ke Bang National Park: Tien Duong Cave, N17°31.17', E106°13.38', 133 m, 18.V.2016, Z.G. Chen & Q.Y. Zhao leg. ***Paratypes*** 3♂ and 4♀, same data as holotype.

**Etymology.** This specific name is derived from the Chinese Pinyin 'zhēn zhuàng', meaning 'needle-shaped', in reference to the shape of the embolus; adjective.

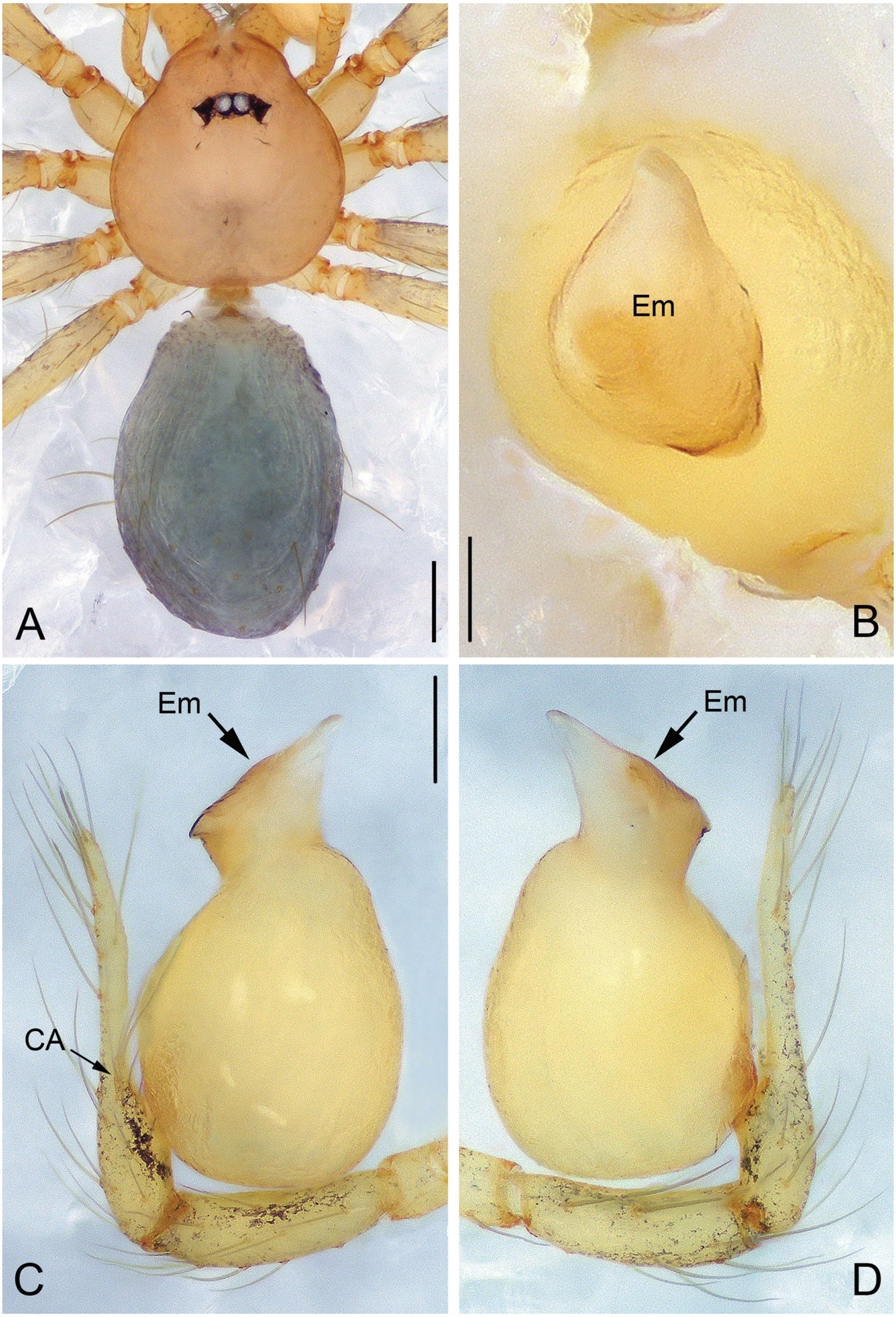

**Figure 16.** *Pinelema xiezi* sp. n., male holotype. **A** Habitus, dorsal view **B** Embolus, apical view **C** Palp, prolateral view **D** Palp, retrolateral view. Scale bars: 0.2 mm (**A**), 0.02 mm (**B**), 0.1 mm (**C–D**).

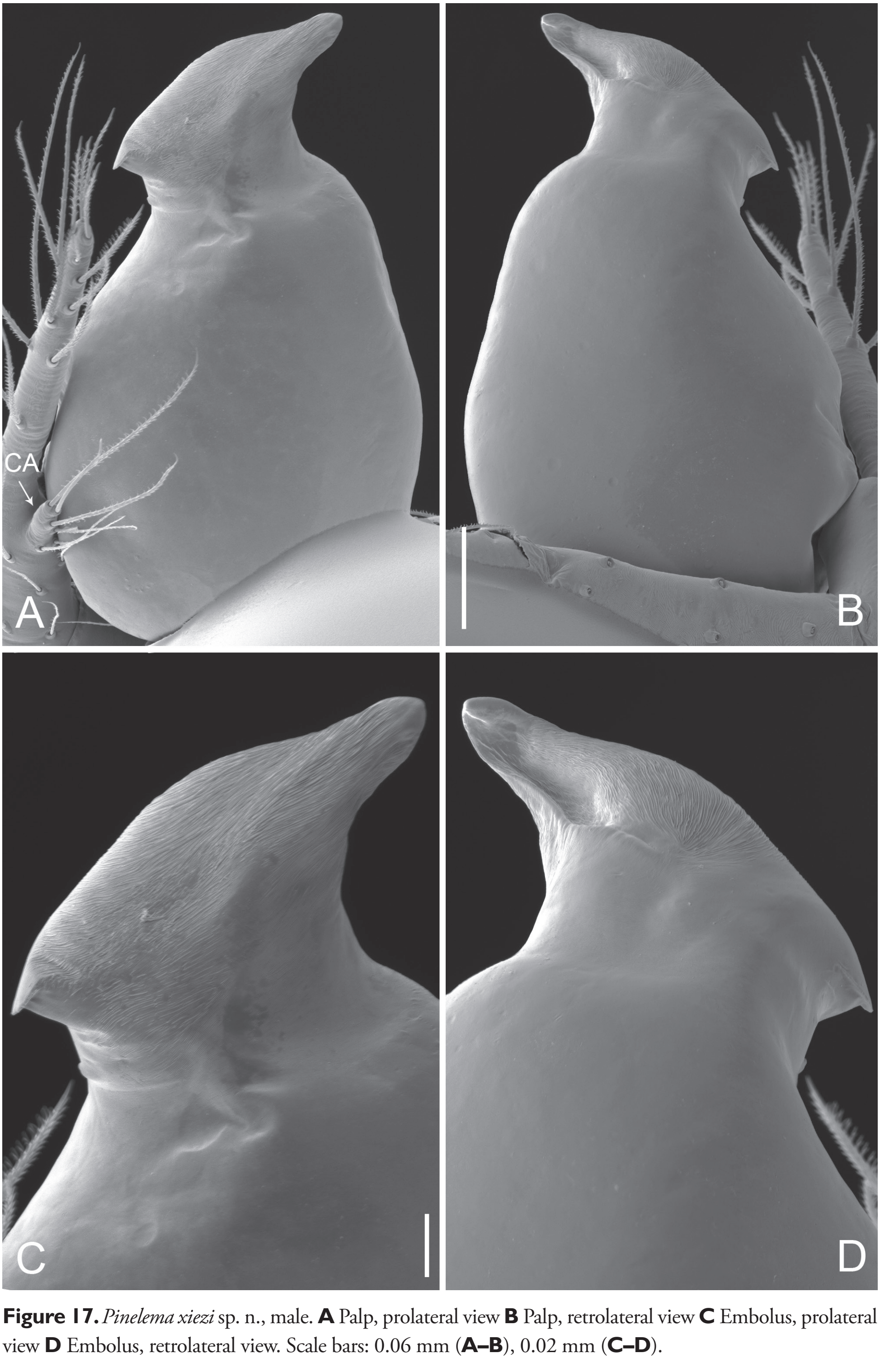

**Figure 17.** *Pinelema xiezi* sp. n., male. **A** Palp, prolateral view **B** Palp, retrolateral view **C** Embolus, prolateral view **D** Embolus, retrolateral view. Scale bars: 0.06 mm (**A–B**), 0.02 mm (**C–D**).

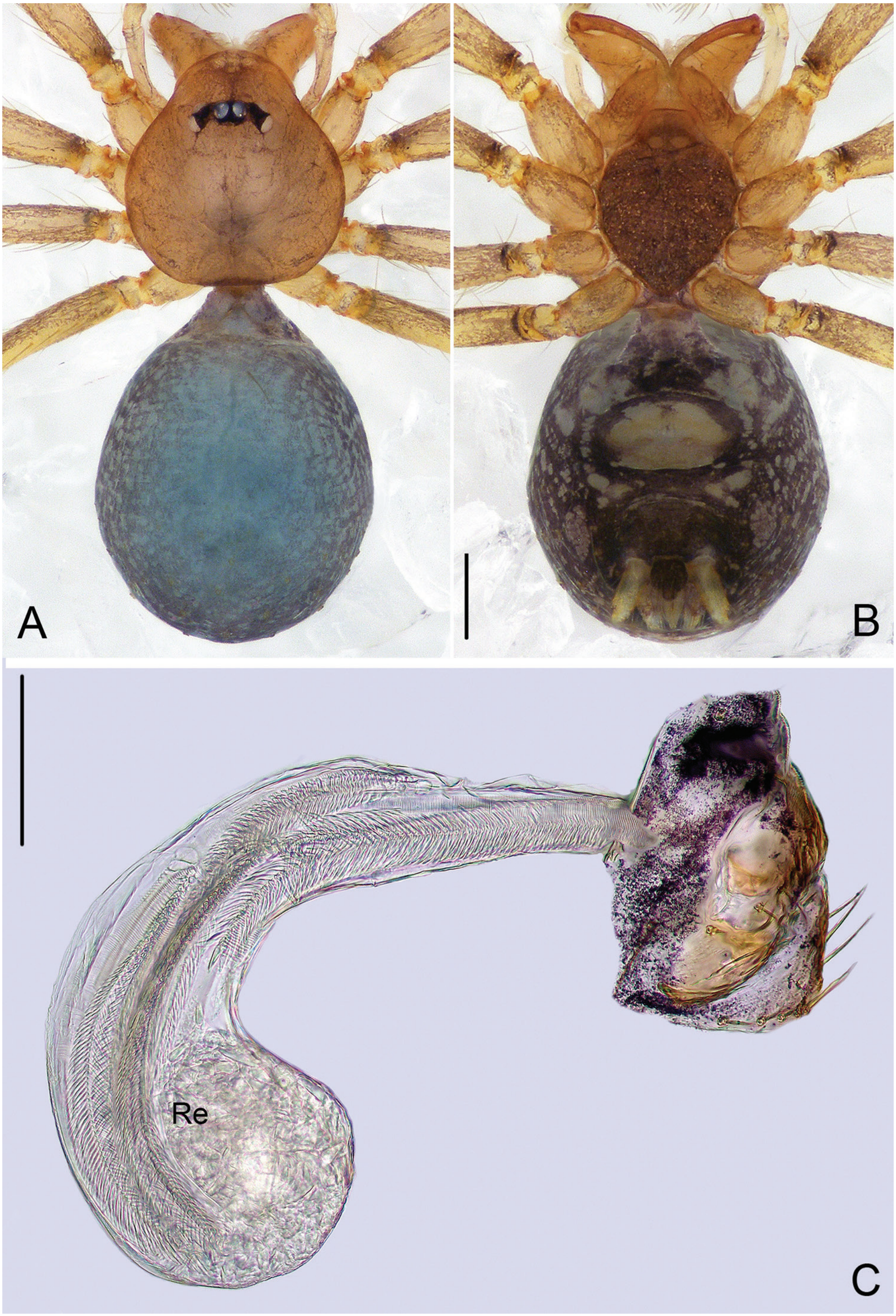

**Figure 18.** *Pinelema xiezi* sp. n., female paratype. **A** Habitus, dorsal view **B** Habitus, ventral view **C** Endogyne, lateral view. Scale bars: 0.2 mm (**A–B**), 0.05 mm (**C**).

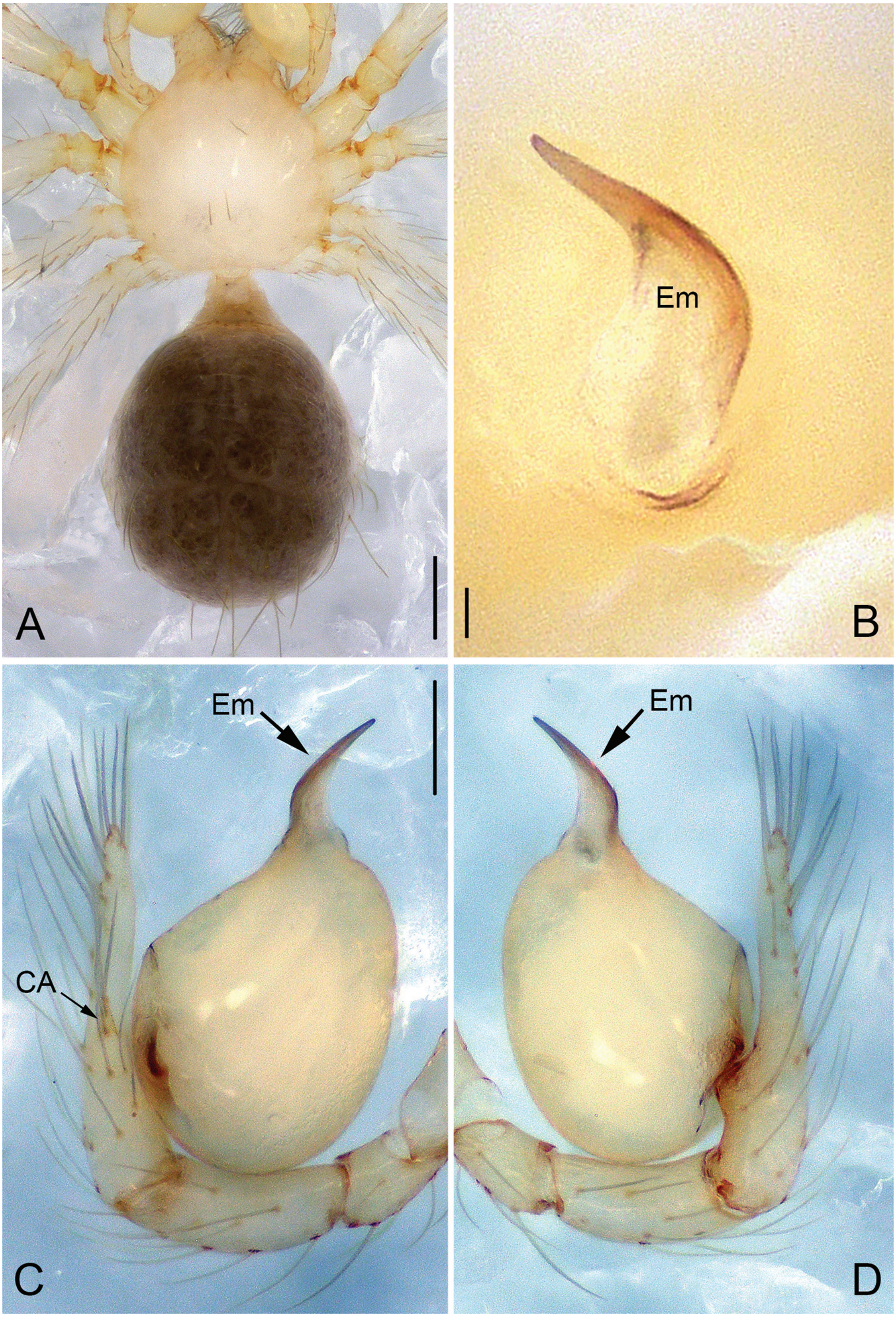

**Figure 19.** *Pinelema zhenzhuang* sp. n., male holotype. **A** Habitus, dorsal view **B** Embolus, apical view **C** Palp, prolateral view **D** Palp, retrolateral view. Scale bars: 0.2 mm (**A**), 0.02 mm (**B**), 0.1 mm (**C–D**).

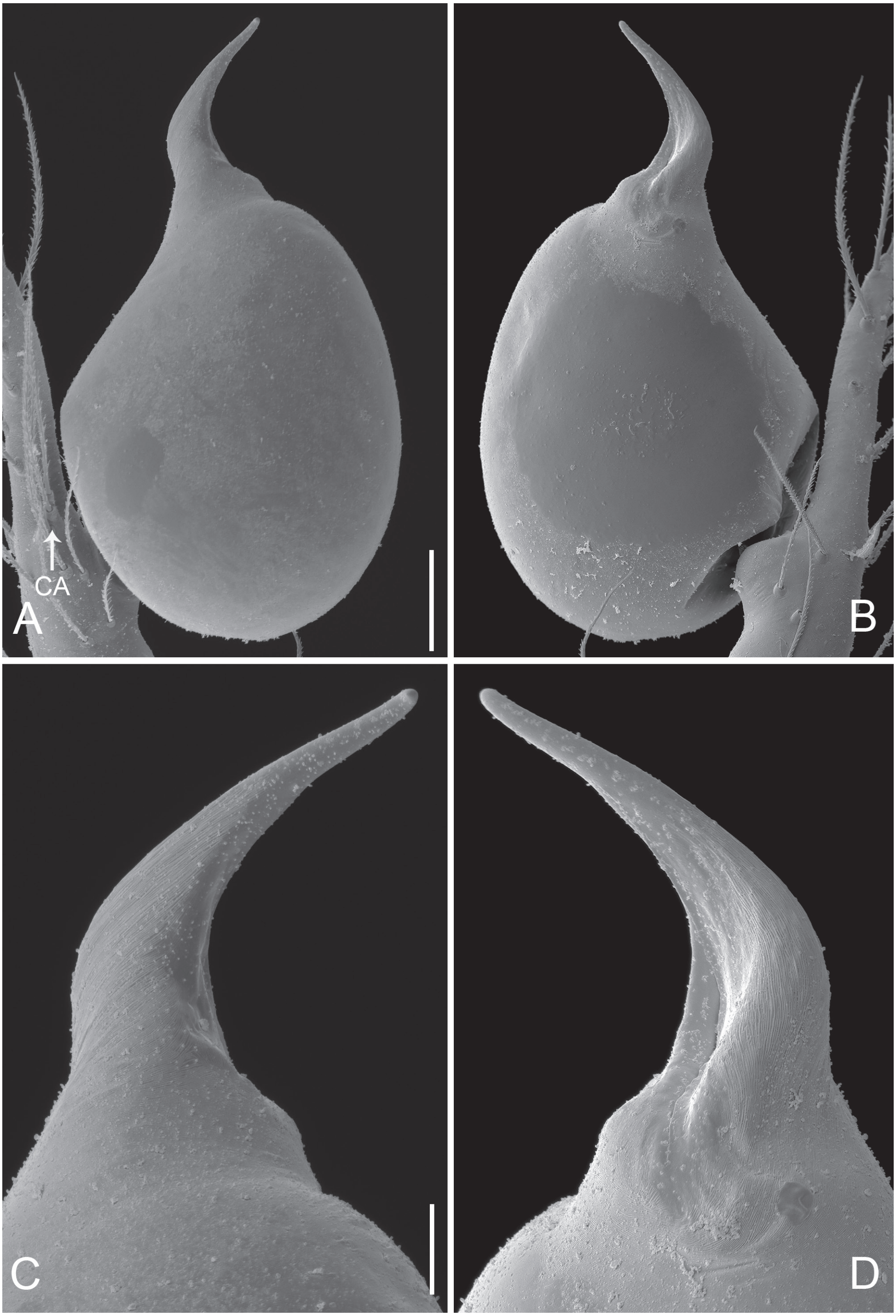

**Figure 20.** *Pinelema zhenzhuang* sp. n., male. **A** Palp, prolateral view **B** Palp, retrolateral view **C** Embolus, prolateral view **D** Embolus, retrolateral view. Scale bars: 0.06 mm (**A–B**), 0.02 mm (**C–D**).

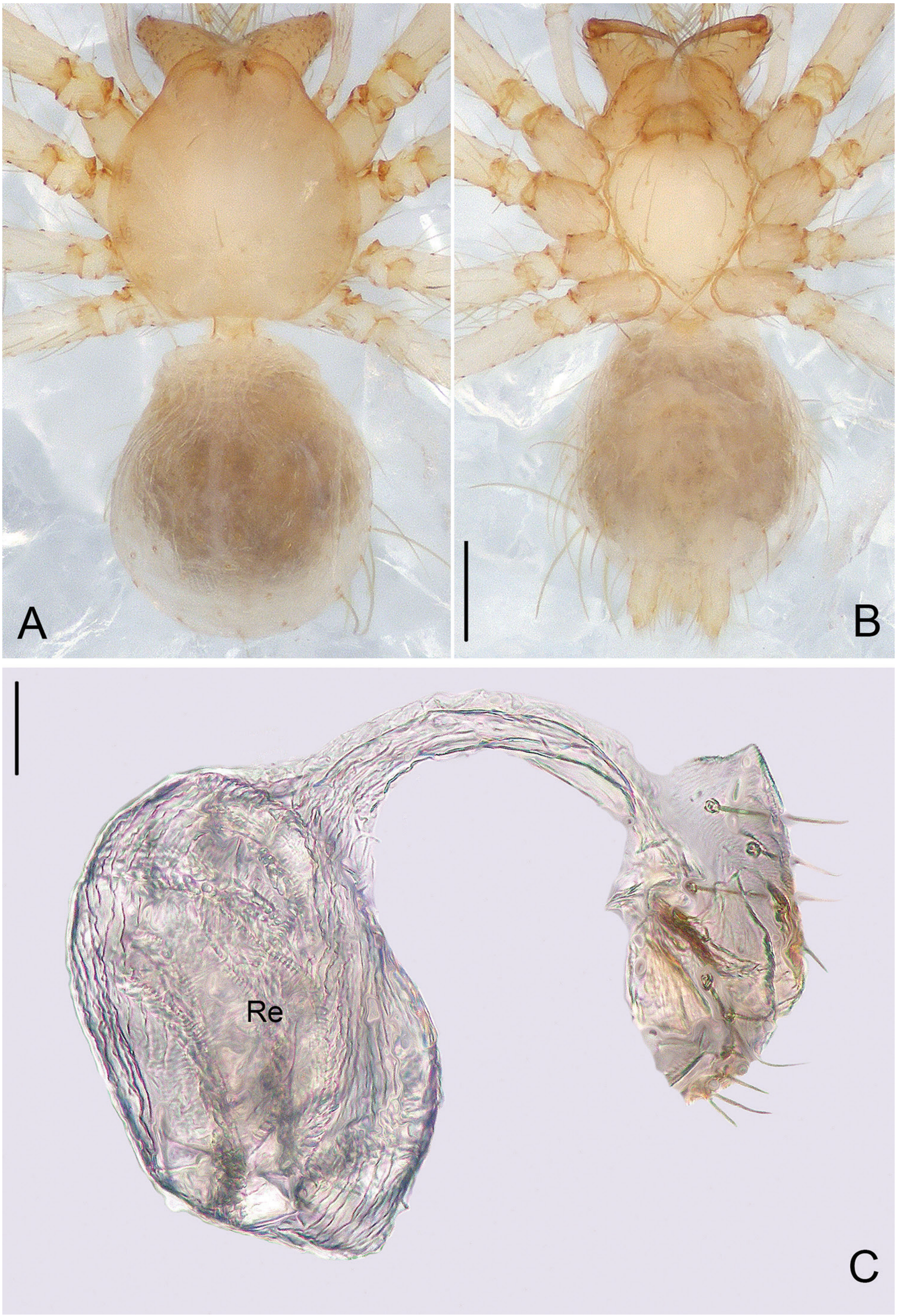

**Figure 21.** *Pinelema zhenzhuang* sp. n., female paratype. **A** Habitus, dorsal view **B** Habitus, ventral view **C** Endogyne, lateral view. Scale bars: 0.2 mm (**A–B**), 0.05 mm (**C**).

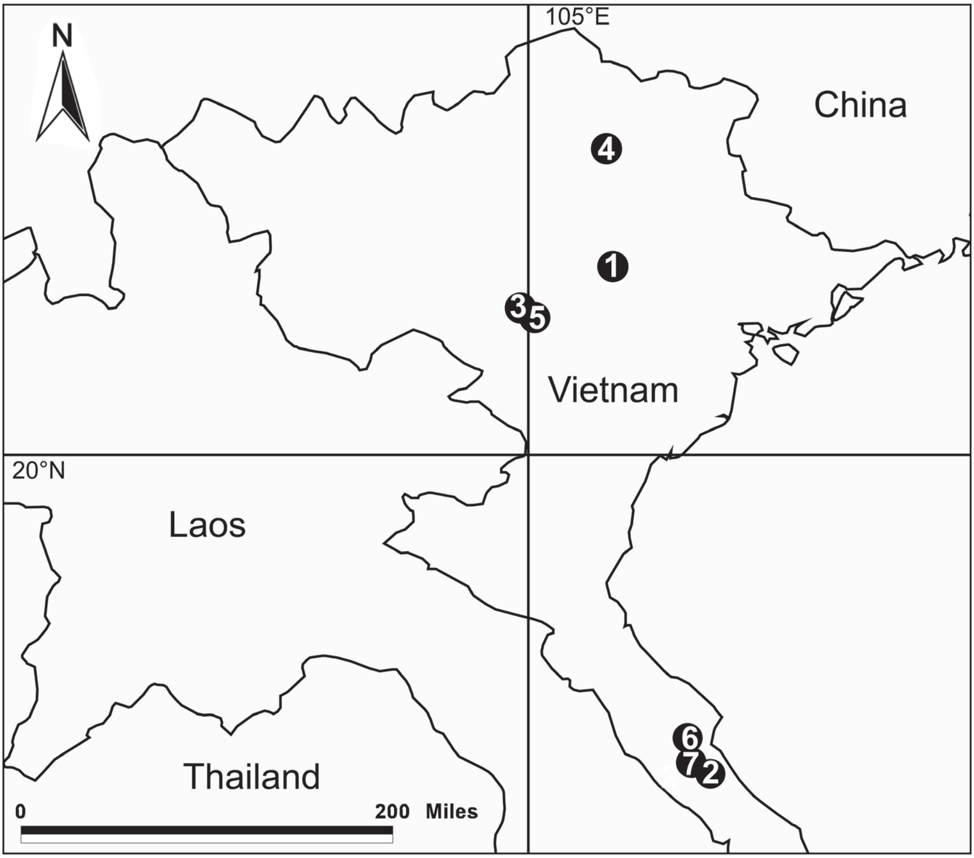

**Figure 22.** Distribution records of seven new *Pinelema* species in Vietnam: **1** *P. damtaoensis* sp. n. **2** *P. nuocnutensis* sp. n. **3** *P. laensis* sp. n. **4** *P. pacchanensis* sp. n. **5** *P. spirulata* sp. n. **6** *P. xiezi* sp. n. **7** *P. zhenzhuang* sp. n.

**Diagnosis.** This new species can be easily distinguished from other congeners by the short needle-shaped embolus (Figs 19B, 20C–D). The embolus of other *Pinelema* species is either long and tube-like, short and triangular or short and trapezoidal.

**Description.** ***Male*** **(holotype).** Total length 1.28. Carapace 0.49 long, 0.50 wide. Abdomen 0.69 long, 0.57 wide. Carapace yellow. Eyes absent. Chelicerae, sternum, and legs yellow. Leg measurements: I 4.80 (1.39, 0.22, 1.53, 0.99, 0.67); II 4.04 (1.20, 0.21, 1.28, 0.79, 0.56); III 2.93 (0.89, 0.18, 0.86, 0.54, 0.46); IV 3.44 (1.09, 0.19, 0.99, 0.71, 0.46). Abdomen brown with sparse long hairs.

Palp: femur 2.2 times longer than patella, tibia 1.8 times longer than patella, cymbial apophysis brown and spine-like (Figs 19C, 20A); REC 0.42; bulb acorn-shaped (Figs 19C–D, 20A–B); embolus bent and needle-shaped (Figs 19B–D, 20C–D), slit extending along entire embolus (Fig. 20B, D).

***Female.*** Total length 1.19 (Fig. 21A–B). Carapace 0.54 long, 0.51 wide. Abdomen 0.60 long, 0.53 wide. Coloration same as in male. Leg measurements: I 4.96

(1.50, 0.24, 1.56, 0.99, 0.67); II 4.25 (1.31, 0.22, 1.31, 0.83, 0.58); III 3.11 (0.99, 0.21, 0.90, 0.59, 0.42); IV 3.61 (1.20, 0.18, 1.05, 0.68, 0.50). Endogyne as in Fig. 21C; insemination duct narrow and its diameter shorter than length of receptacle; receptacle oval.

**Distribution.** Known only from the type locality (Fig. 22).

## Acknowledgements

We thank Yuri Marusik for editing the manuscript. Sarah Crews kindly improved English of the text. Nguyen Van Mui (Phong Nha-Ke Bang) kindly helped in field work. This study was supported by the National Natural Sciences Foundation of China (NSFC–31530067, 31471960) and the Southeast Asia Biodiversity Research Institute, Chinese Academy of Sciences (2015CASEABRI005, Y4ZK111B01). Part of the laboratory work was financially supported by research project of the Vietnam Academy of Science and Technology (VAST04.09/16–17).

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ZooKeys 734: 43–103 (2018)
doi: 10.3897/zookeys.734.21989
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# The tiger beetles (Coleoptera, Cicindelidae) of the southern Levant and adjacent territories: from cybertaxonomy to conservation biology

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Academic editor: *B. Guéorguiev* | Received 1 November 2017 | Accepted 15 January 2018 | Published 5 February 2018

*http://zoobank.org/7C3C687B-64BB-42A5-B9E4-EC588BCD52D5*

**Citation:** Assmann T, Boutaud E, Buse J, Gebert J, Drees C, Friedman A-L-L, Khoury F, Marcus T, Orbach E, Renan I, Schmidt C, Zumstein P (2018) The tiger beetles (Coleoptera, Cicindelidae) of the southern Levant and adjacent territories: from cybertaxonomy to conservation biology. ZooKeys 734: 43–103. https://doi.org/10.3897/zookeys.734.21989

## Abstract

The tiger beetles of the southern Levant (Egypt: Sinai, Israel, Jordan) and adjacent regions of the neighboring countries Lebanon, Syria, Iraq, Saudi Arabia and Egypt are reviewed in terms of species taxonomy, ecological and distributional traits and conservation biology. An illustrated dichotomous identification key from the species of this region is provided. Based on the classical identification key, we developed a digital identification application for smartphones and tablets. The species status of *Calomera aulicoides* (J.R. Sahlberg, 1913) is (re-) established (stat. rest.) as this taxon can be found sympatrically and parapatrically together with *Calomera littoralis winkleri* (Mandl, 1934). Morphological character states are discussed to identify *Cicindela javetii* Chaudoir, 1861 and *C. herbacea* Klug, 1832. *Calomera aphrodisia* (Baudi di Selve, 1864) is recorded for the first time from Israel. The presence of *Calomera aulica* (Dejean, 1831) and *Grammognatha euphratica* (Dejean, 1822) is confirmed by new records. At least five taxa are threatened or extinct in Israel. For one of these species, Israel has a national responsibility for the conservation as the main part of the distribution range is within this country.

Availability: The application TIGER BEETLE ID for Android devices can be freely downloaded at https://doi.org/10.3897/zookeys.734.21989.suppl1. See also disclaimer of warranties.

**Keywords**

Middle East, identification key, Geadephaga, species traits, life history traits, application for smartphones and tablets, Android, mobile devices, species status, sibling species

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## Introduction

As tiger beetles are often colorful and diurnal, they have attracted the attention of academics, citizen scientists, and nature-lovers. For example, there is an entire journal 'Cicindela' devoted exclusively to this group, and highlights the public interest in these animals which belong to the best known insects (Pearson and Vogler 2001). As several tiger beetles are known to be in strong decline, they became one of the most suitable insect groups for conservation biology (e.g. Cassola and Pearson 2000), including action plans for recovery (e.g. U.S. Fish and Wildlife Service 2009; Vogler and DeSalle 1994; Vogler et al. 1993). Numerous species are listed in European Red Lists or in the U.S. Endangered Species Act.

For many regions, updated identification keys, compilations or even field guides for the tiger beetles are available, e.g. for North America, Australia, parts of China, most parts of Europe and Sub-Saharan Africa (Gebert 2006; Golding 2016; Gourvés 2002; Lisa 2002; Pearson et al. 2015; Pearson et al. 2006; Shook and Wu 2007; Werner 1999; 2000). There have been several publications addressing the tiger beetle fauna of the Levant and the surrounding areas (e.g. Abdel-Dayem et al. 2003; Ali 1978; Deuve 2011; 2012; Gebert 2016; Jaskuła and Rewicz 2014; Matalin and Chikatunov 2016; Nussbaum 1987). However, also after the recently published excellent study of the Israeli tiger beetles with an identification key (Matalin and Chikatunov 2016), there are still some open questions and topics:

(1) In the faunistic part of their work Matalin and Chikatunov (2016) addressed mostly older material (until the 1990s) of the Steinhardt National Collection of Natural History at the Tel Aviv University. Further records, especially from the last two decades, are available and must be taken into account. The southern Levant is a poorly studied region in which Geadephaga species may be overlooked (Schuldt et al. 2009). Therefore species from adjacent countries should be incorporated.

(2) An identification key which includes the species of the adjacent countries would be useful. To meet the need of many enthusiasts and laypersons, for example in Facebook groups which discuss entomology, we present a field guide for mobile devices, such as smartphones and tablets (cf. Farnsworth et al. 2013). Moreover, figures depicting both morphological details and the habitus are provided to bolster the identification skills of the general public.

(3) Open systematic questions, for example, the systematic rank of the two parapatric and sympatric "subspecies" of the *Cicindela littoralis* group in the southern Levant, need to be revised.

(4) Finally, as claimed by both taxonomists and conservationists (e.g. Golding and Timberlake 2003), we incorporate in this taxonomic study comprehensive information about habitat preferences and first assessments to identify threatened species of the tiger beetles of the southern Levant.

## Material and methods

### Delineation of the study area

We define the southern Levant as a section of Southwest Asia comprised of the Sinai Peninsula (Egypt), Israel (including areas under Palestinian control), and Jordan. Species known from surrounding regions in Egypt, Lebanon, Syria, Iraq and Saudi-Arabia are also considered. For an overview of the study area see Fig. 1.

### Nomenclature

We rank the tiger beetles as a family within the Geadephaga. In many other systematic compilations of Adephaga, tiger beetles are ranked as a subfamily of Carabidae (e.g. Ball and Bousquet 2001; Beutel et al. 2007; Lawrence and Slipinski 2013; Müller-Motzfeld 2006). However, recent molecular findings reveal the Cicindelidae, together with Trachypachidae, as the sister taxa to all other Geadephaga (Bocak et al. 2014; López-López and Vogler 2017).

Since Rivalier's (1950) basic work on male genitalia, the "former" genus *Cicindela* has been split up into small entities, mainly due to differences in the male genitalia (comparable to those within the genus *Carabus*). However, the taxonomy of these genus group names is not consistently used in the literature, especially experts from the

Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

**Figure 1.** Study area. The line marks the approximate edge of the study area and parts of adjacent lands. Mediterranean islands are excluded.

New World and many professional biologists still adopt the broad and conservative definition of the genus *Cicindela* (cf. Lorenz 2005; Pearson et al. 2006; Pearson and Vogler 2001; Rivalier 1971; Werner 1991; 1992). We do not want to support this taxonomic "arbitrariness" and try to avoid any superfluous nomenclatural changes. Therefore we adopt the genus (and subgenus) nomenclature from the recent publications of Putchkov and Matalin (2017), Lorenz (2005), and a monography on the Palaearctic tiger beetles in preparation (Gebert, Wiesner, Matalin and Franzen, pers. comm.).

Moreover there are differences in the rank of species and subspecies between many authors (Deuve 2011; Mandl 1981b; Putchkov and Matalin 2003, 2017). If there is evidence for a lack of gene flow in parapatric or sympatric situation we rank the given taxa as species following broadly accepted species concepts (e.g. Biological Species Concept).

## Studied material

This study is based on the examination of specimens collected during the authors' field trips in Egypt, Israel, and Jordan, as well as specimens stored in entomological collections (including material from Europe, Africa, and other parts of Asia for comparisons). We studied approximately 2,000 specimens stored in the following collections:

| | |
|---|---|
| **CAL** | Working collection Assmann, Lüneburg, Germany (part of ZSM) |
| **CGD** | Working collection Gebert, Dresden, Germany |
| **COQ** | Working collection Orbach, Qiryat Tiv'on, Israel (will be transferred to SMNHTAU, Israel) |
| **CSW** | Working collection Starke, Warendorf, Germany (will be transferred to Westfälisches Landesmuseum Münster, Germany) |
| **CSH** | Working collection Schnitter, Halle/S., Germany |
| **CWB** | Working collection Wrase, Berlin, Germany (part of ZSM) |
| **SMNHTAU** | Steinhard Museum of Natural History, National Collections, Tel Aviv University, Tel Aviv, Israel |
| **NHMP** | Muséum National d'Histoire Naturelle, Entomology Department, Paris, France |
| **ZISP** | Zoological Institute of the Academy of Sciences, St. Petersburg, Russia |
| **ZSM** | Zoological State Collection Munich (Zoologische Staatssammlung München), München, Germany |

We received information from colleagues about few records from the following collections:

| | |
|---|---|
| **SDEI** | Senckenberg German Entomological Institute (Deutsches Entomologisches Institut), Müncheberg, Germany |
| **ZISP** | Coleoptera Department, Laboratory of Insect Taxonomy, Zoological Institute of the Russian Academy of Sciences, St. Petersburg, Russia |

### Measurements, photographs, distribution records, traits

For detailed explanations about measurements, photography, traits and distributional data see other publications about the carabid beetles of the southern Levant (Assmann et al. 2012; 2015a; 2015b).

### Criteria to classify threatened species

As few biologists and citizen scientists work on tiger beetles in the Middle East, our data do not allow for the estimation of a trend for all species. Thus, we used the approach of Ludwig et al. (2006) to classify threatened species for Red Lists. This approach is based on recent abundance, short-term and long-term trends of populations and habitats as well as the risk factors for the given species. If long-term data (50–150 years) are not available, we set this criterion to 'data deficient' for the identification of the threat categories. Sufficient data on the threat to cicindelid beetles are only available from Israel. Therefore, the assessments are made only for Israel.

If large parts of the distribution range (>67 %) of a taxon are in the study region we derive the national responsibility of the given states for the preservation of the given taxa (cf. Gruttke et al. 2004; Schnittler and Günther 1999).

### Identification keys

We developed two tools for the identification of the tiger beetles in the southern Levant:

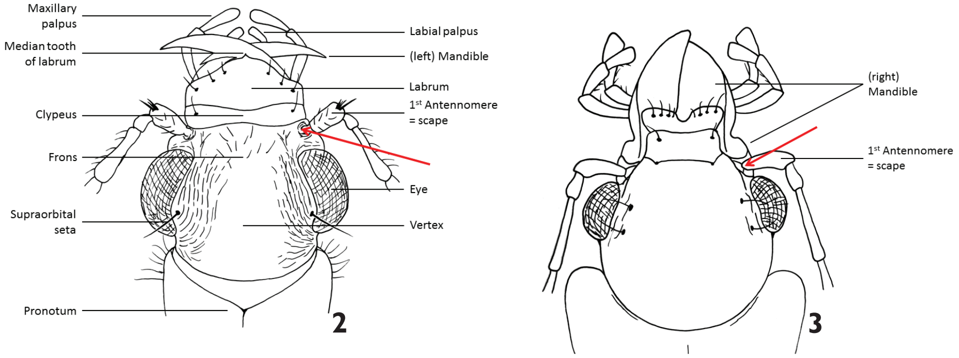
(a) A "classical", dichotomous identification key (Winston 1999) containing textual descriptions and figures. We used simple terminology of morphological characters and their states to make the key user-friendly.

(b) An Android application for mobile phones and tablets (Android Studio environment: Google and Alliance 2016, Android Homepage). Text and figures are adopted from the "classical" identification key.

## Results

### Characterization of the Cicindelidae species in the southern Levant

In general, tiger beetles differ from all other ground beetles in the position of antennae which insert on the frons of head, between the bases of mandibles (Fig. 2). In other ground beetles, the antennae insert in line with and posteriad adjacent mandibular bases (Fig. 3).



**Figures 2, 3.** Head of a tiger beetle (left) and of a ground beetle (right) (dorsal view = upper side) and structures often used for identification. The arrows mark the insertion of antenna.

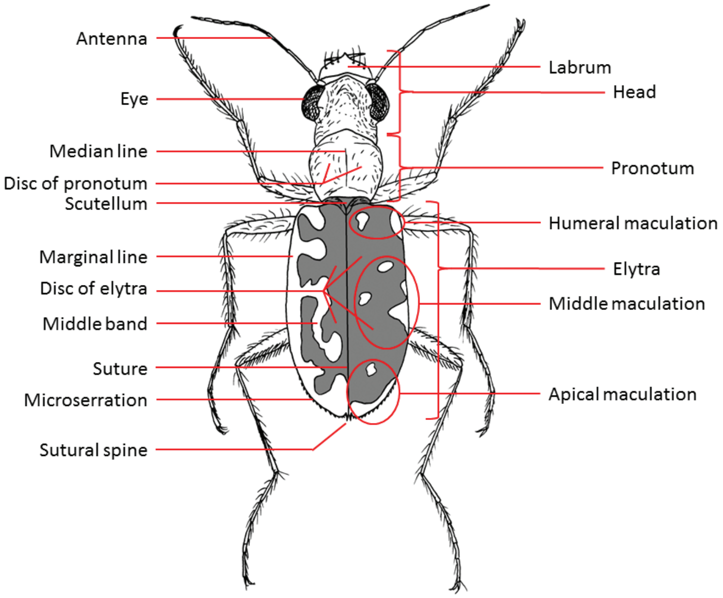


**Figure 4.** Habitus of a tiger beetle (dorsal view = upper side) and structures often used for identification.

Tiger beetles are agile, usually diurnal beetles with a head (including the eyes) wider than the pronotum; long, thin legs and long, sickle-shaped mandibles with long, simple teeth along the inner edge of the mandibles (Figs 2, 3). All species from the Middle East have fully developed wings which are used during short flights for hunting and escape flights.

The habitus photographs (Figs 7–38) provide further assistance in the identification of cicindelids. An overview of the external morphology of cicindelids and the relevant terminology is found in Figs 2 to 5.

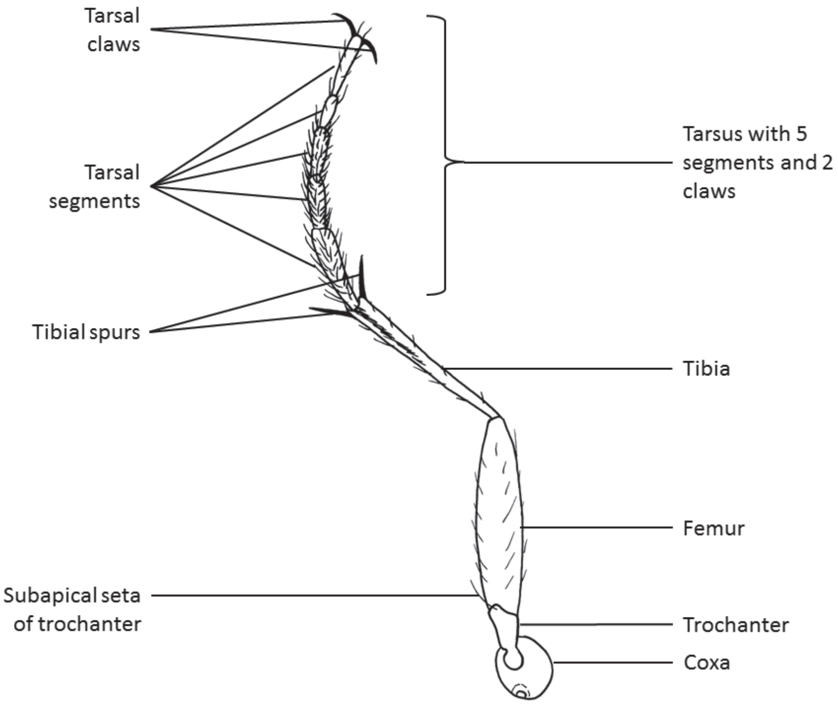


**Figure 5.** Leg of a tiger beetle and structures often used for identification. The prefixes pro-, meso- and meta- are used to indicate parts of the front, middle and hind legs, respectively. For example, metatibia refers to the tibia of hind leg and profemur to the femur of fore leg.

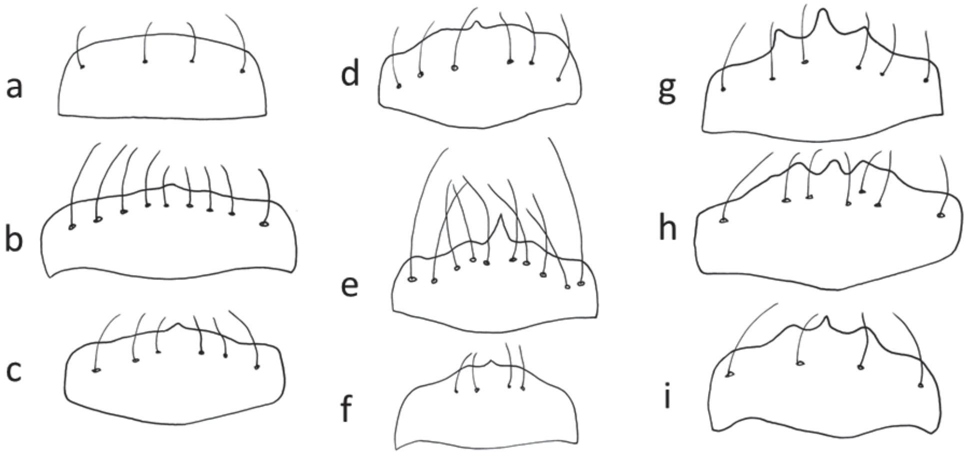
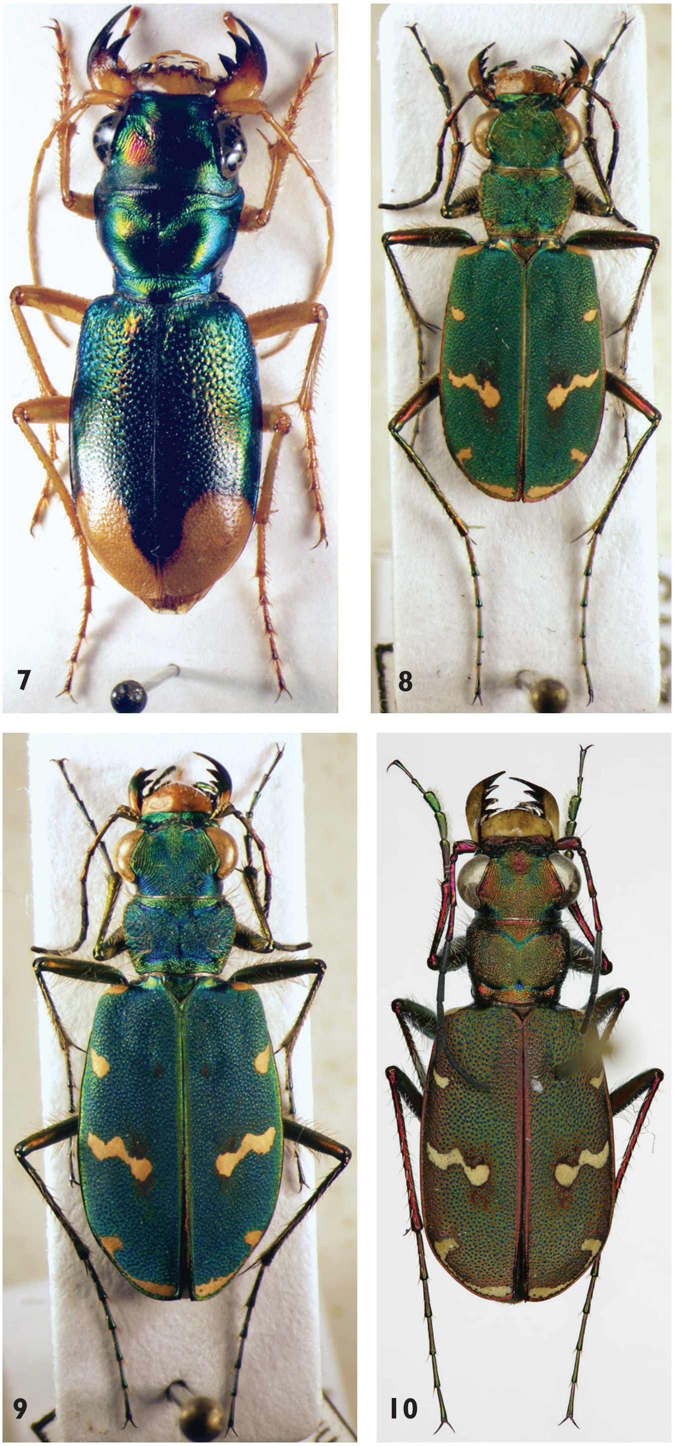


**Figure 6.** Labrum of tiger beetles: **a** without a tooth (*Myriochila melancholica*) **b, c, d, e, f** with 1 tooth (**b** *Cylindera contorta valdenbergi* **c** *Cephalota littorea* **d** *Cicindela javetii* **e** *Cylindera rectangularis* **f** *Cephalota vartianorum*) **g, i** with 3 teeth (**g** *Cicindela asiatica* **i** *Myriochila orientalis*) **h** with 3 to 5 teeth (**h** *Cephalota tibialis*).



**Figures 7–10.** Cicindelidae species: **7** *Grammognatha euphratica* (female) **8** *Cicindela javetii* (male) **9** *C. javetii* (female) **10** *C. javetii* (male, paratype of *thughurica*).

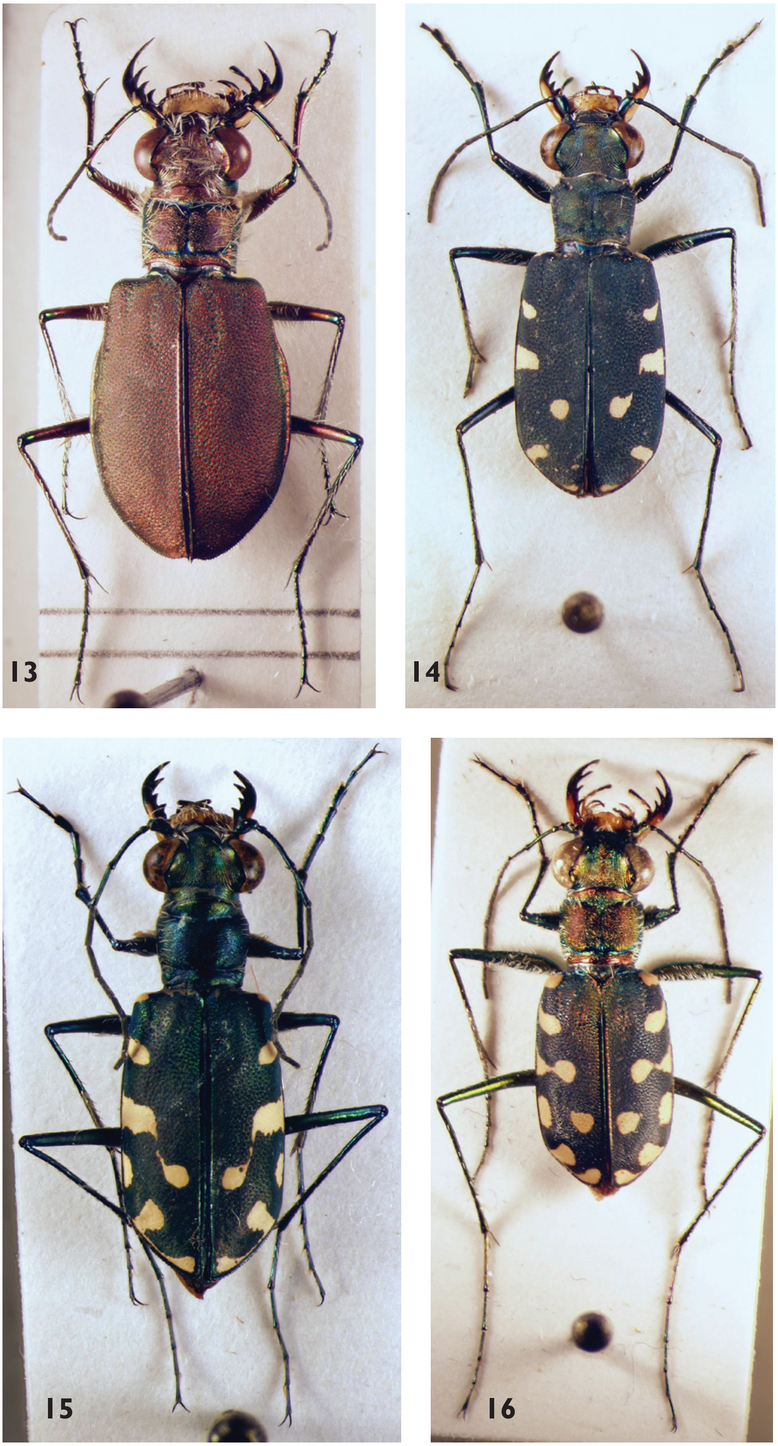
**Figures 11–12.** *Cicindela* species: **11** *C. herbacea* (male) **12** *C. asiatica* (male).

## Identification key to the tiger beetles from the southern Levant and adjacent territories

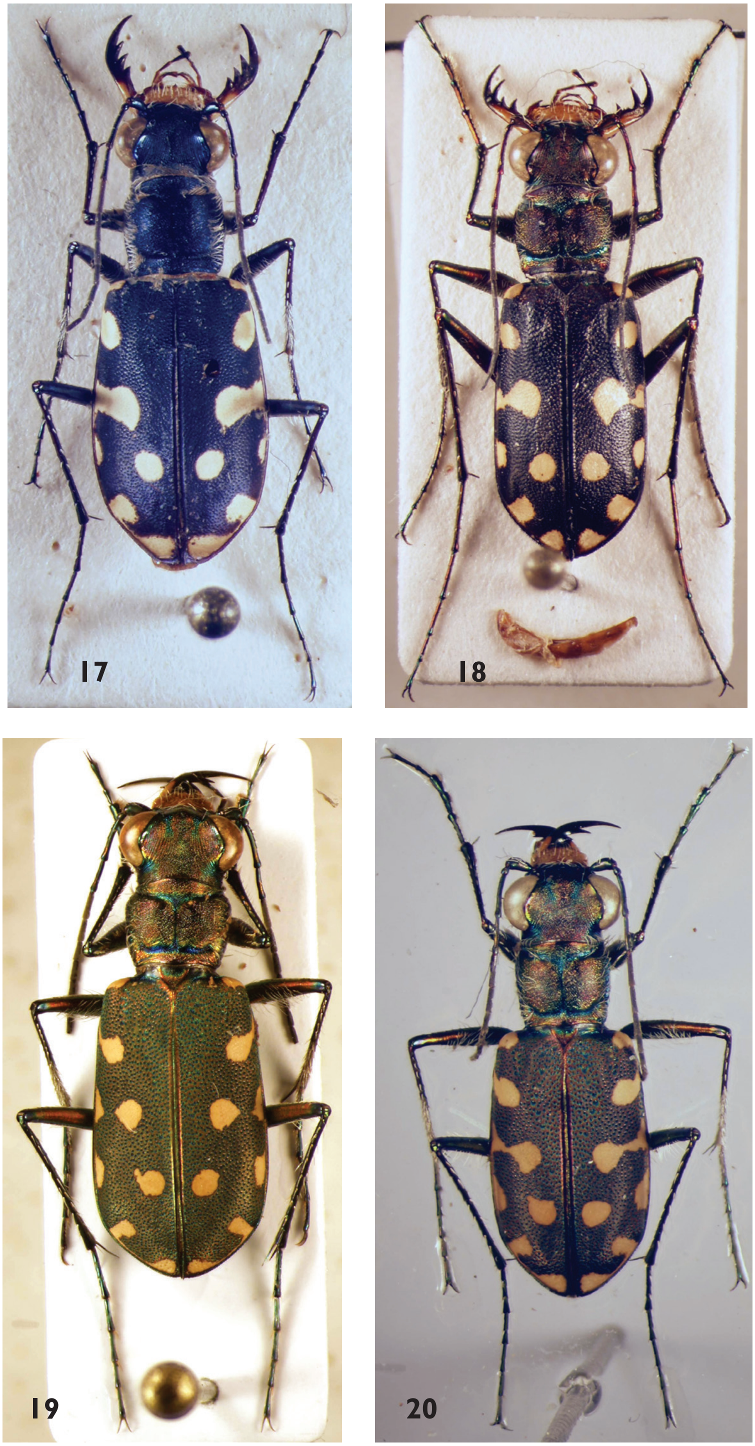
For ease of orientation, the numbering schemes of the species found in the identification key and in the species accounts are identical. Species which are known from adjacent countries, but not from the southern Levant itself are given in parentheses.

Chikatunov et al. (2006) and Ptashkovsky (2013) indicated 29. *Cephalota deserticola* (Faldermann, 1836) for Israel. However, its distribution range stretches from western Iran to Central Asia and China (Gebert 2016; Werner 1992; Wiesner 1992) and therefore, based on geographical considerations, we consider it is unlikely that the species is found in Israel. As no verifiable records from the southern Levant have been preserved in SMNHTAU (including the recently transferred collection of Ptashkovsky), we treat the published records for *C. deserticola* as misidentifications (cf. Matalin and Chikatunov 2016), and do not include this species in the identification keys. Moreover, in SMNHTAU there are no *Cephalota deserticola* specimens with an identification label from Mandl (own observation).

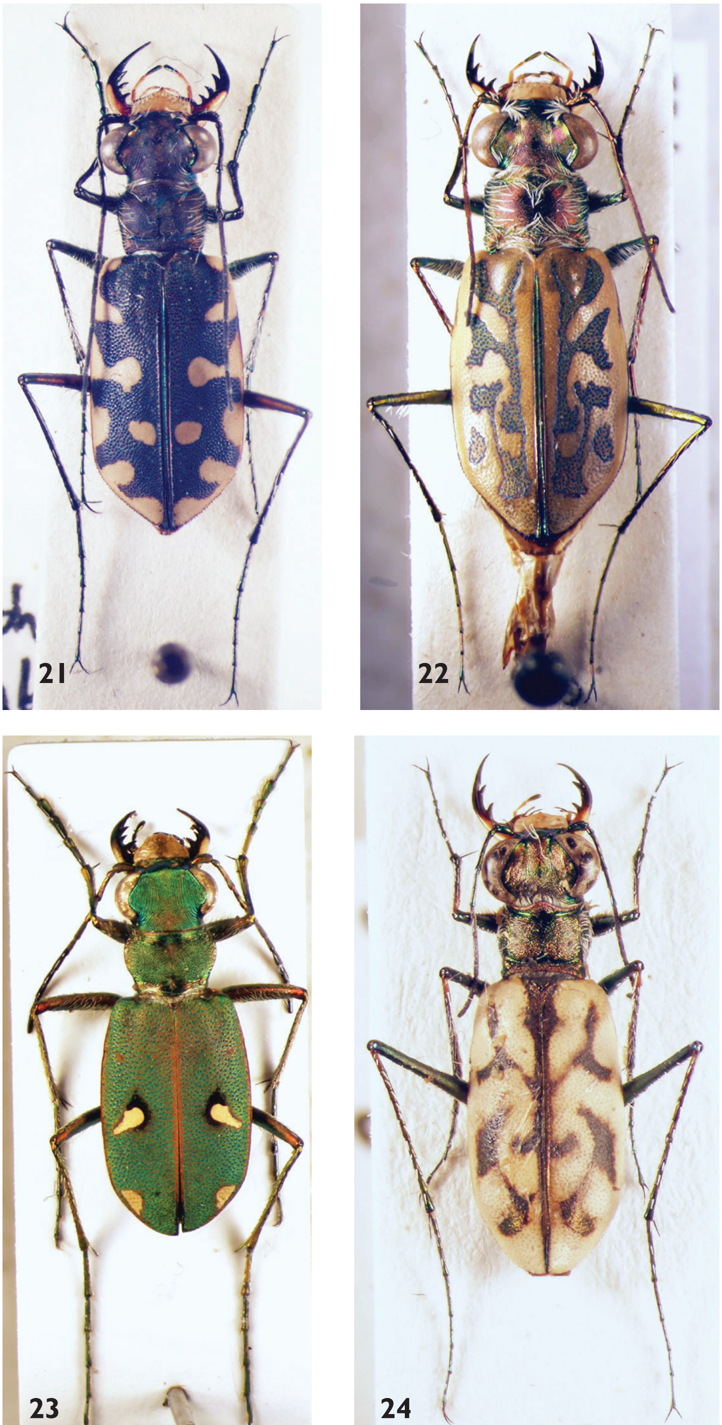
The following species are also not incorporated in the key: 30. *Cylindera pygmaea* (Dejean, 1825), 31. *Calomera caucasica* (Adams, 1817), the *Salpingophora* species 32. *S. bellana* (W. Horn, 1905), 33. *S. hanseatica* (W. Horn, 1927) and 34. *S. rueppelii* (Guérin-Méneville, 1847), and the *Hypaetha* species 35. *H. schmidti* (W. Horn, 1927) and 36. *H. copulata* (Schmidt-Göbel, 1846). These species are recorded from the adjacent countries (e.g. Putchkov and Matalin 2003, 2017; Wiesner 1992), but exclusively from



**Figures 13–16.** *Calomera* species: **13** *C. concolor* (female) **14** *C. fischeri* (male) **15** *C. alboguttata* (male) **16** *C. aulica* (male).



**Figures 17–20.** *Calomera* species: **17** *C. diania* (male) **18** *C. aphrodisia* (male) **19** *C. littoralis winkleri* (male) **20** *C. aulicoides* (male).



**Figures 21–24.** Cicindelid species: **21** *Calomera fimbriata* (male) **22** *Habrodera nilotica* (female) **23** *Homodela ismenia* (male) **24** *Hypaetha singularis* (female).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**Figures 25–28.** *Cephalota* species: **25** *C. littorea* (male) **26** *C. tibialis* (male) **27** *C. circumdata* (male) **28** *C. vartianorum* (male).


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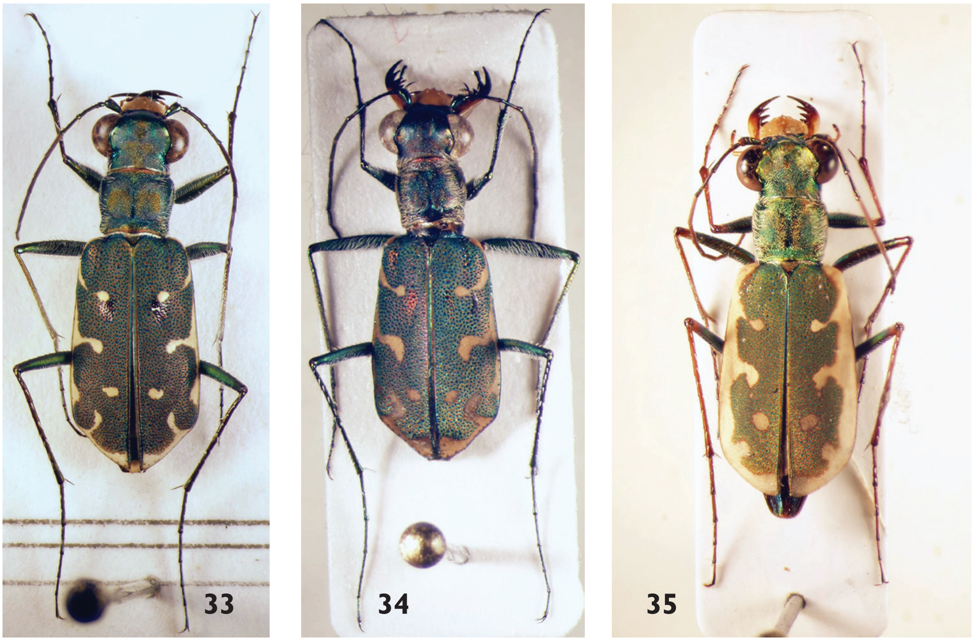
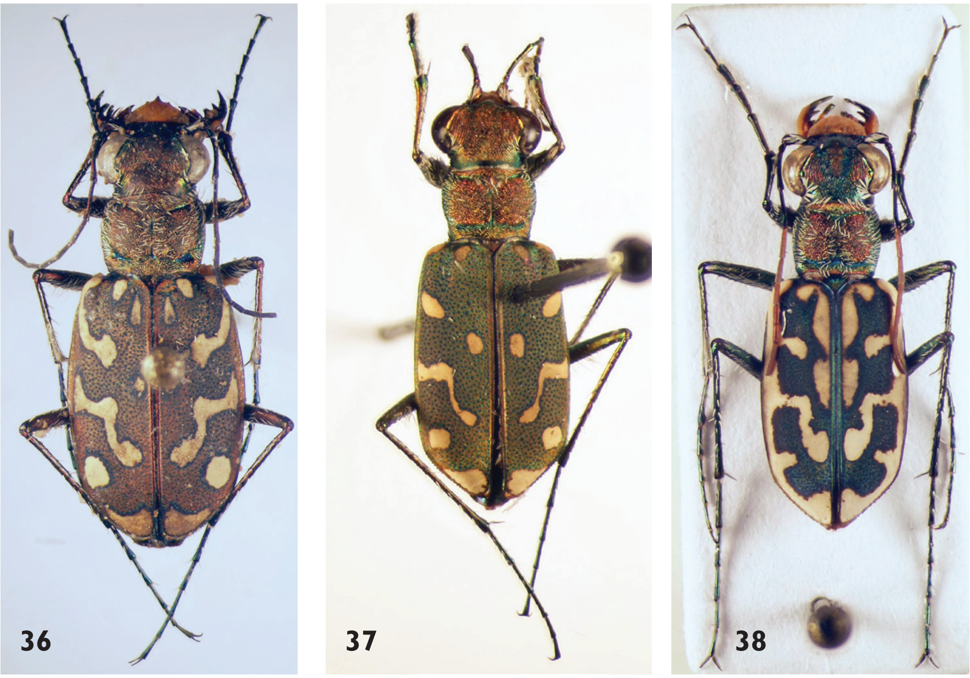
**Figures 29–32.** *Cylindera* (sub-) species: **29** *C. contorta s.str.* (male) **30** *C. rectangularis* (female) **31** *C. contorta valdenbergi* (male) **32** *C. contorta valdenbergi* (female).



**Figures 33–35.** *Myriochila* species: **33** *M. melancholica* (female) **34** *M. orientalis* (female) **35** *M. dorsata* (female).



**Figures 36–38.** *Lophyra* species: **36** *L. flexuosa* (female) **37** *L. hilariola* (male) **38** *L. histrio* (male).

their distant parts (e.g. Caucasus Mountains, the south-eastern coast of the Arabian Peninsula), and thus their occurrence in the southern Levant is unlikely. In many cases, the photographs from Werner (1991; 1992) may be sufficient to identify these species.

1 Larger (19–26 mm). Scutellum not visible in commonly mounted beetles, not triangular. Side margin of pronotum with a forward projecting lobe. Last segment of maxillary palpi shorter than penultimate one. Elytra green (rarely blue or black) with a pale apical spot. Fig. 7...... **1. *Grammognatha euphratica* (Dejean, 1822)**

– Smaller (less than 18 mm). Scutellum clearly visible and triangular. Side margin of pronotum weakly developed, without a forward projecting lobe. Penultimate segment of maxillary palpi as long as the last one or shorter. Coloration different, if green then with more than 1 pale spot.................... **2**

2 Pronotal margin clearly visible on upper side of prothorax, its lateral sides (hypomeron/epimeron) visible from above; anterior margin of pronotum with a dense and regular series of white setae (Fig. 55). Pale pattern of elytra is expanded, on the disc middle band connected with the apical band, but along the suture regularly dark. 7.5–10 mm. Figs 24, 47 ............................................................................ **25. *Hypaetha singularis* (Chaudoir, 1876)**

– Pronotal margin sometimes difficult to detect, but its lateral sides (hypomeron/epimeron) not visible from above; anterior margin of pronotum without white setae or, if they are present, they are irregularly positioned. Middle and apical bands of elytra never broadly connected........................................... **3**

3 Elytra with pale border along the outer edge, not interrupted by dark sections ........................................................................................................ **4**

– Elytra with or without pale border along the outer edge, if present then interrupted by dark sections ........................................................................ **11**

4 Frons (area of forehead between the eyes) with white setae close to the fore margin of the eyes and close to the hind margin (Fig. 55). 1st antennal segment with numerous setae. Genae (lateral side beneath the eyes) with dense white setae (Fig. 48). 7.5–8.5 mm. Fig. 22 ........... **14. *Habrodera nilotica* (Dejean, 1825)**

– Frons without white setae. 1st antennal segment with one or several erect distal setae. Genae without or few setae......................................................... **5**

5 1st antennal segment with several white setae and the usual erect distal seta (sometimes they are broken, but their insertions are still visible) (Fig. 54)... **6**

– 1st antennal segment with only one erect distal seta (Fig. 54) ...................... **7**

6 Frons (area of forehead between the eyes) glabrous, also along the hind margin of eyes glabrous, only with supraorbital setae. Labrum with 1 tooth (cf. Fig. 6). Elytral pale pattern regularly without spots, only bands. 12–15 mm. Figs 27, 43c ............ **17. *Cephalota* (*Taenidia*) *circumdata* (Dejean, 1822)**

– Frons with white setae at the hind margin of eyes, in addition to the supraorbital setae. Labrum with 3 teeth. Elytral pale pattern with at least one pair of discal spots. 10–13 mm. Figs 38, 45c ...... **28. *Lophyra histrio* (Tschitschérine, 1903)**

7 Elytral pale pattern on the disc reduced and constricted, forming spots which are (partly) connected with the pale margin. 9–13 mm. Fig. 35 .................................................... **24. *Myriochila* (*Monelica*) *dorsata* (Brullé, 1834)**

– Elytral pale patterns not or slightly constricted, forming complex bands, not spots; at least middle band bent downwards, sometimes s-shaped (Figs 25, 26, 28, 31, 32) .......... **8**

8 Labrum without or with 1 median tooth (Fig. 6b, c, f) .......... **9**

– Labrum with 3 or more teeth (Fig. 6h). Pale elytral margin wide. Longitudinal row of punctuation parallel to elytral suture. 11–15 mm. Figs 26, 43b.... .......... **16. *Cephalota* (*Taenidia*) *tibialis* (Dejean, 1822)**

9 Labrum with more than 8 setae (Fig. 6b). Elytra in the apical third angularly pointed. Pale elytral pattern strongly bent, middle band s-shaped. 9–10.5 mm. Figs 6b, 31, 32, 44a .......... **20. *Cylindera* (*Eugrapha*) *contorta* (Fischer von Waldheim, 1828), ssp. *valdenbergi* (Mandl, 1981)**

– Labrum with less than 8 setae (Fig. 6c, f). Elytra more evenly rounded. Pale pattern with only slightly bent bands. Specimens regularly larger than 10 mm .......... **10**

10 Maximum width of head (across the eyes) more than 1.3 times wider than pronotum. Fore margin of labrum weakly curved. Apical tooth of the elytra sharply pointed. Elytral pale marginal pattern behind the basal band wider. Antennomeres 5 and following ones less contrasting in coloration from the first four ones. Surface shinier. 10–12 mm. Figs 6c, 25, 43a .......... **15. *Cephalota* (*Taenidia*) *littorea* (Forskål, 1775)**

– Maximum width of head (across the eyes) less than 1.3 times wider than pronotum. Foremargin of labrum strongly curved. Apical tooth of the elytra evenly pointed. Elytral pale marginal pattern narrower behind the apical band strongly constricted, sometimes interrupted. Antennomere 5 contrasting different in coloration from the first four ones. Surface less shiny (dull). 10–14 mm. Figs 6f, 28, 43d .......... **18. *Cephalota* (*Taenidia*) *vartianorum* (Mandl, 1967)**

11 Elytra red to brown or greenish, without any pale pattern (neither bands nor spots). White setae from clypeus to hind margin of eyes. 10–14.5 mm. Fig. 13 .......... **5. *Calomera concolor* (Dejean, 1822)**

– Elytra with pale spots, bands or complex patterns. Sometimes white setae on frons .......... **12**

12 Genae (lateral side beneath the eyes) with some white setae (Fig. 48) .......... **13**

– Genae without distinct setae (sometimes with single setae) .......... **20**

13 White setae between clypeus and eyes and around the antennal basis (Fig. 55) .......... **14**

– White setae on labrum and clypeus, but not between clypeus and eyes or if so, than not around the antennal basis (Figs 50, 51) .......... **16**

14 Large species: 15–18 mm. Fig. 21 .......... **13. *Calomera fimbriata* (Dejean, 1831)**

– Smaller species: <15 mm .......... **15**

15 Apical margin of labrum with a median tooth which is rarely reduced. Head 1.3–1.4 times wider than pronotum. 6 spots at or close to the elytral margin, a marginal spot at the level of the discal spot. In general, two pairs of elytral spots connected with each other: the apical spots as well as the discal and 3rd marginal spots (counted from the base towards the apex), but sometimes the extensions between the given spots interrupted. Larger: 11–15 mm. Figs 15, 55 .................................................. **7. *Calomera alboguttata* (Klug, 1832)**

– Apical margin of labrum smooth. Head less than 1.3 times wider than pronotum. 5 pale spots on the elytral margin. All pale elytral spots isolated from each other, only the apical spots sometimes with an (interrupted) extension. Smaller: 8–12 mm. Fig. 14 ................. **6. *Calomera fischeri* (Adams, 1817)**

16 Posterior part of the metafemur with one complete series of shorter white setae; some setae belonging to a second parallel series occur mainly at the base, but this series is not complete (Fig. 49 left) .............................................. **17**

– Posterior part of metafemur with two almost complete parallel series of longer white setae (Fig. 49 right) ........................................................................ **19**

17 Labrum with less than 25 setae (Figs 50 right, 51). Elytra rounded or parallel-sided. Pronotum shorter (width of pronotum/length of pronotum PW/PL: >1.05). Elytral shoulders less prominent. Elytra dark, not bluish. Median lobe of aedeagus slender and stretched (Fig. 40a, c).................................. **18**

– Labrum with more than 26 setae (Fig. 50 left). Elytra more enlarged in the apical half (dorsal view) and convex (lateral view), pronotum sides less rounded and longer (PW/PL: <1.05). Elytral shoulders prominent. Elytra and forebody bluish. Median lobe of aedeagus wider in the middle and more rounded (Fig. 40b). 12–13.5 mm. Fig. 17 ................... **9. *Calomera diania* (Tschitschérine, 1903)**

18 Elytra less elongate and more ovate. Pronotum more transverse with more rounded sides, body flatter. Forebody more colourful, often with green and red lustre. Width of head/width of pronotum ratio >1.19. Median lobe of aedeagus less rounded (Fig. 40a). 11–13.5 mm. Fig. 16 ............................... ........................................................... **8. *Calomera aulica* (Dejean, 1831)**

– Elytra more elongate and less ovate. Pronotum more parallel-sided. Forebody and elytra darker. Width of head/width of pronotum ratio <1.18. Median lobe of aedeagus more rounded (Fig. 40c). 14–16 mm. Figs 18, 51 ............. ....................................... **10. *Calomera aphrodisia* (Baudi di Selve, 1864)**

19 Long metatibial spur longer, about 2/3 of length of 1st metatarsal segment (hind legs, Fig. 53). 3 teeth on inner side of left mandible, rarely a small fourth tooth developed (Fig. 52). In general, elytral pale spots more isolated; the two discal spots isolated from each other and marginal spots, the extension between the two median marginal spots normally interrupted. Median lobe of aedeagus similar to that one of *C. aulicoides*, but with apical part more strongly bent (Fig. 41). Copulatory piece of median lobe of aedeagus with 2 (or 3) tips which are sideward oriented (Fig. 42 below). 10–13 mm. Fig. 19 .................. ..... **11. *Calomera littoralis* (Fabricius, 1787), ssp. *winkleri* (Mandl, 1934)**

– Long metatibial spur shorter, about half of the length of 1st metatarsal segment (hind legs, Fig. 53). 4 teeth on inner side of left mandible (Fig. 51). In general, elytral pale spots more connected: the fore discal spot with an extension to the neighboring marginal spot; the marginal spots connected to three pairs (humeral, medial, and apical lunules). Median lobe of aedeagus similar to that one of *C. littoralis*, but with apical part less bent ventrally (Fig. 41). Copulatory piece of median lobe of aedeagus straight or slightly curved, tip broadly rounded (Fig. 42 top). 9–13 mm. Fig. 20......................................... ......................... **12. *Calomera aulicoides* (J.R. Sahlberg, 1913), stat. rest.**

20 Elytra green with pale pattern reduced to spots or small bands and small reddish areas (Figs 8–11, 23)........................................................................**21**

– Elytral coloration different, not green, if so then pale patterns larger and complex.........................................................................................**24**

21 Labrum with 3 teeth on anterior margin (Fig. 6). Each elytron with 2 to 4 pale spots which are not connected.........................................................**22**

– Labrum with one tooth on anterior margin (Fig. 6). Each elytron with (4 to) 5 pale spots, the 2 apical spots usually connected at the external margin...**23**

22 Each elytron with 2 (to 3) pale spots. Frons without setae. 1st antennal segment with one erect distal seta. 9.2–13.5 mm. Fig. 23................................. ........................................................ **19. *Homodela ismenia* (Gory, 1883)**

– Each elytron with 4 pale spots. Frons with few setae. 1st antennal segment with few setae. 14–18 mm. Figs 6g, 12........................................................ ..........................................**4. *Cicindela asiatica* Audouin & Brullé, 1839**

23 Pronotum more cordiform, its sides more convex, fore margin (apically to the protruding fore angles) of similar width as (or a little bit wider than) posterior margin. Head in relation to pronotum wider than in *C. herbaceae*. Internal sac of median lobe of aedeagus shorter (lateral view), median lobe less than 3 times longer than structures of internal sac (not evaginated), shape of median lobe in lateral view more rounded, the apex sharper and stronger downward bent (Fig. 39a, b). 11–15 mm. Figs 6d, 8–10............................................... ........................................................ **2. *Cicindela javetii* Chaudoir, 1861**

– Pronotum less cordiform, its sides less convex, fore margin (apically to the protruding fore angles) wider than hind margin (or, rarely of about the same width). Head in relation to pronotum less wide than in *C. javetii*. Internal sac of median lobe of aedeagus longer, median lobe more than 3 times longer than structures of internal sac (not evaginated), shape of median lobe more stretched and slender, the apex more rounded and less downward bent (Fig. 39c). 13.5–17 mm. Fig. 11.....................**3. *Cicindela herbacea* Klug, 1832**

24 1st antennal segment with several white setae (Fig. 54 below)....................25

– 1st antennal segment with 1 distal seta only (Fig. 54 above)........................26

25 Approximately 5 to 15 white frontal setae at hind margin of eyes. 1st antennal segment with numerous setae. 11–14 mm. Figs 36, 45a.............................. ..................................................... **26. *Lophyra flexuosa* (Fabricius, 1787)**

– Approximately 2 to 4 white frontal setae at hind margin of eyes. 1st antennal segment with few setae. 10–12 mm. Figs 37, 45b ........................................ ........................................................ **27. *Lophyra hilariola* (Bates, 1874)**

26 Pale elytral margin only along a short section of the basal half interrupted. (See also no. 10 of the key). 10–14 mm. Figs 6f, 28, 43d............................ ............................ **18. *Cephalota* (*Taenidia*) *vartianorum* (Mandl, 1967)**

– Pale elytral margin along two sections interrupted, both along the basal and the apical part ........................................................................................27

27 Labrum with (6-) 8 - 10 (-12) long hairs, both sexes with one tooth (Fig. 6e). Pale pattern on elytra strongly reduced. Elytral coloration dark brown. 7–10 mm. Figs 6e, 30, 44b .......**21. *Cylindera* (*Ifasina*) *rectangularis* (Klug, 1832)**

– Labrum with (2-) 4 hairs, females with 3 teeth and males with 1 tooth or without teeth (Fig. 6a,i). 9–13.5 mm.......................................................**28**

28 Pale pattern on elytra narrower; basal pale spot of elytra often separated from the humeral lunule; middle band often interrupted and forming both a discal spot and a short maculation; females on the basal third of elytral disc with a smaller smooth, polished shiny area. Elytra towards the apical part less enlarged in both sexes. Smaller: 9–12.5 mm. Figs 6a, 33, 46a......................... ..............................**22. *Myriochila* (*s.str.*) *melancholica* (Fabricius, 1798)**

– Pale pattern on elytra wider, basal pale spot of elytra often linked to the humeral lunule; middle maculation slightly constricted, only rarely interrupted; females on the basal third of elytral disc with a wider smooth, polished shiny area. Elytra towards the apical part in both sexes stronger enlarged. Larger: 10–13.5 mm. Figs 6i, 34, 46b.................................................................. ....................................**23. *Myriochila* (*Monelica*) *orientalis* (Dejean, 1825)**

## TIGER BEETLES ID: the application for smartphones and tablets

The above presented key for the tiger beetles of the southern Levant and adjacent territories is also available as a stand-alone application (app) for portable Android devices (Android-version 5.0 and later releases; Application Programming Interface (API) of 21 or higher is recommended), and can be downloaded from https://doi.org/10.3897/zookeys.734.21989.suppl1. On most devices, the app requires less than 150 Mega bytes (MB) of storage.

After the loading screen, the users will first see a short morphological definition of cicindelids and drawings of the external morphology with key terms indicated (see above). The next screen leads to the dichotomous identification key and to the species list. All photographs and most of the drawings have a zoom function which enables viewing at a higher resolution. Each species name is linked to the species' accounts with information about habitat, distribution and conservation status (shortened version of the species accounts given below). Here too, a habitus photograph which can be enlarged allows for better orientation and helps to verify identification to species level. The species list is probably be more helpful for experienced users, while beginners should start with the identification key. Figure 56 contains screenshots from the app, giving an overview of its architecture.

## Species accounts

All species are macropterous and flight active. If the species are not recorded from the southern Levant, or if not enough data about the populations during the last decades are available, no conservation information is given.

### 1. ***Grammognatha euphratica*** **(Dejean, 1822)**

**Habitat.** In salty habitats, on the Mediterranean coast in marshlands (often with *Anthrocnemum*). Around the Dead Sea and in the Arava Valley in salty wetlands and in date palm plantations (own observations). Nocturnal. Attracted by light.

**Phenology.** Teneral individuals in early spring (Cyprus: February), adults are active until approximately November (own observations). The number of eggs laid per females in a laboratory experiment ranges from 3 to 25 (Aydın 2011a), which is relatively low for an insect.

**Distribution range.** From southern Spain, Morocco and Sardinia to Central Asia (Cassola 1981; Cassola et al. 2014; Franzen 2001b; Franzen and Gigli 2003; Putchkov and Matalin 2003, 2017).

**Distribution in the southern Levant.** Mediterranean Sea coast of the Sinai Peninsula (eastwards to El-Arish) and close to Haifa (Atlit); Red Sea coast of the Sinai Peninsula (incl. near Eilat); in the Dead Sea area (especially in the swamps south of the Dead Sea) and in the Arava Valley (Franzen 2001b; Nussbaum 1987). Putchkov and Matalin (2003, 2017) list the species for Jordan. Nasir and Katbeh-Bader (2017) cited Putchkov and Matalin (2003), but do not know a record from Jordan. We do not know of any verifiable record from this period. Our record for Jordan: "29.03.2016, Pot Ash City environs, Dead Sea (Tamarisk bushes), saltmarshes, close to the edge of the sink holes in mud clefts" (CGD).

**Taxonomic notes.** *Grammognatha* Motschulsky, 1850 is frequently ranked as a subgenus of *Megacephala* Latreille, 1802, but see Gillett (2009). Darker colored morphs occur frequently in the Dead Sea region and resemble the eastern subspecies *armenica* (Laporte de Castelnau, 1834) which occurs westwards to Iran. The dark form also occurs on the Mediterranean Sea coast, though it is rare.

**Conservation.** Endangered in Israel. The species is sensitive to disturbances (drainage of habitats, cattle grazing, etc.) (Aydın 2011b). The populations found along the Mediterranean coast of Israel are in decline, and there is only one known new record in the last two decades (Atlit, late May 2012, record in collection Aligi Bandinelli). Numerous habitats have been destroyed in the Dead Sea region, but the species can sometimes be found in date palm plantations.

### 2. *Cicindela javetii* Chaudoir, 1861

**Habitat.** Open habitats with dwarf shrubs and bare ground, mostly on loamy soils (own observations and Chikatunov pers. comm.), also in quarries. Israeli records from about 1000 m a.s.l. upwards, in Lebanon up to about 2200 m a.s.l. Diurnal.

**Phenology.** Adults found mainly in May (April to June, own observation, Matalin and Chikatunov 2016). No verifiable records for the long activity period reported by Nussbaum (1987).

**Distribution range.** Southern Turkey, Lebanon, southwestern Syria, and northern Israel (Deuve 2011).

**Distribution in the southern Levant.** Some records have been published by Deuve (2011). In Israel the species is only known from two areas: Mount Hermon (in the surrounding of Majdal-Shams) and from Mount Meron (Nussbaum 1987).

**Taxonomic notes.** The *C. campestris* Linné, 1758 group in Asia Minor and the Middle East has been the object of recent studies (e.g. Deuve 2011; Franzen 2007; Matalin and Chikatunov 2016), but the taxonomic status of some populations has not yet been completely resolved. We agree with Azadbakhsh and Nozari (2015) that this entire tiger beetle group from South-west Asia needs to undergo revision. We believe that morphometric and molecular studies are necessary to solve the actual taxonomic and systematic problems of this group. Moreover, large amounts of material are needed for studies as the morphometric variability within populations is large (Franzen 2007).

Following Deuve (2011: 136) the specimens from Israel belong to *C. javetii azari* Deuve, 2011. Two further subspecies occur from Turkey to Lebanon and Syria: *C. j. thughurica* Franzen, 2007 and the nominate subspecies. The taxon *thughurica* (Fig. 10) described from southern Turkey, has been also recorded from south-western Syria (Bludan, north-west of Damascus) (Avgin and Wiesner 2009). The given site is close to the Israeli border. The existence of two subspecies of this flight-active species in this small geographic area seems unlikely. Moreover, the elytral pattern, one of the main characters to distinguish the subspecies, is not constant but varies even within a given population clearly (Figs 8, 9).

The very similar species *C. herbacea* occurs from Lebanon and Syria to Iran including several populations and described subspecies (Deuve 2011; 2012). The separation of these two species may be possible using male genitalia. Deuve emphasized the size and external shape of median lobe of aedeagus (cf. Figs 24–30 in Deuve 2011). Matalin and Chikatunov (2016) also emphasized the length of the median lobe as a distinguishing character. However, we have specimens from northern Lebanon (Les Cedres, Bcharre) in which the median lobe is shorter than indicated by the latter authors. Also the external shape of the median lobe of both species, *C. herbacea* and *C. javetii*, varies greatly, even within a population (e.g. Bludan, Antilebanon, 1700–2300m, Fig. 39), and not only between the populations of *javetii* (cf. Deuve 2011). However, the median lobe of *javetii* is in general more bent than that of *herbacea*. Although the ventrolateral bladders of the median lobes (Matalin and Chikatunov 2016) differ between the two species, they are not a useful character for identification as the procedure of

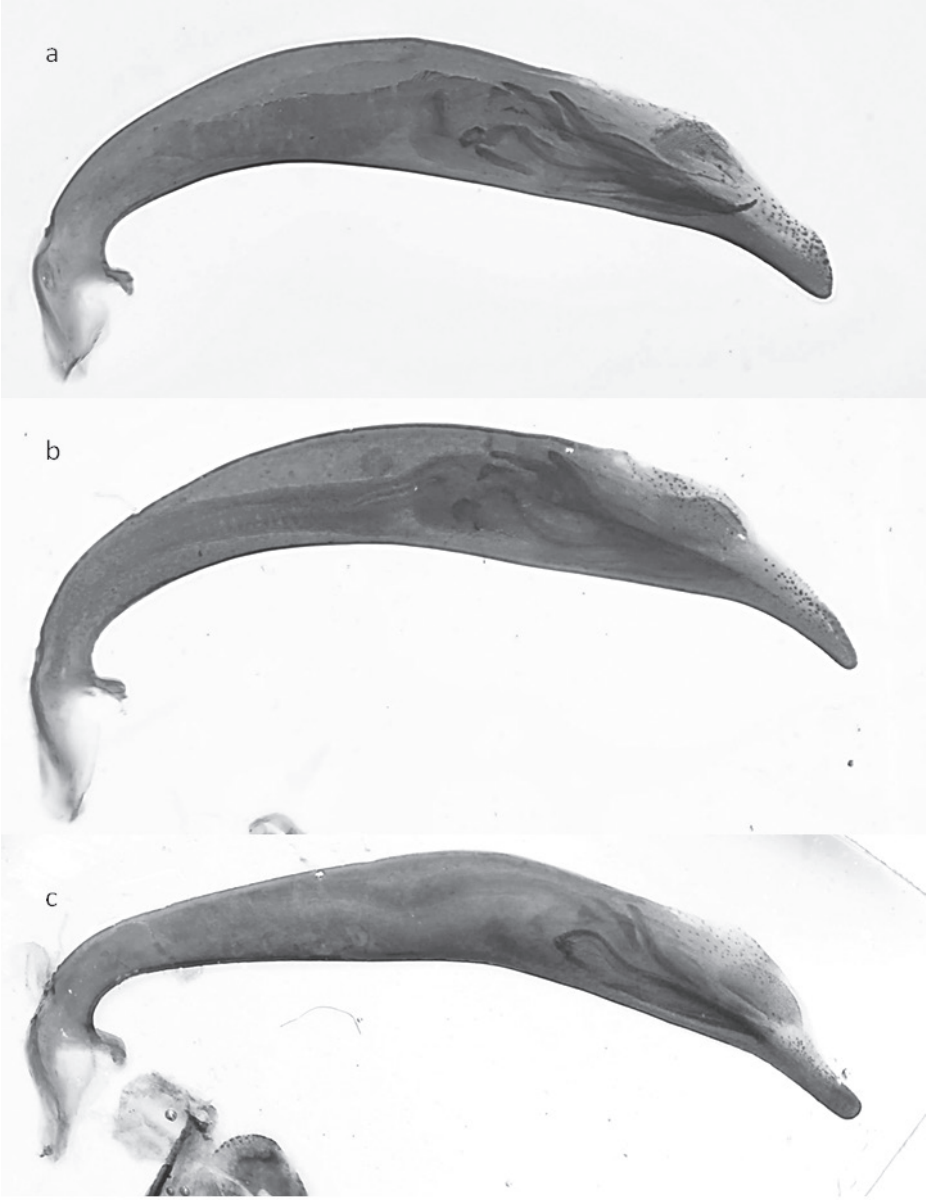


**Figure 39.** Median lobes of the aedeagus of *Cicindela species*: **a, b** *C. javetii* and **c** *C. herbacea*.

evagination of the internal sac is not feasible for many entomologists. However, clear differences in the ratio internal sac to aedeagus length can usually be seen in embedded median lobes of aedeagus (Fig. 39).

The body lengths of *C. javetii* and *C. herbacea* are not a good diagnostic character as the specimens in our collections show a stronger overlap than expected based in Deuve (2011).

However, the proportion of the pronotum as described by Matalin and Chikatunov (2016) seems to be a good character for the identification of the two species.

As *C. javetii* has recently been recognized as a species, the specimens from Israel are listed under the species names *C. campestris* or *C. herbacea* (e.g. Nussbaum 1987; Valdenberg 1983). The specimens from South-west Syria are published under the taxon names *herbacea* and *thughurica* (e.g. Avgin and Wiesner 2009). Ptashkovsky (2013) included a photograph of *C. herbacea*, but it is unlikely that this specimen was collected in Israel.

The correct name of the taxon is *javetii* (Chaudoir 1861: 1), not *javeti* (e.g. Deuve 2011; Matalin and Chikatunov 2016).

**Conservation.** The species is most likely extinct in Israel, as there have been no new records in the last two decades despite intensive searches on the sites from which the species was previously known. In most cases, the relevant habitats have been destroyed. Populations still exist on the Syrian side of the Hermon, as specimens have been collected there as recently as 2007 (<Syria Occ. Bludan / 40 km west of Damascus / 1700–2300m Antilebano(n) / leg. A. Wrzecionko / 5.5.2007> and same locality, but < … 2200m / Skoupý leg.>; CAL, CGS).

### 3. *Cicindela herbacea* Klug, 1832

**Habitat.** Unknown. Diurnal.

**Phenology.** End of March to July (northern Lebanon; CAL, CGS).

**Distribution range.** From southern Asia Minor to Lebanon, Syria, and Iran (Deuve 2011; 2012). Range overlap with *C. javetii* (Deuve 2011).

**Distribution in the southern Levant.** No records, but occurrence possible.

**Taxonomic notes.** see *C. javetii*.

### 4. *Cicindela asiatica* Audouin & Brullé, 1839

**Habitat.** Unknown. Most of the records are from mountain areas (Korell 1988).

**Phenology.** May (CAL).

**Distribution range.** From Turkey to Iran (Wiesner 1992).

**Distribution in the southern Levant.** No records.

**Taxonomic notes.** Two subspecies are known. The nominate form occurs in Syria (Wiesner 1992).

### 5. *Calomera concolor* (Dejean, 1822)

**Habitat.** Sandy beaches (Austin et al. 2008). Larvae inhabit the beach from the high water line to the beginning of dunes (Arndt et al. 2005). Diurnal.

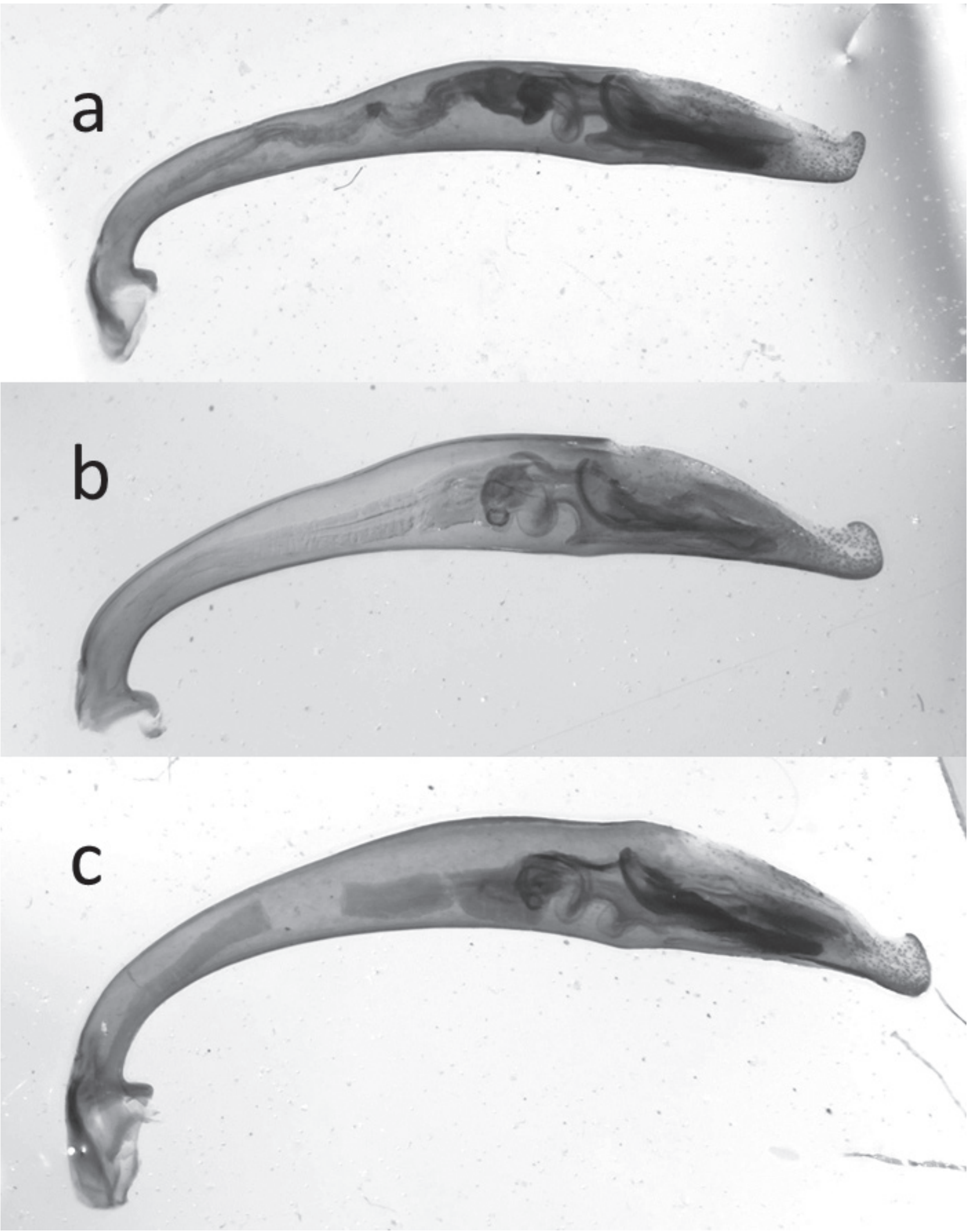


**Figure 40.** Median lobes of the aedeagus of species of the *Calomera aulica* group: **a** *C. aulica* **b** *C. diania* **c** *C. aphrodisia*.

**Phenology.** Main activity period of adults from June to August (Arndt et al. 2005).

**Distribution range.** Along the coasts of the Mediterranean Sea from Aegean Islands to Syria (including Crete, Cyprus, and southern Turkey) (Austin et al. 2008; Franzen 1999).

**Distribution in the southern Levant.** No records.

**Taxonomic notes.** The populations from Cyprus, eastern Turkey and Syria belong to the subspecies *rouxi* (Barthélemy, 1835) (Franzen 1999).

**Conservation.** This species is sensitive to disturbances caused by touristic activities on beaches. Even relatively extensive tourism can reduce the activity of adult beetles, and can prevent the development of larvae (Arndt et al. 2005).

### 6. *Calomera fischeri* (Adams, 1817)

**Habitat.** On river banks and next to freshwater ponds with sparse vegetation on sandy, sometimes cohesive soil (Arndt 2011; Avgin 2006; Werner 1992). In desert habitats the species can be widespread (cf. Wiesner 1996). Diurnal.

**Phenology.** In Turkey, adults from the end of May to the beginning of September (Avgin 2006).

**Distribution range.** from southeastern Europe to central Asia and India, southwards to Turkey and Syria (Acciavatti and Pearson 1989; Werner 1991; Wiesner 1992). Austin et al. (2008: 22) questioned the occurrence on Cyprus. However, Horn and Roeschkle (1891) list the species for Cyprus, and old records exist in SDEI: <Cyprus, Baudi> (3 specimens in the collections of Kraatz and Rottenberg, Lutz Behne, pers. com.) Therefore, the species is listed correctly by Putchkov and Matalin (2003; 2017: 219) for Cyprus.

**Distribution in the southern Levant.** The distribution range of the species in the Middle East seems to be incorrectly reported. Despite the fact that numerous authors mention the species from Israel (Avgin 2006; Putchkov and Matalin 2003), we do not know of any verified record from the country. There are no specimens in SMNHTAU, and the species is mentioned neither by Nussbaum (1987) nor by Valdenberg (1983). No verifiable records are known from Jordan (Putchkov pers. comm.). However, the species is still listed for Jordan in the latest version of the Palaearctic Catalogue of Coleoptera (Putchkov and Matalin 2017).

In Israel and Jordan, the species' typical habitats, such as river banks in dynamic floodplains or wet pioneer vegetation with patches of bare ground, have mostly been destroyed or are strongly influenced by human activity. Therefore, a recent occurrence of *C. fischeri* in the Mediterranean part of the southern Levant is unlikely. There is a small chance that the species can be found in wadis or close to water reservoirs in the desert regions (cf. Wiesner 1996).

**Taxonomic notes.** The nominate subspecies occurs in the northern Levant, while the subspecies *elongatosignata* (W. Horn, 1922) is found on the Arabian Peninsula (Wiesner 1992).

### 7. *Calomera alboguttata* (Klug, 1832)

**Habitat.** In riverbeds with gravel banks and stones, or on sandy ground close to water (Werner 2000).

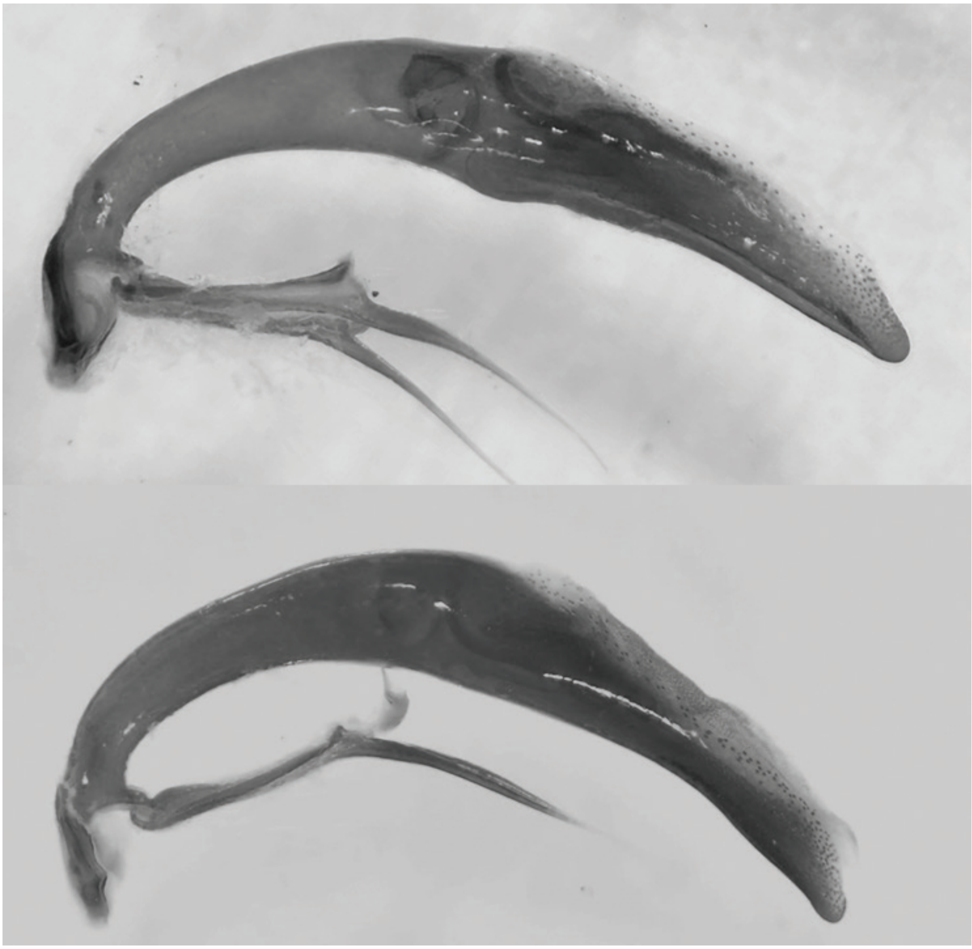


**Figure 41.** Median lobes of the aedeagus of species of *Calomera aulicoides* (above) and *C. littoralis winkleri* (below).

**Phenology.** Unknown.

**Distribution range.** Northeast Africa and the Arabian Peninsula (Werner 2000). Horn (1931) already questioned the validity of the record from Port Said. Not listed by Alfieri (1976) for Egypt.

**Distribution in the southern Levant.** No record. The nearest known population is found in Wadi Sharis (Abdel-Dayem et al. 2003).

## 8. *Calomera aulica* (Dejean, 1831)

**Habitat.** Mainly in salty habitats, such as sea shores and marshlands with salt crusts, or rocky habitats (Abdel-Dayem 2004; Horn 1931; Werner 1991; 2000). Diurnal.

**Phenology.** On the Sinai Peninsula from February until October (Abdel-Dayem et al. 2003), in the Dead Sea region from May to December (Matalin and Chikatunov 2016: 120; Nussbaum 1987).

**Distribution range.** From Senegal through northern Africa and Greece to the Middle East and Pakistan (Acciavatti and Pearson 1989; Arndt 2011; Horn 1931; Werner 2000).

**Distribution in the southern Levant.** In northern and southern Sinai along the coasts of the Mediterranean and of the Red Sea, and along the Suez Canal. In Israel in the Dead Sea region (Abdel-Dayem et al. 2003; Matalin and Chikatunov 2016; Nussbaum 1987). Rittner (pers. comm.) found a population in the vicinity of Akko on a rocky beach (documented by photographs, see the homepage Israel-nature-site 2017). The only known records from Jordan date back to the 1940s (Matalin and Chikatunov 2016; 4 specimens in SMNHTAU). Now also recent records from Jordan: "JOR-at-Tafila, Hammam Afra, Hot Springs, 08.05.2010" (CGD), "Dead Sea, Wadi 'Atun, N Wadi Mujib, same date" (CSH).

**Taxonomic notes.** The coloration can be useful for distinguishing some *Calomera* species, especially *C. aulica*, *C. diania*, *C. littoralis* and *C. aulicoides* (Arndt 2011). Nevertheless, *C. aulica* is extremely variable in color, and the coloration of the elytra ranges from black to bronze or copper with a aditional colors also occurring.

The pale elytral pattern of *C. aulica* is similar to that of *C. aulicoides*. Although the tip of the copulatory pieces of median lobe of aedeagus is similar in both species, they can be easily distinguished from each other by the external shape of the aedeagus (Figs 40, 41). A reliable character for differentiating *C. aulicoides* from related species is the number of teeth on the inner side of the left mandible: *C. aulicoides* has 4 teeth, while *C. aulica* and *C. littoralis* have only 3 (Matalin and Chikatunov 2016) (Figs 51, 52).

**Conservation.** Rare and endangered in Israel. Few records exist from recent decades.

### 9. *Calomera diania* (Tschitschérine, 1903)

**Habitat.** Freshwater habitats. In contrast to *C. aulica*, which can occur on both coastal and inland habitats, *C. diania* is an exclusive inland species (Naviaux 1983).

**Phenology.** End of February to August (Naviaux 1983, ZISP, CGD)

**Distribution range.** From Iraq to Pakistan and the southern Arabian Peninsula (Wiesner 1992).

**Distribution in the southern Levant.** No record.

**Taxonomic notes.** Naviaux (1983) gave an excellent description with which to check any potential records from the Levant.

### 10. *Calomera aphrodisia* (Baudi di Selve, 1864)

**Habitat.** Rocky habitats in the littoral zone (Austin et al. 2008; Aydın 2011c; Franzen 2001a; Horn 1931). Larval development also occurs in this habitat (Lisa 2002).

**Phenology.** May to August (Franzen 2001a; database Gebert; Lisa 2002).

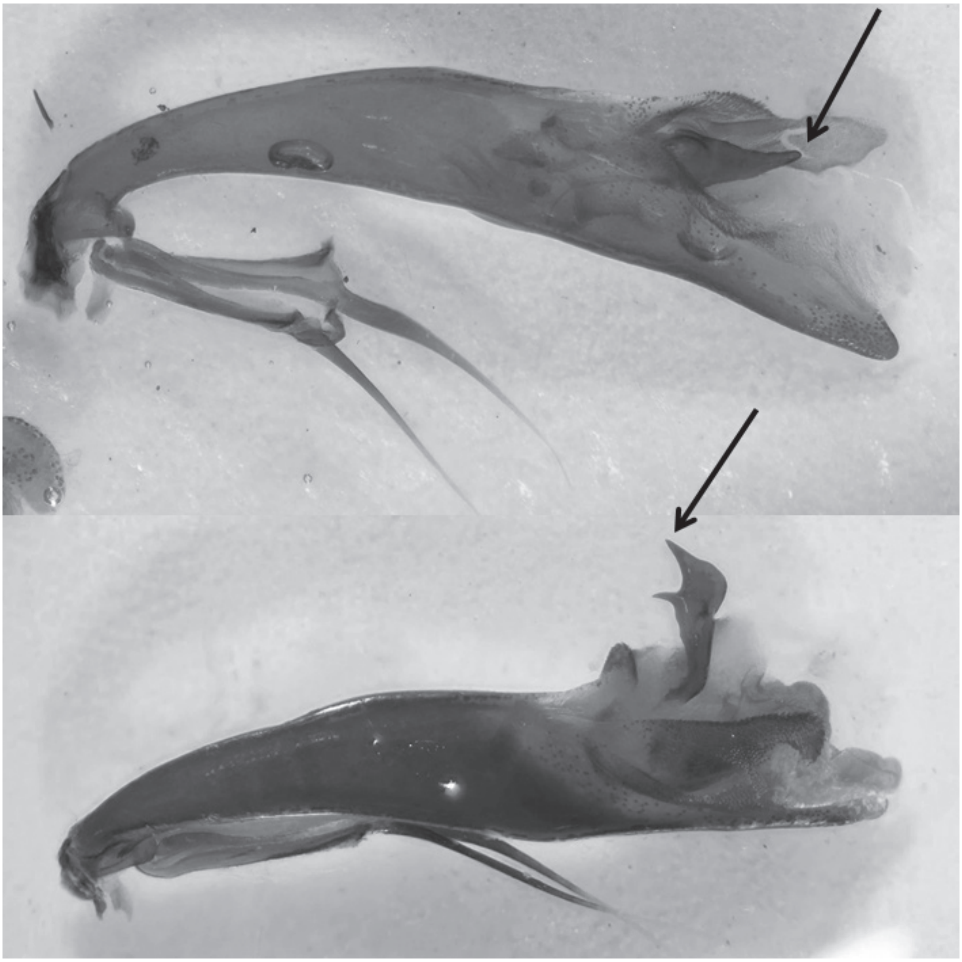


**Figure 42.** Copulatory pieces (arrows) of the median lobes of aedeagi of *Calomera aulicoides* (above) and *C. littoralis winkleri* (below).

**Distribution range.** From Sicily and Greece to Turkey and Syria (Wiesner 1992).

**Distribution in the southern Levant.** The first verifiable record from Israel was found by the cicindelid expert A. Putchkov (pers. comm.). He saw an old specimen from northern Israel (label information: <Izrael: Khaifa env.>), together with an old record from Syria (label information: <N Syrien, Ladyk env.); both specimens are preserved in ZISP. No recent records from Israel, but suitable habitats still exist in northern Israel (e.g. close to Akko and to Hadera).

**Conservation.** Declining in Turkey due to touristic activities on the beaches (Aydın 2011c; Aydın et al. 2005). As the species occurs only locally and in habitats which tend to be under strong human pressure, the species should be classified at least as threatened. Data are deficient for the southern Levant.

**Taxonomic notes.** Three subspecies are known, with the nominate form occurring in Turkey and in Syria (Wiesner 1992).

### 11. *Calomera littoralis* (Fabricius, 1787), ssp. *winkleri* (Mandl, 1934)

**Habitat.** A coastal species which colonizes both sea shores with sandy or with cohesive soils as well as salty marshlands found behind the dunes, especially those covered with salt crusts during the summer and where the vegetation is dominated by *Anthrocnemum* species and by *Tamarix tetragyna*. Also found in river mouths and in freshwater habitats (Austin et al. 2008; Nussbaum 1987; Valdenberg 1983; own observations). Diurnal.

**Phenology.** Middle of February until November (Matalin and Chikatunov 2016; Nussbaum 1987).

**Distribution range.** From Greece to Iran and Central Asia; southwards to Israel (Mandl 1981b).

**Distribution in the southern Levant.** Along the Mediterranean coast from the mouth of Nahal Betzet (=Nakhal Bezet) to the Gaza strip (Matalin and Chikatunov 2016; Nussbaum 1987). It probably also occurs on the northern coast of Sinai Peninsula, but Abdel-Dayem et al. (2003) did not list the subspecies or the nominate form from Egypt. *Calomera littoralis winkleri* is listed by Puchkow and Matalin (2017) and Nasir and Katbeh-Bader (2017) for Jordan, but not by Matalin and Chikatunov (2016). Nasir and Katbeh-Bader (2017) indicate the species from Ma'in Falls, a typical habitat for *C. aulicoides*, from where they mention also *C. littoralis*. We do not know of any verifiable record for Jordan.

**Taxonomic notes.** The subspecies *winkleri* can be differentiated from the other subspecies of *littoralis* using the form of the copulatory piece of the median lobe of the aedeagus (Korell 1988; Mandl 1934; 1981b). Some populations from the eastern part of the distribution range have copulatory pieces which show an intermediate shape between those of *nemoralis* (Olivier, 1790) and *winkleri*. These populations are most probably transitional, and likely are hybrid populations. Nonetheless, they are described as a separate subspecies, *mandli* Mandl, 1934 (Korell 1988; Mandl 1981b).

See also *C. aulica* for further diagnostic characters.

**Conservation.** Not threatened. Although the species lives along seashores which tend to be intensively influenced by touristic activities, the species has not declined as strongly as other littoral tiger beetles (for Greece: Gebert 2013, for Israel: own observation).

### 12. *Calomera aulicoides* (J.R. Sahlberg, 1913), stat. rest.

**Habitat.** On sandy and stony banks close to freshwater (the Jordan River, Sea of Galilee), especially in wadis. Also found in salty habitats close to the Dead Sea. Diurnal.

**Phenology.** Throughout the year (records from February to December) (Nussbaum 1987, own observations).

**Distribution range.** From Egypt and southern Turkey to Iran (Cassola 1999; Korell 1988; Mandl 1981b).

**Distribution in the southern Levant.** In Israel and Jordan along the Jordan Valley from the Hula Valley and the Sea of Galilee to the Dead Sea region, and in the Arava

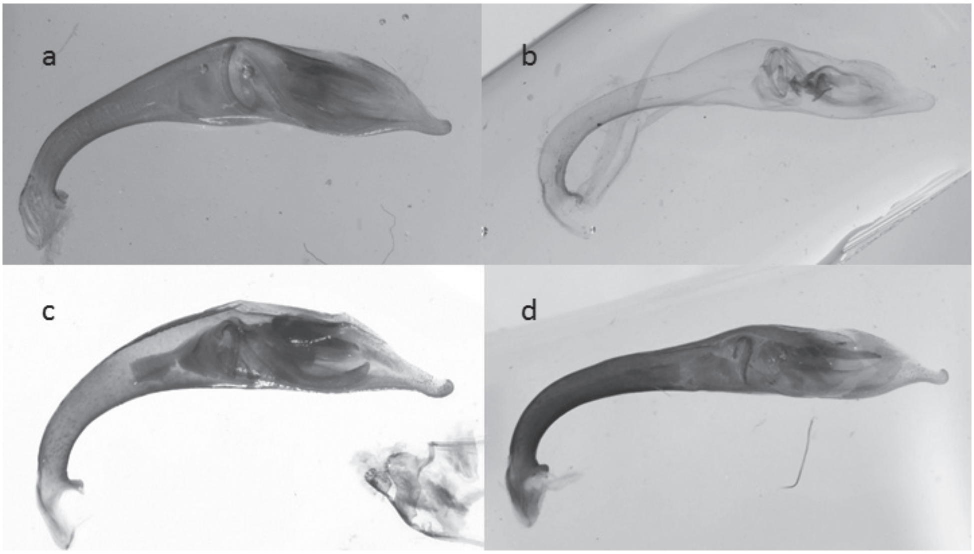


**Figure 43.** Median lobes of the aedeagus of *Cephalota* species: **a** *C. littorea* **b** *C. tibialis* **c** *C. circumdata* **d** *C. vartianorum*.

Valley. In Sinai on the Mediterranean Coast and in South Sinai (Abdel-Dayem et al. 2003; Matalin and Chikatunov 2016; Nussbaum 1987).

**Taxonomic notes.** In the past most authors ranked this taxon as a subspecies (or even as a form with a rank below the subspecies) of *littoralis* (or of another taxon of this species group) (e.g. Mandl 1934). However, later Mandl (1981b) ranked *aulicoides* as a species, though only few authors accepted this ranking (e.g. Korell 1984; Werner 1991), and the majority rank it as a subspecies (Cassola 1999; Matalin and Chikatunov 2016; Putchkov and Matalin 2003, 2017; Wiesner 1992). Pesarini and Monzini (2010: 10) are, to our knowledge, the only authors from the last years, who ranked *aulicoides* as a valid species. However, the authors seem to have confused it with *Calomera aphrodisia* (Baudi, 1864), which occurs in Sicily (Brandmayr et al. 2005; Lisa 2002; Vigna-Taglianti 1993), but is not listed by Pesarini and Monzini (2010).

In the southern Levant, both *littoralis winkleri* and *aulicoides* occur. They live in sympatry in the north of Israel (in the Hula Valley: see records for *C. littoralis winkleri* published by Matalin and Chikatunov 2016, and own records of *C. aulicoides* from Nahal Guvta (= Wadi al-Hashabi, in some maps indicated as Wadi Guyta; close to the Banias, CAL), while further southwest they are (at least) parapatric with a distance of about 20 km (Tamra – Eilabun) between populations. Although both taxa are flight-active, no intermediate forms are known (in contrast to the form of the copulatory pieces in the *littoralis* subspecies, see above). *Calomera aulicoides* has a clear and easily accessible character for differentiation from *C. littoralis.* While the latter one usually has three teeth on the inner side of the left mandible, *C. aulicoides* has four of them (Figs 51 and 52; Matalin and Chikatunov 2016). Sometimes specimens of *C. littoralis winkleri* have a small fourth tooth on the inner edge of the left mandible (Fig. 52). However, these specimens do not represent hybrid populations as the copulatory piece of the median lobe of aedeagus does not show any intermediate characters. The lack of intermediate populations and the sympatric and parapatric distribution ranges in the southern Levant give evidence for the species status of both, *C. aulicoides* and *C. littoralis*.

It is possible that both taxa occur sympatrically in Jordan as well (Ma'in Falls, Nasir and Katbeh-Bader 2017). We do not know any population of *C. littoralis* from Jordan.

The external shapes of the median lobes of the aedeagi of both taxa do not differ strongly from each other (Fig. 40), though the copulatory pieces are strongly differentiated (Fig. 42). The sharp spines of the copulatory piece in these taxa may even act in a similar way to the spines of the endophallus in closely related *Carabus* species of the subgenus *Ohomopterus*, which seem to be an example of lock-and-key genitalia (Sota and Kubota 1998). This is in contrast to most other animals, as in depth discussed by Eberhard (2010; 1985). Caution is necessary in postulating lock-and-key-functions for the genitalia in tiger beetles as we lack empirical evidence.

Moreover, we have to be cautious to establish species ranks solely based on the external shape of the median lobe of aedeagus. In this respect, clearly differentiated taxa of ground beetles can have an excessive geneflow (e.g. Matern et al. 2011).

The change in the taxonomic rank of *C. aulicoides* stat. rest. indicates the need for a revision of the entire *C. littoralis* group. As a recent phylogeographic study from south-eastern Europe reveals, molecular approaches can help to solve the taxonomic chaos in this group with its overlooked or neglected taxa (Jaskuła et al. 2016).

See also *C. aulica* for further diagnostic characters.

**Conservation.** Not threatened in Israel or Jordan. Still widely distributed in the Sea of Galilee region and in the wadis around the Dead Sea, also in strongly grazed habitats.

### 13. ***Calomera fimbriata*** (Dejean, 1831)

**Habitat.** Sandy and stony river banks and on the shore of lakes (Werner 2000). See also *Habrodera nilotica*.

**Phenology.** In Africa throughout most of the year (Werner 2000).

**Distribution range.** From Senegal to Sudan and Ethiopia (Werner 2000). Probably does not occur in Egypt (see discussion in Abdel-Dayem et al. 2003).

**Distribution in the southern Levant.** No record.

**Taxonomic notes.** Described from Ambukol (= Ambukohl) which belongs today to Sudan (Abdel-Dayem et al. 2003).

### 14. ***Habrodera nilotica*** (Dejean, 1825)

**Habitat.** Freshwater habitats (Abdel-Dayem 2004). Sandy and stony banks of rivers and lakes, especially on yellow sand. In Africa it frequently occurs together with *C. fimbriata* (Werner 2000). Diurnal and nocturnal. Attracted by light.

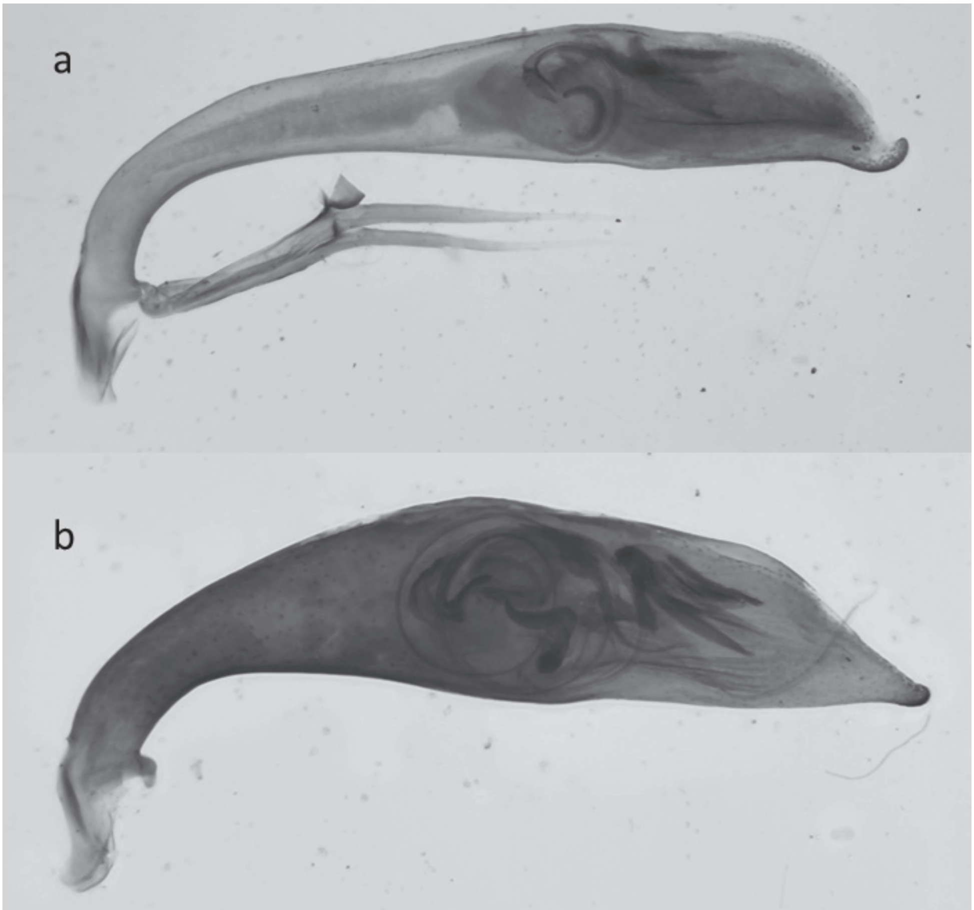


**Figure 44.** Median lobes of the aedeagus of *Cylindera* species: **a** *C. contorta* s.str. **b** *C. rectangularis*.

**Phenology.** In Africa and in the Middle East throughout almost the entire year (Matalin and Chikatunov 2016; Werner 2000). In Egypt records from January, June, August and November (Alfieri 1976).

**Distribution range.** Widely distributed in Africa: From Senegal to Somalia and from Egypt to South Africa (Werner 2000).

**Distribution in the southern Levant.** Wadi Isla (southern Sinai) (Abdel-Dayem et al. 2003; Alfieri 1976). Chikatunov et al. (2006) published records from Israel. We could not find any verifiable record from this survey in SMNHTAU. Therefore, the occurrence of this species in Israel is highly questionable.

### 15. *Cephalota* (*Taenidia*) *littorea* (Forskål, 1775) [sic]

**Habitat.** On seashores and in marshland habitats. Diurnal and nocturnal. Attracted by light (Abdel-Dayem et al. 2003; Cassola 1972; Nussbaum 1987).

**Phenology.** May to September (Abdel-Dayem et al. 2003; Nussbaum 1987).

**Distribution range.** From southern Spain to the Arabian Peninsula and Northeast Africa (Gebert 1991).

**Distribution in the southern Levant.** Only in southern Sinai (Abdel-Dayem et al. 2003; Alfieri 1976; Gebert 1991; Nussbaum 1987). No record from Israel or Jordan (Putchkov and Matalin 2017), but populations still exist not far from the border to both countries (<Bir Suweir / Sinai 30.4.2016 / A. Gera> SMNHTAU, CAL).

**Taxonomic notes.** Only the nominate subspecies occurs in the southern Levant (Gebert 1991). *Cephalota littorea* and *C. tibialis* have long been confused (e.g. Mandl 1935). The revision of Gebert (1991) revealed the species status of both taxa, and described their variability (incl. genitalia and pale coloration pattern on elytra). The subspecies *C. littorea alboreductata* (Horn, 1934) occurs south of the distribution range of *C. littorea* s.str. (Gebert 1991).

Although the taxon *goudotii* (Dejean, 1829), which occurs along the coasts of the western Mediterranean, is currently ranked as a subspecies of *C. littorea*, it is probably a valid species. *Cephalota littorea* s.str. and *goudotii* do not occur parapatrically as their ranges are separated from each other by a gap which is partially filled by the distribution range of *tibialis*. Moreover, the differences in the median lobe of the aedeagus (shape, internal sac) may support the species status of both *goudotii* and *littorea* (but see *C. aulicoides* for discussion of genital structures as characters to delineate species).

The correct spelling of the author name is Forskål (Forskål 1775) and not Forsskål (Putchkov and Matalin 2017).

### 16. ***Cephalota* (*Taenidia*) *tibialis* (Dejean, 1822)**

**Habitat.** Shorelines of salt lakes and ponds (Austin et al. 2008; Jaskuła and Rewicz 2015; Lisa 2002), sandy beaches (Nussbaum 1987). Nocturnal (Abdel-Dayem et al. 2003). Attracted by light (Nussbaum 1987).

**Phenology.** February to September (Abdel-Dayem et al. 2003).

**Distribution range.** From Tunisia to Egypt (Gebert 1991).

**Distribution in the southern Levant.** along the Mediterranean coast of the Sinai Peninsula (Gebert 1991). No record from Israel (Matalin and Chikatunov 2016; Nussbaum 1987).

**Taxonomic notes.** Only the nominate subspecies in the southern Levant, the other two subspecies in northern Africa and on Cyprus (Gebert 1991). See also *C. littorea*.

### 17. ***Cephalota* (*Taenidia*) *circumdata* (Dejean, 1822)**

**Habitat.** On salty habitats which have very sparse vascular plant vegetation. Often found on salty crusts of lagoons and ponds behind the coastal dunes (Lisa 2002), but can also be found in similar habitats farther inland (Cassola 1970; Franzen 1996). Diurnal and nocturnal species. Attracted by light.

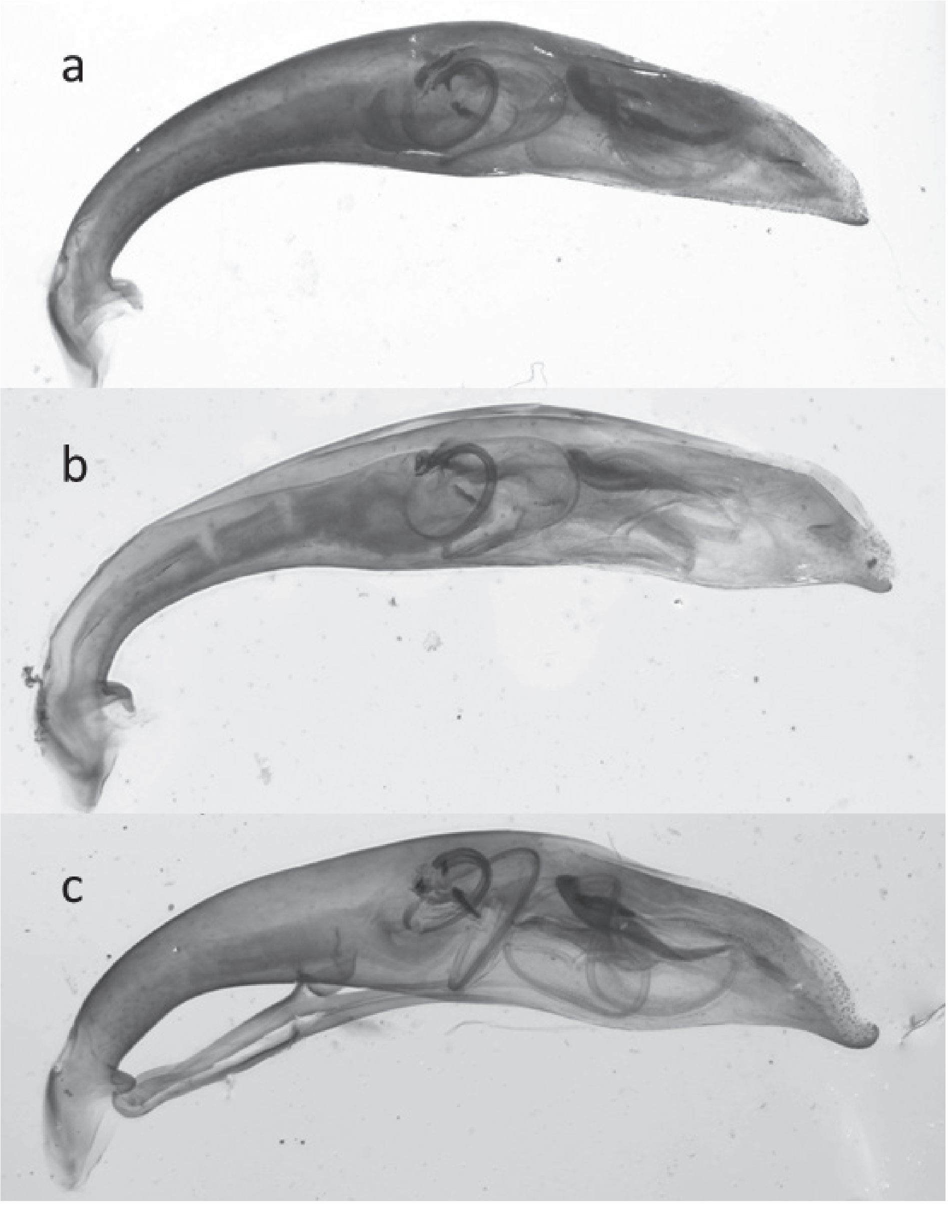


**Figure 45.** Median lobes of the aedeagus of *Lophyridia* species: **a** *L. flexuosa* **b** *L. hilariola* **c** *L. histrio*.

**Phenology.** In Italy from June to October with activity maximum in June and July (Lisa 2002).

**Distribution range.** A Mediterranean species from Spain and Algeria to Turkey (Cassola 1970; Lisa 2002).

**Distribution in the southern Levant.** No verified population. – The occurrence in El Tor (southern Sinai) has been questioned by Horn and Roeschke (1891). Schatzmayr

(1936) could not examine specimens from there or from anywhere else on the peninsula. Alfieri (1976) and Abdel-Dayem et al. (2003) and Abdel-Dayem (2004) list the species for southern Sinai, while Nussbaum (1987) and Matalin and Chikatunov (2016) do not. Horn et al. (1990) report that Alfieri's beetle collection has been incorporated into the collection of Frey, which is now preserved in the natural history museum in Basel. However, no verifiable specimens of *C. circumdata* from Sinai are preserved in the Frey collection, and only few tiger beetle individuals from Alfieri's collection are found in Basel (Sprecher-Uebersax, pers. comm.). We do not know of any verifiable record from the Sinai. As all other populations are known from areas with a typical Mediterranean climate, we believe that *C. circumdata* is not found in the Sinai (cf. Matalin and Chikatunov 2016).

**Taxonomic notes.** *Cephalota circumdata* has several subspecies which are mainly characterized by the elytral pale patterns. However, Franzen (1996) reported strong pattern variability within some populations.

## 18. *Cephalota* (*Taenidia*) *vartianorum* (Mandl, 1967)

**Habitat.** Saline habitats with sparse vegetation and salt crusts during summer. Diurnal and nocturnal. Attracted by light (Korell 1984).

**Phenology.** Spring, records from February to June (Gebert 2016; Matalin and Chikatunov 2016; Nussbaum 1987).

**Distribution range.** Israel, Syria to Iran (Gebert 2016).

**Distribution in the southern Levant.** In the Dead Sea region of Israel (Gebert 2016; Matalin and Chikatunov 2016; Nussbaum 1987). We do not know any verifiable record from Jordan. This is in agreement with the distribution indications of Puchkov and Matalin (2003) and Wiesner (1992), but it is in disagreement with Puchkow and Matalin (2017). The country indications for Saudia-Arabia, Yemen and Jordan have not been verified (Matalin pers. comm. to Jörg Gebert on November 26, 2017).

**Taxonomic notes.** While in older publications this taxon is listed as a subspecies of *C. zarudniana* (Tschitschérine, 1903), Gebert (2016) elevated it to full species rank. *Cephalota vartianorum* differs from *C. zarudniana* by slightly slender habitus as well as shape of the median lobe of aedeagus, and in the complete lack of white setae on the genae.

**Conservation.** Critically endangered in Israel. Israel has a national responsibility for the worldwide conservation of the taxon.

Tiger beetles of coastal habitats are often sensitive to touristic use of beaches (Aydın et al. 2005; U.S. Fish and Wildlife Service 2009). Most of the Israeli beaches known to host this species are intensively used as recreational areas. With high probability at least some of the (local) populations have become extinct. Matalin and Chikatunov (2016) stated that the most recent records date from the late 80's to the 90's of the last century. Our most recent records are from 1990 in Israel (Neot HaKikkar = Neot Hakikar, 13. May 1990, leg. E. Orbach, COQ, CAL) and from 2000 in Syria (Euphrates, database

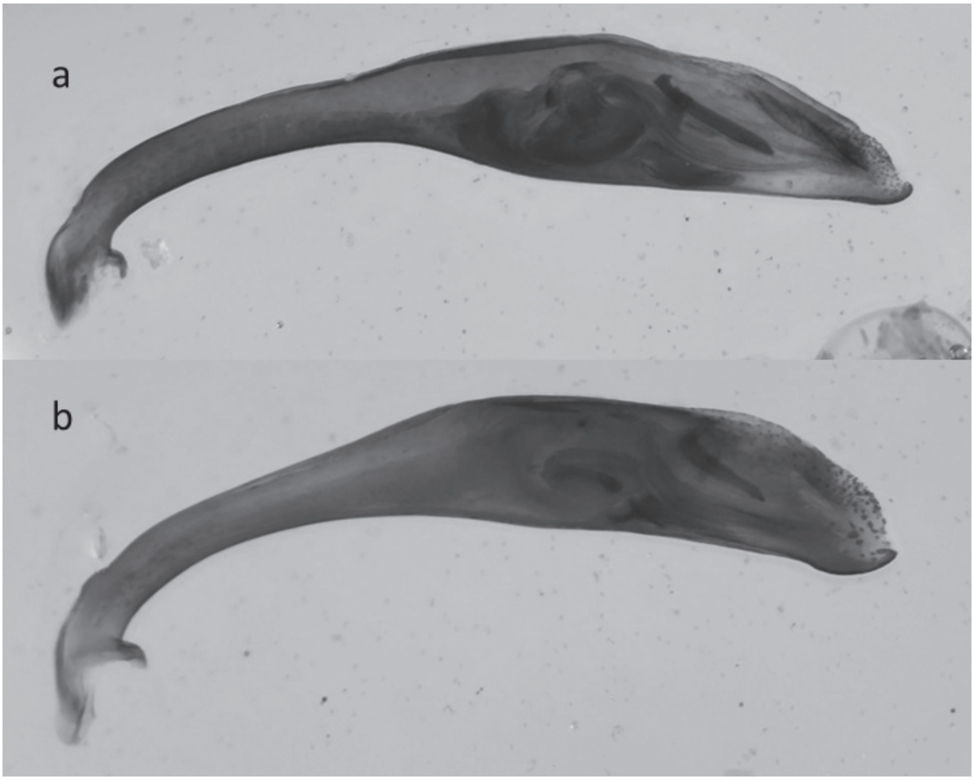


**Figure 46.** Median lobes of the aedeagus of *Myriochila* species: **a** *M. melancholica* **b** *M. orientalis*.

Gebert). All other 34 entries in the database Gebert date back to the late 1980s and 1990s. Intensive searches, including use of light traps at night, of several sites in Israel such as the Enot Tsukim Reserve (= Enot Zuqim = Enot Zukim = Einot Zukim = En Fescha) from where populations have been previously recorded, have yielded no new records. The lowering of the water table and changes in land use in the Dead Sea region have strongly impacted many habitats, both freshwater and saltwater. Therefore, at further studies of the Dead Sea region, both on the Israeli and the Jordanian side, are needed to establish wether or not populations still exist.

## 19. *Homodela ismenia* (Gory, 1883)

**Habitat.** In open forests and in grasslands, mainly on sandy ground in higher elevations (Avgin 2006; Korell 1988).

**Phenology.** Spring species (Korell 1988).

**Distribution range.** Turkey and Syria (Franzen 2003; Wiesner 1992).

**Distribution in the southern Levant.** No records.

## 20. *Cylindera* (*Eugrapha*) *contorta* (Fischer von Waldheim, 1828), ssp. *valdenbergi* (Mandl, 1981)

**Habitat.** In the southern Levant found exclusively in sandy shore habitats along the Mediterranean Sea. Larval development takes place a few centimeters above the mean sea level, just above where most of the waves break (Valdenberg 1983), though larval holes are occasionally flooded by seawater. The nominate subspecies is found in both coastal and inland habitats (Cassola and Jaskuła 2004). Attracted by light (own observation).

**Phenology.** Adults from the beginning of May until mid-November (Valdenberg 1983). Few adults also from March onwards (Matalin and Chikatunov 2016; Nussbaum 1987). The larvae overwinter mostly as second and third instars (and rarely also first instars). Egg laying begins immediately with the appearance of the adults in spring, and in certain years a few individuals may complete an entire life-cycle in the same summer, though most do not (Valdenberg 1983).

**Distribution range.** The nominate form is found from south-eastern Europe (Romania and Ukraine) and Asia Minor to Central Asia and China. The subspecies *valdenbergi* is patchily located in a small area along the Mediterranean coast from western Egypt to northern Israel (Horn 1931, Mandl 1981). The nominate form does not occur along the Mediterranean coast (Wiesner 1992).

**Distribution in the southern Levant.** In Egypt around Abu Qir, Maadia and Ras el Bar (Abdel-Dayem et al. 2003; Alfieri 1976; Horn 1931; Mandl 1981a; Nussbaum 1987). In Israel from Bat Yam to Akko, though the Bat Yam population is thought to be extinct since several decades (Valdenberg 1983; own observation).

**Taxonomic notes.** Mandl (1981a) described the taxon *valdenbergi* from Ma'agan Michael as a subspecies. It is characterized by the excessive pale elytral pattern (Figs 31, 32), though there is some variation in the pattern between individuals. However, the pale elytral coloration differs even within the nominate form strongly. Some populations from the Caspian Sea show similar elytral pattern as *valdenbergi* (cf. Mandl 1981a; Werner 1992). Mandl mentioned in his description small differences in the copulatory pieces of the median lobe of aedeagus. As we believe this character is still not sufficiently studied. But the material we studied let us assume that *valdenbergi* differs from the nominate subspecies at least in the proportion and shape of the pronotum and the elytra (Fig. 29). We recommend conducting a detailed study, including morphometric and molecular methods, to clarify the status of both taxa. Ptashkovsky (2013) includes a photograph of "*Lophyra contorta valdenbergi*", but the shown specimen belongs to the nominate subspecies of *Cylindera contorta* (cf. Fig. 29), and with all probability the photographed specimen was not collected in Israel.

**Conservation.** Critically endangered in Israel. Tiger beetles of coastal habitats tend to be very sensitive to touristic use of beaches (Aydın et al. 2005; U.S. Fish and Wildlife Service 2009). Most of the Israeli beaches which are known to host this species are intensively used as recreational areas, and therefore at least many of the populations have gone extinct. As a metapopulation structure may be possible in this species, the decrease in some populations can have a tremendous effect on the survival of the

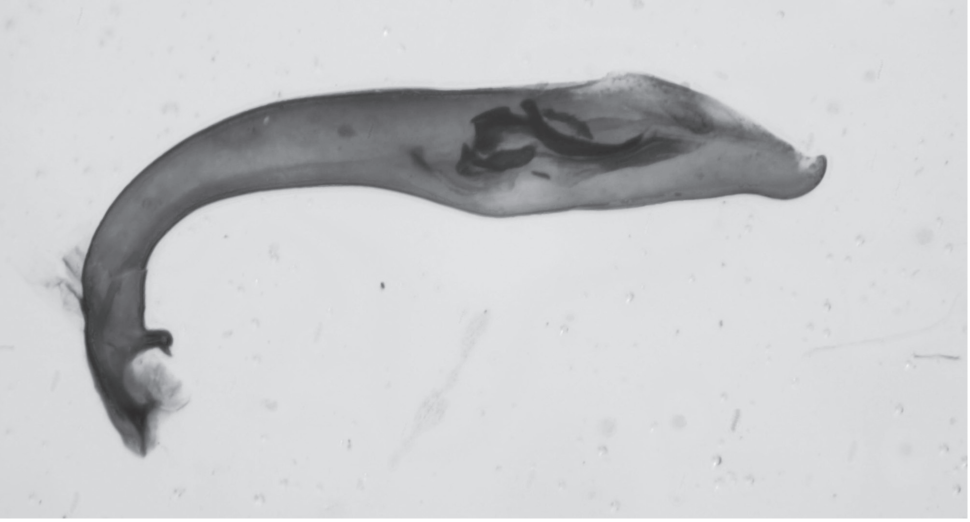


**Figure 47.** Median lobe of the aedeagus of *Hypaetha singularis*.

entire subspecies. Matalin and Chikatunov (2016) stated that the latest records date from the late 80s to the 90's of the last century, and our most recent records are from 2003 (Shefeh Na'aman Nature Reserve, COQ). As the entire world population of this taxon is located in Israel (the majority of the known populations) and in Egypt, these countries bear the responsibility for the worldwide preservation of this subspecies.

### 21. *Cylindera* (*Ifasina*) *rectangularis* (Klug, 1832)

**Habitat.** Banks of freshwater in wadis (Abdel-Dayem and Kippenhan 2013), especially on loamy soil (Werner 2000). In Saudi Arabia it co-occurs with *Calomera aulica*, *C. alboguttata* and *Myriochila melancholica* (Abdel-Dayem and Kippenhan 2013).

**Phenology.** March, but more frequently in June (Abdel-Dayem and Kippenhan 2013).

**Distribution range.** From Central Africa to Sudan and Saudi Arabia (Abdel-Dayem and Kippenhan 2013).

**Distribution in the southern Levant.** No record.

### 22. *Myriochila* (*s.str.*) *melancholica* (Fabricius, 1798)

**Habitat.** Margins of both stagnant and running freshwater bodies, including artificial water reservoirs, and in salty habitats (Austin et al. 2008; Jaskuła and Rewicz 2015; Lisa 2002). Diurnal. Attracted by light (Abdel-Dayem et al. 2003).

**Phenology.** March to December (Abdel-Dayem et al. 2003; Matalin and Chikatunov 2016; Nussbaum 1987).

**Distribution range.** From southern Europe to southern Africa and from the Cape Verde Islands to China (Wiesner 1992).

**Distribution in the southern Levant.** Widespread in Sinai, Israel and Jordan (Matalin and Chikatunov 2016; Nasir and Katbeh-Bader 2017; Wiesner 1992).

**Conservation.** Not endangered, it is abundant even in habitats strongly influenced by human activity (e.g. on intensively grazed sites or on wet fallow land close to Tel Aviv and Amman).

### 23. *Myriochila* (*Monelica*) *orientalis* (Dejean, 1825)

**Habitat.** Unknown.

**Phenology.** Unknown.

**Distribution range.** From Turkey and Syria to China (Wiesner 1992).

**Distribution in the southern Levant.** No record.

### 24. *Myriochila* (*Monelica*) *dorsata* (Brullé, 1834)

**Habitat.** Semi-desert and savanna habitats (Werner 2000).

**Phenology.** Unknown.

**Distribution range.** Southern Sahel zone from Mauritania and Senegal to Sudan (Werner 2000). Listed by Horn and Roeschke (1891) also for Egypt. Horn (1931) knew of four specimens labelled “Egypt”, all from different collections. Therefore it seems unlikely that all records are mislabelled. Nonetheless, the records may refer to Egypt in its historical sense which includes parts of modern-day Sudan (cf. Alfieri 1976).

**Distribution in the southern Levant.** No record.

### 25. *Hypaetha singularis* (Chaudoir, 1876)

**Habitat.** Sandy seashores (Abdel-Dayem et al. 2003).

**Phenology.** Recorded in Egypt from May to August (Abdel-Dayem et al. 2003, Matalin and Chikatunov 2016). In SMNHTAU are also specimens collected in September (own observation).

**Distribution range.** From Egypt east of the Nile to the Arabian Desert (Oman, Yemen), also found in tropical Africa (Werner 2000; Wiesner 1992).

**Distribution in the southern Levant.** Only in southern Sinai (Abdel-Dayem et al. 2003; Nussbaum 1987), from where the SMNHTAU records also originate (Matalin and Chikatunov 2016). Ptashkovsky (2013) recorded the species for Israel, but no verifiable records are found in SMNHTAU, which includes the collection of Ptashkovsky.

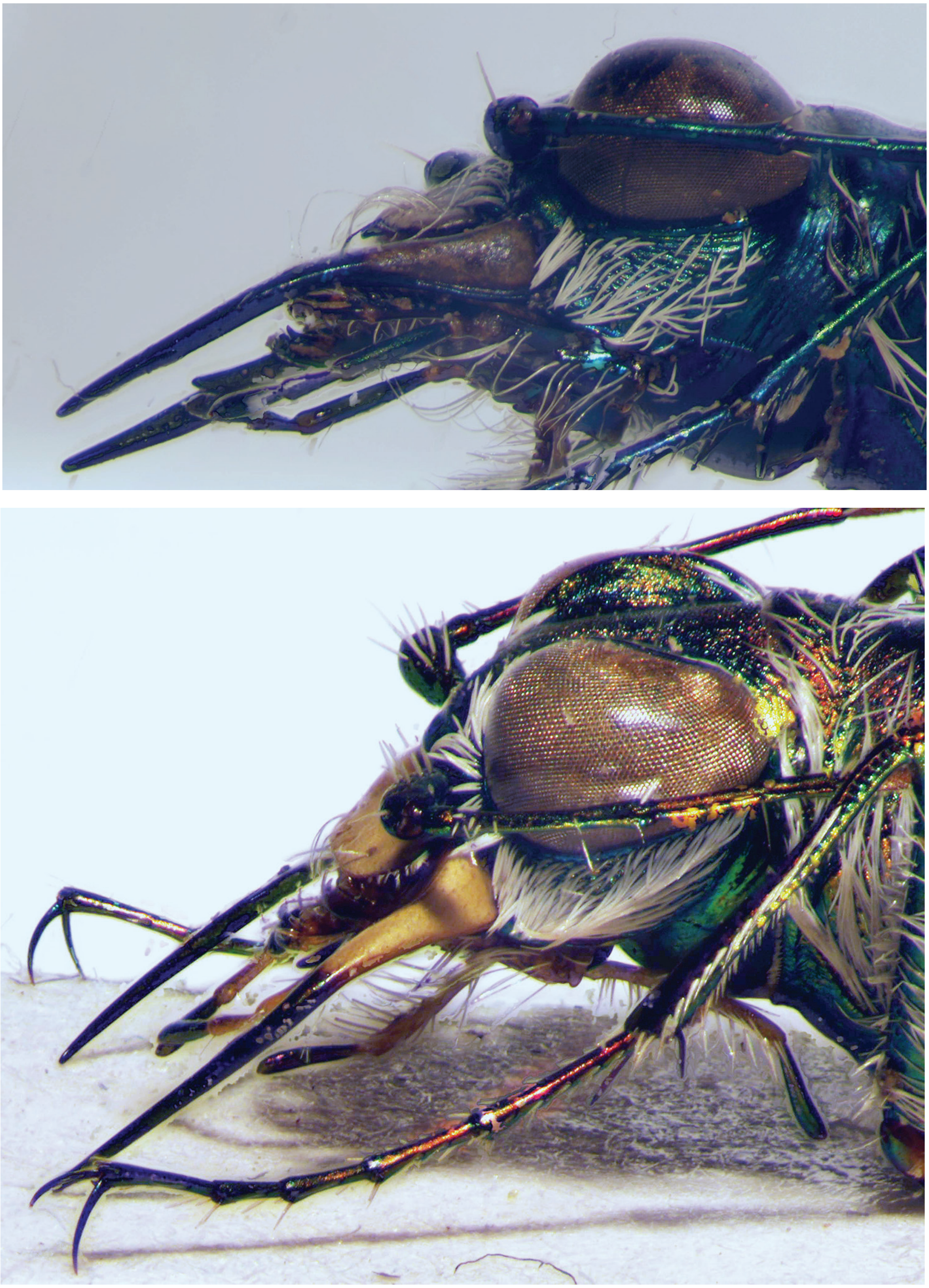


**Figure 48.** Head in lateral view: *Calomera alboguttata* (above) and *Habrodera nilotica* (below).

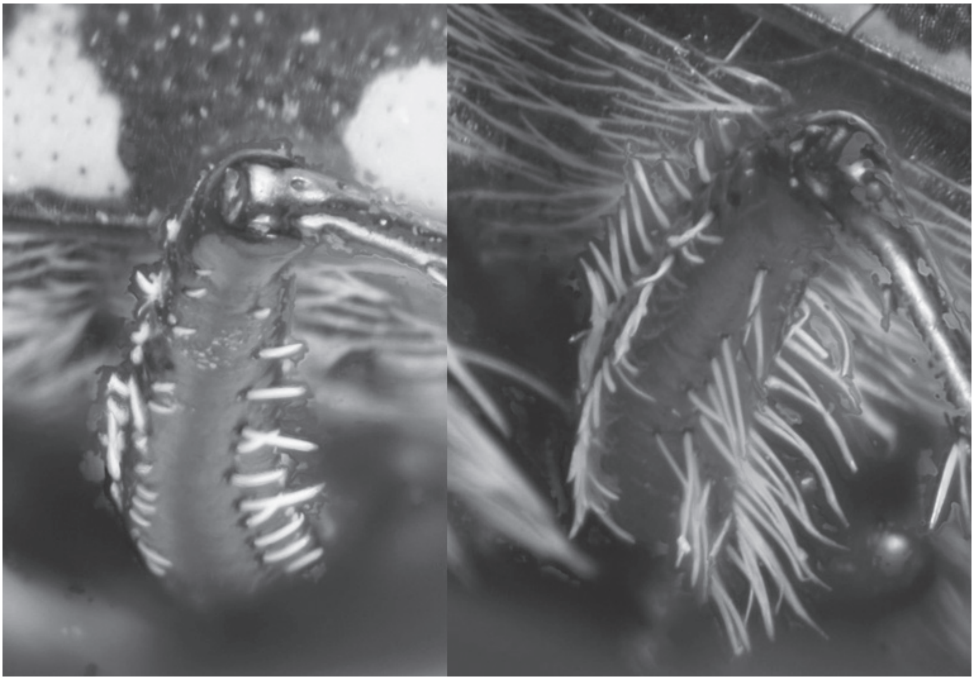


**Figure 49.** Metafemora, lateral view on lower side: *C. aulica* (left), *C. aulicoides* (right).

## 26. *Lophyra flexuosa* (Fabricius, 1787)

**Habitat.** Eurytopic species found on sea shores, in saltmarshes, in dune depressions, on river banks, in oases and in palm plantations, not restricted to coastal habitats (Abdel-Dayem et al. 2003; Jaskuła and Rewicz 2015; Lisa 2002; Nussbaum 1987).

**Phenology.** Throughout most of the year, from February to December (Matalin and Chikatunov 2016; Nussbaum 1987).

**Distribution range.** From Morocco to Israel (Wiesner 1992).

**Distribution in the southern Levant.** Numerous records from the Mediterranean coast in Israel and northern Sinai, southwards to the Negev and central Sinai (Abdel-Dayem et al. 2003; Horn 1931; Matalin and Chikatunov 2016; Nussbaum 1987).

**Conservation.** Not threatened. A widespread species which also can be found in highly disturbed habitats.

## 27. *Lophyra hilariola* (Bates, 1874)

**Habitat.** On sparsely vegetated escarpments along rivers (Franzen and Bischoff 1995).

**Phenology.** Poorly known, records from April and May, but may have a longer activity period (Franzen and Bischoff 1995).

**Distribution range.** From Turkey to Iran (Wiesner 1988).

**Distribution in the southern Levant.** No record.

**Figure 50.** Head of *Calomera* species in dorsal view: *C. diania* (left), *C. aulica* (right).

**Taxonomic notes.** A table found in Franzen and Bischoff (1995) can be used to differentiate *L. hilariola* from *L. flexuosa*.

### 28. *Lophyra histrio* (Tschitschérine, 1903)

**Habitat.** On beaches, in salt marshlands and in freshwater habitats; can be found together with *C. fischeri* (Wiesner 1996).

**Phenology.** February to September (Wiesner 1996).

**Distribution range.** From the Arabian Peninsula to India (Wiesner 1992).

**Distribution in the southern Levant.** No record.

## Compilation of the distribution of the tiger beetles in the southern Levant and adjacent lands

Verifiable records are ascertained for 14 species from the southern Levant, as 10 of them live in Israel, 10 occur in the Sinai and 4 live in Jordan. From the adjacent countries, 20 additional species have been recorded (Table 1).

**Table 1.** The tiger beetle species of the southern Levant (Israel, Jordan, Sinai) and adjacent areas of the neighboring countries (Egypt west of the Nile, western Iraq, Lebanon, northern Saudi Arabia, Syria without its eastern parts). Species with numbers larger than 29 are not mentioned in the keys and the species accounts. V: vulnerable, E: endangered, CE: critically endangered or extinct. X: species with verifiable record(s), data deficient for a threatened category or not threatened. (X): species found in Egypt, Syria, Iraq and/or Saudi Arabia, but outside the range of the identification keys. No: listed, but no verifiable records from the given country, probably misidentified. – : no record and not listed.

| Species | Egypt (Sinai) | Israel | Jordan | Adjacent countries |
|---|---|---|---|---|
| 1. *Grammognatha euphratica* (Dejean, 1822) | X | E | X | X |
| 2. *Cicindela javetii* Chaudoir, 1861 | – | CE | – | X |
| 3. *Cicindela herbacea* Klug, 1832 | – | – | – | X |
| 4. *Cicindela asiatica* Audouin & Brullé, 1839 | – | – | – | X |
| 5. *Calomera concolor* (Dejean, 1822) | – | – | – | X |
| 6. *Calomera fischeri* (Adams, 1817) | – | No | No | (X) |
| 7. *Calomera alboguttata* (Klug, 1832) | – | – | – | X |
| 8. *Calomera aulica* (Dejean, 1831) | X | E | X | X |
| 9. *Calomera diania* (Tschitschérine, 1903) | – | – | – | (X) |
| 10. *Calomera aphrodisia* (Baudi di Selve, 1864) | – | X | – | X |
| 11. *Calomera littoralis* (Fabricius, 1787), ssp. *winkleri* (Mandl, 1934) | – | X | – | X |
| 12. *Calomera aulicoides* (J.R. Sahlberg, 1913), stat. rest. | X | X | X | X |
| 13. *Calomera fimbriata* (Dejean, 1831) | – | – | – | (X) |
| 14. *Habrodera nilotica* (Dejean, 1825) | X | No | – | X |
| 15. *Cephalota* (*Taenidia*) *littorea* (Forskål, 1775) | X | – | – | X |
| 16. *Cephalota* (*Taenidia*) *tibialis* (Dejean, 1822) | X | – | – | X |
| 17. *Cephalota* (*Taenidia*) *circumdata* (Dejean, 1822) | No | – | – | – |
| 18. *Cephalota* (*Taenidia*) *vartianorum* (Mandl, 1967) | – | CE | – | X |
| 19. *Homodela ismenia* (Gory, 1883) | – | – | – | X |
| 20. *Cylindera* (*Eugrapha*) *contorta* (Fischer von Waldheim, 1828), ssp. *valdenbergi* (Mandl, 1981) | X | CE | – | – |
| 21. *Cylindera* (*Ifasina*) *rectangularis* (Klug, 1832) | – | – | – | (X) |
| 22. *Myriochila* (s.str.) *melancholica* (Fabricius, 1798) | X | X | X | X |
| 23. *Myriochila* (*Molenica*) *orientalis* (Dejean, 1825) | – | – | – | X |
| 24. *Myriochila* (*Molenica*) *dorsata* (Brullé, 1834) | No | – | – | (X) |
| 25. *Hypaetha singularis* (Chaudoir, 1876) | X | No | – | X |
| 26. *Lophyra flexuosa* (Fabricius, 1787) | X | X | – | X |
| 27. *Lophyra hilariola* (Bates, 1874) | – | – | – | (X) |
| 28. *Lophyra histrio* (Tschitschérine, 1903) | – | – | – | (X) |
| 29. *Cephalota deserticola* (Faldermann, 1836) | – | No | – | – |
| 30. *Cylindera pygmaea* (Dejean, 1825) | – | – | – | (X) |
| 31. *Calomera caucasica* (Adams, 1817) | – | – | – | (X) |
| 32. *Salpingophora bellana* (W. Horn, 1905) | – | – | – | (X) |
| 33. *Salpingophora hanseatica* (W. Horn, 1927) | – | – | – | (X) |
| 34. *Salpingophora rueppelii* (Guérin-Méneville, 1847) | – | – | – | (X) |
| 35. *Hypaetha schmidti* (W. Horn, 1927) | – | – | – | (X) |
| 36. *Hypaetha copulata* (Schmidt-Göbel, 1846) | – | – | – | (X) |

**Figure 51.** Head of *Calomera* species in dorsal view: *C. aphrodisia* (left), *C. aulicoides* (right).

Three species are listed from the southern Levant, but their occurrence is questionable as verifiable records are missing: *Calomera fischeri, Cephalota circumdata* and *Cephalota deserticola.*

## Discussion

### Identification tools

We present two formats of the same key which enables the identification of the tiger beetles of Egypt, western Iraq, Israel (including the areas under Palestinian control), Jordan, Lebanon, Syria (without the easternmost parts) and northern Saudi Arabia. In the investigated study region, the southern Levant, there are Geadephaga species for which poleward shifts in their distribution ranges due to global change have been identified (e.g. Drees et al. 2011). The incorporation of the southern areas in our study may ease the identification of  comparable shifts in tiger beetles.

Under laboratory conditions, all species can be reliably identified using the "classical" identification key, including those requiring the dissection of the male genitalia (e.g. sibling species *Cicindela javetii*, *C. herbacea*; *Calomera aulicoides*, *C. littoralis*, and *C. aulica*). However, the majority of the species can be identified correctly under field conditions, by examining live individuals using basic magnification tools. In such circumstances the Android application may be more useful rather than the classic key. We hope that both identification tools will be useful in a range of contexts, such as

**Figure 52.** Head of *Calomera littoralis winkleri*: with regular form of left mandible (left) and a small fourth tooth on the inner side of left mandible (arrow, right).

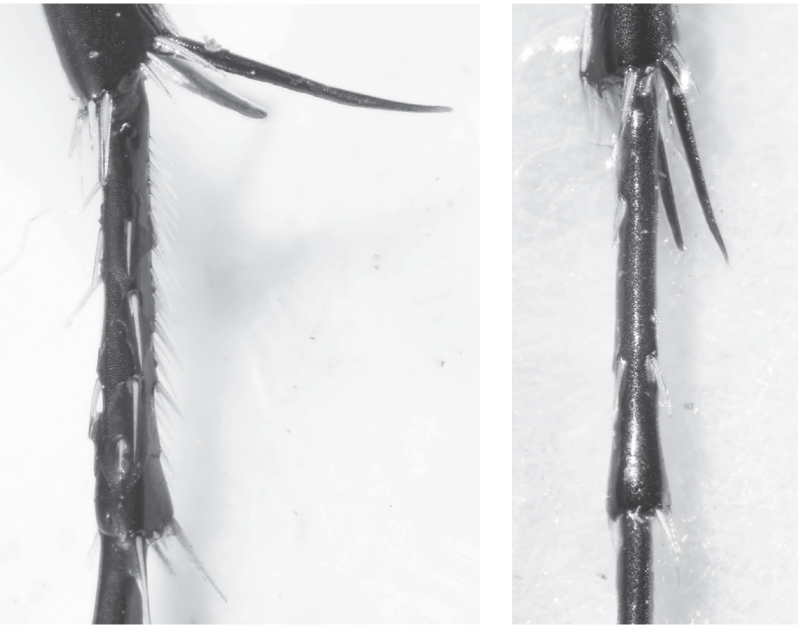


**Figure 53.** Tibial spurs and 1st tarsal segment of *Calomera littoralis winkleri* (left) and *Calomera aulicoides* (right).

education at levels, academic research, the activities of citizen scientists and in practical conservation work like surveying.

Our application for mobile Android devices, TIGER BEETLES ID, can serve as a starting point for the development of additional tools, with the translation of the app's text into both Hebrew and Arabic being greatly desired. Moreover, a simple version of the identification application is possible by deleting those alternatives considering the

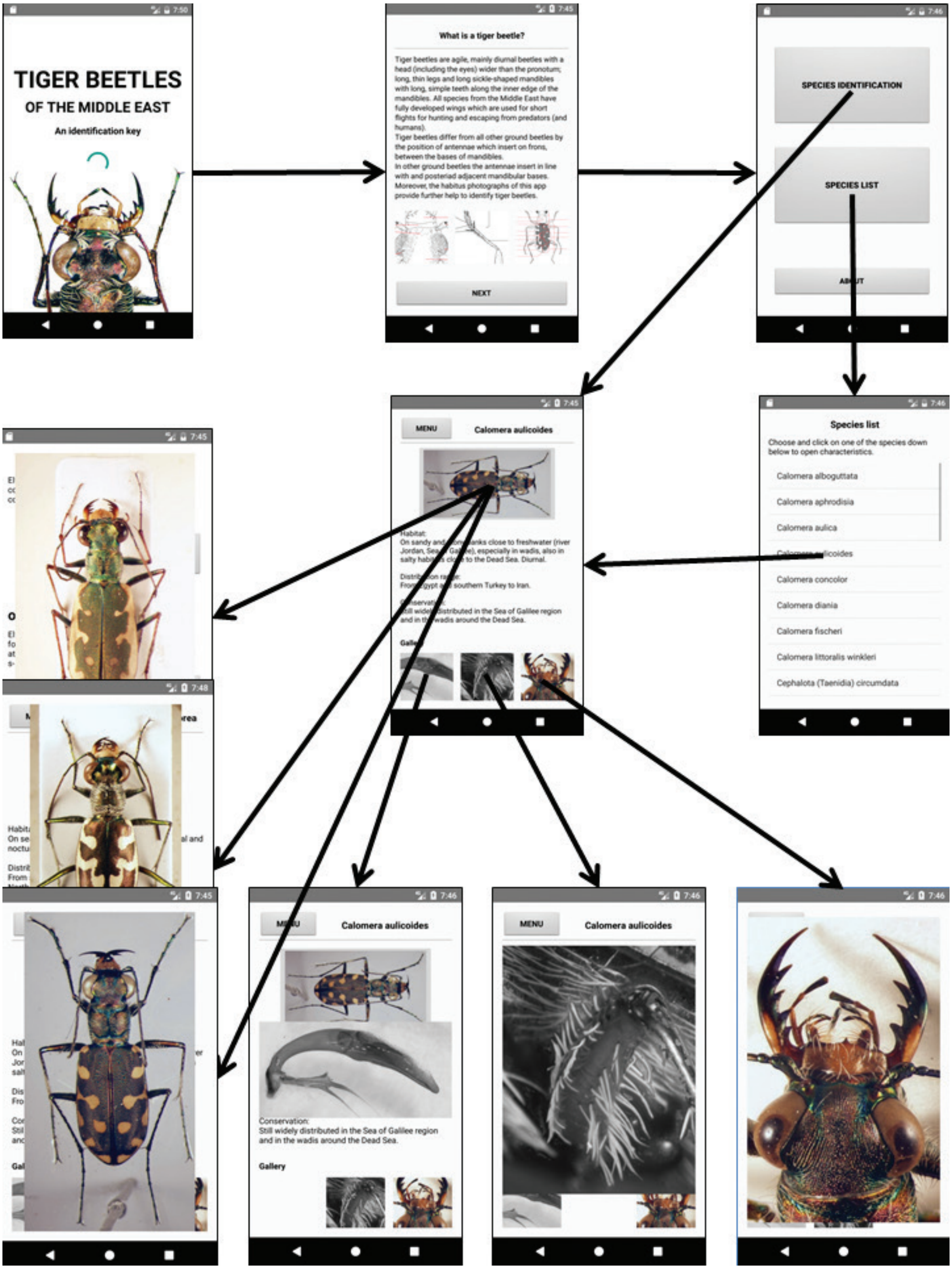
**Figure 54.** 1st antennal segment: with only one erect distal seta (*Calomera alboguttata*; above) and with one erect distal seta and additional recumbent white setae (*Lophyra histrio*; below).

species which occur exclusively outside of Israel, the areas under Palestinian control, and Jordan. The simplified version may better address the need of less experienced users such as biology teachers at secondary schools and their students. For this version, appropriate translations of morphological terms (for example genae, palpi, etc.) must be taken into consideration, and in some cases may need to be developed, as established terms in Hebrew and in Arabic are in many cases lacking.

## Faunistic inventory of the tiger beetles of the southern Levant

As far as we know, the first record of *Calomera aphrodisia* for Israel has now been documented in the form of an old specimen in ZISP. The occurrence of two species is confirmed by new records from Jordan (*Grammognatha euphratica* and *Calomera aulica*). It is likely that additional species which occur in Jordan have not yet been recorded (e.g., *Cephalota vartianorum* in the vicinity of the Dead Sea, see also below), especially as the oases in the eastern part of the country have, to our knowledge, not yet been sampled.

**Figure 55.** Forebody of cicindelid species: *Hypaetha singularis* (above, left), *Habrodera nilotica* (above, right), and *Calomera alboguttata* (below).



What is a tiger beetle?

Tiger beetles are agile, mainly diurnal beetles with a head (including the eyes) wider than the pronotum; long, thin legs and long sickle-shaped mandibles with long, simple teeth along the inner edge of the mandibles. All species from the Middle East have fully developed wings which are used for short flights for hunting and escaping from predators (and humans).
Tiger beetles differ from all other ground beetles by the position of antennae which insert on frons, between the bases of mandibles.
In other ground beetles the antennae insert in line with and posteriad adjacent mandibular bases.
Moreover, the habitus photographs of this app provide further help to identify tiger beetles.

Species list

Choose and click on one of the species down below to open characteristics.

- Calomera alboguttata
- Calomera aphrodisia
- Calomera aulica
- Calomera aulicoides
- Calomera concolor
- Calomera diania
- Calomera fischeri
- Calomera littoralis winkleri
- Cephalota (Taenidia) circumdata

Habitat:
On sandy and stony banks close to freshwater (river Jordan, Sea of Galilee), especially in wadis, also in salty habitats close to the Dead Sea. Diurnal.

Distribution range:
From Egypt and southern Turkey to Iran.

Conservation:
Still widely distributed in the Sea of Galilee region and in the wadis around the Dead Sea.

**Figure 56.** Overview of the main functions of the application TIGER BEETLES ID. This stand-alone application for mobile Android devices (smartphones, tablets) can be freely downloaded at https://doi.org/10.3897/zookeys.734.21989.suppl1.

In terms of tiger beetle faunistics, Israel is certainly the best-studied country in the Middle East, as shown by the number of records found in SMNHTAU which are listed by Matalin and Chikatunov (2016). However, here too, we list one first record for Israel (see above) as well as first local records (for example *Calomera aulicoides* for the northern Hula Valley, *Calomera littoralis* in eastern Lower Galilee, *Calomera aulica* on the Mediterranean Sea coast). The material found in the collection of the Steinhardt Museum at the Tel Aviv University (SMNHTAU) can be used to help bridging the gap between taxonomy and nature conservation biology. Thus the knowledge of the distribution of tiger beetles can be deepened, and the decline of many tiger beetle species can be investigated. This is of particular importance in regions such as the southern Levant, where species diversity has not yet been thoroughly studied in terms of taxonomy and systematics (cf. Braby and Williams 2016). Additional intensive sampling, especially of protected areas, is needed across the region.

## Conservation biology of tiger beetles in the southern Levant

For the classification of threatened species, we used an approach which is widely used in Central Europe (Ludwig et al. 2006; Seibold et al. 2015). In general, threatened species are classified following the IUCN criteria for Red Lists (IUCN 2004; 2017). However, these criteria are sometimes criticized, especially for the classification of insects (e.g. Braby and Williams 2016). To allow for more convenient comparison with vertebrates and plants, we plan to apply the IUCN criteria in a future publication.

Five tiger beetle species have been classified as threatened. Two species, *Grammognatha euphratica* and *Calomera aulica*, are defined as vulnerable, meaning that they have become rare in Israel, and probably in Jordan as well. However, both taxa are widely distributed outside of the southern Levant and seem not to be threatened in other parts of their distribution ranges. *Grammognatha euphratica* is apparently expanding its distribution range northwards (Cassola et al. 2014), perhaps as result of climate change.

Three critically endangered species have not been recorded in Israel during the last decade. Matalin and Chikatunov (2016) stated that there are no records for these species since the 1980s or 1990s. Despite the existence of additional, more recent records (see above), the populations of these species are clearly in decline, and they are most likely very rare, already extinct, or close to extinction, at least in Israel. The three species are:

(a) *Cephalota vartianorum*, for which apparently suitable habitats remain in the salt marshes on both the Israeli and on the Jordanian sides of the Dead Sea. However, this species seems to have disappeared from nature reserves where it was recorded in 1994 (e.g. Enot Zuqim), as we did not find individuals in any of our collecting trips, including nocturnal light trapping methods. Specifically in Enot Zuqim, a decline of the phytodiversity in this nature reserve has been reported (Olsvig-Whittaker et al. 2009).

(b) The known habitat of *Cicindela javetii* in the Golan Heights has been destroyed, and no further records since the 1990s are known from Israel. Due to the high power of dispersal of the species, with all individuals being fully winged and flight-active, (re-) colonization of suitable habitats in the southern Levant is possible.

(c) Israel and Egypt are responsible for the world-wide preservation of *Cylindera contorta valdenbergi*, as its entire distribution range is confined to these two countries. However, it is unclear if populations of this taxon still exist, or if *C. contorta valdenbergi* is extinct. The definition of national responsibility is important in the assessment of national conservation priorities as well as in decision making about inclusion in international conventions on species conservation. The larval development of *Cylindera contorta valdenbergi* occurs in close proximity to sea water line on beaches, a habitat which is often extremely disturbed by tourism and recreational activities such as swimming facilities and off-road vehicles which compress the soil and sand and destroy the habitat of the species. For *Habroscelimorpha dorsalis* s.str. Say (= *Cicindela dorsalis* s.str.), an endangered species covered by the U.S. Endangered Species Act (Knisley et al. 1998) which inhabits similar habitats in North America, such vehicles have been identified as the main cause in the species' decline (Knisley et al. 2016). We suggest a thorough survey of all near-natural beach sections between Gaza Strip and Akko, particularly where *C. contorta valdenbergi* has previously been recorded, in order to ascertain whether any population of this taxon still exists. Such a survey can serve as the basis for the development of conservation policy and as a baseline for future monitoring of population sizes. Relevant methods developed for *H. dorsalis* can be found in Knisley et al. (2016).

We hope that our identification tools and the species' accounts describing the ecology and conservation biology of the tiger beetles of the southern Levant will encourage further work on tiger beetles in the Middle East and enhance the conservation and preservation of these attractive insects.

## Acknowledgements

We would like to thank all who supplied us with information or loaned us specimens in their care, especially Dr. Michael Balke (ZSM, Munich), Dr. Lutz Behne (SDEI, Müncheberg), Dr. Thierry Deuve (NHMP, Paris), Michael Franzen (ZSM, Munich), Achikam Gera (Be'er Sheva), Dr. Lars Hendrich (ZSM, Munich), Armin Korell (Kassel, †), Prof. Dr. Karl Mandl (Wien, †), Dr. Alexandr Putchkov (Kiev), Werner Starke (Warendorf), Dr. Eva Sprecher-Uebersax (Basel) and Gerhard Wagner (Hamburg). Thanks also to Jürgen Wiesner (Wolfsburg), Andrey Matalin (Moscow) and Borislav Guéorguiev (Sofia) for their comments during the review process.

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## Supplementary material 1

### TIGER BEETLE ID

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Link: https://doi.org/10.3897/zookeys.734.21989.suppl1

ZooKeys 734: 105–119 (2018)
doi: 10.3897/zookeys.734.23023
http://zookeys.pensoft.net

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# A new species of Turbanellidae (Gastrotricha, Macrodasyida) from Jamaica, with a key to species of *Paraturbanella*

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Academic editor: *P. Stoev* | Received 14 December 2017 | Accepted 17 January 2018 | Published 5 February 2018

*http://zoobank.org/1FAEB917-58A4-48B0-8EA7-7C3AEB00ECC5*

**Citation:** Dal Zotto M, Leasi F, Todaro MA (2018) A new species of Turbanellidae (Gastrotricha, Macrodasyida) from Jamaica, with a key to species of *Paraturbanella*. ZooKeys 734: 105–119. https://doi.org/10.3897/zookeys.734.23023

## Abstract

The study falls within the framework of a wider research programme aimed at investigating the gastrotrich diversity of the Tropical North-Western Atlantic (TNWA). A new macrodasyidan gastrotrich is described from fine-medium sand collected at Duncans Bay, Jamaica. The description is based on observations carried out on living specimens using differential interference contrast microscopy. *Paraturbanella xaymacana* **sp. n.**, the third gastrotrich taxon reported from Jamaica, is a mid-sized species, up to 564 µm long, with a feeble peribuccal swelling. The most obvious autapomorphic traits pertain to the testes and the male pore, both of which are located approximately at mid body, rather than at- or near the pharyngo-intestinal junction as occur in the other species of the genus. Additional differences with congeners are discussed and a key to the *Paraturbanella* species is provided, in the hope it will be useful to both gastrotrich experts and marine ecologists who discover these microscopic metazoans during their research.

## Keywords

Benthos, biodiversity, Caribbean Sea, meiofauna, taxonomy

## Introduction

The biodiversity of microscopic organisms belonging to meiofauna is scarcely known compared to other metazoans. Knowledge is particularly scarce for the 'minor phyla', such as Kinorhyncha (Dal Zotto 2015, Sørensen et al. 2015, Dal Zotto and Todaro 2016) or Gastrotricha (Todaro et al. 2011, 2015). Gastrotricha includes microscopic, vermiform invertebrates found in both freshwater and marine ecosystems (see Kieneke and Schmidt-Rhaesa 2014). As of December 2017, the group comprises 840 species divided into the two orders Macrodasyida and Chaetonotida (Todaro 2017). Macrodasyida generally includes taxa living interstitially in marine sandy bottoms (but see e.g., Todaro et al. 2012), while Chaetonotida comprises species found from marine to freshwater environments. The alpha biodiversity and systematics of the Phylum are changing at a fast pace, as shown by the continuous finding and description of new taxa (for marine taxa, e.g., Hochberg et al. 2014, Todaro et al. 2014, 2015, Lee and Chang 2017) and the in-group phylogenetic reassessments (e.g., Kånneby et al. 2013, Todaro et al. 2014, Kånneby and Todaro 2015).

The present study is part of a larger research programme aimed at shedding light on the diversity and phylogeny of gastrotrich species of the Tropical North-Western Atlantic. From 2010 to 2013, several international groups of researchers surveyed the gastrotrich fauna of different islands in the South Floridian, Bahamian, Lesser Antilles and Central Caribbean ecoregions. Accounts of these studies can be found in, e.g., Hochberg and Atherton (2010, 2011), Hummon (2010a), Atherton and Hochberg (2012a, b), Hochberg et al. (2013, 2014), Atherton (2014), Kånneby et al. (2014), Von Und Zu Gilsa et al. (2014), Kieneke et al. (2015), Araujo and Hochberg (2017a, b), Schuster et al. (2017). Research teams headed by one of us (MAT) have visited three islands: St. John in the US-Virgin islands, Jamaica, and Curaçao. Part of the information and/or taxa found have appeared in several papers (e.g., Hummon et al. 2010, Kånneby et al. 2012, 2013, 2014, Todaro et al. 2012, Schuster et al. 2017). Specifically devoted to the Jamaican survey were two papers dealing with the description a new species of *Macrodasys* and the description of a new species, genus and family (Todaro and Leasi 2013, Todaro et al. 2014).

We describe here a new species of *Paraturbanella* from the northern shore of Jamaica. It shares the same position of the male gonads with a recently described species from South Africa. In addition, we propose a determination key to the species of the genus.

## Methods

Sampling campaign took place in February 2011 and included 10 locations along the North and West coasts of Jamaica. The species described herein was found in samples collected by hand from the shallow sublittoral (- 0.5 m); about 1 L of sandy sediment was placed into 500 mL plastic jars (Todaro 2002) and soon after brought to the field laboratory (Discovery Bay Marine Laboratory). The specimens were extracted daily with the narcotisation-decantation technique using a 7 % magnesium chloride solution, within one week from collection. The supernatant was poured, without filtering, into plastic Petri dishes (3.0 cm diameter) and scanned for gastrotrichs at max. 50 × magnification under a Wild 3 stereomicroscope (Todaro and Hummon 2008).

The gastrotrich specimens of interest were picked out with a micro-pipette, mounted on glass slides in a drop of 7 % $MgCl_2$ solution, and studied in vivo with Nomarski differential interference contrast optics using a Zeiss Axio Scope A1. Photographs and measurements were taken with a DS-5M Nikon digital camera and Nikon NIS-F software. The description of the new species follows the convention of Hummon et al. (1993), whereas the position of some morphological characteristics along the body are given in percentage units (U) of total body length measured from anterior to posterior ends.

Abbreviations used in the text are as follows: PhIJ, pharyngo-intestinal junction; TbA, adhesive tubes of the anterior series; TbD, adhesive tubes of the dorsal series; TbDL, adhesive tubes of the dorsolateral series; TbL, adhesive tubes of the lateral series; TbP, adhesive tubes of the posterior series; TbV, adhesive tubes of the ventral series; TbVL, adhesive tubes of the ventrolateral series.

Granulometric analysis of the substrata was carried out according to Todaro et al. (2006). Mean grain size, sorting coefficient, kurtosis, and skewness were calculated by a computerised programme based on the equation of Seward-Thompson and Hails (1973).

Frequency of a species within collected samples follows Hummon et al. (1992) and is denoted as: 1) Sparse, when a species is found in less than 10 % of samples; 2) Occasional when found in 10–30 % of samples; 3) Common, in 30–60 % of samples; and 4) Usual, in more than 60 % of samples. Abundance of a species within a sample is classified as: 1) Rare, when contributing less than 1 % of a sample; 2) Scarce, 3–5 % of a sample; 3) Numerous, 10–20 % of a sample (often a sub-dominant); and 4) Prevalent, more than 30 % of a sample (usually dominant or co-dominant).

In the identification key we consider as ventrolateral the adhesive tubes that in some instances have been called, by other authors, lateral tubes. Furthermore, we consider *Paraturbanella dolichodema* Hummon, 2010 furnished with dorsal adhesive tubes and lacking ventral adhesive tubes, contra the original description that indicated that dorsal tubes are absent and the ventral tubes are present (Hummon 2010b). Our choice is based on information derived from the video sequences of the species made available from the original author (see especially vid5 at http://www.gastrotricha.unimore.it/moviegallery.htm). It should be noted that in *Paraturbanella*, ventral adhesive tubes have been reported only for *P. dolichodema*. This fact, and the position of the tubes described as originating in-between the ventral locomotory cilia raised our initial concern.

## Taxonomic account

**Phylum Gastrotricha Metschnikoff, 1865**
**Order Macrodasyida Remane, 1925 [Rao & Clausen, 1970]**
**Family Turbanellidae Remane, 1926**
**Genus *Paraturbanella* Remane, 1927**

### *Paraturbanella xaymacana* sp. n.

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Figs 1–3

**Type locality.** The sediment samples were collected on 24 February 2011 from Duncans Bay, Duncans, Jamaica (Lat. 18°29'13.05'N; Long. 77°32'03.23"W).

**Type specimen.** Holotype: the 542 µm long adult specimen shown in Figures 2, 3, no longer extant (International Code of Zoological Nomenclature, Articles 73.1.1 and 73.1.4), collected on 24 February 2011 (MAT & FL legit).

**Examined material.** Two adults (including the holotype) collected by MAT & FL from the type locality; specimens were observed alive and are no longer extant i.e., both physical specimens were inadvertently destroyed during the study. Considering the size and nature of these organisms, the provided drawings, and the original multiple photos of the studied animals, the establishment of a new species-group taxon should be considered valid under the recommendation 73G-J of Declaration 45 – Addition of Recommendations to Article 73 (ICZN 2017).

**Ecology.** Sparse in frequency of occurrence (10 % of samples), scarce in abundance (3–5% of a sample); sub-littoral at a water depth of about 0.5 m in sediment made up of fine, moderately sorted carbonate sand (mean grain size, 0.18 mm; sorting 0.59; kurtosis, 2.52; skewness, 0.43). Values of salinity and temperature of the interstitial water at the time of sampling were 34 ‰ and 26 °C respectively.

**Diagnosis.** Body strap-shaped, up to 564 µm in length. Head with a feeble peribuccal swelling, with a slight constriction at U3.7; pestle organs present. PhJIn at U31; body widest from mid-pharynx to mid-intestine, thinning gradually to the caudal base; caudum bilobed, incised from its tips to U95, with a clearly visible medial cone; distance between apices of outermost TbP on either side is 1.3 times the width of the caudal base. About 20–23 glands are distributed along both lateral body margins in a single column per side. TbA six per side, the innermost being the shortest, whereas the adjacent being the longest, occur on fleshy hands that insert at approximately U11; TbV, TbVL, TbL and TbD absent; TbP, six per side, occurring as 4, 1, 1, the outermost being the longest; caudal cone present; accessory adhesive tubes (called also dohrni/Seitenfüsschen) two per side, posterolaterally directed (longer tube = 21 µm, shorter tube = 14 µm), inserting ventrolaterally just behind the hands at U14. Locomotor ciliature runs from the TbA rearward in two longitudinal bands that trace the lateral body margins, joining after the anus. Mouth terminal, width narrow; buccal cavity medium-sized, mug-shaped; walls heavily cuticularized; pharyngeal pores near the base at U28;

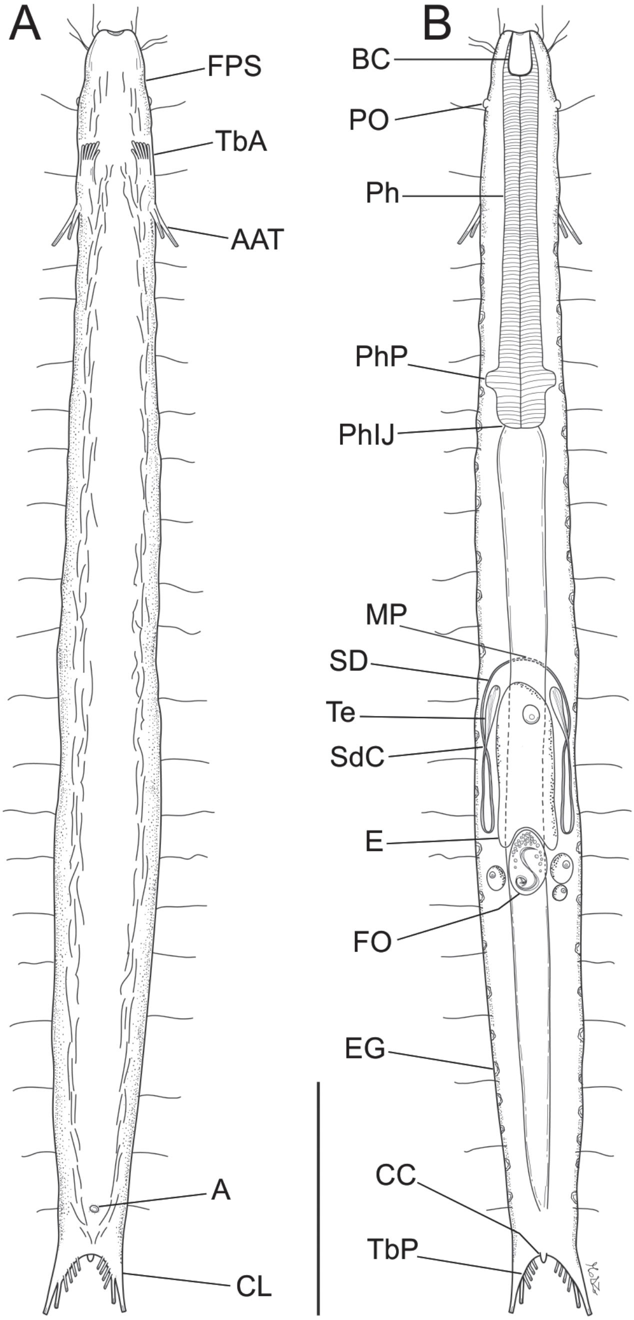

**Figure 1.** Line-art illustration of *Paraturbanella xaymacana* sp. n. **A** Habitus as seen from the ventral side **B** Habitus as seen from the dorsal side, showing the internal anatomy. Abbreviations: **A** anus **AAT** additional adhesive tubes (Seitenfüsschen) **BC** buccal cavity **CC** Caudal cone **CL** caudal lobe **E** egg **EG** epidermal gland **FO** frontal organ **FPS** Fleeble peribuccal swelling **MP** male pore **Ph** pharynx **PhIJ** pharyngo-intestinal junction **PhP** pharyngeal pore **PO** pestle organ **Sd** sperm duct **SdC** sperm duct crossing **TbA** anterior adhesive tubes **TbP** posterior adhesive tubes **Te** testis. Scale bar: 100 µm.

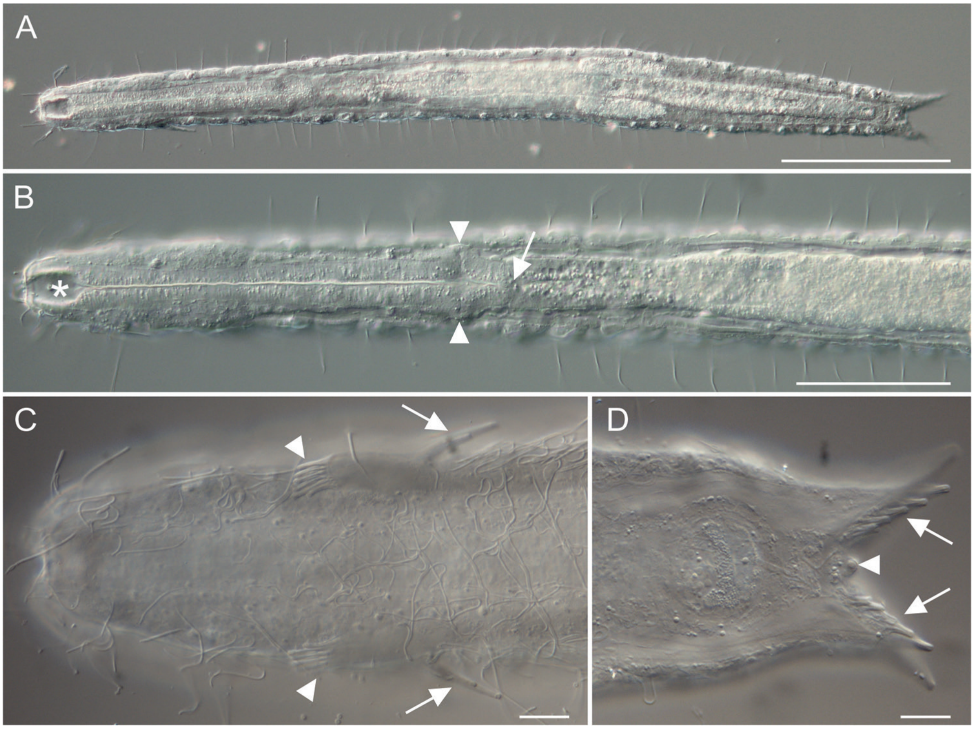

**Figure 2.** *Paraturbanella xaymacana* sp. n., holotype. Differential interference contrast photomicrographs. **A** Habitus, ventral view **B** Anterior region, ventral view, showing the buccal cavity (asterisk), the pharyngeal pores (arrowheads), and the pharyngo-intestinal junction (arrow) **C** Anterior region, ventral view, showing the lateral and ventral ciliation, the anterior adhesive tubes (arrowheads), and the additional adhesive tubes (Seitenfüsschen) (arrows) **D** Posterior region, ventral view, showing the medial cone (arrowhead) and the posterior adhesive tubes (arrows). Scale bars: 100 µm (**A**), 50 µm (**B**), 20 µm (**C–D**).

intestine straight, broadest in front; anus ventral at U91. Hermaphroditic, paired testes extend rearward from U51, with sperm ducts recurving to the fore at U63 and emptying to the exterior via a common pore at U49; paired ovaries, the largest ovum occurs in the mid-gut region at U51. Frontal organ dorsal to the intestine at U63.

**Etymology.** The specific name alludes to the original name of Jamaica: *Xaymaca*, (adjective: xaymacana) an Arawak word meaning "land of wood and water".

**Description.** Mostly based on the adult holotype, 542 µm in total length. Body strap-shaped; head with a feeble peribuccal swelling and a slight constriction at U04 and then the body proper. Pestle organs, small, at U5; body widest at mid-intestine, thinning gradually to the caudal base; caudum bilobed, deeply incised from its tips to U95, with a visible medial cone; distance between apices of outermost TbP on either side is 1.3 times the width of the caudal base. Widths at outer oral opening/head constriction/mid-pharynx/PhJIn/mid-intestine/furcal base, and their locations along the body length are: 12/26/33/39/45/29 µm at U0/U04/U17/U31/U61/U95. Epidermal glands are in one column per side, scattered along the body margins, up to 20–23 and variable in size (4–7 µm in diameter).

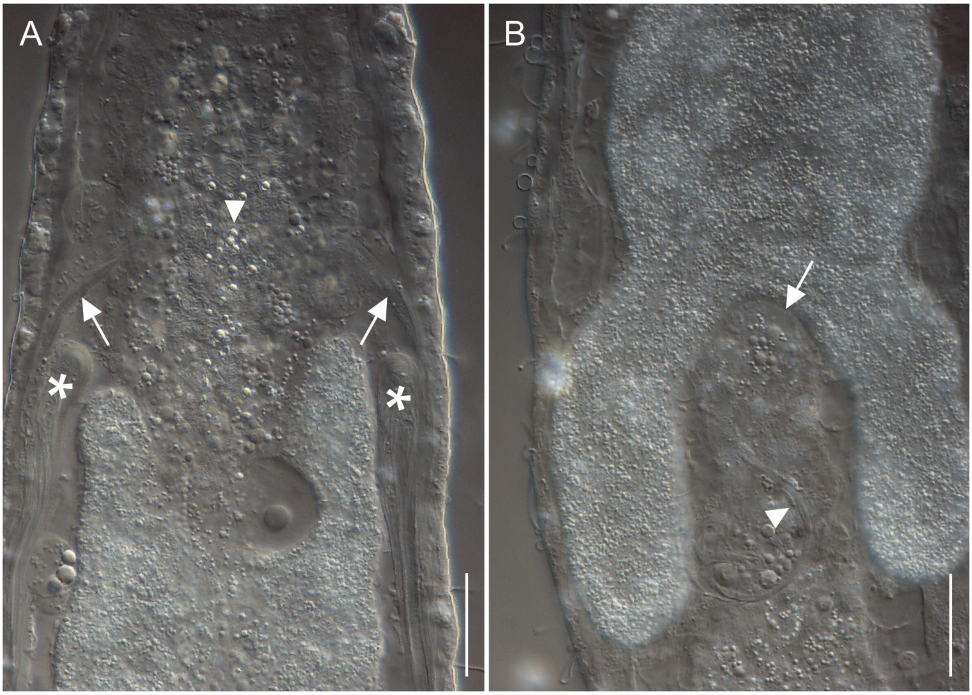

**Figure 3.** *Paraturbanella xaymacana* sp. n., holotype. Differential interference contrast photomicrographs. **A** Mid body, dorsal view, showing the testes (asterisks) beside a ripe egg, the sperm ducts (arrows), and the position of the male pore (arrowhead) **B** Mid body, dorsal view, showing the frontal organ (arrow) and a cluster of sperm (arrowhead). Scale bars: 20 µm (**A–B**).

*Adhesive tubes.* TbA, six per side (7–11 µm in length), all occurring on fleshy hands that insert at approximately U11; the innermost, mimicking a thumb, is the shortest, while the second from the inner side is the longest; TbV, TbVL,TbL, TbD absent; TbP, six per side, occurring as two groups of 4, 1, 1 elements each, along the inner (4 + 1 tube) and distal margin of each lobe (1 tube); the distal tube being the longest (14 µm in length) and the four proximal ones the shortest (6–7 µm in length); a caudal medial cone is present, but it is rather short, 4 µm in length. Accessory adhesive tubes (known also as dohrni tubes or Seitenfüsschen) two per side, posterolaterally directed (longer tube=21 µm, shorter=13.7 µm from their base), arise ventrolaterally just behind the fleshy hands at U14, usually being held close to the body.

*Ciliation.* Tufts of sparse cilia (11–21 µm in length) occur on lateral and dorsal sides of the head, behind the mouth. Additional sensory hairs, of similar length (13–19 µm), occur along the pharyngeal and intestinal region, organized in lateral, dorsolateral and dorsal columns, with about 20–23 hairs per column. Ventral locomotor cilia (16–20 µm in length) flow from the head constriction rearward in two longitudinal bands that trace the lateral body margins, and join behind the level of the anus.

*Digestive tract*. Mouth terminal, narrow (9 µm diameter); buccal cavity large, mug-shaped, 18 µm in length and approximately 11 µm in width, with walls heavily cuticularized; Pharynx 153 µm in length, with pharyngeal pores near the base at about U28; PhJIn at U31; intestine straight, broadest in front; anus ventral at U91.

*Reproductive tract*. Hermaphroditic; paired testes extend posteriorly from U51, with short sperm ducts recurving toward the front at U63, and emptying to the exterior via a common pore located at U49; ovaries paired, with the oocytes occurring from U64 to U68 and maturing from posterior to anterior; a large egg (approximately 70 by 24 µm) was present in the mid-gut region centred at U51. Caudal organ absent; frontal organ, vesicular, dorsal to the intestine centered at about U63; it is ovoid in shape (28 by 26 µm) and contains sparse spermatozoa and secretory material.

**Variability and remarks.** The other studied adult specimen was 564 µm in total body length, with 154 µm long pharynx. Number and arrangement of TbA, and of the TbP along the caudal lobes matched those of the holotype. The placement of the testes and the male pore is similar to that of the holotype. Unfortunately the animal got destroyed during the study so no further details could be acquired. The unfortunate event happened while we were trying to confirm the crossing of the ascended and descendent tracts of the sperm ducts observed in the holotype (see Figures 1B, 3A), a trait never recorded before in Gastrotricha. Future studies could indicate whether the crossing is an autapomorphic character of the species or just a feature of the holotype.

**Taxonomic affinities.** Prior to the current study there were 22 described species of *Paraturbanella* (Hummon 2010b, 2011, Hummon and Todaro 2010, Todaro et al. 2017). *P. xaymacana* sp. n., in virtue of its testes, located at about mid body instead than at- or near the PhIJ, approaches *P. africana* Todaro, Dal Zotto, Bownes & Perissinotto, 2017, recently described from the KwaZulu-Natal coast of South Africa (Todaro et al. 2017). These two species can easily been differentiated based on the following traits which, in our opinion, should be considered in order of importance: i) position of the male pore: located near the PhIJ in *P. africana* vs at about mid body in *P. xaymacana* sp. n.; ii) buccal swelling, very clear in *P. africana* vs almost non-existent in the new species; iii) TbA, number and arrangement: 5 tubes per side and without the innermost short "thumb" in the African species vs 6 tubes per side and with the shortest tube being the innermost one in the Jamaican species; iv) TbP, number and arrangement: 5 tubes, organized as 3, 1, 1 in *P. africana* vs 6 tubes organized as 4, 1, 1 in *P. xaymacana* sp. n.

## Taxonomic key

Several taxonomic keys to species of Gastrotricha have been developed in the last two decades (e.g. Todaro 2002, 2012, Clausen 2004, Kånneby et al. 2009, Todaro et al. 2009, Von Und Zu Gilsa et al. 2014, Garraffoni and Melchior 2015, Kieneke et al. 2015, , Kånneby 2016, Minowa and Garraffoni 2017). However, none of them have dealt with species of *Paraturbanella*. The tabular key of Clausen (1996) is of some utility but at least one species has been omitted (e.g., *P. brevicaudata* Rao, 1991) and several others have been described in the meanwhile. In marine habitats, the genus *Paraturbanella* is one of the most species rich and widespread; consequently, we hope

**Table 1.** Described species of *Paraturbanella* and their distribution.

| Taxon | Distribution |
|---|---|
| *Paraturbanella africana* | KwaZulu-Natal, South Africa |
| *Paraturbanella aggregotubulata* | Florida, USA |
| *Paraturbanella armoricana* | Bretagne, France |
| *Paraturbanella boadeni* | Andaman, India |
| *Paraturbanella brevicaudata* | Lakshadweep, India |
| *Paraturbanella cuanensis* | Ireland and UK |
| *Paraturbanella dohrni* | Throughout the North Sea and the Mediterranean Sea; Gulf and Atlantic* coast of Florida, US; Red Sea*; Somalia (as *P.* cf *dohrni*) |
| *Paraturbanella dolichodema* | Pacific coast of the US |
| *Paraturbanella eireanna* | North Ireland |
| *Paraturbanella intermedia* | Washington State, US |
| *Paraturbanella levantia* | East Mediterranean Sea |
| *Paraturbanella manxensis* | Isle of Man, UK |
| *Paraturbanella mesoptera* | Andhra Pradesh, India |
| *Paraturbanella pacifica* | Galapagos Islands, Ecuador |
| *Paraturbanella pallida* | Throughout the Mediterranean Sea; Isles of Scilly, UK; Hawaii*. |
| *Paraturbanella palpibara* | Andhra Pradesh, India |
| *Paraturbanella pediballetor* | British Isles; Normandy, France |
| *Paraturbanella sanjuanensis* | Washington State, US |
| *Paraturbanella scanica* | Norway |
| *Paraturbanella solitaria* | Pacific coast of the US |
| *Paraturbanella stradbroki* | Queensland, Australia; Hawaii* |
| *Paraturbanella teissieri* | Throughout the North Sea and the Mediterranean Sea; Gulf and Atlantic coast of Florida, US |

*, WD Hummon, personal communication.

the new key will prove useful not only to gastrotrich specialists but also to marine ecologists who find these peculiar metazoans in the course of research on interstitial meiobenthos. We warn the readers to refer to the original descriptions of the species, especially if the keyed-out taxa fall outside of their known geographic range of occurrence (see Table 1).

## Taxonomic key to genus *Paraturbanella*

1 TbVL present ........................................ **2**
– TbVL absent ........................................ **10**
2 TbD present ........................................ **3**
– TbD absent ........................................ **8**
3 TbD and TbVL clustered in the mid trunk region ........................................ ........................................ ***P. aggregotubulata* Evans, 1992**
– TbD and TbVL uniformely distributed along the trunk region .................. **4**

4 TbP in a single row per side .......... **5**

– TbP in a double row per side .......... ***P. armoricana* (Swedmark, 1954a)**

5 Mouth protruding outwardly; testes just behind the PhIJ .......... **6**

– Mouth not protruding outwardly; testes at some distance from the PhIJ .......... 7

6 Head slightly narrowing forward; pestle organs faint; caudal cone elongate .......... ***P. dolichodema* Hummon, 2010**

– Head deeply narrowing forward; pestle organs prominent; caudal cone usually not presen .......... ***P. levantia* Hummon, 2011**

7 Head slanted anteriorly; pestle organs and caudal cone absent .......... ***P. stradbroki* Hochberg, 2002**

– Head not slanted anteriorly; pestle organs and caudal cone present .......... ***P. scanica* Clausen, 1996**

8 TbP in a single row per side .......... **9**

– TbP in a double row per side .......... ***P. manxensis* Hummon, 2008**

9 TbA, 5–6 per side; TbP, 7 per side .......... ***P. eiranna* Maguire, 1976**

– TbA, 11–12 per side; TbP, 10–13 per side .......... ***P. intermedia* Wieser, 1957**

10 Head with a peribuccal swelling .......... **11**

– Head without a peribuccal swelling .......... **17**

11 Head bearing anteriorly two pairs of club-shaped sensory palps .......... ***P. palpibara* Rao & Ganapati, 1968**

– Head lacking sensory palps .......... **12**

12 Testes at or near the PhIJ .......... **13**

– Testes at or passed mid body .......... **16**

13 Head bearing ventral papillae .......... ***P. teissieri* Swedmark, 1954b**

– Head lacking ventral papillae .......... **14**

14 TbA, less than 8 per side .......... ***P. solitaria* Todaro, 1995**

– TbA, 8 or more per side .......... **15**

15 TbP, 8 per side occurring in pairs; caudal cone elongate .......... ***P. sanjuanensis* Hummon, 2010**

– TbP, 8–10 evenly spaced, caudal cone short .......... ***P. mesoptera* Rao, 1970**

16 Peribuccal swelling noticeable; testes at mid body; TbA, 6 per side; TbP, 5 per side arranged as 3, 1, 1 elements .......... ***P. africana* Todaro, Dal Zotto, Bownes & Perissinotto, 2017**

– peribuccal swelling feeble ; testes passed mid body; TbA, 6 per side; TbP, 6 per side arranged as 4, 1, 1 elements .......... ***P. xaymacana* sp. n.**

17 TbP in a single row per side .......... **18**

– TbP in a double row per side .......... **22**

18 Total body length > 860 µm; caudal cone absent .......... ***P. pediballetor* Hummon, 2008**

– Total body length < 760 µm; caudal cone present .......... **19**

19 TbA inserted on the outer side of a cuticular rod .......... ***P. boadeni* Rao & Ganapati, 1968**

– TbA inserted in hand-like fashion on a fleshy base....................................**20**
20 Pestle organs absent ..........................................***P. cuanensis* Maguire, 1976**
– Pestle organs present ........................................................................**21**
21 Caudal lobes short and reduced; TbA, 6 per side; TbP, 5 per side.................
.....................................................................***P. brevicaudata* Rao, 1991**
– Caudal lobes normally developed; TbA, 5–6 per side; TbP, 5–8 per side.......
....................................................................... ***P. dohrni* Remane, 1927**
22 Total body length < 400 µm; pestle organs absent....***P. pacifica* Schmidt, 1974**
– Total body length > 600 µm; pestle organs present ......................................
...................................***P. pallida* Luporini, Magagnini & Tongiorgi, 1971**

## Acknowledgements

This work was mainly supported by a grant from the US-National Science Foundation to R. Hochberg (n. DEB 0918499). Additional funding was obtained from the Italian MIUR: "*Finanziamento annuale individuale delle attività base di ricerca*" grant to M.A. Todaro. Many thanks are due to the staff of the Discovery Bay Marine Laboratory for the assistance received during FL and MAT stay in Jamaica. Authors are thankful to R. Hochberg and T. Kånneby for their constructive comments on an early draft of the manuscript.

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ZooKeys 734: 121–135 (2018)
doi: 10.3897/zookeys.734.22774
http://zookeys.pensoft.net

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# Review of the genus *Coccus* Linnaeus from Korea, with description of a new species (Hemiptera, Coccomorpha, Coccidae)

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Academic editor: *R. Blackman* | Received 5 December 2017 | Accepted 20 December 2011 | Published 5 February 2018

*http://zoobank.org/2FD0E47C-9C5C-4022-ABF7-8482872414A0*

**Citation:** Choi J, Lee S (2018) Review of the genus *Coccus* Linnaeus from Korea, with description of a new species (Hemiptera, Coccomorpha, Coccidae). ZooKeys 734: 121–135. https://doi.org/10.3897/zookeys.734.22774

## Abstract

The genus *Coccus* from Korea is reviewed, including a new species, *C. ficicola* **sp. n.**, and a first record of *C. malloti* (Takahashi, 1956). The new species is characterized by a distinctive pattern of ventral tubular ducts on medial area of head and thorax, and submarginal area of abdomen. The adult female of *Coccus ficicola* **sp. n.** is described and illustrated, and a morphological comparison is given with congeners. *Coccus malloti* is redescribed and illustrated based on the adult female specimens from Korea. A key to the four species of *Coccus* known from Korea is provided with diagnoses and photographs.

## Keywords

Coccinae, Coccini, soft scale insect, taxonomy

## Introduction

The genus *Coccus* Linnaeus, 1758, which is a species-rich group in the family Coccidae, comprises approximately 111 species worldwide (Hodgson 1994; García-Morales et al. 2016). This group is defined morphologically by the distribution of ventral tubular ducts, the shape of dorsal and marginal setae, and the presence of a tibio-tarsal articulatory sclerosis on each leg (Hodgson 1994); however, the molecular phylogeny using some of the taxa included in Coccidae revealed that it is not a monophyletic group and needs taxonomic revision (Lin et al. 2013). Among the genus *Coccus*, *C. hesperidum* Linnaeus, *C. viridis* Green, and *C. celatus* De Lotto are known as economic pests of ornamental and agricultural products (Kapranas et al. 2007; Waller et al. 2007). Two species of the genus, *C. hesperidum* and *C. pseudomagnoliarum* (Kuwana) have been previously recorded from Korea. Here, a new species is described, *Coccus ficicola* sp. n. and its morphology is compared with congeners. A hitherto unrecorded species is also redescribed, *C. malloti* (Takahashi) and recorded for the first time from Korea.

## Materials and methods

The specimens were mounted on microscope slides using the method of Hodgson and Henderson (2000) and Danzig and Gavrilov-Zimin (2014). The micrographs of slide-mounted materials were taken and measured using analysis software (Active Measure ver. 3.0.3, Mitani Co. Ltd, Japan). The terminology follows Hodgson (1994) and Hodgson and Henderson (2000), except that the term "pregenital disc-pores" is replaced with "multilocular pores" suggested by Kondo and Hardy (2008). The type specimens are deposited in the Insect Biosystematics Laboratory, Research Institute for Agriculture and Life Science, Seoul National University, Korea (**SNU**).

## Taxonomy

### Genus *Coccus* Linnaeus, 1758: 455

**Type species.** *Coccus hesperidum* Linnaeus, 1758, designated by Opinion 1303 (1985).

**Diagnosis.** Dorsal setae pointed or blunt; dorsal tubular ducts and dorsal tubercles present or absent; marginal setae with pointed or frayed apices; ventral tubular ducts present or absent, if present, mainly distributed on medial area of thorax or submarginal area; a tibio-tarsal articulatory sclerosis present or absent on each leg. For further diagnostic characteristics, see Hodgson (1994) and Wang and Feng (2012).

### Key to species of genus *Coccus* in Korea

1 Dorsal tubercles absent; legs without tibio-tarsal articulatory scleroses; ventral tubular ducts present on abdomen only.... ***C. pseudomagnoliarum* (Kuwana)**
– Dorsal tubercles present; legs with tibio-tarsal articulatory scleroses; ventral tubular ducts present on thorax and abdomen ........................................... **2**
2 Ventral tubular ducts of three types (Type I: each with a broad inner ductule; Type II: each with a narrow inner ductule; Type III: each with a filamentous inner ductule) present............................................ ***C. malloti* (Takahashi)**
– Ventral tubular ducts of type I, each with a narrow inner ductule ............... **3**

3 Antenna 7-segmented; ventral tubular ducts scarce: a small group of 0–3 ducts present between mouthparts and each procoxa; a thin transverse band containing one or two ducts vertically present between mesocoxae; absent on inner submarginal area of abdomen .................... ***C. hesperidum* (Linnaeus)**

– Antenna 8-segmented; ventral tubular ducts abundant: a large group of 16–20 ducts present between mouthparts and each procoxa; a broad transverse band containing 4–7 ducts present vertically between mesocoxae; present on inner submarginal area of abdomen .................................... ***C. ficicola* sp. n.**

***Coccus ficicola* sp. n.**

http://zoobank.org/1C880C8E-9D53-4418-A87D-EFBBB2227497

Figs 1A–D, 2A–Q

**Material examined. Holotype:** adult female: Korea, Gangnam-gu, Yeoksam-dong, 18.iv.2015, coll. J.Y. Choi, on *Ficus benghalensis* L. (Moraceae). **Paratypes:** same data as holotype, 9♀♀.

**Diagnosis.** Adult females in life (Fig. 1A–D) with a reticulated pattern of brown stripes and a longitudinal ridge medially on dorsum; dermal areolations present but small; dorsal tubercles present; dorsal tubular ducts sparse on submarginal area; dorsal setae with bluntly rounded apices; marginal setae usually with simple pointed apices; multilocular disc-pores usually with ten loculi; ventral tubular ducts with a narrow inner ductule, frequent on posterior region of the head, medial area of thorax, and inner submarginal area of abdomen; antennae each with eight segments; legs each with a tibio-tarsal sclerosis on the articulation.

**Description. Adult female. Living appearance** (Fig. 1A–D). Body oval, flattened, or moderately convex. Young adult females yellowish to brownish, with a reticulated pattern of brown stripes except for a longitudinal ridge on mid dorsum. Older adult females becoming more convex and darker. Eggs not seen.

**Slide-mounted material** (Fig. 2A–Q). Body oval, 2.6–3.5 mm long, 2.0–3.6 mm wide, with distinct stigmatic cleft; anal clefts approximately 1/6 of body length.

*Dorsum***.** Derm membranous. Dermal areolations oval and small, each with a microduct. Dorsal tubercles normally convex, present on submarginal area, 4–6 in total on each side: two between apex of head and anterior stigmatic cleft, one or two between anterior and posterior stigmatic clefts, and one or two between posterior stigmatic cleft and anal cleft. Dorsal setae cylindrical, short, stout, blunt apically, each 6–9 µm long, moderately distributed on dorsum. Dorsal tubular ducts each with a developed outer ductule and a slender inner ductule with a developed terminal gland, sparsely present on submargin. Dorsal microducts evenly scattered over entire dorsum. Preopercular pores round and small, rather inconspicuous, 6–7 µm wide, set in a small group of approximately 6–15 in front of anal plates. Anal plates quadrate, 190–223 µm long, 160–203 µm wide, usually posterolateral margin slightly longer than anterolateral margin; anterolateral margin 119–144 µm long, posterolateral margin 130–154 µm

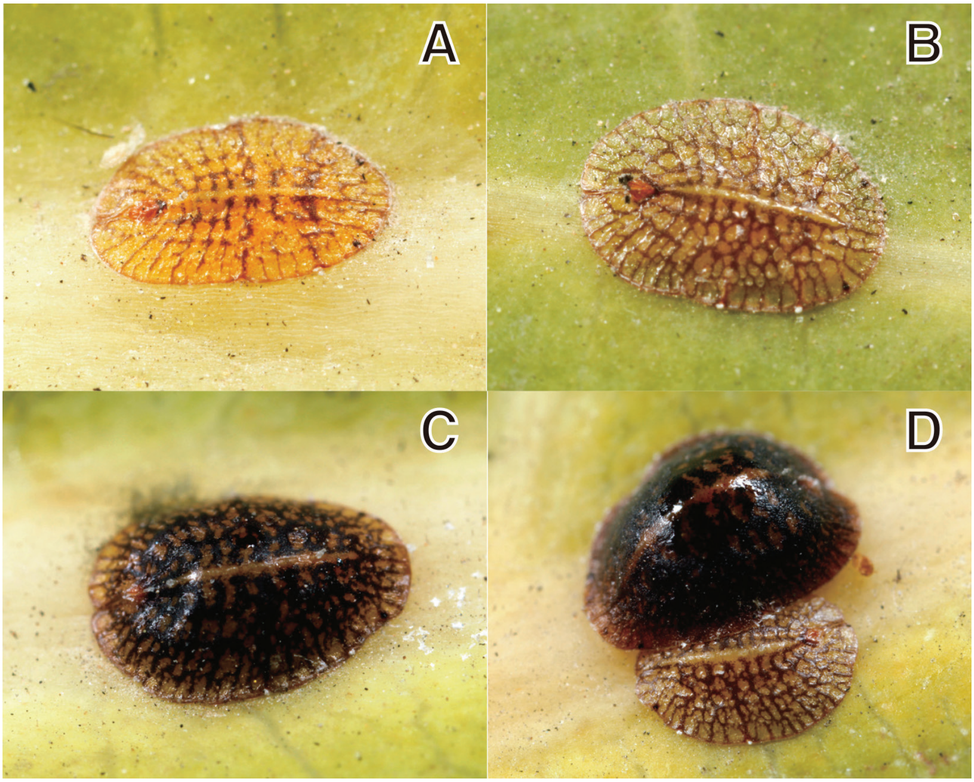

**Figure 1.** *Coccus ficicola* Choi & Lee sp. n. **A** instar female **B** immature adult female **C** mature adult female **D** mature (upper) and immature (under) adult females.

long; each plate with four apical setae. Ano-genital fold with two pairs of anterior and three pairs of lateral margin setae. Anal ring with six long setae.

*Margin***.** Marginal setae spinose, slender, slightly bent, each 16–32 µm long, mostly with simple pointed apices, but sometimes with bifid tips; with 52–59 present between anterior stigmatic clefts; 12–17 laterally present between anterior and posterior stigmatic clefts, 45–53 present between posterior stigmatic cleft and anal clefts. Stigmatic clefts deep, each with three stigmatic spines, median spine 2–3 times as long as lateral spine: medians 48–77 µm long, laterals 14–30 µm long. Eyespots located near margin.

*Venter***.** Derm membranous. Multilocular disc-pores 7–8 µm wide, each with 10–12 loculi, mostly with ten loculi, abundant around vulvar area, but less frequent on anterior segments of abdomen. Spiracular pores 4–5 µm wide, each with five loculi, in a narrow band 1–2 pores wide between each spiracle and stigmatic cleft. Ventral tubular ducts of a single type, each 21–28 µm long, with a developed outer ductule and a narrow inner ductule with a flower-shaped terminal gland, approximately 16–20 ducts densely present between mouthparts and procoxa on each side; a broad transverse band containing around 4–7 ducts vertically present between mesocoxae; abundant between each meso- and metacoxa, extending around spiracles; and also sparsely scattered on

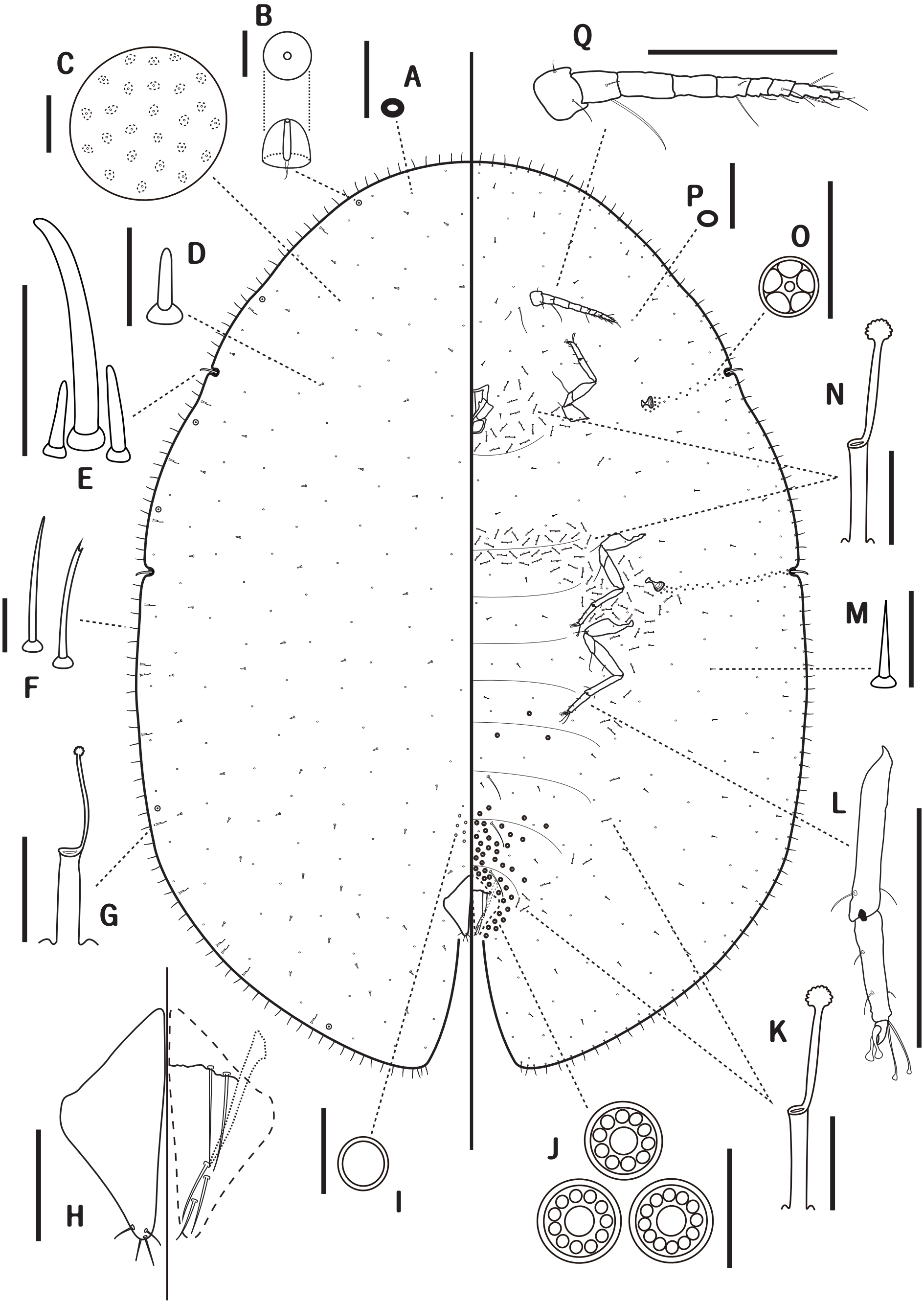

**Figure 2.** *Coccus ficicola* sp. n., adult female. **A** dorsal microduct **B** dorsal tubercle **C** dermal areolations **D** dorsal seta **E** stigmatic spines **F** marginal setae **G** dorsal tubular duct **H** anal plates **I** preopercular pore **J** multilocular disc-pores **K** ventral tubular duct on abdomen **L** leg **M** ventral seta **N** ventral tubular duct on head and thorax. **O** spiracular pore **P** ventral microduct **Q** antenna. Scale bars: 200 µm (**L, Q**); 100 µm (**H**); 50µm (**C, E**); others = 10µm.

inner submarginal area between anal plates and each metacoxa. Ventral microducts present on entire venter, especially frequent on submargin. Ventral setae with three pairs of long pregenital setae; two pairs of long setae between antennae; other setae sharply spinose, each 7–14 µm long, moderately distributed over entire venter. Legs well developed, each with a tibio-tarsal articulation and an articulatory sclerosis; total length of each metathoracic leg 560–638 µm long: each coxa 138–163 µm long, trochanter+femur 181–213 µm long, tibia+tarsus 218–237 µm long, claw 17–26 µm long. Tarsal digitules thinner and longer than claw digitules. Spiracles normal, mostly posterior peritreme broader than anterior: anterior peritremes each 38–49 µm wide, posterior peritremes each 45–57 µm wide. Antenna 8-segmented, each 279–339 µm long. Clypeolabral shield 127–138 µm wide.

**Etymology.** Named after its host plant, *Ficus benghalensis* L.

**Host plant.** Moraceae: *Ficus benghalensis* L.

**Comments.** *Coccus ficicola* sp. n. is probably a non-endemic species because it occurs on an imported ornamental plant, *Ficus benghalensis*, which is widely cultivated in tropical areas (Starr et al. 2003). In order to know the exact origin of the new species, further investigations are needed.

**Morphological comparison of adult females of *Coccus ficicola* sp. n. and its related taxa.** Based on taxonomic articles, such as Gill et al. (1977), Ben-Dov (1981), Avasthi and Shafee (1991), and Lin et al. (2017), we selected ten species morphologically similar to *C. ficicola* sp. n.: *C. capparidis* (Green, 1904), *C. discrepans* (Green, 1904), *C. elatensis* (Ben-Dov, 1981), *C. formicarii* (Green, 1896), *C. gymnospori* (Green, 1908), *C. hesperidum* (Linnaeus, 1758), *C. latioperculatum* (Green, 1922), *C. moestus* (De Lotto, 1959), *C. praetermissus* Lin & Tanaka, 2017, and *C. sulawesicus* Gavrilov, 2013. The morphological characters of adult females of *Coccus ficicola* and the ten species are summarized in Table 1.

In the morphological comparison, *Coccus ficicola* shows a new combination of morphological characters; in particular, the distributional pattern of ventral tubular ducts of the species reveals uniqueness among the nine morphological characters. *Coccus ficicola* is most closely related to *C. gymnospori* (Green), in having (i) dorsal tubercles, (ii) dorsal tubular ducts on submarginal area, (iii) dorsal setae with bluntly rounded apices, (iv) preopercular pores, (v) marginal setae with pointed or frayed apices, (vi) antenna with eight segments, (vii) three pairs of pregenital setae, and (viii) tibio-tarsal sclerosis. However, *C. ficicola* differs from *C. gymnospori* in having the following combination of character states (character states of *C. gymnospori* in parenthesis): (i) ventral tubular ducts abundant, 16 to 20 ducts present between mouthparts and each procoxa (few, only 3 or 4 ducts); a broad transverse band containing 4–7 ducts vertically between metacoxae (thin, containing one or two ducts); and present on inner submarginal area of abdomen (entirely absent), and (ii) multilocular disc-pores extending further anteriorly (restricted to preceding two abdominal segments) (Ben-Dov 1981; Avasthi and Shafee 1989).

Although the African species, *C. africanus* (Newstead) and *C. alpinus* De Lotto, are not included in the list of related taxa for morphological comparison, *C. ficicola* is

**Table 1.** Comparison of morphological characters of adult females of *Coccus ficicola* sp. n. and its related taxa.

| Species | Dorsal tubercles | Dorsal tubular ducts | Dorsal setae | Preopercular pores | Marginal setae | Antenna | Pregenital setae | Tibio-tarsal sclerosis | Ventral tubular ducts | Reference |
|---|---|---|---|---|---|---|---|---|---|---|
| *C. ficicola* sp. n. | Present | Present | Bluntly rounded | Present | Pointed or frayed | Eight segments | Three pairs | Present | Present on medial area of head, pro-, and mesothorax; submarginal area of abdomen | This study |
| *C. capparidis* | Present | Absent | Bluntly rounded | Present | Pointed or frayed | Six or seven segments | One or two pairs | Absent | Present on submarginal area of abdomen | Williams and Watson 1990 |
| *C. discrepans* | Present | Absent | Sharply pointed or bluntly rounded | absent | Pointed or frayed | Seven segments | Three pairs | Present | Present on medial area of mesothorax | Avasthi and Shafee 1991; Tao et al. 1983 |
| *C. elatensis* | Present | Present | Bluntly rounded | Present | Pointed or frayed | Eight segments | Four pairs | Present | Present on medial area of mesothorax | Ben-Dov 1981 |
| *C. formicarii* | Absent | Absent | Sharply pointed (setose) | Present | Pointed (setose) | Seven or eight segments | Three pairs | Absent | Present on medial area of head, pro-, and mesothorax | Hodgson 1994 |
| *C. gymnospori* | Present | Present | Bluntly rounded | Present | Pointed or frayed | Eight segments | Three pairs | Present | Present on medial area of head and mesothorax | Ben-Dov 1981 |
| *C. hesperidum* | Present | Present or absent | Sharply pointed | Present | Pointed or frayed | Seven segments | Three pairs | Present | Present on medial area of pro- and mesothorax; laterad to genital opening | Hodgson 1994; Lin et al. 2017 |
| *C. latioperculatum* | Absent | Absent | Bluntly rounded | Present | Frayed | Seven segments | Two pairs | Present | Present on medial area of pro- and mesothorax | Avasthi and Shafee 1991 |
| *C. moestus* | Present | Present | Bluntly rounded | Present | Frayed | Seven or eight segments | Three pairs | Present | Present on medial area of mesothorax | Gill et al. 1977 |
| *C. praetermissus* | Present | Present | Bluntly rounded | Present | Pointed or frayed | Seven segments | Three pairs | Present | Present on medial area of mesothorax | Lin et al. 2017 |
| *C. sulawesicus* | Absent | Absent | Sharply pointed | Present | Pointed or frayed | Seven or eight segments | Three pairs | Present | Present on medial area of meso- and metathorax | Gavrilov-Zimin 2013 |

similar to both species in having abundant ventral tubular ducts. However, *C. ficicola* does not have continuous ventral tubular ducts between the metacoxae, whereas both African species have this character state (De Lotto 1957; De Lotto 1960; Granara de Willink et al. 2010).

### *Coccus hesperidum* (Linnaeus, 1758)

Fig. 3A–F

*Coccus hesperidum* Linnaeus, 1758: 455.

**Material examined.** Adult female: Daehak-dong, Gwanak-gu, Seoul, 09.iv.2014, coll. J.Y. Choi, on Orchidaceae sp., 5♀♀; Sinhyo-dong, Seogwipo-si, Jeju-do, 14.ix.2014, coll. J.Y. Choi, on *Asplenium antiquum* Makino (Aspleniaceae), 5♀♀; Sinbuk-eup, Chuncheon-si, Gangwon-do, 31.v.2015, coll. J.Y. Choi, on *Heteropanax fragrans* (Roxb.) (Araliaceae), 5♀♀; Geumam-dong, Deokjin-gu, Jeonju-si, Jeollabuk-do, 06.vi.2015, on same host, 5♀♀; Songhyeon-dong, Andong-si, Gyeongsangbuk-do, 07.vi.2015, on same host, 5♀♀; Guseo-dong, Geumjeong-gu, Busan, 07.vi.2015, on *Ficus benghalensis* L., 5♀♀.

**Diagnosis.** Adult females in life (Fig. 3A–F) highly variable in body color and pigment pattern, but usually dorsum pale yellowish to brownish, with black or brown spots; dermal areolations present; dorsal tubercles present; dorsal tubular ducts present or absent; dorsal setae with sharply pointed apices; marginal setae usually with pointed, bifid or fimbriate apices; multilocular disc-pores usually with ten loculi; ventral tubular ducts with a narrow inner ductule, few present around meso- and procoxa, and anal plates; antennae each 7-segmented; legs each with a tibio-tarsal articulatory sclerosis.

**Host plant**. Recorded from 346 genera in 121 families (García-Morales et al. 2016). For Korean records, see Paik (1978).

**Distribution.** Known from all zoogeographical regions (García-Morales et al. 2016).

### *Coccus malloti* (Takahashi, 1956)

Figs 4A–B, 5A–Q

*Pulvinaria malloti* Takahashi, 1956: 25.

**Material examined.** Adult female: Jeollanam-do, Gwangyang-si, Ongnyong-myeon, Chusan-ri, 28.v.2015, coll. J.Y. Choi, on *Ilex cornuta* Lindl. (Aquifoliaceae), 9♀♀; Jeju-do, Seogwipo-si, Andeok-myeon, Gamsan-ri, 27.iv.2016, coll. J.Y. Choi, on *Aphananthe aspera* (Thunb.) (Cannabaceae), 1♀.

**Diagnosis.** Adult females in life (Fig. 4A–B) with a reticulated pattern of black stripes and a longitudinal band medially on dorsum; dermal areolations present but small; dorsal tubercles present; dorsal tubular ducts absent; dorsal setae sharply spinose; marginal setae mostly with simple pointed apices; multilocular disc-pores usually with

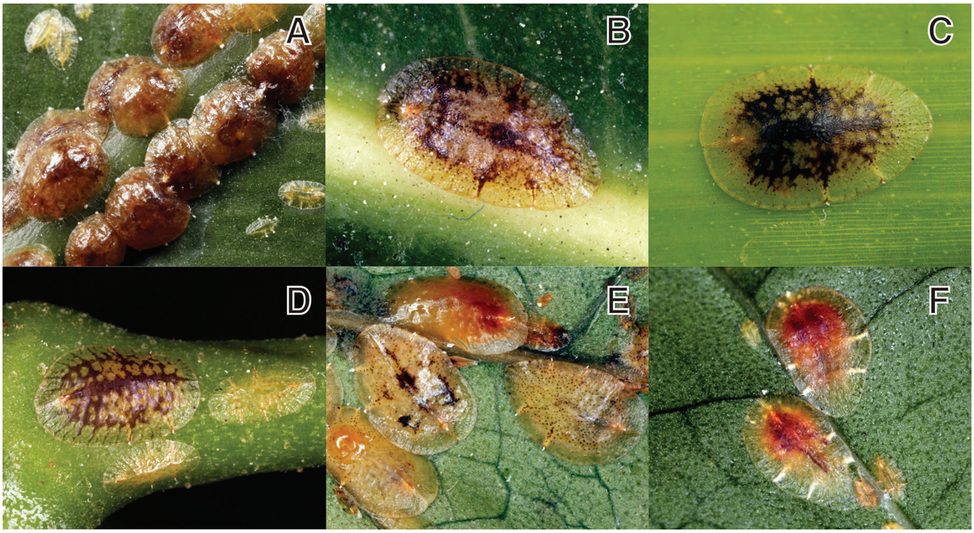

**Figure 3.** *Coccus hesperidum* (Linnaeus, 1758). **A** population on *Asplenium antiquum* **B** adult female on *Ficus benghalensis* **C** adult female on Orchidaceae sp. **D, E, F** populations on *Heteropanax fragrans*.

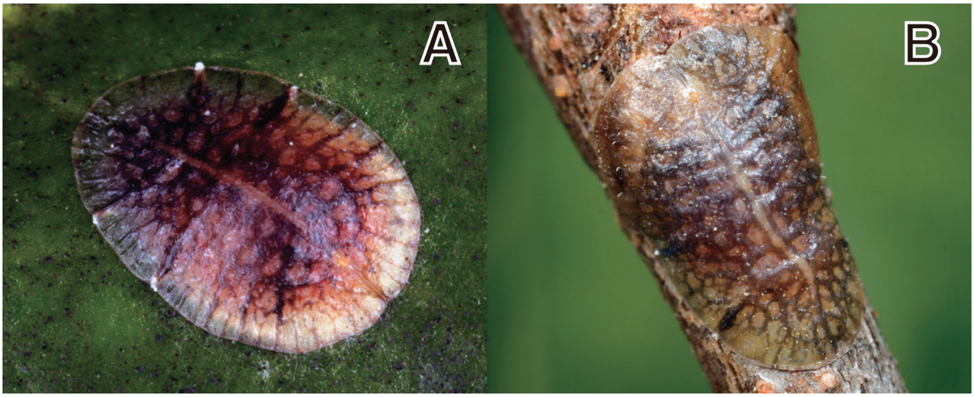

**Figure 4.** *Coccus malloti* (Takahashi, 1956). **A** adult female on *Ilex cornuta* **B** adult female on *Aphananthe aspera*.

ten loculi; ventral tubular ducts of three types: Type I with a broad inner ductule, densely present on posterior medial area of head; frequent on anterior medial area of prothorax, extending to inner submarginal area of thorax; and also sparsely scattered on inner submarginal area of abdomen; Type II with a narrow inner ductule and a large flower-shaped terminal gland, rarely present on inner submarginal area and posterior medial area of abdomen; Type III with a long filamentous inner ductule and a quite small terminal gland, moderately present on submarginal area between anal clefts and each posterior spiracular furrow; all types of ventral tubular ducts absent on medial area of meso-, metathorax and anterior abdomen, and submarginal area of head; antennae each eight segments; legs each with a tibio-tarsal sclerosis on the articulation.

**Redescription. Adult female. Living appearance** (Figs 4A–B). Body elongate oval, flattened, or slightly convex. Young adult females yellowish to dark brownish, with a reticulated pattern of brown or black stripes, getting darker at maturity. Eggs reddish in color, stored beneath venter.

**Slide-mounted material** (Fig. 5A–Q). Body elongate oval, 3.6–4.8 mm long, 2.2–3.3 mm wide, with shallow to deep stigmatic cleft; anal clefts approximately 1/6 of body length.

*Dorsum*. Derm membranous. Dermal areolations oval and small, each with a microduct. Dorsal tubercles normally convex, present on submarginal area, 1–5 in total on each side: one or two between apex of head and anterior stigmatic cleft, zero to two between anterior and posterior stigmatic clefts, and zero or one between posterior stigmatic cleft and anal cleft. Dorsal setae sharply spinose, short, stout, each 6–9 µm long, moderately distributed on dorsum. Dorsal tubular ducts absent. Dorsal microducts evenly scattered over entire dorsum. Preopercular pores round and small, 3–5 µm wide, set in a small group of approximately 8 in front of anal plates. Anal plates quadrate, 217–249 µm long, 169–198 µm wide, each with slightly concaved posterolateral margin, usually posterolateral margin quite longer than anterolateral margin; anterolateral margin 123–143 µm long, posterolateral margin 150–169 µm long; each plate with four apical setae. Ano-genital fold with two pairs of anterior and three pairs of lateral margin setae. Anal ring with six long setae.

*Margin*. Marginal setae spinose, straight or slightly bent, each 14–22 µm long, mostly with simple pointed apices; with 30–43 present between anterior stigmatic clefts; 13–17 laterally present between anterior and posterior stigmatic clefts, 22–38 present between posterior stigmatic cleft and anal clefts. Stigmatic clefts shallow to deep, each with three stigmatic spines, median spine nearly twice as long as lateral spine: medians 60–75µm long, laterals 24–38 µm long. Eyespots located near margin.

***Venter.*** Derm membranous. Multilocular disc-pores 6–7 µm wide, each with 8–10 loculi, mostly with ten loculi, abundant around vulvar area; one or two transverse rows on each abdominal segments; and also small groups present laterad of each metacoxa and mesocoxa, but not observed around procoxa. Spiracular pores 4–5 µm wide, each with five loculi, in a narrow band 2–4 pores wide between each spiracle and stigmatic cleft. Ventral tubular ducts of three types: Type I each with 33–39 µm long, with a developed outer ductule and a moderately broad inner ductule, straight or slightly curved, with a flower-shaped terminal gland, densely present on posterior medial area of head; frequent on anterior medial area of prothorax, extending to inner submarginal area of thorax; and also sparsely scattered on inner submarginal area of abdomen; Type II each with 16–24 µm long, with a narrow inner ductule and a large flower-shaped terminal gland, rarely present on inner submarginal area and posterior medial area of abdomen; Type III each with 15–24 µm long, with a long filamentous inner ductule and a quite small terminal gland, moderately present on submarginal area between anal clefts and each posterior spiracular furrow; all types of ventral tubular ducts absent on medial area of meso- and metathorax and anterior abdomen, and submarginal area of head. Ventral microducts present on entire venter, especially frequent on sub-

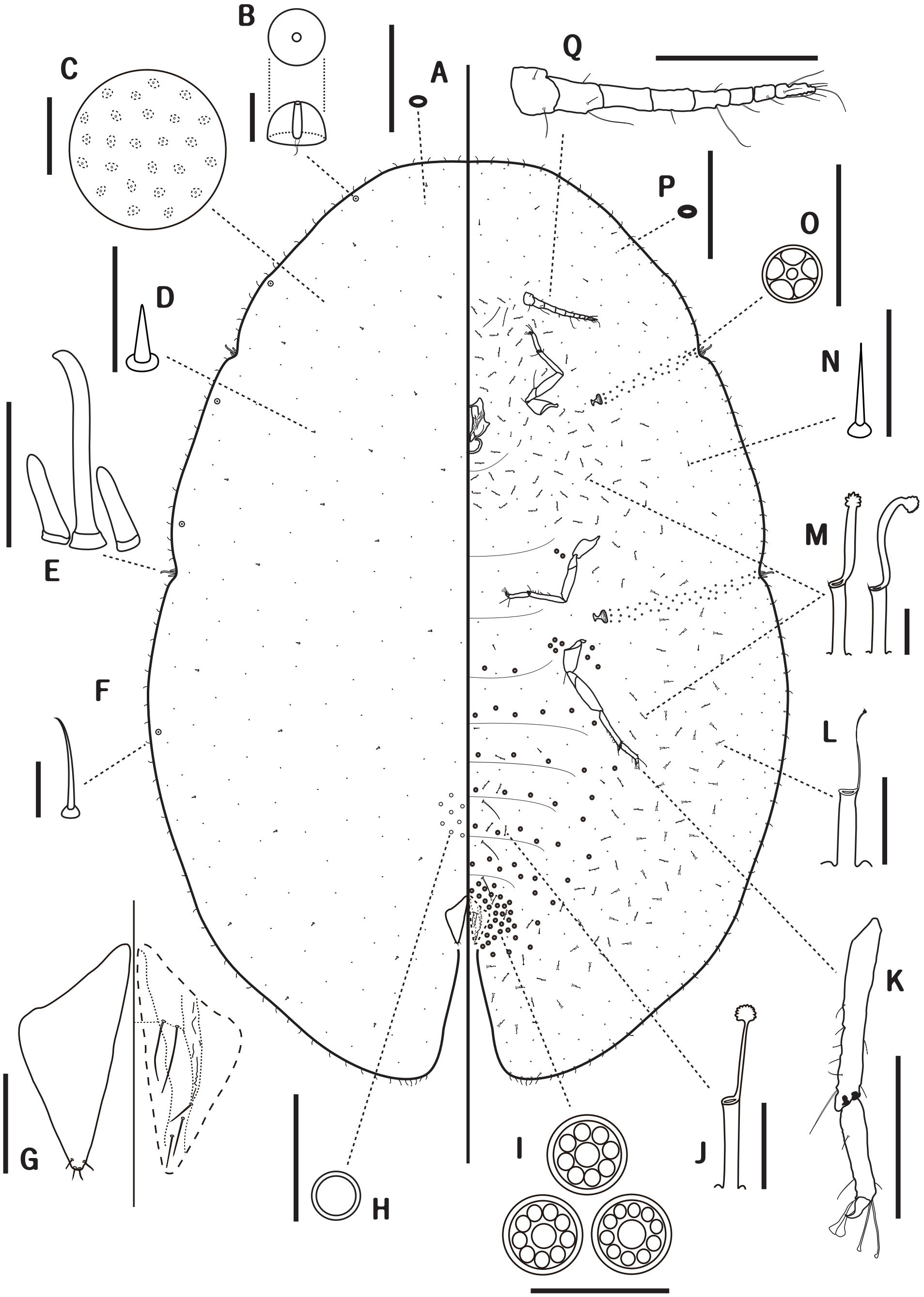

**Figure 5.** *Coccus malloti* (Takahashi, 1956), adult female. **A** dorsal microduct **B** dorsal tubercle **C** dermal areolations **D** dorsal seta **E** stigmatic spines **F** marginal seta **G** anal plates **H** preopercular pore **I** multilocular disc-pores **J** ventral tubular duct (Type II) **K** leg **L** ventral tubular duct (Type III) **M** ventral tubular ducts (Type I) **N** ventral seta **O** spiracular pore **P** ventral microduct **Q** antenna. Scale bars: 200 µm (**K, Q**); 100µm (**G**); 50 µm (**C, E**); others = 10 µm.

margin. Ventral setae with three pairs of long pregenital setae; approximately three or four pairs of long and short setae between antennae; other setae sharply spinose, each 5–10 μm long, sparsely distributed over entire venter. Legs well developed, each with a tibio-tarsal articulation and an articulatory sclerosis; total length of each metathoracic leg 614–769 μm long: each coxa 141–189 μm long, trochanter+femer 209–257 μm long, tibia+tarsus 243–311 μm long, claw 17–24 μm long. Tarsal digitules thinner and longer than claw digitules. Spiracles normal, mostly posterior peritreme broader than anterior: anterior peritremes each 37–52 μm wide, posterior peritremes each 45–61 μm wide. Antenna 8-segmented, each 339–399 μm long. Clypeolabral shield 138–157 μm wide.

**Host plant.** Recorded from six genera in six families (García-Morales et al. 2016). In Korea, it was found on *Aphananthe aspera* (Cannabaceae) and *Ilex cornuta* (Aquifoliaceae).

**Distribution.** Only known from Japan (Takahashi 1956); first record for Korea.

**Comments.** The above description based on Korean specimens agrees well with that of Takahashi (1956), except that variation in the number of dorsal tubercles and marginal setae, and exact distributions of each type of ventral tubular ducts are newly provided in this study. *Coccus malloti* probably has intermediate morphological characters between the tribes Coccini and Pulvinariini. However, the woolly test, known as ovisac and one of the typical characters of the Pulvinariini, is not observed in the species. In addition, some slide-mounted specimens of *C. malloti* contain eggs and nymphs in their body, which indirectly indicates that they would not produce an ovisac for oviposition. Although *Coccus malloti* would be retained in the tribe Coccini, it needs to be reviewed with its type materials to clarify the exact generic position of the species.

### ***Coccus pseudomagnoliarum* (Kuwana, 1914)**

Fig. 6A–B

*Lecanium* (*Eulecanium*) *pseudomagnoliarum* Kuwana, 1914: 7.

**Material examined.** Adult female: Sujeong-dong, Yeosu-si, Jeollanam-do, 27.v.2015, coll. J.Y. Choi, on *Celtis* sp. (Cannabaceae), 10♀♀.

**Diagnosis.** Adult females in life (Fig. 6A–B) greenish or greyish, with light or dark yellow mottling; dermal areolations present; dorsal tubercles absent; dorsal tubular ducts absent; dorsal setae with sharply pointed apices; marginal setae with simple pointed or spatulate apices; multilocular disc-pores usually with 6–10 loculi; ventral tubular ducts with a narrow inner ductule, few present on submaginal area of posterior abdomen; antennae each 8-segmented; legs without tibio-tarsal articulatory scleroses.

**Host plant.** Recorded from six genera in five families (García-Morales et al. 2016). In Korea, it has been recorded from the following plants: *Celtis willdenowiana* (Cannabaceae), *Citrus* sp., *Phellodendron amurense*, *Poncirus trifoliata* (Rutaceae), *Clerodendron trichotomum* (Lamiaceae), and *Zelkova serrata* (Ulmaceae) (Paik 1978).

**Distribution.** Mainly known from Palearctic Region including Australia, Europe, Iran, Israel, Japan, Russia, Korea, and USA (García-Morales et al. 2016).

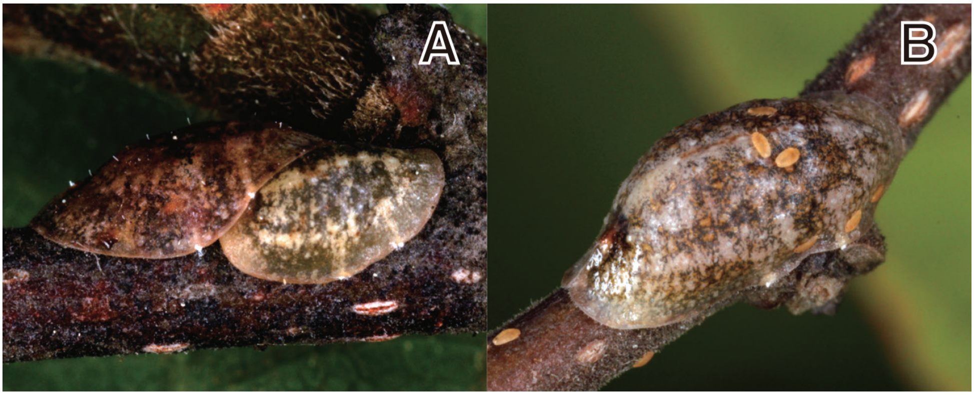

**Figure 6.** *Coccus pseudomagnoliarum* (Kuwana, 1914). **A** immature adult females **B** mature adult female and 1st instars.

## Discussion

Recently, Lin et al. (2017) described *Coccus praetermissus* Lin & Tanaka, which could be confused with a cosmopolitan species, *Coccus hesperidum* Linnaeus, 1758, based on morphological and molecular evidences. They pointed out that a morphological difference exists between the adult females of two genetically distinct species, the shape of dorsal setae, although molecular data (COI) should be used for exact identification. The adult female of *Coccus praetermissus* has dorsal setae with bluntly rounded apices, whereas those of *C. hesperidum* have sharply pointed tips. *Coccus ficicola* sp. n. is close to *C. praetermissus* in having the former type of dorsal setae, but differs in the distributional pattern of ventral tubular ducts, which is a reliable and constant character in each species within the genus *Coccus*. The ventral tubular ducts of *Coccus ficicola* are present on medial area of head, pro- and mesothorax, and submarginal area of abdomen, whereas *C. praetermissus* has the structures on medial area of mesothorax only.

Under the morphological comparison with congeners, we conclude that *Coccus ficicola* sp. n. is a distinct species which is a morphologically differentiated lineage. The distinctive pattern of ventral tubular ducts seems to be an autapomorphic feature of *Coccus ficicola* because it shows uniqueness in the comparison of morphological characters. In order to clarify the phylogenetic relationships of a new species within the genus *Coccus*, molecular analysis employing mitochondrial and nuclear loci are required.

## Acknowledgments

We thank Dr. Sora Kim for reviewing the manuscript for this study. We are also grateful for a colleague, Mr. Seunghyun Lee (Department of Agricultural Biotechnology, Seoul National University, Seoul, Korea), who provided specimens. We also thank Dr. Chris J. Hodgson (Department of Biodiversity and Biological Systematics, The National Museum of Wales, Cardiff, UK), Dr. T. Kondo (Corporación Colombiana de Investigación Agropecuaria, Corpoica, Colombia) and Dr. Yen P. Lin (School of Biological Sciences, The University of Queensland, Brisbane, Australia) for the useful comments. In addition, we thank Dr. H. Tanaka (Ehime University, Ehime, Japan) for comparing our samples with Japanese samples.

The research on the species newly recorded in Korea was supported by a grant from the National Institute of Biological Resources (NIBR), funded by the Ministry of Environment (MOE) of the Republic of Korea (NIBR201701203).

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ZooKeys 734: 137–148 (2018)
doi: 10.3897/zookeys.734.22901
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# The dating of the fourth volume of Guillaume-Antoine Olivier's "Entomologie, ou histoire naturelle des insectes"

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Academic editor: *N. Evenhuis* | Received 11 December 2017 | Accepted 18 January 2018 | Published 5 February 2018

*http://zoobank.org/1BAB1D56-AB9B-4CFA-BD76-F98A96582071*

**Citation:** Bousquet Y (2018) The dating of the fourth volume of Guillaume-Antoine Olivier's "Entomologie, ou histoire naturelle des insectes". ZooKeys 734: 137–148. https://doi.org/10.3897/zookeys.734.22901

## Abstract

Despite the title page is dated 1795, the fourth volume of Olivier's *Entomologie, ou histoire naturelle des insectes* was issued in two parts, one probably in 1795 and the second in 1800. All new taxa made available in this work have previously been dated 1795 in the literature. A list of new species described in 1795 and a list of those that have to be dated 1800 are appended. The genus *Necrobia* should be credited to Latreille, 1797, not Olivier, 1795.

## Keywords

Coleoptera, beetles, date of publication, literature

Born in the commune Les Arcs (also known as Les Arcs-sur-Argens), a small village near Toulon in the Var department, southeastern France, on 19 January 1756, Guillaume-Antoine Olivier (Fig. 1) was a French physician and naturalist. He studied medicine at Montpellier and at 17 years old practiced medicine in his native town but soon found his job uninteresting and poorly paid. In 1783, he moved to Paris and worked for Louis Bénigne François Bertier de Sauvigny (b. 1737; d. 1789), the intendant of Paris, and conducted a statistical survey on the generality of Isle de France. Later he was hired by Jean-Baptiste Gigot d'Orcy (b. 1737; d. 1793), the wealthy finance receiver general, to write a natural history of the insects and this is the reason behind

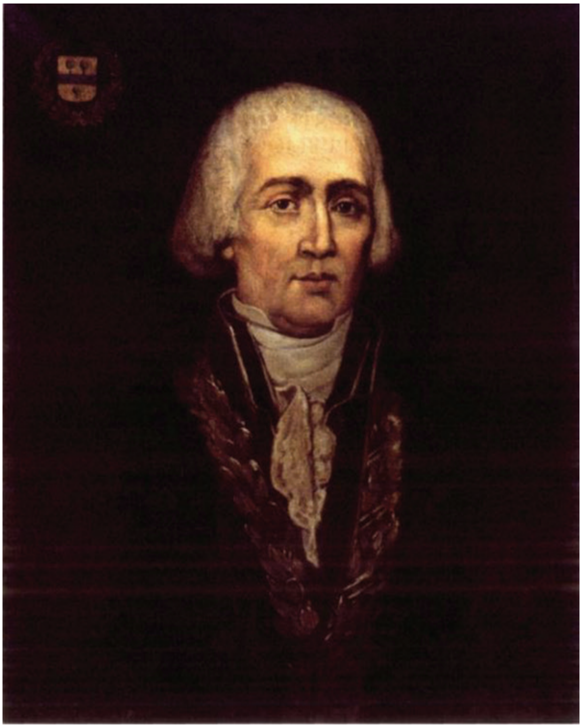

**Figure 1.** A photographic reproduction of an oil portrait of Guillaume-Antoine Olivier [source: Bernard (1997: fig. 1)].

Olivier's connection with the *Entomologie ou histoire naturelle des insectes*. For this project, Olivier travelled to Britain and the Netherlands to describe the insects and have them illustrated. At about the same time, Olivier was approached to contribute to the natural history of the insects for Charles-Joseph Panckoucke's (b. 1736; d. 1798) *Encyclopédie méthodique*, one of the major scientific publication achievements of all time (Evenhuis 2003). In October 1792, Olivier and his friend Jean Guillaume Bruguière (b. 1749/1750; d. 1798) were chosen by the French government to take part in a scientific and diplomatic mission to the Ottoman Empire, Egypt, and Persia. The two sailed from Marseille in April 1793 and for the next six years visited many places in the Middle East where they had the opportunity to collect natural history specimens. Olivier returned to France in December 1798 while Bruguière died in Ancôme on the journey back. Upon his return, Olivier became a member of the prestigious *Académie des Sciences* in 1800 and worked mainly at writing his two major entomological works and the account of his trip, which was published in three volumes of text in quarto and one volume of plates in 1801, 1804, and 1807. In 1811, he was appointed professor of zoology at *L'École nationale vétérinaire d'Alfort* but soon suffered from anaemia (wasting disease). In 1814, he went to his native town to rest and on his way back stopped at Lyon where he was found dead, from an aortic aneurism, in his bed on October 1. He was 58 years old. Olivier was a close friend to Johan Christian Fabricius and a patron to Pierre André Latreille particularly during the French Revolution. This account of Olivier's life is derived from Cuvier (1818) and Walckenaer (1830).

One of the two major publications of Olivier is his *Entomologie ou histoire naturelle des insectes*. As the title suggests, Olivier apparently intended to treat all insect orders, but in the end only the Coleoptera were dealt with. Six volumes of text and two of plates were published between 1789 and 1808. Each genus in the first four volumes was given a number and separately paginated. The entire work consisted of 3,162 pages and 363 plates (either black and white or colored) issued in 30 livraisons (Anonymous 1808).

The fourth volume treated 18 genera: No 66, Prione / *Prionus* (41 pp.); No 67, Capricorne / *Cerambix* [*Cerambyx*] (132 pp.); No 68, Saperde / *Saperda* (41 pp.); No 69, Stencore / *Stenocorus* (30 pp.); No 70, Callidie / *Callidium* (72 pp.); No 71, Spondyle / *Spondylis* (4 pp.); No 72, Calope / *Calopus* (4 pp.); No 73, Lepture / *Leptura* (34 pp.); No 74, Nécydale / *Necydalis* (10 pp.); No 74*bis*, Cucuje / *Cucujus* (10 pp.); No 75, Donacie / *Donacia* (12 pp.); No 75*bis*, Lupère / *Luperus* (4 pp.); No 76, Clairon / *Clerus* (18 pp.); No 76*bis*, Nécrobie / *Necrobia* (6 pp.); No 77, Bostriche / *Bostrichus* (18 pp.); No 78, Scolyte / *Scolytus* (14 pp.); No 79, Bruche / *Bruchus* (24 pp.); No 80, Macrocéphale / *Macrocephalus* (16 pp.). Its title page is dated 1795 (Fig. 2) and all publications seen citing the volume have dated it as 1795. However, *livraison* 23 of the *Entomologie ou histoire naturelle des insectes* by the citoyen Olivier was announced on 14 Fructidor an 8 (= 31 August 1800) in the *Gazette Nationale ou Le Moniteur Universel* and in the Fructidor an VIII (= 18 August–22 September 1800) issue of the *Journal Général de la Littérature de France*, both journals recording new books published in France. The citation mentioned that the continuation of Olivier's work was postponed because of the six-year voyage of the author in the Orient, and that the present livraison contains about three-quarters of the fourth volume, including the explanatory text of 56 plates. There is other evidence that part of Olivier's fourth volume of his *Entomologie* was issued after 1795. The work contains five explicit references to Fabricius' *Supplementum entomologiae systematicae* which was published in 1798: "Lamia bicincta. Fab. suppl. Ent. Syst. pag. 145" under Capricorne continu (No 67, p. 123), "Lamia marmorata. Fab. Suppl. Ent. Syst. pag. 144. n°.1" under Capricorne bigarré (No 67, p. 124), "Cucujus rufus. Fab. Suppl. Ent. Syst. emend. pag. 123" under Cucuje fauve (No 74*bis*, p. 5), "Lema flavipes. Fab. Suppl. Ent. Syst. pag. 93. n°. 21" under Lupère flavipède (No 75*bis*, p. 4), and "Anthribus *niveirostris* rostro latissimo plano elytrorumque apicibus anoque albis. Fab. Ent. Syst. Suppl. pag. 160" under Macrocéphale nivéirostre (No 80, p. 8). In addition, on page 121 (No 67, footnote), Olivier mentioned "Ce genre ayant été imprimé pendant mon voyage dans les contrées orientales, on a omis quelques descriptions que je m'empresse de donner ici" [This genus was printed during my voyage to the oriental region and some descriptions were omitted which I hasten to present here]. As mentioned previously, Olivier returned from his trip in December 1798. Finally, Illiger (1800: ix) mentioned in the *Vorrede*, dated 15 April 1800, of the first volume of his German translation of Olivier's work "Entomologie" that the fourth volume of the series was not yet published [*Der vierte noch nicht erschienene Band wird wahrscheinlich der Werk schliessen*].

One problematic question remains. What exactly is the content of *livraison* 23 since the recording journals cited above simply mentioned that it included about three-quarters of the fourth volume? Bousquet (2016: 393) surmised that it could comprise the text from page 81 of the Capricorne (No 67). In fact there is a clue in the text suggesting that this could be the case. All capricorne species described up to page 80 have the Latin generic name incorrectly spelled *Cerambix*, while those on the following pages have the name correctly spelled *Cerambyx*. This is circumstantial evidence that a break occurred in the printing of the text. So, as far as I am concerned all new species described from page 81 (No 67) onwards should be dated 1800. A list of them is given in Appendix 2.

The genus *Necrobia* has been attributed to "Olivier 1795" from this work by almost all authors seen. The name is so entered in the *Official List of Generic Names in Zoology* following Opinion 604 (ICZN 1961). However, this is incorrect since the name appeared in *livraison* 23 of Olivier's *Entomologie* which, as previously mentioned, was published in 1800. Olivier (1800: 1, No 76*bis*) wrote under *Necrobia* "Le cit. Latreille est le premier qui ait senti que ces insectes [*Clerus*] devoient être séparés des uns et des autres, et former un genre particulier, auquel il a donné le nom de Nécrobie..." [Latreille is the first that saw the necessity to separate these insects (referring to those of the genus *Clerus*) and formed a peculiar genus to which he gave the name Necrobie (i.e., *Necrobia*)[1]]. Latreille (1797: 35) indeed first proposed the name *Necrobia* and made it available. This was recognized by Sherborn (1902: 650) who correctly credited the genus from Latreille's *Précis des caractères génériques des insectes* while Neave (1940: 276) wrote beside *Necrobia* "Olivier 1795 [?], Entomologie 4, no. 76 (*bis*); Latreille 1796, Préc. Car. Ins., 35." Although Latreille described the genus, he did not include any species under it. The nominal species first subsequently and expressly included in the genus *Necrobia* are the three cited by Olivier (1800), namely *N. violacea*, *N. rufipes*, and *N. ruficollis*. In Opinion 604 (ICZN 1961), *Dermestes violaceus* Linnaeus, 1758 was validated as the type species of the genus.

There are 72 plates associated with the genera treated in volume 4 of Olivier's *Entomologie*: 13 for *Prionus* (No 66), 23 for *Cerambix / Cerambyx* (No 67), 4 for *Saperda* (No 68), 3 for *Stenocorus* (No 69), 8 for *Callidium* (No 70), 1 for *Spondylis* and *Calopus* (Nos 71 and 72); 4 for *Leptura* (No 73); 1 for *Necydalis* (No 74); 1 for *Cucujus* (No 74*bis*); 1 for *Donacia* and 1 for *Donacia* and *Luperus* (Nos 75 and 75*bis*); 1 for *Clerus* and 1 for *Clerus* and *Necrobia* (Nos 76 and 76*bis*); 3 for *Bostrichus* (No 77); 2 for *Scolytus* (No 78); 3 for *Bruchus* (No 79); 2 for *Macrocephalus* (no 80). There are no scientific names on the plates[2], except for the respective genus at the top. At the recommendation of the editor, these plates were usually placed in the eighth volume (the second of the plates) of the series. The title page is dated 1808 but it is obvious that most, if not

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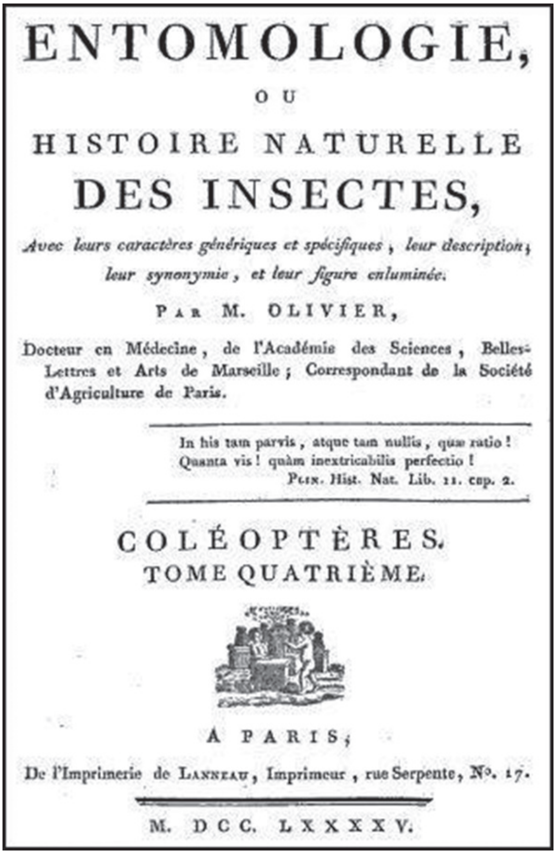
[1] It is ironic that Latreille proposed the generic name for the insect [*Necrobia ruficollis* (Fabricius)] that saved his life a few years prior when he was jailed as a non-jurist priest waiting for deportation (see Peyerimhoff 1932: 66–67, for the story). Latreille's friends, who paid for his monument, had the figure of the beetle engraved along with these words "*Necrobia ruficollis*, Latreillii salus" (Lemaout 1842: 322).

[2] The copy on Biodiversity Heritage Library has handwritten specific names added subsequently.



ENTOMOLOGIE,
OU
HISTOIRE NATURELLE
DES INSECTES,
*Avec leurs caractères génériques et spécifiques, leur description, leur synonymie, et leur figure enluminée.*
PAR M. OLIVIER,
Docteur en Médecine, de l'Académie des Sciences, Belles-Lettres et Arts de Marseille; Correspondant de la Société d'Agriculture de Paris.

In his tam parvis, atque tam nullis, quæ ratio!
Quanta vis! quàm inextricabilis perfectio!
PLIN. Hist. Nat. Lib. 11. cap. 2.

COLÉOPTÈRES.
TOME QUATRIÈME.

A PARIS,
De l'Imprimerie de LANNEAU, Imprimeur, rue Serpente, N°. 17.
M. DCC. LXXXXV.

**Figure 2.** Title page of Olivier's tome 4 of the *Entomologie, ou histoire naturelle des insectes*.

all, of the plates were issued prior to this date. For example, Fabricius (1792) cited the following plates from Olivier's volume 4: 1–6, 12 (*Prionus*), 1–12, 14–19 (*Cerambyx*), 1 and 2 (*Saperda*), 2 (*Stenocorus*), 1–7 (*Callidium*), 1 and 2 (*Leptura*).

The question remaining is when the first part of Olivier's volume 4 (i.e., Nos 66 and 67 up to page 80) was actually published. I have been unable to find the *livraison* in which this part was published nor did I find a date of publication in a recording journal for livraison 22 of the work, which could deal with the first part. *Livraison* 21 was noticed in 1796 in the third volume of the second year of the *Magasin Encyclopédique ou Journal des Sciences, des Lettres et des Arts* (p. 558) but no indication was provided as to its content. What is puzzling is that the first author I found giving reference to any of the species included in the entire fourth volume is Latreille (1804), more than eight years after the alleged publication of the first part in 1795. Even Fabricius (1801), who intended to treat all Coleoptera known at the time, did not include any of the new species described in Olivier's entire fourth volume of his *Entomologie*. Since the title page is dated 1795 (Fig. 2), the date of 31 December 1795 should be adopted as the correct date of publication of the first part (ICZN 1999, Article 21.3.2) until additional evidence is found. A list of the new species described in the first part is included in Appendix 1.

## Acknowledgments

I thank Anthony Davies, Neal L. Evenhuis, and Martyn E.Y. Low for reviewing the manuscript and providing comments that improved it.

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## Appendix I

List of new species described in Olivier's first part of volume 4 of his *Entomologie* (Nos 66 and 67 up to p. 80), dated 1795, along with the original localities mentioned. Note. *Cerambix denticornis* [67: 60; pl. 5, fig. 33] is a replacement name for *Lamia spinicornis* Fabricius, 1781 and *Cerambix sulcatus* [67: 28; pl. 16, fig. 113] is a replacement name for *Cerambyx festivus* Fabricius, 1775.

*Prionus accentifer* [66: 8; pl. 4, fig. 16] [[Locality not indicated]]
*Prionus angulatus* [66: 31; pl. 1, fig. 2] [Locality not indicated]
*Prionus ater* [66: 11; pl. 7, fig. 24] Cayenne
*Prionus castaneus* [66: 23; pl. 8, fig. 28, 29] [Locality not indicated]
*Prionus cinereus* [66: 35; pl. 13, fig. 55] Surinam
*Prionus corticinus* [66: 21; pl. 9, fig. 34] Cayenne
*Prionus crenatus* [66: 27; pl. 12, fig. 45] Cayenne
*Prionus exsertus* [66: 17; pl. 8, fig. 31] Saint-Domingue
*Prionus maculatus* [66: 27; pl. 4, fig. 14] Sénégal
*Prionus obscurus* [66: 26; pl. 1, fig. 7] Provence

*Prionus octangularis* [66: 33; pl. 6, fig. 19 + pl. 13, fig. 54] [Locality not indicated]
*Prionus orientalis* [66: 28; pl. 13, fig. 51] Ceylan
*Prionus quadrilineatus* [66: 40; pl. 3, fig. 11] [Locality not indicated]
*Prionus scutellaris* [66: 14; pl. 2, fig. 9] Cayenne
*Prionus senegalensis* [66: 22; pl. 7, fig. 25] Sénégal
*Prionus sericeus* [66: 16; pl. 8, fig. 26] Cayenne
*Prionus serraticornis* [66: 14; pl. 9, fig. 33] [Locality not indicated]
*Prionus speciosus* [66: 31; pl. 4, fig. 13] [Locality not indicated]
*Prionus sulcatus* [66: 39; pl.8, fig. 27] Cayenne
*Prionus tuberculatus* [66: 20; pl. 6, fig. 22] Amérique méridionale
*Prionus undatus* [66: 32; pl. 13, fig. 53] Surinam
*Prionus vittatus* [66: 39; pl. 6, fig. 20] Indes orientales

*Cerambix analis* [67: 37; pl. 19, fig. 144] [Locality not indicated]
*Cerambix angolator* [67: 71; pl. 22, fig. 170] Angole
*Cerambix bicinctus* [67: 46; pl. 21, fig. 166] [Locality not indicated]
*Cerambix bilineatus* [67: 17; pl. 21, fig. 161] [Locality not indicated]
*Cerambix crassicornis* [67: 51; pl. 20, fig. 150] [Locality not indicated]
*Cerambix emarginatus* [67: 48; pl. 22, fig. 82] Brésil
*Cerambix fuliginosus* [67: 14; pl. 10, fig. 64] [Locality not indicated]
*Cerambix globosus* [67: 27; pl. 12, fig. 81] Batavia
*Cerambix hirtipes* [67: 36; pl. 20, fig. 157] Cap de Bonne-Espérance
*Cerambix humeralis* [67: 38; pl. 19, fig. 141] [Locality not indicated]
*Cerambix maculatus* [67: 68; pl. 7, fig. 49 + pl. 22, fig. 174] Indes orientales
*Cerambix maxillosus* [67: 52; pl. 20, fig. 147] [Locality not indicated]
*Cerambix nigripes* [67: 52; pl. 20, fig. 149] [Locality not indicated]
*Cerambix papulosus* [67: 72; pl. 20, fig. 156] Indes orientales
*Cerambix rugosus* [67: 12; pl. 21, fig. 159] Cayenne
*Cerambix scapularis* [67: 17; pl. 21, fig. 162] [Locality not indicated]
*Cerambix scutellaris* [67: 16; pl. 21, fig. 160] [Locality not indicated]
*Cerambix subocellatus* [67: 69; pl. 2, fig. 12] [Locality not indicated]
*Cerambix unidentatus* [67: 20; pl. 19, fig. 145] [Locality not indicated]
*Cerambix verrucosus* [67: 63; pl. 20, fig. 148] [Locality not indicated]
*Cerambix virescens* [67: 77; pl. 2, fig. 8] [Locality not indicated]

## Appendix 2

List of new species described in Olivier's second part of volume 4 of his *Entomologie* (from No 67 page 81 to the end), issued in 1800, along with the original localities mentioned.

*Cerambyx aestuans* [67: 123; pl. 23, fig. 176] Sénégal
*Cerambyx armatus* [67: 121; pl. 19, fig. 14] Surinam

*Cerambyx bifasciatus* [67: 94; pl. 14, fig. 98] Afrique équinoxiale
*Cerambyx caelatus* [67: 99; pl. 11, fig. 79 + pl. 12, fig. 79] Indes orientales
*Cerambyx continuus* [67: 123; pl. 23, fig. 177] Afrique
*Cerambyx crocatus* [67: 92, pl. 12, fig. 80] Madagascar
*Cerambyx decorus* [67: 128; pl. 5, fig. 38] Sénégal
*Cerambyx dentifer* [67: 132; pl. 23, fig. 185] Afrique
*Cerambyx didymus* [67: 125; pl. 23, fig. 179] Amérique méridionale
*Cerambyx formosus* [67: 86, pl. 20, fig. 153] [Locality not indicated]
*Cerambyx gallo-provincialis* [67: 125, pl. 3, fig. 17] Provence
*Cerambyx hemipterus* [67: 127; pl. 23, fig. 181] Java
*Cerambyx lateralis* [67: 129; pl. 5, fig. 36] [Locality not indicated]
*Cerambyx macularis* [67: 98; pl. 20, fig. 154] Surinam
*Cerambyx obsoletus* [67: 130; pl. 13, fig. 90] Caroline, Pensylvanie
*Cerambyx ornatus* [67: 88; pl. 4, fig. 24 + pl. 1, fig. 6] Afrique
*Cerambyx pectoralis* [67: 122; pl. 23, fig. 175] Sénégal
*Cerambyx plumosus* [67: 98; pl. 20, fig. 152] Indes orientales
*Cerambyx sanguinolentus* [67: 93; pl. 20, fig. 155] [Locality not indicated]
*Cerambyx sordidus* [67: 124; pl. 1, fig. 5] Sénégal
*Cerambyx spinipes* [67: 103; pl. 10, fig. 66] isle de Bourbon
*Cerambyx stigma* [67: 126; pl. 23, fig. 180] Amérique méridionale
*Cerambyx umbraticus* [67: 129; pl. 11, fig. 75] Cayenne
*Cerambyx villicus* [67: 102; pl. 10, fig. 72] isle de Bourbon

*Saperda annularis* [68: 11; pl. 4, fig. 36] Espagne
*Saperda bicolor* [68: 32; pl. 3, fig. 25] Amérique septentrionale, en Géorgie
*Saperda bicornis* [68: 27; pl. 4, fig. 46] [Locality not indicated]
*Saperda bimaculata* [68: 21; pl. 4, fig. 43] Département du Var
*Saperda cinerea* [68: 28; pl. 3, fig. 35] Amérique septentrionale
*Saperda cornuta* [68: 26; pl. 4, fig. 45] Surinam
*Saperda elegans* [68: 15; pl. 4, fig. 40] [Locality not indicated]
*Saperda elongata* [68: 19; pl. 3, fig. 34] Chine
*Saperda fasciculata* [68: 14; pl. 1, fig. 3] Amérique méridionale
*Saperda filiformis* [68: 28; pl. 4, fig. 47] Sénégal
*Saperda hirticollis* [68: 11; pl. 4, fig. 37] [Locality not indicated]
*Saperda hirtipes* [68: 14; pl. 1, fig. 8] Amérique méridionale, Cayenne, Surinam
*Saperda lunaris* [68: 7; pl. 2, fig. 21] Indes orientales
*Saperda maculata* [68: 32 + 68: 39; pl. 3, fig. 33] Amérique septentrionale, dans la Géorgie
*Saperda mucronata* [68: 30; pl. 1, fig. 10] [Locality not indicated]
*Saperda pallipes* [68: 31; pl. 4, fig. 49] Surinam
*Saperda plumbea* [68: 21; pl. 4, fig. 42] Amérique septentrionale
*Saperda rufipes* [68: 25; pl. 2, fig. 14] Département du Var
*Saperda thoracica* [68: 18; pl. 2, fig. 19] [Locality not indicated]
*Saperda tridentata* [68: 30; pl. 3, fig. 48] Canada

*Stenocorus bicolor* [69: 16; pl. 1, fig. 4] [Locality not indicated]
*Stenocorus humeralis* [69: 22; pl. 2, fig. 18] Allemagne et en Hongrie
*Stenocorus laevis* [69: 21; pl. 3, fig. 25] France
*Stenocorus lineatus* [69: 13; pl. 3, fig. 22] Amérique
*Stenocorus niger* [69: 19; pl. 3, fig. 24] Mont-Pila
*Stenocorus scrutator* [69: 10; pl. 3, fig. 21] Autriche
*Stenocorus sericeus* [69: 20; pl. 1, fig. 8] France
*Stenocorus suturalis* [69: 29; pl. 4, fig. 29] Indes orientales
*Stenocorus testaceus* [69: 27; pl. 2, fig. 20] Cap de Bonne-Espérance et dans la Géorgie

*Callidium abdominale* [70: 70; pl. 8, fig. 103] midi de la France
*Callidium araneiforme* [70: 61; pl. 7, fig. 90] Saint-Domingue
*Callidium arvicola* [70: 64; pl. 8, fig. 93] midi de la France
*Callidium campestre* [70: 65; pl. 8, fig. 95] Amérique septentrionale
*Callidium cinereum* [70: 69; pl. 8, fig. 102] Saint-Domingue
*Callidium decorum* [70: 63; pl. 8, fig. 92] Newyork
*Callidium irroratum* [70: 70; pl. 8, fig. 104] Saint-Domingue
*Callidium lucidum* [70: 59; pl. 7, fig. 86] Saint-Domingue
*Callidium notatum* [70: 61; pl. 7, fig. 89] New-York
*Callidium palmatum* [70: 29; pl. 7, fig. 82] Amérique méridionale
*Callidium pini* [70: 71; pl. 8, fig. 105] New-York
*Callidium pulverulentum* [70: 69; pl. 8, fig. 101] Amérique septentrionale
*Callidium rhombifer* [70: 46; pl. 4, fig. 51] Géorgie
*Callidium rufum* [70: 28; pl. 7, fig. 81] [Locality not indicated]
*Callidium ruricola* [70: 65; pl. 8, fig. 96] Saint-Domingue
*Callidium spinicorne* [70: 68; pl 8, fig. 100] Saint-Domingue
*Callidium suturale* [70: 62; pl. 7, fig. 91] Saint-Domingue
*Callidium unicolor* [70: 58; pl. 7, fig. 84] côtes de Barbarie; Asie mineure, dans la Mésopotamie
*Callidium verrucosum* [70: 67; pl. 8, fig. 98] New-York
*Callidium villicum* [70: 64; pl. 8, fig. 94] Amérique septentrionale

*Leptura acuminata* [73: 20; pl. 3, fig. 35] Amérique septentrionale
*Leptura arcuata* [73: 32; pl. 4, fig. 47] Amérique septentrionale
*Leptura canadensis* [73: 8; pl. 3, fig. 27] Canada
*Leptura circumdata* [73: 32; pl. 4, fig. 48] Amérique septentrionale
*Leptura cordifera* [73: 25; pl. 4, fig. 41] Amérique septentrionale
*Leptura cruciata* [73: 7; pl. 1, fig. 5] environs de Paris
*Leptura decem-punctata* [73: 26; pl. 4, fig. 42] Hongrie, aux environs de Paris
*Leptura lateralis* [73: 22; pl. 3, fig. 37] Amérique septentrionale
*Leptura limbata* [73: 31; pl. 2, fig. 20] Europe
*Leptura notata* [73: 11; pl. 1, fig. 11] Europe
*Leptura vagans* [73: 31; pl. 4, fig. 46] Amérique septentrionale

*Leptura velutina* [73: 18; pl. 3, fig. 32] Amérique septentrionale
*Leptura vittata* [73: 30; pl. 4, fig. 45] Canada
*Leptura zebra* [73: 19; pl. 3, fig. 33] Amérique septentrionale

*Necydalis abdominalis* [74: 8; pl. 1, fig. 5] Cayenne
*Necydalis analis* [74: 7; pl. 1, fig. 4] [Locality not indicated]
*Necydalis fasciata* [74: 10; pl. 1, fig. 9] Amérique méridionale
*Necydalis nigricornis* [74: 10; pl. 1, fig. 8] Surinam
*Necydalis sanguinicollis* [74: 9; pl. 1, fig. 7] Amérique septentrionale

*Cucujus americanus* [74*bis*: 7; pl. 7, fig. a.b.] Cayenne
*Cucujus ater* [74*bis*: 9; pl. 1, fig. 10.a.b.] Europe

*Donacia caerulea* [75: 10; pl. 2, fig. 10] Caroline
*Donacia palmata* [75: 8; pl. 1, fig. 7] Amérique septentrionale

*Clerus leucopsideus* [76: 8; pl. 1, fig. 6] Catalogne
*Clerus quadriguttatus* [76: 18; pl. 2, fig. 23] Caroline
*Clerus scabrosus* [76: 16; pl. 2, fig. 19] Afrique équinoxiale
*Clerus thoracicus* [76: 18; pl. 2, fig. 22] Caroline
*Clerus umbellatarum* [76: 5; pl. 1, fig. 2] Barbarie

*Bostrichus bidentatus* [77: 16; pl. 3, fig. 20] Syrie
*Bostrichus lineatus* [77: 18; pl. 3, fig. 23] Europe
*Bostrichus longicornis* [77: 15; pl. 3, fig. 18] Saint-Domingue
*Bostrichus rufipes* [77: 17; pl. 3, fig. 21] Paris
*Bostrichus rugosus* [77: 18; pl. 3, fig. 24] Amérique septentrionale
*Bostrichus trispinosus* [77: 16; pl. 3, fig. 19] Mésopotamie

*Scolytus destructor* [78: 5; pl. 1, fig. 4] Europe
*Scolytus frontalis* [78: 13; pl. 2, fig. 20] Amérique septentrionale
*Scolytus impressus* [78: 12; pl. 2, fig. 19] Paris
*Scolytus pusillus* [78: 14; pl. 2, fig. 23] Paris
*Scolytus quadridentatus* [78: 5; pl. 1, fig. 3] Amérique septentrionale
*Scolytus retusus* [78: 10; pl. 2, fig. 14] Paris
*Scolytus sexdentatus* [78: 11; pl. 2, fig. 15] Paris
*Scolytus spinosus* [78: 9; pl. 2, fig. 11] Java
*Scolytus terebrans* [78: 7; pl. 1, fig. 6] Amérique septentrionale
*Scolytus varius* [78: 11; pl. 2, fig. 17] France

*Bruchus biguttatus* [79: 20; pl. 3, fig. 27] France, îles de l'Archipel
*Bruchus bimaculatus* [79: 18; pl. 3, fig. 22] France
*Bruchus coryphae* [79: 16; pl. 2, fig. 18] Amérique septentrionale

*Bruchus fasciatus* [79: 20; pl. 3, fig. 25] environs de Paris
*Bruchus hibiscus* [79: 21; pl. 3, fig. 28] Amérique septentrionale
*Bruchus irroratus* [79: 21; pl. 3, fig. 29] Java
*Bruchus nebulosus* [79: 20; pl. 3, fig. 26] France
*Bruchus quinqueguttatus* [79: 15; pl. 2, fig. 16] Barbarie, aux îles de l'Archipel, sur les Cistes
*Bruchus tragacanthae* [79: 15; pl. 2, fig. 17] Perse
*Bruchus unicolor* [79: 17; pl. 2, fig. 20] Europe
*Bruchus varius* [79: 18; pl. 3, fig. 23] Europe
*Bruchus viciae* [79: 12; pl. 2, fig. 11] midi de la France

*Macrocephalus bidens* [80: 13; pl. 2, fig. 18] Saint-Domingue
*Macrocephalus bimaculatus* [80: 14; pl. 2, fig. 19] Géorgie
*Macrocephalus cinereus* [80: 4; pl. 1, fig. 2] Indes-Orientales
*Macrocephalus fasciatus* [80: 9; pl. 1, fig. 9] Amérique septentrionale, à la Géorgie
*Macrocephalus fuliginosus* [80: 11; pl. 2, fig. 13] Indes-Orientales
*Macrocephalus lugubris* [80: 13; pl. 2, fig. 17] Géorgie
*Macrocephalus maculatus* [80: 11; pl. 2, fig. 14] Indes-Orientales
*Macrocephalus marmoreus* [80: 12; pl. 2, fig. 16] Géorgie, en Caroline
*Macrocephalus murinus* [80: 12; pl. 2, fig. 15] Indes-Orientales
*Macrocephalus nebulosus* [80: 5; pl. 1, fig. 3] Cayenne
*Macrocephalus transversus* [80: 10; pl. 1, fig. 12] Indes-Orientales
*Macrocephalus tuberculatus* [80: 10; pl. 1, fig. 11] Afrique
*Macrocephalus variegatus* [80: 4; pl. 1, fig. 1] [Locality not indicated]
*Macrocephalus verrucosus* [80: 6; pl. 1, fig. 5] [Locality not indicated]