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A new species of the genus *Hexapleomera* Dudich, 1931 from the South Korea, with molecular evidence (Crustacea, Tanaidacea, Tanaididae)

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Abstract

Two populations of new species are described for *Hexapleomera* Dudich, 1931 from the southeastern coast and Jeju island of South Korea (north west Pacific). The specimens were collected using a light trap set overnight at the entrance near a pier or harbour. *Hexapleomera ulsana* **sp. n.** is clearly differentiated from other species in the genus by the uropod with five articles, a maxillule palp with four distal setae, the maxilliped coxa with three proximal setae, the epignath with short and blunt spiniform seta, the propodus of pereopods 2–3 with three ventral setae, and the maxilla with a rugged shape of the distal margin. Differences of mitochondrial cytochrome c oxidase subunit I (mtCOI) gene observed between two populations of *H. ulsana* from different regions (Ulsan and Jeju Island) and between *H. ulsana* and *H. urashima* (Japan) were 1.1 % and 32.4 %, respectively. Two genetically-close populations differed in the setae on pleopod 3, the proximal setae on the maxilliped coxa, and the ventral setae on pereopods 2–3, which showed that geographical distance affected the morphological divergence. In addition, a comprehensive comparison with previous records of *Hexapleomera* was conducted and close examinations on the appendages, known to have morphological variations between the individuals of one species and/or between different genders, were carried out based on new species and discussed herein.

Keywords

genetic analysis, *Hexapleomera*, sexual dimorphism, Tanaidacea, Tanaidomorpha

Introduction

Tanaidaceans are represented by almost 1,200 mostly marine species, and these are distributed from almost any type of marine habitat (Błażewicz-Paszkowycz and Bamber 2012), providing a main food source for fishes (Nagelkerken et al. 2000, Edgar 2008). Tanaidaceans are small benthic crustaceans with a benthic life cycle and low dispersion rates. Some of the taxa are dispersed by marine vertebrates (Moore 1894, Morales-Vela et al. 2008, Bamber et al. 2009), floating algae (Bamber and Costa 2009), anthropogenic transport such as shipping (Bamber et al. 2009), and by prevailing sea-currents (Bamber 1998). The genus *Hexapleomera* Dudich, 1931 has been found to be taxon commensal on turtles, or manatees and regarded to show cosmopolitan distribution (Heard et al. 2004, Edgar 2008, Morales-Vela et al. 2008). Recent studies revealed that some species of the genus inhabit diverse environments, such as on the hulls of yachts and benthic sediments (Bamber et al. 2009, Bamber 2012). Species of *Hexapleomera* in the present study were found in harbour benthic habitats.

The genus *Hexapleomera* was defined by Sieg (1980) with characteristics of the narrow anterior pereonites, five distinct pleonites, the differentiation between the pleopods 1–2 and pleopod 3, and the distal article of the uropod without reduction. Males represent the sexual dimorphism in the antennule, antenna, and cheliped. Up to quite recently, *Hexapleomera robusta* described by Sieg (1980) from the Atlantic coasts of Brazil, or the Galapagos Island, has been considered as a cosmopolitan species (Bamber 2012). In particular, due to the absence of the type material of *H. robusta*, many described species of *Hexapleomera* having a commensal ecology with motile organisms have been regarded as *H. robusta*: specimens recorded by Riggio (1976, 1996), Sieg (1980), Heard et al. (2004), Edgar (2008), Morales-Vela et al. (2008), and Bamber et al. (2009). Recently, *H. edgari* Bamber, 2012 and *H. satella* Bamber, 2012, which have also been known as *H. robusta*, were newly assigned as morphologically distinct species. Currently, *Hexapleomera* consists of nine species including species of this study (WoRMS 2017) and *H. crassa* Riggio, 1975 in status of 'nomen nudum'. As with most other genera of Tanaididae, some features of the genus *Hexapleomera*, which contains the relative lengths of antennule articles 1 and 2, the number of setae consisting of the setal row represented as lacinia mobilis of the mandible, and the number and shape of uropod articles, are considered to vary with the growth of individuals (Larsen and Wilson 1998, Edgar 2008). In addition, some previous descriptions and figures of the species within the genus were limited to the highly dimorphic male [e.g. *H. edgari* and *H. moverleyi* (Edgar 2008)]. Therefore, a more detailed analysis of the female morphology is necessary for a full understanding of the species (Bamber 2012). Moreover, a combined molecular and morphological analysis can be an adequate solution to a taxonomic problem caused by cryptic speciation and/or invasions of new habitats (Edgar 2008). This paper examined the morphological and genetic characteristics based on mature females and males of species of Korean *Hexapleomera* in different regions to reveal if the geographical distance affected morphological features.

Materials and methods

The material was obtained from the bottom of entrances near two harbours of South Korea: Ulsan (35°22'7.47"N; 129°35'25.47"E) in January 2016 and Jeju Island (33°14.0'N; 126°22.6'E) in May 2016, using a light trap set. The light trap set was made with a PVC pipe (10 cm in diameter, 50 cm long) and a LED lamp on the mouth, placed on mud-sandy bottom of 3m in depth at the seawalls in harbors after sunset. The samples caught overnight in the light trap were filtered through a plankton net with 350 µm mesh at dawn. The specimens were preserved in 99 % alcohol solution. The individuals were dissected under a dissection microscope (Nikon SMZ745T) in CMC-10 aqueous mounting medium (Masters, Wood Dale, IL, USA), mounted on slides, and then sealed with high-quality nail varnish. Drawings were generated using a differential interference contrast microscope (Nikon Y-IM) that was equipped with a drawing tube. The total body length was measured from the tip of the rostrum to the pleotelson apex in the dorsal view. Scale bars are given in mm. The morphological terminology follows Larsen (2003). The type and other material examined were deposited in the collections of the Marine Biodiversity Institute of Korea (**MABIK**), Seocheon, South Korea.

Molecular analysis

DNA extraction, amplification, sequencing, and analysis

The total genomic DNA was extracted from five specimens of *Hexapleomera* (*H. ulsana*: two females MABIK CR00240699, MABIK CR00240701, and one male MABIK CR00240704; Jeju population of *H. ulsana*: one female MABIK CR00240707, and one male MABIK CR00240710). To extract genomic DNA, a centrifuge tube (1.5 mL) each containing 90 µL of 10 % Chelex suspension (Bio-Rad Laboratories Inc.), 10 µL of Proteinase K (10 mg/ml, iNtRON Biotechnology, Inc.) and grinded tissues were incubated at 56 °C for 3 hours. The extracted genomic DNAs were used as templates to amplify the target regions on the mtCOI gene. Polymerase chain reaction (PCR) was performed on a Mastercycler PCR thermal cycler (Eppendorf Co.). A pair of primer for COI was jgLCO1490 and jgHCO2198 (Geller et al. 2013). PCR mixtures contained 16 µL of deionized water, 1 µL of each primer (10 µM), 2 µL of DNA template and PCR premix (BiONEER Co.). The cycle parameters consisted of initial denaturation at 95 °C for 3 min, denaturation at 95°C for 30 s, annealing at 48 °C (45 s) and extension at 72 °C (1 min) repeated for 40 cycles, with a final extension time of 7 min at 72 °C. The results of the PCR amplification were confirmed on 1.0 % agarose gels by using ethidium bromide staining. The obtained PCR products were purified and sequenced at the Macrogen Inc. facilities (Seoul, Korea). The sequences were aligned with those from *H. urashima* Tanabe et al. (2017) (accession number LC322243–322248) on a Chromas software version 2.33 (Technelysium Pty. Ltd.).

Systematics

Order Tanaidacea Dana, 1849
Family Tanaididae Nobili, 1906
Subfamily Pancolinae Sieg, 1980
Tribe Pancolini Sieg, 1980
Genus *Hexapleomera* Dudich, 1931

***Hexapleomera ulsana* sp. n.**
http://zoobank.org/168A8768-3D0A-437D-99C6-028B62310729
Figs 1–6

Type-specimens. Holotype. (MABIK CR00235364) ovigerous female dissected and mounted in eight slides, collected from the Ulsan of Korea (35°22'7.47"N, 129°21'25.47"E) in January 2016. **Allotype.** (MABIK CR00235366) male dissected and mounted in four slides, same locality as for holotype. **Paratypes.** Four females partially dissected and mounted in three slides (MABIK CR00235365), two slides (MABIK CR00240699), five slides (MABIK CR00240700), and two slides (MABIK CR00240701); two intact females in one vial (MABIK CR00240702); four males partially dissected and mounted in two slides (MABIK CR00235367), four slides (MABIK CR00240703), one slide (MABIK CR00240704), one slide (MABIK CR00240705); two intact males in one vial (MABIK CR00240706). Same locality as for holotype.

Diagnosis. Uropod endopod 4-articulate. Pleopods 1–3 endopod with one seta on inner margin. Pleopod 3 basal article with four outer setae and no inner seta; pleopods 1–2 each with six outer setae and one inner seta on basal article. Pereopod 1 coxa lacking apophysis and having two dorsal setae. Pereopods 2–3 propodus with two simple setae and one bifurcated pinnate spiniform seta on ventral margin. Mandible setal row consists of two pinnate setae. A maxillule palp with four distal setae. Maxilliped coxa with three proximal setae; endite bearing two long plumose setae, two short plumose spiniform setae, and two simple spiniform setae. Dactylus of male cheliped with spinules along cutting edge.

Description of female. ***Body*** (Fig. 1A): With developed brood sacs each with 20 eggs. Length 3.4 mm, 4.2 times as long as wide. Chocolate brown pigmentation on most of dorsal surface, including antennule and cheliped, patterned with un-pigmented lacunae. Cephalothorax with densely coalescing flecks but pereonites, pleonites, and pleotelson with scattered spots.

Cephalothorax (Fig.1A): Posterolateral margin rounded, anteriorly narrowing, as long as wide, 22 % of body length, with two anterolateral simple setae, one mid-lateral seta, and posterolateral seta.

Pereon (Fig. 1A): About 55 % of body length, 2.3 times as long as wide, with several fine setae along antero, mid, and posterolateral margins. Pereonites 1–6 proportional lengths of 10.6: 13.3: 16.4: 14.9: 22.2: 21.5: 16.0.

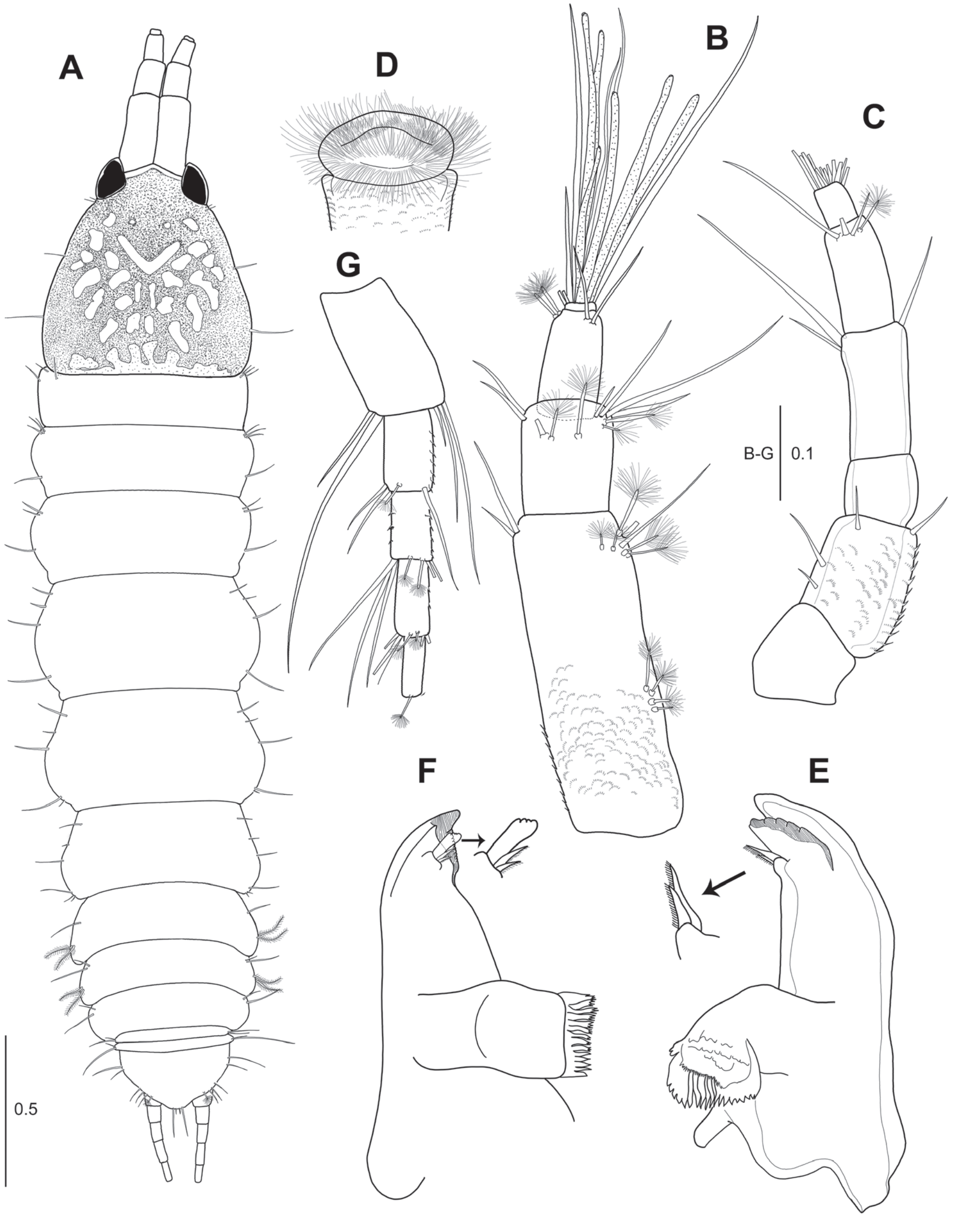

Figure 1. *Hexapleomera ulsana* sp. n., female holotype, **A** habitus, dorsal **B** antennule **C** antenna **D** labrum **E** left mandible **F** right mandible. Scale bars in mm.

Pleon (Fig. 1A): Pleonites 1–5 18.6 % of body length, 1.2 times as long as wide. Pleonites 1–3 gradually decreasing in width. Pleonite 1 0.8 times as long as pereonite 6, 0.3 times as long as wide, with one simple seta and two plumose setae on lateral margin. Pleonite 2 0.7 times as long as pleonite 1, 0.2 times as long as wide, with two simple setae and two plumose setae on lateral margin. Pleonite 3 almost as long as pleonite 2, 0.3 times as long as wide, with two simple setae. Pleonites 4 and 5 equal in length, each with two simple setae on lateral margin. Pleotelson 0.9 times as long as pleonite 1, half as long as wide, with two simple setae on mid-lateral margin, three simple setae and one broom seta on sub-posterolateral margin, and four simple setae of unequal length terminally.

Antennule (Fig. 1B): 4-articulate, proportional lengths of articles 60.5: 21.1: 16.9: 1.5. Length 68 % of cephalothorax. Article 1 2.7 times as long as wide, outer margin with four medial broom setae and five broom setae and two simple setae on distal margin; inner margin with two distal simple setae. Article 2 1.2 times as long as wide, with four broom setae and seven simple setae on distal and subdistal margins. Article 3 1.5 times as long as wide, with two broom setae and two simple setae on distal and subdistal margins. Article 4 very short, with seven simple setae and six aesthetascs.

Antenna (Fig. 1C): 6-articulate, slightly longer than antennule, proportional lengths of articles 16.6: 23.2: 12.3: 21.8: 18.8: 7.3. Article 1 naked. Article 2 with four simple setae, microtrichia, and setules along outer margin. Article 3 naked. Article 4 with three simple setae on distal margin. Article 5 with two simple and two broom setae. Article 6 with twelve simple setae on distal margin.

Labrum (Fig. 1D): Rounded, ornamented with numerous setules and microtrichia.

Left mandible (Fig. 1E): Incisor stout, smooth. Lacinia mobilis wide, with five denticles along distal margin. Setal row with two pinnate spiniform setae. Molar broad, corrugate and with several distal teeth. *Right mandible* (Fig. 1F): Incisor with several small denticles on distal margin. Lacinia mobilis reduced to blunt spine partly fused with incisor with small denticles on distal margin. Setal row with two pinnate setae of unequal length. Molar broad, with several distal teeth.

Labium (Fig. 2A): Wide, all lobes covered with setules on distal margin, with twelve lateral proximal spines (arrowed); labial palp rounded, 1.4 times as long as wide, with numerous setules.

Maxillule (Fig. 2B, B'): Endite with seven strong spiniform setae and one slender setulose seta on distal margin and patch of fine simple setae near base of terminal setae on outer margin, surface ornamented with microtrichia, and palp with four distal setae.

Maxilla (Fig. 2C): With sinuous distal margin (arrowed), covered with microtrichia.

Maxilliped (Fig. 2D): Coxa with three inner proximal simple setae. Basis twice as long as wide, with single subdistal seta, and covered with microtrichia. Palp article 1 with one outer subdistal seta. Palp article 2 with one outer seta and seven inner plumose setae. Palp article 3 with twelve inner plumose setae. Palp article 4 with twelve plumose setae. Endite with setules on distal margin, two long densely plumose setae, two setulose spiniform setae, and two round simple spiniform setae.

Epignath (Fig. 2E): With short blunt plumose seta terminally and fringed by setules (arrowed).

Cheliped (Fig. 2F, G): Basis 1.1 times as long as wide, with single seta each on dorsodistal and ventral margin. Merus triangular, with four ventral setae and two dorsal setae. Carpus 1.1 times as long as basis, 1.4 times as long as wide, with four ventro-

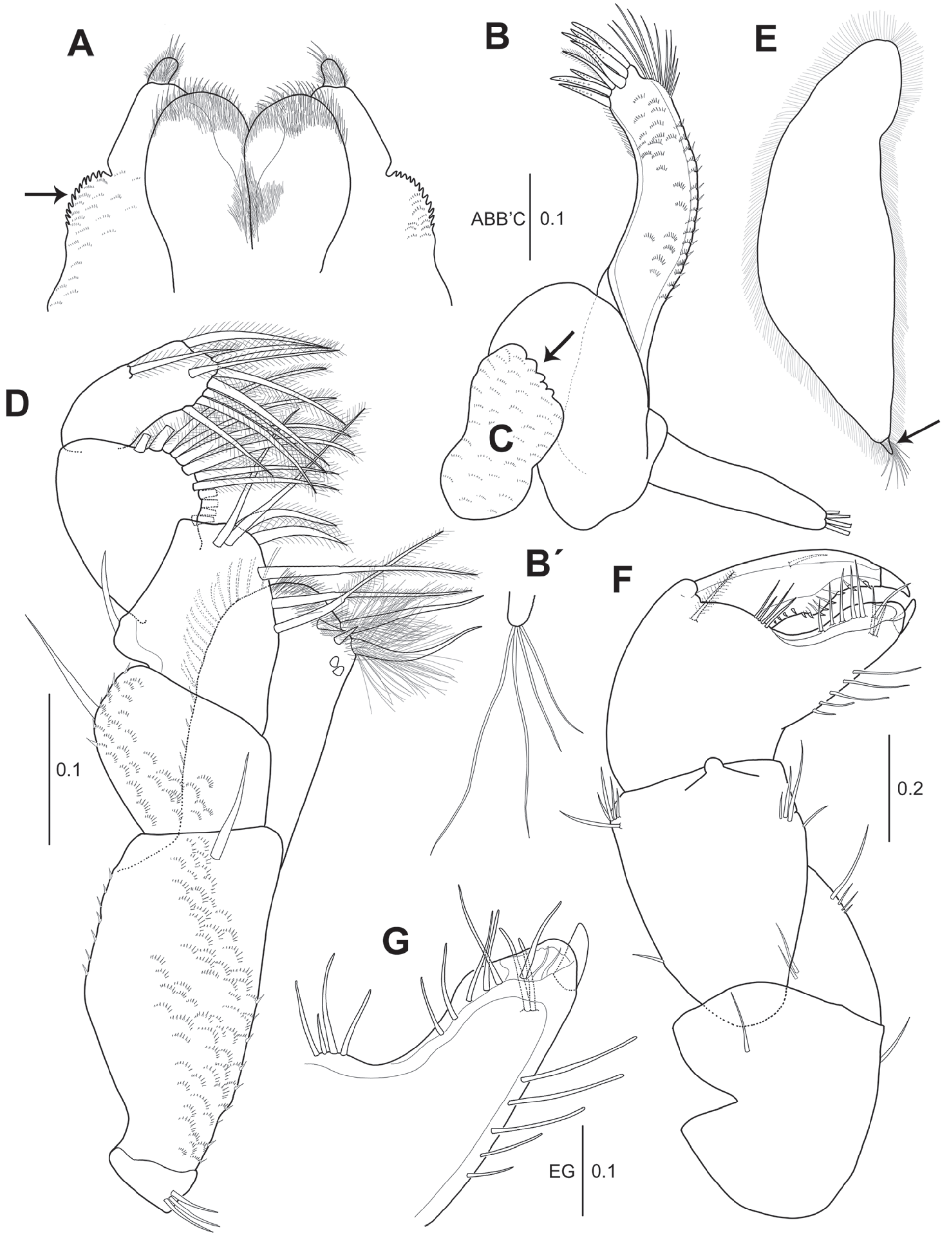

Figure 2. *Hexapleomera ulsana* sp. n., female holotype **A** labium **B** maxillule **B´** distal setae of maxillule palp **C** maxilla **D** maxilliped **E** epignath **F** cheliped **G** fixed finger of cheliped. Scale bars are given in mm.

subdistal setae and one dorso-subproximal and five dorsodistal setae. Propodus 1.3 times as long as carpus, 1.9 times as long as wide, with one plumose inner seta and four simple setae near insertion of dactylus. Fixed finger with five simple ventral setae, two inner simple setae, and six simple setae along cutting edge. Cutting edge distally expanded into rounded lamella. Dactylus with twelve small denticles along cutting edge and inner medial simple seta.

Pereopod 1 (Fig. 3A): Coxa without small apophysis, with two simple setae. Ischio-basis 4.3 times as long as wide, with one broom seta, one ventrodistal and one dorsodistal simple setae on dorsoproximal margin and one ventrodistal simple seta. Merus 0.3 times as long as ischio-basis, with one short ventrodistal simple seta. Carpus 1.2 times as long as merus, with two dorsal simple setae and one ventral simple seta. Propodus 2.1 times as long as carpus, with one distal simple seta and one broom seta on dorsal margin, three simple setae on ventro-subdistal margin, and one inner subdistal seta. Ischio-basis, merus, carpus, and propodus covered by microtrichia. Dactylus and unguis combined 0.6 times as long as propodus. Dactylus with simple seta on dorso-subproximal margin. Unguis 1.3 times as long as dactylus.

Pereopod 2 (Fig. 3B, B'): Ischio-basis 3.2 times as long as wide, with two broom setae and one simple seta on dorsoproximal margin and two ventrodistal simple setae. Merus 0.4 times as long as ischio-basis, with two simple setae and one spiniform seta on ventrodistal margin and one dorsodistal simple seta. Carpus 0.6 times as long as merus, with two spiniform setae and two slender setae on dorsodistal margin and two ventrodistal spiniform setae. Propodus 1.5 times as long as carpus, with two distal simple setae of unequal length and one dorsal broom seta and two simple setae and one short bifurcate pinnate spiniform seta on ventral margin (Fig. 3B'). Dactylus and unguis combined half as long as propodus. Ischio-basis, merus, carpus, and propodus covered by microtrichia. Dactylus with one dorsoproximal simple seta. Unguis 1.4 times as long as dactylus.

Pereopod 3 (Fig. 3C): Ischio-basis 2.8 times as long as wide, with two broom setae and one simple seta on dorso-subproximal margin and two ventrodistal simple setae. Merus half as long as ischio-basis, setation equal to pereopod 2. Carpus 0.6 times as long as merus, with three ventrodistal setulose spiniform setae and two setulose spiniform setae and two slender setae on dorsodistal margin. Propodus 1.4 times as long as carpus, setation equal to that of pereopod 2. Ischio-basis, merus, carpus, and propodus covered by microtrichia. Dactylus and unguis combined as long as that of pereopod 2. Unguis 1.5 times as long as dactylus.

Pereopod 4 (Fig. 3D): Ischio-basis 2.7 times as long as wide, with two dorso-subproximal broom setae, one ventro-subdistal broom seta, and two ventrodistal simple setae. Merus 0.6 times as long as ischio-basis, with three dorsodistal setae and two setulose spiniform setae and one seta on ventro-subdistal margin. Carpus 0.7 times as long as merus, with two slender setae and five setulose spiniform setae on distal margin. Propodus 1.2 times as long as carpus, with one dorso-subdistal broom seta, three subdistal simple setae, and two ventral slender simple setae. Ischio-basis, merus, carpus, and propodus covered by microtrichia. Dactylus and unguis fused into claw, with comb-like lateral rows of five flattened setae distally.

Pereopod 5 (Fig. 4A): Ischio-basis 2.5 times as long as wide, with two dorso-subproximal broom setae and two ventrodistal simple setae. Merus 0.4 times as long as

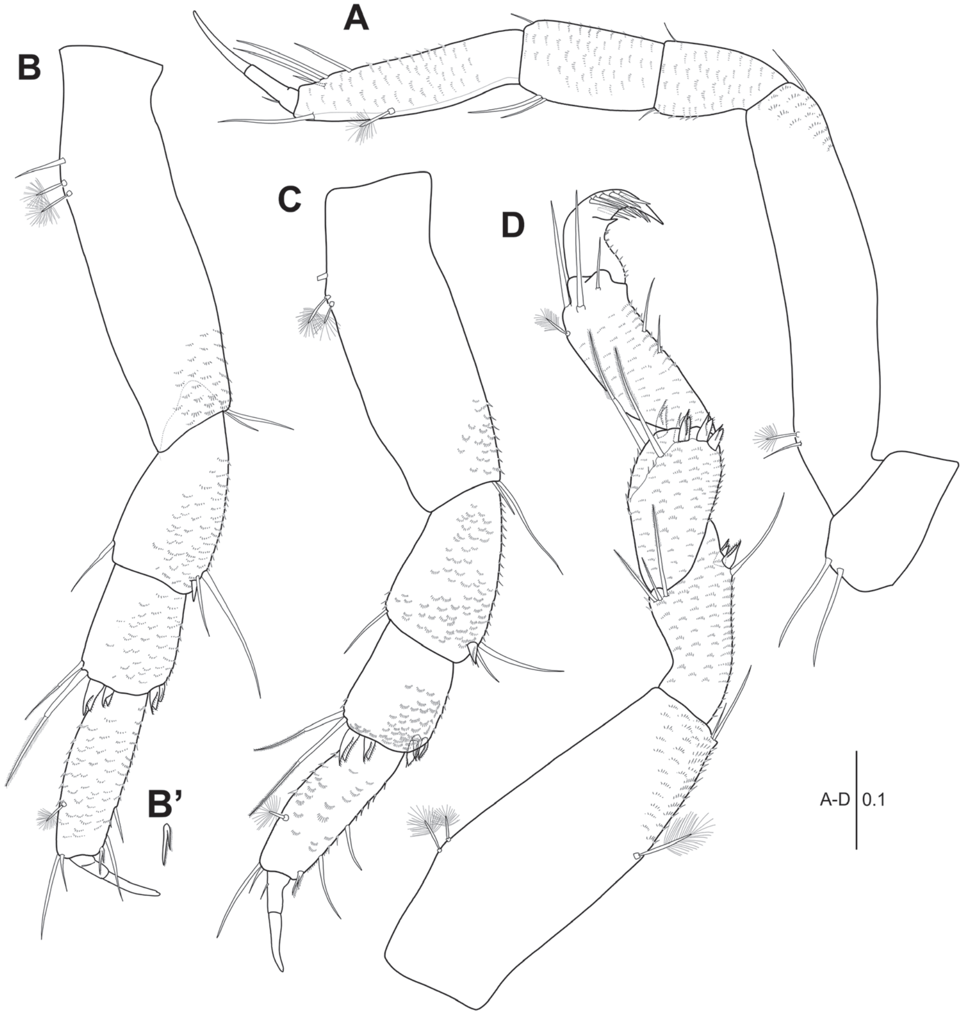

Figure 3. *Hexapleomera ulsana* sp. n., female holotype, **A** pereopod 1 **B** pereopod 2 **C** pereopod 3 **D** pereopod 4. Scale bars in mm.

ischio-basis, with four simple setae and two seutlose spiniform setae. Carpus 0.8 times as long as merus, with five setulose spiniform plus two simple setae on distal margin. Propodus 1.4 times as long as carpus, setation equal to that of pereopod 4. Ischio-basis, merus, carpus, and propodus covered by microtrichia. Dactylus and unguis similar to those of pereopod 4.

Pereopod 6 (Fig. 4B): Ischio-basis 3.1 times as long as wide, with two dorso-subproximal broom setae and two ventrodistal setae. Merus 0.4 times as long as ischio-basis, with three dorsodistal setae and two setulose spiniform setae and two simple setae on ventrodistal margin. Carpus slightly longer than merus, with five setulose spiniform setae and three setae. Propodus 1.1 times as long as carpus, with seven flattened denticulate spiniform setae and one simple seta on subdistal margin, one dorsal broom seta, two distal setae, and two ventral slender simple setae. Ischio-basis, merus, carpus, and propodus covered by microtrichia. Dactylus and unguis similar to those of pereopod 5.

Pleopod 1 (Fig. 4C, D): Basal article as long as wide, with one inner and five outer plumose setae. Exopod with 27 plumose setae along outer margin. Endopod with one inner and eleven outer plumose setae and one robust spiniform plumose seta bearing two spines and one setulose seta (arrowed in Fig. 4D).

Pleopod 2 (not figured): Similar to pleopod 1, except for outer margin of exopod with smaller plumose setae (26).

Pleopod 3 (Fig. 4E): Basal article lacking inner seta (arrowed) and with four outer plumose setae. Exopod with 24 outer plumose setae. Endopod with one inner plumose seta and ten outer plumose plus one robust setae.

Uropod (Fig. 1A, G): Basal article 1.7 times as long as wide, with three outer distal setae and two inner distal setae. Endopod 4-articulate.

Description of male. *Body* (Fig. 5A): Length 3.4 mm, three times as long as wide. Pigmentation similar to female. Cephalothorax pear-shaped, one-third of body length, 1.1 times as long as wide, with antero- and mid-lateral simple setae, tapering towards to rostrum.

Pereon (Fig. 5A): 44 % of body length, 1.3 times as long as wide, with several fine setae along lateral margins. Pereonites 1–6 proportional lengths of 13.7: 13.2: 15.6: 21.0: 20.5: 16.0.

Pleon (Fig. 6A): Pleonites 1–5 18.1 % of body length, 0.7 times as long as wide. Pleonites 1–3 gradually decreasing in width. Pleonite 1 almost equal length of pereonite 6, 0.2 times as long as wide, with two simple and two plumose setae on lateral margin. Pleonite 2 0.7 times as long as pleonite1, 0.2 times as long as wide, with two simple and two plumose setae on lateral margin. Pleonite 3 slightly shorter than pleonite 2, 0.2 times as long as wide, with two simple setae on anterolateral margin. Pleonites 4 and 5 combined half as long as pleonite 3, 0.7 times as wide as pleonite 3, each with two lateral simple setae. Pleonite 4 with two anterodorsal setae. Pleotelson (Fig. 5A) about 0.7 times as long as pereonite 1, 0.3 times as long as wide, with three simple setae on sub-anterolateral margin, one broom seta and two simple setae on sub-posterolateral margin, and four simple setae of unequal length on distal margin.

Appendages similar to those of female except for antennule, antenna, mandible, maxilliped, cheliped, and uropod:

Antennule (Fig. 5B): 4-articulate, elongate. Proportional lengths of articles 63.3: 20: 15.4: 1.3. Length 1.7 times as long as cephalothorax. Article 1 5.6 times as long as wide, outer margin with three subproximal broom setae and two broom plus four simple setae on distal margin; inner margin with two medial simple setae and two broom and two simple setae on distal margin. Article 2 1.8 times as long as wide, with three simple setae and eight broom setae on subdistal margin. Article 3 2.3 times as long as wide, with two broom setae and four simple setae on distal margin. Article 4 small, with six aesthetascs and several simple setae on distal margin.

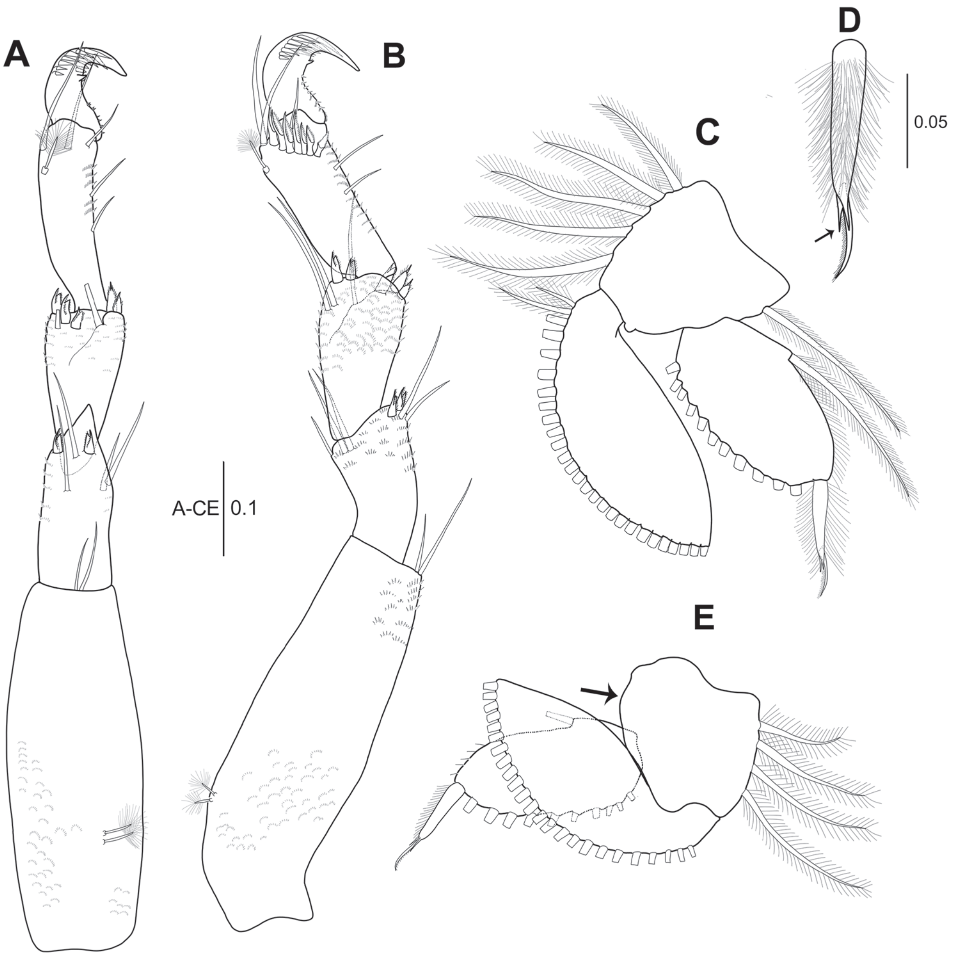

Figure 4. *Hexapleomera ulsana* sp. n., female holotype, **A** pereopod 5 **B** pereopod 6 **C** pleopod 1 **D** distal seta of pleopod1 endopod **E** pleopod 3. Scale bars in mm.

Antenna (Fig. 5C): 6-articulate, 0.8 times as long as antennule. Proportional lengths of articles 9.3: 24.1: 12.5: 29.5: 17.2: 7.4. Article 1 naked. Article 2 with one medial simple seta and two distal simple setae. Article 3 ornamented with microtrichia. Article 4 longest, with two distal simple setae. Article 5 with one broom seta and one simple seta on inner distal margin. Article 5 shortest, with one broom seta and ten simple setae on distal margin.

Left mandible (Fig. 5D): Incisor with small denticles along distal margin. *Right mandible* (Fig. 6E): Lacinia mobilis without distal denticles.

Cheliped (Fig. 6A): Much stouter than that of female. Basis 1.3 times as long as wide, with one ventrodistal simple seta and one dorsodistal simple seta. Merus subtriangular, ventrodistally protruded (arrowed), with two ventral simple setae and two dorsal setae. Carpus 1.1 times as long as basis, almost as long as wide, with two ventral

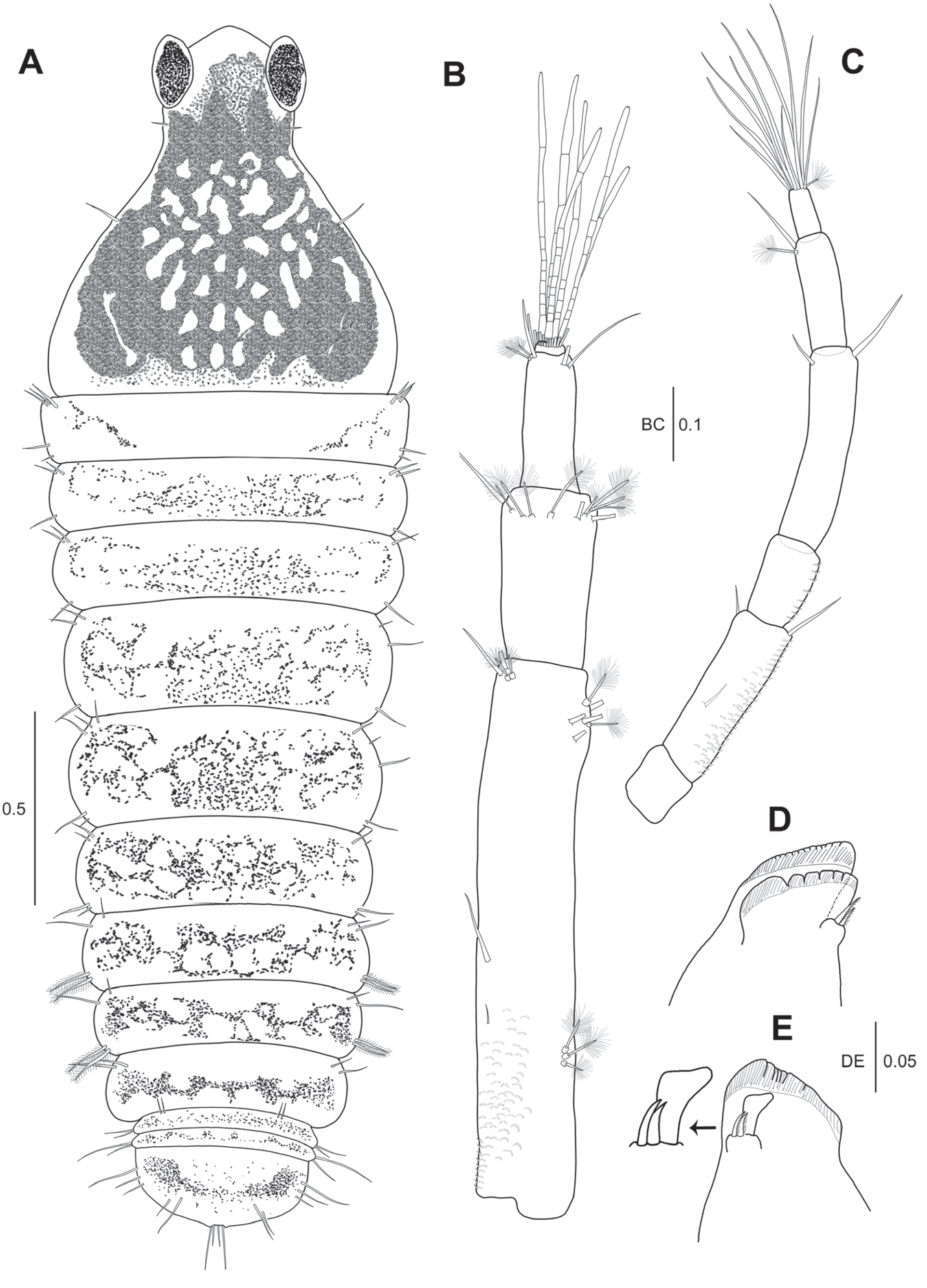

Figure 5. *Hexapleomera ulsana* sp. n., male allotype, **A** habitus, dorsal, all pigmentations except that on carapace not presented **B** antennule **C** antenna **D** left mandible, incisor, lacinia mobilis, and setal row **E** right mandible, incisor, lacinia mobilis, and setal row. Scale bars in mm.

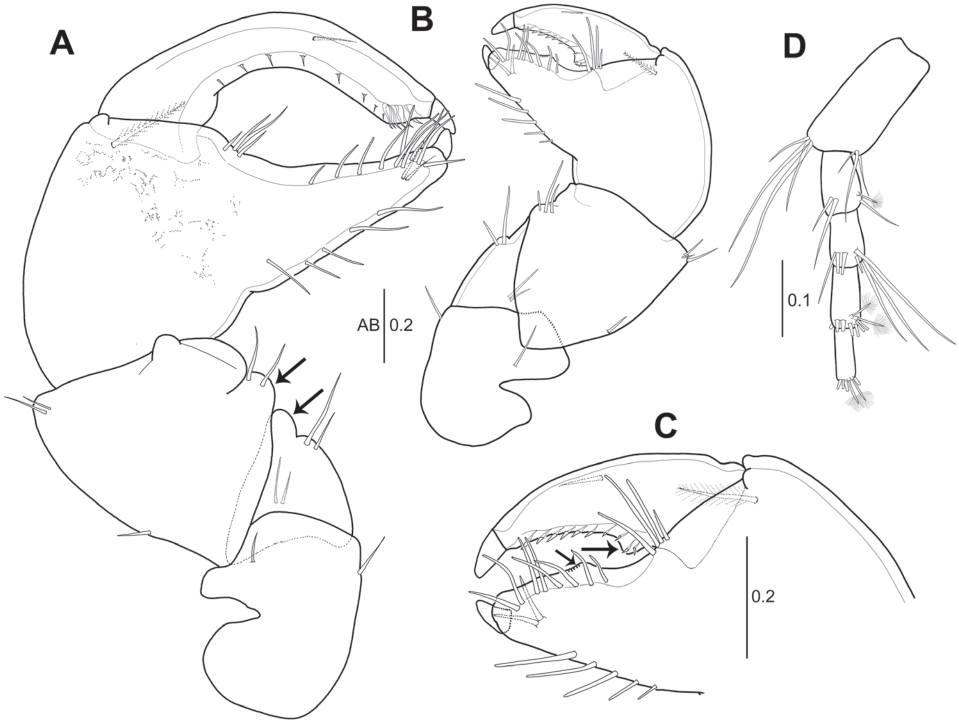

Figure 6. *Hexapleomera ulsana* sp. n., male allotype, **A** cheliped **B–C** male paratype **B** cheliped **C** cheliped chela **D** allotype male, uropod. Scale bars in mm.

protrusions (arrowed), two ventral simple setae, one dorsoproximal simple seta, and two dorsodistal simple setae. Propodus 2.1 times as long as carpus, 1.9 times as long as wide, with one inner plumose seta and four simple setae near dactylus insertion. Fixed finger with five ventral simple setae, two inner distal setae, and ten simple setae along cutting edge. Dactylus with 14 small denticles along cutting edge and inner medial seta.

Uropod (Fig. 6D): Basal article 2.2 times as long as wide, with four outer distal simple setae and three inner distal simple setae.

Cheliped of smaller male (Body length 2.1 mm) (Fig. 6B, C): Basis as long as wide. Merus with one ventral protrusion, two ventral simple setae, and two dorsal simple setae. Carpus with weakly developed protrusion on ventral margin. Propodus 1.5 times as long as carpus, 1.9 times as long as wide, with one inner plumose seta and four simple setae near dactylus insertion. Fixed finger with five ventral simple setae, two inner distal setae, small protrusion bearing small denticles (arrowed in Fig. 6C), and eight simple setae along cutting edge. Dactylus not extended and just weakly curved, and with proximal protrusion (arrowed in Fig. 6C) and small denticles along cutting edge.

Etymology. The specific name refers to Ulsan, a harbour city near the type locality.

Table 1. Morphological comparison between nine species within the genus *Hexapleomera.*

Key characters \ species	***H. bultidactyla***	***H. edgari***	***H. moverleyi***	***H. robusta sensu* Moore**	***H. robusta sensu* Sieg**	***H. satella***	***H. ulsana***	***H. urashima***	***H. wombat***
	F/M	F/M	F/M	F/M	F/M	F/M	F/M	F/M	F/M
Number of uropod articles	4/4	4/4	–/5	4/–	4/4	4/4	5/5	4/4	5/5
Number of inner seta on pleopod 3 basal article	0/0	1/1	–/1	–	0/0	0/0	0/0	0/0	0/0
Pereopod 1 coxa with apophysis	yes	yes	yes	–	no	yes	no	yes	no
Number of seta on maxillule palp	4	5	5	8	8	4	4	6	5
Maxilliped									
Basis setae	2	2	1	–	2	2	1	1~2	1
Coxa setae	2	3	2	–	2	2	3	2	3
Endite with distal plumose setae	yes	yes	yes	–	yes	no	yes	yes	no
Right/Left Mandibles									
Setae number of setal row	1	1	1	–	2	1	2	2	1
Pereopods 2–3									
Ventral setae on propodus	2, 2	4, 4	2, 2	–	3, 2	1, 2	3, 3	3, 3	2, 3
Habitat	aquaculture fouling	turtles	epifaunal	turtles	turtles	benthic/ epifaunal	benthic/ epifaunal	turtles	yacht hulls

Remarks. *Hexapleomera ulsana* sp. n. can be differentiated from other species of the genus by the following combination of characteristics (Table 1): in both sexes, 1) the uropod has five articles; 2) the basal article of the pleopod 3 lacks inner seta and has four outer setae; 3) the pereopod 1 coxa lacks apophysis; 4) the maxillule palp has four distal setae; in the maxilliped, 5) a coxa has three distal setae; 6) the basis has one subdistal seta; 7) each setal row of the right and left mandibles has two pinnate setae; and 8) the propodus of pereopods 2–3 each has two slender simple setae and one bifurcate spiniform seta on the ventral margin. Just as *H. urashima*, *Hexapleomera ulsana* lacks an inner seta on the pleopod basal article, has the same number of distal setae on the maxillule endite (6), setae of the mandible setal row (2), and ventral setae on the pereopods 2–3 propodus (3), but can be distinguished by the pereopod 1 coxa lacking apophysis (vs. presence), the number of uropod article (5 vs. 4), and the number of proximal seta on the maxilliped coxa (3 vs. 2). In addition, the findings of the maxilla forming a rugged shape on the distal margin and an epignath with substantially short and blunt spiniform distal seta are noted. In other species of *Hexapleomera*, the maxilla represents a simple and round shape, and the distal seta of the epignath is much slender. The cheliped of the smaller male is very similar to those of females without any trace of oostegites; however, it differs in the location of a protrusion on the dactylus and fixed finger. Particularly, the cutting edge of the fixed finger of the female is smooth, without a protrusion, while it has a weak protrusion with small denticles in the smaller male.

Jeju population of *Hexapleomera ulsana*

Figs 7–12

Material examined. Yerae (33°27'30.0"N, 126°20'18.0"E), Jeju Island of Korea in May 2016. Ovigerous female dissected and mounted in five slides (MABIK CR00235368). Male dissected and mounted in five slides (MABIK CR00235370). Three females partly dissected and mounted in five slides (MABIK CR00235369), one slide (MABIK CR00240707), three slides (MABIK CR00240708); two partly dissected females in one vial (MABIK CR00240709); three males dissected and mounted in one slide (MABIK CR00235371), one slide (MABIK CR00240710), one slide (MABIK CR00240711); two partly dissected males in one vial (MABIK CR00240712).

Description of female (with a budding of oostegites). *Body* (Fig. 7A): With developed brood sacs each with 18 eggs. Length 2.6 mm, 4.3 times as long as wide. Chocolate brown pigmentation on most of dorsal surface, including antennule and cheliped, patterned with un-pigmented lacunae, cephalothorax with densely coalescing flecks focused on anterior part and eyes. Cephalothorax 1.1 times as long as wide, 26 % of body length, with two pairs of simple slender setae on antero- and mid-lateral margins.

Pereon (Fig. 7A): About 51 % of body length, 2.2 times as long as wide, with several fine setae along lateral margins. Pereonites 1–6 proportional lengths of 10.8: 12.5: 16.5: 22.6: 21.1: 16.5.

Pleon (Fig. 7A): Pleonites 1–5 18% of body length. Pleonite 1 0.9 times as long as pereonite 6, 0.35 times as long as wide, with one simple seta on anterodorsal margin, simple seta on sub-anterolateral margin, and two plumose setae on posterolateral margin. Pleonite 2 0.8 times as long as pleonite 1, 0.3 times as long as wide, with two simple setae on sub-anterolateral margin and two plumose setae on sub-posterolateral margin. Pleonite 3 0.8 times as long as pleonite 2, 0.2 times as long as wide, with two simple setae on sub-anterolateral margin. Pleonites 4 and 5 each with two simple setae on lateral margin. Pleotelson (Fig. 7A): 0.7 times as long as pleonite 1, 0.4 times as long as wide, with two simple setae of unequal length on sub-anterolateral margin, three simple setae and one broom seta on sub-posterolateral margin, and four simple setae of unequal length on posterior margin.

Antennule (Fig. 7B): 4-articulate. Proportional lengths of articles 57.1: 22.4: 17.3: 3.2. Length 0.7 times as long as cephalothorax. Article 1 2.5 times as long as wide, with one medial broom seta and distally eight broom setae and three simple setae. Article 2 1.2 times as long as wide, with five broom setae and three simple setae on distal mar-

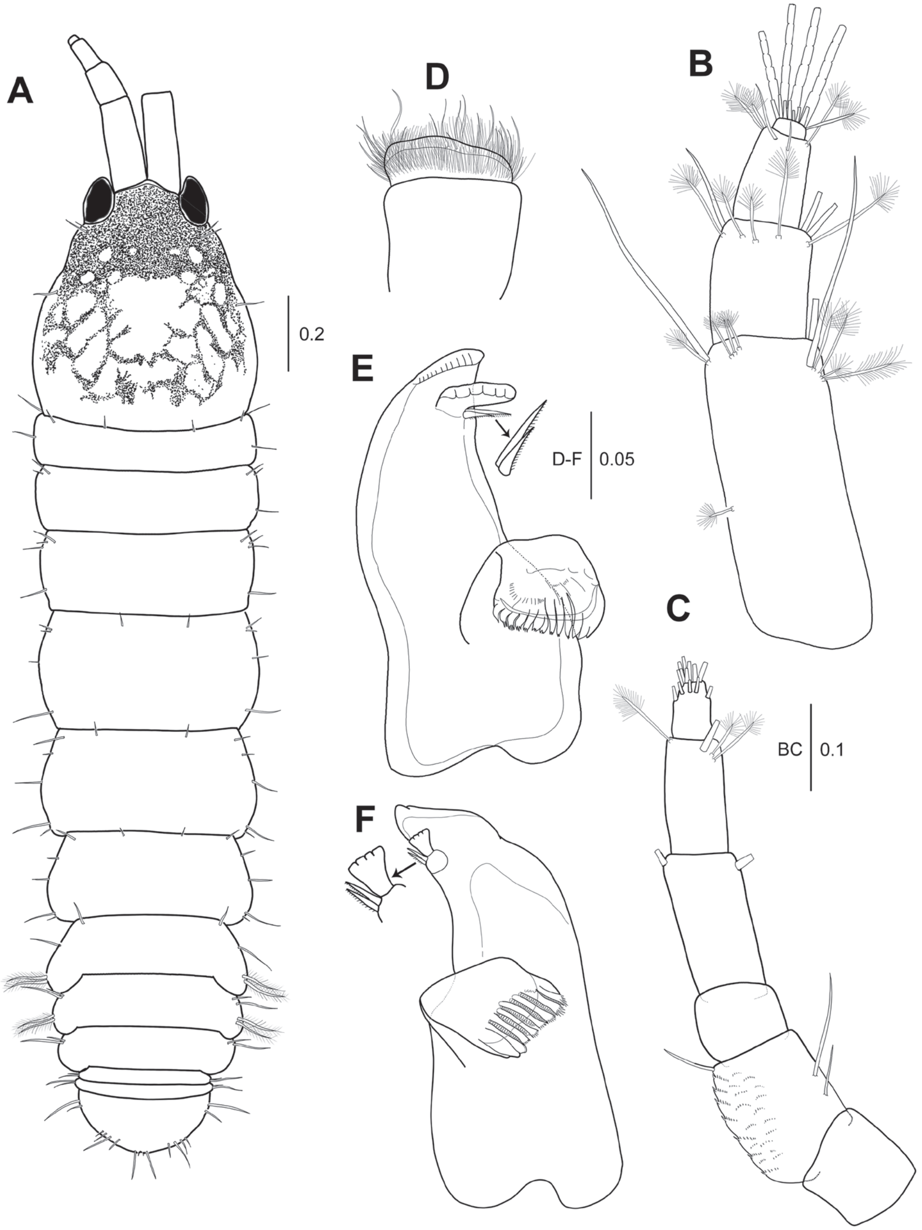

Figure 7. *Hexapleomera ulsana* sp. n., Jeju population, female, **A** habitus, dorsal, all pigmentations except that on carapace not presented **B** antennule **C** antenna **D** labrum **E** left mandible **F** right mandible. Scale bars in mm.

gin. Article 3 1.5 times as long as wide, with five broom setae and two simple setae. Article 4 with seven simple setae, one broom seta, and four aesthetascs.

Antenna (Fig. 7C): 6-articulate, 1.4 times as long as antennule. Proportional lengths of articles 15.4: 22.4: 11.4: 22.8: 18.5: 9.5. Article 1 naked. Article 2 with three simple setae and microtrichia. Article 3 naked. Article 4 with two distal simple setae. Article 5 with one simple seta and three broom setae on distal margin. Article 6 with twelve simple setae on distal and sub-distal margins.

Labrum (Fig. 7D): With numerous setules.

Left mandible (Fig. 7E): Incisor with small denticles along distal margin. Lacinia mobilis wide, with six denticles along distal margin. Setal row with two pinnate spiniform setae of unequal length. Molar similar to that of Ulsan population. *Right mandible* (Fig. 7F): Incisor distally smooth. Lacinia mobilis reduced to blunt spine with four distal denticles. Setal row with two pinnate spiniform setae of similar length. Molar similar to that of left mandible.

Labium (Fig. 8A): With six lateral spines; labial palp 1.9 times as long as wide, covered with setules.

Maxillule (Fig. 8B): Endite with seven strong setulate spiniform setae and one slender setulose seta on distal margin and patch of simple slender setae on outer subdistal margin; palp with six distal setae.

Maxilla (Fig. 8C): Distal margin simple.

Maxilliped (Fig. 8D): Coxa with two inner proximal simple setae. Basis 2.2 times as long as wide, with one distal seta. Palp article 1 with one outer subdistal seta. Palp article 2 with one outer seta and seven inner plumose setae. Palp article 3 with seven inner plumose setae. Palp article 4 with ten plumose setae. Endite with two plumose setae, two short simple spiniform setae, and two blunt spiniform setae on distal and subdistal margins. *Epignath* (Fig. 8E): Similar to that of Ulsan population.

Cheliped (Fig. 9A, B): Basis 1.2 times as long as wide, with one dorsal seta, one ventral seta, and microtrichia on ventroproximal margin. Merus with two ventral setae and two dorsal setae. Carpus 1.2 times as long as basis, 1.6 times as long as wide, with four ventral setae, three dorsodistal setae, and one dorsomedial seta. Propodus 1.1 times as long as carpus, 1.9 times as long as wide, with three simple setae and one inner setulose seta near insertion of dactylus (Fig. 9B). Fixed finger with three simple setae on ventral margin, two inner simple setae, and five outer simple setae along cutting edge. Dactylus with seven small denticles along cutting edge and inner surface with one simple seta medially and covered with squama-like ornamentations.

Pereopod 1 (Fig. 9C): Coxa with two simple setae, without apophysis. Ischio-basis 4.2 times as long as wide, with one simple seta and one broom seta on dorso-subproximal margin and one simple ventrodistal seta. Merus 0.4 times as long as ischio-basis, with one ventrodistal seta and one dorsodistal seta. Carpus as long as merus, with one ventrodistal seta and one dorsodistal seta. Propodus 1.7 times as long as carpus, with three ventro-subdistal setae, one dorsomedial broom seta, one inner subdistal seta, and one dorso-subdistal seta. Dactylus and unguis combined 0.7 times as long as propodus. Dactylus with simple seta on dorsoproximal margin. Unguis 1.5 times as long as dactylus.

Pereopod 2 (Fig. 10A): Ischio-basis 3.3 times as long as wide, with two broom setae and one simple seta on dorsal margin and one ventrodistal simple seta. Merus 0.4 times as long as ischio-basis, with one setulose spiniform seta and two simple setae on ventrodistal

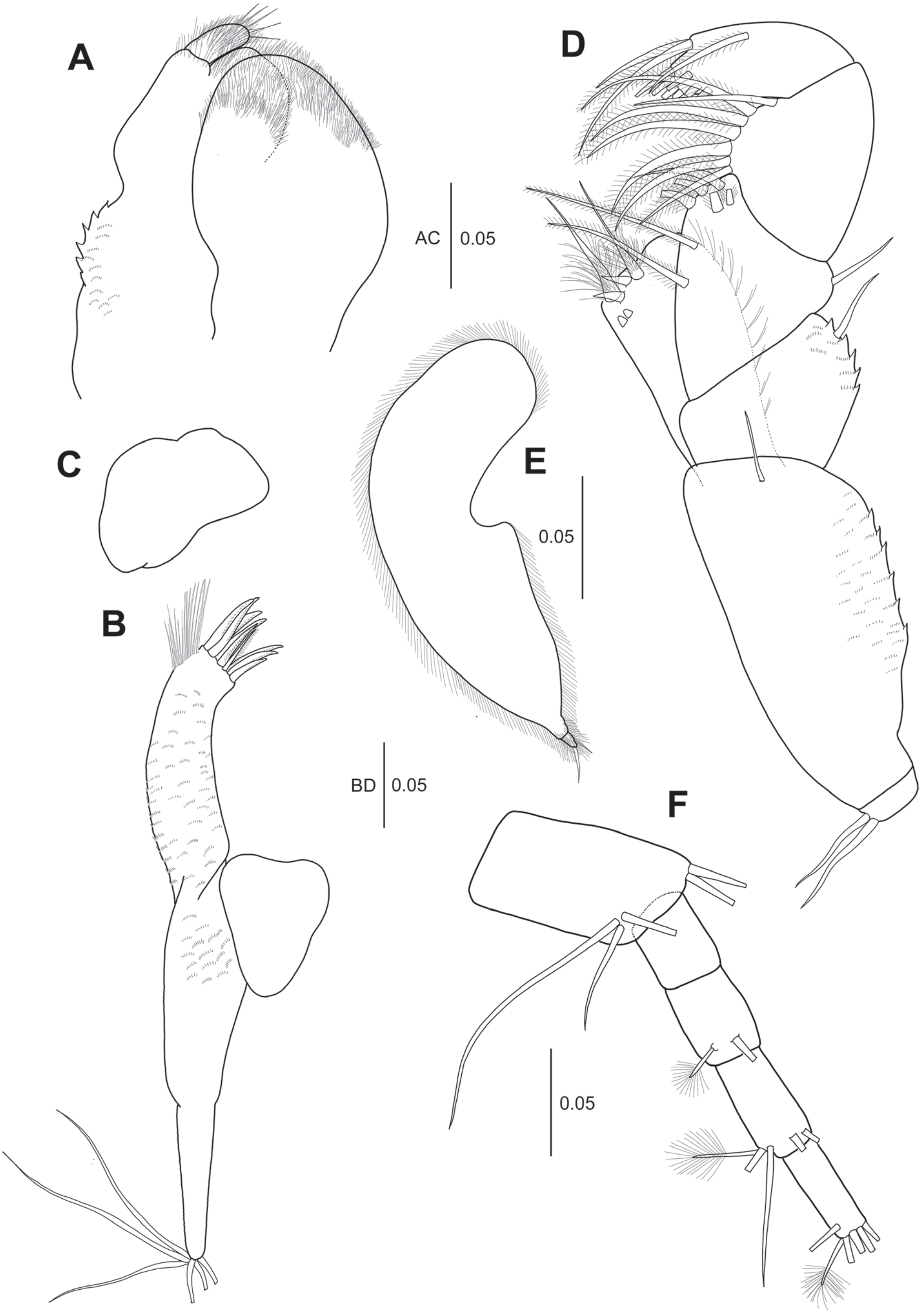

Figure 8. *Hexapleomera ulsana* sp. n., Jeju population, female, **A** labium **B** maxillule **C** maxilla **D** maxilliped **E** epignath **F** uropod. Scale bars in mm.

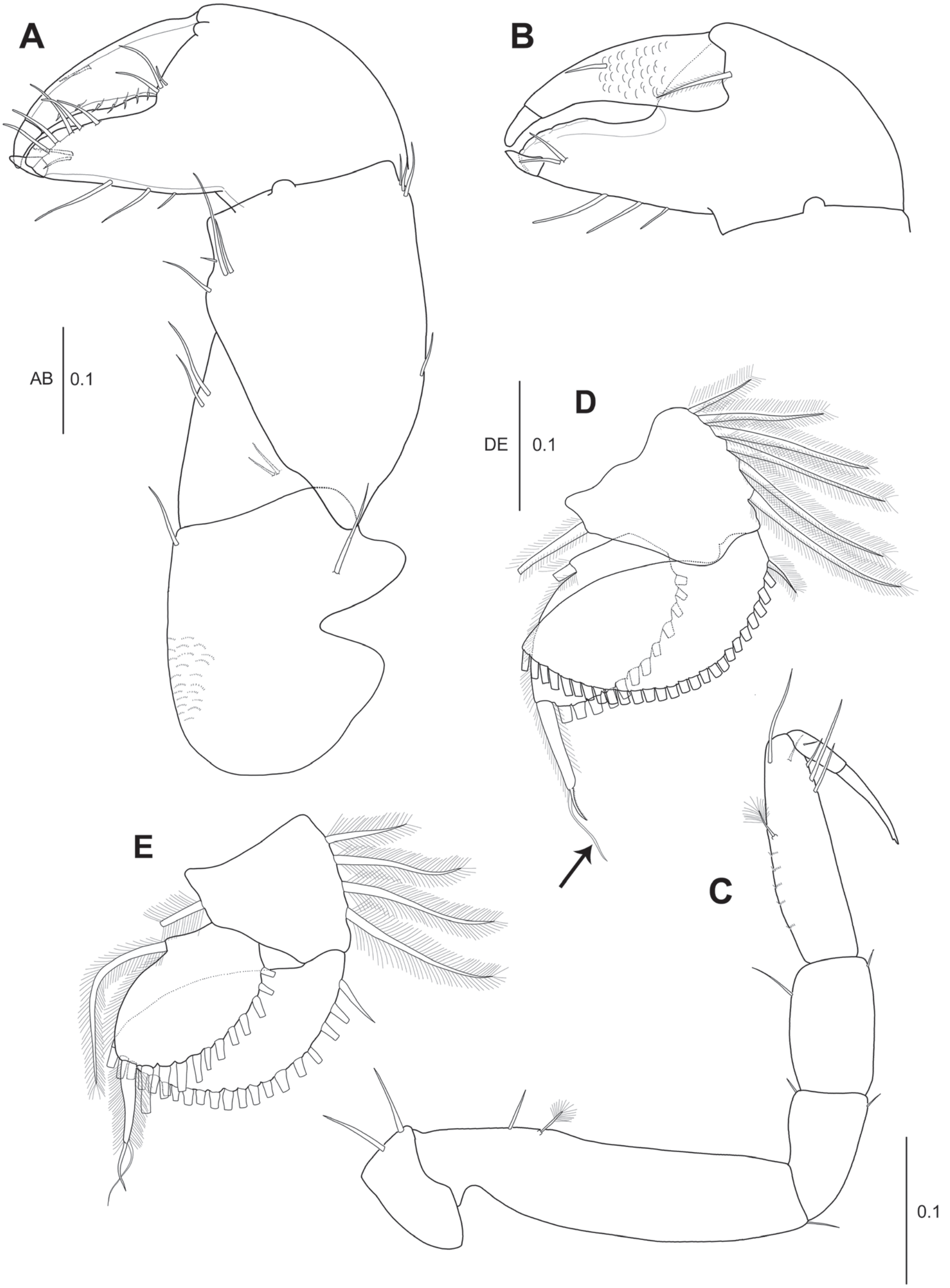

Figure 9. *Hexapleomera ulsana* sp. n., Jeju population, female, **A** cheliped **B** cheliped chela, inner surface **C** pereopod 1 **D** pleopod 1 **E** pleopod 3. Scale bars in mm.

margin and one dorsodistal simple seta. Carpus 0.7 times as long as merus, with four setulose spiniform setae and two simple setae on distal margin. Propodus 1.6 times as long as carpus, with two simple ventral setae of unequal length, one simple dorsodistal seta, and one dorso-subdistal broom seta. Dactylus and unguis combined 0.6 times as long as propodus. Dactylus with short proximal simple seta. Unguis 1.6 times as long as dactylus.

Pereopod 3 (Fig. 10B): Ischio-basis 3.1 times as long as wide, with two broom setae and one simple seta on dorsal margin, one ventromedial broom seta, and one ventrodistal simple seta. Merus half as long as ischio-basis, setation equal to that of pereopod 2. Carpus 0.6 times as long as merus, with three setulose spiniform setae and one simple seta on ventrodistal margin and two setulose spiniform setae and one simple seta on dorsodistal margin. Propodus 1.8 times as long as carpus, setation equal to that of pereopod 2. Dactylus and unguis combined half as long as propodus. Dactylus with subproximal simple seta. Unguis 1.3 times as long as dactylus.

Pereopod 4 (Fig. 10C): Ischio-basis 2.5 times as long as wide, with one broom seta and two ventrodistal simple setae. Merus half as long as ischio-basis, with two setulose spiniform setae and two ventrodistal and two dorsodistal simple setae. Carpus 0.7 times as long as merus, with five setulose spiniform setae and two simple setae. Propodus 1.4 times as long as carpus, with one ventral and one mid-inner distal simple setae, two dorsodistal setae, and one dorsal broom seta. Dactylus and unguis fused into claw, with comb-like lateral rows of five flattened setae.

Pereopod 5 (Fig. 10D): More robust than in pereopod 4. Ischio-basis with two ventral broom setae, one dorsal simple seta, two ventrodistal simple setae, and two dorsodistal simple setae. Carpus 0.8 times as long as merus. Setation of merus, carpus, and propodus equal to those of pereopod 4. Propodus 1.2 times as long as carpus. Claw with comb-like lateral rows of six flattened setae.

Pereopod 6 (Fig. 10D): Ischio-basis three times as long as wide, with two dorso-subproximal broom setae and two ventrodistal simple setae. Merus half as long as ischio-basis, setation equal to that of pereopod 5. Carpus equal to that of pereopod 5. Propodus with four flattened denticulate setae on distal margin, one ventral simple and one mid-inner setae, two dorsodistal setae, and one dorso-subdistal broom seta. Claw similar to that of pereopod 5.

Pleopod 1 (Fig. 9D): Basal article almost as long as wide, with one inner plumose seta and six outer plumose setae. Exopod with 27 outer plumose setae. Endopod with one inner and twelve outer plumose setae and one robust spiniform seta bearing one setulose spine and one long seta (arrowed).

Pleopod 2 (not figured): Basal article and exopod similar to those of pleopod 1. Endopod with one inner and eleven outer plumose setae and one robust seta.

Pleopod 3 (Fig. 9E): Basal article with four outer plumose setae and one inner plumose seta. Exopod with 20 outer plumose setae. Endopod with one inner and eleven outer plumose setae and one robust seta.

Uropod (Fig. 8F): Basal article 1.7 times as long as wide, with two inner distal setae and three outer distal setae. Endopod with four articles.

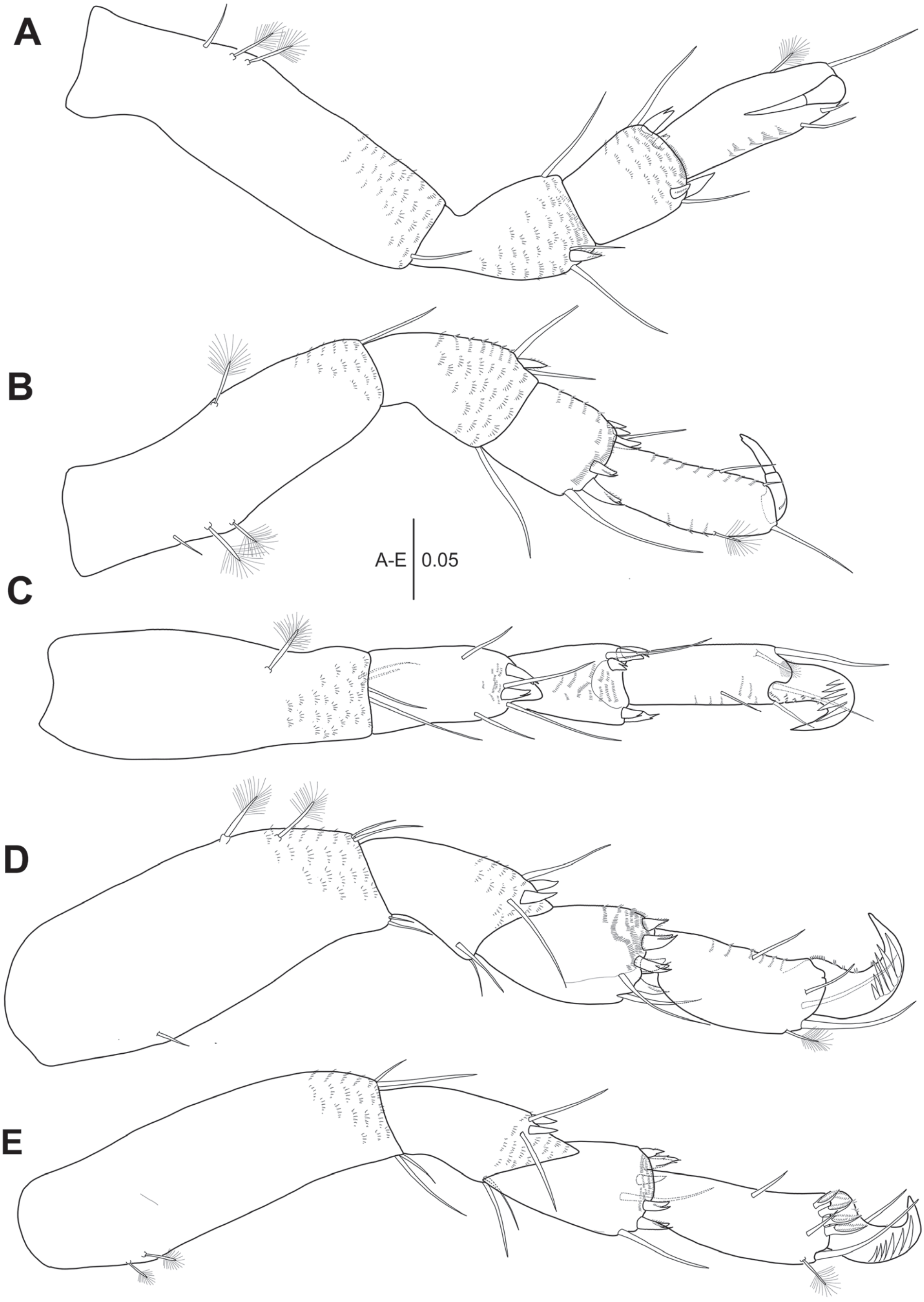

Figure 10. *Hexapleomera ulsana* sp. n., Jeju population, female, **A** pereopod 2 **B** pereopod 3 **C** pereopod 4 **D** pereopod 5 **E** pereopod 6. Scale bars in mm.

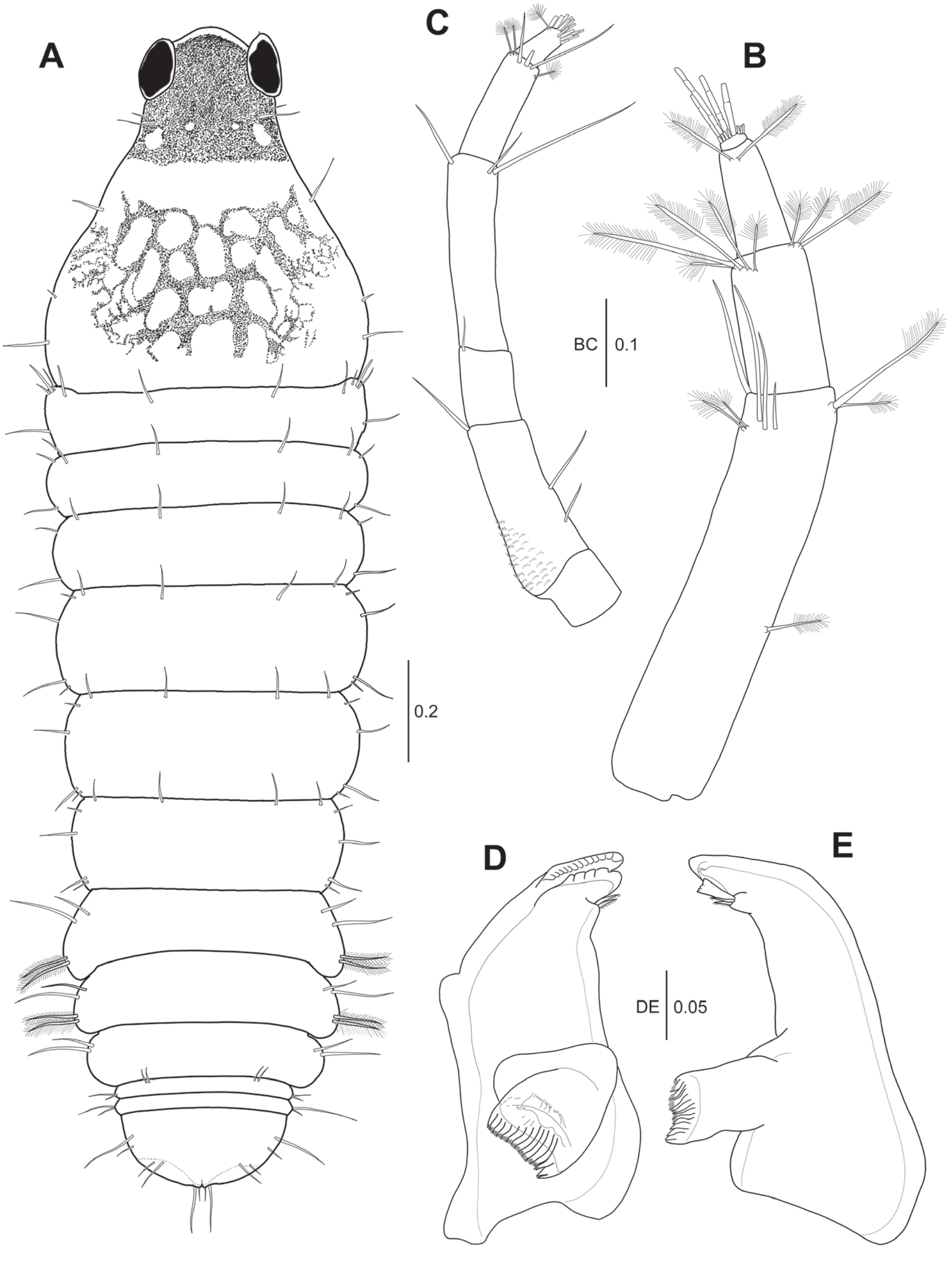

Figure 11. *Hexapleomera ulsana* sp. n., Jeju population, male, **A** habitus, dorsal **B** antennule **C** antenna **D** left mandible **E** right mandible. Scale bars in mm.

Description of male. *Body* (Fig. 11A): Length 2.4 mm, 3.6 times as long as wide. Pigmentation similar to female. Cephalothorax 31 % of body length, 1.1 times as long as wide, with two simple setae on sub-anterolateral margin, one mid-lateral seta, and two sub-posterolateral setae.

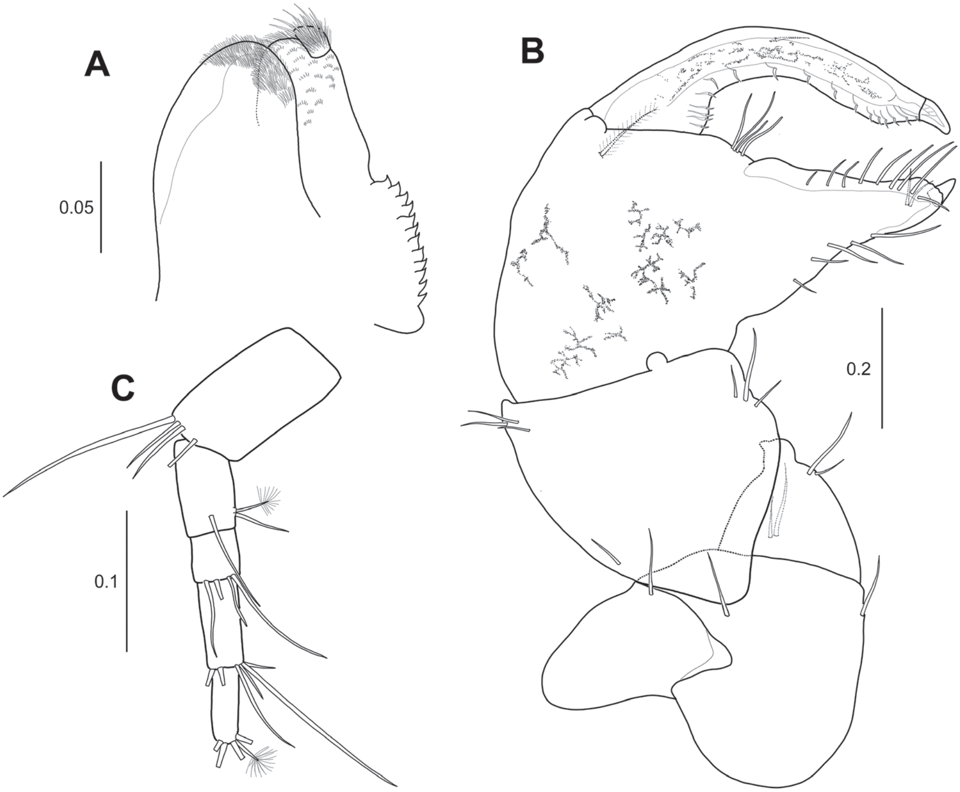

Figure 12. *Hexapleomera ulsana* sp. n., Jeju population, male, **A** labium **B** cheliped **C** uropod. Scale bars in mm.

Pereon (Fig. 11A): 43 % of body length, 1.6 times as long as wide. Pereonites 1–6 with several simple setae along lateral margin, proportional lengths of 10.6: 12.7: 16.2: 20.8: 21.7: 18.0.

Pleon (Fig. 11A): Pleonites 1–5 20.3 % of body length, 0.8 times as long as wide. Pleonite 1 0.8 times as long as pereonite 6, 0.3 times as long as wide, with two simple setae and two plumose setae on lateral margin. Pleonites 2 and 3 each slightly shorter than pleonite 1, with two simple setae and two plumose setae. Pleonites 4 and 5 each with two lateral simple setae of unequal length. Pleonite 4 with two pairs of two simple setae on dorsoproximal margin. Pleotelson 0.8 times as long as pleonite 1, half as long as wide, with two simple anterior setae, two medial simple setae, and four distal simple setae.

Appendages similar to those of female except for antennule, antenna, mandibles, cheliped, and uropod:

Antennule (Fig. 12B): 1.1 times as long as cephalothorax. Proportional length of articles 61.3: 21.2: 15.8: 1.7. Article 1 4.2 times as long as wide, with one outer medial broom seta, two outer distal broom setae, three simple setae and two broom setae on subdistal margin, and one inner distal simple seta. Article 2 1.8 times as long as wide, with eight distal broom setae. Article 3 1.9 times as long as wide, with two broom setae on subdistal margin. Article 4 with four aesthetascs and several simple setae.

Antenna (Fig. 12C): 0.9 times as long as antennule. Proportional lengths of articles 9.3: 26.7: 11.8: 28.7: 16.7: 6.8. Article 1 naked. Article 2 with two medial simple setae, one outer distal seta, and proximally microtrichia. Article 3 with one distal simple seta. Article 4 longest, with three distal simple setae. Article 5 with three simple setae and three broom setae. Article 6 with one broom seta and 14 simple setae on distal margin.

Left mandible (Fig. 11D): Two setae of setal row smaller than those of female. *Right mandible* (Fig. 11E): Lacinia mobilis reduced to blunt spine, about twice as long as two pinnate setae of setal row.

Labium (Fig. 12A): Lobe with 12 lateral spines; labial palp 1.6 times as long as wide.

Cheliped (Fig. 12B): Basis 1.1 times as long as wide, with one ventro-subdistal seta and one dorso-subdistal seta. Merus slightly protruded on ventrodistal margin, with two ventromedial setae and two dorsal setae. Carpus equal to basis in length and width, with three ventromedial setae, one dorso-subproximal seta, and three dorso-distal setae. Propodus 1.8 times as long as wide, with one setulose inner seta and four simple setae near insertion of dactylus. Fixed finger with five simple setae along ventral margin and nine simple setae along cutting edge and two inner simple setae. Dactylus with 17 small denticles along cutting edge and one inner medial seta.

Uropod (Fig. 12C): Basal article 1.8 times as long as wide, with four distal setae.

Remarks

Two populations of *Hexapleomera ulsana* from the Ulsan and Jeju Island exhibited a morphological divergence in the number of the setae on the maxilliped coxa (3 vs. 2), setae on the maxillule palp (4 vs. 6), setae on the pleopod basal article (absence vs. presence), pattern of pigmentation of cephalothorax, and the number of ventral setae on the pereopods 2–3 propodus (3 vs. 2). On the other hand, specimens of both populations coincided in the number of uropod articles (5), the presence of apophysis on the pereopod 1 coxa, the number of setae on the mandible setal row, and the number of setae on the maxilliped endite. Little morphological variation was found in each population. These results show that the geographical isolation can affect the morphological divergence between two populations of *H. ulsana*.

Molecular results

The mtCOI gene sequences between two populations of *H. ulsana* from Ulsan and Jeju Island showed somewhat low molecular divergence (1.1 %). The divergence values are genetically indicative of the same species when compared with other taxa of Tanaididae

(Larsen et al. 2014, in table 2), in which different species of *Zeuxo* represented a genetic divergence in the mtCOI gene ranging from 10.7 % to 28.5 %. Therefore, the genetic results may mean that separation at the population level is ongoing. Genetic divergence of the mtCOI between *H. ulsana* and *H. urashima* (Japan) was distinct (32.4 %) revealing the two species to be different. The sequences of mtCOI of two populations of *H. ulsana* were submitted to GenBank under the accession numbers of KY303901–KY303903 (Ulsan) and KY303904–KY303905 (Jeju Island), respectively: KY303901 was extracted from the female paratype (MABIK CR00240699), KY303902 from the female paratype (MABIK CR00240701), KY303903 from the male paratype (MABIK CR00240704) of the Ulsan population; KY303904 from the female paratype (MABIK CR00240707) and KY303905 from the male paratype (MABIK CR00240710) of the Jeju population.

Discussion

The family Tanaididae Nobili, 1906 consists of five subfamilies, 19 genera, and 87 species (Anderson 2017). The subfamily Pancolinae Sieg, 1980 is divided into two tribes, Anatanaini Sieg, 1980 and Pancolini Sieg, 1980. Pancolini includes five genera, including *Aviatanais* Bamber, 2005, *Hexapleomera* Dudich, 1931, *Monoditanais* Sieg, 1980, *Pancoloides* Sieg, 1980, and *Pancolus* Richardson, 1905. The tribe is defined by the reduction of pleonites 3–5, pleopod 3 being smaller than pleopods 1–2, and sexual dimorphism in the cheliped, antennule, and antenna (Sieg 1980). Until quite recently, several species of *Hexapleomera* have been recorded as *H. robusta* from diverse regions (Anderson 2017, page 648–650), which has been regarded as cosmopolitan species due to a unique ecology related to sea-going turtles as their host. Bamber (2012) re-assessed *Hexapleomera* by examining previous literature and material of free-living benthic specimens from the eastern Mediterranean; he concluded that the genus was comprised by seven species. Currently, the genus contains nine species including new species of this study. To clarify species described in the present study to be new, Table 1 presents a comparison of the morphological characteristics between both sexes of new species from Korea and eight previously described species of *Hexapleomera*.

Morphological comparison among nine species within the genus *Hexapleomera*

Nine species of *Hexapleomera* were compared based on the combination of morphological characteristics (Table 1). These characters include the presence/absence of coxa of the pereopod 1, the number of uropod article, the number of inner setae on the pleopod 3 basal article, the number of setae on the maxilliped palp, the setae on the basis, coxa, and the endite of the maxilliped, which were suggested diagnostic features of species within the genus by Bamber (2012, in Table 1). Recently, Tanabe et al. (2017) recorded the stable and variable characters of species in *Hexapleomera* based on the morphological and genetic examination of *H. urashima*. As a result, the number of uropodal articles, setae of pleopod 3 basal article, setae of maxilliped coxa, and endite were confirmed to have stability. The number of setae of the mandible setal row and the number of ventral setae on the pereopods 2–3 propodus were newly added as key characters in this study, which showed difference in *H. edgari*, *H. robusta sensu* Sieg, *H. satella*, and *H. wombat* but equal in *H. bultidactyla* and *H. moverleyi* (2 and 2) and *H. ulsana* and *H. urashima* (3 and 3). In the case of the mandible, some authors (Larsen and Wilson 1998, Edgar 2008) mentioned that the form and number of setae consisting of the setal row of mandibles varied with growth as well as between individuals within populations. However, those of *H. ulsana* showed difference only in size. The presence of an inner seta on the pleopod 3 basal article was found only in two species from Australia (*H. edgari* and *H. moverleyi*). Two setae of the mandible setal row were present only in *H. robusta sensu* Sieg, *H. ulsana*, and *H. urashima*, while the other species contained only one seta on the mandible setal row.

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RESEARCH ARTICLE

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A new cave-dwelling species of *Deuteraphorura* from northern Italy (Collembola, Onychiuridae)

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Abstract

A new cave-dwelling species, *Deuteraphorura pieroluccii* **sp. n.**, is described from northern Italy. The size of adult specimens, number, and distribution of dorsal and ventral pseudocelli, and number of compound vesicles of the post antennal organ were used to distinguish it among other congeneric species.

Keywords

Chaetotaxy, Onychiuridae, springtails, taxonomy

Introduction

Several species of *Deuteraphorura* have been recently described, or re-described (Gruia and Popa 2005, Dallai and Fanciulli 2009, Fanciulli et al. 2010, Jordana et al. 2012, Weiner and Fiera 2014, Arbea and Park 2015, Parimuchová and Kováč 2016, Arbea 2017), updating the total number of the species of the genus to 83 (Bellinger et al. 1996–2017). The defining characters of the genus *Deuteraphorura* appear to be well-established due to the revision carried out by Weiner (1996) and Pomorski (1998), and to the introduction of some updated systematic keys (Jordana et al. 2012; Weiner and Fiera 2014). The Italian fauna of *Deuteraphorura* includes 16 species both from caves and open habitats (Fanciulli et al. 2010), with most of them being endemic along the Italian peninsula. In the present paper, a new cave-dwelling species of *Deuteraphorura* is described from northern Italy; furthermore, an updated key of the species recorded on the Italian peninsula is proposed. The new species was already reported as *Deuteraphorura* sp. in Fabbri and Poletti (2015).

Materials and methods

Specimens of *Deuteraphorura pieroluccii* sp. n. were collected by hand inside the caves “Abisso Luigi Fantini” and “Buco del Noce” located very close to each other in the Messinian gypsum outcrops of the Vena del Gesso Romagnola (Brisighella, Ravenna Province, northern Italy) and preserved in 75% alcohol, until their preparation. The two caves both have small entrances. Abisso Luigi Fantini Cave (cave code ER RA 121; 44°13'23.08"N; 11°44'31.84"E) has an entrance at 426 m asl, spatial development of 1500 m and elevation difference of 117 m. Buco del Noce Cave (cave code ER RA 107; 44°13'34.68"N, 11°45'39.61"E) has entrance at 233 m asl, spatial development of 384 m and elevation difference of 43 m (Gruppo Speleologico Faentino & Speleo GAM Mezzano 2015). The specimens were subsequently cleared with lactic acid and mounted on slides with Gisin and Marc Andrè II solutions. Observations were performed with a Leitz Laborlux S microscope equipped with a camera lucida. In the description, the nomenclature proposed by Weiner (1996), Pomorski (1998), Jordana et al. (1997, 2012), and Fjellberg (1999) were considered in addition to the latest descriptions of Fanciulli et al. (2010) and Weiner and Fiera (2014). Pseudocellar formulae correspond to the number of pseudocelli per half-tergum/ half-sternum.

Abbreviation used in the text

Th	thoracic segment,
Abd	abdominal segment,
Ant	antennal segment,
AOIII	sensory organ of antennal III segment,
ms	microsensillum,
PAO	postantennal organ,
pso	pseudocellus,
VT	ventral tube,
d0	unpaired chaeta on area frontalis of the head,
p0	unpaired chaeta on abdominal terga IV and VI.

Taxonomy

Deuteraphorura pieroluccii **sp. n.**
http://zoobank.org/A8250415-1C64-4F4D-A120-EC8F2DE9913F
Figs 1–3, Tables 1–4

Material examined. Holotype female, Italy, Ravenna Province, near the locality Brisighella, Rontana Mount, 426 m asl, “Abisso Luigi Fantini” Cave (cave code ER RA

121; 44°13'23.08"N, 11°44'31.84"E), hand collected, 15 October 2013, leg. Poletti, Fabbri & Turri.

Paratypes: Abisso Luigi Fantini Cave, 1 female hand collected, 5 December 2013; Ravenna Province, Brisighella, locality of Monticino, 233 m asl, “Buco del Noce” Cave (cave code ER RA 107; 44°13'34. 68"N, 11°45'39.61"E), 4 females hand collected, 18 September 2013, leg. Poletti, Fabbri & Turri.

Holotype and five paratypes (all females) are deposited in the collembolan collection of the Department of Life Sciences, University of Siena.

Diagnosis. Mean body length 2.7 mm. Pso formula dorsally: 32/033/33353; ventrally: 3/011/3212. Subcoxae I-III with 2 pso. AOIII made of five papillae, five guard chaetae, two small rods, two ribbed sensory clubs, and 1 ms. PAO with 21–22 compound vesicles, unpaired d0 chaeta present on the head. Abd. IV and VI with unpaired p0 chaeta. Without anal spines.

Description. Average length 2.7 mm (2.4–3.1mm), body shape cylindrical with fine and uniform cuticle granulation. Colour in alcohol white. Length of Ants I, II, III and IV 65 µm, 120 µm, 130 µm and 170 µm, respectively. Antennae shorter than head (Ant/head diagonal ratio = 0.8). Area antennalis clearly -marked. Ant. IV with sub-apical organite and one ms at its base in ventro-lateral position. Sensilla on Ant. IV not clearly distinguishable from ordinary chaetae (Fig. 2B). Ant. I, II and III with 8–9, 13–14, and 18–19 chaetae, respectively (Fig. 2A). AOIII consisting of two ribbed sensory organs, two sensory rods, five papillae and five guard chaetae (Fig. 2D). Ms on Ant. III in ventro-lateral position below the level of the last guard chaeta of AOIII (Fig. 2A). PAO consists of 21–22 compound vesicles arranged in two parallel rows (Fig. 1G). Labrum with 5/4/2 chaetae as in Fig. 1C; labium (submentum) with 4 + 4 chaetae (Fig. 1E), basolateral field (mentum) with five chaetae; maxillary outer lobe with one basal chaeta and two sub-lobal hairs (Fig. 1F). Labial palp of AB type according to Fjellberg (1999) with six proximal chaetae; labial papillae A, B, C, D, and E with 1, 4, 0, 3, and 3 chaetae respectively (Fig. 1D), 6+6 postlabial setae along the ventral groove. Mandibles with strong molar plate and four apical teeth, jaws not clearly distinguishable in the preparations. VT with 8–9 + 8–9 abdominal lateral chaetae, without basal chaeta (Fig. 3D). Body chaetae differentiated into meso- and macrochaetae; Th.II – III with lateral ms. Dorsal chaetotaxy as in Fig. 1A, Tables 1–3. Dorsal cephalic chaeta d0 present (Fig. 1A). Abd. IV and V with p0 chaeta; anal spines absent. Extra chaetae and both left and right asymmetries have been observed. M/s ratio = 3.57 on Adb. V. Thoracic sterna without ventral chaetae. Ventral chaetotaxy of head and abdomen as in Fig. 1C, B. Furca reduced to a small papilla with 2 + 2 chaetae. Female genital plate with 25–27 chaetae (Fig. 3D). Tibiotarsi I, II and III with 18, 18, and 17 chaetae respectively; distal whorl with nine chaetae (Fig. 3B). Claw not elongated, without inner tooth; slender empodial appendage, without inner basal lamella, reaching 9/10 of the inner edge of the claw (Fig. 3B). Each subcoxa, coxa, trochanter, and femur with 5, 14–15, 7–9, and 12–15 chaetae respectively (Fig. 3A). Pso formula dorsally: 32/033/33353; ventrally: 3/011/3212; Subcoxae with two pso each. Parapseudocelli on sterna and femora weakly visible.

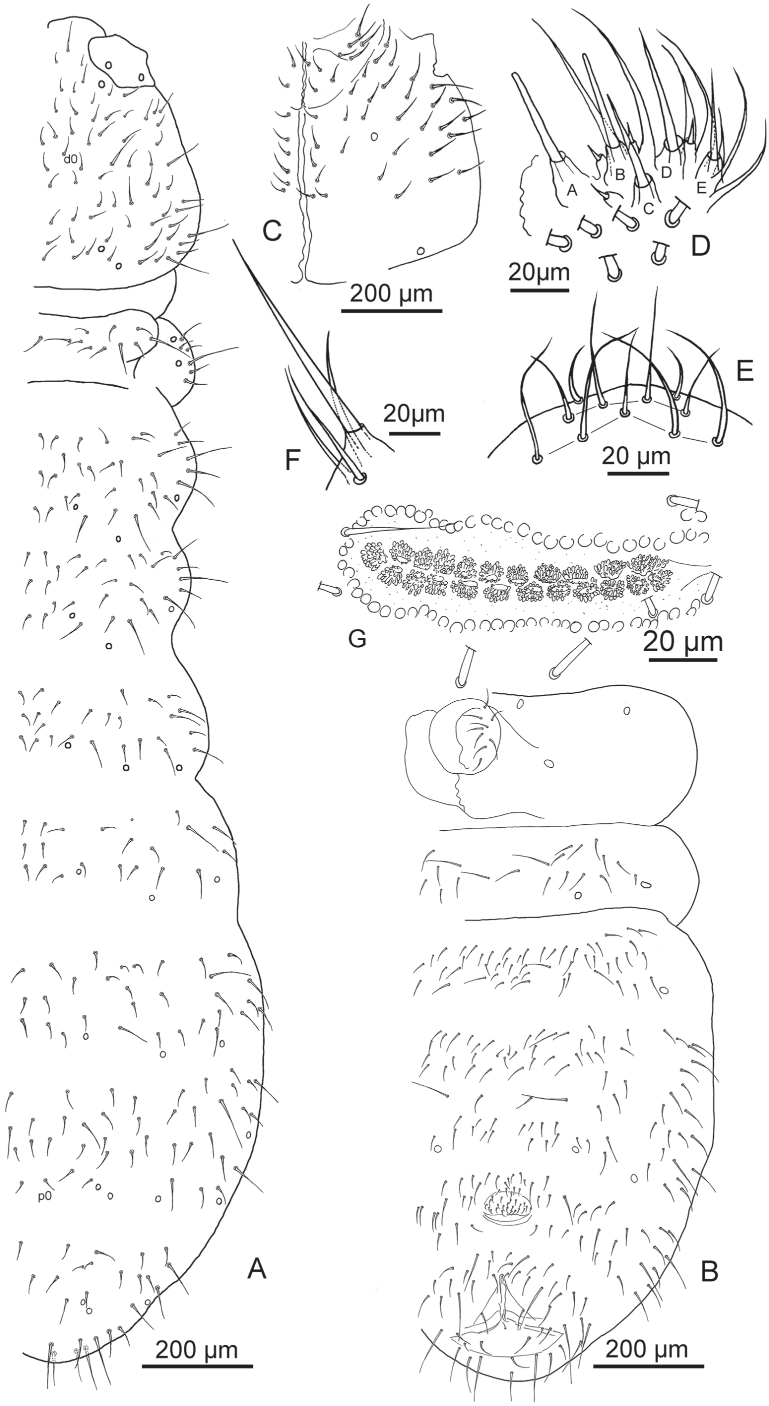

Figure 1. *Deuteraphorura pieroluccii* sp. n. **A** dorsal chaetotaxy **B** ventral chaetotaxy of the abdomen **C** ventral chaetotaxy of the head **D** chaetotaxy of the labial palp **E** chaetotaxy of the labrum **F** maxillary outer lobe **G** PAO.

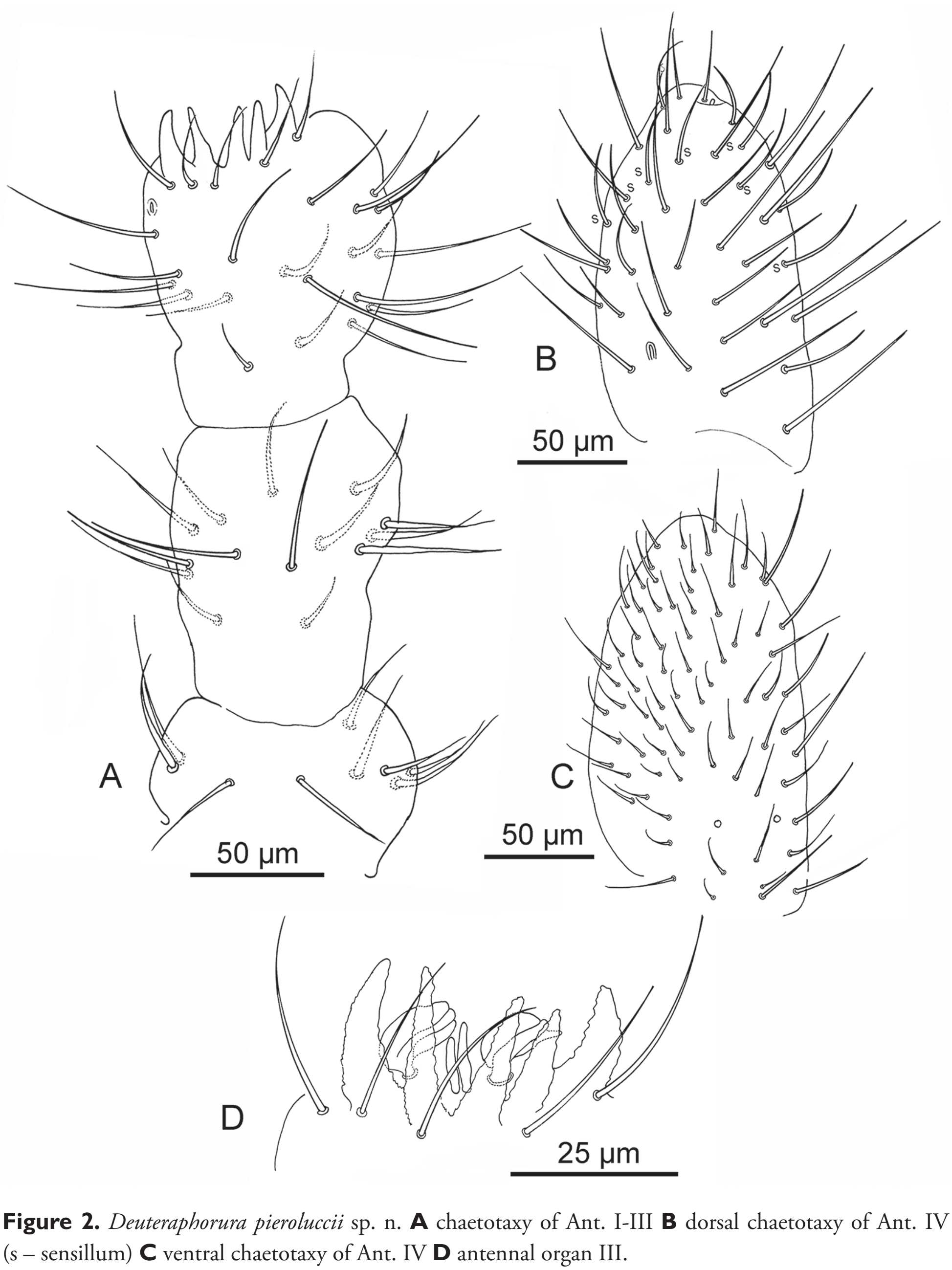

Figure 2. *Deuteraphorura pieroluccii* sp. n. **A** chaetotaxy of Ant. I-III **B** dorsal chaetotaxy of Ant. IV (s – sensillum) **C** ventral chaetotaxy of Ant. IV **D** antennal organ III.

Etymology. The species name is derived from Piero Lucci, former President of the Speleological Federation of Emilia-Romagna Region and current President of Speleo GAM Mezzano Caving Club. He was the coordinator of the speleological research project framework in which the new species was found.

Table 1. *Deuteraphorura pieroluccii* sp. n. Dorsal chaetotaxy of the head. Abbreviations: m micro-mesochaetae; M macrochaetae.

row	
d	m0, m1, m2, m3, m4
sd	m1, m2, m3, m3’, m4, M5
sd’	m1, M2, m3, m4
v	m1, m2, m3, M4
ca	M5
cm	m3, m4
cb	m1, m2, m5, m6
cp	m1, m4, m6
p	m1, m2, m3, m4, m5
g	approx. 10 chaetae.

Table 2. *Deuteraphorura pieroluccii* sp. n. Dorsal chaetotaxy of the thorax. Abbreviations: m micro-mesochaetae; M macrochaetae;* – sometimes absent; ● – variable in length.

row	**Thorax I**	**Thorax II**	**Thorax III**
a	m2, m4, m6	m2, m4, m5, m6, M7	m2, m3, m4, m5, m6, M7
m		m1, m2, m3*, m4 (m4’), M6●, M7	m1, m2, m3, m4, M6●, M7●
ca		m5, m6, M7	m5, M7
cp		m1, m2, m4, m6, M7	m1, m2, m4, m5, M7
p	M1, m2, m3, m4, M5, m6, M7	m1, m2, M3, m4, M5, m6, m7	m1, m2, M3, m4, M5, m6 (m6’), M7

Table 3. *Deuteraphorura pieroluccii* sp. n. Dorsal chaetotaxy of the abdomen. Abbreviations: m micro-mesochaetae; M macrochaetae; * – sometimes absent.

row	**Abdomen I**	**Abdomen II**	**Abdomen III**
a	m1, m2, m5, m6, m7	m1, m2, m4, m5*, m6, m7	m3, m5, m7
m	m1, m2, m3, M7	m1, m2*, m4, M7	m1, m2, m4, m5, M7, M8
ca	m4, m5, M7	m5, M7	m1, m4, M7, m8
p	m1, m2, m3, M4, m5, m6, M7	m1, m2, m3, M4, m5, M6, M7	m1, m2, m3, M4, m4’, m5, m6, M7, m8
row	**Abdomen IV**	**Abdomen V**	**Abdomen VI**
a	m1, m3, m4, m5, m6, m7, M8		
m	m1, M2, m3, m4, m5, m6, M7, m8	m2, m3, m5, m6, M7	
ca	m1, m2, m3, m4, m5, m6, m7	m2, m3, m4, m5	
p	m0, m1, m3, M5, m6, m7, M8	m1, m2, m3s, M5, m6, M7	M0, m1, M2, m3, m4

Ecology. The new species does not show particular morphological adaptations to the cave life; the claws, as well as the legs, the antennae and their sensillae are of normal shape, not elongated as is usually observed in the troglobitic species. However, to

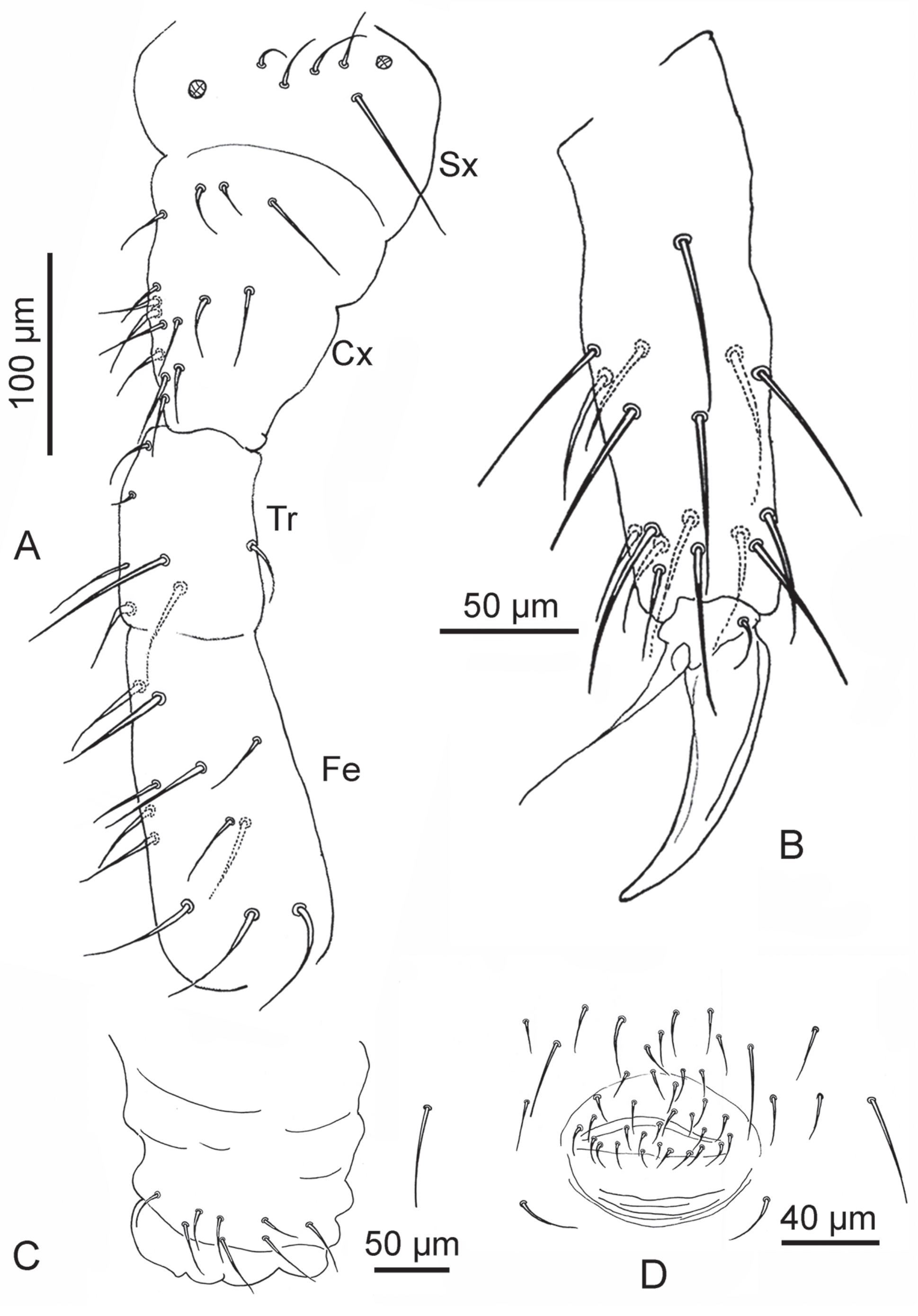

Figure 3. *Deuteraphorura pieroluccii* sp. n. **A** chaetotaxy of leg III from subcoxae to femur (Sx – subcoxae; Cx – coxae; Tr – trochanter; Fe – femur) **B** tibiotarsus III **C** ventral tube **D** female genital opening.

Table 4. Diagnostic characters between *D. pieroluccii* sp. n *and D. frasassii.*

Species	Body lenght	PAO compound vesicles	Setae tibiotarsi I-III	Postlabial setae ventral groove	Coxae	Ventral tube	Th. I
D. frasassii	1.6 mm	16–17	17,18,18	4+4	10–12	6–7	p3, p6 absent
D. pieroluccii sp. n.	2,7 mm	21–22	18,18,17	6+6	14–15	8–9	p3, p6 present
Species	**Th. II**	**Th. III**	**Abd. I**	**Abd. II**	**Abd. III**	**Abd. IV**	**Abd. V**
D. frasassii	m3 absent	m3 absent	m3 absent	a4 absent	m5, ca1 absent	a4, ca1, ca2 absent. p2 present	m3, ca2, ca3 absent
D. pieroluccii sp. n.	m3 sometimes absent	m3 present	m3 present	a4 present	m5, ca1 present	a4, ca1, ca2 present. p2 absent	m3, ca2, ca3 present

define whether or not a species is a true troglobitic species many other aspects of their biology and ecophysiology should be considered (Thibaud 1986), which at the moment cannot be ascertained. Specimens were collected in the two caves on winter bat guano in the internal part of the cave (aphotic with stable conditions). The quantity of guano in the caves is significant and is laid from more than one species of Chiroptera. *Deuteraphorura pieroluccii* sp. n. is to be considered as a guanobic element. The type locality of the new species is approximately 135 km from the type locality of *D. frasassii* (Fanciulli, 1999) (Frasassi Caves, Ancona, Italy).

Discussion. The new species belongs to the group of *Deuteraphorura* without pseudocelli on the Th. I tergum. This character is typical of several *Deuteraphorura* species included in the updated identification key proposed by Weiner and Fiera (2014). Six species possess the same dorsal pso formula as *Deuteraphorura pieroluccii* sp. n. (32/033/33353): *D. bosnaria* (Gisin, 1964), *D. frasassii* (Fanciulli, 1999), *D. ossaria* (Gisin, 1964), *D. scotaria* (Gisin, 1954), *D. silesiaca* (Dunger, 1977), and *D. dianae* Weiner & Fiera, 2014. However, five of them differ from the new species by their ventral pso formulae: *D. bosnaria* 3/022/3212; *D. ossaria* 3/022/3222; *S. scotaria* 2/022/2212; *D. silesiaca* 2/011/1212; *D. dianae* 3/011/3112. *Deuteraphorura caprelleana* Fanciulli et al., 2010 and *D. pseudobosnaria* (Dallai, 1970) are similar to new species in their ventral pso formulae (3/011/3212), but differ in the dorsal pso formulae (*D. caprelleana*: 32/033/33354; *D. pseudobosnaria*: 33/033/33353). The dorsal and ventral pso formulae of the new species correspond to *D. frasassii* (Fanciulli, 1999) which may be distinguished by body size (2.6–3.1 mm in *Deuteraphorura pieroluccii* sp. n. vs. 1.3–1.6 mm in *D. frasassii*), number of distal chaetae on ventral tube (8–9 + 8–9 in *Deuteraphorura pieroluccii* sp. n. vs. 6–7 + 6–7 in *D. frasassii*), number of postlabial setae along the ventral groove (6+6 in *Deuteraphorura pieroluccii* sp. n. vs 4+4 in *D. frasassii*), and the number of compound vesicles in PAO (21–22 in the new species vs. 16–17 in *D. frasassii*). Further differences, especially in the dorsal chaetotaxy, between the two species are summarised in Table 4.

Key to the Italian species of *Deuteraphorura* (based on dorsal and ventral formulae of pseudocelli; modified from Fanciulli et al. 2010)

1 Th. I without pso **2**

– Th. I with 1+1 pso **10**

2 Hind margin of the head with 3+3 pso **3**

– Hind margin of the head with 2+2 pso **4**

3 Abd. I–IV ventrally with 3212, Abd. IV with chaeta p4 .... ***D. pseudobosnaria* (Dallai)**

– Abd. I–IV ventrally with 1212, Abd. tergum IV without chaeta p4 .... ***D. apuanica* (Dallai)**

4 Abd. I with 5+5 .... ***D. spipolae* (Massera)**

– Abd. I with 3+3 pso **5**

5 Abd. V with 3+3 pso **6**

– Abd. V with 4+4 pso **8**

6 Abd. I–IV ventrally with 2212, PAO with 18–20 compound vesicles, body length 1.8–2.5 mm .... ***D. banii* Dallai & Fanciulli**

– Abd. I–IV ventrally with 3212 .... **7**

7 PAO with 16–17 compound vesicles, body length 1.3–1.4 mm .... ***D. frasassii* (Fanciulli)**

– PAO with 21–22 compound vesicles, body length 2.6–3.1 mm .... ***D. pieroluccii* sp. n.**

8 Head ventrally with 2+2 pso .... ***D. ghidinii* (Denis)**

– Head ventrally with 3+3 pso **9**

9 Abd. I–IV ventrally with 3212, body length 2,4–2,6 mm, PAO with 19–21 compound vesicles, Abd. IV without Ca0 chaeta .... ***D. caprelleana* Fanciulli, Loreti & Dallai**

– Abd. I–IV ventrally with 2212, body length 1,41–1,85 mm, PAO with 14–16 compound vesicles, Abd. IV with Ca0 chaeta .... ***D. pseudoghidinii* (Dallai)**

10 Abd. V ventrally with 3+3 pso **11**

– Abd. V ventrally with 4+4 pso **13**

11 Head ventrally with 2+2 pso .... ***D. eduardi* (Denis)**

– Head ventrally with 3+3 pso **12**

12 Abd. I–IV ventrally with 3222 .... ***D. silvaria* (Gisin)**

– Abd. I–IV ventrally with 1212 .... ***D. pseudoinsubraria* (Dallai)**

13 Head ventrally with 2+2 pso **14**

– Head ventrally with 3+3 pso **15**

14 Pso ventrally as 2/000/2212, PAO with 20 compound vesicles .... ***D. bergamaria* (Gisin)**

– Pso ventrally as 2/011/1212, PAO with 15 compound vesicles .... ***D. defensaria* (Gisin)**

15 Pso ventrally as 3/011/2212 .... **16**

– Pso ventrally as 3/011/3212 .... ***D. cebennaria* (Gisin)**

16 Posterior part of Abd. V with only one macrochaeta positioned laterally to the most lateral pso .... ***D. imperfecta* (Denis)**

– Posterior part of Abd. V with two macrochaetae, one between pso a, other laterally to pso d .... ***D. dunaria* (Gisin)**

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Paravietnura gen. n., a new intriguing genus of Neanurini from the Caucasus (Collembola, Neanuridae, Neanurinae)

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Abstract

Paravietnura **gen. n.** is described and established for two new species of Neanurini from the Caucasus. The new genus is characterized by an unusual combination of features: the fusion of all lateral tubercles on the head into a single mass, the strong reduction of chaetae on the head, the fusion of cephalic tubercles Af and Oc into a transverse band, the absence of labial chaetae f, the presence of microchaetae on furca rudimentary, and the penultimate abdominal tergum with two tubercles separated along the midline. *Paravietnura* **gen. n.** strongly resembles *Vietnura* Deharveng & Bedos, 2000, a monotypic genus up to date known only from Vietnam. The main characteristics of *Paravietnura notabilis* **sp. n.** include an ogival labrum, the absence of chaetae A on the head, relatively thick and widely sheathed long macrochaetae, and minute microchaetae without chaetopores on furca rudimentary. *Paravietnura insolita* **sp. n.** differs from the previous species in chaetotaxic details, the size of furcal microchaetae, and the shape of the labrum. Short comments on the generic diversity of the tribe in the Western Palaearctic are also provided.

Keywords

Paravietnura notabilis sp. n., *Paravietnura insolita* sp. n., Russia, springtails, taxonomy

Introduction

The subfamily Neanurinae, with more than 800 recognized species, is certainly one of the richest and most diversified taxa among springtails (Collembola). It is also one of the most recognizable ones within Collembola as its members possess very characteristic cuticular tubercles on the dorsal side of the body and completely lack the furca, the organ typical for most described springtails. Regarding the taxonomy of Neanurinae, all species are classified into six established tribes (Cassagnau 1989). Among them, Neanurini is the second largest, after Paleonurini, with over 170 species belonging to 23 genera (Cassagnau 1989, Hopkin 1997, Deharveng and Bedos 2000, Deharveng et al. 2007, Smolis 2007, 2011, Mayvan et al. 2015). The number of eyes, the shape of mandibles, as well as the number and arrangement of tubercles on the body are typically used to separate the genera within the tribe. In the lateral part of the head, for instance, there are four main types of tubercle arrangements. The commonest situation is with lateral tubercles L and So fused but tubercle Dl separate. In turn, a complete fusion of all lateral tubercles seems to be the rarest option, only observed in two species of Neanurini, *Vietnura caerulea* Deharveng & Bedos, 2000, and *Monobella cassagnaui* Deharveng, 1981.

The examination of rich Neanurinae materials from the north-western Caucasus has revealed two unknown species. They belong to the mentioned tribe because of a presence of blue hypodermic pigment, the last abdominal segment bilobed and well developed tubercles on the body. Interestingly, both the undescribed taxa are characterized by the complete fusion of the outlined cuticular structures on the lateral part of head. This and other features of these species support proposal of a new genus within the tribe. Its detailed and illustrated description is provided with comments on the present stage of knowledge on Neanurini diversity in the Western Palaearctic region.

Terminology

Terminology for the description follows that of Deharveng (1983), with rationale for the definition of chaetae categories), Deharveng and Weiner (1984), Smolis and Deharveng (2006) and Smolis (2008).

Abbreviations used

General morphology:

Abd	abdomen,	**Scx2**	subcoxa 2,
Ant	antenna,	**T**	tibiotarsus,
AOIII	sensory organ of antennal segment III,	**Th**	thorax,
Cx	coxa,	**Tr**	trochanter,
Fe	femur,	**VT**	ventral tube.

Groups of chaetae on body excluding antennae:

Ag	antegenital,
An	chaetae of anal lobes,
Fu	furcal,
Ve	ventroexternal,
Vea	ventroexternoanterior,
Vem	ventroexternomedial,
Vep	ventroexteroposterior,
Vel	ventroexternolateral,
Vec	ventroexternocentral,
Vei	ventroexternointernal,
Vi	ventrointernal,
Vl	ventrolateral.

Groups of chaetae on antennae:

ap	apical,
ca	centroapical,
cm	centromedial,
cp	centroposterior,
d	dorsal,
vc	ventrocentral,
ve	ventroexternal,
vi	ventrointernal.

Tubercles:

Af	antenno–frontal,
Cl	clypeal,
De	dorsoexternal,
Di	dorsointernal,
Dl	dorsolateral,
L	lateral,
Oc	ocular,
So	subocular.

Types of chaetae:

Ml	long macrochaeta,
Mc	short macrochaeta,
Mcc	very short macrochaeta,
me	mesochaeta,
mi	microchaeta,
ms	s–microchaeta,
S or **s**	chaeta s,
bs	s–chaeta on Ant. IV,
miA	microchaetae on Ant. IV,
iv	ordinary chaetae on ventral Ant. IV,
or	organite of Ant IV,
brs	border s–chaeta on Ant. IV,
i	ordinary chaeta on Ant. IV,
mou	cylindrical s–chaetae on Ant. IV (“soies mousses”),
x	labial papilla x,
L’	ordinary lateral chaeta on Abd. V,
B4, B5	ordinary chaetae on tibiotarsi,
sgv	s–chaeta on Ant. III.

Materials and methods

The specimens were cleared in Nesbitt’s fluid, subsequently mounted on slides in Phoera liquid and studied using a Nikon Eclipse E600 phase contrast microscope. Figures were drawn with camera lucida and prepared for publication using Adobe Photoshop CS3.

Institutions of depository of materials:

DIBEC	Department of Invertebrate Biology, Evolution and Conservation, Institute of Environmental Biology, University of Wrocław, Poland.
MSPU	Moscow State Pedagogical University, Institute of Biology and Chemistry, Moscow, Russia.

Taxonomy

Paravietnura gen. n.

http://zoobank.org/0785483E-E218-48BB-8DD9-19BAEE8E6D0A

Type species. *Paravietnura notabilis* sp. n. (here designated).

Diagnosis. Blue pigment present on the body. Tubercles on body well developed, free chaetae on abdomen absent. Two pigmented eyes on each side of head. Mouth parts reduced, maxilla styliform, mandible thin and tridentate. Six tubercles on head, with Dl fused to (L + So), Af fused to Oc, and Di fused to De. Chaetotaxy of head strongly reduced, with chaetae C, D, E, Oca, Di2 and De2 absent. Labrum with four or two prelabral chaetae. Labial chaetae f absent. Tubercles (Di+De+Dl) on Abd. V separate along midline. Cryptopygy present as Abd. VI poorly visible from dorsal side. Claw untoothed.

Etymology. The name "*Paravietnura*" refers to its strong similarity to *Vietnura*.

Remarks. The following characters: the presence of 2+2 eyes, the fusion of all lateral tubercles into a single mass on the head, the fusion of cephalic tubercles Af and Oc into a transverse band, the absence of cephalic chaetae Di2 and De2 and the presence of strong cryptopygy place *Paravietnura* gen. n. very close to *Vietnura*, the genus established by Deharveng and Bedos (2000) for a single Vietnamese species, *V. caerulea* Deharveng & Bedos, 2000. As both these genera are distributed in separate biogeographical regions, *Paravietnura* gen. n. in the Western Palaearctic and *Vietnura* in the Oriental region, it is recognized that this similarity is probably the result of convergence. Furthermore, they differ in a few essential characters, important from the taxonomic point of view: presence/absence of cephalic chaetae Ocp (in *Paravietnura* gen. n. present, in *Vietnura* absent), presence/absence of labial chaetae f (absent in *Paravietnura* gen. n., Figs 18, 19; present in *Vietnura*, Fig. 21), the number of tubercles on Abd. V (two tubercles (Di+De+Dl) in *Paravietnura* gen. n.; three tubercles: 2 (De+Dl) and (Di+Di) in *Vietnura*), and presence/absence of microchaetae on furca rudimentary (present in *Paravietnura* gen. n.; absent in *Vietnura*).

Because of the fusion of lateral tubercles on head, *Paravietnura* gen. n. resembles *Monobella cassagnaui* Deharveng, 1981, the species belonging to the European genus *Monobella* Cassagnau, 1979. Nevertheless, this similarity seems to be definitely superficial given the fact that *M. cassagnaui* differs from *Paravietnura* gen. n. in a number of characters e.g.: fusion of tubercles (Di+De) on head along midline (separate in *Paravi-*

etnura gen. n.), presence of chaetae Di2 and De2 on head (absent in *Paravietnura* gen. n.), fusion of tubercles Di and De on Th. II–III and Abd. I–II (separate in *Paravietnura* gen. n.), fusion of tubercles Di on Abd. III along midline (separate in *Paravietnura* gen. n.) and presence of one tubercle (2Di+2De+2Dl) on Abd. V (two tubercles (Di+De+Dl) in *Paravietnura* gen. n.).

***Paravietnura notabilis* sp. n.**

http://zoobank.org/62DA9C9D-CFE3-495C-BC51-CBDE1DC22BF9
Figs 1–8, 19, 20 Table 1, 2, 3

Type material. Holotype: female on slide, Russia, NW Caucasus, Adygeya, Caucasus Nature Reserve, Lagonaki Plateau (‘Kamennoye More’ ridge), 1843 m.alt., litter of rocky pine forest with birch, N44.06159° E40.02103°, 03.07.2014, leg. M. Potapov, N. Kuznetsova, A. Kremenitsa 2014, leg. (MSPU). Paratype: juvenile on slide, ibid., southern slope, 1847 m alt., mixed forest (pine, birch), coniferous litter, N44.06096° E40.02112°, 21.07.2015, leg. M. Potapov, N. Kuznetsova, A. Kremenitsa, L.Vanyavina (DIBEC).

Etymology. The name reflects the notable morphology of this new generotype species.

Diagnosis. Body stumpy and relatively short. Macrochaetae long, thick and widely sheathed. Buccal cone long, labrum ogival. Labrum with two prelabral chaetae. Tubercle (Af +2Oc) on head with chaetae B, Ocm and Ocp, chaetae A absent. Tubercles (Dl+L+So) on head with ten chaetae, chaetae So2 absent. Furca rudimentary with minute and difficult to detect microchaetae, without chaetopores.

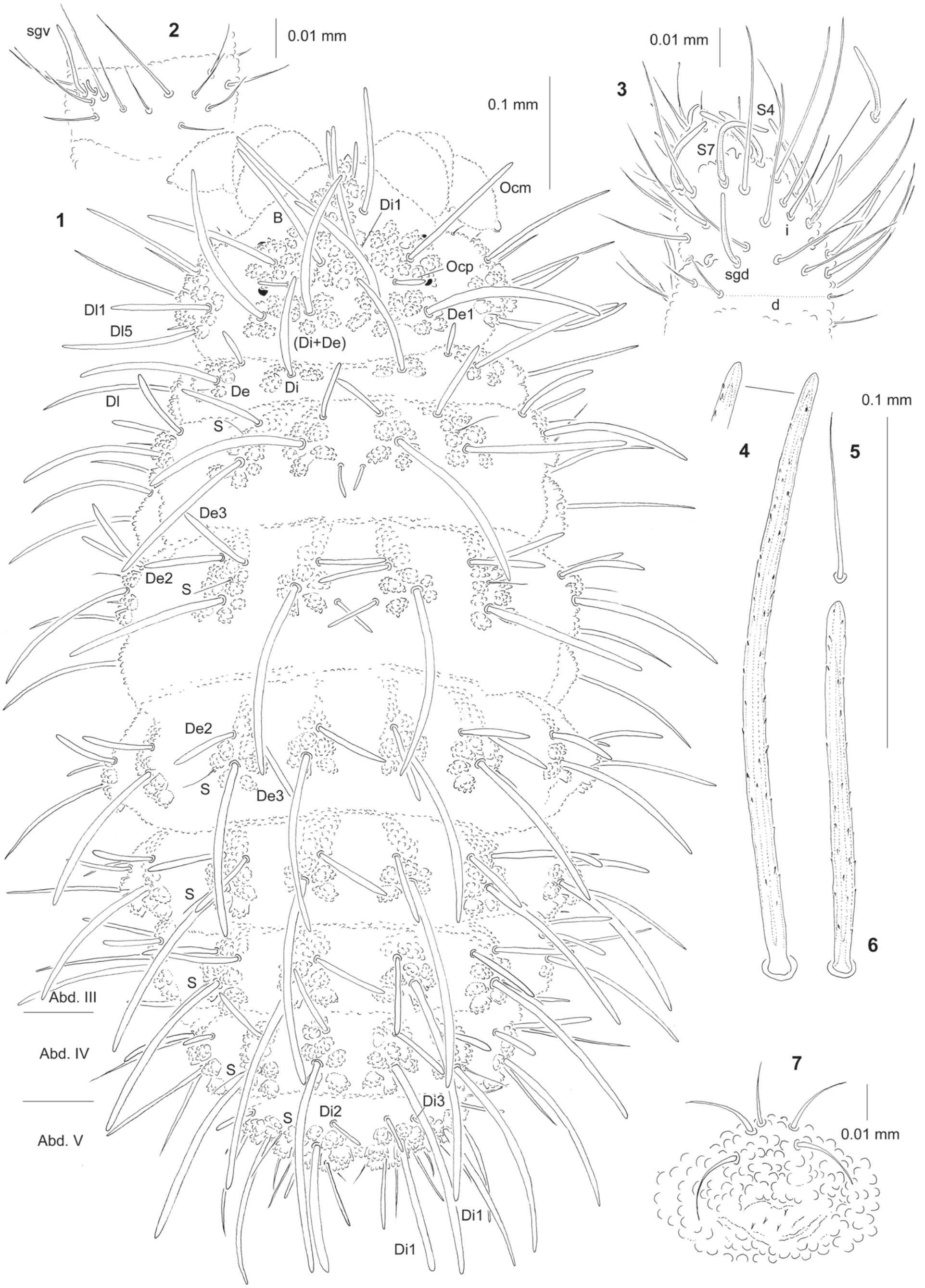
Description. *General.* Body length (without antennae): 0.55 (juvenile) to 0.85 mm (holotype). Colour of the body bluish. 2+2 black eyes of medium size (Fig. 1).

Chaetal morphology. Dorsal ordinary chaetae of four types: long macrochaetae (Ml), short macrochaetae (Mc), very short macrochaetae (Mcc) and mesochaetae. Long macrochaetae of large length (distinctly longer than length of segment), thick, slightly arc-like or straight, widely sheathed, strongly serrated and apically rounded (Figs 1, 4, 6). Macrochaetae Mc and Mcc morphologically similar to long macrochaetae, but much shorter. Mesochaetae similar to ventral chaetae, thin, smooth and pointed. S–chaetae of tergites thin, smooth, and very short, from three to six times shorter than nearby macrochaetae (Figs 1, 5).

Antennae. Dorsal chaetotaxy of Ant. III–IV as Fig. 3 and Table 2. S–chaetae of Ant. IV long and moderately thickened, S4 and S7 slightly longer than others (Fig. 3). Apical vesicle distinctly bilobed. Ventral chaetotaxy of Ant. III as Fig. 2 and Table 2, sensillum sgv notably long and s-shaped.

Mouthparts. Buccal cone particularly long with labral sclerifications ogival (Fig. 20). Labrum chaetotaxy: 2/2, 4. Labium with three basal, three distal, and three lateral chaetae, papillae x absent (Fig. 19). Maxilla styliform, mandible thin and tridentate.

Dorsal chaetotaxy and tubercles. Chaetotaxy of head as Fig. 1 and Table 1. Chaetotaxy of Th. and Abd. as Table 3. Thorax and abdomen with chaetae De2 and De3 not free



Figures 1–7. *Paravietnura notabilis* sp. n.: **1** habitus and dorsal chaetotaxy (holotype) **2** ventral chaetotaxy of Ant. III **3** dorsal chaetotaxy of Ant. III–IV **4** chaeta Di1 of Abd. IV **5** sensillum of Abd. V **6** chaeta Di1 of Abd. V **7** furca rudimentary.

Table 1. Cephalic chaetotaxy of *Paravietnura notabilis* sp. n., dorsal side.

Tubercle	Number of chaetae	Types of chaetae	Names of chaetae
Cl	4	Ml	F
		Mc	G
(Af+2Oc)	6	Ml	B, Ocm
		Mc	Ocp
(Di+De)	2	Ml	Di1, De1
(Dl+L+So)	10	Ml	Dl1, Dl5, L1, So1
		Mc	L4
		Mcc	Dl4
		me	So3–6

Table 2. Antennal chaetotaxy of *Paravietnura notabilis* sp. n.

Segment, Group	Number of chaetae	Segment, Group	Number of chaetae adult
I	7	IV	or, 8 S, i, 12 mou, 6 brs, 2 iv
II	11		
III	5 sensilla AO III		
ve	5	ap	8 bs, 5 miA
vc	4	ca	2 bs, 3 miA
vi	4	cm	3 bs, 1 miA
d	4	cp	8 miA, 1 brs

Table 3. Postcephalic chaetotaxy of *Paravietnura notabilis* sp. n.

Terga					Legs				
	Di	**De**	**Dl**	**L**	**Scx2**	**Cx**	**Tr**	**Fe**	**T**
Th. I	1	2	1	-	0	3	6	13	19
Th. II	3	2+s	3+s+ms	3	2	7	6	12	19
Th. III	3	3+s	3+s	3	2	8	6	11	18
					Sterna				
Abd. I	2	3+s	2	3	VT: 4				
Abd. II	2	3+s	2	3	Ve: 4; chaeta Ve1 absent				
Abd. III	2	3+s	2	3	Vel:4; Fu: 5 me, 4 mi				
Abd. IV	2	2+s	3	5	Vel: 4; Vec: 2; Vei: 2; Vl: 4				
Abd. V	6–7+s				Ag: 3; Vl: 1				
Abd. VI		7			Ve: 9–10; An: 2mi				

(Fig. 1). On Abd. I–III, the line of chaetae De1–chaeta s perpendicular to the dorsomedian line. On Abd. IV chaetae Di1 distinctly longer than on Abd. V (Figs 1, 4, 6). On Abd. V chaetae Di3 present or absent (Fig. 1). Cryptopygy present, strongly developed.

Ventral chaetotaxy. On head, groups Vea, Vem and Vep with 3, 2, 4 chaetae respectively. Group Vi on head with six chaetae. On Abd. IV, furca rudimentary with minute microchaetae (Fig. 7). On Abd. IV, tubercle L with five chaetae. On Abd. V, chaetae L' absent.

Figure 8. Rocky pine-birch forest in Caucasus Nature Reserve, type locality of *Paravietnura notabilis* sp. n.

Legs. Chaetotaxy of legs as in Table 3. Claw without internal tooth. On tibiotarsi, chaeta M present and chaetae B4 and B5 relatively short and pointed.

Remarks. See Remarks of *Paravietnura insolita* sp. n.

Ecological note. The new species seems to be very local and connected with specific climatic or vegetation conditions (rocky pine-birch forest, Fig. 8) since it has been never recorded outside *locus typicus* despite many investigations conducted in different parts of the Caucasus.

Paravietnura insolita **sp. n.**

http://zoobank.org/20AB2ACF-C891-4361-9EF7-87B68DB1B127
Figs 9–18, Table 4, 5, 6

Type material. Holotype: male on slide, Russia, Caucasus, Northern Ossetia, North Ossetia Nature Reserve, surroundings of the village Tsey, Kalpersky ridge, southern slope, 2160 m alt., litter of rocky pine grass forest, 19.8.1977, leg. M. Rudakovsky, N. Kuznetsova (MSPU). Paratype: male on slide, ibid., green moss pine forest, in mosses, 23.9.1980, leg. I. Kuchiev (DIBEC).

Etymology. Its name reflects a later discovery of another species within the genus (Latin word "*insolita*" means not lonely).

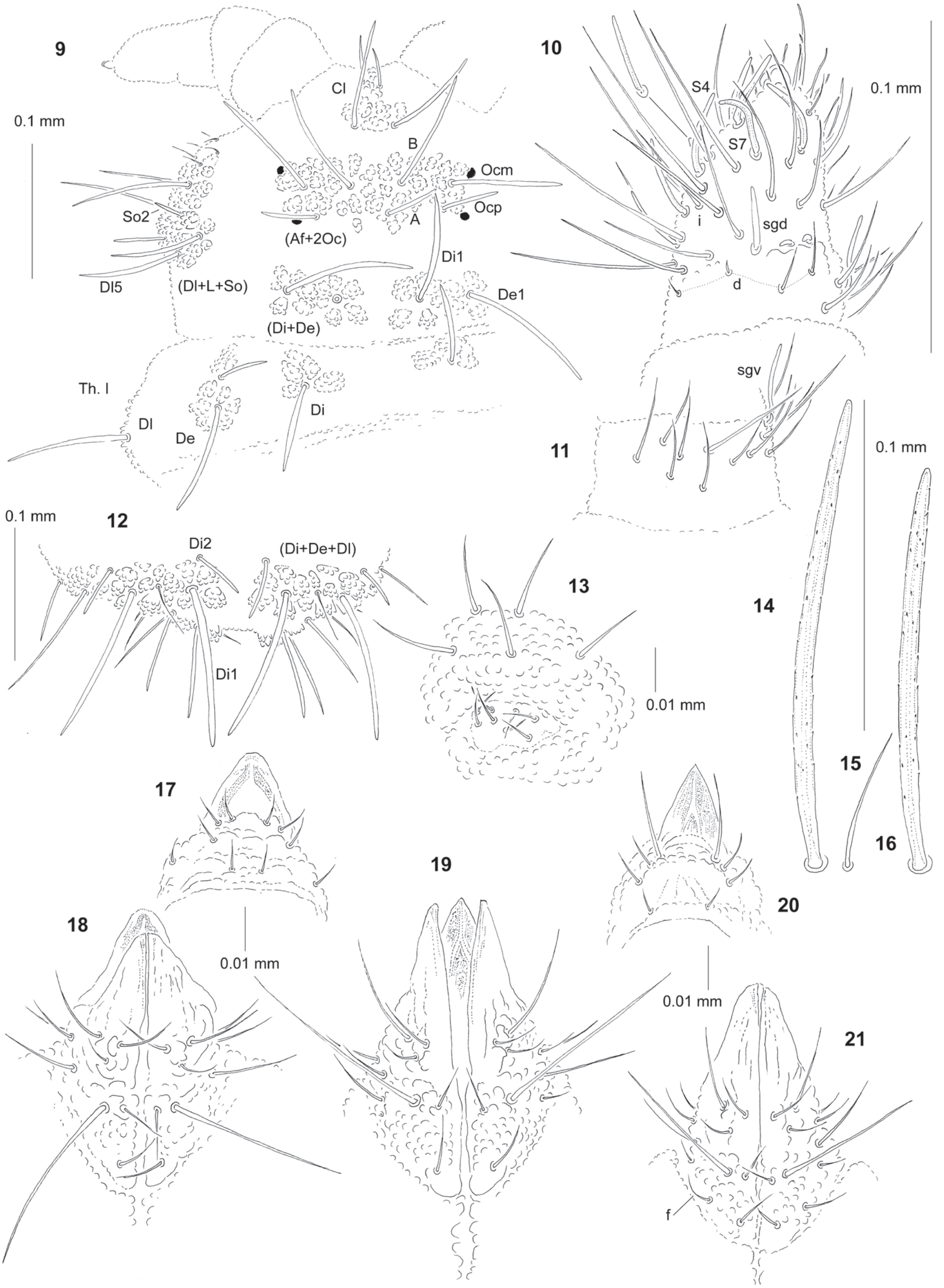
Diagnosis. Body relatively short and squarish. Macrochaetae long, relatively thin and narrowly sheathed. Buccal cone rather short, labrum non ogival. Labrum with four prelabral chaetae. Tubercle (Af +2Oc) on head with chaetae A, B, Ocm and Ocp. Tubercles (Dl+L+So) on head with eleven chaetae, chaetae So2 present. Furca rudimentary with well visible microchaetae, with chaetopores.

Description. *General.* Body length (without antennae): 1.10 (paratype) to 1.35 mm (holotype). Colour of the body bluish. 2+2 black eyes of medium size (Fig. 9).

Chaetal morphology. Dorsal ordinary chaetae of four types: long macrochaetae (Ml), short macrochaetae (Mc), very short macrochaetae (Mcc) and mesochaetae. Long macrochaetae of medium length (longer than length of segment), relatively thin, slightly arc-like or straight, narrowly sheathed, strongly serrated and apically rounded (Figs 9, 12, 14, 16). Macrochaetae Mc and Mcc morphologically similar to long macrochaetae, but much shorter. Mesochaetae similar to ventral chaetae, thin, smooth, and pointed. S–chaetae of tergites thin, smooth, and markedly short, three or four times shorter than nearby macrochaetae (Figs 12, 15).

Antennae. Dorsal chaetotaxy of Ant. III–IV as Fig. 10 and Table 5. S–chaetae of Ant. IV long and moderately thickened, S4 and S7 slightly longer than others (Fig. 10). Apical vesicle distinct bilobed. Ventral chaetotaxy of Ant. III as Fig. 11 and Table 5, sensillum sgv notably elongate and s-shaped.

Mouthparts. Buccal cone short with labral sclerifications non-ogival (Fig. 17). Labrum chaetotaxy: 4/2, 4. Labium with three basal, three distal and three lateral chaetae, papillae x absent (Fig. 18). Maxilla styliform, mandible thin and tridentate.



Figures 9–21. *Paravietnura insolita* sp. n.: **9** dorsal chaetotaxy of head and Th. I (holotype) **10** dorsal chaetotaxy of Ant. III–IV **11** ventral chaetotaxy of Ant. III **12** dorsal chaetotaxy of Abd. V–VI **13** furca rudimentary **14** chaeta Di1 of Abd. IV **15** chaeta Di1 of Abd. V **16** sensillum of Abd. V **17** labrum **18** labium. *Paravietnura notabilis* sp. n.: **19** labium **20** labrum. *Vietnura caerulea* Deharveng and Bedos, 2000: **21** labium.

Table 4. Cephalic chaetotaxy of *Paravietnura insolita* sp. n., dorsal side.

Tubercle	Number of chaetae	Types of chaetae	Names of chaetae
Cl	4	Ml Mc	F G
(Af+2Oc)	8	Ml Mc	B, Ocm A, Ocp
(Di+De)	2	Ml	Di1, De1
(Dl+L+So)	11	Ml Mc Mcc me	Dl, Dl5, L1, So1 L4 Dl4, So2 So3–6

Table 5. Antennal chaetotaxy of *Paravietnura insolita* sp. n.

Segment, Group	Number of chaetae	Segment, Group	Number of chaetae adult
I	7	IV ap	or, 8 S, i, 12 mou, 6 brs, 2 iv
II	11		
III ve	5 sensilla AO III		
	5		8 bs, 5 miA
vc	4	ca	2 bs, 3 miA
vi	4	cm	3 bs, 1 miA
d	4	cp	8 miA, 1 brs

Table 6. Postcephalic chaetotaxy of *Paravietnura insolita* sp. n.

	Terga				Legs				
	Di	**De**	**Dl**	**L**	**Scx2**	**Cx**	**Tr**	**Fe**	**T**
Th. I	1	2	1	-	0	3	6	13	19
Th. II	3	2+s	3+s+ms	3	2	7	6	12	19
Th. III	3	3+s	3+s	3	2	8	6	11	18
					Sterna				
Abd. I	2	3+s	2	3	VT: 4				
Abd. II	2	3+s	2	3	Ve: 5; chaeta Ve1 present				
Abd. III	2	3+s	2	3	Vel: 4; Fu: 5–6 me, 8 mi				
Abd. IV	2	2+s	3	5	Vel: 4; Vec: 2; Vei: 2; Vl: 4				
Abd. V	6+s				Ag: 2; Vl: 1, L‘: 1				
Abd. VI		7			Ve: 11–12; An: 2mi				

Dorsal chaetotaxy and tubercles. Chaetotaxy of head as Fig. 9 and Table 4. Chaetotaxy of Th. and Abd. as Table 6. Thorax and abdomen with chaetae De2 and De3 not free. On Abd. I–III, the line of chaetae De1–chaeta s perpendicular to the dorsomedian line. On Abd. IV chaetae Di1 longer than on Abd. V (Figs 14, 16). On Abd. V chaetae Di2 present and Di3 absent (Fig. 12). Cryptopygy present, well developed.

Ventral chaetotaxy. On head, groups Vea, Vem and Vep with 3, 2, 4 chaetae respectively. Group Vi on head with six chaetae. On Abd. IV, furca rudimentary with clearly visible microchaetae, each with chaetopore (Fig. 13). On Abd. IV, tubercle L with five chaetae. On Abd. V, chaetae L' present.

Legs. Chaetotaxy of legs as in Table 6. Claw without internal tooth. On tibiotarsi, chaeta M present and chaetae B4 and B5 relatively short and pointed.

Remarks. *Paravietnura insolita* sp. n. can be confused with the only other described species in the genus *Paravietnura notabilis* sp. n., which has thick and widely sheathed long macrochaetae (distinctly thinner and narrowly sheathed in *insolita*), an ogival labrum (non-ogival in *insolita*), chaetae A and So2 reduced on the head (present in *insolita*), chaetae L' reduced on Abd. V (present in *insolita*), and the furca rudimentary with minute microchaetae without chaetopores (longer microchaetae with distinct chaetopores in *insolita*).

Ecological note. Similarly to the previous species, *Paravietnura insolita* sp. n. seems to be very local and connected with specific climatic and vegetation conditions, probably with mountain xeric pine forest.

Variabilty. We observed an asymmetrical absence of chaeta A in the holotype (Fig. 9).

Discussion

As noted in the Introduction, the tribe Neanurini, containing more than 170 species in 23 genera, is the second largest within the subfamily Neanurinae. Paradoxically, in spite of such a large number of known species belonging to the tribe, knowledge about its distribution and diversity seems to be still incomplete and far from satisfactory. For example, the largest generic and species diversity of Neanurini occurs in the Western Palaearctic, where currently 18 genera and nearly 150 species are known. It should be mentioned that the tribe in this region absolutely dominates and constitutes more than 80% of all genera and species of Neanurinae. The other four Neanurinae tribes are represented only by single native species (Paranurini, Sensillanurini), single introduced species (Lobellini), and a few genera with relatively small numbers of species (Paleonurini). However, presently the picture of the generic distribution of Neanurini is highly uneven as its seven genera are known exclusively from Europe (*Albanura* Deharveng, 1982; *Cansilianura* Dallai & Fanciulli, 1983; *Catalanura* Deharveng, 1983; *Lathriopyga* Caroli, 1910; *Monobella* Cassagnau, 1979; *Neanurella* Cassagnau, 1968; *Pumilinura* Cassagnau, 1979), and the next seven taxa (*Balkanura* Cassagnau, 1979, *Cryptonura* Cassagnau, 1979; *Deutonura* Cassagnau, 1979; *Endonura* Cassagnau, 1979; *Neanura* MacGillivray, 1893; *Protanura* Börner, 1906; *Thaumanura* Börner, 1932) are present both in Europe and in areas around it, e.g., Asia Minor, the Middle East, the Caucasus, or North Africa. That means that as many as 14 genera of the tribe, of 18 known in the western part of the Palaearctic, are present in Europe. Fortunately, to better understand the distributional pattern of Neanurini, a substantial number of studies dedicated to poorly investigated areas outside the continent have been undertaken during the last three decades. They have resulted the descriptions of four unknown genera, i.e. *Caucasanura* Kuznetsova & Potapov, 1988; *Edoughnura* Deharveng, Hamra-Kroua

& Bedos, 2007; *Ghirkanura* Kuznetsova & Potapov, 1988; *Persanura* Mayvan, Shayanmehr, Smolis & Skarżyński, 2015; and many new species and records of known taxa (e.g., Kuznetsova and Potapov 1988, Deharveng et al. 2007, 2015, Smolis and Kaprus' 2009, Mayvan et al. 2015, Smolis et al. 2011, 2012, 2016a, b, c, 2017). These papers, including the work presented here, show that the diversity of Neanurini in some regions of the Western Palaearctic is still underestimated, and that this diversity can be crucial to assessing the history of this megadiverse tribe of Nenurinae.

Acknowledgments

The work was financially supported by the Russian Foundation for Basic Research (grant 04-16-01228) and the Institute of Environmental Biology, Faculty of Biological Science, University of Wrocław, Poland (project no. 1076/Ś/IBŚ/2017). We are grateful to Prof. Pietro Paolo Fanciulli and Prof. Gang Jiang who reviewed the manuscript. We are also much indebted to the Editor Prof. Louis Deharveng for helpful remarks.

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RESEARCH ARTICLE

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Two new species of the genus *Andixius* Emeljanov & Hayashi from China (Hemiptera, Fulgoromorpha, Cixiidae)

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Abstract

Two new cixiid planthopper species: *Andixius longispinus* Zhi & Chen, **sp. n.** and *A. trifurcus* Zhi & Chen, **sp. n.** are described and illustrated from China (Yunnan Province) to provide the genus with four species in total. The generic characteristics are redefined. A key based on male genitalia to the four known species of this genus and a map of their geographic distributions are provided.

Keywords

Fulgoroidea, morphology, planthopper, taxonomy

Introduction

Emeljanov and Hayashi (2007) established the cixiid planthopper genus *Andixius* with two species: *Andixius nupta* Emeljanov & Hayashi, 2007 (as its type species) from Japan and *Andixius venustus* (Tsaur & Hsu, 1991) (previously placed in the genus *Brixia* Stål, 1856) from China. This genus belongs to the tribe Andini of subfamily Cixiinae (Hemiptera: Cixiidae). Characteristics of the tribe Andini are the downward bend of the apical part of segment XI which is usually longer than the anal style, and also anastomoses in one point (as if a crossing) of veins MP and CuA in the hindwing. So far, this genus includes only two species (Tsaur and Hsu 1991; Emeljanov and Hayashi 2007).

Herein, two new species: *Andixius longispinus* Zhi & Chen, sp. n. and *A. trifurcus* Zhi & Chen, sp. n. are described and illustrated from Yunnan province, China. The genus *Andixius* now contains four species, including three from China. A key based on male genitalia to all known species is provided as well as a map of their geographic distributions.

Materials and methods

The morphological terminology and measurements follow Tsaur et al. (1988) and Löcker et al. (2006). Body length was measured from apex of vertex to tip of forewing; vertex length was measured the median length of vertex (from apical transverse carina to tip of basal emargination). External morphology and drawings were done with the aid of a Leica MZ 12.5 stereomicroscope. Photographs of the types were taken with KEYENCE VHX-1000 system. Illustrations were scanned with CanoScan LiDE 200 and imported into Adobe Photoshop CS7 for labelling and plate composition. The dissected male genitalia are preserved in glycerine in small plastic tubes pinned together with the specimens.

The type specimens examined are deposited in the Institute of Entomology, Guizhou University, Guiyang, Guizhou Province, China (**IEGU**).

Taxonomy

Andixius Emeljanov & Hayashi, 2007

Andixius Emeljanov & Hayashi, 2007: 127.

Type species. *Andixius nupta* Emeljanov & Hayashi, 2007, original designation.

Diagnosis. The distinctive characters proposed by Emeljanov and Hayashi (2007) are modified as follows: head including eyes distinctly narrower than pronotum. Apical transverse carina of vertex weak and low, meeting the main part of frons at slightly obtuse angle or arc. Subapical carina of vertex as strong as conjunct lateral carinae. A small almost quadrangular fossette between vertex and frons. Vertex narrowest at apex, widened to base, disc arcuately and deeply excavated, lateral carinae strongly elevated. Lateral carinae of frons and postclypeus foliate, directed forward; carinae of posclypeus slightly lower than those of frons. Lower part of frons with convex disc separated from lateral carinae; its upper part deeply trough-like. Frontoclypeal suture slightly arched dorsally at middle. Middle ocellus apart from postclypeus. Middle carina of frons only in lower part or absent. Clypeus with distinct median carina. Frontoclypeus compressed, without lateral carinae. Rostrum long, extended considerably beyond hind coxae. Antennae medium-sized; pedicellum rounded conical and isodiametric. Pronotum short, with anterior margin straight and posterior margin deeply emarginated in an angle; intermediate carinae of pronotum encircling eyes from behind and below. Lateral carinae of pronotum between eye and tegula, separating paranotal lobes of pronotum from upper part behind postocular carinae. Tegmina long, tectiform, gradually but distinctly expanded towards end, rounded at apex, ScR (ScRA and RP) forming a short common stalk. Legs simple, fore coxae without angular apical lobe, hind tibia with six apical spines.

Remarks. This genus can be easily distinguished from other genera of Andini by the following characters: forewings without trifid branching of ScRA, RP and M near basal cell, ScR (ScRA and RP) forming a short common stalk. Legs simple, fore coxae without angular apical lobe.

Distributions. China, Japan.

Checklist and distributions of species of *Andixius* Emeljanov & Hayashi

A. longispinus Zhi & Chen, sp. n., China (Yunnan).
A. nupta Emeljanov & Hayashi, 2007, Japan (Ryukyu).
A. trifurcus Zhi & Chen, sp. n., China (Yunnan).
A. venustus (Tsaur & Hsu, 1991), China (Taiwan).

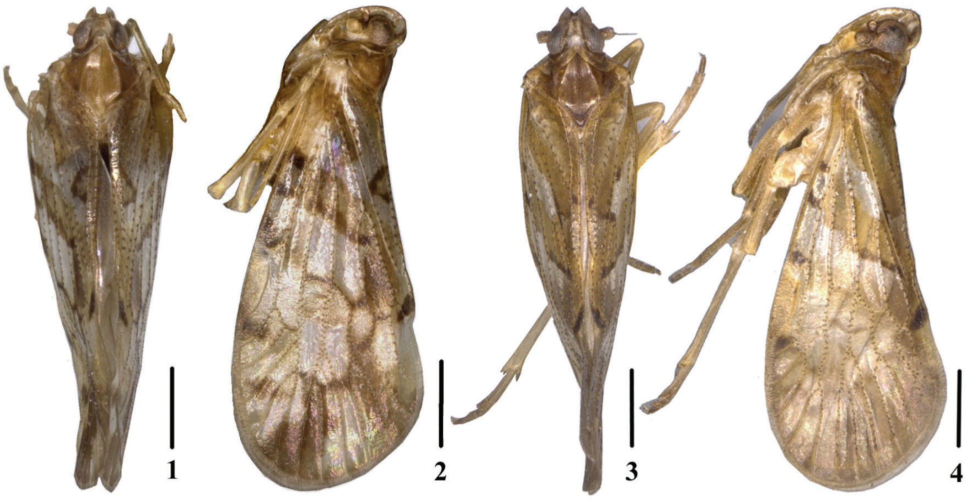
Key to species of *Andixius* (males)

1 Periandrium with an expanded semi-enclosed structure around the left side and ventral margin of periandrium. Ventral margin of the expanded structure trifurcated into three long processes (Figs 25–28) .... ***A. trifurcus* sp. n.**
– Periandrium without expanded semi-enclosed structure............................. **2**
2 Left side of periandrium with a bifurcate process (Emeljanov and Hayashi 2007: 130, figs 11–13)... ***A. nupta***
– Left side of periandrium without process or the process on left side of periandrium not bifurcated.. **3**
3 Ventral margin of periandrium without process, right side of flagellum with a large bifurcate process (Hsu and Stalle 1991: 66, fig. 33 (D–F))...... ***A. venustus***
– Ventral margin of periandrium with a projection, of which basal 1/3 longitudinally and distal 2/3 horizontally extended, flagellum with two “simple” processes, not bifurcate (Figs 13–16).......................... ***A. longispinus* sp. n.**

Andixius longispinus Zhi & Chen, sp. n.

http://zoobank.org/E3AD0FA5-2544-47DD-8ADF-0609D2D9167D
Figs 1–2, 5–16

Type material. Holotype: ♂, **China**: Yunnan, Lushui County, Pianma Town (26°N, 98°36'E), 16 August 2000, Xiang-Sheng Chen; paratypes: 1♂1♀, same data as holotype.



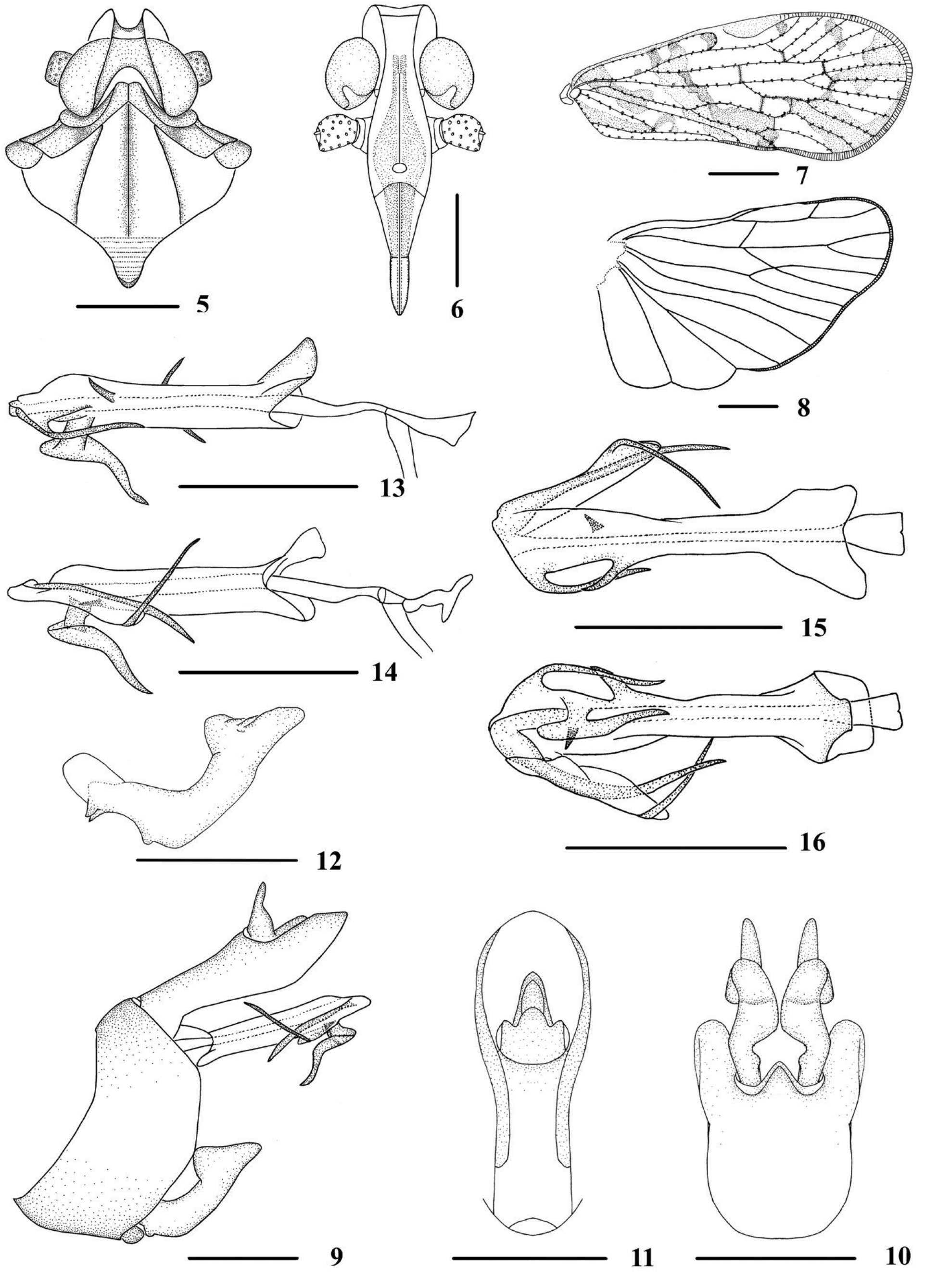
Figures 1–4. 1–2. *Andixius longispinus* sp. n., male. **1** Dorsal view **2** Lateral view **3–4.** *Andixius trifurcus* sp. n., male **3** Dorsal view **4** Lateral view. Scale bars: 1.0 mm.

Description. Body length: male 6.2–6.5mm (*N* = 2), female 7.2 mm (*N* = 1); forewing length: male 5.4–5.5 mm (*N* = 2), female 6.3 mm (*N* = 1).

Coloration. General color yellowish brown (Figs 1–2). Eyes brown, ocelli faint yellow, semi-translucent. Antenna, vertex, face and rostrum generally yellowish brown. Pronotum with discal area yellowish brown and lateral areas dark yellowish brown. Mesonotum with areas between lateral carinae yellowish brown, lateral areas brown. Forewing semi-translucent, costal vein with 3 small spaced dark brown spots; slightly behind stigma, near claval fork and behind clavus with an irregular tan spot respectively, basal and middle part of forewings with two inner oblique brown stripes; apical half of wing with brown patches. Hind tibiae and ventral abdomen yellowish brown.

Head and thorax. Vertex (Figs 1, 5) 0.8 times longer than wide; anterior margin nearly straightly, posterior margin V-shaped recessed, median carina absent. Frons (Fig. 6) 2.6 times as long as wide. Pronotum (Figs 1, 5) 1.8 times longer than vertex; posterior margin obtuse-angled. Mesonotum 1.4 times longer than pronotum and vertex combined. Forewing (Figs 2, 7) 2.2 times longer than wide, with twelve apical cells and six subapical cells. Hind tibia with six lateral spines, usually small; chaetotaxy of hind tarsi: 7/6–7, 2nd hind tarsus with 0–3 platellae.

Male genitalia. Pygofer (Figs 9–10) symmetrical, dorsal margin shallowly concave and U-shaped ventrally, widened towards apex, slightly concaved medially; in lateral view, lateral lobes trapezoidal and extended caudally. Medioventral process triangular in ventral view, apical margin rounded. Anal segment (Figs 9, 11) tubular, dorsal margin almost straight, ventral margin waved in lateral view; 2.6 times longer than wide in dorsal view; anal style strap-shaped, not beyond anal segment. Genital styles (Figs 10, 12) symmetrical ventrally, inner margin with a small curved process near base; in lateral view, dorsal margin bending inwards medially, apical margin



Figures 5–16. *Andixius longispinus* sp. n., male **5** Head and thorax, dorsal view **6** Face, ventral view **7** Forewing **8** Hindwing **9** Genitalia, lateral view **10** Pygofer and genital styles, ventral view **11** Anal segment, dorsal view **12** Genital styles, lateral view **13** Aedeagus, right side **14** Aedeagus, left side **15** Aedeagus, dorsal view **16** Aedeagus, ventral view. Scale bars: 0.5 mm (**5–6, 9–16**); 1.0 mm (**7–8**).

pediform. Aedeagus (Figs 13–16) with six processes. Right side of periandrium with a slender process, curved downwards basally and paralleled with periandrium distally; another short reversed spinose process directed dorsocaudally arising from basal 1/3 of right side of periandrium. Ventral margin with a large projection near apex, of which basal 1/3 longitudinally and distal 2/3 horizontally extended, directed ventrocephalically. Left side of periandrium with a very short spinose process, directed ventrocaudally. Flagellum with two processes, semi-sclerotized, generally curved in left side; apex with a very fine process, curved dorsocephalically; a process arising from base of flagellum, along the dorsal edge of the flagellum, directed ventrocephalically.

Distribution. China (Yunnan) (Fig. 29).

Etymology. The specific name is derived from the Latin adjective *long*- and *spinus*, referring to the one long process arising from the base of the flagellum, along the dorsal edge of the flagellum.

Remarks. This species is similar to *Andixius nupta* Emeljanov & Hayashi, 2007 in appearance, but differs in: (1) right side of periandrium with a short reversed spinose process at apical 1/3 (*A. nupta* without process in the same position); (2) left side of periandrium with a small process, not furcate (left side of periandrium with a large bifurcate process in *A. nupta*); (3) flagellum with two processes (without process in *A.* n*upta*).

Andixius nupta Emeljanov & Hayashi, 2007

Andixius nupta Emeljanov & Hayashi, 2007: 128–130, figs 1, 8–13.

Distribution. Japan (Ryukyu) (Fig. 29).

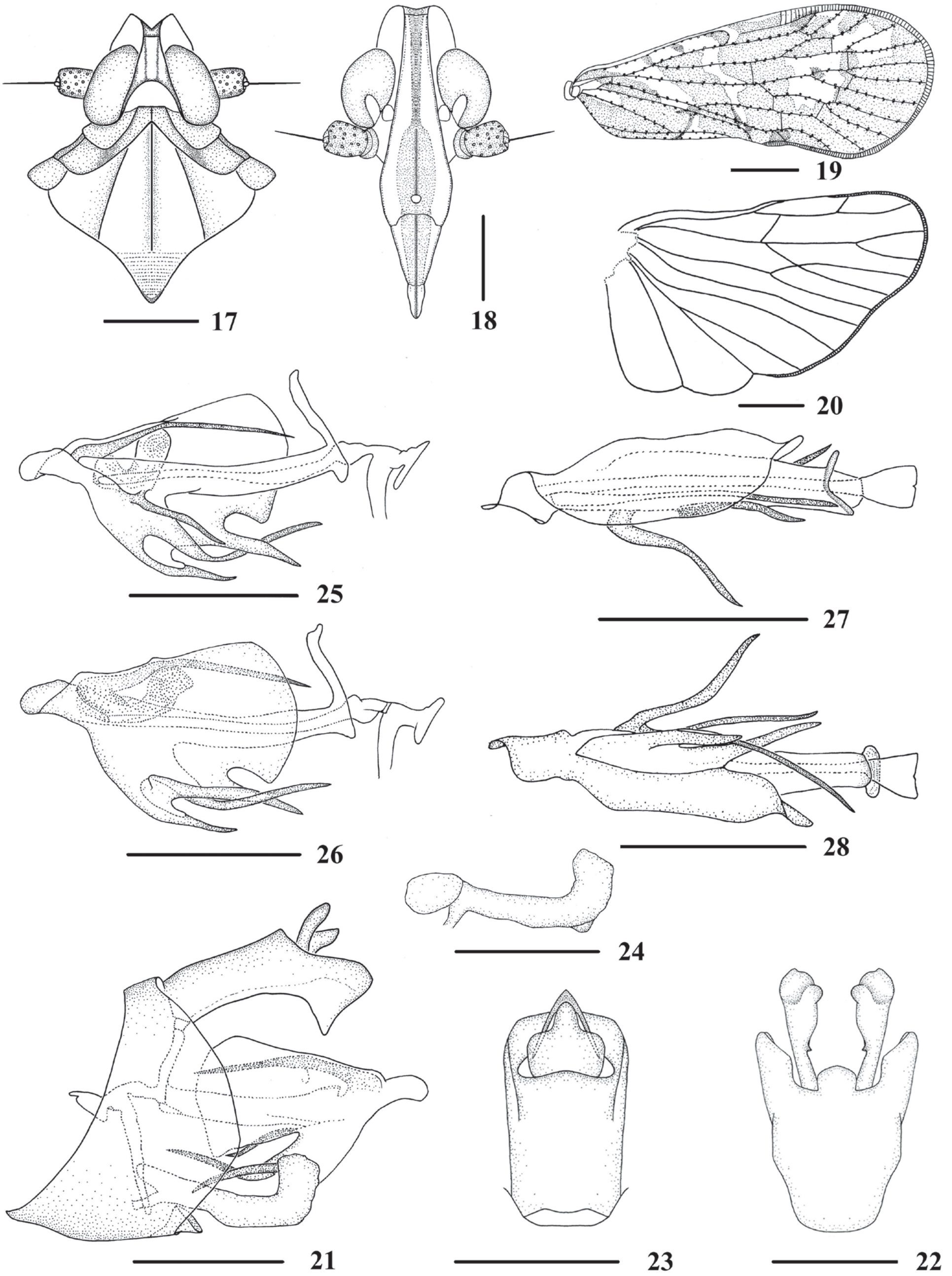
Remarks. Based on the description and the figures by Emeljanov and Hayashi (2007), this species can be distinguished from the other species of the genus by the following characters: left side of periandrium with a bifurcate process medially; left-ventral margin with a reversed process and right-ventral margin with a long process apically.

Andixius trifurcus Zhi & Chen, sp. n.

http://zoobank.org/C1B50C3D-4399-4ED0-BCDC-C4870F268D1D
Figs 3–4, 17–28

Type material. Holotype: ♂, **China:** Yunnan, Lushui County, Pianma Town (26°N, 98°36'E), 17–19 June 2011, Jian-Kun Long; paratypes: 4♂♂5♀♀, same data as holotype, Jian-Kun Long, Yu-Jian Li; same collecting site as holotype, 14 August 2006, Pei Zhang.

Description. Body length: male 6.4–6.8mm (*N* = 5), female 7.9–8.2mm (*N* = 5); forewing length: male 5.4–5.9 mm (*N* = 5), female 7.1–7.3 mm (*N* = 5).



Figures 17–28. *Andixius trifurcus* sp. n., male **17** Head and thorax, dorsal view **18** Face, ventral view **19** Forewing **20** Hindwing **21** Genitalia, lateral view **22** Pygofer and genital styles, ventral view **23** Anal segment, dorsal view **24** Genital styles, lateral view **25** Aedeagus, right side **26** Aedeagus, left side **27** Aedeagus, dorsal view **28** Aedeagus, ventral view. Scale bars: 0.5 mm (**17–18, 21–28**); 1.0 mm (**19–20**).

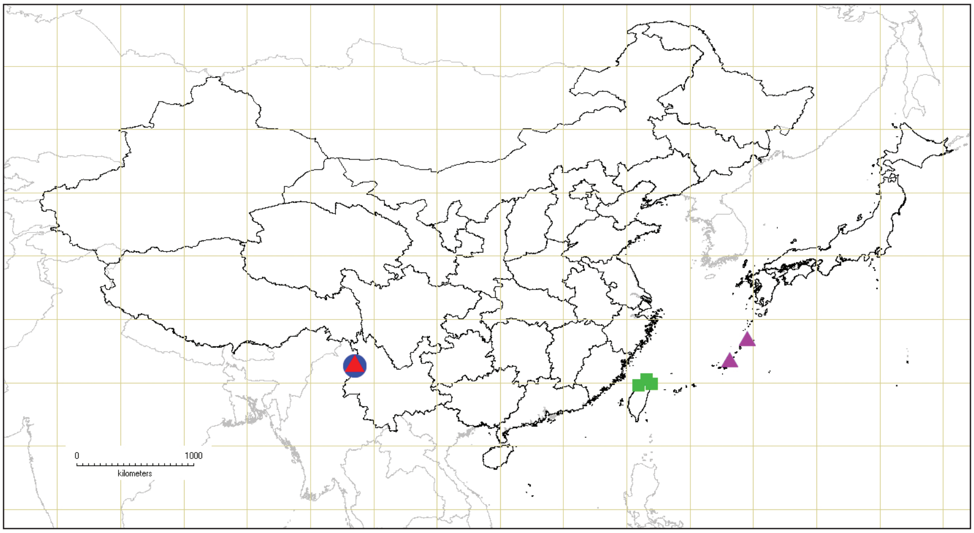


Figure 29. Geographic distributions of *Andixius* species: *A. longispinus* sp. n. (▲); *A. nupta* (▲); *A. trifurcus* sp. n. (●); *A. venustus* (■).

Coloration. General color yellowish brown (Figs 3–4). Eyes brown, ocelli faint yellow, semi-translucent. Antenna blackish brown. Vertex generally blackish brown with two short longitudinally yellow strips. Face generally brown. Postclypeus yellowish brown, rostrum yellowish brown except for apex dark brown. Pronotum with discal area light yellowish brown and lateral areas yellowish brown. Mesonotum brown. Forewing similar to *Andixius longispinus* sp. n., but without a tan spot near claval fork and distal half of forewing with larger brown patches. Hind tibiae and ventral abdomen yellowish brown.

Head and thorax. Vertex (Figs 3, 17) almost equal to width; anterior and posterior margin recessed in acute angle, median carina absent. Frons (Fig. 18), 2.6 times as long as wide. Pronotum (Figs 3, 17) 1.5 times longer than vertex; posterior margin recessed in a right angle. Mesonotum 1.4 times longer than pronotum and vertex combined. Forewing (Figs 4, 19) 2.3 times longer than wide, with twelve apical cells and seven subapical cells. Hind tibia with six lateral spines, chaetotaxy of hind tarsi: 6/6, 2nd hind tarsus with two platellae.

Male genitalia. Pygofer (Figs 21–22) symmetrical, dorsal margin shallowly concave and U-shaped ventrally, widened towards apex; in lateral view, lateral lobes trapezoidal and extended caudally. Medioventral process round in ventral view. Anal segment (Figs 21, 23) with dorsal margin nearly straight, ventral margin with an antler-like process extending to apex ventrally in lateral view; 1.6 times longer than wide in dorsal view; anal style strap-shaped, slightly beyond anal segment. Genital styles (Figs 21, 24) symmetrical ventrally, inner margin with a small odontoid process medially and an obtuse process near apex, gradually widened towards apex; dorsal and ventral margins subparallel, apical part strongly bent upward and apical margin truncated in lateral view. Aedeagus (Figs 25–28) with five large processes. Dorsal margin of aedeagus near apex with a long process, slightly directed ventrocephalically. Periandrium with an expanded semi-enclosed structure around the left side and ventral margin of periandrium, ventral margin of the expanded structure with three long processes: apical one wide, slightly curved and directed cephalically; middle one longest, narrowed from base to end, curved upwards and directed dorsocephalically; basal one wide, slightly curved and directed ventrocephalically. A slender process arising from apical 1/3 of left side of periandrium, directed ventrocephalically. Flagellum short and small, slightly sclerotized, without process.

Distribution. China (Yunnan) (Fig. 29).

Etymology. The specific name is derived from the Latin prefix *tri-* plus the Latin word *furcus*, referring to the trifurcated ventral margin of the periandrium.

Remarks. This species is similar to *Andixius longispinus* sp. n. in appearance, but differs in: (1) dorsal margin of aedeagus with a long process near apex (*A. longispinus* without process in the same position); (2) periandrium with an expanded semi-enclosed structure around left side and ventral margin of periandrium (not as above in *A. longispinus*); (3) flagellum without process (two processes in *A. longispinus*).

***Andixius venustus* (Tsaur & Hsu, 1991) in Tsaur, Hsu & Stalle, 1991**

Brixia venusta Tsaur & Hsu, 1991, in Tsaur et al. 1991: 66, fig. 33 (A–I).
Andixius venustus (Tsaur & Hsu, 1991): Emeljanov and Hayashi 2007: 129.

Distribution. China (Taiwan) (Fig. 29).

Remarks. Based on the description and the figures by Tsaur & Hsu, 1991, *Andixius venustus* closely resembles *A. nupta* Emeljanov & Hayashi, 2007, but can be distinguished from the latter by the following characters: (1) right side of flagellum with a large bifurcate process basally (flagellum without process in *A. nupta*); (2) left side of periandrium with a medium process apically and without process medially (*A. nupta* without process apically and with a bifurcate process medially).

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Oculogryphus chenghoiyanae sp. n. (Coleoptera, Lampyridae): a new ototretine firefly from Hong Kong with descriptions of its bioluminescent behavior and ultraviolet-induced fluorescence in females

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Abstract

The first *Oculogryphus* species with associated males and female was found in Hong Kong and is described as new: *O. chenghoiyanae* **sp. n.** Adults of both sexes were collected live in the field and their bioluminescent behavior is reported for the first time in the genus. The captive males emit weak and continuous light from a pair of light spots on abdominal ventrite 6 or do so when disturbed. The larviform (highly paedomorphic) females can glow brightly from a pair of light-emitting organs on the abdomen. The females of *Oculogryphus* and *Stenocladius* are to date the only documented representatives of paedomorphism in ototretine fireflies. The finding is consistent with the evidence from male morphology and bioluminescent behavior, supporting the close relationship between the two genera. A key to the *Oculogryphus* species is provided. The *Oculogryphus* females can fluoresce with a blue-green light through the whole body under ultraviolet illumination, a phenomenon reported in the Lampyridae for the first time. The co-occurrence of bioluminescence and fluorescence is rare in terrestrial ecosystems, previously known only in some millipedes (Diplopoda). The fluorescence and bioluminescence abilities of *Oculogryphus* females are functionally independent: abdominal light-emitting organs producing bright yellowish green light while the body wall fluoresces with blue-green light. In contrast, fluorescence and bioluminescence in millipedes are biochemically linked, like in some jellyfish (Cnidaria: Medusozoa).

Keywords
Behavior, bioluminescence, Hong Kong, *Oculogryphus chenghoiyanae* sp. n., Ototretinae, paedomorphic female, *Stenocladius*, UV-fluorescence

Introduction

The firefly subfamily Ototretinae is non-typical for having drilid- or cantharid-like appearance, with bioluminescent organs small or absent. It has gone through extensive modifications in familial assignment, ranked hierarchy, definition, and spectrum of included taxa through time, and become stabilized only recently (Olivier 1907, 1910, Wittmer 1944, McDermott 1964, 1966, Crowson 1972, Branham and Wenzel 2001, Geisthardt and Satô 2007, Jeng 2008, Janisova and Bocakova 2013). Several new genera and species, including *Oculogryphus* Jeng, Engel & Yang, were added over the last two decades (Kawashima 1999, 2007, Kawashima et al. 2005, Jeng et al. 2007, 2011, Brancucci and Geiser 2009, Bocakova and Janisova 2010, Janisova and Bocakova 2011, 2013, Jeng and Engel 2014, Bocakova et al. 2015, Bocakova and Bocak 2016). Currently there are approximately 100 documented species in 21 genera, distributed in the Palaearctic and Oriental Asia with only a few species in the Nearctic realm and in New Guinea of Oceanian realm sensu Holt et al. (2013) (Janisova and Bocakova 2013). Many of the genera contain only few species, and some remain monotypic.

Several historical factors or practical limitations have hampered the progress of biodiversity and ecological studies in Ototretinae. The chaotic taxonomic history of the subfamily was addressed by Janisova and Bocakova (2013). A major practical obstacle to study ototretines is the paucity of both museum specimens and field observations. Little is known about the ecology of most ototretine members because of their crypsis in the field. In general, male ototretines are cryptic morphologically and ecologically. Some are diurnal but many more fly in twilight or night time with dim or no bioluminescence, making them difficult to observe or collect. The availability of female specimens is even more limited than of males. To date, females are known only from a few species in three out of the 21 ototretine genera (Janisova and Bocakova 2013, see discussion).

The genus *Oculogryphus* together with its type species, *O. fulvus* Jeng, 2007, was described from one male specimen from Vietnam. Two more species have been added to the genus, from Vietnam and China, each based on few male specimens (Jeng et al. 2011, Jeng and Engel 2014). Recently the junior author found an *Oculogryphus* species in Hong Kong and collected live adults of both sexes. The species is described as new, and the first account of a female is provided. Bioluminescent behavior for the genus, and of fluorescence by the females is also provided.

Materials and methods

Four specimens were collected alive by YV from Hong Kong in May, 2017. Female and male are associated by observation of a mating pair in the field. Behavioral observations were done both in the field and in captivity. Photos of bioluminescence were taken by a 100 mm-focal-length macro lens attached to a digital single-lens reflex camera, with exposure time from 0.25 to 60 seconds.

Methodology and morphological terminology follows Jeng et al. (2007). Measurements were made by depicting the contour of the target structure under a Nikon SMZ1500 microscope equipped with a camera lucida attached. The abbreviations **BL, BW, EL, EW, PL,** and **PW** are employed for "body length", "body width", "elytral length", "elytral width", "pronotal length", and "pronotal width", respectively. Body length is the distance between the anterior head margin and elytral apex; body width is the greatest distance across the elytra or twice the width of an elytron (**BW = 2EW**). The term "ventrite" is used for the visible abdominal sternite; **T#** and **S#** represent the true #th tergite or sternite of the abdomen, respectively; the last abdominal tergite is T8; "**aedeagal sheath**" is composed of a syntergite (T9 + 10) and sternite IX [S9 = ventrite 8 (V8)]. Measurement of the females was based on specimens fixed in 95% ethyl alcohol. Hind wing, male genital segments, female heads, and front legs were removed from bodies for examination and illustrated under a Leica DM2500 light microscope. Venation follows Jeng and Engel (2014).

The holotype and a female paratype are deposited in the Insect Museum of Tai Lung Experimental Farm, Agricultural, Fisheries and Conservation Department, Hong Kong, and the other pair of paratypes in the National Museum of Natural Science (**NMNS**), Taichung, Taiwan.

Taxonomy

Oculogryphus chenghoiyanae **sp. n.**

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Figs 1–11

Holotype. ♂, HONG KONG: Lantau Island (大嶼山島), Tei Tong Tsai (地塘仔), 5.V.2017, V Yiu leg.

Paratypes. 1♂, type locality, 8.V.2017, V Yiu leg.; 1♀, same data as holotype; 1♀, type locality, 12.V.2017, V Yiu leg.

Type-locality. Hong Kong, Lantau, Tei Tong Tsai, 22.25722°N, 113.92604°E, altitude 200 m to 420 m.

Diagnosis. Males of the species may be recognized by the following combination of characters: body size small (5.1–5.2 mm long); coloration dark brown to black thorough dorsally or orange brown in pronotum, opaquely brown in abdominal V1–5 and middle part of V6, yellowish brown in V7–8; head partially exposed from pronotum, nearly as wide as pronotum; compound eyes strongly emarginate posteriorly and approximate ventrally; antennae 11-articled, filiform; mandibles short and strongly curved; pronotum with narrowly explanate lateral margins and close pronotal hypomeron; abdomen with eight abdominal ventrites (including exposed sternite of

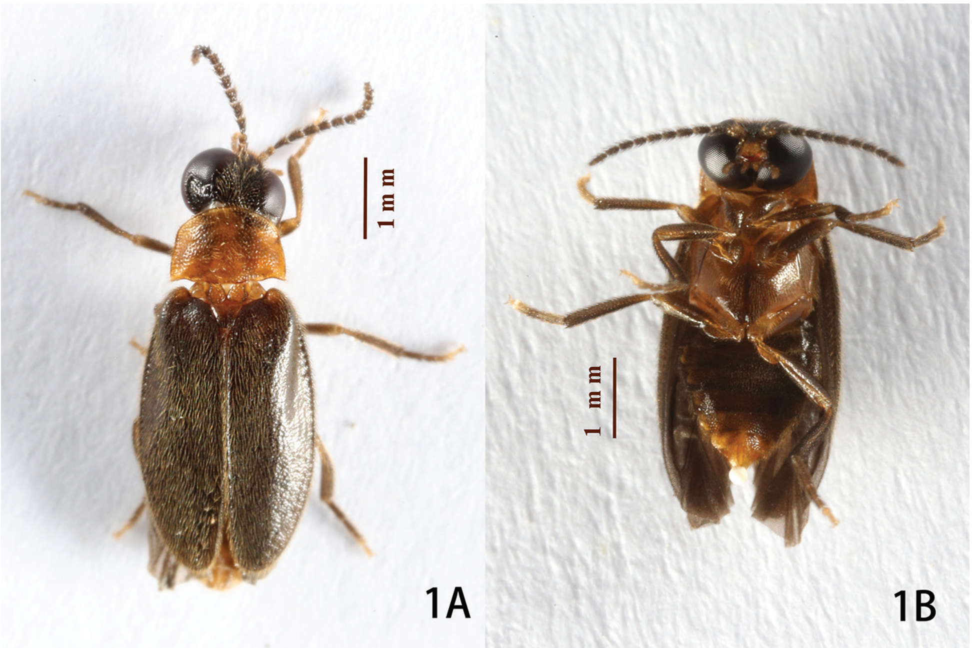


Figure 1. Habitus of holotype of *Oculogryphus chenghoiyanae* sp. n., dorsal (**A**) and ventral (**B**) aspects.

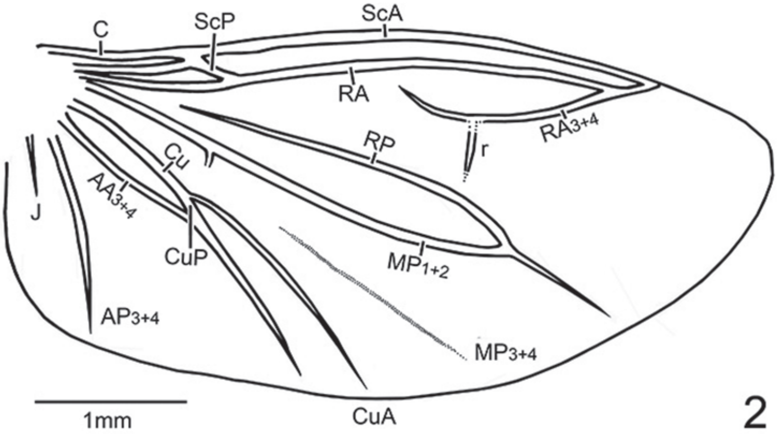
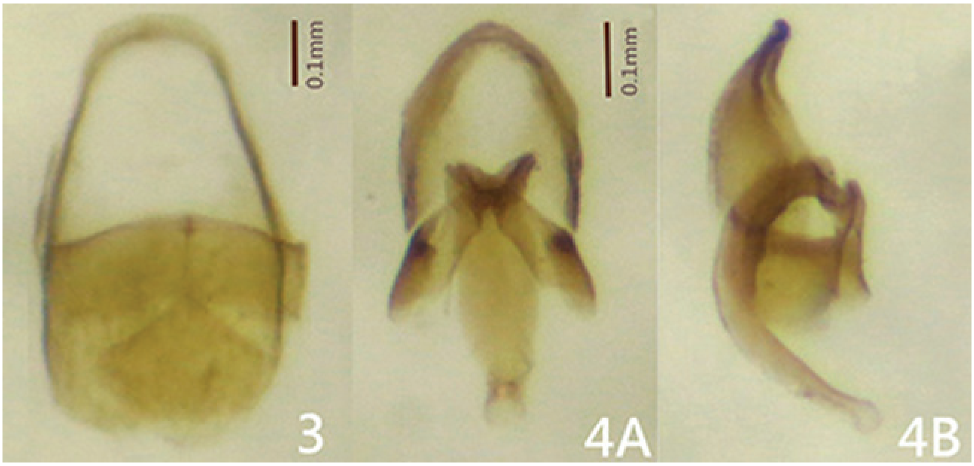


Figure 2. *Oculogryphus chenghoiyanae* sp. n., male, hind wing.

aedeagal sheath); abdominal tergites not lobed; no recognizable photogenic organs externally when not glowing; male genitalia with median lobe strongly curved laterally; parameres short, with apices reaching apical half of median lobe; basal piece approximately as long as median lobe, roughly a U-shaped band.

Description. Male (Figs 1–4). BL: 5.1–5.2 mm; BW: 2.2–2.4 mm; PW/PL = 1.4–1.5; EL/ EW = 3.2–3.6; EL/PL = 3.6–3.7; BW/PW = 1.4–1.5. The species is very



Figures 3–4. *Oculogryphus chenghoiyanae* sp. n., male. **3** aedeagal sheath, dorsal aspect **4** aedeagus, dorsal (**A**) and lateral (**B**) aspects.

similar to *O. fulvus* Jeng et al. 2007 in external morphology most characteristics are not repeated here. As described for *O. fulvus* except: head capsule and antennae black; pronotum dark brown with posterior angles brown and mesoscutellum dark brown in the anterior half and brown in the posterior half; elytra and epipleura black except humeri brown; thoracic sternites dark brown in the middle; all coxae, trochanters and subapices of femora yellow-brown, other parts of legs black; abdominal V1–5 and mesal part of V6 opaquely black, lateral areas of V6 and V7–8 yellowish brown. Hind wing (Fig. 2) with vestigial MP_{3+4}. Aedeagal sheath (Fig. 3) 0.64 mm in length and 0.36 mm broad, basal end broadly rounded, T10 significantly longer than T9; aedeagus (Fig. 4) 0.55 mm long and 0.25 mm broad; aedeagus with median lobe surpassing apex of parameres by approximately 1/2 length of median lobe, subparallel-sided dorso-ventrally, with apex dilated as a lobe in lateral aspect.

Female (Figs 5–8). BL 7.8-8.4 mm, BW 1.4-1.6 mm. Ground coloration pale yellow, with flecked reddish brown markings on all thoracic tergites and abdominal tergites 1-4th, most profound on anterior half of mesonotum; sides of cranium, mandibles and coxae brown, compound eyes and their surrounding areas black. Highly paedomorphic and weakly sclerotized. Body elongate, more or less cylindrical, gradually broadened from prothorax toward abdominal segment 4, subparallel sided in segments 4-7, slightly tapering in segment 8, then somewhat abruptly narrowed down toward apex (Fig. 5). Head (Fig. 6) transverse, more or less depressed dorsoventrally, inverted trapezoid in shape, with antennae and mouthparts similar to those of larvae. Epicranium more pigmented laterally than dorsally, epicranial and frontal sutures obscure. Compound eyes small, slightly produced laterally, facing forward rather, with 13 ommatidia. Antennae 3-segmented, with basal two antennomeres subequal in length and 3rd shortest, with translucent sensory organs on apex of antennomere 3. Labrum transverse, weakly sclerotized; Mandibles strong, somewhat upward crossing curved,

Figure 5. *Oculogryphus chenghoiyanae* sp. n., female, dorsal (**A**) and lateral (**B**) aspects.

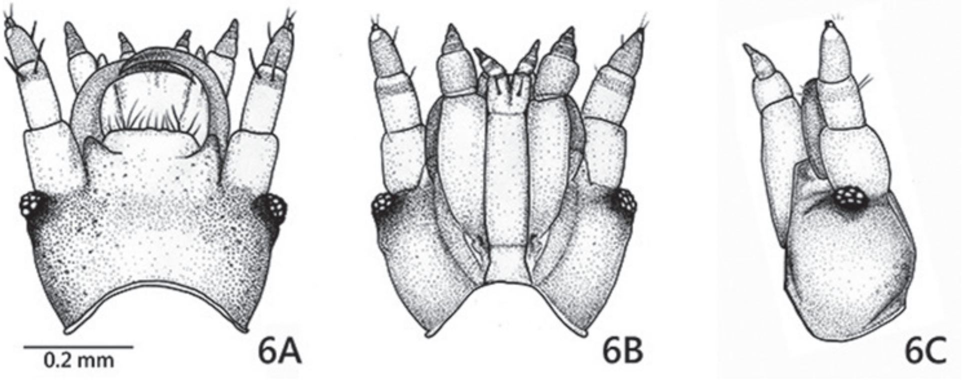


Figure 6. *Oculogryphus chenghoiyanae* sp. n. female, head, dorsal (**A**), ventral (**B**) and left side (**C**) aspects.

pointed apically, without inner tooth. Maxillary stipes elongate, palpus 3-segmented. Labium with mentum and submentum combined as long as stipe, elongate and subparallel sided; prementum notched apically; labial palpus 2-segmented. Prothorax semi-elliptical dorsally, broader than long by 1.4 times; meso- and meta- thoracies subtrapezoid, twice broader than long, better pigmented dorsally than other areas. Legs (Fig. 7) with coxa longest, cone-shaped and better sclerotized; femur slightly longer than trochanter, tubular in shape; tibia short, nearly 1/2 femoral length and as long as wide; tarsus 2-segmented, basal segment short, 2/3 of tibial length, apical segment as long as femur, with two simple apical claws. Abdomen 10-segmented, weakly sclerotized both dorsally and ventrally, without clear sclerites as commonly seen in ototretine larvae; a pair of light organs located on lateral sides of 7th segment, but unrecognizable if not glowing; sternite of segment 7 (S7) with a small transversely elliptical sclerite near central apex; S8 weakly roundly emarginate at apex; segment 9

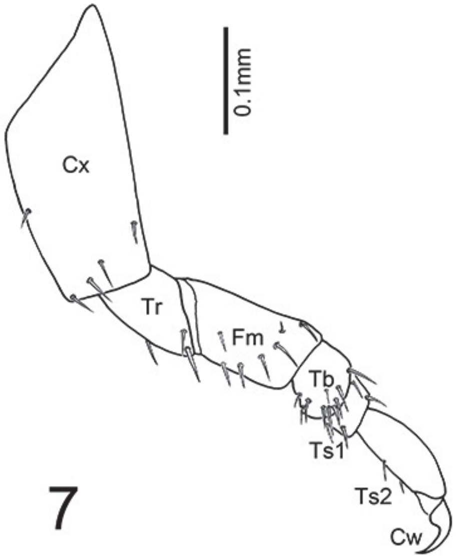


Figure 7. *Oculogryphus chenghoiyanae* sp. n. female, left front leg, coxa (**Cx**), trochanter (**Tr**), femur (**Fm**), tibia (**Tb**), tarsomeres 1–2 (**Ts1-2**), and claws (**Cw**).

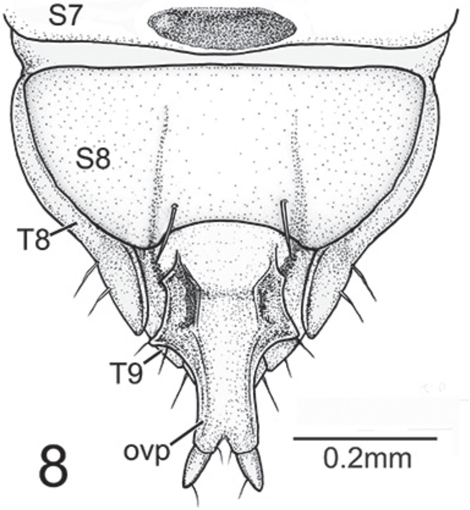


Figure 8. *Oculogryphus chenghoiyanae* sp. n. female, abdominal apical segments, ventral aspect, sternites 7 & 8 (**S7, S8**), tergites 8 & 9 (**T8,T9**), and ovipositor (ovp).

and 10 small, visible in lateral aspect but barely seen in ventral aspect; segment 10 with ovipositor exposed, better sclerotized at sides (Fig. 8).

Variations. The holotype male is vivid bicolored (Fig. 1A), while the paratype male has a more or less uniformly dark brown dorsal coloration.

Remarks. The new species is more similar to *O. fulvus* from Vietnam than other congeners based on male genitalia. Both species have their median lobes far surpassing apex of parameres by 1/2 length of median lobe, but only slightly surpassing apex of parameres in *O. shuensis* and *O. bicolor*. In comparison with *O. fulvus*, the new species has dark brown elytra whereas the former is brown throughout; its MP_{3+4} of hind wings is vestigial but well-defined in *O. fulvus*; basal end of the aedeagal sheath is broadly rounded instead of tapering towards base in *O. fulvus*; the median lobe of *O. chenghoiyanae* is more slender than in *O. fulvus* in lateral aspect. This new species is also the smallest – males are only 5.1–5.2 mm long on relation to 6.7–7.1 mm for *O. shuensis*, 6.2–7.1 mm for *O. bicolor* and 6.0 mm for *O. fulvus*. In summary, *O. chenghoiyanae* differs from all other species by its small size, dark coloration, reduced MP_{3+4} in hind wings, multiple male aedeagal features, and separated biogeographic distribution, thus there is strong evidence that this represents a new species.

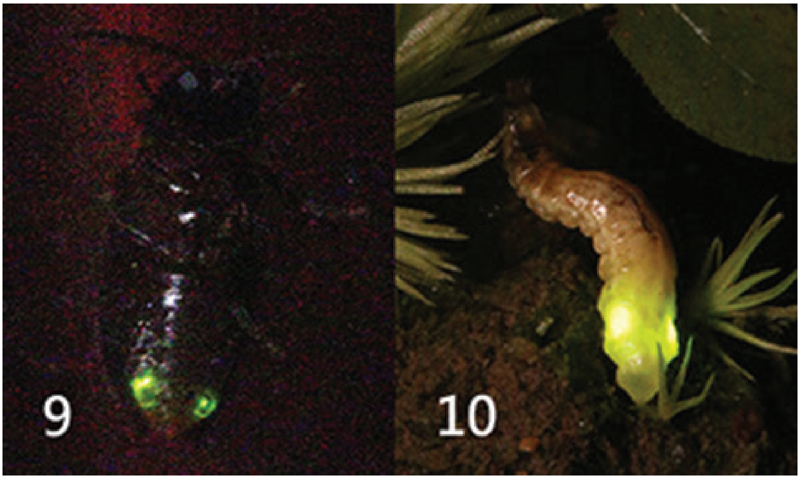
Females of *O. chenghoiyanae* are, to date, the only representative in the genus. Their external morphology highly resembles *Stenocladius* females (c.f. Ohba et al 1997). Some minor differences like the orientation of eyes and number of ommatidia are observed. Owing to the conservative nature of paedomorphic characters and limited taxon sampling, it is currently hard to make a differential diagnosis between the two genera.

Etymology. The species is named after Momo Hoi-yan Cheng, in honor of her contribution on saving a life as well as infusing positive energy and love to our Society. She bravely and selflessly donated two-thirds of her liver to a dying women she had never met before in April, 2017, Hong Kong.

Phenology. Adults appear in May.

Ecology. This species known only from the type locality. The higher portion of its habitat is dense natural woodland and the lower portion is sparse, disturbed shrubland. The females were first recorded in 2014 May in the type locality. They were repeatedly seen in May of 2015 and 2016. They initially were mistaken for larvae until YV found a mating pair of the new species in 2017. Light emitting females could be found on exposed rocks, concrete surfaces, soil surfaces, dead leaves and on fallen branches. When disturbed by a beam of white light, the females slowly moved into soft soil or under litter.

Bioluminescent behavior. A pair of oval light emitting organ is located at the lateral sides of the 7th abdominal segment of the female adult. Females displayed light from 19:40 hours (approximately 45 minutes after sunset) to 20:40 hours in the field. Most were generally stationary, lying flat (not raising abdomen as in *Rhagophthalmus*) when glowing (Fig. 10). A mating pair of *O. chenghoiyanae* was found in the field at 20:10 hours, May 5th, 2017. Glowing light from the female was visible from several meters but no light was observed from the male. Another male was found flying to a green betalight three days later, ca. 300 m away from the place where the mating pair was found. In captive condition, the males occasionally produced dim light from a pair of light spots on abdominal ventrite 6 spontaneously or did so when disturbed (Fig. 9). The light was barely visible by naked eyes only in a dark room or through long exposure photography. Light organs were otherwise not visible.



Figures 9–10. *Oculogryphus chenghoiyanae* sp. n., bioluminescence **9** male, emitting dim light from two side-spots at abdominal ventrite 6 **10** female, glowing brightly from a pair of light organs on sides of abdominal segment 7.

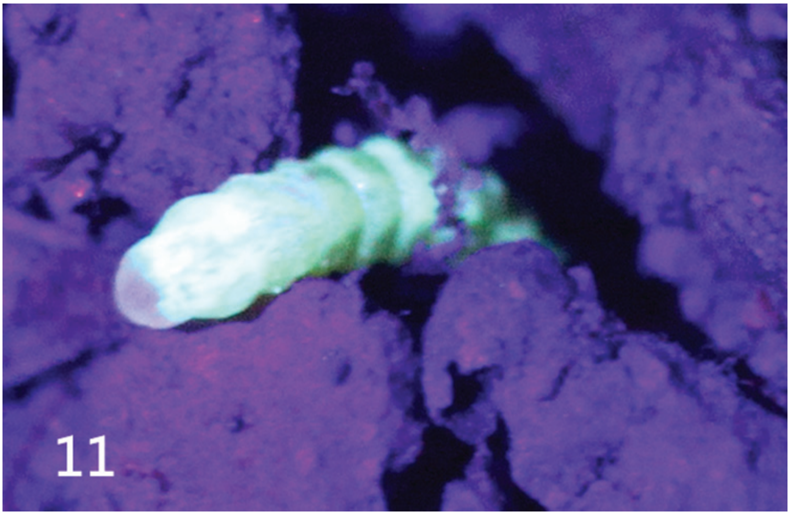


Figure 11. *Oculogryphus chenghoiyanae* sp. n., a female fluorescing in bluish green from body under ultraviolet illumination (UVA, 365–375 nm).

UV-fluorescence. YV used a UVA LED torch (365–375 nm, min mW 15) to illuminate the female. The female was observed fluorescing brightly with blue-green light throughout the body (Fig. 11). Dead females in ethanol also showed a lesser amount of fluorescence when exposed to UV light (both 365–375 nm, min mW 15 and 395 nm, mW 5). Male specimens also produced a blue-green fluorescence, but only from their enlarged compound eyes.

Key to species of *Oculogryphus* (male)

1 Aedeagus with median lobe far surpassing apex of parameres by ca. 1/2 length of median lobe **2**

– Aedeagus with median lobe only slightly surpassing apex of parameres **3**

2 Body size smaller (BL 5.1–5.2 mm); elytra dark brown, ventral side with thoracic ventrites paler than abdominal ventrites in coloration; aedeagus with median lobe slender, more or less uniform in thickness in lateral aspect; hind wing with vestigial MP_{3+4} .... ***O. chenghoiyanae* sp. n.** (Hong Kong)

– Body size larger (BL 6.0 mm); elytra and ventral surface more or less uniformly brown in coloration; aedeagus with median lobe tapering toward apex in lateral aspect; hind wing with well-defined MP_{3+4} .... ***O. fulvus* Jeng** (Vietnam)

3 Pronotum and elytra similar in coloration, though elytral color somewhat heterogeneous, with base, lateral margins and sutures paler; hind wings with MP_{3+4} bifurcate .... ***O. bicolor* Jeng, Branham & Engel** (Vietnam)

– Pronotum and elytra highly contrast in coloration, orange brown on pronotum and black in elytra; hind wings with MP_{3+4} not bifurcate...................... .... ***O. shuensis* Jeng & Engel** (China: Chongqing, Sichuan)

Discussion

Significance of the *Oculogryphus* female to the systematic classifications of Ototretinae

Before the present study, females were described for only three of 21 genera of Ototretinae (*Stenocladius*, *Drilaster* and *Mimophaeopterus*). The documented females, however, exhibit extreme difference at genus level both morphologically and ecologically: *Stenocladius* and *Oculogryphus* females are highly paedomorphic and are active only nocturnally, using bioluminescence and pheromones to attract mates (Kawashima 1999, Chen 2003), whereas *Drilaster* and *Mimophaeopterus* show only minor sexual dimorphism in antennae and abdominal ventrites, and are essentially diurnal, relying on chemical cues to search mates (Ohba 2004; Kawashima et al. 2005, Janisova and Bocakova 2013, Chen and Jeng 2014). Descriptions of newly found females for further taxa may improve our predictive ability and collecting techniques to find additional females in the future.

For example, *Oculogryphus* and *Stenocladius* are so far the only documented examples with paedomorphic females in Ototretinae. This is consistent with the evidence from male morphology and bioluminescent behavior, supporting the close relationship of the two genera as Jeng et al. (2011) and Jeng and Engel (2014) argued. Lately we discovered another paedomorphic female from Ototretinae: a *Brachypterodrilus* species in the Philippines (JML, unpublished). According to the key by Janisova and Bocakova (2013), all three genera together with *Baolacus* and *Falsophaeopterus* belong to an ototretine subgroup whose lateroposterior angles of the pronotum are less prominent (see the key in Janisova and Bocakova (2013)). This subgroup is actually a clade, separated from the other clade composed of *Drilaster* and its allied genera, supported by our tentative molecular phylogeny (JML, unpublished). *Baolacus* and *Falsophaeopterus* may have paedomorphic females with high probability.

UV-fluorescence of *Oculogryphus*

Although UV-induced fluorescence is documented in many terrestrial arthropods (Lawrence 1954), very little has been reported in the fireflies. Metcalf (1943) isolated a red-fluorescent pigment named lampyrine from *Photinus marginellus* fireflies. Sannasi (1970) reported the cuticular-resilin-resulted UV-fluorescence from the compound eyes of the north American *Photinus pyralis* (L.). In this study, *Oculogryphus* females represent the first example of fireflies possessing UV-fluorescence in the cuticular regions of the body. They are also significant because of their co-occurrence of fluorescence and bioluminescence, a phenomenon so far only known in some marine animals but very rare in terrestrial or freshwater ecosystems (Matz et al. 2006, Oba et al. 2017, Marek and Moore 2015, Marek 2017). When bioluminescence accompanies fluorescence, the production of light is often biochemically linked whereby the fluorophore is the ultimate light emitter through energy transfer (Shimomura 2006, Marek 2017). *Oculogryphus* females, however, are not congruent with this general principle. *Oculogryphus* females glow to attract mates in the night. But is the UV-fluorescence functional?

Possible adaptive functions of fluorescence include prey attraction, aposematism, camouflage, sexual signaling or species recognition, photo-protection, and shelter finding (Heiling et al. 2005, Andrews et al. 2007, Lim et al. 2007, Li et al. 2008, Gaffin et al. 2012, Guillermo-Ferreira et al. 2014, Marek and Moore 2015, Brandt and Masta 2017). Firefly males are likely to have ultraviolet vision (Martin et al. 2015, Sander and Hall 2015). *Oculogryphus* species, however, are only active in the night when ultraviolet light is weak or totally absent, thus no UV-fluorescence by the females. In addition, the co-occurrence but physiologically independence of bioluminescence and fluorescence in *Oculogryphus* females makes many of the proposed adaptive functions difficult to apply. Aposematism and sexual signaling in dim light environment are worthy to be tested.

Alternatively, the fluorescence may play no ecological role but just exist as a byproduct of a pigment or other molecule (Wiesenborn 2011, Marshall and Johnsen 2017). For example, Wiesenborn (2011) observed UV-fluorescence in various degrees from many insects, and weakly sclerotized body parts usually showed stronger fluorescence without clear function. This seems a reasonable explanation for the *Oculogryphus* females. This could be a hypothesis to be tested in the future by comparing the relative strength of fluorescence among females with different paedomorphic degrees, and commonness of fluorescence between paedomorphic versus ordinary females of fireflies.

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RESEARCH ARTICLE

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Genome-wide SNP data and morphology support the distinction of two new species of *Kovarikia* Soleglad, Fet & Graham, 2014 endemic to California (Scorpiones, Vaejovidae)

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Abstract

Morphologically conserved taxa such as scorpions represent a challenge to delimit. We recently discovered populations of scorpions in the genus *Kovarikia* Soleglad, Fet & Graham, 2014 on two isolated mountain ranges in southern California. We generated genome-wide single nucleotide polymorphism data and used Bayes factors species delimitation to compare alternative species delimitation scenarios which variously placed scorpions from the two localities with geographically adjacent species or into separate lineages. We also estimated a time-calibrated phylogeny of *Kovarikia* and examined and compared the morphology of preserved specimens from across its distribution. Genetic results strongly support the distinction of two new lineages, which we describe and name here. Morphology among the species of *Kovarikia* was relatively conserved, despite deep genetic divergences, consistent with recent studies of stenotopic scorpions with limited vagility. Phylogeographic structure discovered in several previously described species also suggests additional cryptic species are probably present in the genus.

Keywords
arachnid, Bayes factor delimitation, RADseq, species tree, Vaejovidae

Introduction

Species delimitation of morphologically conserved taxa has been a historically challenging endeavor for taxonomists. Recent developments in both DNA sequencing and species delimitation modeling have alleviated much of this burden by providing researchers with new ways to systematically classify similar-looking yet evolutionary distinct species. Although many species delimitation methods were originally designed and tested using only a handful of genes (e.g., Yang and Rannala 2010, Grummer et al. 2014), the rapid development of next-generation DNA sequencing means these methods can now be used with thousands of base-pairs of DNA acquired from across the entire genome (Leaché et al. 2014, Yang and Rannala 2014, Yang 2015).

Scorpions represent a well-known group of animals with a relatively conserved morphology. Thought to be derived from amphibious ancestors that lived more than 425 million years ago, their body plan appears to have changed relatively little since their adaptation to land (Coddington et al. 2004). Recent molecular studies have found that many wide-ranging scorpion species often represent species complexes (e.g., Bryson et al. 2013, 2016, Miller et al. 2014, Graham et al. 2017), with conserved external morphologies often masking more complex evolutionary histories. In these studies, geography was shown to be a better predictor of diversity than the morphological characters used to delineate species.

California is a global biodiversity hotspot and home to numerous endemic scorpions (i.e., Soleglad and Fet 2004, Soleglad et al. 2011, Webber et al. 2012, Savary and Bryson 2016). Scorpions in the genus *Kovarikia* Soleglad, Fet & Graham, 2014 are restricted to humid rocky microhabitats in several counties of southern California. The three currently recognized species in the genus, *K. angelena* (Gertsch & Soleglad, 1972), *K. bogerti* (Gertsch & Soleglad, 1972), and *K. williamsi* (Gertsch & Soleglad, 1972), are relatively rare and known from fewer than seven documented localities each (Soleglad et al. 2014). We discovered populations of *Kovarikia* on two different mountains seemingly isolated from other species in the genus. To test the hypothesis that they might represent new species, we generated genome-wide single nucleotide polymorphism data and used species delimitation modelling to compare alternative species delimitation scenarios which variously placed scorpions from the two new localities with geographically adjacent species or into separate lineages. We then estimated a time-calibrated phylogeny of *Kovarikia* and examined and compared the morphology of specimens from across its distribution. Using this approach, we address the taxonomy of *Kovarikia* and provide a key for species identification.

Methods

Taxon sampling, DNA sequencing, and SNP data assembly

We sequenced 36 samples of *Kovarikia* from 16 localities representing all described species and the new populations from the Santa Ana and San Gabriel Mountains (Table 1). We generated genome-wide single nucleotide polymorphism (SNP) data using the double-digest restriction-digest associated DNA marker (ddRADseq) protocol of Peterson et al. (2012). We extracted high molecular-weight genomic DNA from pedipalp tissue using Qiagen DNeasy Blood & Tissue Kits (Qiagen Inc.), and followed the ddRADseq wet-lab protocol for scorpions published in Bryson et al. (2016). Pooled ddRAD libraries were sent to the Vincent J. Coates Genomics Sequencing Laboratory at UC Berkeley for 150-base single-end sequencing on one lane of an Illumina HiSeq4000 (combined with 10 pooled libraries in the lane).

We demultiplexed and processed Illumina reads using pyRAD v2.16.1 (Eaton and Ree 2013, Eaton 2014). Sequences were clustered at 90% similarity within samples using USEARCH v7.0.1090 (Edgar 2010) and aligned with MUSCLE v3.8.31 (Edgar 2004). Error rate and heterozygosity were jointly estimated from the base counts in each site across all clusters. Consensus sequences with less than five reads, more than five undetermined sites, more than five heterozygous sites, or more than two haplotypes were discarded. Consensus sequences were then clustered across samples using the same 90 % similarity threshold and aligned. Any locus with a site appearing heterozygous across more than 50 % of samples was discarded as likely representing a clustering of paralogs. We set the minimum number of samples in a final locus to 16, allowing up to 46 % missing data per locus.

Species delimitation

We performed Bayes factor species delimitation using BFD* (Grummer et al. 2014, Leaché et al. 2014) implemented using the SNAPP v1.3.0 (Bryant et al. 2012) plugin for BEAST v2.4.3 (Bouckaert et al. 2014). We tested 11 competing models which variously placed scorpions from the two new localities with geographically adjacent species or into separate lineages (Fig. 1, Table 2). We set the unsampled mutation rates u and v to 1, alpha to 1, beta to 250, lambda to 20, sampled a coalescence rate initially set to 10, and used default settings for all other parameters. We conducted path sampling for a total of 24 steps, running each for 200,000 MCMC generations and sampling every 1,000 steps to estimate marginal likelihoods for each competing model. We ranked and compared the resulting marginal likelihood values using Bayes factors (Kass and Raftery 1995). We repeated the analyses using default settings for the mutation rates u and v, alpha, beta, lambda, and coalescence rate to evaluate potential impacts of using different priors.

Table 1. Genetic samples of *Kovarikia* used in this study. Additional details on collecting localities are listed in Appendix 1.

Sample numbers	Species	Locality
sky241, sky263, sky264	*K. angelena*	CA: Ventura Co: Yerba Buena Road, Santa Monica Mountains
sky464, sky465, sky466, sky499	*K. angelena*	CA: Los Angeles Co: Kanan-Duma Road, Santa Monica Mountains
sky266, sky498	*K. bogerti*	CA: San Bernardino Co: Mountain Home, San Bernardino Mountains
sky470, sky471, sky472	*K. bogerti*	CA: Riverside Co: Mountain Center, San Jacinto Mountains
sky467, sky468, sky469	San Gabriel Mtns	CA: Los Angeles Co: Eaton Canyon Falls, San Gabriel Mountains
sky250, sky516, sky517	Santa Ana Mtns	CA: Orange Co: Trabuco Creek Road, Santa Ana Mountains
sky518	Santa Ana Mtns	CA: Orange Co: Silverado Canyon Road, Santa Ana Mountains
sky248, sky249	*K. williamsi*	CA: San Diego Co: Palomar Mountain
sky251	*K. williamsi*	CA: San Diego Co: San Diego Zoo Safari Park
sky274, sky276	*K. williamsi*	CA: San Diego Co: Barrett Flume
sky277	*K. williamsi*	CA: San Diego Co: Barrett Lake Road
sky275, sky519, sky520	*K. williamsi*	CA: San Diego Co: Escondido
sky511	*K. williamsi*	CA: San Diego Co: Indian Valley Road
sky273, sky504	*K. williamsi*	CA: San Diego Co: Mission Trails
sky512, sky513	*K. williamsi*	CA: San Diego Co: Padre Dam
sky494, sky514, sky515	*K. williamsi*	CA: San Diego Co: Santa Ysabel

Table 2. Bayes factor comparisons of 11 competing models of species delimitation in *Kovarikia*. Marginal likelihood estimates (MLE) and Bayes factors comparisons (2*ln*BF) shown; the model that received the best marginal likelihood score is indicated by a 2*ln*BF score of NA. SGM = San Gabriel Mountains, SAM = Santa Ana Mountains.

Model	Species	Groupings	MLE	Rank	2lnBF
M1	3	*angelena*, SGM + *bogerti*, SAM + *williamsi*	-25035.20	8	14165.49
M2	3	*angelena* + SGM, *bogerti*, SAM + *williamsi*	-26835.35	9	15965.64
M3	3	*angelena*, SGM + *bogerti* + SAM, *williamsi*	-24961.18	7	14091.47
M4	3	*angelena* + SGM, *bogerti* + SAM, *williamsi*	-28211.23	11	17341.52
M5	5	*angelena*, SGM, *bogerti*, SAM, *williamsi*	-10869.71	1	–
M6	4	*angelena*, SGM, *bogerti*, SAM + *williamsi*	-14205.08	2	3335.37
M7	4	*angelena*, SGM, *bogerti* + SAM, *williamsi*	-14849.95	3	3980.24
M8	4	*angelena*, SGM + *bogerti*, SAM, *williamsi*	-18460.44	4	7590.73
M9	4	*angelena* + SGM, *bogerti*, SAM, *williamsi*	-19812.85	6	8943.14
M10	4	*angelena*, SGM + SAM, *bogerti*, *williamsi*	-19084.64	5	8214.93
M11	3	*angelena* + SGM + SAM, *bogerti*, *williamsi*	-27947.41	10	17077.70

We generated a final species tree in SNAPP based on the best-ranked species model from BFD*. We ran the analysis for 1,000,000 MCMC generations, sampling every 1,000 steps. We confirmed convergence and high ESS values using Tracer v1.5 (Rambaut and Drummond 2009), and produced a maximum clade credibility tree after a 25 % burnin using TreeAnnotator v1.7.5 (Drummond and Rambaut 2007).

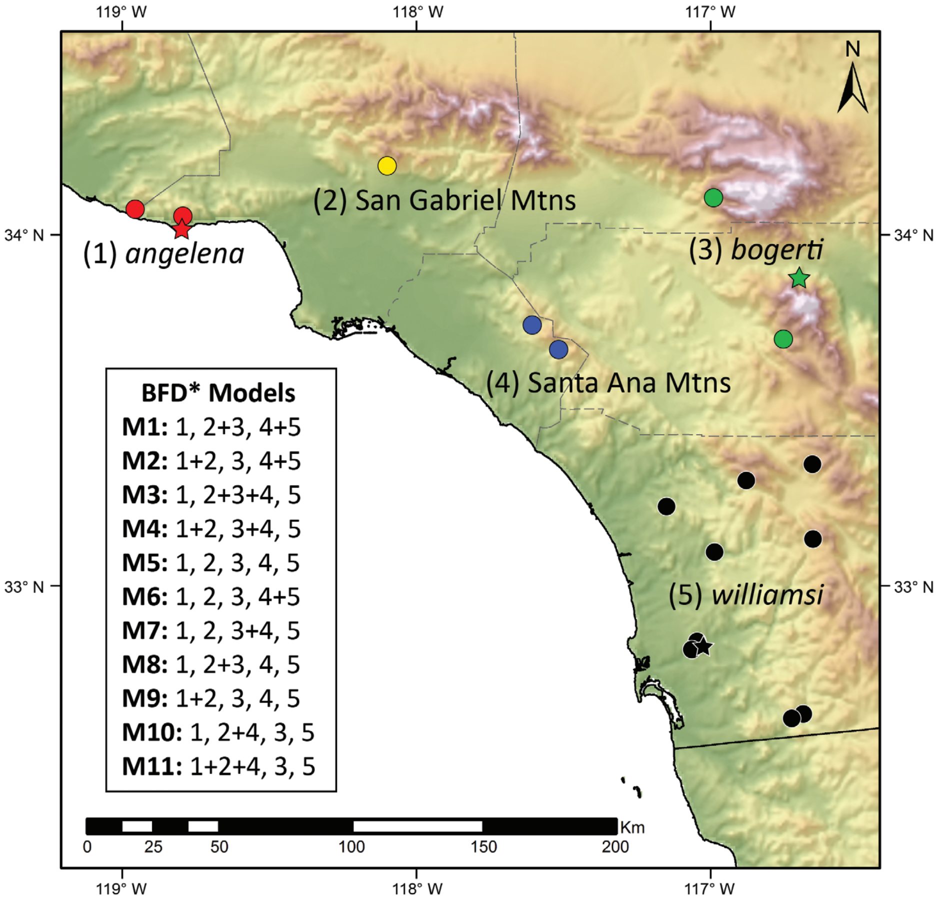

Figure 1. Sampling localities for genetic samples of scorpions in the genus *Kovarikia*. Type localities (star symbols) are shown for reference. Inset shows the 11 competing BFD* models used in species delimitation; numbers correspond to species (**1** *K. angelena* **3** *K. bogerti* **5** *K. williamsi*) or new localities (**2** San Gabriel Mountains **4** Santa Ana Mountains).

Phylogenetic relationships

To examine phylogenetic relationships within *Kovarikia* and estimate approximate dates of divergences among lineages, we estimated a time-calibrated phylogeny from the concatenated RAD loci using BEAST v1.8.2 (Drummond et al. 2012). We used the same priors and calibrations specified in Bryson et al. (2016), which included giving the ucld.mean parameter a lognormal distribution to span mean substitution rates previously calculated for nine nuclear genes in scorpions (Gantenbein and Keightley 2004). We ran the analysis for 80 million generations and retained trees and parameters every 10,000 steps. We displayed results in Tracer to assess convergence and effective sample sizes for all estimated parameters. We discarded the first

25% of trees as burnin and summarized the maximum clade credibility (MCC) tree with median heights using TreeAnnotator v1.8.2 (Drummond et al. 2012). We repeated the analysis using different starting seeds to confirm adequate mixing and consistent results.

Morphological assessments

We examined the morphology of 40 preserved specimens of *Kovarikia* (Appendix 1). Our terminology and conventions followed Stahnke (1971) and Sissom et al. (1990) for mensuration, Soleglad and Sissom (2001) for pedipalp finger dentition and chelal carinae, Vachon (1974) for trichobothrial patterns, Soleglad and Fet (2003a) for sternum terminology, Soleglad and Fet (2003b) for cheliceral dentition terminology, and Soleglad and Fet (2008) and Ayrey and Soleglad (2015) for the hemispermatophore description. We limited the use of morphological data published in previous studies to avoid possible researcher-based biases in counts or measurements.

Results

Genetic data

One sample of *K. williamsi* from the San Diego Zoo Safari Park contained a high percentage of missing data (>90 %) and was not included in the final SNP data assembly. The final aligned data set with all RAD loci contained 35 samples, 2,915 loci and 414,566 nucleotides. The final data set for species delimitation contained 35 samples and 1,123 unlinked SNPs after sites with missing data were removed by SNAPP. Datasets were deposited in Dryad.

Species delimitation

The BFD* model with the best marginal likelihood value strongly supported a five-species model that placed scorpions from the San Gabriel and Santa Ana Mountains into separate lineages (Table 2). Analyses using default settings resulted in the same model rankings. The MCC species tree showed uncertainty in the phylogenetic placement of these five species (Fig. 2). *Kovarikia angelena* and scorpions from the San Gabriel Mountains were placed together in a strongly supported relationship. Scorpions from the Santa Ana Mountains were sister to this grouping, although nodal support for this relationship was weak (0.84 posterior probability). *Kovarikia bogerti* and *K. williamsi* were placed together in a separate clade with 0.91 posterior probability support.

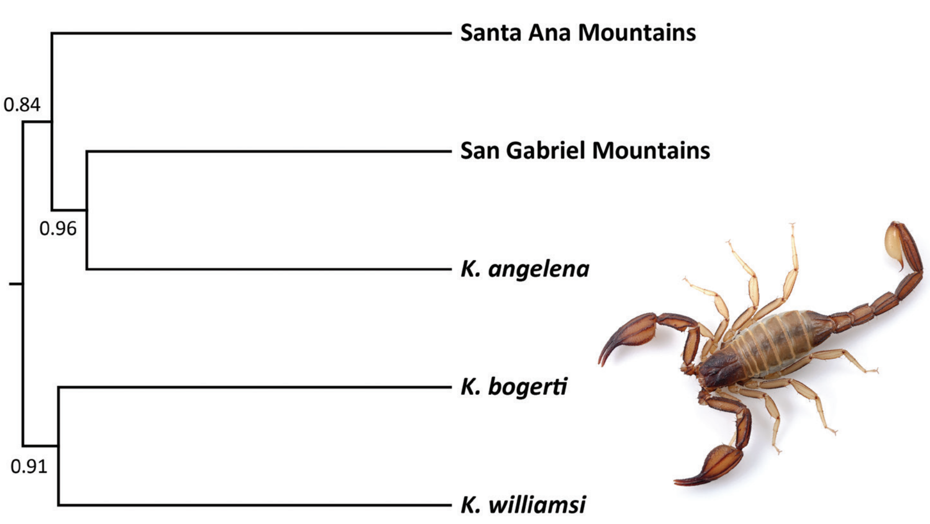

Figure 2. Species tree of scorpions in the genus *Kovarikia* reconstructed from 1,123 unlinked SNPs, based on the best-ranked five-species model (Table 2). Numbers represent posterior probability support for nodes. Shown is an adult female *Kovarikia* from the San Gabriel Mountains.

Phylogenetic relationships

Phylogenetic analysis of the concatenated RAD loci produced a well-supported tree (Fig. 3). Samples from the San Gabriel Mountains, the Santa Ana Mountains, and *K. angelena*, *K. bogerti*, and *K. williamsi* formed five unique clades. The relationships among these clades matched those in the species tree (Fig. 2), although two nodes near the base of the tree were not strongly supported (< 0.95 posterior probability). Phylogeographic structure was present within *K. williamsi*, with samples from the northern distribution (Escondido, Palomar Mountain, Indian Valley Road, and Santa Ysabel) and southern distribution (Mission Trails, Padre Dam, Barrett Flume, and Barrett Lake Road) forming two well-supported clades ("North" and "South", Fig. 3). Additional phylogeographic structure was present in each of these clades of *K. williamsi*. *Kovarikia bogerti* from the San Bernardino Mountains and San Jacinto Mountains also formed geographically cohesive clades (Fig. 3).

Estimated divergence dates among the five major clades of *Kovarikia* predated the start of the Pleistocene 2.6 million years ago (Ma), based on mean dates (Fig. 3). However, 95% posterior credibility intervals for divergence date estimates were large, encompassing millions of years. Mean dates of divergences among clades within *K. williamsi* and *K. bogerti* were estimated between 1.6–2.8 Ma.

Morphological assessments

Morphological assessments revealed several characters that differentiated *K. angelena*, *K. bogerti*, *K. williamsi*, and specimens from the San Gabriel Mountains and the

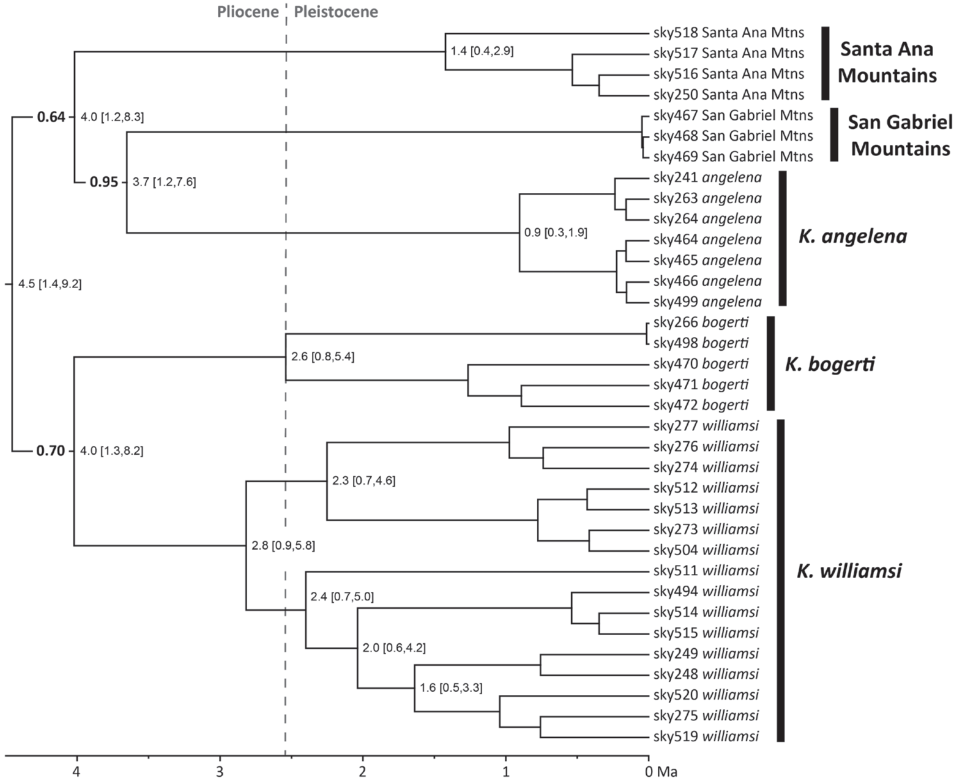

Figure 3. Time-calibrated phylogeny of scorpions in the genus *Kovarikia* inferred from 414,566 base-pairs of concatenated RAD loci. Nodes that received less than 1.0 posterior probability support are labeled and in bold. Mean estimated divergence date (in millions of years ago, Ma) followed by 95% highest posterior density intervals in brackets. SBM = San Bernardino Mountains, SJM = San Jacinto Mountains.

Santa Ana Mountains (Appendix 2). Telson shape varied substantially among and within the species, with female telsons of *K. bogerti* and *K. williamsi* being smaller than those of *K. angelena*, specimens from the San Gabriel Mountains, and specimens from the Santa Ana Mountains (Fig. 4). Female telsons of *K. bogerti* were significantly less wide than those of *K. williamsi*. *Kovarikia angelena* and specimens from the Santa Ana Mountains exhibited relatively longer telson vesicles than *K. bogerti*, *K. williamsi*, and specimens from the San Gabriel Mountains. Both fixed (FF) and movable (MF) chelal fingers in female *K. bogerti* and *K. williamsi* were also longer than those of *K. angelena*, specimens from the San Gabriel Mountains, and specimens from the Santa Ana Mountains. Carapace lengths varied, with *K. williamsi* being the largest species and *K. angelena* being the smallest. Pectine tooth counts overlapped in both sexes for all species except *K. angelena*, which had fewer pectine teeth. Pectine tooth counts were highest for the largest species, *K. williamsi*, and lowest for the smallest

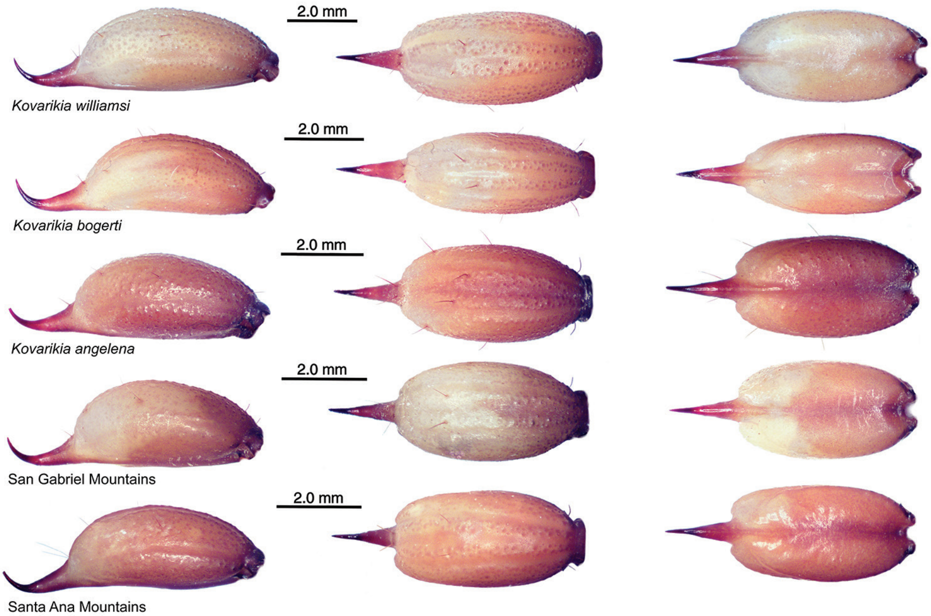

Figure 4. Telson of adult females of genus *Kovarikia*, lateral (left column), ventral (middle column), and dorsal (right column) views. In *K. bogerti* the vesicle width is noticeably thinner than in the other species and the vesicular ridges are more reduced (see ventral and dorsal views). Note, the vesicular linear patch found on the dorsal surface of adult males is absent in the females.

species, *K. angelena*. Additional details on morphological characters are provided in the Discussion. These differences were used to diagnose five species in our "Key to Species of *Kovarikia*".

Discussion

Our genetic data strongly support the recognition of *Kovarikia* from the San Gabriel Mountains and the Santa Ana Mountains as distinct lineages, which we describe as new species and name below. Based on the topography of southern California and our current understanding of the distribution of *Kovarikia* (Fig. 1), both species appear to be geographically isolated. Morphology among the species of *Kovarikia* is relatively conserved, despite deep genetic divergences, consistent with recent studies of other stenotopic scorpions (e.g., Bryson et al. 2013; Talal et al. 2015). Phylogeographic structure within *K. williamsi* and *K. bogerti* suggest additional cryptic species are probably present in the genus and reveal the need for future research with denser sampling. Although California is a relatively well-studied state biologically, our study highlights the fact that new populations await discovery and that morphologically conserved taxa such as scorpions, and other arachnids (e.g., Satler et al. 2013), likely harbor unexpected species-level diversity.

Systematics

Family Vaejovidae Thorell, 1876

Subfamily Vaejovinae Thorell, 1876

Genus *Kovarikia* Soleglad, Fet & Graham, 2014

Kovarikia savaryi Bryson, Graham & Soleglad, sp. n.

http://zoobank.org/CB431CD7-8707-43FC-9152-79D4FDE90428
Figs 5–7; Table 3

Type material. *United States*: *California*: *Orange Co*: male holotype (DMNS ZA.38170), Trabuco Creek Road near the entrance to Holy Jim Canyon, Santa Ana Mountains. 33.67699°N, 117.51733°W, 527 m. 15 April 2015. R.W. Bryson. Paratypes: Same locality. 15 April 2015. R.W. Bryson. 1 ♂, 5 ♀ (DMNS ZA.38171–ZA.38176). *Orange Co*: Silverado Canyon Road, Santa Ana Mountains. 33.74614, -117.59327, 524 m. 16 April 2015, R.W. Bryson. 1 ♂ (DMNS ZA.38177).

Etymology. Patronym honoring Warren E. Savary for his contributions to vaejovid scorpion taxonomy.

Diagnosis. Large sized species for the family, with males up to 50.5 mm and females reaching 57.0 mm; pectinal tooth counts 12–13 for males and 11–13 for females. The species possesses the characteristics of genus *Kovarikia*: i.e. neobothriotaxy on ventral surface of chela, secondary lamellar hook on spermatophore, large crescent-shaped barb with a smooth edge on the mating plug, and secondary exteromedian (EM_c) carina on pedipalp patella (Soleglad et al. 2014). The holotype differs from the *K. oxy* sp. n. holotype in the following: median eyes protrude only slightly above carapace surface (eyes are well above in *K. oxy*); median carinal pair on sternite VII essentially obsolete except for a few scattered small granules (obsolete in *K. oxy*); moderately granular intermediary carinae occur on metasomal segment I, the posterior 1/5 of segment II, and posterior 1/6 of segment III (strongly granular on segment I, the posterior 1/4 on segment II and posterior 1/5 of segment III in *K. oxy*); lateral carinae on metasomal segment V crenulate and connecting with dorsolateral carinae at posterior 1/3 of segment (posterior 1/4 in *K. oxy*); internal surface of femur with scattered granules of various size, mostly on proximal 1/2 (few large granules arranged in a line along proximal 1/3 in *K. oxy*); basitarsus retroventral setae count of 4/4:5/5:5/5:7/6 (4/4:7/7:7/7:8/7 in *K. oxy*). Differs from the other *Kovarikia* spp. by pectine counts and morphology of the chelal fingers and telson, as outlined below in the "Key to Species of *Kovarikia*".

Description of holotype. *Color* (Fig. 5): Carapace, trochanter, femur, patella, tergites, and metasoma have a brown base color with dark brown to black markings along the carinae of the pedipalp and metasoma. Legs are yellow brown with dark brown carinae. Pedipalp chelae are brown in color with darker reddish-brown coloration at the anterior portion of the palm where the fixed finger and movable finger meet. Chelicerae are light yellow with dark reddish-brown dentition. Vesicle

Figure 5. Dorsal and ventral views of *Kovarikia savaryi* sp. n. male holotype.

portion of the telson is yellow-orange proximally, fading to very light yellow on the distal third, with a dark reddish-brown to black aculeus. Pectines and genital operculum are light yellow to cream colored. *Morphology*: Carapace: trapezoidal with strongly emarginated anterior margin; surface with scattered granules; a strong median furrow traverses length of carapace; ratio of location of median eyes location (from anterior edge)/carapace length = 0.348; median eyes protrude only slightly above carapace surface. Tergites: surface with small granules on distal 1/3–2/3 of tergites II–VI; tergite VII with two pairs of granular lateral carinae, and a strong median hump. Sternites: III–VI smooth to very finely granular and without carinae; VII with granular ventral lateral carinae on posterior 2/3, median carinal pair essentially obsolete except for a few scattered small granules. Spiracles: slightly ellipsoid and with median side rotated 30° away from posterior sternite margin. Genital Operculum: sclerites separated on posterior 1/5 exposing conspicuous genital papillae. Pectines: tooth count 12/13; middle lamellae 7/6; sensorial areas present on all pectine teeth. Metasoma: ratio of segment I length/width 1.15; segment II length/width 1.39; segment III length/

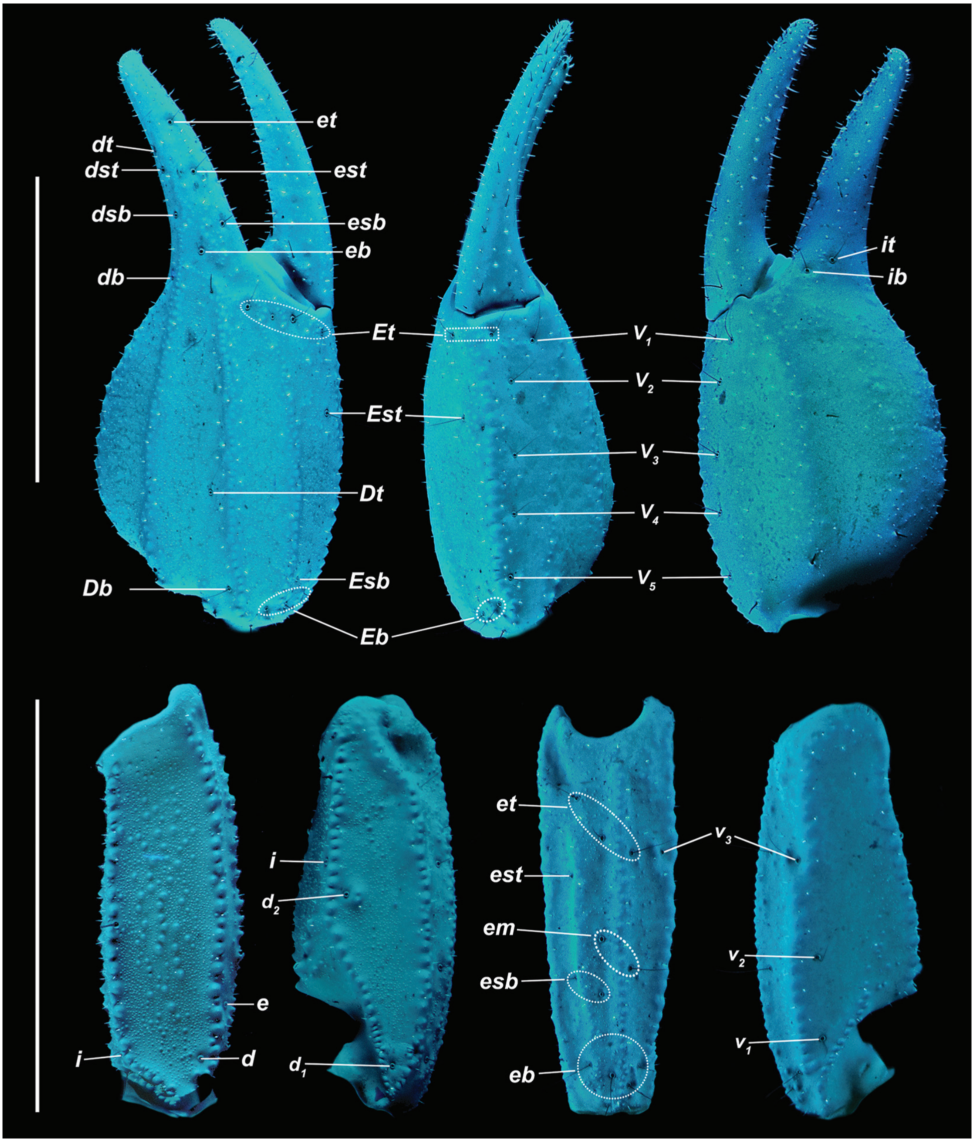

Figure 6. *Kovarikia savaryi* sp. n. male holotype. Trichobothrial pattern. Scale bar = 5 mm; top bar for chela, bottom applies to femur and patella.

width 1.56; segment IV length/width 2.09; segment V length/width 3.33. Segments I–IV: dorsal carinae are moderately denticulate on segments I–IV and have slightly enlarged distal denticles; dorsolateral carinae are moderately denticulate on segments I–IV with slightly enlarged posterior denticles; ventrolateral carinae are moderately crenulate on segments I–IV; moderately granular intermediary carinae occur on segment I, the posterior 1/5 of segment II, and posterior 1/6 of segment III; ventromedian carinae are crenulate on segments I–IV; ventrolateral setae 2/2:2/2:2/2:2/2; ventral

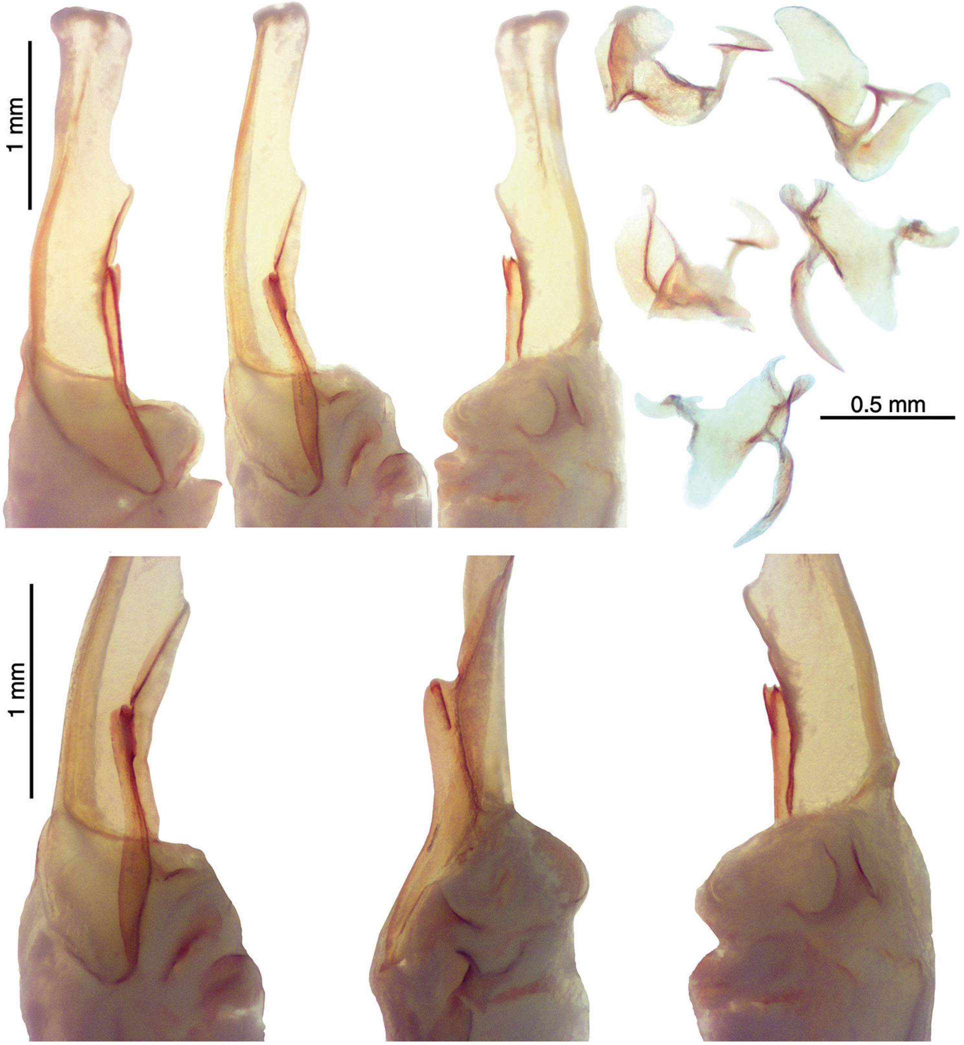

Figure 7. *Kovarikia savaryi* sp. n., male holotype. Right hemispermatophore and mating plug (submerged in alcohol). **Upper-Left** Hemispermatophore median area and lamina, dorsal, interodorsal, and ventral views **Lower** Closeup of the median area and lamellar hooks, interodorsal, internal, and ventral views. Note, embedded mating plug is visible in ventral view **Upper-Right** Mating plug, four dorsal views at various angles and one exteroventral view (bottom).

submedian setae 2/2:3/3:3/3:3/3. Segment V: dorsolateral carinae crenulate; lateral carinae crenulate and connecting with dorsolateral carinae at posterior 1/3 of segment; ventrolateral carinae crenulate; ventromedian carinae crenulate; intercarinal spaces with sparsely scattered granules; dorsolateral setation 2/2; lateral setation 2/2; ventrolateral setation 4/4; ventromedian setation 4/4. Telson: smooth to slightly granular with no subaculear tubercule and lacking laterobasal aculear serrations (LAS; Fet et al. 2006); posterior end of vesicle inflated toward the aculeus forming a pair of smooth ventral

Table 3. Measurements (in mm) of the type series of *Kovarikia savaryi* sp. n.

	Male holotype (DMNS ZA.38170)	Male paratype 1 (DMNS ZA.38171)	Male paratype 2 (DMNS ZA.38177)	Female paratype 1 (DMNS ZA.38172)	Female paratype 2 (DMNS ZA.38173)	Female paratype 3 (DMNS ZA.38174)	Female paratype 4 (DMNS ZA.38175)	Female paratype 5 (DMNS ZA.38176)
Total L	50	50.5	49	47.5	57	53	47	57
Cara L	5.85	6.5	6.15	5.75	6.5	6.3	6.05	7.2
Meso L	14.95	15.7	14.1	15.8	17.65	17.8	13.6	17.3
Met I L	3	2.95	2.9	2.75	3.1	2.95	2.65	3.2
Met I W	2.6	2.95	2.9	2.55	2.7	2.7	2.6	2.95
Met II L	3.55	3.55	3.5	3.25	3.65	3.5	3.3	3.9
Met II W	2.55	2.9	2.8	2.5	2.55	2.55	4.45	2.85
Met III L	3.9	3.95	3.9	3.55	3.9	3.75	3.5	4.2
Met III W	2.5	2.85	2.7	2.4	2.45	2.5	2.3	2.8
Met IV L	4.8	4.95	5	4.5	4.95	4.75	4.35	4.5
Met IV W	2.3	2.65	2.5	2.3	2.2	2.3	2.2	2.6
Met V L	7.5	7.3	7.65	6.85	7.7	7.35	6.7	8.2
Met V W	2.25	2.5	2.4	2.2	2.3	2.3	2.15	2.5
Tel L	-	6.3	-	6.2	7.2	6.9	6.2	7.3
Ves L	5.2	4.75	4.1	4.5	5.4	5.1	4.6	5.55
Ves W	2.6	2.6	2.8	2.35	2.6	2.5	2.5	3
Ves D	2.05	2.1	2.2	2	2.1	2.15	1.95	2.3
Acu L	-	1.6	1.6	1.7	1.85	1.75	1.65	1.7
Fem L	5.4	5.5	5.6	5.5	5.95	5.7	5.35	6.4
Fem W	1.9	1.95	1.9	1.8	2.1	2	1.95	2.2
Pat L	5.25	5.3	5.5	5.4	5.8	5.6	5.3	6.3
Pat W	2.25	2.25	2.35	2.3	2.3	2.35	2.3	2.6
Chel L	10	9.95	10.4	10.1	11.5	10.8	9.85	12.35
Palm L	5.55	5.8	5.9	5.55	6.4	6.05	5.5	6.8
Palm W	3	2.55	3.3	2	3.2	3.05	2.85	3.5
Palm D	4.2	4.45	4.65	2.8	4.3	3.95	4	4.75
FF L	3.85	5.2	4.1	4	4.4	4.1	3.75	4.75
MF L	5.25	5.15	5.5	5.25	6	5.55	5.05	6.45
Pect Teeth	12/13	13/12	12/12	11/11	12/11	11/10	11/11	12/13

grooves and carinae that stop at aculeus base; vesicle length/width 2.00; vesicle length/depth 2.54. Chelicerae: dorsal edge of fixed finger with four teeth, one distal, one subdistal, one median, and one basal, the latter two denticles formed as a bicuspid; ventral edge smooth; dorsal edge of movable finger has five teeth total comprised of one distal, two subdistal, one median tooth, and one basal tooth; ventral edge smooth; serrula with approximately 25 tines. Pedipalps (Fig. 6): trichobothrial pattern type C, neobothriotaxic: trichobothria *ib-it* positioned on very base of fixed finger, distance between positions of *Dt* and *Est* is less than that of *Dt* from palm base, *Db* dorsal of digital carina, *Et1* is clearly closer to the movable finger than V1, five ventral trichobothria (*V1–V5*); ratio of chela length/width 3.33; femur length/width 2.84; patella length/width 2.33; fixed finger length/carapace length 0.66. Chela: median denticles

(MD) of fixed finger aligned and divided into six subrows by five outer denticles (OD); flanked by six inner denticles (ID); movable finger with six subrows of MD, five OD and seven ID. Chela carinae: Digital carina strong and crenulate; subdigital carina strong and crenulate but obsolete on distal 7/8; dorsosecondary moderate and crenulate; dorsomarginal very rounded, with large scattered granules; dorsointernal obsolete; interomedian weak, rounded with scattered granules; external carina moderate and crenulate; ventroexternal strong and crenulate; ventromedian moderate and crenulate on proximal 1/5, fading to scattered granules and essentially obsolete on distal 3/5; ventrointernal moderate to weak, rounded, with small scattered granules. Femur: dorsointernal and ventrointernal strong, black in color, and crenate; dorsoexternal carinae crenulate, brown to burgundy in color; ventroexternal reddish orange with scattered granules of various size; internal surface has scattered granules of various size, mostly on proximal 1/2. Patella: dorsointernal and dorsoexternal carinae are crenulate and dark brown to burgundy in color; ventral internal and ventroexternal carinae crenate to crenulate and dark brown to burgundy; external median carinae dark brown to burgundy and crenulate; seconday external median carina strong and on proximal 3/4, obsolete on distal 1/4, dark brown to burgundy and crenulate; internal surface has a large spur flanked by a few large granules. Legs: Ventral surface of telotarsi with single median row of 17–27 spinules terminating distally with two pairs of spinules. Two rows of small spinules occur on all basitarsi, fading proximally, but are very weak on basitarsus IV. Basitarsus populated with large irregularly placed darkly pigmented setae as follows: vental setae 5/5:5/6:6/6:6/5, retroventral setae 4/4:5/5:5/5:7/6, retromedian accessory setae 2/2:3/2:3/3:3/3, retrosuperior setae 2/2:2/2:2/2:2/2, and superior setae 3/3:3/3:3/3:3/3 (excluding DSM and DPS). Hemispermatophore (Fig. 7): Left hemispermatophore is 5.7 mm in length; lamina length 2.9, primary lamellar hook length 1.3, secondary lamellar hook length 0.5 (distance between tips of primary and secondary hooks), and trough difference (vertical distance between ventral and dorsal troughs) 1.0. Lamellar edges roughly parallel, a slight constriction adjacent to (distal) the secondary lamellar hook; terminus blunted with a very slight distal crest on the dorsal side. Primary lamellar hook extends somewhat from lamina base, is distinctly bifurcated, and is formed entirely from the dorsal trough. Secondary lamellar hook not bifurcated and forms a slight expansion of the lamina. A sclerotized mating plug with large asymmetric barb with a smooth edge was extracted from the ventrointernal aspect of the hemispermatophore median area.

Measurements of male holotype (mm). Total L, 50.0; carapace L, 5.85; mesosoma L, 14.95; metasoma L (additive without telson), 22.75. Metasomal segments: I L/W, 3.00/2.60; II L/W, 3.55/2.55; III L/W, 3.90/2.50; IV L/W, 4.80/2.30; V L/W, 7.50/2.25. Telson: vesicle L/W/D, 5.20/2.06/2.05. Pedipalps: femur L/W, 5.40/1.90; patella L/W, 5.25/2.25; chela L/W/D, 10.00/3.00/4.20; fixed finger L, 3.85; movable finger L, 5.25; palm L, 5.55. Note: Aculeus is broken so Telson L and Aculeus L are omitted.

Male and female variability. Slight sexual dimorphism was evident in telson and metasoma morphology for *K. savaryi*. Two-tailed Student's t-tests indicated that the length of metasomal segment V is significantly larger in males (p = 0.048). The telson aculeus is significantly longer in females (*p*=0.019). Differences may also occur in lengths and widths of additional metasomal segments, as well as femur, patella, and chela morphology, but small sample sizes hindered statistical power in our analyses.

Kovarikia oxy Bryson, Graham & Soleglad, sp. n.

http://zoobank.org/C9589607-5BA9-4986-A038-258A4E182CD6
Figs 8–10; Table 4

Type material. *United States*: *California*: *Los Angeles Co*: male holotype (DMNS ZA.38178), Eaton Canyon Falls, San Gabriel Mountains. 34.19665°N, 118.10210°W, 475 m. 15 May 2014. R.W. Bryson Jr. and E. Zarza. Paratypes: Same locality. 15 May 2014. R.W. Bryson Jr. and E. Zarza, 2 ♂, 4 ♀ (DMNS ZA.38179–ZA.38184).

Etymology. The specific name is a noun in apposition in reference to Occidental College, commonly referred to as Oxy, which lies at the base of the San Gabriel Mountains near Eaton Canyon, the type locality.

Diagnosis. Large sized species for the family, with males up to 51.0 mm and females reaching 52.0 mm; pectinal tooth counts 12 for males and 11–13 for females. The species possesses the characteristics of genus *Kovarikia*: i.e. neobothriotaxy on ventral surface of chela, secondary lamellar hook on spermatophore, large crescent-shaped barb with a smooth edge on the mating plug, secondary exteromedian (EM_c) carina on pedipalp patella. The holotype differs from the *K. savaryi* sp. n. holotype in the following: median eyes protrude well above carapace surface (only slightly above in *K. savaryi*); median carinal pair on sternite VII obsolete (essentially obsolete except for a few scattered small granules in *K. savaryi*); strongly granular intermediary carinae on metasomal segment I, the posterior 1/4 on segment II and posterior 1/5 of segment III (moderately granular on segment I, the posterior 1/5 of segment II, and posterior 1/6 of segment III in *K. savaryi*); lateral carinae on metasomal segment V crenulate and connecting with dorsolateral carinae at posterior 1/4 of segment (posterior 1/3 in *K. savaryi*); internal surface of femur with a few large granules arranged in a line along proximal 1/3 (scattered granules of various size, mostly on proximal 1/2 in *K. savaryi*); basitarsus retroventral setae count of 4/4:7/7:7/7:8/7 (4/4:5/5:5/5:7/6 in *K. oxy*). Differs from the other *Kovarikia* spp. by pectine counts and morphology of the chelal fingers and telson, as outlined below in the "Key to Species of *Kovarikia*".

Description of holotype. *Color* (Fig. 8): Carapace, trochanter, femur, patella, tergites, and metasoma have a brown base color with dark brown to black markings along the carinae of the pedipalp and metasoma. Legs are yellow brown with dark brown carinae. Pedipalp chelae are brown in color with darker reddish-brown coloration at the anterior portion of the palm where the fixed finger and movable finger meet. Chelicerae are light yellow with dark reddish-brown dentition. Vesicle portion of the telson is yellow-orange proximally, fading to cream on the distal third, with a dark reddish-brown to black aculeus. Pectines and genital operculum are light yellow to cream colored. *Morphology*: Carapace: trapezoidal with strongly emarginated anterior margin; surface

Figure 8. Dorsal and ventral views of *Kovarikia oxy* sp. n. male holotype.

with scattered granules; moderate median furrow traverses length of carapace; ratio of location of median eyes location (from anterior edge)/carapace length = 0.350; median eyes protrude well above carapace surface. Tergites: surface with small granules on distal 1/3–2/3 of tergites III–VI; tergite VII with two pairs of granular lateral carinae, and a moderate median hump. Sternites: III–VI smooth to very finely granular and without carinae; VII with granular ventral lateral carinae on posterior 2/3, median carinal pair obsolete (smooth). Spiracles: slightly ellipsoid and with median side rotated 30° away from posterior sternite margin. Genital Operculum: sclerites separated on posterior 1/5 exposing conspicuous genital papillae. Pectines: tooth count 12/12; middle lamellae 7/7; sensorial areas present on all pectine teeth. Metasoma: ratio of segment I length/width 1.02; segment II length/width 1.30; segment III length/width 1.54; segment IV length/width 2.07; segment V length/width 3.14. Segments I–IV: dorsal carinae are moderately denticulate on segments I–IV and have slightly enlarged distal denticles; dorsolateral carinae are moderately denticulate on segments I–IV with slightly enlarged posterior denticles; ventrolateral carinae are moderately crenulate on segments I–IV; strongly granular intermediary carinae occur on segment I, the posterior 1/4 on segment II and posterior 1/5 of segment III; ventromedian carinae are crenulate on segments I–IV; ventrolateral setae 2/2:2/2:2/2:2/2; ventral submedian setae 2/2:3/3:3/3:3/3. Segment V: dorsolateral carinae crenulate; lateral carinae crenulate and connecting with dorsolateral carinae at posterior 1/4 of segment; ventrolateral carinae crenulate; ventromedian carinae crenulate; intercarinal spaces with sparsely scattered granules; dorsolateral setation 2/2; lateral setation 2/2; ventrolateral setation 4/4; ventromedian setation 4/4. Telson: smooth to slightly granular with no subaculear tubercule and lacking LAS; posterior end of vesicle inflated toward the aculeus slightly forming a pair of smooth ventral grooves and carinae that stop at aculeus base; vesicle length/width 1.77; vesicle length/depth 2.30; vesicle length/aculeus length 2.66. Chelicerae: dorsal edge of fixed finger with four teeth, one distal, one subdistal, one median, and one basal, the latter two denticles formed as a bicuspid; ventral edge smooth; dorsal edge of movable finger has five teeth total comprised of one distal, two subdistal, one median tooth, and one basal tooth; ventral edge smooth; serrula with approximately 34 tines. Pedipalps (Fig. 9): trichobothrial pattern type C, neobothriotaxic: trichobothria *ib-it* positioned on very base of fixed finger, distance between positions of *Dt* and *Est* is less than that of *Dt* from palm base, *Db* dorsal of digital carina, *Et1* is clearly closer to the movable finger than V1, five ventral trichobothria (*V1–V5*); ratio of chela length/width 3.37; femur length/width 3.03; patella length/width 2.51; fixed finger length/carapace length 0.67. Chela: median denticles (MD) of fixed finger aligned and divided into six subrows by five outer denticles (OD); flanked by six inner denticles (ID); movable finger with six subrows of MD, five OD and seven ID. Chela carinae: Digital carina strong and crenulate; subdigital carina strong and crenulate but obsolete on distal 7/8; dorsosecondary moderate and crenulate; dorsomarginal very rounded, with large scattered granules; dorsointernal obsolete; interomedian weak, rounded with scattered granules; external carina moderate and crenulate; ventroexternal strong and crenulate; ventromedian moderate and crenulate on proximal 1/5, fading to smooth granules and essentially obsolete on distal 3/5; ventrointernal moderate to weak, rounded, with small scattered granules. Femur: dorsointernal and ventrointernal strong, black in color, and crenate; dorsoexternal carinae crenulate, brown to burgundy in color; ventroexternal reddish orange with scattered granules of various size; internal surface has a few large granules arranged in a line along proximal 1/3. Patella: dorsointernal and dorsoexternal carinae are crenulate and dark brown to burgundy in color; ventral internal and ventroexternal carinae crenate and dark brown to burgundy; external median carinae dark brown to burgundy and crenulate; seconday external median carina strong and on proximal 3/4, obsolete on distal 1/4, dark brown to burgundy and crenulate; internal surface has a large spur flanked by a few large granules. Legs: Ventral surface of telotarsi with single median row of 16–23 spinules terminating distally with two pairs of spinules. Two rows of small spinules occur on all basitarsi, fading proximally, but are very weak on basitarsus IV. Basitarsus populated with large irregularly placed darkly pigmented setae as follows: vental setae 5/5:6/6:6/6:6/6, retroventral setae 4/4:7/7:7/7:8/7, retro-

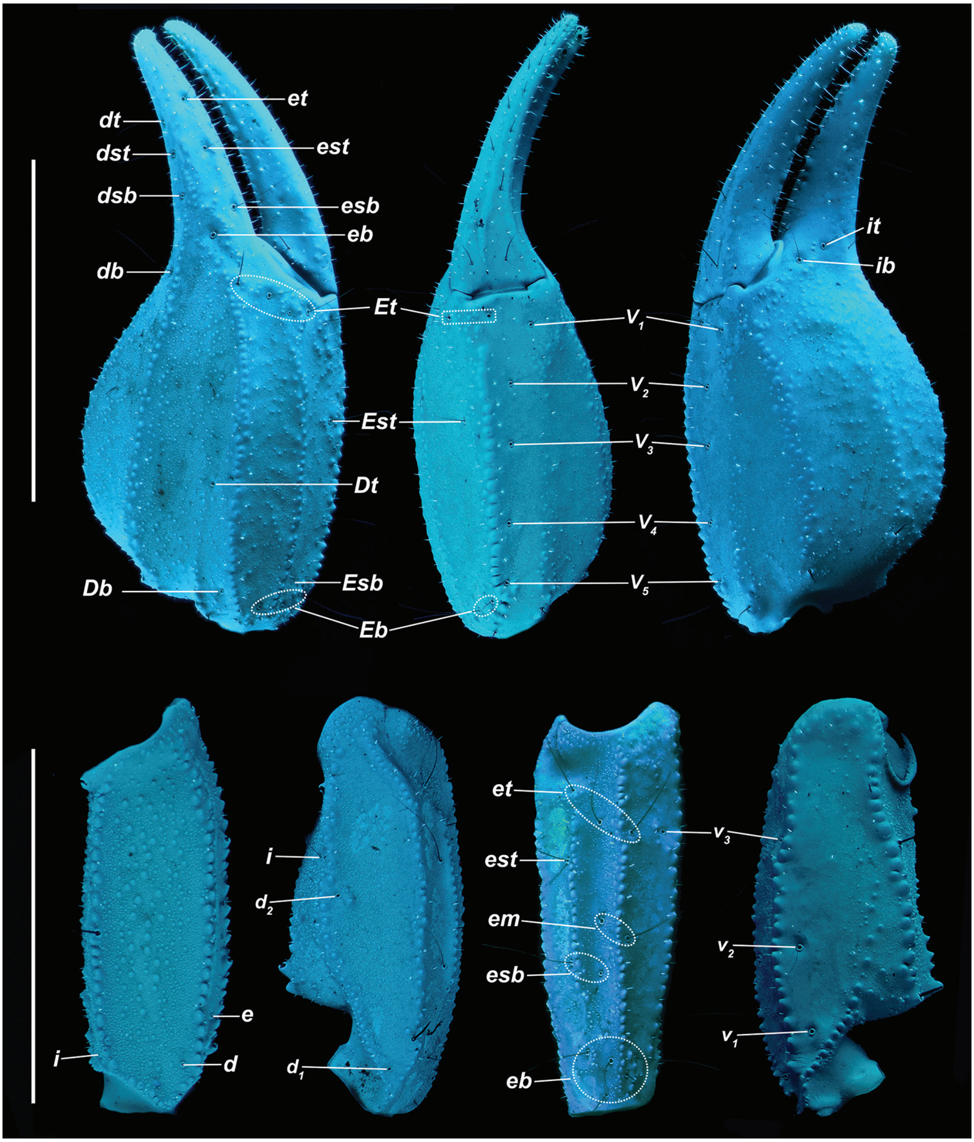

Figure 9. *Kovarikia oxy* sp. n. male holotype. Trichobothrial pattern. Scale bar = 5 mm; top bar for chela, bottom applies to femur and patella.

median accessory setae 2/2:2/3:3/3:3/3, retrosuperior setae 2/2:2/2:2/2:2/2, and superior setae 3/3:3/3:3/3:3/3 (excluding DSM and DPS). Hemispermatophore (Fig. 10): Left hemispermatophore is 5.5 mm in length; lamina length 3.3, primary lamellar hook length 1.5, secondary lamellar hook length 0.5 (distance between tips of primary and secondary hooks), and trough difference (vertical distance between ventral and dorsal troughs) 1.0. Lamellar edges roughly parallel; terminus blunted with a very slight distal crest on the dorsal side. Primary lamellar hook extends somewhat from lamina base, is

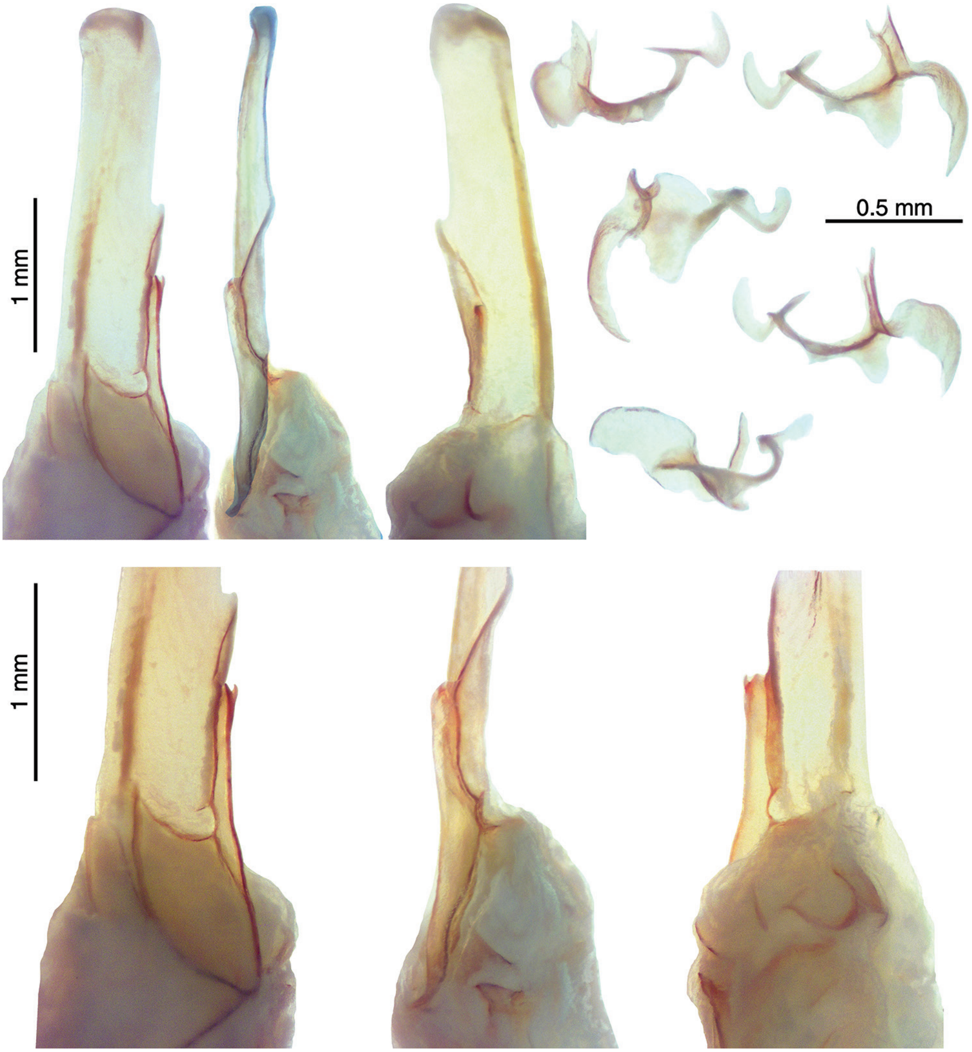

Figure 10. *Kovarikia oxy* sp. n., male holotype. Right hemispermatophore and mating plug (submerged in alcohol). **Upper-Left** Hemispermatophore median area and lamina, dorsal, internal, and ventroexternal views **Lower** Closeup of the median area and lamellar hooks, dorsal, internal, and ventral views. Note, embedded mating plug is visible in ventral view **Upper-Right** Mating plug, three dorsal views (left) and two ventral views (right).

distinctly bifurcated, and is formed entirely from the dorsal trough. Secondary lamellar hook not bifurcated. A sclerotized mating plug with large asymmetric barb with a smooth edge was extracted from the ventrointernal aspect of the hemispermatophore median area.

Measurements of male holotype (mm). Total L, 45.0; carapace L, 5.35; mesosoma L, 14.70; metasoma L (additive without telson), 20.10; telson L, 5.75. Metasomal segments: I L/W, 2.50/2.45; II L/W, 3.00/2.30; III L/W, 3.55/2.30; IV L/W, 4.45/2.15; V L/W,

Table 4. Measurements (in mm) of the type series of *Kovarikia oxy* sp. n.

	Male holotype (DMNS ZA.38178)	Male paratype 1 (DMNS ZA.38179)	Male paratype 2 (DMNS ZA.38180)	Female paratype 1 (DMNS ZA.38181)	Female paratype 2 (DMNS ZA.38182)	Female paratype 3 (DMNS ZA.38183)	Female paratype 4 (DMNS ZA.38184)
Total L	45	51	47	41	42.5	52	43
Cara L	5.35	6.2	5.8	5.75	6	6.1	6.1
Meso L	14.7	15.2	13.2	10.8	10.5	17.5	10.5
Met I L	2.5	3	2.7	2.4	2.5	2.65	2.6
Met I W	2.45	2.95	2.55	2.45	2.5	2.7	2.6
Met II L	3	3.5	3.3	2.9	2.95	3.2	3.1
Met II W	2.3	2.9	2.55	2.35	2.35	2.5	2.5
Met III L	3.55	3.95	3.7	3.2	3.35	3.6	3.4
Met III W	2.3	2.8	2.4	2.2	2.3	2.45	2.35
Met IV L	4.45	4.85	4.7	4	4.15	4.4	4.3
Met IV W	2.15	2.7	2.25	2.1	2.1	2.3	2.2
Met V L	6.6	7.6	7.1	6.2	6.3	6.8	6.6
Met V W	2.1	2.5	2.2	2.05	2.15	2.2	2.15
Tel L	5.75	6.55	6.25	5.8	6	6.25	na
Ves L	4.25	4.9	4.6	4	4.25	4.5	4.35
Ves W	2.4	2.7	2.6	2.25	2.45	2.5	2.55
Ves D	1.85	2.2	2	1.75	2	2.05	2
Acu L	1.6	1.7	1.65	-	1.75	1.8	
Fem L	5	5.75	5.5	5.1	5.35	5.55	5.5
Fem W	1.65	1.95	1.7	1.7	1.9	2	1.85
Pat L	4.9	5.65	5.2	5	5.35	5.55	5.4
Pat W	1.95	2.25	2.05	2.05	2.2	2.25	2.2
Chel L	9.1	10.4	10.05	9.4	9.85	10.35	10.1
Palm L	5	6.05	5.6	5	5.45	5.8	5.55
Palm W	2.7	3.1	3.15	2.8	2.85	3.05	2.85
Palm D	3.85	4.5	4.3	3.75	3.95	4.1	4.1
FF L	3.6	4.15	4.05	3.8	3.9	4.25	4.2
MF L	4.9	5.55	5.45	5.05	5.3	5.6	5.45
Pect Teeth	12/12	-/12	12/12	11/11	11/11	13/12	11/11

6.60/2.10. Telson: vesicle L/W/D, 4.25/2.40/1.85; aculeus L, 1.60. Pedipalps: femur L/W, 5.00/1.65; patella L/W, 4.90/1.95; chela L/W/D, 9.10/2.70/3.85; fixed finger L, 3.60; movable finger L, 4.90; palm L, 5.00.

Male and female variability. Sexual dimorphism was evident in several morphological characters for *K. oxy*. Two-tailed Student's t-tests indicated that the length of metasomal segment IV is significantly larger in males ($p = 0.012$) and that chelal palms are significantly wider ($p = 0.019$). One-tailed tests indicate that metasomal segment II is also longer in males ($p = 0.048$), telson vesicle widths are wider ($p = 0.033$), and that males have wider ($p = 0.009$) and deeper ($p = 0.031$) chelal palms. Larger sample sizes may reveal differences in additional characters, especially the lengths of the femur and metasomal segments I, III, and V.

Key to species of *Kovarikia* Soleglad, Fet & Graham, 2014*

1 Chelal fingers are relatively long when compared to the telson vesicle width: vesicle width / movable finger 0.35–0.41 (0.382) in the female and vesicle width / fixed finger 0.46–0.57 (0.510) **2**

– Chelal fingers are relatively short when compared to the telson vesicle width: vesicle width / movable finger length 0.43–0.50 (0.463) for the female and 0.43–0.51 (0.480) for the male, and vesicle width / fixed finger length 0.59–0.67 (0.619) for the female and 0.58–0.68 (0.642) for the male **3**

2 Telson vesicular ridges are well developed and protrude beyond the aculeus juncture; telson vesicle is relatively wide, chelal palm depth / vesicle width 1.52–1.89 (1.680) for the female and 1.73–1.86 (1.803) for the male .... ***Kovarikia williamsi* (Gertsch & Soleglad, 1972)**

– Telson vesicular ridges are of medium development and do not protrude beyond the aculeus juncture; telson vesicle is relatively thin, chelal palm depth / vesicle width 1.96–2.19 (2.052) for the female .... ***Kovarikia bogerti* (Gertsch & Soleglad, 1972)**

3 Pectinal tooth counts of male 12–13 and female 11–13 .... **4**

– Pectinal tooth counts of male 9–11 and female 10–11 .... ***Kovarikia angelena* (Gertsch & Soleglad, 1972)**

4 Telson vesicle is relatively long when compared to the chelal fingers, movable finger length / vesicle length 1.09–1.16 (1.115) for the female and 1.01–1.08 (1.047) for the male, and fixed finger length / vesicle length 0.80–0.86 (0.822) for the female and 0.74 (0.740) for the male .... ***Kovarikia savaryi* Bryson, Graham & Soleglad**

– Telson vesicle is relatively short when compared to the chelal fingers, movable finger length / vesicle length 1.24–1.26 (1.252) for the female and 1.13–1.18 (1.157) for the male, and fixed finger / vesicle length 0.92–0.97 (0.944) for the female and 0.85–0.88 (0.858) for the male .... ***Kovarikia oxy* Bryson, Graham & Soleglad**

* excluding male *K. bogerti*, unavailable at the time of study

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Appendix 1

Material examined

Kovarikia angelena. *USA: California*: *Los Angeles Co*: Kanan-Duma Road above Malibu, Santa Monica Mountains. 34.05224, -118.79741, 378 m. 18 May 2014. R.W. Bryson Jr. and E. Zarza. 1 ♂ 3 ♀. *Ventura Co*: Yerba Buena Road near intersection with Hwy 1, Santa Monica Mountains. 34.07145, -118.95732, 134 m. 27 September 2013. R. W. Bryson Jr. 3 ♂.

Kovarikia bogerti. *USA: California*: *San Bernardino Co*: near Mountain Home Village, San Bernardino Mountains. 34.10895, -116.99125, 1244 m. 2 June 2013. R. W. Bryson Jr. 1 ♂ 1 ♀. *Riverside Co*: Hwy 74 near Mountain Center, San Jacinto Mountains. 33.70707, -116.75529, 987 m. 24 May 2014. D. Wood and C. Rochester. 4 ♀.

Kovarikia oxy. *USA: California*: *Los Angeles Co:* Eaton Canyon Falls, San Gabriel Mountains. 34.19665°N, 118.10210°W, 475 m. 15 May 2014. R.W. Bryson Jr. and E. Zarza. 3 ♂, 4 ♀.

Kovarikia savaryi. *USA: California*: *Orange Co*: Trabuco Creek Road near the entrance to Holy Jim Canyon, Santa Ana Mountains. 33.67699°N, 117.51733°W, 527 m. 15 April 2015. R.W. Bryson. 2 ♂, 5 ♀. *Orange Co*: Silverado Canyon Road, Santa Ana Mountains. 33.74614, -117.59327, 524 m. 16 April 2015, R.W. Bryson. 1 ♂.

Kovarikia williamsi. *USA: California*: *San Diego Co*: Barrett Flume. 32.62023, -116.72719, 449 m. 18 February 2014. D. Wood and D. Stokes. 1 ♂. *San Diego Co*: Escondido. 33.222830, -117.156470, 340 m. 10 March 2014. D. Wood and D. Stokes. 2 ♀. *San Diego Co*: Indian Valley Road, ca. 7 mi from junction with Hwy 79. 33.34891, -116.65568, 1176 m. 14 April 2014. D. Wood and D. Stokes. 1 ♀. *San Diego Co:* Mission Trails Regional Park. 32.82059, -117.06362, 80 m. 7 February 2014. D. Wood, R. Wood, and S. Wood. 1 ♂ 3 ♀. *San Diego Co*: Santa Ysabel Ecological Reserve, near USGS, San Diego Field Station Array 15. 33.13501, -116.65312, 1045 m. 6 March 2014. D. Wood and D. Stokes. 1 ♀. Same locality. 16 April 2015. D. Wood and D. Stokes. 1 ♀. *San Diego Co*: Mission Gorge. 32.81177, -117.07151, 34 m. 2010. M.R. Graham. 1 ♂, 1 ♀.

Appendix 2

Morphological variation among female *Kovarikia* measured for this study. For each character, the mean ± standard deviation are provided, with ranges in parentheses. All measurements are in mm.

	K. angelena **(N = 3)**	***K. bogerti*** **(N = 4)**	***K. williamsi*** **(N = 6)**	***K. oxy*** **(N = 4)**	***K. savaryi*** **(N = 5)**
Total L	44.67±5.80 (38.8–50.0)	49.38±1.89 (47.5–51.0)	48.92±1.59 (47.0–50.5)	44.63±4.99 (41.0–43.0)	52.30±4.89 (47.0–57.0)
Cara L	5.83±0.67 (5.10–6.40)	6.66±0.13 (6.50–6.80)	6.96±0.33 (6.40–7.30)	2.99±0.14 (5.75–6.10)	6.36±0.55 (5.75–7.20)
Met I L	2.65±0.25 (2.40–2.90)	2.70±0.22 (2.45–2.95)	2.88±0.13 (2.70–3.00)	2.54±0.10 (2.40–2.65)	2.93±0.23 (2.65–3.20)
Met I W	2.55±0.28 (2.30–2.85)	2.75±0.04 (2.70–2.80)	2.85±0.11 (2.70–3.05)	2.56±0.10 (2.45–2.70)	2.70±0.15 (2.55–2.95)
Met II L	3.13±0.25 (2.90–3.40)	3.29±0.11 (3.15–3.40)	3.41±0.20 (3.15–3.60)	3.04±0.12 (2.90–3.20)	3.52±0.27 (3.25–3.90)
Met II W	2.40±0.20 (2.20–2.60)	2.65±0.06 (2.60–2.70)	2.68±0.15 (2.50–2.95)	2.43±0.08 (2.35–2.50)	2.95±0.83 (2.50–4.45)
Met III L	3.32±0.18 (3.15–3.50)	3.65±0.13 (3.50–3.80)	3.73±0.23 (3.45–4.00)	3.39±0.14 (3.20–3.60)	3.78±0.28 (3.50–4.20)
Met III W	2.30±0.20 (2.10–2.50)	2.55±0.09 (2.45–2.65)	2.56±0.14 (2.40–2.80)	2.33±0.09 (2.20–2.45)	2.49±0.19 (2.30–2.80)
Met IV L	4.22±0.23 (4.00–4.45)	4.58±0.14 (4.40–4.75)	4.50±0.36 (4.00–4.95)	4.21±0.15 (4.00–4.40)	4.61±0.24 (4.35–4.95)
Met IV W	2.15±0.15 (2.00–2.30)	2.31±0.05 (2.25–2.35)	2.39±0.12 (2.25–2.60)	2.18±0.08 (2.10–2.30)	2.32±0.16 (2.20–2.60)
Met V L	6.67±0.50 (6.20–7.20)	6.84±0.23 (6.65–7.15)	7.27±0.44 (6.80–7.80)	4.28±0.18 (4.00–4.50)	7.36±0.62 (6.70–8.20)
Met V W	2.15±0.23 (1.90–2.35)	2.24±0.05 (2.20–2.30)	2.36±0.14 (2.20–2.55)	2.14±0.05 (2.05–2.20)	2.29±0.13 (2.15–2.50)
Ves L	4.57±0.18 (4.40–4.75)	4.40±0.15 (4.25–4.60)	4.79±0.54 (4.00–5.45)	4.28±0.18 (4.00–4.50)	5.03±0.47 (4.50–5.55)
Ves W	2.47±0.15 (2.30–2.60)	2.21±0.08 (2.15–2.30)	2.50±0.21 (2.20–2.80)	2.44±0.11 (2.25–2.55)	2.59±0.25 (2.35–3.00)
Ves D	2.03±0.16 (1.85–2.15)	1.94±0.05 (1.90–2.00)	2.11±0.22 (1.80–2.40)	1.95±0.12 (1.75–2.05)	2.10±0.14 (1.95–2.30)
Fem L	5.17±0.60 (4.50–5.65)	6.18±0.25 (6.00–6.55)	6.38±0.31 (5.90–6.70)	5.38±0.18 (5.10–5.55)	5.78±0.41 (5.35–6.40)
Fem W	2.18±0.63 (1.60–2.85)	2.19±0.03 (2.15–2.22)	2.24±0.09 (2.15–2.35)	1.86±0.11 (1.70–2.00)	2.01±0.15 (1.80–2.20)
Pat L	5.03±0.57 (4.40–5.50)	5.71±0.13 (5.60–5.90)	6.04±0.28 (5.60–6.40)	5.33±0.20 (5.10–5.55)	5.68±0.40 (5.30–6.30)
Pat W	2.18±0.28 (1.90–2.45)	2.53±0.12 (2.40–2.65)	2.60±0.14 (2.40–2.75)	2.18±0.08 (2.05–2.25)	2.37±0.13 (2.30–2.60)
Palm L	5.50±0.56 (4.90–6.00)	6.11±0.17 (6.00–6.35)	6.52±0.29 (6.10–6.80)	5.45±0.29 (5.00–5.80)	6.06±0.56 (5.50–6.80)
Palm W	3.50±0.88 (2.85–4.50)	3.09±0.10 (3.00–3.20)	3.29±0.28 (2.90–3.65)	2.89±0.10 (2.80–3.05)	2.37±0.13 (2.00–3.50)
Palm D	3.83±0.35 (3.50–4.20)	4.54±0.16 (4.40–4.70)	4.56±0.28 (4.15–4.90)	3.98±0.14 (3.75–4.10)	3.96±0.72 (2.80–4.75)
FF L	3.90±0.28 (3.60–4.15)	4.58±0.15 (4.40–4.70)	4.74±0.31 (4.30–5.10)	4.04±0.19 (3.80–4.25)	4.20±0.39 (3.75–4.75)
MF L	5.20±0.52 (4.60–5.50)	6.03±0.10 (5.95–6.15)	6.38±0.38 (5.80–6.75)	5.35±0.20 (5.05–5.60)	5.66±0.57 (5.05–6.45)
Pect Teeth	10.20±0.84 (9–11)	11.50±0.53 (11–12)	12.00±0.47 (11–13)	11.38±0.74 (11–13)	11.30±0.82 (10–13)

Morphological variation among male *Kovarikia* measured for this study. For each character, the mean ± standard deviation are provided, with ranges in parentheses. All measurements are in mm.

	K. angelena **(N = 4)**	***K. williamsi*** **(N = 3)**	***K. oxy*** **(N = 3)**	***K. savaryi*** **(N = 3)**
Total L	43.45±1.94 (41.30–46.00)	50.67±2.08 (49.0–53.0)	47.67±3.06 (45.0–51.0)	49.83±0.76 (49.0–50.5)
Cara L	5.25±3.33 (4.80–5.50)	7.05±0.25 (6.80–7.30)	5.78±0.43 (5.32–6.20)	6.18±0.33 (5.85–6.50)
Met I L	5.12±5.07 (2.42–2.70)	3.40±0.48 (3.10–3.95)	2.73±0.25 (2.50–3.00)	2.95±0.05 (2.90–3.00)
Met I W	2.48±0.20 (2.22–2.70)	3.05±0.13 (2.95–3.20)	2.65±0.27 (2.45–2.95)	2.82±0.19 (2.60–2.95)
Met II L	3.08±0.21 (2.80–3.30)	3.77±0.06 (3.70–3.80)	3.27±0.25 (3.00–3.50)	3.53±0.03 (3.50–3.55)
Met II W	2.40±0.16 (2.18–2.55)	2.95±0.18 (2.80–3.15)	2.58±0.30 (2.30–2.90)	2.75±0.18 (2.55–2.90)
Met III L	3.30±0.22 (3.00–3.50)	4.13±0.08 (4.05–4.20)	3.73±0.20 (3.55–3.95)	3.92±0.03 (3.90–3.95)
Met III W	2.30±0.19 (2.03–2.45)	2.87±0.18 (2.70–3.05)	2.50±0.26 (2.30–2.80)	2.68±0.18 (2.50–2.85)
Met IV L	4.19±0.24 (3.90–4.45)	4.90±0.62 (4.20–5.40)	4.67±0.20 (4.45–4.85)	4.92±0.10 (4.80–5.00)
Met IV W	2.09±0.13 (1.90–2.20)	2.67±0.18 (2.50–2.85)	2.37±0.29 (2.15–2.70)	2.48±0.18 (2.30–2.65)
Met V L	6.41±0.41 (5.95–6.80)	8.00±0.22 (7.85–8.25)	7.10±0.50 (6.60–7.60)	7.48±0.18 (7.30–7.65)
Met V W	2.04±0.13 (1.90–2.15)	2.65±0.13 (2.50–2.75)	2.27±0.21 (2.10–2.50)	2.38±0.13 (2.25–2.50)
Ves L	4.18±0.32 (3.90–4.50)	5.52±0.32 (5.15–5.75)	4.58±0.33 (2.40–2.70)	4.68±0.55 (4.10–5.20)
Ves W	2.26±0.17 (2.10–2.40)	2.87±0.15 (2.70–3.00)	2.57±0.15 (2.40–2.70)	2.67±0.12 (2.60–2.80)
Ves D	1.81±0.24 (1.55–2.10)	2.40±0.18 (2.20–2.55)	2.02±0.18 (1.85–2.20)	2.12±0.08 (2.05–2.20)
Fem L	4.88±0.26 (4.50–5.10)	6.70±0.33 (6.40–7.05)	5.42±0.38 (5.00–5.75)	5.50±0.10 (5.40–5.60)
Fem W	1.69±0.10 (1.55–1.80)	2.25±0.15 (2.10–2.40)	1.78±0.16 (1.65–1.95)	1.92±0.03 (1.90–1.95)
Pat L	4.79±0.22 (4.50–5.00)	6.22±0.30 (5.90–6.50)	5.25±0.38 (4.90–5.65)	5.35±0.13 (5.25–5.50)
Pat W	1.98±0.14 (1.82–2.15)	2.63±0.15 (2.50–2.80)	2.08±0.15 (1.95–2.25)	2.28±0.06 (2.25–2.35)
Palm L	4.80±0.56 (4.20–5.50)	6.93±0.40 (6.50–7.30)	5.55±0.53 (5.00–6.05)	5.75±0.18 (5.55–5.90)
Palm W	2.66±0.22 (2.45–2.90)	3.60±0.26 (3.40–3.90)	2.98±0.25 (2.70–3.15)	2.95±0.38 (2.55–3.30)
Palm D	3.70±0.27 (3.35–4.00)	5.17±0.25 (4.90–5.40)	4.22±0.33 (3.85–4.50)	4.43±0.23 (4.20–4.65)
FF L	3.70±0.18 (3.50–3.90)	5.02±0.38 (4.65–5.40)	3.93±0.29 (3.60–4.15)	4.38±0.72 (3.85–5.20)
MF L	4.69±0.41 (4.15–5.10)	6.67±0.60 (6.10±7.30)	5.30±0.35 (4.90–5.55)	5.30±0.18 (5.15–5.50)
Pect Teeth	10.88±0.35 (10–11)	12.83±0.41 (12–13)	12.00±0.00 (12)	12.33±0.52 (12–13)

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RESEARCH ARTICLE

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New data on the longhorn beetles of Mongolia with particular emphasis on the genus *Eodorcadion* Breuning, 1947 (Coleoptera, Cerambycidae)

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Abstract

New data on the distribution, biology, and ecology of the longhorn beetles occurring in Mongolia are presented together with a list of 35 species that were collected during a one-month entomological expedition in August 2015. New localities of some rare taxa endemic to Mongolia, such as *Eodorcadion dorcas dorcas* (Jakovlev, 1901), *E. humerale impluviatum* (Faldermann, 1833), and *E. intermedium intermedium* (Jakovlev, 1889) are given. High-quality photographs of several rather unique species, i.e., *Pachytodes longipes* (Gebler, 1832), *Eodorcadion maurum australe* Danilevsky, 2014, *E. oryx* (Jakovlev, 1895), *Monochamus impluviatus impluviatus* (Motschulsky, 1859), and *M. sutor longulus* (Pic, 1898) along with images of their habitats or feeding grounds are also presented. Furthermore, the ecological role of the fireweed *Chamaenerion angustifolium* (L.) Scop. in the case of boreal anthophilous cerambycid species is highlighted for the first time.

Keywords

Chamaenerion angustifolium, desert steppe, endemic species, faunistics, mountain forest steppe, Onagraceae, taiga, zoogeography

Introduction

The longhorn beetle family (Cerambycidae) is one of the most species-rich groups of beetles (Coleoptera) with approximately 35,000 described species (Švácha and Lawrence 2014). The cerambycid fauna of Mongolia is represented by 167 species (Danilevsky 2017c). Several of these species, especially ones in the genera *Brachyta* and *Eodorcadion*, are represented by a few subspecies.

Due to their almost pristine habitats, the cerambycid fauna of Mongolia is quite unique. Many boreal species, which are very rare and threatened in Europe, e.g., *Pachyta lamed* (Linnaeus, 1758), *Macroleptura thoracica* (Creutzer, 1799), *Lepturalia nigripes* (DeGeer, 1775) and *Exocentrus stierlini* Ganglbauer, 1883, are abundant in the area of the southern Siberian taiga in the north of the country. On the other hand, desert and desert steppe habitats in the southern part of the country are inhabited by many endemic longhorn beetles, especially from genera such as *Rapuzziana*, *Brachyta*, *Pachytella*, *Anoplistes*, and *Eodorcadion*.

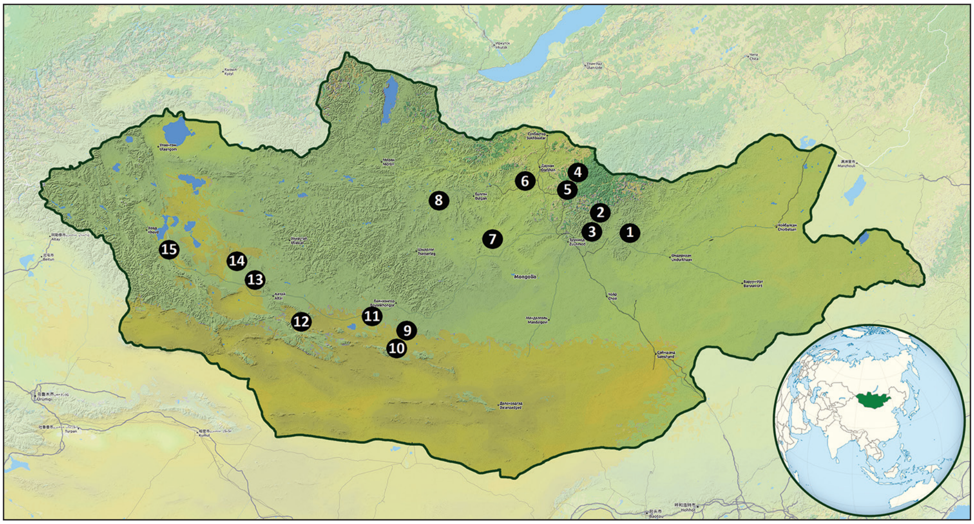
The state of the knowledge of the longhorn fauna of Mongolia as well as information about biology and ecology of some of the species distributed in the region is still poor. Therefore, the present study aims to supplement the knowledge in this field.

Study area and methods

Mongolia, which spans the southernmost border of the permafrost and the northernmost deserts of Inner Asia, is located in a transitional zone between the boreal forests of Siberia and the Gobi Desert. Due to its great distance from oceans, being surrounded by high mountains and being situated at a high elevation of more than one and half km above sea level on average, this landlocked country has an extreme continental climate with marked ranges of seasonal and diurnal temperatures and low amounts of precipitation. The extreme range of its temperatures varies from between -80 and 60 °C and the annual precipitation varies from 50 mm in the Gobi Desert to 400 mm in the northern mountainous area. Approximately 85% of the total precipitation falls from April to September (MNET 2009a).

The country is also characterised by a wide variety of habitats, from high mountains with taiga or forest steppe in the north, through steppes and desert steppes in the central part of the country, to the Gobi Desert in the south. The northern forests in the area of the Khan Khentey Mountains can be divided into the light taiga with *Betula platyphylla*, *Larix sibirica*, and *Pinus sylvestris* and the dark taiga with *Picea obovata*, *Abies sibirica, Pinus sibirica*, and *Larix sibirica* (Ermakov et al. 2002). This wide range of relatively intact ecosystems provides suitable habitats for a variety of plant and animal species. Mongolia is one of the few countries that is still considered to be relatively untouched in regard to many environmental conditions (MNET 2009a).

The entomological expedition, which consisted of three scientists from the Department of Zoology, University of Silesia (Poland), took place in August 2015. During the one-month-long research, several sampling trips to various locations in the northern, central, and south-western parts of Mongolia in the Töv, Selenge, Khovd, Govi-Altai, Bayankhongor, Övörkhangai, Bulgan and Khentii Aimags were carried out (Map 1). The investigations were conducted in several research plots, *inter alia* in the villages or environs of Ulaanbaatar, Erdenet, Altai, Khukhmorit, Bayankhongor, Bogd and Arvaikheer. The part of our study that focused especially on immature stages of longhorn beetles was carried out in the West Khentey region (the Khonin Nuga Research Station), which is situated in the buffer zone of the Strictly Protected Area of Khan Khentey.



Map 1. Research plots in Mongolia: **1** 40 km NE of Baganuur (47°51'N, 108°54'E) **2** four neighbouring localities: 70 km NE of Ulaanbaatar (47°57'N, 107°49'E); 75 km NE of Ulaanbaatar (48°10'N, 107°55'E); 80 km NE of Ulaanbaatar (48°06'N, 107°50'E); 80 km NE of Ulaanbaatar (48°13'N, 107°43'E) **3** 60 km E of Ulaanbaatar (47°52'N, 107°39'E) **4** four neighbouring localities: 35 km NE of Zuunkharaa (48°59'N 106°55'E); 40 km NE of Zuunkharaa (48°57'N 107°05'E); 50 km NE of Zuunkharaa (49°05'N, 107°17'E); 25 km NE of Zuunkharaa (49°04'N, 106°49'E) **5** two neighbouring localities: 10 km NE of Zuunkharaa (48°54'N, 106°43'E); 5 km E of Zuunkharaa (48°51'N, 106°36'E) **6** 5 km W of Khötöl (49°05'N, 105°29'E) **7** 20 km N of Ulaanshiveet (47°37'N, 103°51'E) **8** 5 km E of Khairkhan (48°37'N, 102°01'E) **9** 10 km S of Khairkhandulaan (45°48'N, 101°59'E) **10** five neighboring localities: 33 km S of Nariinteel (45°39'N, 101°22'E); 20 km NEE of Bogd (45°17'N, 101°02'E); 20 km SE of Bogd (45°05'N, 101°08'E); 10 km W of Baruunbayan-Ulaan (45°08'N, 101°14'E); 5 km W of Baruunbayan-Ulaan (45°10'N, 101°17'E) **11** 35 km SE of Bumbugur (45°59'N, 99°50'E) **12** two neighboring localities: 10 km NW of Biger (45°47'N, 97°02'E); 30 km NW of Biger (45°50'N, 96°45'E) **13** three neighboring localities: 20 km SSW from Bayan-Uul (46°51'N, 95°07'E); 20 km E of Sain-Ust (47°22'N, 94°42'E); 3 km E of Chuchmorit (47°21'N, 94°33'E) **14** 20 km NW of Zereg (47°23'N, 92°28'E) (OpenStreetMap contributors).

The most effective standard methods for collecting beetles, such as shaking them down into an entomological umbrella, sweep netting, and analyses of the inhabited material, were used during the field research. Beetles were studied using an Optek SZM7045-J4L microscope at 7–90× magnifications. Photographs of the cerambycids in nature, their host plants and habitats, were taken with Canon EOS 550D and Canon EOS 600D cameras. Photographs of the habitus were taken with a Canon EOS 50D digital camera equipped with a MP-E 65 mm macro lens. The images that were produced were stacked, aligned, and combined using ZERENE STACKER software (www.zerenesystems.com). The geographical coordinates were read off and recorded using a Garmin Oregon 550T 3-Inch Handheld GPS Navigator. For each collected specimen, exact location (including GPS coordinates), altitude, date and names of the collectors are given. Additionally, information about general distribution and biology of the species are also provided.

The following abbreviations are used in the text:

LK	Lech Karpiński,
MW	Marcin Walczak,
WTS	Wojciech T. Szczepański.

The specimens are preserved in the entomological collections of the Department of Natural History of the Upper Silesian Museum in Bytom and the Department of Biology of National University of Mongolia as well as in the authors' private collections.

This is the second of a series of papers on longhorn beetles from the area of central-east Asia. The first one (Kadyrov et al. 2016) was devoted to Cerambycidae of west Tajikistan.

Results

During the one-month-long expedition, a total of 36 taxa (including one subspecies) belonging to three subfamilies (Lepturinae, Cerambycinae, Lamiinae) was recorded. They represent approximately 20% of the Mongolian cerambycid fauna. The list of the recorded taxa, along with the new localities, general characteristics, and remarks on the species biology and ecology is presented here.

Lepturinae Latreille, 1802

Pachyta lamed (Linnaeus, 1758)

Fig. 1G

Material examined. Selenge Aimag: 35 km NE of Zuunkharaa, dark taiga (48°59'N, 106°55'E), 1399 m a.s.l., 05 VIII 2015, 1♂, on *Chamaenerion angustifolium*, leg. MW.

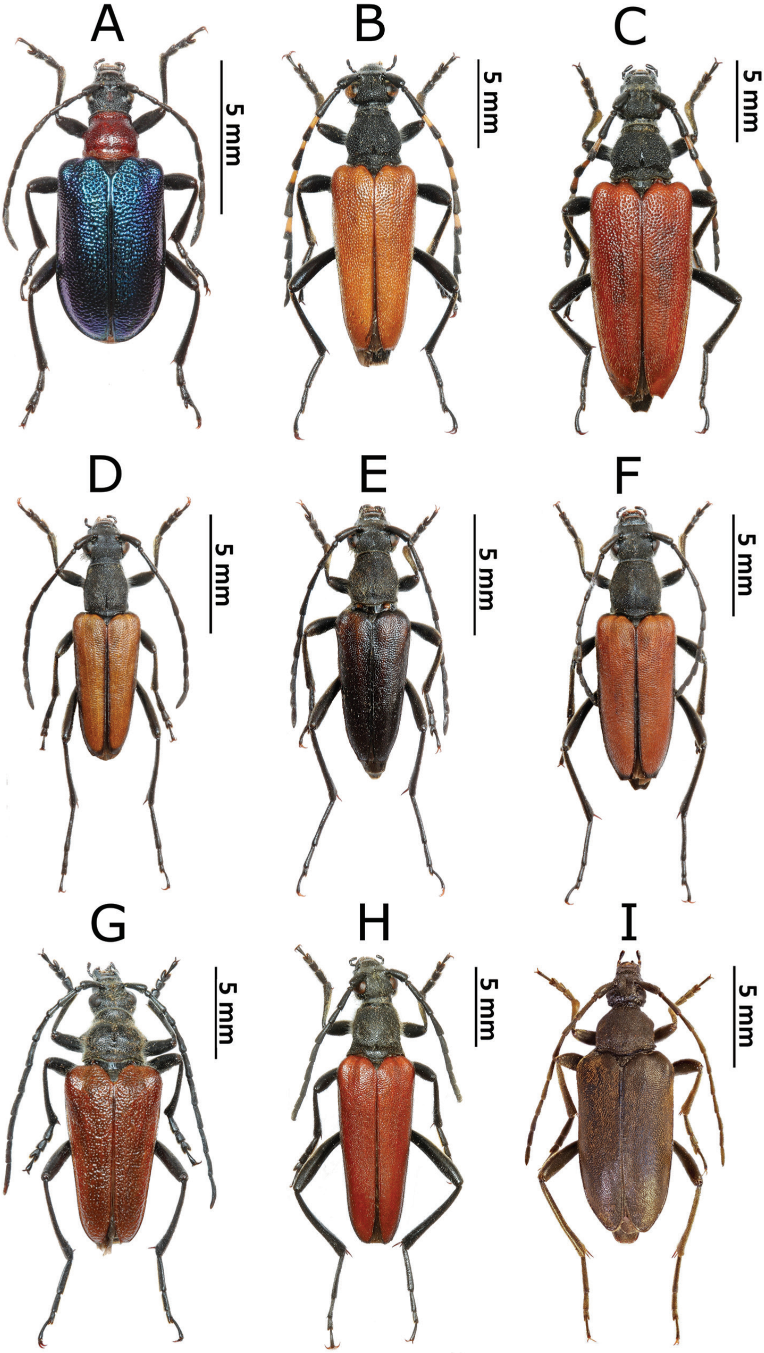


Figure 1. Photos of longhorn beetles specimens collected during the expedition to Mongolia in 2015: **A** *Gaurotes virginea aemula* (female) **B** *Stictoleptura variicornis* (male) **C** *S. variicornis* (female) **D** *Anastrangalia sequensi* (male) **E** *A. sequensi* (male, melanistic form) **F** *A. sequensi* (female) **G** *Pachyta lamed* (male) **H** *Lepturalia nigripes rufipennis* (male) **I** *Pachytodes longipes* (female).

Remarks. *Pachyta lamed* is a widely distributed Holarctic species. In the Palaearctic region, it primarily occurs in the northern parts of Europe and Asia (Cherepanov 1990a). The species mainly inhabits coniferous forests having a large share of spruce (*Picea* spp.), which is the host plant of the larvae. The adults fly from the end of June to mid-August. After mating, the females lay eggs on the thin roots of decaying thick-trunked trees. After their third hibernation, the larvae abandon the galleries and make pupal cells in the upper layer of the soil (Cherepanov 1990a).

In Mongolia, it is rarely encountered in the taiga ecosystem (e.g., Namhaidorzh 1972, Müller et al. 2013).

Only a single male was observed on the fireweed *Chamaenerion angustifolium* on the exposed site in dark taiga habitat (Fig. 6A).

Pachyta quadrimaculata (Linnaeus, 1758)

Material examined. Selenge Aimag: 40 km NE of Zuunkharaa, dark taiga (48°57'N, 107°05'E), 1270 m a.s.l., 04 VIII 2015, 2♂♂, on *Chamaenerion angustifolium*, leg. MW.

Remarks. An ordinary Palaearctic species that is distributed alike *P. lamed* but in the east it only reaches the Trans-Baikal region (Cherepanov 1990a). It is definitely more frequent than the previous species. The larvae develop in the roots (under the bark and in the wood) of coniferous trees, mostly pines (*Pinus* spp.) Their biology is also similar to the previously described species (Cherepanov 1990a).

In Mongolia, *P. quadrimaculata* occurs in the taiga in the northern part of the country, although it is probably also present in Khovd Province (Namhaidorzh 1972).

We observed this species in the dark taiga habitat together with *P. lamed*.

Gaurotes virginea aemula (Mannerheim, 1852)

Fig. 1A

Material examined. Selenge Aimag: 40 km NE of Zuunkharaa, dark taiga (48°57'N, 107°05'E) (Fig. 6B), 1270 m a.s.l., 04 VIII 2015, 1♀, on *Chamaenerion angustifolium*, leg. LK.

Remarks. The species is distributed in the North Palaearctic region from Europe to Siberia, Sakhalin and the Korean peninsula (Sama 2002), where it is divided into five subspecies (Danilevsky 2017a). According to Danilevsky (2017), *G. virginea aemula* occurs from East Russia to the Far East, through Kazakhstan, northern Mongolia and China. It is probably polyphagous on coniferous trees. The larvae feed on dead stems, stumps and thicker branches. After two years, the larvae pupate in the soil (Cherepanov 1990a).

In Mongolia, the species is also known from Töv Aimag. It was usually observed singly, e.g., 1 ex., 18 VI 1963; 1 ex., 23–24 VII 1965 (Heyrovský 1964, 1967b). Only a single, still inactive female was found inside the calyx of *Chamaenerion angustifolium* in the morning, which may suggest that the species overnights in this plant.

Stictoleptura variicornis **(Dalman, 1817)**

Fig. 1B, C

Material examined. Selenge Aimag: 40 km NE of Zuunkharaa, dark taiga (48°57'N, 107°05'E), 1270 m a.s.l., 04 VIII 2015, 3♂♂, 3♀♀, on *Filipendula palmata*, 7♂♂, 3♀♀, on *Chamaenerion angustifolium*, leg. MW; 10♂♂, 2♀♀, on *Filipendula palmata*, leg. WTS; 3♂♂, on *Filipendula palmata*, leg. LK; 35 km NE of Zuunkharaa (48°59'N, 106°55'E), 1399 m a.s.l., 05 VIII 2015, 3♂♂, on Apiaceae, leg. LK.

Remarks. *Stictoleptura variicornis* is distributed from eastern Europe to the Pacific Ocean coast including Japan (Danilevsky 2017a). This species, which is rare in Europe, reaches the Białowieża Forest in Poland (Gutowski 1995), where it is strictly protected by European law. It inhabits dead thick-trunked trees and the stumps of various coniferous and deciduous species. The larva initially lives under the bark and then in the wood, where it usually makes a pupal cell after its second hibernation. The flight period of this beetle occurs between the second half of June to mid-August (Cherepanov 1990a). It is a common species in the Mongolian taiga. It was also recorded from Bulgan Aimag by Heyrovský (1973a).

Although the specimens were observed on the flowers of a few plant species, they seemed to prefer *Filipendula palmata* (Fig. 6C).

Anastrangalia sequensi **(Reitter, 1898)**

Figs 1D–F, 6D

Material examined. Töv Aimag: 70 km NE of Ulaanbaatar (47°57'N, 107°49'E), 1833 m a.s.l., 30 VII 2015, 2♂♂, on *Seseli condensatum*, leg. MW; 5♂♂ (2♂ melanistic form), on *Seseli condensatum*, leg. WTS; 1♀, on *Seseli condensatum*, leg. LK; 80 km NE of Ulaanbaatar (48°06'N, 107°50'E) (Fig. 6E), 1538 m a.s.l., 31 VII 2015,1♀, on *Apiaceae*, leg. LK; 4♂♂, 2♀♀, on flowers near river, leg. MW; 80 km NE of Ulaanbaatar (48°13'N, 107°43'E), 1778 m a.s.l., 31 VII 2015, 1♂, on *Apiaceae*, leg. LK; Selenge Aimag: 40 km NE of Zuunkharaa (48°57'N, 107°05'E), 1270 m a.s.l., 04 VIII 2015, 3♀♀, on *Chamaenerion angustifolium*, leg. WTS; 35 km NE of Zuunkharaa (48°59'N, 106°55'E), 1399 m a.s.l., 05 VIII 2015, 1♂, 1♀, on *Apiaceae*, leg. WTS; 1♂, on *Apiaceae*, leg. LK; Khentii Aimag: 40 km NE of Baganuur (47°51'N, 108°54'E), 1612 m a.s.l., 22 VIII 2015, 1♂, leg. WTS.

Remarks. This species is only distributed in northern Asia, where its range is from the Urals to the Pacific Ocean including Japan and in the south, it reaches northern Mongolia and China (Cherepanov 1990a). Its flight period lasts from the end of May to the third week of August. After mating, the females lay eggs in the bark crevices of the stumps and trunks of various standing coniferous trees. The life cycle of this species usually lasts two years with pupation in spring and early summer (Cherepanov 1990a).

Although it is one of the most common anthophilous species in Mongolia, it is distributed exclusively in the northern part of the country. The species is rather variable regarding the colour of the elytra, which ranges from brownish yellow to black. Entirely black specimens of *A. sequensi* might be confused with *Anastrangalia renardi* (Gebler, 1848), which differs mainly in its more parallel-sided elytra and their outer angles that are rounded.

Lepturobosca virens (Linnaeus, 1758)

Material examined. Selenge Aimag: 40 km NE of Zuunkharaa, dark taiga (48°57'N, 107°05'E), 1270 m a.s.l., 04 VIII 2015, 4♂♂, 3♀♀, on *Chamaenerion angustifolium*, leg. MW; 05 VIII 2015, 1♀ on *Chamaenerion angustifolium*, leg. LK.

Remarks. This ordinary Palaearctic species is distributed from the Atlantic to the Pacific Ocean (Danilevsky 2017a), where it mainly inhabits mountain and taiga zones. *Lepturobosca virens* is ecologically related with coniferous trees (*Pinus*, *Picea*, *Abies*) but it is also known from *Betula* (Danilevskaya et al. 2009). The species is very abundant locally (e.g., Siberia) (Cherepanov 1990a).

Pachytodes longipes (Gebler, 1832)

Fig. 1I

Material examined. Selenge Aimag: 50 km NE of Zuunkharaa (49°05'N, 107°17'E), 930 m a.s.l., 02 VIII 2015, 1♀, leg. MW.

Remarks. The species is distributed in northern Asia eastwards from about Baikal Lake to the Pacific Ocean. According to Danilevsky (2014a), all records for Altay and Tuva were connected with misidentifications of *Pachytodes bottcheri* (Pic, 1911). The southern edge of its occurrence reaches the forest areas of northern Mongolia, China, and Korea (Cherepanov 1990a, Danilevsky 2017a). *Pachytodes longipes* is probably a polyphagous species, which usually inhabits the basal zones of deciduous wood species. The larvae develop in rotten wood around and in roots. Adults were found from July to August. The species is characterised by the highly variable colour of the elytra (Cherepanov 1990a).

The species was recorded in Mongolia by Lobanov et al. (1981), but with no specific locality data (Danilevsky 2017b). It is well known from Töv and Arkhangai Aimags (Danilevsky 2014a). Recently, one specimen of this species was also collected by Müller et al. (2013) in the West Khentey region.

A single specimen was caught flying in the light taiga habitat next to a river (Fig. 6F). Our finding confirms its presence in this region.

Oedecnema gebleri (Ganglbauer, 1889)

Material examined. Khentii Aimag: 40 km NE of Baganuur (47°51'N, 108°54'E), 1612 m a.s.l., 22 VIII 2015, 4 larvae, *Larix sibirica*, leg. LK, WTS.

Remarks. *Oedecnema gebleri* is distributed from Eastern Europe (Ukraine and Russia) to the Pacific Ocean (Danilevsky 2017a). Its polyphagous larvae develop in the basal zones of dead trees and in the stumps of both deciduous and coniferous species. Pupation occurs in the wood or in the soil. The life cycle usually lasts two or three years. The adults feed on various flowers from the end of May to August (Švácha and Danilevsky 1989, Cherepanov 1990a).

The larvae (Fig. 6G) were found at ground level in the basal zones of thin larches *Larix sibirica* in the forest steppe (Fig. 6H). It is a rather common species in the Mongolian taiga and forest steppe.

Macroleptura thoracica (Creutzer, 1799)

Material examined. Selenge Aimag: 25 km NE of Zuunkharaa (49°04'N, 106°49'E), 1399 m a.s.l., 01 VIII 2015, 1♂, 1♀, dead imagines, *Populus tremula*, leg. LK.

Remarks. The species is distributed from northern and eastern Europe through Siberia, northern China, Mongolia, the Korean peninsula, and Sakhalin to Japan (Danilevsky 2017a). In Europe, this species is strictly protected by European law. Although *Macroleptura thoracica* is mostly polyphagous on deciduous trees (Švácha and Danilevsky 1989, Sama 2002), it was also observed on the fir *Abies* sp. in Japan (Sama 2002). The species inhabits the dead, rotten wood of thick trunks. The adults fly from June to August and usually stay on their host plants; they rarely visit flowers (Sama 2002). In Mongolia, this is rare species that is not numerous (e.g., Namhaidorzh 1972, 1976a).

The remains of two specimens were found deep in the wood of the trunk of the stately poplar *Populus tremula* together with numerous larval feeding grounds. This primeval forest relict species, which is very rare in Europe, appears to be rather numerous in this region. This indicates the high degree of the naturalness of the Mongolian habitats.

Leptura aethiops Poda von Neuhaus, 1761

Material examined. Selenge Aimag: 40 km NE of Zuunkharaa (48°57'N, 107°05'E), 1270 m a.s.l., 04 VIII 2015, 1♂, on *Chamaenerion angustifolium*, leg. MW.

Remarks. *Leptura aethiops* occurs in almost the entire Palaearctic region from France to Japan (Sama 2002, Danilevsky 2017a). The species has a broad spectrum of host plants. The larvae usually develop in the stumps of dead deciduous trees but they have occasionally been found in conifers (Švácha and Danilevsky 1989, Sama 2002).

Leptura annularis Fabricius, 1801

Material examined. Selenge Aimag: 40 km NE of Zuunkharaa (48°57'N, 107°05'E), 1270 m a.s.l., 04 VIII 2015, 1♂, on *Filipendula palmata*, leg. MW; 2♂♂, 2♀♀, on *Chamaenerion angustifolium*, leg. MW; 4♂♂, 1♀, on *Chamaenerion angustifolium*, leg. WTS; 2♂♂, on *Chamaenerion angustifolium*, leg. LK; 35 km NE of Zuunkharaa (48°59'N, 106°55'E), 1399 m a.s.l., 05 VIII 2015, 1♀, on *Chamaenerion angustifolium*, leg. LK.

Remarks. This species is widely distributed from Europe, where it is considered to be a montane subalpine species, to the Pacific Ocean, including Mongolia, China, and the Korean peninsula. A closely related species *Leptura mimica* Bates, 1884 is endemic to Japan and Sakhalin Islands. Its divergence has been confirmed in both morphological and genetic studies (Makihara and Saito 1985, Makihara et al. 1991, Saito et al. 2002, Rossa et al. 2017). The biology of *L. annularis* is similar to that of the previously described species (Švácha and Danilevsky 1989).

***Lepturalia nigripes rufipennis* (Blessig, 1873)**

Fig. 1H

Material examined. Töv Aimag: 70 km NE of Ulaanbaatar (47°57'N, 107°49'E), 1833 m a.s.l., 30 VII 2015, 1♂, on *Seseli condensatum*, leg. MW; Selenge Aimag: 50 km NE of Zuunkharaa (49°05'N, 107°17'E), 930 m a.s.l., 02 VIII 2015, 8 larvae, *Betula platyphylla*, leg. LK, MW, and WTS.

Remarks. This is a temperate Palaearctic species that is distributed from north-eastern Europe to the Far East (Švácha and Danilevsky 1989, Sama 2002). Moreover, the subspecies *L. nigripes rufipennis* is known to occur in the easternmost part of its territory from East Siberia and Kazakhstan to the Far East (Danilevsky 2017a).

In Mongolia, it is a quite common species, especially in stands having a large share of birch trees (e.g., Namhaidorzh 1972, Cherepanov 1990a, Müller et al. 2013), which is the main preferred host plant species. The development of the larvae takes place in trunks, branches, and decaying stumps. The adults fly from May to August and feed on the flowers of various species (Cherepanov 1990a, Sama 2002).

A single male was observed on flowers in the forest steppe (Fig. 7A). The larvae (Fig. 7B) were found in the rotten stumps of the birch *Betula platyphylla* in their basal zones in the light taiga (Fig. 7C). Like *L. thoracica*, this species, which is very rare in Europe, seems to be rather common in pristine local habitats of both Mongolian taiga and forest steppe.

***Stenurella melanura* (Linnaeus, 1758)**

Material examined. Selenge Aimag: 40 km NE of Zuunkharaa (48°57'N, 107°05'E), 1270 m a.s.l., 04 VIII 2015, 3♂♂, 2♀♀, on *Achillea asiatica*, leg. MW; 1♂, on *Chamaenerion angustifolium*, leg. MW; 1♀, on *Achillea asiatica*, leg. WTS.

Remarks. This is a species that is very common and widespread throughout Europe and the Palaearctic part of Asia (Danilevsky 2017a). It is a polyphagous species, whose larvae feed on the decaying wood of stumps or branches of both deciduous and coniferous trees (Sama 2002).

Cerambycinae Latreille, 1802

Clytus arietoides Reitter, 1900

Fig. 2A

Material examined. Töv Aimag: 75 km NE of Ulaanbaatar (48°10'N, 107°55'E), 1589 m a.s.l., 30 VII 2015 (22 II 2016, ex cult), 1♀, from *Larix sibirica*, leg. MW.

Remarks. This oriental species is distributed widely from the Urals to Sakhalin and Japan (Sama 2002, Danilevsky 2017a). It is ecologically associated with coniferous forests. The larvae develop in dead or drying trunks and twigs of various conifers, especially larches. After two years, the larvae pupate in wood during summer and the imagines emerge the next spring. The adults fly from May to August and, during the mating season, they stay on their host plants and occasionally visit flowers (Švácha and Danilevsky 1988, Cherepanov 1990b).

In Mongolia, the species is also known, *inter alia*, from Khovd Aimag (Heyrovský 1969).

One female was reared from a branch of a fallen larch *Larix sibirica* collected in the forest steppe (Fig. 7D). The same material was inhabited by larvae of *Monochamus impluviatus* (Motschulsky, 1859) and *M. sutor* (Linnaeus, 1758).

Xylotrechus hircus (Gebler, 1825)

Fig. 2B, C

Material examined. Selenge Aimag: 50 km NE of Zuunkharaa (49°05'N, 107°17'E), 930 m a.s.l., 02 VIII 2015 (24 III 2016, ex cult), 1♂, from *Betula platyphylla*, leg. MW; (09 III 2016, ex cult), 1♀, from *Betula platyphylla*, leg. WTS.

Remarks. *Xylotrechus hircus* occurs exclusively in Northern Asia from Altai to Japan (Cherepanov 1990b, Danilevsky 2017a). The species is ecologically associated with birch, which is the only known host plant to date. The larvae initially live under the bark and then in the wood where they pupate after about two years of development. The imagines are usually active from June to July (Cherepanov 1990b).

This is a rather infrequent taxon in Mongolia and is absent in most of the papers about this region. Recently, two specimens of this species were collected in the West Khentey region (Müller et al. 2013).

One male (Fig. 2B) and one female (Fig. 2C) were reared from the top part of a broken trunk of the birch *Betula platyphylla* (approx. 10 cm in diameter) (Fig. 7E) found in the light taiga habitat (Fig. 7F). The same material was additionally inhabited by larvae of *Aegomorphus obscurior* (Pic, 1904), *Saperda scalaris* (Linnaeus, 1758) and *Mesosa myops* (Dalman, 1817).

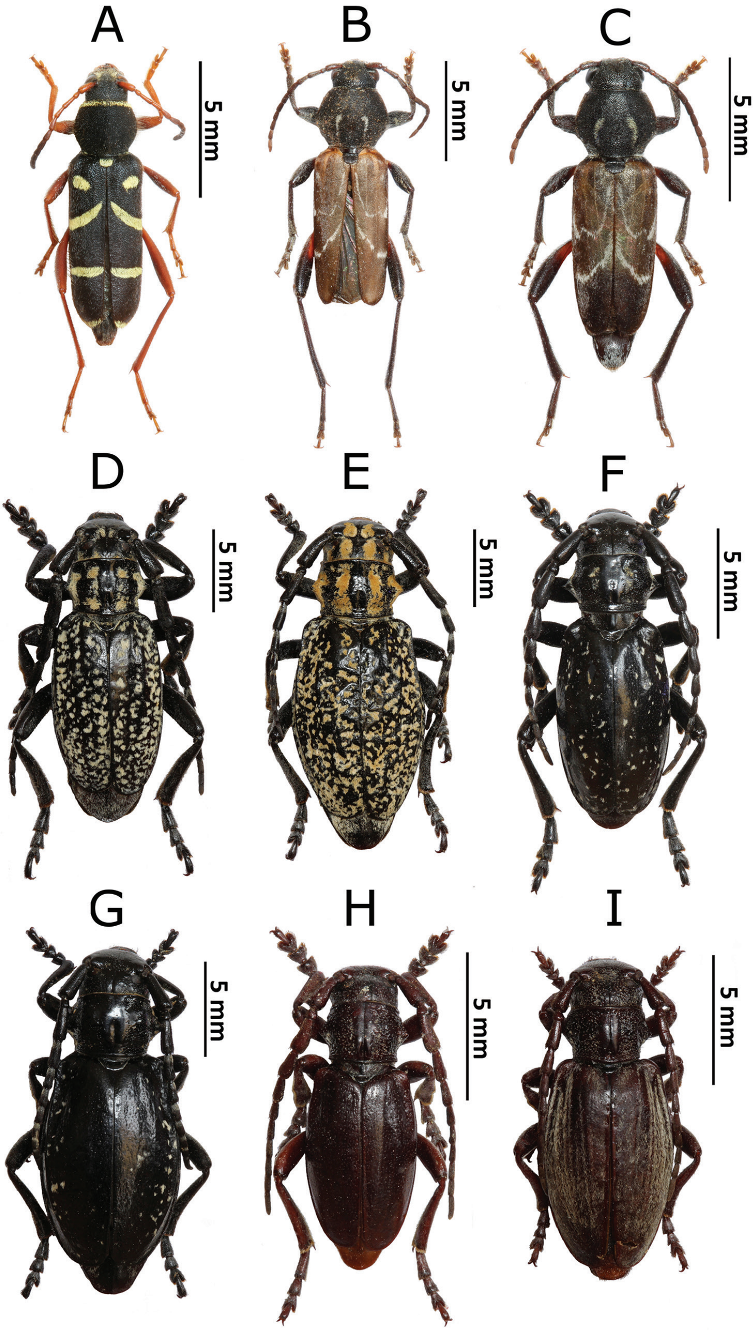


Figure 2. Photos of longhorn beetles specimens collected during the expedition to Mongolia in 2015: **A** *Clytus arietoides* (female) **B** *Xylotrechus hircus* (male) **C** *X. hircus* (female) **D** *Eodorcadion humerale impluviatum* (male) **E** *E. humerale impluviatum* (female) **F** *E. humerale impluviatum* (male, Khentey Mountains) **G** *E. humerale impluviatum* (female, Khentey Mountains) **H** *Eodorcadion carinatum involvens* (male) **I** *E. carinatum involvens* (female).

Xylotrechus pantherinus (Savenius, 1825)

Material examined. Selenge Aimag: 50 km NE of Zuunkharaa (49°05'N, 107°17'E), 930 m a.s.l., 02 VIII 2015, 1 larva, *Salix* sp., leg. LK.

Remarks. This species is widespread in the Palaearctic region and is distributed from western Europe to the Far East (Danilevsky 2017a). It is monophagous on *Salix* (*S. caprea* in Europe and *S. fragilis*, *S. sibirica* and *S. xerophila* in Siberia). The larvae develop in healthy or weakened trunks and branches, where they feed deep in the wood. Adults can be found on their host plants from June to August (Cherepanov 1990b, Sama 2002).

A single larva (Fig. 7G) was found deep in the wood of a standing willow trunk *Salix* sp. (Fig. 7H) in the light taiga next to a river.

Amarysius altajensis (Laxmann, 1770)

Material examined. Selenge Aimag: 50 km NE of Zuunkharaa (49°05'N, 107°17'E), 930 m a.s.l., 02 VIII 2015, 20 larvae, *Malus baccata* and *Prunus padus*, leg. LK, MW and WTS; 40 km NE of Zuunkharaa (48°57'N, 107°05'E), 1270 m a.s.l., 04 VIII 2015, several larvae, (09 II 2016, ex cult), 1♂, from *Salix* sp., leg. WTS.

Remarks. This species is distributed from Kazakhstan to the Far East, including northern Mongolia, China, and the Korean peninsula (Danilevsky 2017a). This forest species inhabits small diameter shoots and twigs of various deciduous plant species. Its life cycle lasts about three years. The imagines fly from May to June and frequently visit flowers (Švácha and Danilevsky 1988, Cherepanov 1990b).

It seems to be a rather numerous taxon in the Mongolian taiga. Several dozen larvae (Fig. 8A) were frequently found in shoots and twigs of three deciduous plant species, *Malus baccata* (Fig. 8B), *Prunus padus* (Fig. 8C) and *Salix* sp. (Fig. 8D), in both light and dark taiga. The larvae which were found in *Malus* wood were definitely more yellowish (Fig. 8E). In this area, fifteen specimens of *A. altajensis* were collected by Müller et al. (2013).

Anoplistes halodendri minutus Hammarström, 1892

Material examined. Govi-Altai Aimag: 20 km E of Sain-Ust (47°22'N, 94°42'E), 1646 m a.s.l., 12–13 VIII 2015, several larvae, *Caragana bungei*, leg. LK, MW; Övörkhangai Aimag: 10 km W of Baruunbayan-Ulaan (45°08'N, 101°14'E), 1264 m a.s.l., 18 VIII 2015, several larvae and remains of one imago, *Caragana leucophloea*, leg. LK, MW.

Remarks. *Anoplistes halodendri* is an east-Palaearctic species that is distributed from the Balkans to the Russian Far East, China, Korea and Japan (Danilevskaya et al. 2009). Within its range, it was divided into seven subspecies (Danilevsky 2017a): *A. h. balcanicus* Sláma, 2010, *A. h. ephippium* (Steven & Dalman, 1817), *A. h. halo-*

dendri (Pallas, 1773), *A. h. heptapotamicus* (Semenov, 1926), *A. h. kasatkini* Lazarev, 2014, *A. h. minutus* Hammarström, 1892 and *A. h. pirus* (Arakawa, 1932). The species is ecologically associated with deciduous trees and shrubs (e.g., *Acacia*, *Daphne mezereum*, *Quercus*) in the steppe and forest-steppe habitats. Adults begin emerging in July (Cherepanov 1990b).

The larvae (Fig. 8F, G) collected in the first locality (Fig. 8H) in stems of *Caragana bungei* (Fig. 9A) clearly belong to the genus *Anoplistes*, but the exact species could not be identified with certainty. They are preliminarily classified in this taxon since it is the most common *Anoplistes* species in the country. Moreover, *minutus* is the only subspecies of *A. halodendri* that occurs in Mongolia. It was already recorded from this Province by Heyrovský (1969) and additionally from Khovd and Ömnögovi Aimags (Heyrovský 1965, 1969). It is worth noting that one of the larvae among this material belongs to the tribe Clytini, most probably to the genus *Chlorophorus*.

Regarding the second locality (Fig. 9B), several larvae were found together with the remains of a single male imago in stems of *Caragana leucophloea*. In both cases, the larval feeding grounds (Fig. 9C) were located from a few centimetres below to approx. 10 cm above ground level. Most of the emergence holes (Fig. 9D) of the adults were found on stems approx. a few centimetres above ground level. Both research plots are located in semi-desert habitats.

Apart from *Anoplistes halodendri minutus*, four other species of this genus were already recorded for Mongolia: *A. gobiensis* Namkhaidorzh, 1973, *A. kozlovi* Semenov & Znoiko, 1934, *A. mongolicus mongolicus* Ganglbauer, 1889 and *A. tuvensis* Tsherepanov, 1978 (Danilevsky 2017a). *Anoplistes tuvensis* is distributed exclusively in the region of the Tuva basin and it is ecologically associated with *Nanophyton erinaceum* (Cherepanov 1990b). *Anoplistes kozlovi* was recorded, *inter alia*, from Dundgovi, Ömnögovi and Govi-Altai Aimags (Heyrovský 1965, 1968) and *A. mongolicus* from Khovd, Govi-Altai, Ömnögovi, Bayankhongor and Dundgovi Aimags (Heyrovský 1968, 1970). However, taxonomy, distribution (especially in the Mongolia and China region) and biology of most of the species in this genus need to be thoroughly studied and revised.

Lamiinae Latreille, 1825

Aegomorphus obscurior (Pic, 1904)

Fig. 5A

Material examined. Selenge Aimag: 50 km NE of Zuunkharaa (49°05'N, 107°17'E), 930 m a.s.l., 02 VIII 2015 (10 IX 2016, ex cult), 1♂, from *Betula platyphylla*, leg. WTS.

Remarks. *Aegomorphus obscurior* was recently raised to the species level by Hilszczański (2008). After the revision of specimens, it is known to be broadly distributed in Russia and in the Siberian part of Kazakhstan (Danilevsky and Shapovalov

2007) as well as in Mongolia (Hilszczański 2008). In Europe, it reaches Latvia (Telnov 2016) and eastern Poland (Hilszczański 2008, Danilevsky 2017a). The species was recently included in the Mongolian fauna (Hilszczański 2008) based on four specimens that were collected 30 km north of Batsumber by B. Burakowski and H. Szelęgiewicz in 1963. The larvae feed on dead trees or dead parts of living trees of their host plants: *Quercus robur* (Hilszczański and Bystrowski 2005), *Betula* sp. and *Alnus* sp. (Danilevsky and Shapovalov 2007). The life cycle lasts two years. The adults are active from the second half of May (Hilszczański and Bystrowski 2005).

A single male was reared from the top part of a broken trunk of the birch *Betula platyphylla* (approx. 10 cm in diameter) (Fig. 7E) that was found in the light taiga habitat (Fig. 7F). The same material was additionally inhabited by larvae of *Xylotrechus hircus*, *Saperda scalaris*, and *Mesosa myops*. Our findings constitute the second record of this species from Mongolia.

Saperda similis Laicharting, 1784

Material examined. Selenge Aimag: 50 km NE of Zuunkharaa (49°05'N, 107°17'E), 930 m a.s.l., 03 VIII 2015, 1 larva, *Salix* sp., leg. LK.

Remarks. *Saperda similis* is a rather rare but widespread species that is distributed from Europe to the Far East (Danilevsky 2017a). Although this species is ecologically associated with willows (Cherepanov 1991b), according to Sama (2002), it is probably monophagous on *Salix caprea*. The larvae develop in thin stems and branches of willows that are still growing (Cherepanov 1991b). The adults are active at dusk and during the night in June and July and can be found on their host plants (Sama 2002).

A single larva in a pupal cell (Fig. 9E) was found in the trunk of a recently dead willow *Salix* sp. in the light taiga next to a river (Fig. 9F).

Saperda scalaris hieroglyphica (Pallas, 1773)

Material examined. Selenge Aimag: 50 km NE of Zuunkharaa (49°05'N, 107°17'E), 930 m a.s.l., 02 VIII 2015, 2 larvae, *Betula platyphylla*, leg. LK.

Remarks. *Saperda scalaris hieroglyphica* is distributed from European Russia to the Far East (Danilevsky 2017a). This subspecies is sometimes recognised as a synonym of the nominotypical subspecies (e.g., Sama 2002) from which it differs only by its whitish not yellowish pubescence. In Asia, this polyphagous species is ecologically more associated with birch (Cherepanov 1991b).

Two larvae (Fig. 9G), which were boring in a thick layer of cambium in a broken trunk of *Betula platyphylla* (of diameter approx. 20 cm), were found under the bark (Fig. 9H) in the light taiga habitat (Fig. 7F). The same material was additionally inhabited by *Xylotrechus hircus*, *Aegomorphus obscurior* and *Mesosa myops* in their immature stages.

Saperda alberti Plavilstshikov, 1916

Material examined. Selenge Aimag: 50 km NE of Zuunkharaa (49°05'N, 107°17'E), 930 m a.s.l., 03 VIII 2015, 1 larva, *Salix* sp., leg. LK.

Remarks. This East-Asian species is distributed from western Siberia throughout north Kazakhstan, Mongolia, and China as well as to the Far East and Japan (Danilevsky 2017a). The larvae develop under bark that has recently died and in the wood of certain deciduous plants, e.g., *Populus*, *Salix*, *Chosenia*. They pupate in sapwood or under or inside the bark. The imagines are active from early June to mid-August and can be found on their host plants or they are sometimes attracted to artificial light sources (Cherepanov 1991b, Danilevskaya et al. 2009).

A single early larval instar was found under the bark of a broken trunk of willow *Salix* sp. in the light taiga. A large number of this species was collected in this area by Müller et al. (2013).

Agapanthia pilicornis pilicornis (Fabricius, 1787)

Fig. 5H

Material examined. Selenge Aimag: 50 km NE of Zuunkharaa (49°05'N, 107°17'E), 930 m a.s.l., 02 VIII 2015, 2♂♂, leg. MW.

Remarks. *Agapanthia pilicornis pilicornis* is distributed in the Ussuri-Primor'e region, Trans-Baikal, Sakhalin, northern Mongolia, northeast China, Korean peninsula, and Japan (Cherepanov 1991a). The second subspecies, *A. pilicornis laushanensis* Breuning, 1965, is known exclusively from two Chinese provinces: Henan and Shāndōng (Danilevsky 2017a). Little is known about the biology of this species. The imagines are active in June and July, but the life cycle and the preimaginal stages are not clearly understood (Cherepanov 1991a). This species is quite similar to *Agapanthia amurensis* Kraatz, 1879; however, it can be easily distinguished *inter alia* by variegated antennae and darker body colour.

This is a rather infrequent taxon in Mongolia and is absent in most of the papers about this region (e.g., Heyrovský 1964–1975). The only records of approx. ten specimens, collected from the second half of June to mid-July, are included in the work of Namhaidorzh (1972).

Our finding extends the known period of occurrence of this species to the beginning of August. Two males were collected in the light taiga habitat (Fig. 7C) by sweep-netting method.

Eodorcadion carinatum involvens (Fischer von Waldheim, 1823)

Figs 2H, I, 10A–C

Material examined. Töv Aimag: 60 km E of Ulaanbaatar (47°52'N, 107°39'E), 1499 m a.s.l., 30 VII 2015, 29♂♂, 13♀♀ (5♀♀ white pubescence form (Fig.

10C)), leg. MW; 20♂♂, 8♀♀ (2♀♀ white pubescence form), leg. WTS; 11♂♂, 10♀♀ (4♀♀ white pubescence form), leg. LK; 80 km NE of Ulaanbaatar (48°13'N, 107°43'E), 1778 m a.s.l., 31 VII 2015, 3♂♂, 2♀♀, leg. MW; 1♂, 1♀, leg. WTS; 1♂, leg. LK; Selenge Aimag: 10 km NE of Zuunkharaa (48°54'N, 106°43'E), 999 m a.s.l., 05 VIII 2015, 1♂, 1♀, leg. LK; 2♂♂, leg. MW; 2♂♂, 2♀♀, leg. WTS; 5 km E of Zuunkharaa (48°51'N, 106°36'E), 916 m a.s.l., 05 VIII 2015, 1♂, 1♀, leg. WTS; 5 km W of Khötöl [Хөтөл] (49°05'N, 105°29'E), 809 m a.s.l., 06 VIII 2015, 1♂, 1♀, leg. LK; 1♂, leg. WTS; Arkhangai Aimag: 15 km S of Khairkhan (48°22'N, 101°52'E), 1437 m a.s.l., 07 VIII 2015, 1♂, leg. LK; 5 km E of Khairkhan (48°37'N, 102°01'E), 1398 m a.s.l., 07 VIII 2015, 1♀ (white pubescence form), leg. WTS.

Remarks. *Eodorcadion carinatum involvens* is one of the five subspecies that have already been described; they are distributed from the Jenisei River to the Far East. This taxon is the most common and widespread in the northern and central parts of Mongolia where it has been recorded from many localities; to the south, it reaches the Mongolian and Gobi Altai Mountains. The imagines are active from the end of June to August (Namhaidorzh 1972, Danilevsky 2007).

We observed a mass occurrence of this species (more than one hundred specimens) approx. 60 km E of Ulaanbaatar during moderately warm (22 °C) and cloudy weather conditions in the steppe habitat (Fig. 10D) at the turn of July and August. Most of the specimens were found in the interstices of the grass where they were mating. Single specimens were walking slowly. Some specimens were also found at a higher elevation (1778 m a.s.l) on xerothermic mountain slopes (Fig. 10E) sympatrically with *Eodorcadion humerale impluviatum* (Faldermann, 1833) and *Monochamus impluviatus impluviatus* (Motschulsky, 1859). Another plot, which was located approx. 15 km S of Khairkhan (48°22'N, 101°52'E), turned out to be the most westward locality of this taxon towards the city of Altai. Towards the Khangai Mountains, we did not find any further individuals despite checking numerous plots.

Eodorcadion maurum australe Danilevsky, 2014

Figs 3I, 4A, 10F, G

Material examined. Khovd Aimag: 20 km NW of Zereg (47°23'N, 92°28'E), 1158 m a.s.l., 14 VIII 2015, 10♂♂, 2♀ (1♀ dead – remains), leg. LK; 21♂♂, leg. MW; 14♂♂, leg. WTS.

Remarks. This is a recently described subspecies that is distributed in the northern and central parts of Khovd Aimag. All previously known specimens were collected from end of June to July (Danilevsky 2014b). Two other taxa occur in Mongolia: *E. m. katharinae* Reitter, 1898 and *E. m. maurum* Jakovlev, 1889 (Danilevsky 2017c).

Before noon, during rather windy and cold weather, nearly 50 individuals were observed on the border of tall and short grass meadows (Fig. 10H). The population was dominated by males (Fig. 10F); the only living female (Fig. 10G) was collected in

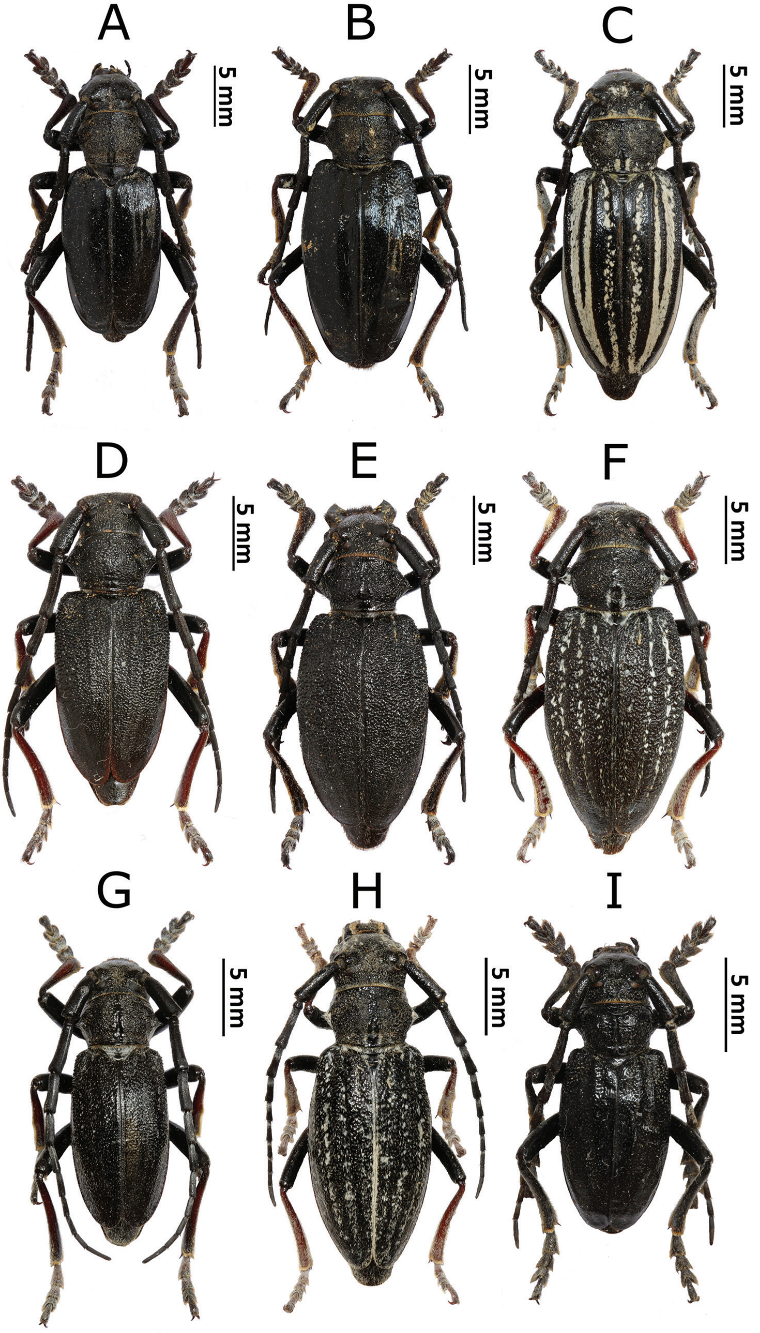


Figure 3. Photos of longhorn beetles specimens collected during the expedition to Mongolia in 2015: **A** *Eodorcadion consentaneum* (male) **B** *E. consentaneum* (female, black form) **C** *E. consentaneum* (female, striped form) **D** *Eodorcadion dorcas scabrosum* (male) **E** *E. dorcas scabrosum* (female, black form) **F** *E. dorcas scabrosum* (female, striped form) **G** *Eodorcadion dorcas dorcas* (male) **H** *E. dorcas dorcas* (female) **I** *Eodorcadion maurum australe* (male).

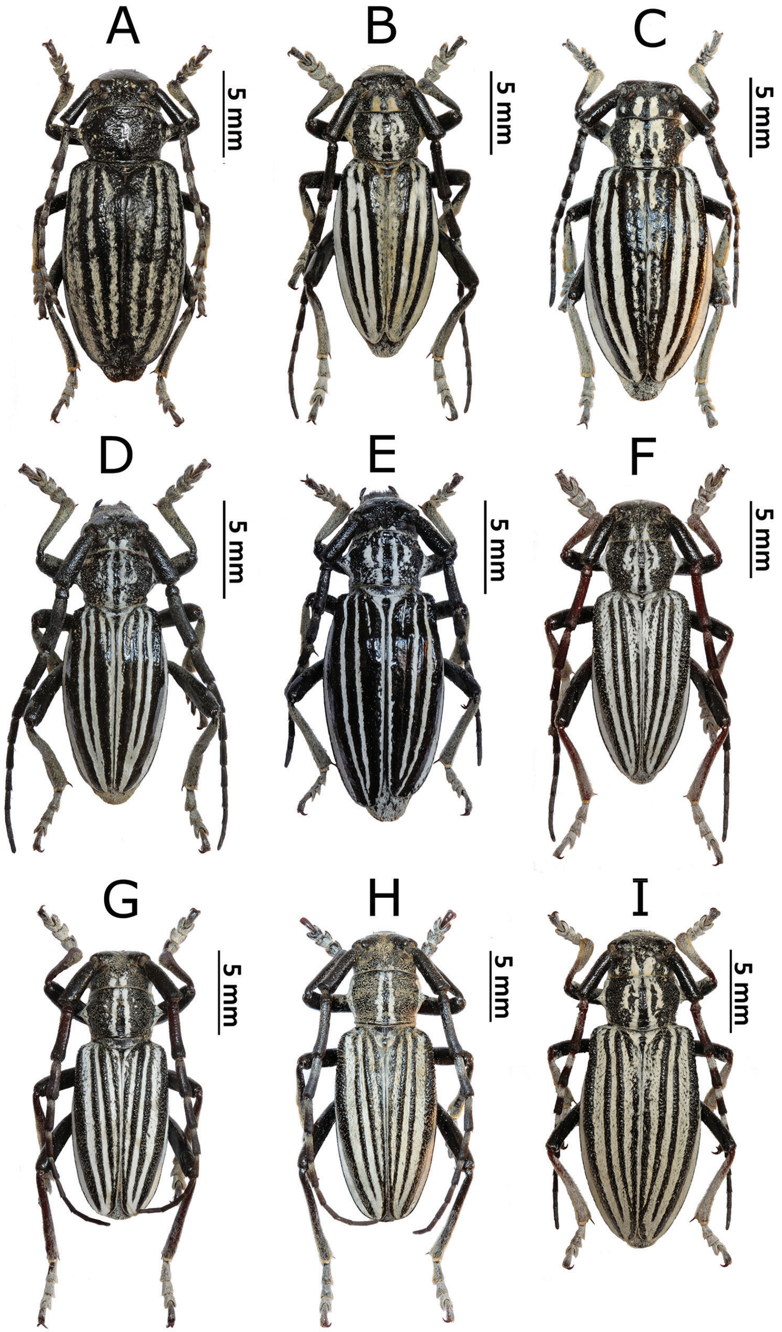


Figure 4. Photos of longhorn beetles specimens collected during the expedition to Mongolia in 2015: **A** *Eodorcadion maurum australe* (female) **B** *Eodorcadion oryx* (male) **C** *E. oryx* (female) **D** *Eodorcadion exaratum argali* (male) **E** *E. exaratum argali* (female) **F** *Eodorcadion intermedium intermedium* (male, reddish form) **G** *E. intermedium intermedium* (male, intermediate form) **H** *E. intermedium intermedium* (male, blackish form) **I** *E. intermedium intermedium* (female, reddish form).

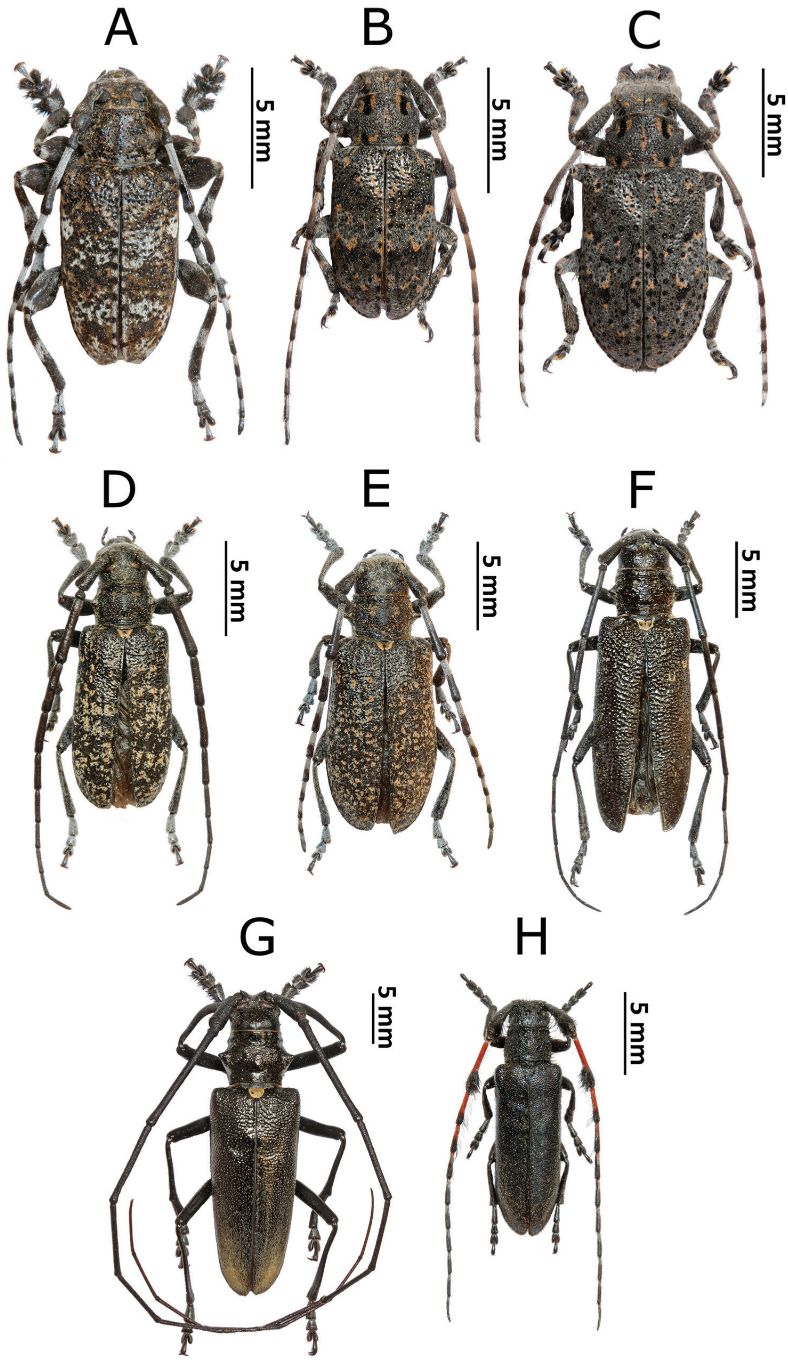


Figure 5. Photos of longhorn beetles specimens collected during the expedition to Mongolia in 2015: **A** *Aegomorphus obscurior* (male) **B** *Mesosa myops* (male) **C** *M. myops* (female) **D** *Monochamus impluviatus impluviatus* (male) **E** *M. impluviatus impluviatus* (female) **F** *Monochamus sutor longulus* (female) **G** *Monochamus sartor urussovii* (male) **H** *Agapanthia pilicornis pilicornis* (male).

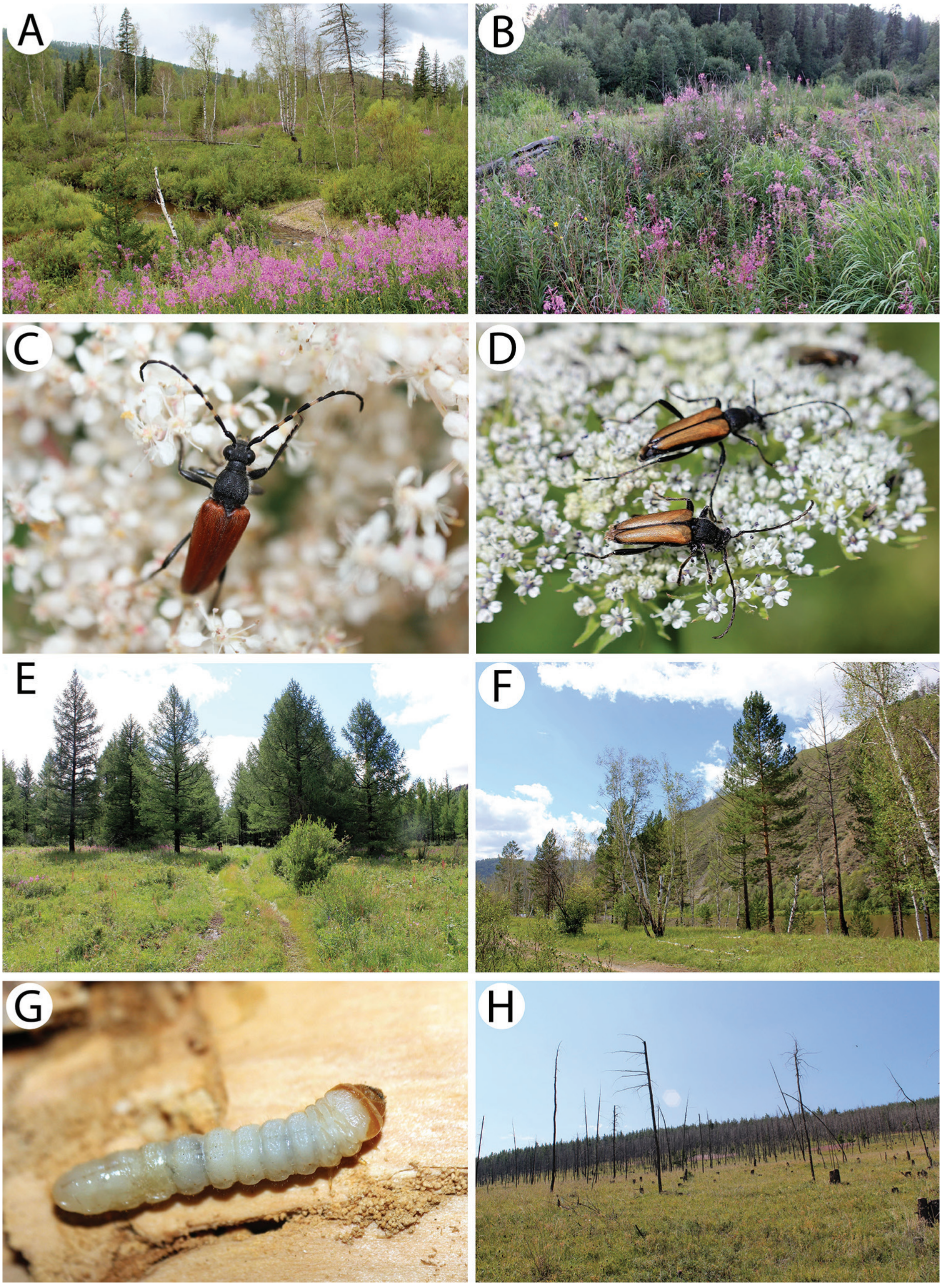


Figure 6. Field photos of imagines in nature, immature stages and habitats of typical Mongolian cerambycid species: **A** spruces, firs and birches in dark taiga, the habitat of *Pachyta lamed*, *P. quadrimaculata* and *Lepturobosca virens* **B** site with fireweed *Chamaenerion angustifolium* in dark taiga, the habitat of several anthopilous species e.g., *Gaurotes virginea aemula*, *Stictoleptura variicornis* **C** male of *S. variicornis* on *Filipendula palmata* **D** males of *Anastrangalia sequensi* on *Seseli condensatum* **E** larches in forest steppe, the habitat of *A. sequensi* **F** riverbank in light taiga, the habitat of *Pachytodes longipes* **G** larva of *Oedecnema gebleri* in larch wood **H** burned larches in forest steppe, the habitat of *O. gebleri* and *A. sequensi*.

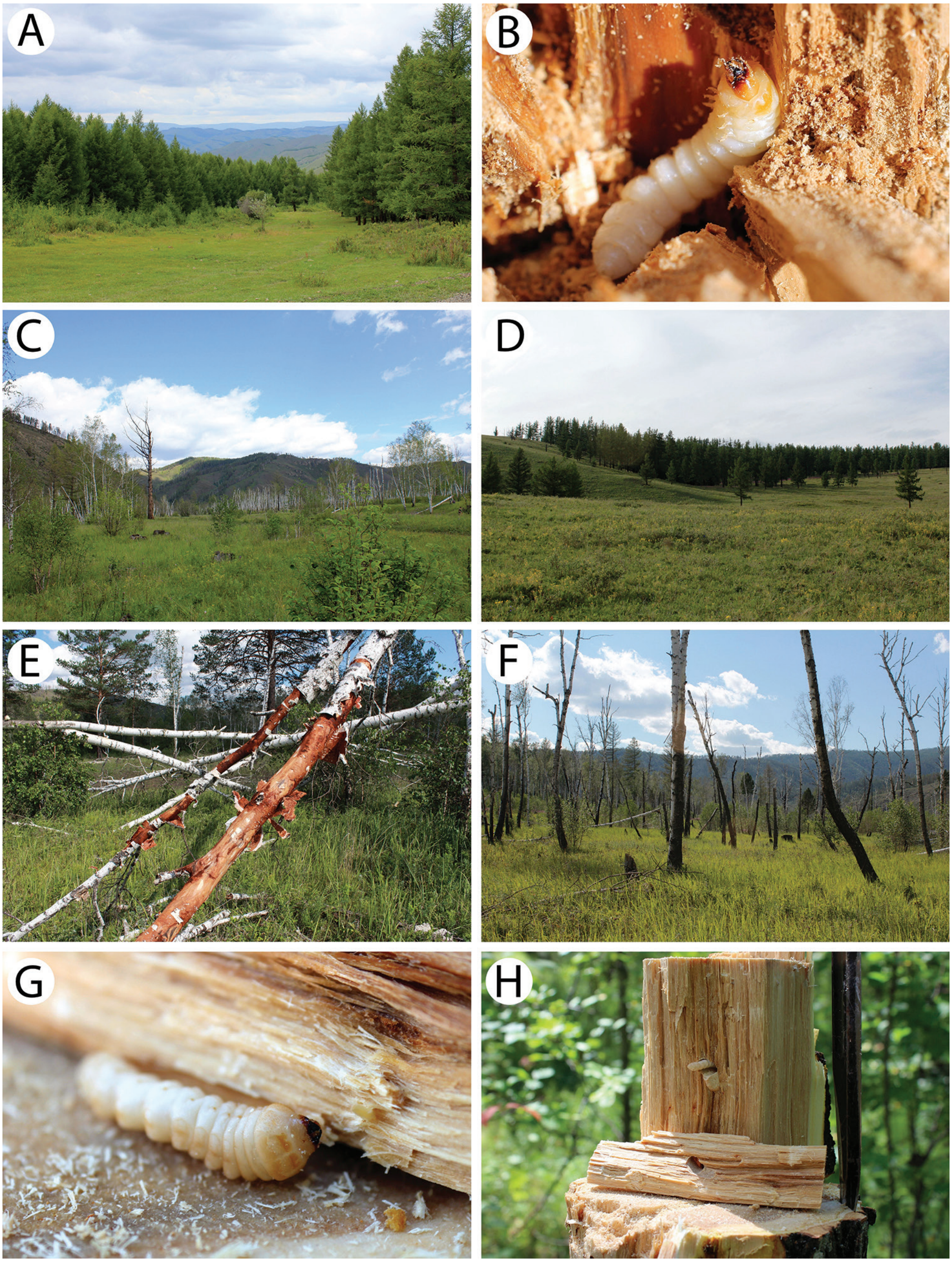


Figure 7. Field photos of immature stages and habitats of typical Mongolian cerambycid species: **A** larches in forest steppe, the habitat of *Lepturalia nigripes rufipennis* **B** larva of *L. nigripes* in a birch stump **C** site in light taiga, the habitat of *L. nigripes rufipennis* and *Agapanthia pilicornis pilicornis* **D** site in forest steppe, the habitat of *Clytus arietoides*, *Monochamus impluviatus impluviatus* and *M. sutor longulus* **E** broken trunk of the birch in light taiga, the microhabitat of *inter alia Xylotrechus hircus* and *Aegomorphus obscurior* **F** birches in light taiga, the habitat of *X. hircus*, *A. obscurior*, *Saperda scalaris hieroglyphica* and *Mesosa myops* **G** larva of *Xylotrechus pantherinus* **H** larva of *X. pantherinus* deep in the wood of a standing willow trunk.

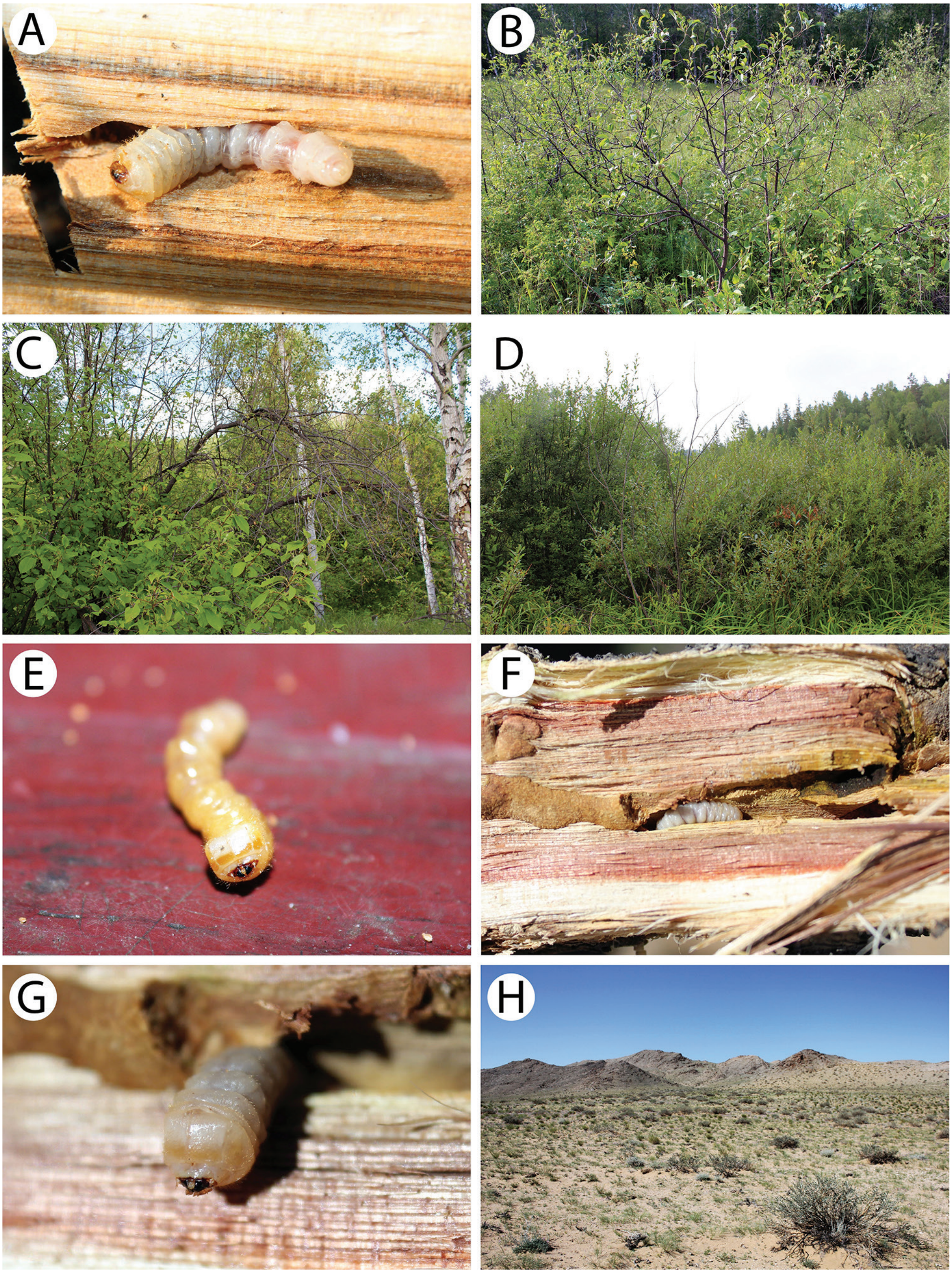


Figure 8. Field photos of immature stages and habitats of typical Mongolian cerambycid species: **A** larva of *Amarysius altajensis* in a bird cherry branch **B** site with young Siberian crab apple trees in light taiga, the habitat of *A. altajensis* **C** dead branches of bird cherry in light taiga, the microhabitat of *A. altajensis* **D** willow bushes in dark taiga, the habitat of *A. altajensis* **E** yellowish larva of *A. altajensis* found in a Siberian crab apple branch **F** *Anoplistes* larva in its feeding ground in a stem of *Caragana bungei* **G** larva of *Anoplistes* from *C. bungei* (detailed view) **H** *C. bungei* shrubs in semi-desert, the habitat of *Anoplistes* sp.

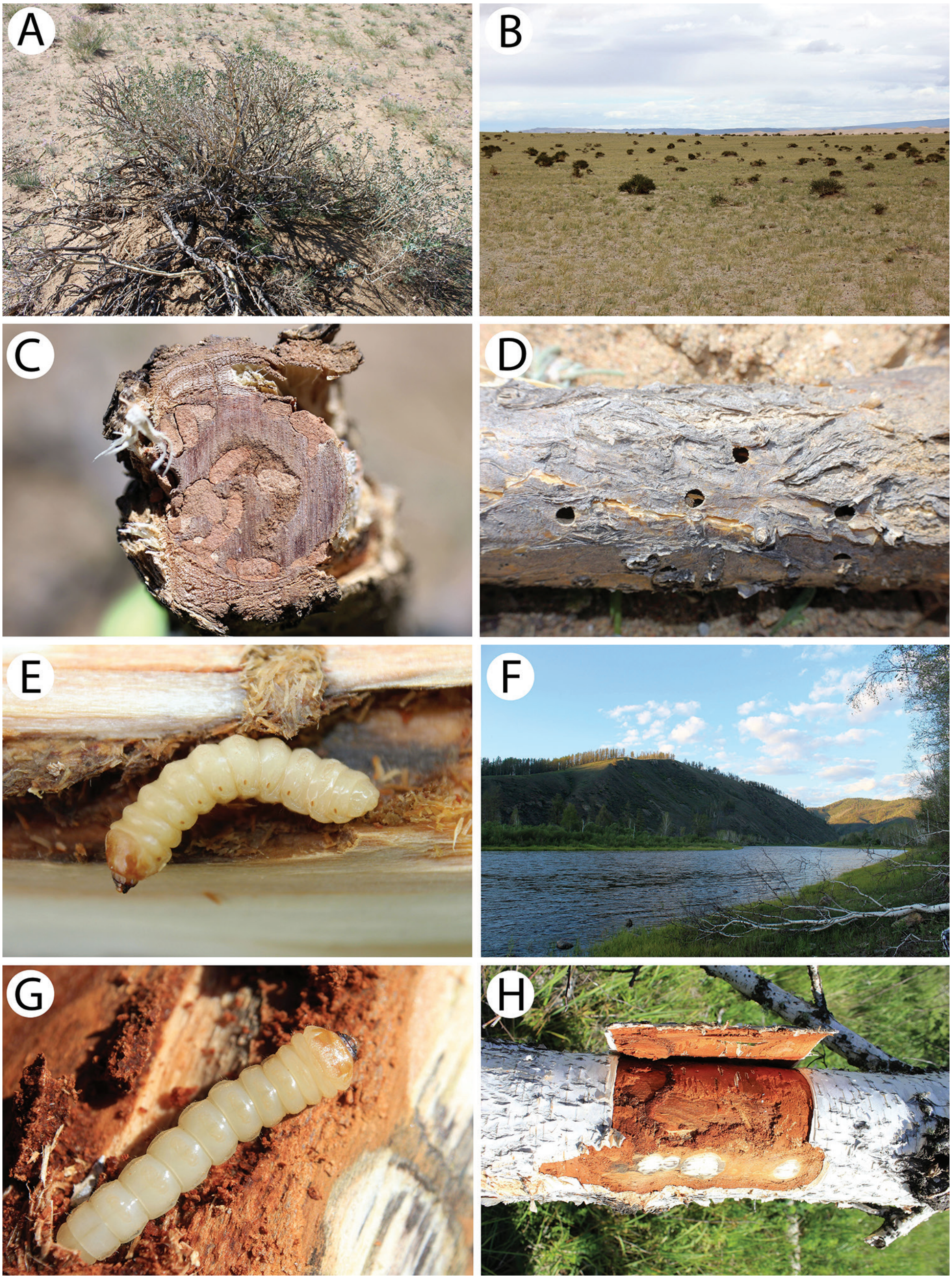


Figure 9. Field photos of immature stages and habitats of typical Mongolian cerambycid species: **A** shrub of *Caragana bungei*, the host plant of *Anoplistes* and *Chlorophorus* species **B** *Caragana leucophloea* shrubs in semi-desert, the habitat of *Anoplistes halodendri minutus* **C** cross-section of larval feeding grounds of *Anoplistes halodendri* in *Caragana* stem **D** adults emergence holes of *Anoplistes halodendri* **E** larva of *Saperda similis* in its pupal cell **F** riverbank in light taiga, the habitat of *S. similis* **G** larva of *Saperda scalaris* **H** thick layer of cambium under the bark of broken birch trunk, the microhabitat of *S. scalaris* and *Mesosa myops*.

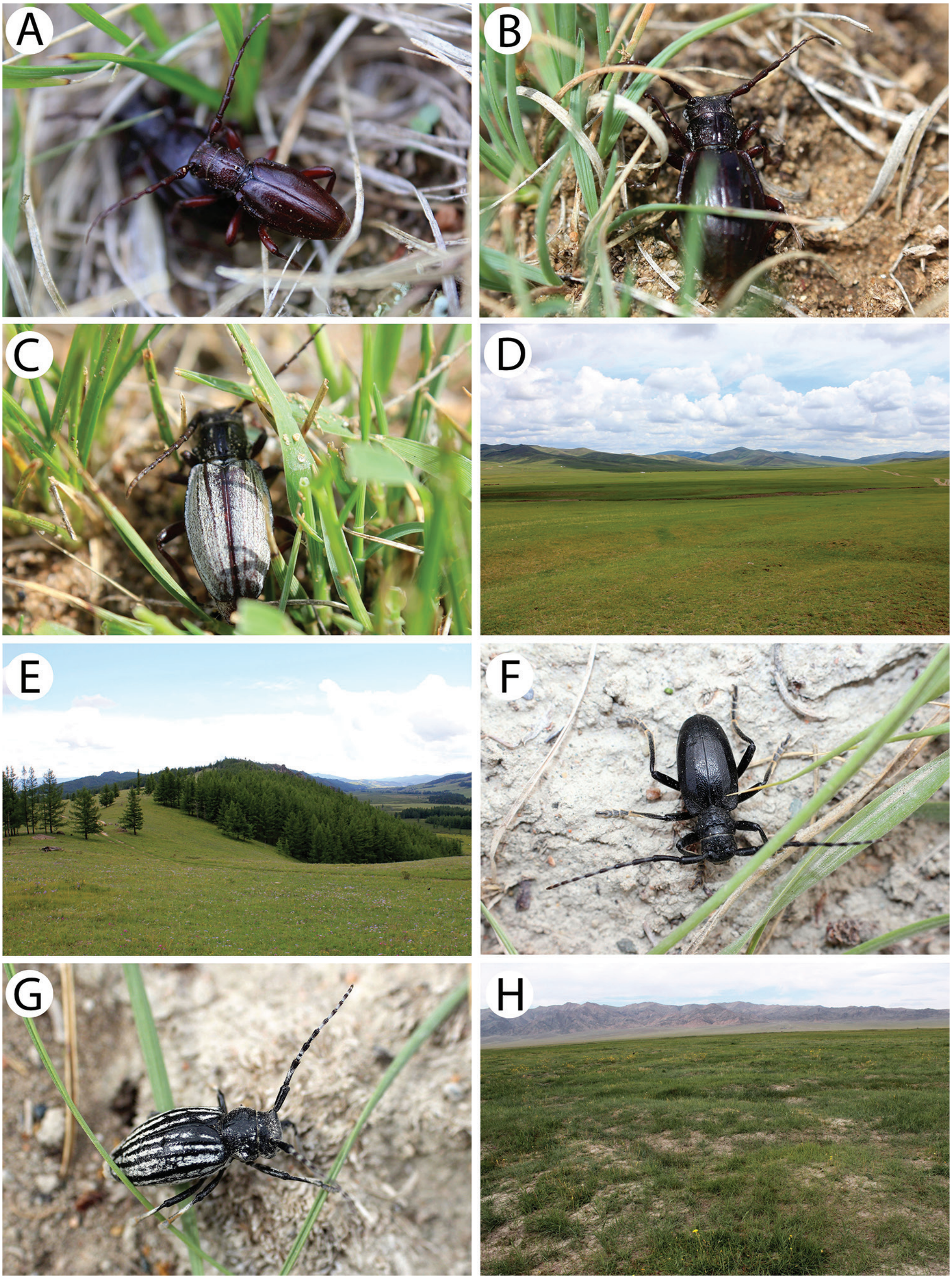


Figure 10. Field photos of imagines in nature and habitats of typical Mongolian cerambycid species: **A** male of *Eodorcadion carinatum involvens* **B** female of *E. carinatum involvens* **C** female of *E. carinatum involvens* (white pubescence form) **D** steppe in Ulaanbaatar environs, the habitat of *E. carinatum involvens* **E** xerothermic mountain slopes, the habitat of *E. carinatum involvens* and *Eodorcadion humerale impluviatum* **F** male of *Eodorcadion maurum australe* **G** female of *E. maurum australe* **H** short grass meadow in Zereg environs, the habitat of *E. maurum australe*.

the afternoon at the end of our stay at this locality. The males behaved rather apathetically, hiding and still drying from the morning dew in the grass. The females are likely to have been more active later than males when the weather conditions had improved. The remains of approx. ten males and one female were also found in the grass.

Eodorcadion dorcas dorcas (Jakovlev, 1901)

Figs 3G, H, 11A

Material examined. Govi-Altai Aimag: 20 km SSW of Bayan-Uul (46°51'N, 95°07'E), 1878 m a.s.l., 11 VIII 2015, 1♂, 2♀♀, leg. MW; 4♂♂, leg. LK.

Remarks. This taxon is endemic to Mongolia and is distributed from the Khovd environs to the west and the southern parts Zavkhan Aimag and then to the northern part of Gobi-Altai Aimag (Danilevsky 2007).

Only a few specimens were collected in the late afternoon in a small enclave (Fig. 11B) with high tufts of grass *Achnatherum splendens* (Fig. 11C) during rather cold (22 °C), cloudy and windy weather. The males (Fig. 11A) were rather mobile, running and trying to hide in the tufts of grass. In this locality, the remains of several imagines were found (Fig. 11D).

Eodorcadion dorcas scabrosum Namkhaidorzh, 1972

Figs 3D–F, 11E–H

Material examined. Govi-Altai Aimag: 3 km E of Khukhmorit [Хөхморьт] (47°21'N, 94°33'E), 1470 m a.s.l., 13 VIII 2015, 31♂♂, 19♀♀ (12♀♀ striped form, 7♀♀ black form), leg. MW; 29♂♂, 8♀♀ (3♀♀ striped form, 5♀♀ black form), leg. WTS; 19♂♂, 8♀♀ (4♀♀ striped form, 4♀♀ black form), leg. LK.

Remarks. The taxon is endemic to Mongolia; all hitherto known specimens were collected in the Khukhmorit environs (Danilevsky 2007).

All of the specimens were collected from one plot in a semi-desert habitat (Fig. 12A, B) with very poor vegetation. The most common plant species on the plot was *Iris tenuifolia* (Fig. 12C), and therefore, it can be possibly the host plant of the larvae. Moreover, we have observed the females eating the leaf blades of irises (Fig. 11F, G) as well as apparently laying the eggs in their roots (Fig. 11F, H). During a hot (25 °C) and sunny evening, we observed plenty of incredibly active individuals (more than two hundred), whose males (Fig. 11E) were quickly moving on the sand. The females were mainly hiding in the tufts of irises and moved only occasionally. The population was dominated by males (ratio of approx. 3:1) and most of the observed females were copulating (Fig. 11G, H). This was probably the climax of the appearance of this species. It is worth noting that we have never observed any of the Dorcadionini species in such a barren desert habitat.

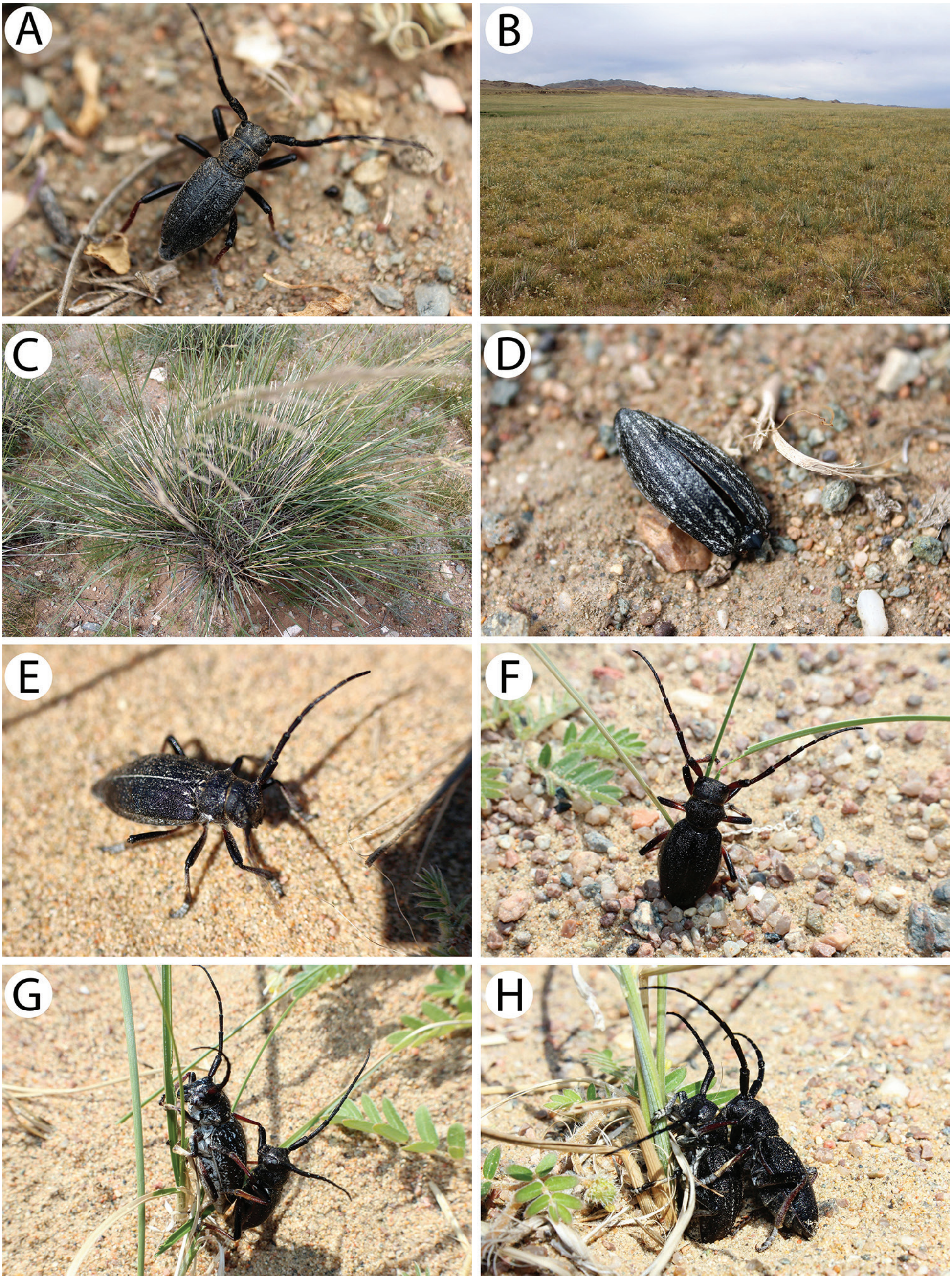


Figure 11. Field photos of imagines in nature and habitats of typical Mongolian cerambycid species: **A** male of *Eodorcadion dorcas dorcas* **B** small enclave with high tufts of grass, the habitat of *E. dorcas dorcas* **C** tuft of needlegrass *Achnatherum splendens*, the possible host plant of larvae of *E. dorcas dorcas* **D** remains of a female of *E. dorcas dorcas* **E** male of *Eodorcadion dorcas scabrosum* **F** female of *E. dorcas scabrosum* during eating a blade of *Iris tenuifolia* **G** pair of *E. dorcas scabrosum in copula* on *I. tenuifolia* **H** attempt to mate while laying eggs by a female of *E. dorcas scabrosum* in the roots of *I. tenuifolia*.

Eodorcadion consentaneum (Jakovlev, 1899)

Figs 3A–C, 12D–G

Material examined. Govi-Altai Aimag: 10 km NW of Biger [Бигэр] (45°47'N, 97°02'E), 1331 m a.s.l., 15 VIII 2015, 29♂♂, 35♀♀ (18♀♀ striped form, 17♀♀ black form), leg. MW; 24♂♂, 15♀♀ (6♀♀ striped form, 9♀♀ black form), leg. LK; 32♂♂, 25♀♀ (13♀♀ striped form, 12♀♀ black form), leg. WTS; 30 km NW of Biger [Бигэр] (45°50'N, 96°45'E), 1688 m a.s.l., 15 VIII 2015, body remains, leg. LK, WTS.

Remarks. This is an endemic Mongolian species with its known distribution limited to a few localities in the northeastern part of Gobi-Altaj Aimag and southern Khovd Aimag. The imagines are active in July and August (Danilevsky 2007).

In the late evening (around 5–7 p.m.), despite the quite cold (15 °C) and cloudy weather with extremely gusty winds, we observed plenty (more than two hundred) of imagines that were rather active. Most of the observed specimens were mating (Fig. 12G); the ratio of males (Fig. 12D) and females was approximately equal. This was probably the climax of the appearance of this species. This was also confirmed by the very small number of dead individuals that have been found in the locality. Among the females, the black forms dominated (Fig. 12E) over the striped ones (Fig. 12F). The species inhabits the periphery of a drying lake with a sandy substrate and tufts of high grass growing out of ground elevations (Fig. 12H). The dominant plant species on the plot was *Achnatherum splendens* (Fig. 13A) and it is most probably the host plant of the larvae. Numerous emergence holes of the beetles were also observed in the sand (Fig. 13B).

Our own observations indicate that the species of the genus *Eodorcadion* seem to be more resistant to difficult weather conditions compared to other Dorcadionini. However, in the case of this taxon, although these conditions were extremely difficult, they apparently did not disturb the functioning and copulation of the beetles.

Eodorcadion intermedium intermedium (Jakovlev, 1889)

Figs 4F–I, 13C–F

Material examined. Bayankhongor Aimag: 35 km SE of Bumbugur [Бөмбөгөр] (45°59'N, 99°50'E), 1598 m a.s.l., 16 VIII 2015, 3♂♂, 1♀ (including dead specimens), leg. MW; 1♀ (dead), leg. LK; 20 km NEE of Bogd [Богд] (45°17'N, 101°02'E), 1298 m a.s.l., 17 VIII 2015, 9♂♂, 3♀♀ (including dead specimens), leg. MW; 3♂♂, 2♀♀, leg. WTS; 7♂♂, 1♀ (including dead specimens; all with reddish antenna), leg. LK; 20 km SE of Bogd [Богд] (45°05'N, 101°08'E), 1263 m a.s.l., 18 VIII 2015, 1 dead imago, leg. LK; Övörkhangai Aimag: 10 km W of Baruunbayan-Ulaan [Баруунбаян-Улаан] (45°08'N, 101°14'E), 1264 m a.s.l., 18 VIII 2015, 2♂♂, leg. WTS; 5 km W of Baruunbayan-Ulaan [Баруунбаян-Улаан] (45°10'N, 101°17'E), 1266 m a.s.l., 18 VIII 2015, 11♂♂, 12♀♀, leg. MW; 4♂♂, 2♀♀ (specimens with black antenna (Fig. 13D)), leg. WTS; 4♂♂, 2♀♀ (most specimens with black antenna), leg. LK.

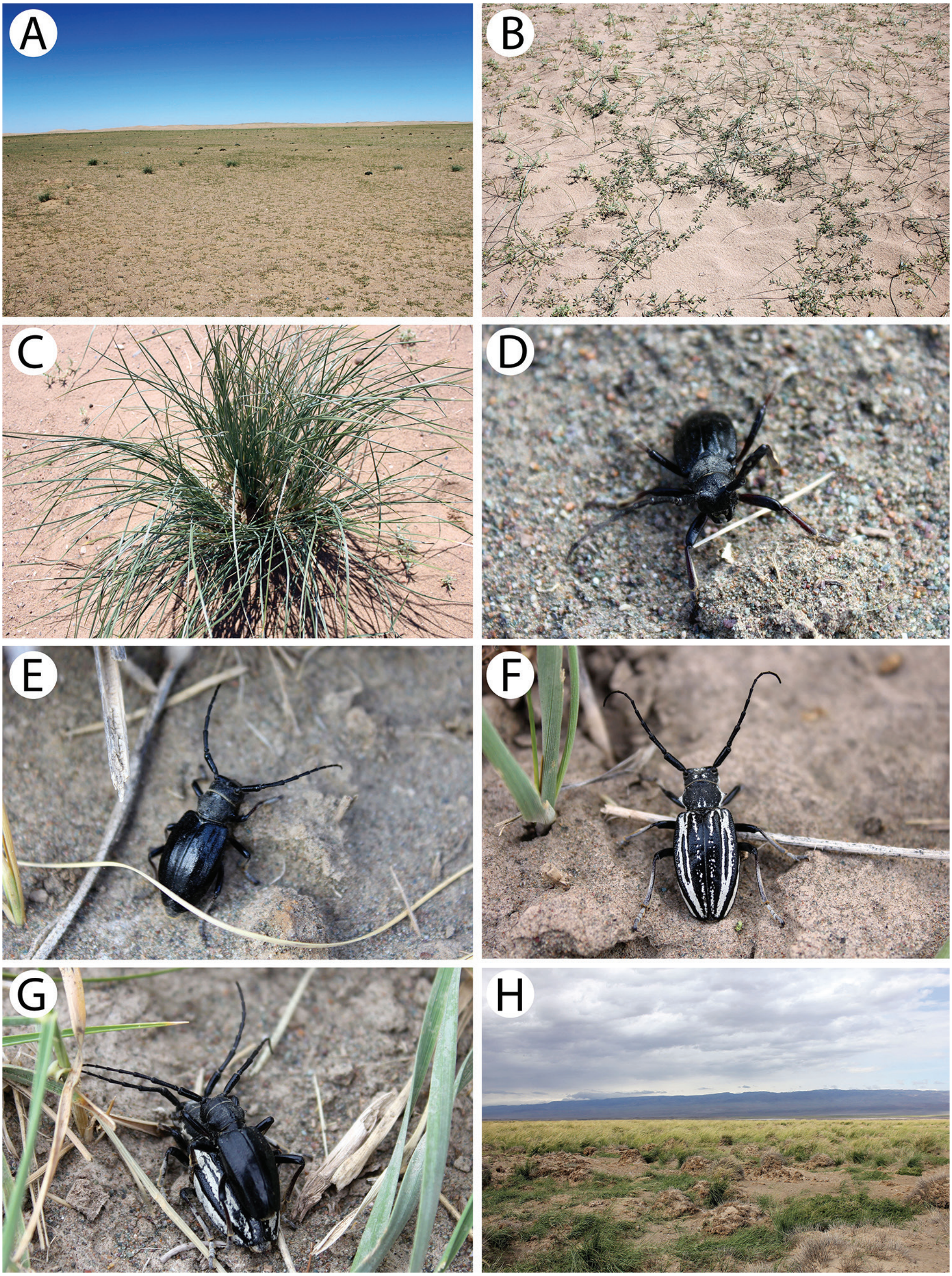


Figure 12. Field photos of imagines in nature and habitats of typical Mongolian cerambycid species: **A** semi-desert in Khukhmorit environs, the habitat of *Eodorcadion dorcas scabrosum* **B** detailed view of the habitat of *E. dorcas scabrosum* **C** tuft of perennial *Iris tenuifolia*, the most likely host plant of larvae of *E. dorcas scabrosum* **D** male of *Eodorcadion consentaneum* **E** female of *E. consentaneum* (black form) **F** female of *E. consentaneum* (striped form) **G** pair of *E. consentaneum in copula* **H** periphery of a drying lake with a sandy substrate and tufts of high grass, the habitat of *E. consentaneum*.

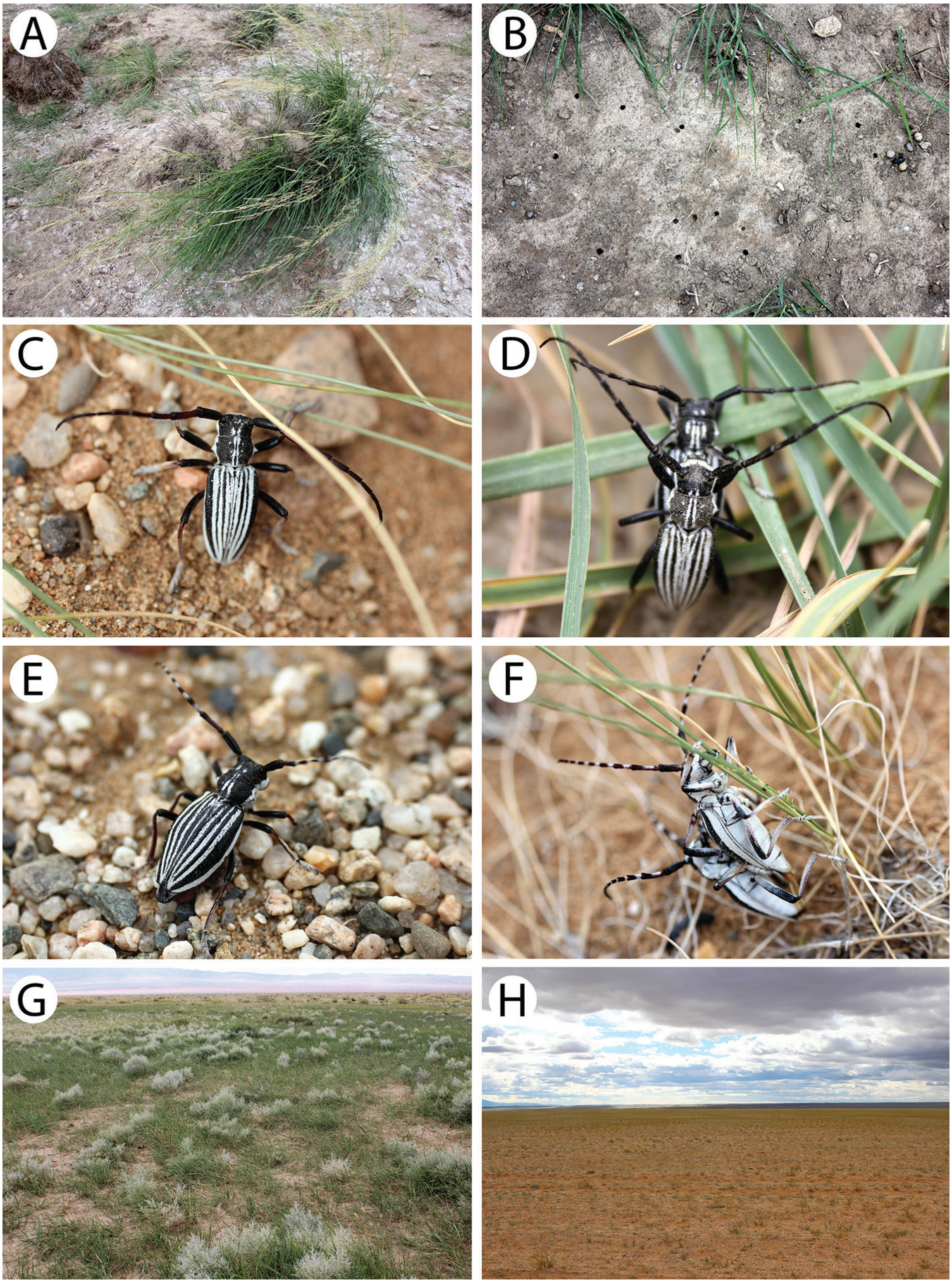


Figure 13. Field photos of imagines in nature and habitats of typical Mongolian cerambycid species: **A** tuft of needlegrass *Achnatherum splendens*, the possible host plant of larvae of *Eodorcadion consentaneum* **B** adults emergence holes of *E. consentaneum* in the sand **C** male of *Eodorcadion intermedium intermedium* (reddish form) **D** male of *Eodorcadion intermedium intermedium* (blackish form) **E** female of *E. intermedium intermedium* (reddish form) **F** pair of *E. intermedium intermedium in copula* **G** steppe in Baruunbayan-Ulaan environs, one of the habitat types of *E. intermedium intermedium* **H** semi-desert in Bogd environs, one of the habitat types of *E. intermedium intermedium*.

Remarks. The species is widespread in the southern parts of Mongolia, where it is divided into two subspecies. The nominative subspecies is distributed in the western part of its range, where it occurs in many localities mainly in Bayankhongor and Gobi-Altaj Aimags. According to Danilevsky (2007), this taxon is characterised by a great deal of individual and geographical variability. We also observed elytral stripes – similar to *E. intermedium kozlovi* (Suvorov 1912) – and antennal colour variations, even in the case of specimens that were collected from the same locality. The species seems to have the ability to adapt to a wide range of ecological conditions; we observed it in various localities in high-grass enclaves, steppe and semi-desert habitats (Fig. 13G, H). The males (Fig. 13C) were primarily collected at different times of the day during rather cloudy (occasional shower) and cold (15-20 °C) weather; only a few pairs were copulating (Fig. 13F). Many specimens were already dead, which indicates the end of the appearance of this species. According to Danilevsky (2007), *E. intermedium* is ecologically associated with *Lasiagrostis*. At one of the localities, we found the remains of imago in a bird's pellet (Fig. 14A).

Eodorcadion oryx (Jakovlev, 1895)

Figs 4B, C, 14B, C

Material examined. Bayankhongor Aimag: 10 km S of Khairkhandulaan [Хайрхандулаан] (45°48'N, 101°59'E), 1748 m a.s.l., 18 VIII 2015, 1♂; 19 VIII 2015, 13♂♂, 2♀♀, leg. LK; 16♂♂, 6♀♀, leg. MW; 7♂♂, 2♀♀, leg. WTS.

Remarks. *Eodorcadion oryx* is an endemic Mongolian species that is distributed in the south-western part of the country. It is a species that has very rarely been collected and there are records from only two known localities to date (Danilevsky 2007).

In the investigated locality, the species inhabits the periphery of a drying lake that has a mix of high and low grass (Fig. 14D, E). We collected most of the specimens before noon (10 a.m. – 12 p.m.) during sunny weather. Although the population was dominated by males (Fig. 14B), females (Fig. 14C) probably began to come out of hiding a little later. The day before, in the late evening, only lifeless imagines were observed, i.e., freshly dead female at the front of a rodent hole.

Eodorcadion exaratum argali (Jakovlev, 1889)

Figs 4D, E, 14F, G

Material examined. Bulgan Aimag, 20 km N of Ulaanshiveet, (47°37'N, 103°51'E), 1108 m a.s.l.; 19 VIII 2015: 6♂♂, 3♀♀, leg. MW; 3♂♂, 4♀♀, leg. WTS; 1♂, 4♀♀, leg. LK.

Remarks. This subspecies is distributed in the eastern part of Mongolia from the western boundary of Khentey Aimag to the Chinese border (Danilevsky 2007).

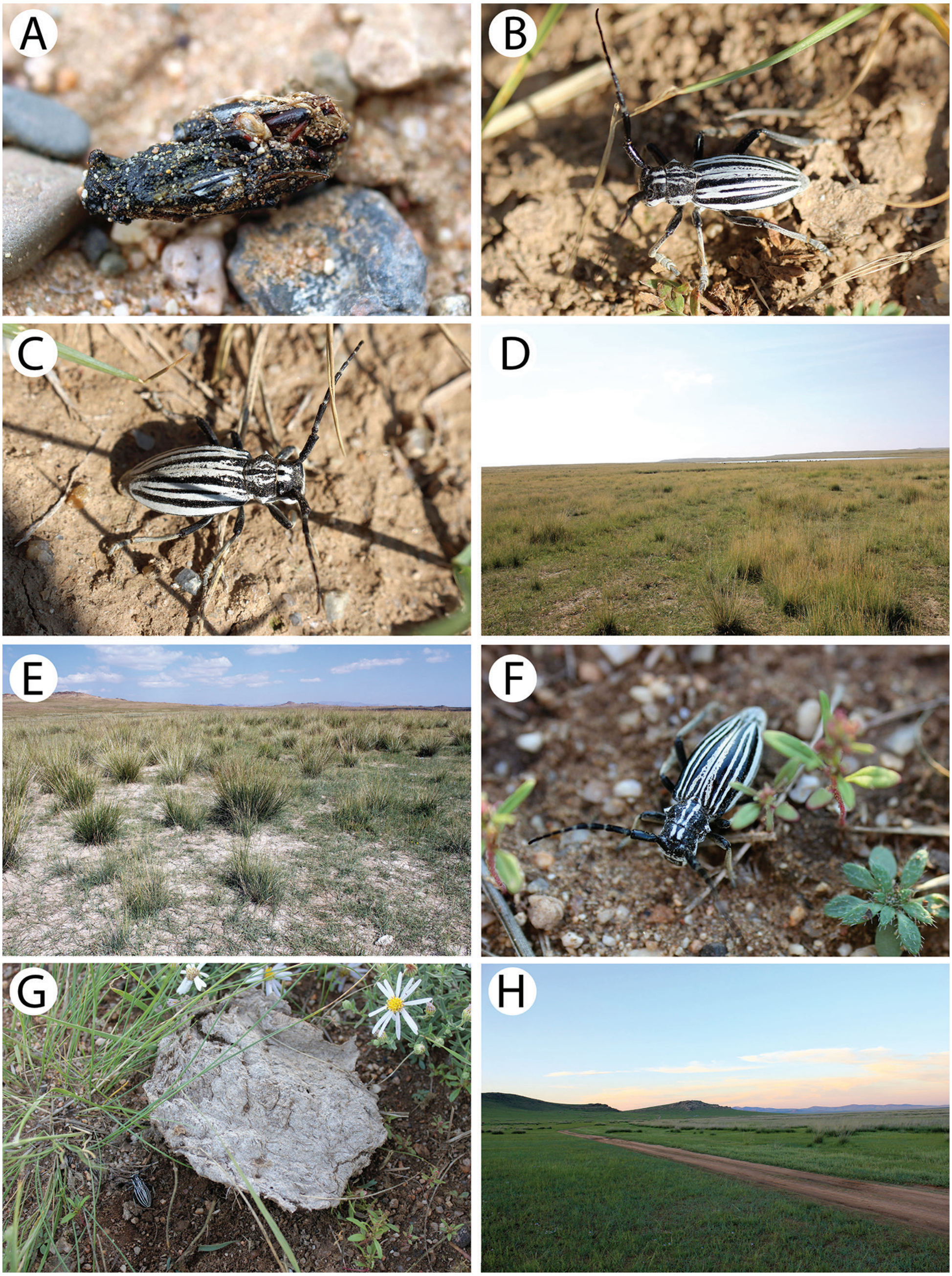


Figure 14. Field photos of imagines in nature and habitats of typical Mongolian cerambycid species: **A** remains of imago of *Eodorcadion intermedium intermedium* in a bird's pellet **B** male of *Eodorcadion oryx* **C** female of *E. oryx* **D** periphery of a drying lake with a mix of high and low grass, the habitat of *E. oryx* and *Eodorcadion humerale impluviatum* **E** detailed view of the habitat of *E. oryx* and *E. humerale impluviatum* **F** female of *Eodorcadion exaratum argali* **G** female of *E. exaratum argali* under cow dung **H** pasture with low grass and herbs in Ulaanshiveet environs, the habitat of *E. exaratum argali*.

The adults are active at the turn of July and August. Danilevsky (2007) observed imagines of this species feeding on *Caragana* stems. This shrub has not been found in the presented locality.

In the late evening hours (about 8–9 p.m.), the specimens were collected during slightly windy weather from a habitat (pasture) that was mainly covered with low grass and herbs (Fig. 14H). In this locality, most of the beetles were hidden under rocks and cow dung (Fig. 14G).

Eodorcadion humerale impluviatum (Faldermann, 1833)

Figs 2D–G, 15A–D

Material examined. Töv Aimag: 80 km NE of Ulaanbaatar [Улаанбаатар] (48°13'N, 107°43'E), 1778 m a.s.l., 31 VII 2015, 17♂♂, 7♀♀, leg. MW; 9♂♂, 4♀♀, leg. LK; 11♂♂, 1♀, leg. WTS (exclusively smaller and darker forms); Bayankhongor Aimag: 35 km SE of Bumbugur [Бөмбөгөр] (45°59'N, 99°50'E), 1598 m a.s.l., 16 VIII 2015, 9♂♂, 7♀♀, leg. MW; 4♂♂ (including 3 dead specimens), leg. WTS; 3♂♂, 1♀, leg. LK (exclusively yellow coloured forms); 33 km S of Nariinteel [Нарийнтэл]; (45°39'N, 101°22'E), 1626 m a.s.l., 17 VIII 2015, 1♂ (dead specimen), leg. MW; 1♀ (dead specimen), leg. LK; 10 km S of Khairkhandulaan [Хайрхандулаан] (45°48'N, 101°59'E), 1748 m a.s.l., 18–19 VIII 2015, 2♂♂, leg. LK; 1♂, leg. MW; 1♂, leg. WTS.

Remarks. This widespread species, which contains three subspecies, is distributed in Russia from Transbaikalia to the Pacific Ocean in the Primorsky region, in the central and north-eastern parts of Mongolia and in north-eastern China. *Eodorcadion humerale humerale* is limited to the territory of Mongolia, where it has many known localities in the areas of Bayankhongor Aimag and Ulaanbaatar (Danilevsky 2007).

This taxon was observed sympatrically with other *Eodorcadion* species, i.e., *E. intermedium* and *E. oryx*, in steppe habitats (Fig. 14D) that had tufts of high grass (*inter alia Achnatherum splendens*). In addition to the typical form (Fig. 15A), that was collected in most of the presented localities, in the Khentey Mountains, we found a specific population characterised by a definitely smaller body size and by elytra covered with fewer white spots of hairs (sometimes almost completely black) (Fig. 15B–D). This population inhabits a xerothermic slope with a rich plant community on the edge of a larch woodlot in a forest-steppe habitat (Figs 10E, 15E). During rather cloudy weather before a storm, some specimens were still active and copulating (Fig. 15D) in the afternoon hours (about 1 p.m.). On the same plot, we also observed approximately ten specimens of *E. carinatum involvens* and one female of *Monochamus impluviatus impluviatus*. Due to the considerable dissimilarity in body size and type of biotope, this population requires further research and possibly represents a transitional form between two subspecies (*E. h. impluviatum* and *E. h. humerale*).

Monochamus impluviatus impluviatus **(Motschulsky, 1859)**

Figs 5D, E, 15F

Material examined. Töv Aimag: 75 km NE of Ulaanbaatar (48°10'N, 107°55'E), 1589 m a.s.l., 30 VII 2015 (1 II 2016, ex cult), 1♂, 1♀, from *Larix sibirica*, leg. MW; 80 km NE of Ulaanbaatar (48°13'N, 107°43'E), 1778 m a.s.l., 31 VII 2015, 1♀, leg. WTS.

Remarks. This is a Siberian species that is distributed from Ural to the Far East, including northern Mongolia, China, and North Korea (Sama 2002, Danilevsky 2017a). *Monochamus impluviatus* is a comparatively rare species that feeds exclusively on larch *Larix*. One generation takes two years to complete. The imagines are active from June to the first half of August. The species is sometimes found sympatrically with *Acanthocinus carinulatus* Gebler, 1833 and *Rhagium inquisitor* (Linnaeus, 1758) (Cherepanov 1990c).

Two specimens were also recorded from Bulgan Aimag by Heyrovský (1967a).

A single female (Fig. 15F) was found moving on the ground under a larch tree (Fig. 15G). One couple was additionally reared from a branch of a fallen *Larix sibirica* collected in forest steppe habitat (Fig. 7D). The same material was inhabited by larvae of *Clytus arietoides* and *Monochamus sutor*.

Monochamus sutor longulus **(Pic, 1898)**

Fig. 5F

Material examined. Töv Aimag: 75 km NE of Ulaanbaatar (48°10'N, 107°55'E), 1589 m a.s.l., 30 VII 2015 (26 II 2016, ex cult), 1♀, from *Larix sibirica*, leg. MW.

Remarks. *Monochamus sutor* is a boreal montane species that is widely distributed in Europe; in Asia, it is known from Georgia, Russia, Kazakhstan, and Mongolia. It is also an invasive species in North America (Danilevsky 2017a). This species is ecologically associated with various conifer trees. Its life cycle lasts from one to three years. The imagines are active from June to mid-September (Cherepanov 1990c, Kolk and Starzyk 1996).

Monochamus sutor longulus has a more eastern range compared to the nominative subspecies, and is distributed from East Siberia through northern Mongolia, China and North Korea to the Far East and Japan. It differs from the nominative form *inter alia* in its slightly more elongated elytra with glabrous and shining surface. According to Wallin et al. (2013), there is no difference in the male genitalia characters between the examined specimens of those two subspecies.

In Mongolia, this taxon was probably incorrectly identified in certain works (e.g., Heyrovský 1965, 1969, 1973a) and it was recorded as *Monochamus sutor* var. *pellio* (Germar, 1818), which is currently recognized as a synonym of the nominative subspecies.

One female was reared from a branch of a fallen tree of *Larix sibirica* collected in forest steppe habitat (Fig. 7D). The same material was inhabited by larvae of *Clytus arietoides* and *Monochamus impluviatus*.

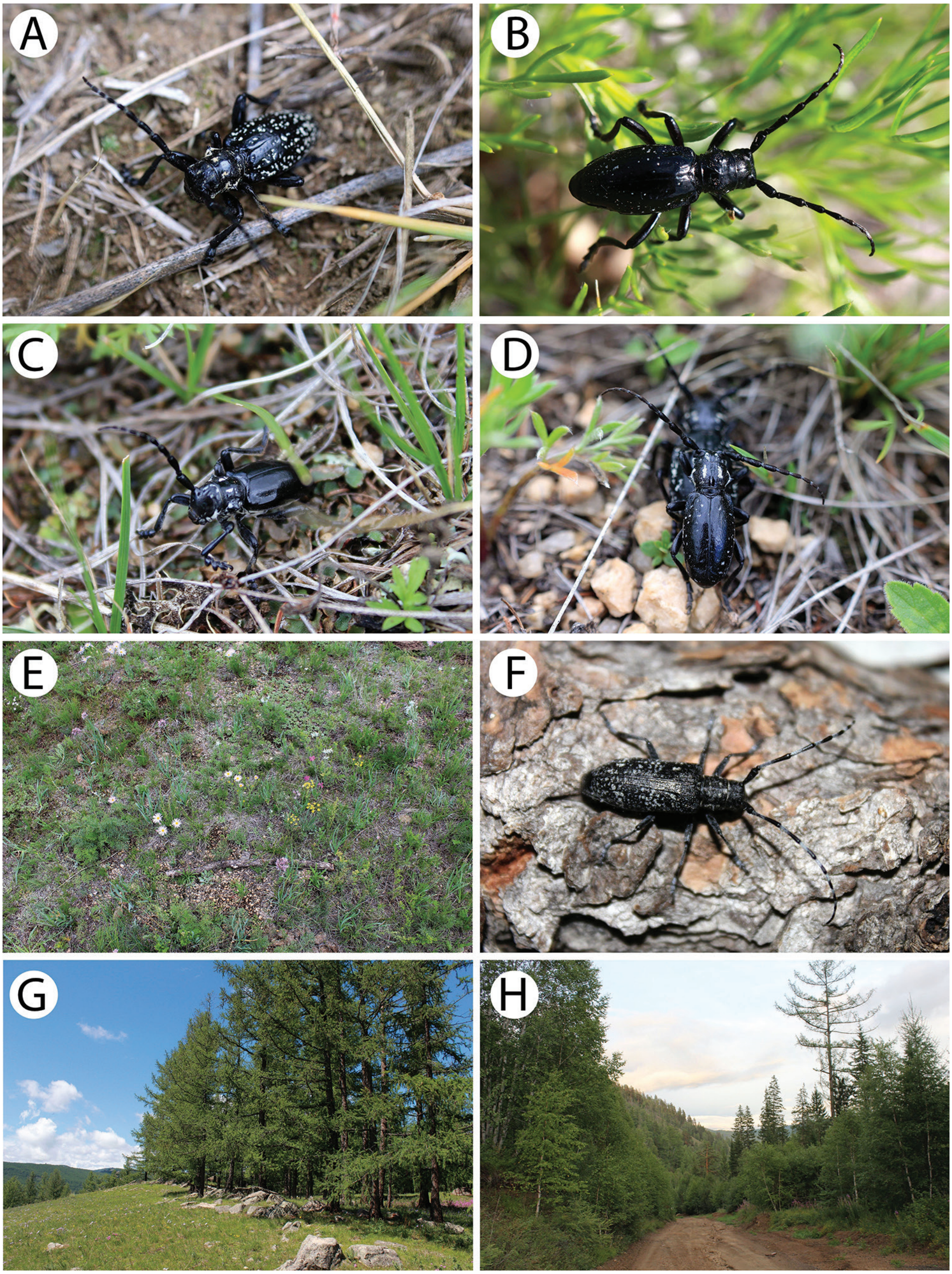


Figure 15. Field photos of imagines in nature and habitats of typical Mongolian cerambycid species: **A** male of *Eodorcadion humerale impluviatum* (typical form) **B** male of *E. humerale impluviatum* (Khentey Mountains) **C** male of *E. humerale impluviatum* (Khentey Mountains, entirely black elytra form) **D** pair of *E. humerale impluviatum in copula* (Khentey Mountains) **E** detailed view of the habitat of *E. humerale impluviatum* (Khentey Mountains) **F** female of *Monochamus impluviatus impluviatus* **G** larches in forest steppe, the habitat of *M. impluviatus impluviatus* **H** various species of coniferous trees and birches in dark taiga, the habitat of *Monochamus sartor urussovii*.

Monochamus sartor urussovii (Fischer von Waldheim, 1805)

Fig. 5G

Material examined. Selenge Aimag: 50 km NE of Zuunkharaa (49°05'N, 107°17'E), 930 m a.s.l., 03 VIII 2015, 1♂, leg. LK; several larvae, *Larix sibirica* leg. MW; Selenge Aimag: 35 km NE of Zuunkharaa (48°59'N, 106°55'E), 1399 m a.s.l., 05 VIII 2015, 1♂, leg. MW.

Remarks. The taxonomic status of this species is uncertain. Cesari et al. (2005), Sláma (2006), and Wallin et al. (2013) considered *M. urussovii* to be a subspecies of *Monochamus sartor* (Fabricius, 1787). This taxon is widespread in Siberia and is distributed from Eastern Europe to the Far East and Japan (Danilevsky 2017a). Depending on the region, the larvae can develop in various conifers (mostly in *Abies* and *Picea*) and also sporadically on deciduous trees (Cherepanov 1990c, Wallin et al. 2013). In the Mongolian taiga, in addition to conifers, this species was found on birches (Müller et al. 2013). Its larval development usually takes two years. The imagines are active from the second half of May to the end of September (Cherepanov 1990c). Two single males were caught flying in both light and dark taiga (Fig. 15H).

Mesosa myops (Dalman, 1817)

Figs 5B, C, 16A

Material examined. Selenge Aimag: 50 km NE of Zuunkharaa (49°05'N, 107°17'E), 930 m a.s.l., 02 VIII 2015, numerous larvae and pupae, 1♂, 1♀, *Betula platyphylla*, leg. LK, WTS, MW; (III 2016, ex larva), 1♂, leg. MW; (02–10 VIII 2015, ex pupa), 1♂, 5♀♀, leg. WTS; (05 VIII 2015, ex pupa), 2♂♂, 1♀, leg. LK.

Remarks. This species is distributed from Eastern Europe (where it reaches eastern Poland) through Siberia, including northern Mongolia and China, to the Far East and Japan (Sama 2002, Danilevsky 2017a). It is listed in the Annexes of the European Habitats Directive (92/43/EEC), and therefore, it is strictly protected in the entire European Union. However, in the centre of its range (including Mongolia), *M. myops* is considered to be a common species and it is often numerously found in this region (e.g., Müller et al. 2013). This species is polyphagous on a large number of deciduous trees and shrubs. Its larval development usually takes two years. The pupation of the larvae takes place in the summer. After emerging from the pupae, the adult beetles emerge from their pupal cells from July to September; afterwards they probably overwinter in leaf litter. The imagines occur throughout entire warm season from May to September (Cherepanov 1990c).

Several dozen larvae (Fig. 16B), some pupae (Fig. 16C, D) and newly emerged imagines (Fig. 16A) were observed under the bark (Fig. 9H) of rather thin broken *Betula platyphylla* (5–20 cm in diameter) (Fig. 16E) in the light taiga habitat (Fig. 7F) at the beginning of August. Several emergence holes of adults were also found on both branches and stems (Fig. 16F). The same material was additionally inhabited by larvae of *Xylotrechus hircus*, *Aegomorphus obscurior* and *Saperda scalaris*.

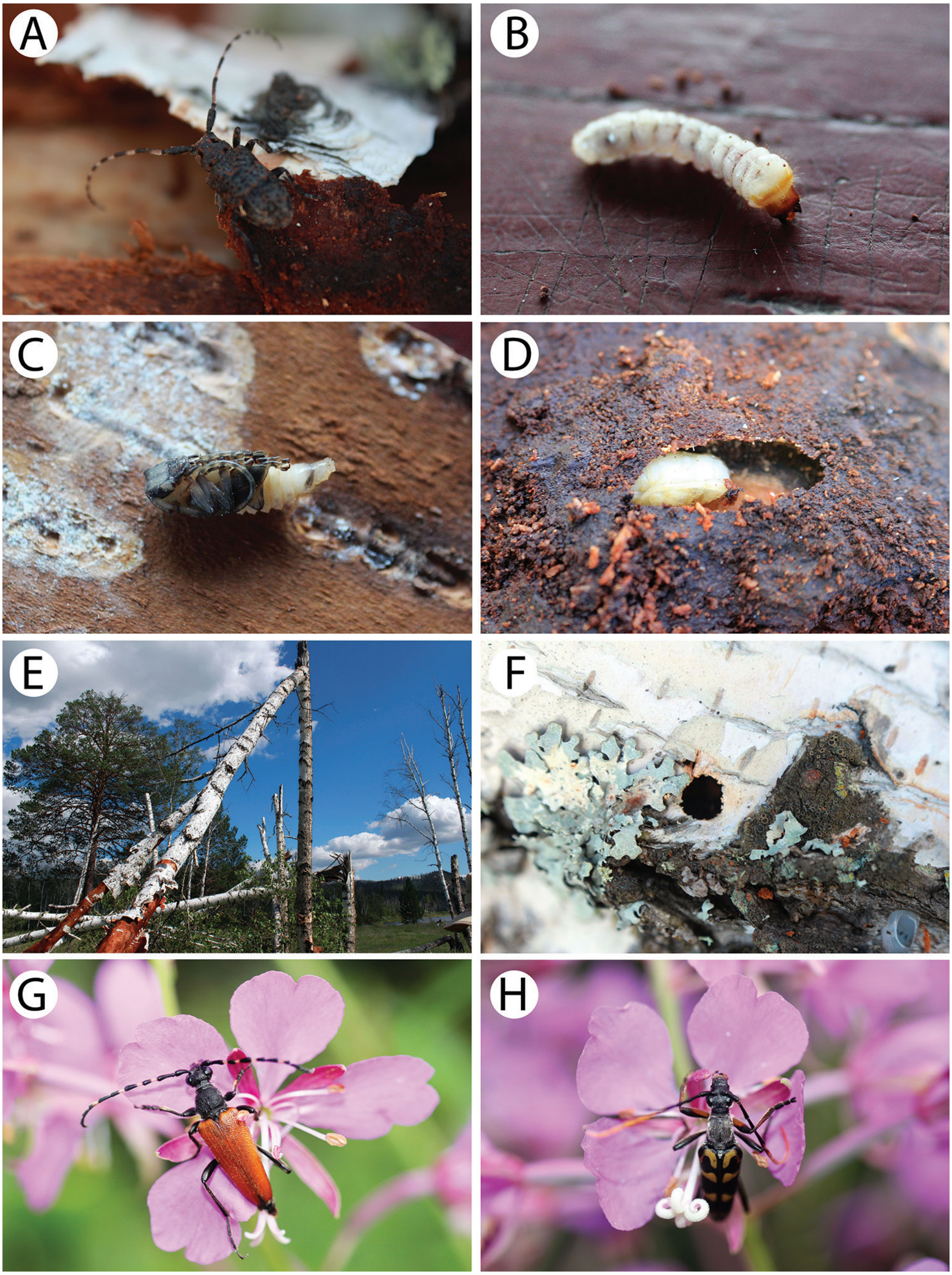


Figure 16. Field photos of imagines in nature, their immature stages and habitats of typical Mongolian cerambycid species: **A** newly emerged male of *Mesosa myops* **B** larva of *M. myops* **C** one of the last pupal instars of *M. myops* **D** pupa of *M. myops* in thick layer of cambium under the bark of broken birch trunk **E** broken trunk of the birch in light taiga, the microhabitat of *M. myops* **F** adults emergence holes of *M. myops* **G** *Stictoleptura variicornis* on *Chamaenerion angustifolium* **H** *Leptura annularis* on *Chamaenerion angustifolium*.

Discussion

Many international expeditions (i.e., the USSR, Hungary, Poland, Germany) together with local specialists have intensively studied the Mongolian entomofauna in the second half of the 20th century. The results of this research on different taxonomic groups of insects have been published in many different journals. Among those which were elaborated in the USSR, eleven volumes of scientific papers on Mongolian insect fauna (1972–1990) were published as part of the series "Insects of Mongolia". The main emphasis was placed on two large orders of Insects: Coleoptera and Lepidoptera (Kovalenko et al. 2016).

The greatest contribution regarding Mongolian longhorn beetles has been made by Namhaidorzh (1972, 1974, 1976a,b, 1979, 1982) and Heyrovský (1964, 1965, 1967a,b, 1968, 1969, 1970, 1973a,b, 1975), the latter of whom elaborated the material collected by Zoltán Kaszab during his six expeditions conducted between 1963 and 1968, in the series entitled "Ergebnisse der Zoologischen Forschungen von Dr. Z. Kaszab in der Mongolei". Additional data in this field was also published, *inter alia*, by Faldermann (1833), Jakovlev (1889), Janovsky (1974, 1977, 1980), Murzin (1977), Lindeman and Lyamtseva (1979), and Niisato (1994).

Despite all of these studies, the Mongolian cerambycid fauna is still not sufficiently recognised. This is evidenced by recently published descriptions of a new genus (*Rapuzziana* Danilevsky, 2006), several new species (*Pachytella churkini* Danilevsky, 2011; *Xylotrechus medvedevi* Danilevsky, 2009; *Eodorcadion savitskyi* Danilevsky, 2014; *E. gorbunovi* Danilevsky, 2004) and many subspecies (e.g., *E. rubrosuturale kerulenum* Danilevsky, 2007; *E. maurum australis* Danilevsky, 2014; *Cleroclytus semirufus savitsky* Lazarev, 2014). Moreover, some already known taxa might still be found here as new to the country, e.g., *Exocentrus stierlini* (Ganglbaur, 1883), which was recorded by Müller et al. (2013) from the Khan Khentey region.

In addition to taxonomic studies, the biology and ecology of Mongolian longhorn beetles (especially endemic species) should also be thoroughly investigated. For example, in this work, we report on the clearly important ecological role of the fireweed *Chamaenerion angustifolium* (= *Epilobium angustifolium*) (Onagraceae) in the life processes of many boreal anthophilous species, which has largely been neglected in the literature on the subject. This plant species, which is native throughout the temperate Northern Hemisphere, is very common in both light and dark Mongolian taiga. We observed ecological relationships between this plant and several cerambycid species: *Pachyta lamed*, *P. quadrimaculata*, *Gaurotes virginea*, *Stictoleptura variicornis* (Fig. 16G), *Anastrangalia sequensi*, *Lepturobosca virens*, *Leptura aethiops*, *L. annularis* (Fig. 16H), and *Stenurella melanura*. Numerous individuals of those species not only feed on *Chamaenerion angustifolium* but they also used the calyces of the flowers of this plant to protect themselves from the rain and to overnight in. Most of the abovementioned cerambycids appeared to prefer this plant compared to other Asteraceae and Rosaceae occurring in these habitats.

Research on beetles, and on insects in general, in Mongolia is very important due to its pristine habitats. Consequently, some ecological patterns can still be studied here in comparatively untouched habitats. The Mongolian endemics are particularly vulnerable and unique. Moreover, since the territory of this country is located between Russia and China, it may constitute a transit zone for the establishment of some quarantine pests from southern Asia. Therefore, from the point of view of science, it is extremely important to preserve these more and more vulnerable habitats.

Mongolian ecosystems are under unprecedented pressures. The climate change occurring globally happens at a much greater rate in Mongolia than the global average (the mean annual temperature has increased 2.14 °C in the last 70 years, MNET 2009b, MEGD 2014). This warming trend, coupled with changes in the precipitation patterns (Goulden et al. 2016, Vandandorj et al. 2017), results in an overall drying tendency of ecosystems and the loss of surface waters. Another big challenge is the increase of livestock since it was privatised in 1992. In December 2016, Mongolia had 61.5 million heads of livestock, which was the highest number of free-ranging animals in the country (NSO 2016), thus causing overgrazing in many areas, especially near settled areas and water bodies. Even though the Mongolian ecosystems have been subject to pastoral livestock grazing, they have not been subjected to this level of livestock grazing pressure which is impacting the ecosystems simultaneously with the climate change. Both factors have been the main cause of land degradation in the country, even though simultaneously effects of which have been difficult to determine. However, the effects of grazing on insect diversity have been documented for certain groups of insects, e.g., moths (Enkhtur et al. 2017). According to some reports, close to 78 per cent of the Mongolian territory has been affected by land degradation (MEGD 2014). Although one could question the methodology of such an estimate, it is a clear sign of land degradation and desertification. Finally, another big factor in the local and regional-scale changes is the mining industry (MNET 2011). Over the last couple of decades, the Mongolian government has been encouraging foreign mining companies to invest and to start businesses in Mongolia (Farrington 2005). Various environmental issues have been raised as a consequence of mining, such as the development of, or lack thereof, linear infrastructures, elevated levels of dust and heavy metals pollution and threats to access to water resources.

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We would like to dedicate this work to late Balgan Namkhaidorj, who was the cerambycid specialist of Mongolia and who was a senior researcher of the 1995 American-Mongolian Expedition to Lake Hovsgol National Park, Mongolia, which was BB's first professional expedition. We want to express special thanks to Dr. Petr Švácha (Czech Academy of Sciences) for his help with identifying the larval material, and to Lech Kruszelnicki (Poland) for taking and stacking the high-resolution photographs of the specimens. We are also grateful to Dr. Artur Taszakowski (University of Silesia, Poland) for his help in preparing the map of research plots as well as to the reviewers and the ZooKeys publishing team for valuable comments and constructive suggestions. BB also wishes to acknowledge the support by the Taylor Family-Asia Foundation Endowed Chair in Ecology and Conservation Biology.

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RESEARCH ARTICLE

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New genus and species of sisyrids (Insecta, Neuroptera) from the Late Cretaceous Myanmar amber

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Abstract

A new genus and species of Sisyridae, *Stictosisyra pennyi* **gen. et sp. n.**, is described from the Late Cretaceous (earliest Cenomanian/late Albian) Myanmar amber. It can be easily distinguished from other sisyrids genera by the configuration of wing venation such as forewing with four ra-rp crossveins, M forked distal to the separation of RP1, CuA pectinate and CuP simple; hind wing 1r-m long and sinuous. Besides, the newly documented spongillaflies bore distinct, irregularly distributed spots on the forewings.

Keywords

spongillaflies, Burmese, Mesozoic, fossil, color spots

Introduction

Sisyridae is a small and one of the most ancient family of Neuroptera, comprising about 70 extant species (Oswald 2015) assigned to four genera (*Sisyra* Burmeister, 1839, *Sisyrina* Banks, 1939, *Sisyborina* Monserrat, 1981, and *Climacia* McLachlan, 1869). *Sisyra* is cosmopolitan. *Climacia* are distributed in the Nearctic and Neotropics. *Sisyrina* are in the Afrotropics, Indomalaya and Australasia. *Sisyborina* is restricted to the Afrotropics (Oswald 2015). The fossil record of Sisyridae is very rare, dating back to the Late Cretaceous. To date, three extinct genera with six species have been described, all from Eurasia: *Paleosisyra eocenica* Nel, Menier,Waller, Hodebert & de Ploëg, 2003; *P. electrobaltica* Wichard, Gröhn & Seredszus, 2009; *P. minor* Wichard, Wedmann & Weiterschan, 2016; *Prosisyrina sukachevae* Perkovsky & Makarkin, 2015; *P. sphinga* Makarkin & Perkovsky, 2016; and *Paradoxosisyra groehni* Makarkin, 2016. Also Perkovsky and Makarkin (2016) give a list of known fossil Sisyridae including undetermined species.

Here, we describe a new genus and species, *Stictosisyra pennyi* gen. et sp. n., of Sisyridae, from the lowermost Cenomanian Myanmar amber. This is the second species of the family in this locality. The former described species, *Paradoxosisyra groehni*, possessing relatively long, siphonate mouthparts, is unique among Sisyridae. Based on this species, the extinct subfamily Paradoxosisyrinae was erected. Paradoxosisyrinae are common in Burmese amber, with tens of specimens found (pers. obs.). The new genus and species described here does not belong to Paradoxosisyrinae, but shares more characters in common with the extant Sisyridae.

Material and methods

This study is based on one male specimen from Myanmar amber. The amber pieces were collected in the Hukawng Valley (the state of Kachin in northern Myanmar). A map of the Hukawng Valley is given by Grimaldi et al. (2002, fig. 1). The volcaniclastic matrix of the amber is estimated to be ~98.79 ± 0.62 million years old, i.e., near the Albian/Cenomanian (Early/Late Cretaceous) boundary (Shi et al. 2012). The biological inclusions of Myanmar amber represent a sample of a tropical forest community in equatorial southeastern Asia at ~12_N paleolatitude (Grimaldi et al. 2002; Poinar et al. 2008; Zhang et al. 2017; Ren et al. 2017). The specimen is housed in the collection of the Key Laboratory of Insect Evolution & Environmental Changes, College of Life Sciences, Capital Normal University, Beijing, China (CNUB; Dong Ren, Curator). The specimen was examined using a Zeiss Discovery V20 stereomicroscope and photographed with an AxioCam HRc digital camera attached to the Zeiss Discovery V20 stereomicroscope (both instruments Carl Zeiss Light Microscopy, Göttingen, Germany). Line drawings were prepared with the CorelDraw X4 graphics software and with the aid of Adobe Photoshop CC.

Venation terminology in general follows Kukalová-Peck and Lawrence (2004) as interpreted by Yang et al. (2012, 2014). Terminological details of venation (e.g., spaces, veinlets, traces) follows Oswald (1993). Crossveins are designated after the longitudinal veins with which they connect and are numbered in sequence from the wing base, e.g., 1r-m, a crossvein connecting R/RP and M/MA in the first series.

Abbreviations: AA1–AA3, first to third anterior anal vein; CuA, anterior cubitus; CuP, posterior cubitus; MA and MP, anterior and posterior branches of media; RA, anterior radius; RP, posterior sector; RP1, proximal-most branch of RP; RP2, branch of RP distad RP1; ScA, subcosta anterior; ScP, subcosta posterior.

Systematic paleontology

Class Insecta Linnaeus, 1758
Order Neuroptera Linnaeus, 1758
Family Sisyridae Banks, 1905

Genus *Stictosisyra* Yang, Shi, Wang & Pang, gen. n.

http://zoobank.org/DD782A02-2AA7-4578-A18C-10F8CBE41B9F

Type and only species. *Stictosisyra pennyi* Yang, Shi, Wang & Pang, gen. et sp. n.

Etymology. The generic name is a combination of *stict-* (Greek, meaning speckled, flecky), in reference to the irregular brown spots distributed on the forewings; and *Sisyra*, type genus of the family. Gender feminine.

Diagnosis. Forewing with four ra-rp crossveins, M forked distal to the separation of RP1, CuA pectinately branched, CuA branches simple, CuP simple. Forewing with irregularly distributed spots over whole wing. Hind wing with one ra-rp, 1r-m very long and sinuous, connected stem of RP and M.

Stictosisyra pennyi Yang, Shi, Wang & Pang, sp. n.

http://zoobank.org/C0203F16-A571-4B38-AD51-61593094D8F8
Fig 1–3

Etymology. The specific epithet is in memory of Dr. Norman D. Penny (1946–2016), in recognition of his great contribution to the lacewing study. The first two authors were impressed by his kindles and generosity when visiting the California Academy of Sciences in 2016.

Diagnosis. As for the genus.

Holotype. CNU-NEU-MA2017006, assumed male, nearly complete and well preserved specimen.

Locality and horizon. Hukawng Valley, Kachin State, northern Myanmar; lowermost Cenomanian, Upper Cretaceous.

Description. Holotype CNU-NEU-MA2017006. Total body length 2.9 mm. Head and body with numerous scattered, fine setae; head about as wide as long. Compound eyes large. Antenna moniliform, with scattered setae all over; scape nearly 2 times as long as wide, slightly thicker than flagellum; pedicel elongate, about 2 times as long as wide; flagellum with about 25 flagellomeres, first flagellomere longer than others, about as long as pedicel, and last one elongate, about 2.5 times as long as other flagellomeres, apically tapered. Pronotum narrower than head, twice as long as wide; pro-, meso- and metanotum with scattered, fine, long setae. Legs relatively long and slender, with numerous short setae intermixed with long setae. Foreleg: coxa elongated; femur long and slender; tibia nearly as long as femur; basitarsus nearly thrice as long as second tarsomere, the last four tarsomeres of same length.

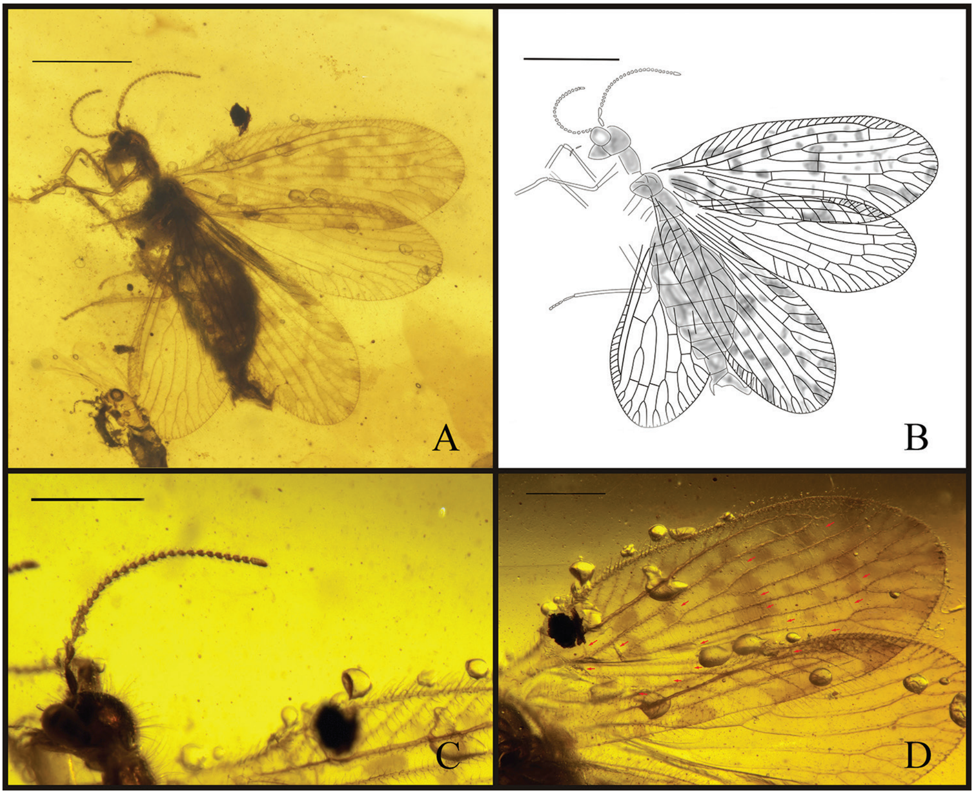

Figure 1. *Stictosisyra pennyi* gen. et sp. n., holotype CNU-NEU-MA2017006. **A** photograph of holotype **B** line drawing of holotype **C** detail photograph of antenna **D** forewing with a squint view, red arrow shows the distribution of crossveins. Scale bars: 1 mm (**A, B**); 0.5mm (**C, D**).

Mid-, hind legs poorly preserved. Abdomen nine segments, with scattered short setae.

Forewing length 3.0 mm, width 1.1 mm (right forewing); elongated ovoid, apex rounded, with dense relatively short setae on veins and longer setae on margins; membrane with fuscous spots over whole wing; trichosors prominent along entire wing margin. Humeral vein short and simple, not recurrent, perpendicular to ScP; presumable ScA not detected; costal space narrow; subcostal veinlets simple, not forked, pterostigma not present. ScP and RA fused distally, entering margin before wing apex. Only one sc-r present. Four ra-rp crossveins, distalmost ra-rp crossvein located at fusion of ScP and RA; RP separated from RA just proximal to sc-r, with three branches. RP1, RP2 configuration similarly, dichotomously forked, RP3 with a distal fork, about two crossveins between RP1, RP2, and one crossvein between RP2, RP3. M divided into MA and MP at 2m-cu, far from separation of RP1 from RP stem, one ma-mp crossvein present; MA distally forked twice, MP pectinately forked, with two branches distally; three r-m crossveins between RP and M; Cu divided into CuA and CuP near wing base at level of RP origin, three m-cu crossveins; CuA pectinately forked, with three (right forewing) or

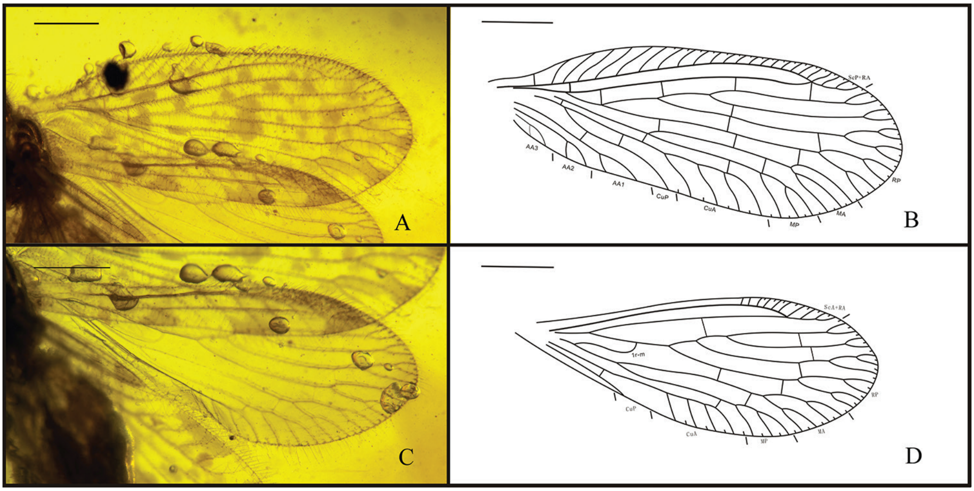

Figure 2. *Stictosisyra pennyi* gen. et sp. n., holotype CNU-NEU-MA2017006. **A** photograph of forewing **B** line drawing of forewing **C** photograph of hind wing **D** line drawing of hind wing. Scale bars: 0.5 mm.

four (left forewing) simple branches distal to 2m-cu; CuP simple, one crossvein between CuA, CuP; only one 2cu-aa visible; AA1, AA2, AA3 configuration similarly, each with a distal fork, no crossveins detected between AA region.

Hind wing elongate, slightly smaller than forewing, length 2.5 mm, width 0.9 mm (right hind wing). Trichosors prominent along entire wing margin. No color spots on wing or along margin. Costal space narrow, distally dilated, especially distad fusion of ScP and RA. Subcostal veinlets simple, sparsely spaced, pterostigma not present. Subcostal space broader than costal space, basally narrowed; no crossvein detected. ScP, RA fused distally. ScP+RA entering wing margin before apex, with three simple distal veinlets. RA space wider than subcostal space, with one crossveins located between origin of RP2 and RP3. RP originated near wing base, with three branches originating far from wing base, each forked distally. Stem of RP and RP3 just with a distal fork; RP1 dichomously forked, RP2 forked twice distally. Three crossvein between RP region; three r-m crossveins between RP and M, basal 1r-m between stem R and M long and strongly sinuous. M forked distad origin of RP and proximal to origin of RP1. MA dichotomously branched distally; MP forked twice distally. Only one crossvein between MA and MP. CuA long, pectinately branched with about three simple branches; CuP long and simple. One crossvein between M and Cu; one crossvein visible between CuA and CuP. Anal veins not preserved.

Remarks. *Stictosisyra* gen. n. is different from other fossil sisyrids genera in the following characters: 1) without long siphonate mouthparts (*Paradoxosisyra* with long siphonate mouthparts); 2) forewing with four ra-rp (*Paleosisyra eocenica* with two, *P. electrobaltica* and *P. minor* with three); 3) hind wing ScP and RA fused before entering the margin, and with one ra-rp (*Prosisyrina* hind wing ScP and RA terminate separately, with two ra-rp).

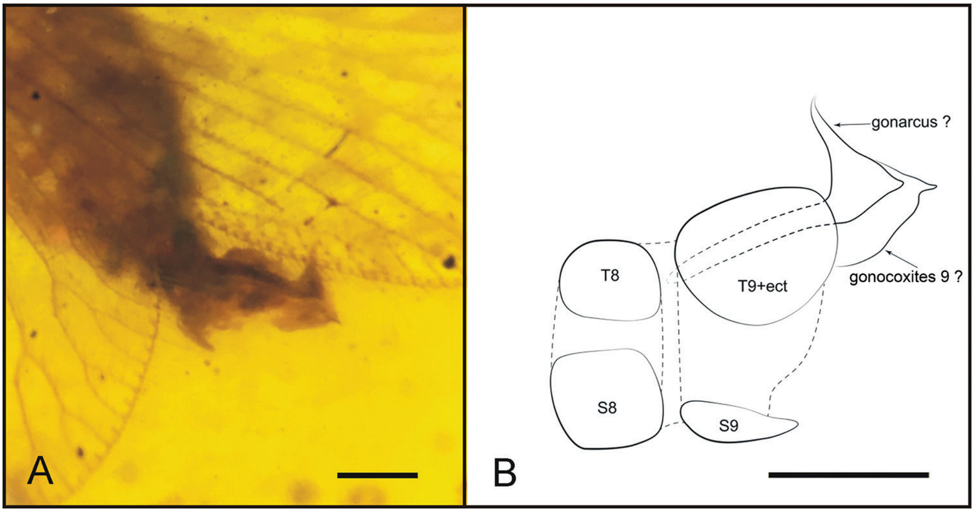

Figure 3. *Stictosisyra pennyi* gen. et sp. n., holotype CNU-NEU-MA2017006. **A** photograph of genitalia **B** line drawing of genitalia (T: tergite; S: sternite; ect: ectoproct). Scale bars: 0.2 mm.

Comments. ***Male genitalia.*** The genitalia of the holotype was not well preserved in the amber; furthermore, the morphology is quite different from that of other sisyrids. Herein we tentatively assume the specimen to be a male based on the morphology of abdomen, especially of the terminalia, and the preserved posture. The genitalia are interpreted as follows: tergite 9 and ectoproct fused; sternite 9 shorter than tergite 9+ectoproct; gonarcus extend beyond tergite 9+ectoproct, otherwise, may be caused by posteriorly incomplete preservation of tergite 9+ectoproct; gonarcus narrowly arched medially, with two arms ventrally and afterwards anteriorly extended; each arm with a tiny extension pointed posteriorly; large, and almost whole external gonocoxites 9, connected with gonarcus.

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