





Description of a new species of *Agathodesmus* Silvestri, 1910 from Australia (Polydesmida, Haplodesmidae) with an urban distribution and a key to species in New South Wales

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Abstract

A new species of millipede in the genus *Agathodesmus* Silvestri, 1910 is described from Australia: *Agathodesmus urbanus* sp. nov. It is described from five localities in Sydney, New South Wales, from collections obtained in suburban parks and reserves. The new species is distinguished by gonopod morphology, especially in that the median branch of the telopodite is distally divided into three lobes and curves in front of the main branch of the distal portion of the telopodite. A key to all four species that occur in New South Wales is provided.

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Introduction

Agathodesmus Silvestri, 1910 is a diverse genus from Australasia, with a distinctive gonopod conformation: there is no cannula or prostatic groove, and the telopodite is sharply bent mid-length at a 'knee' topped with a thin tab (Mesibov 2013). The genus *Agathodesmus* currently comprises 22 recognised species (Mesibov 2009; 2013) of which *A. bacchatus* (Carl, 1926) is endemic to New Caledonia, while the other 21 species are distributed among Australian states as follows: 15 in Queensland (Qld), two in Victoria (Vic), two in New South Wales (NSW), one in South Australia (SA), and one in both Vic and NSW. In Australia, *Agathodesmus* is distributed on the east and south-east coasts, in the wet rainforests

of Qld, in the drier sclerophyll eucalypt forests of NSW, SA and Vic, and on the summit of Mt Aggie, NSW (Mesibov 2009; 2013). This work presents the description of *Agathodesmus urbanus* sp. nov. with five records from Sydney, highlighting the distribution of this group in urbanised areas of Australia and the potential for continued species discovery, even in highly developed and relatively well-studied regions.

Methods

Specimens were hand-collected in five localities in Sydney, NSW, Australia, from July to August, 2023. Specimens are stored in 75 and 96% v/v ethanol. Images of the habitus of the holotype (KS.131507) and a female (KS.131515) were taken in the laboratory using a NIKON

SMZ18 stereomicroscope connected to a DS-Fi3 camera. Scanning electron microscopy (SEM) was performed using a JEOL JSM-6480 on gold-coated specimens. The resulting micrographs were then processed and assembled using the software Adobe Photoshop CS6. After examination, the material was returned from the SEM stubs to ethanol.

To describe colour the standard names of the 267 Color Centroids of the NBS/IBCC Color System were used as named in Centore (2016). The terminology used for the description of the gonopods and other somatic structures follows Akkari & Enghoff (2011) and Mesibov (2009; 2013).

The holotype and some paratypes are deposited in the Australian Museum (AM), Sydney, Australia (curator: M. Shaw) and the remaining paratypes are deposited in the Museo de Historia Natural, Universidad Pedagógica Nacional, Bogotá, Colombia (curator: M. García) and the Instituto de Ciencias Naturales, Universidad Nacional de Colombia, Bogotá, Colombia (curator: E. Flórez).

DNA extraction was performed on a topotype via the salting-out method. Polymerase chain reaction (PCR) of the gene cytochrome c oxidase subunit 1 (COI) was then attempted using primers as in Folmer et al. (1994). PCR of the genes 12S rRNA (12S), 18S rRNA (18S), and 28S rRNA (28S) was attempted using the following primer pairs (5'-3'): AACTTAANRWTTTGRCRGTDHHTA plus AARARTGACGGGCRATRTGTACAT, CATACGCTCGTCTCAAAGATTAAGCCAT plus GGATAGTAGCGACGGGCGGTGTGTA, and GAAGAGCCCAWCGCCGAATCC plus GACTGACCCACGTTCAACCGCT (Hering, pers. comm.). The following thermocycling conditions were used in PCR: 98°C for 10 min; 40 cycles of 98°C for 45 s, 49°C for 45 s, and 72°C for 1 min; and finally, 72°C for 5 min. Production of amplicons of the expected size was checked using 1.5% agarose gel electrophoresis with GelRed nucleic acid stain. Successfully amplified samples were submitted to Macrogen Inc. for purification and bidirectional Sanger sequencing with the same primers used in PCR.

ABBREVIATIONS

Anterior part of the prozonite = **a**, apical setae = **as**, apical tab = **at**, posterior part of the prozonite = **b**, basal extension of telopodite = **be**, distal portion of telopodite = **dp**, limbus = **L**, main branch of distal portion of telopodite = **mab**, median branch of distal portion of telopodite = **mab**, proximal portion of telopodite = **pp**, ridge = **r**, spherical knobs = **s**, tooth-like lobe = **t**.

Results

Molecular data

PCR amplification was unsuccessful for COI and 12S. 18S and 28S amplified successfully, and respectively yielded 1547 bp and 836 bp sequences (GenBank (NCBI) accession numbers: OR815424, OR815425)

Discussion

Until this study, *Agathodesmus* was known from New Caledonia and forested areas on the east and southeast coasts of Australia; where only *A. steeli*, *A. johnsi*, and *A. carorum* were recorded for NSW (Mesibov 2009; 2013). With the discovery and description of *Agathodesmus urbanus* sp. nov. in Sydney, we consider that the distribution of the genus is potentially much wider than previously believed, suggesting new discoveries remain plausible in other areas, even within highly developed regions of Australia.

The findings of this study also emphasise the importance of establishing and maintaining urban reserves for native habitat, as the conservation of some narrow-range endemic species may depend on them.

Molecular data was obtained in this study in an attempt to resolve the phylogenetic position of the genus *Agathodesmus*, which is variously considered a member of the family Haplodesmidae, Dalodesmidae, or *incertae sedis* (Mesibov, 2009). However, no haplodesmid or dalodesmid 18S or 28S sequences have been previously submitted to GenBank, and so the sequences generated in this study will not be informative for fine-scale phylogenetic analysis until additional data becomes available for comparison.

Taxonomy

Key to species of *Agathodesmus* occurring in New South Wales, Australia

- 1 Head + 19 rings, gonopod median branch of distal portion of telopodite (**mab**) does not curve in front of gonopod main branch of distal portion of telopodite (**mab**). 2
- 2 Head + 20 rings, gonopod **mab** curves in front of gonopod **mab**; divided into three lobes with apical tab of telopodite (**at**) very short, in transverse plane (Sydney). ***Agathodesmus urbanus* sp. nov.**
- 2 Gonopod **mab** widely divided into two subequal lobes and with **at** very short, in transverse plane (Avoca area). ***A. steeli* Silvestri, 1910.**
Gonopod **mab** with single lobe. 3
- 3 Gonopod **mab** emarginate in its medial portion and with **at** long and curving posteromedially, in transverse plane (in far southeastern NSW). ***A. carorum* Mesibov, 2013.**
Gonopod **mab** apically tapering and curving basally with **at** short, triangular in shape and with tip slightly curved posteriorly, in transverse plane (Brindabella Ranges). ***A. johnsi* Mesibov, 2009.**

Class Diplopoda Gervais 1844

Order Polydesmida Pocock, 1887

Suborder Polydesmidea Pocock, 1887

Superfamily Haplodesmoidea Cook, 1895

Family Haplodesmidae Cook, 1895

Genus *Agathodesmus* Silvestri, 1910

Agathodesmus: Silvestri 1910

Type species: *Agathodesmus steeli* Silvestri, 1910, by original designation; of *Atopogonus*, *A. baccatus* (Carl, 1926), by monotypy.

Agathodesmus Silvestri 1910: 362; Attems 1914: 282; 1940: 487; Brölemann 1916: 547, 587; Jeekel 1971: 310; 1982: 11; 1983: 146; 1985: 50, 51; 1986: 46; Hoffman 1980: 184; Mesibov 2009: 92; 2013: 35.

Atopogonus Carl 1926: 386; Attems 1940: 477; Verhoeff 1941: 406. Jeekel 1971: 314; 1984: 88; 1986: 46; Hoffman 1980: 186; 1999: 480; Simonsen 1990: 57; Golovatch et al. 2001: 185; 2009: 2, 44; Mesibov 2009: 92 (synonymised).

Other assigned species:

A. adelphus Mesibov, 2013, *A. aenigmaticus* Mesibov, 2013, *A. agnus* Mesibov, 2013, *A. anici* Mesibov, 2013, *A. bonang* Mesibov, 2013, *A. bucculentus* (Jeekel, 1986), *A. carorum* Mesibov, 2013, *A. chandleri* Mesibov, 2013, *A. gayundah* Mesibov, 2013, *A. hahnensis* Mesibov, 2013, *A. johnsi* Mesibov, 2009, *A. kerensis* Mesibov, 2013, *A. kirrama* Mesibov, 2013, *A. millaa* Mesibov, 2013, *A. morwellensis* Mesibov, 2013, *A. parapholeus* Mesibov, 2013, *A. quintanus* Mesibov, 2013, *A. sagma* Mesibov, 2013, *A. summus* Mesibov, 2013, *A. urbanus* sp. nov. Romero-Rincon & Douch, *A. yuccabinensis* Mesibov, 2013.

Agathodesmus urbanus sp. nov.

(Figs 1–5)

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Holotype. Australia • ♂; NSW, Sydney, Meadowbank, Memorial Park, 33°49'11.1"S, 151°05'14.0"E, 14 m a.s.l., 15.VII.2023, Douch, J. leg., riparian parkland with low-density coverage of Eucalyptae spp., underside of rock, facing soil and underside of adjacent fallen bark, facing soil, (AM KS.131507).

Paratypes. Australia • 1 ♂, collected with holotype, (AM KS.131508) • 1 ♂, collected with holotype, (AM KS.131509) • 1 ♂, NSW, Sydney, Clifton Gardens Reserve, 33°50'12.0"S, 151°15'14.0"E, 78 m a.s.l., 22.VII.2023, Douch, J. leg., coastal shrubland, underside of log, facing soil (AM KS.131526) • 1 ♂, NSW, Sydney, Macquarie Park, Macquarie University, Mars Creek, 33°46'29.4"S, 151°06'31.5"E, 64 m a.s.l., 21.VIII.2023, Douch, J. leg., riparian bushland dominated by ironbark (*Eucalyptus* spp.) and *Syncarpia glomulifera*, underside of log, facing soil, (AM KS.131528) • 1 ♂, 4 ♀, 5 juveniles, NSW, Carling-

ford, Galaringi, 33°46'58.6"S, 151°03'13.0"E, 100 m a.s.l., 23.VII.2023, Douch, J. leg., Cumberland Plain bushland dominated by Eucalyptae spp., underside of log, facing soil, (MHN-UPN-MD-182) • 8 ♂, 3 ♀, NSW, Rydalmere, Vineyard Creek, 33°48'47.7"S, 151°01'36.9"E, 9 m a.s.l., 12.VIII.2023, Douch, J. leg., Cumberland Plain riparian bushland dominated by Eucalyptae spp., underside of log, facing soil, (MHN-UPN-MD-183) • 1 ♂, 1 ♀, same collection data as for preceding, (ICN-MD-2912).

Diagnosis: *Agathodesmus urbanus* sp. nov. differs from congeneric males distributed in NSW by having H + 20 rings (vs. H + 19 rings) and the following gonopodal conformation: telopodite (Fig. 3) with **pp** straight; **at** in transverse plane, short, rounded, and slightly bent posteriorly; **dp** directed laterobasally at base; **mab** directed laterobasally and curved mediobasally, narrows abruptly at its distalmost portion, before the spoon-shaped apex; **meb** curves in front of **mab** (vs. **meb** does not curve in front of **mab** in all congeners); divided into three lobes; lateral **meb** lobe directed laterobasally towards base and then curved mediobasally; tapering towards midlobe but distally slightly enlarged with a small projection directed lateroapically; medial **meb** lobules subequal in size, directed mediobasally towards the base, slender and tapering towards the apical region.

Description: Adult male and female with head + 20 rings (Fig. 1). Male/female ca. 9.0/11.0 mm long; ring 12 maximum diameter ca. 0.9/1.0 mm, maximum width ca. 1.0/1.1 mm.

Colouration in alcohol of metazonites, prozonites, and collum deep orange yellow 69 to dark orange yellow 72 (some freshly preserved individuals concentrate pigmentation on the lateral ends of the keels in deep reddish brown 41); head, legs, and antennae pale greenish yellow 104.

Head wider than long; about as wide as collum (Fig. 2A–B), facing downwards (Fig. 2A), front microvillose and microgranulate, mostly with needle-like setae (Fig. 2B).

Antennae (Fig. 2B) short, stout, clavate, densely setose, setae being long, antennae held close to head. Antennomere 6 widest and longest; antennomeres 2–5 about equal in length, decreasing slightly in diameter from antennomere 5 to 2. Antennomere 8 with four sensory cones apically.

Collum margins convex, slightly on anterior and broadly on posterior; corners rounded; first anterior row of tubercles with setae short, slightly globulate at the apex (Fig. 2A). Ring 2 tergite largest, extending basally, laterally, and anteriorly well below the collum corner (Fig. 2A–B). Ring 2 and 3 tergites edged with five to six and four large tubercles, respectively (Fig. 2A). Posterior rings, including apodous ring 19, with a row of four large tubercles just above leg bases forming narrow pseudo-paranota.



Figure 1 - *Agathodesmus urbanus* sp. nov., habitus stacked stereomicrograph. Female (below; KS.131515) and male holotype (above). Scale bar: 1 mm.

Ozopore (Fig. 4B) very small, with opening on a rounded disc, slightly raised but lacking a porostele, they are externally bordered with microtubercles, just above the pseudo-paranotum (Fig. 4A). Pore formula normal (5, 7, 9, 10, 12, 13, 15–19).

Sternites on diplosegments are narrow, not setose, with longitudinal depression between coxae deep and narrow (Fig. 2C). Legs short, stout; relative length of podomeres: tarsus > prefemur > femur > (postfemur ≥ tibia); claw large, about the length of the postfemur or tibia. Spiracles with minute openings (Fig. 2D) located near the anterior base of each leg (diplo- and haplosegments). Telson facing downwards. Paraprocts parallel to substrate and almost flat (Fig. 4C). Epiproct very short, flattened dorsoventrally, with four inconspicuous setae (spinnerets), each spinneret with single, low sheath, each seta inside a deep, circular, walled depression (Fig. 4C–D). Hypoproct subtrapeziform (Fig. 4C).

Tegument with microsculpture (Figs 2B–D; 4C; 5A–C). Most of the body in the form of a cellular mesh with narrow irregular folds, often with minute bumps between or near the folds. The integument is further raised into tubercles of different sizes and shapes on the head, collum, tergites, metatergites, and telson (Figs 2A–B, 4A, 4C, 5A); some tubercles with a single seta; small, lobed at apex, with a single, low sheath in a deep circular depression (Fig. 5C). Irregular cell boundaries in the posterior part of the metazonite extend basally over the limbus (Fig. 5C). Pointed, tooth-like lobules on limbus (Fig. 5C).

Prozonites sharply demarcated from metazonites (Figs 2A–B, 2D; 4A; 5A). Prozonite (Fig. 5B): anterior part of prozonite (a) with small irregular units arranged in transverse "rows", units in anterior rows (1–3) are scale-like and overlap units in posterior rows. Some microtubercles are present in the joints of the units. The transverse ridge (r) is marked by some larger posterior tubercles at the joints of the units. The posterior part of the prozonite (b) has spherical knobs (s) of unequal shape and size, superimposed on hollow chambers. Setae of normal type on the antennae and legs, without a single, low sheath (at least visible; Figs 2A–C).

Gonopod aperture ovular (Fig. 3), rim slightly raised laterally. Gonocoxae (Fig. 3) with microgranular integumental sculpture and no setae. Telopodite (Fig. 3) long, when retracted reaching base of legs 5 (Fig. 2A). Basal portion of telopodite with blunt, basally directed projection arising posteromedial to junction with gonocoxa; with three large setae in a row on lateral edge of posterior surface of terminal tab (Fig 3).

Other material examined. Australia • 1 ♂, collected with holotype, (AM KS.131510) • 1 ♂, collected with holotype, (AM KS.131511) • 1 ♂, collected with holotype, (AM KS.131512) • 1 ♂, collected with holotype, (AM KS.131513) • 1 ♂, collected with holotype, (AM KS.131514) • 1 ♀, collected with holotype, (AM KS.131515) • 1 ♀, collected with holotype, (AM KS.131516) • 1 ♀, collected with holotype, (AM KS.131517) • 1 ♀, collected with holotype, (AM KS.131518) • 3 ♀, (fragmented), collected with holotype,

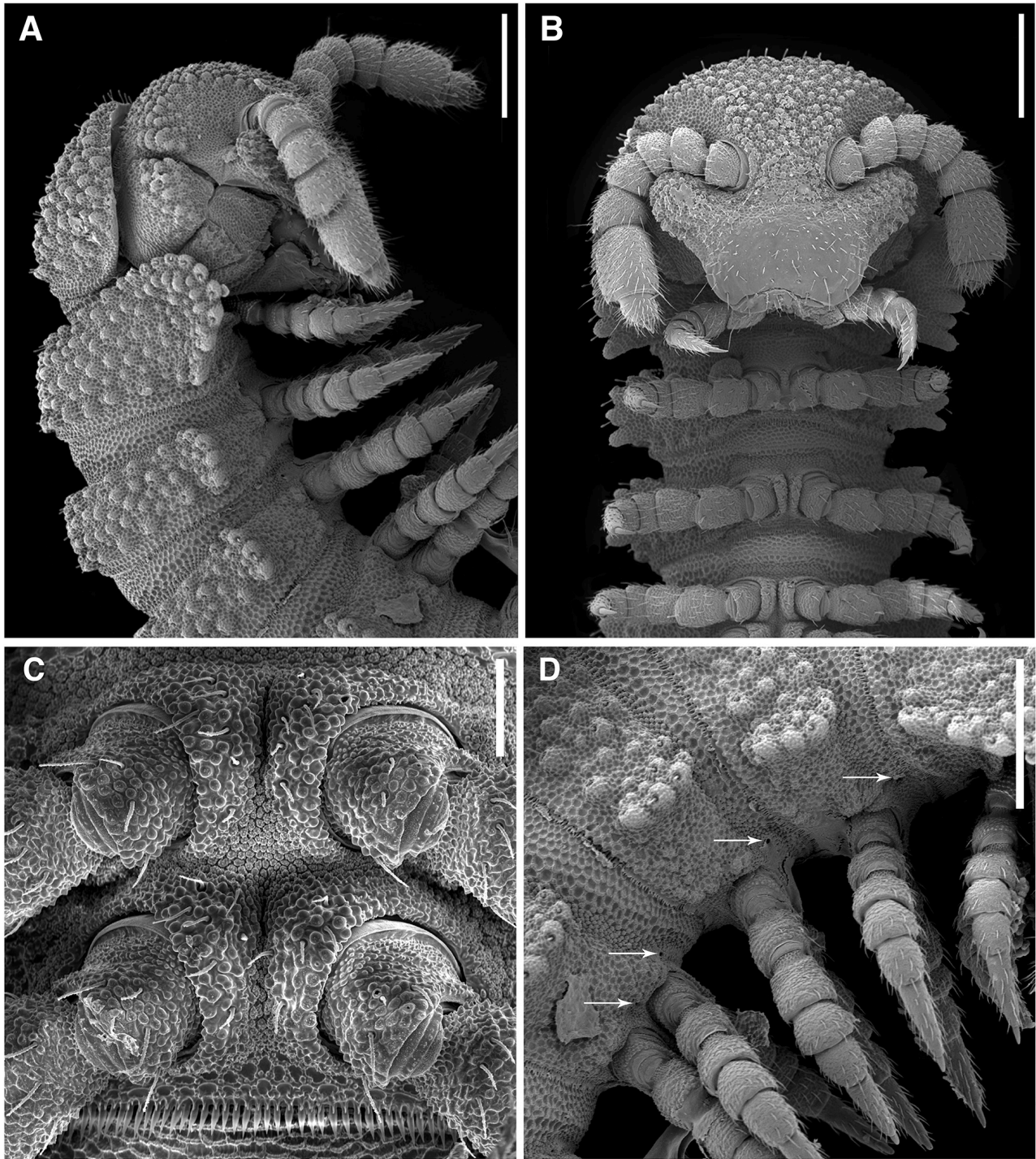


Figure. 2 – *Agathodesmus urbanus* sp. nov. **A.** Male paratype (KS.131526) **C.** Male paratype (MHN-UPN-MD-182) **B, D.** Male holotype **A.** Right anterolateral view **B.** Ventral view of head. **C.** Midbody sternite (anterior towards top). **D.** Right anterolateral view (posterior towards right); spiracular openings (arrows). Scale bar: (A, B, D) = 0.2 mm (C) = 0.05 mm.

(AM KS.131522) • 4 juveniles, collected with holotype, (AM KS.131523) • 8 juveniles, collected with holotype, (AM KS.131524) • 3 juveniles, collected with holotype, (MHN-UPN-MD-184) • 1 juvenile, NSW, Sydney, Clifton Gardens Reserve, 33°50'12.0"S, 151°15'14.0"E, 78 m a.s.l., 22.VII.2023, Douch, J. leg., coastal shrubland, underside of log, facing soil, (AM KS.131527) • 1 ♂, Sydney, Macquarie Park, Macquarie University, Mars Creek, 33°46'29.4"S, 151°06'31.5"E, 64 m a.s.l., 21.VIII.2023,

Douch, J. leg., riparian bushland dominated by ironbark (*Eucalyptus* spp.) and *Syncarpia glomulifera*, underside of log, facing soil, (AM KS.131529) • 1 ♂, same collection data as for preceding, (AM KS.131530) • 1 ♂, same collection data as for preceding, (AM KS.131531) • 1 ♂, same collection data as for preceding, (AM KS.131532) • 1 ♂, same collection data as for preceding, (AM KS.131533) • 1 ♂, same collection data as for preceding, (AM KS.131534) • 1 ♂, same collection data as for preceding,

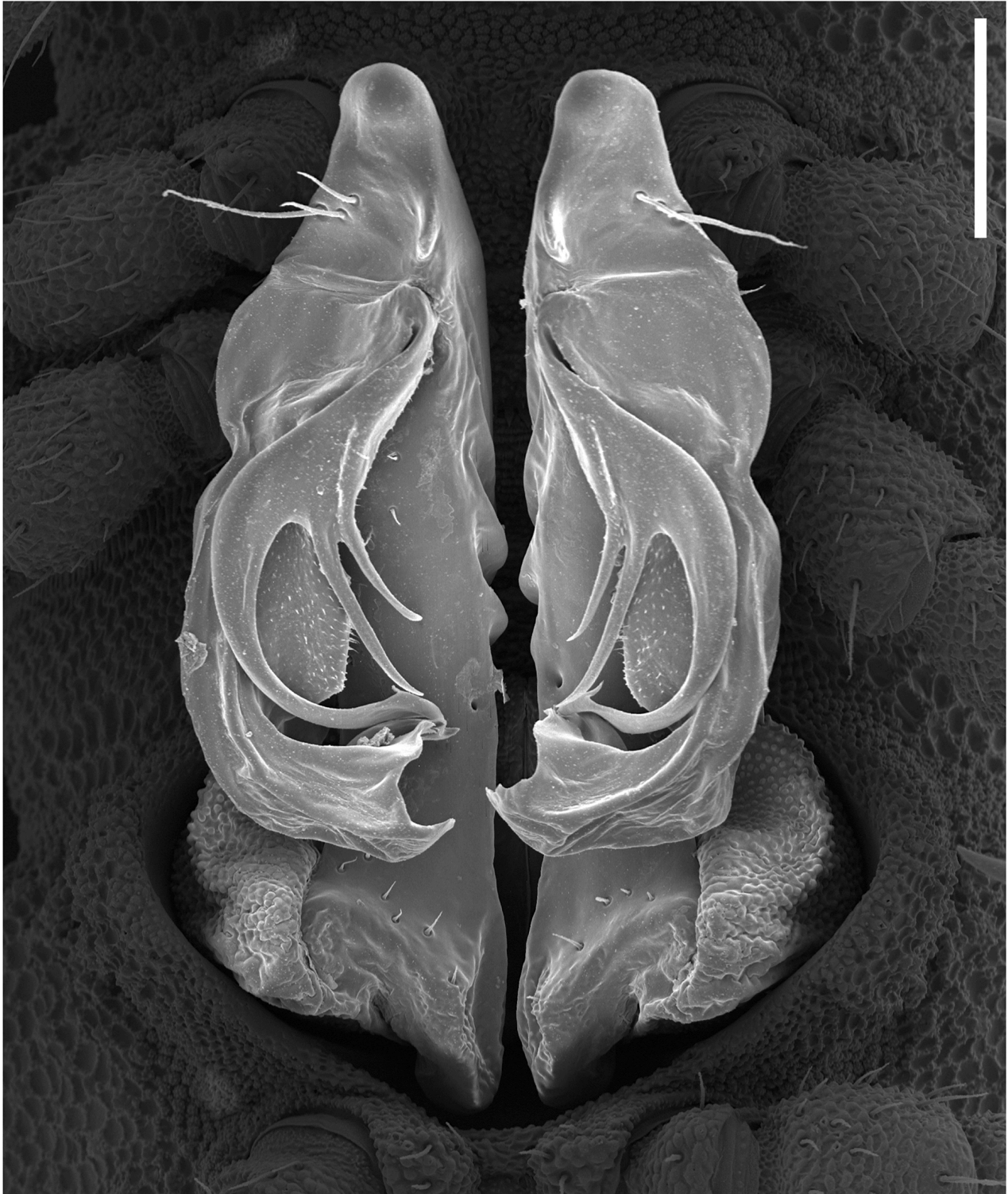


Figure. 3 - Ventral view of gonopods of *Agathodesmus urbanus* sp. nov., male paratype (MHN-UPN-MD-182). Scale bars: 0.1 mm.

(AM KS.131535) • 1 ♂, same collection data as for preceding, (AM KS.131536) • 1 ♂, same collection data as for preceding, (AM KS.131537) • 1 ♀, same collection data as for preceding, (AM KS.131538) • 1 ♀, same collection data as for preceding; (AM KS.131539) • 1 ♀, same collection data as for preceding, (AM KS.131540) • 1 ♀, same collection data as for preceding; (AM KS.131541) • 1 ♀, same collection data as for preceding, (AM KS.131542)

• 1 juvenile, same collection data as for preceding, (AM KS.131543) • 1 juvenile (fragmented), same collection data as for preceding, (AM KS.131544).

Distribution: Known from the suburban localities of Vineyard Creek (Rydalmere), Galaringi (Carlingford), Memorial Park (Meadowbank), Mars Creek (Macquarie

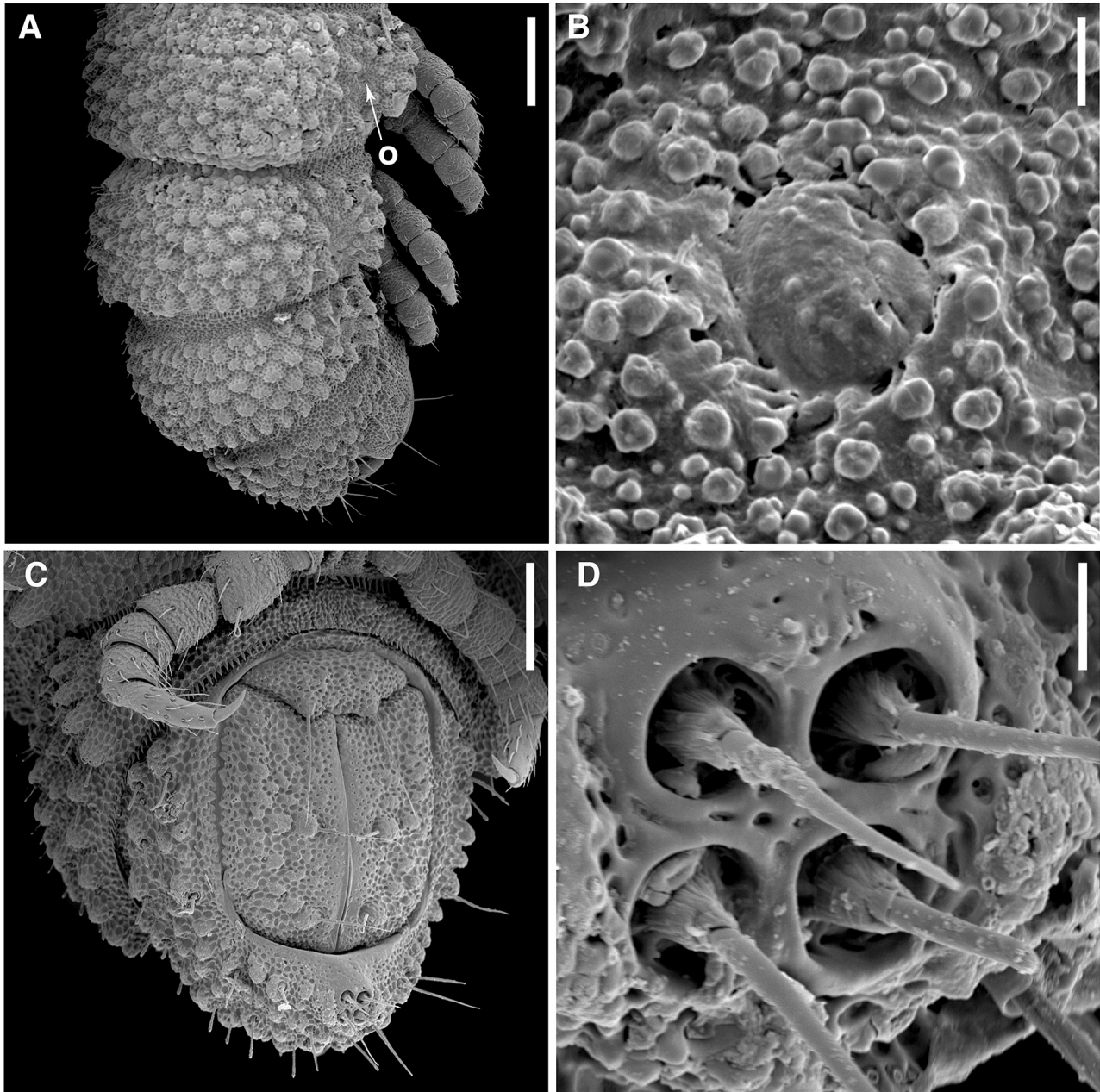


Figure. 4 – *Agathodesmus urbanus* sp. nov. **A, B.** Male paratype (KS.131508) **C, D.** Male paratype (MHN-UPN-MD-182). **A.** Left lateral view of posterior; o = ozopore area. **B.** Enlargement of **A** Showing sculpture of the ozopore. **C.** Ventral view of telson. **D.** Enlargement of **C** Showing spinnerets. Scale bar: (A), (D) = 0.01 mm (B), (C) = 0.1 mm

Park), and Clifton Gardens Reserve, in Sydney, New South Wales, Australia.

Etymology: Latin *urbanus* 'urban', adjective. This species was found in several areas enveloped by human development in Sydney, Australia.

Remarks: Live or preserved individuals of *Agathodesmus urbanus* sp. nov. do not display complete volvation. This species was often found to be sharing microhabitat with other species of invertebrates, often including siphonotid millipedes.

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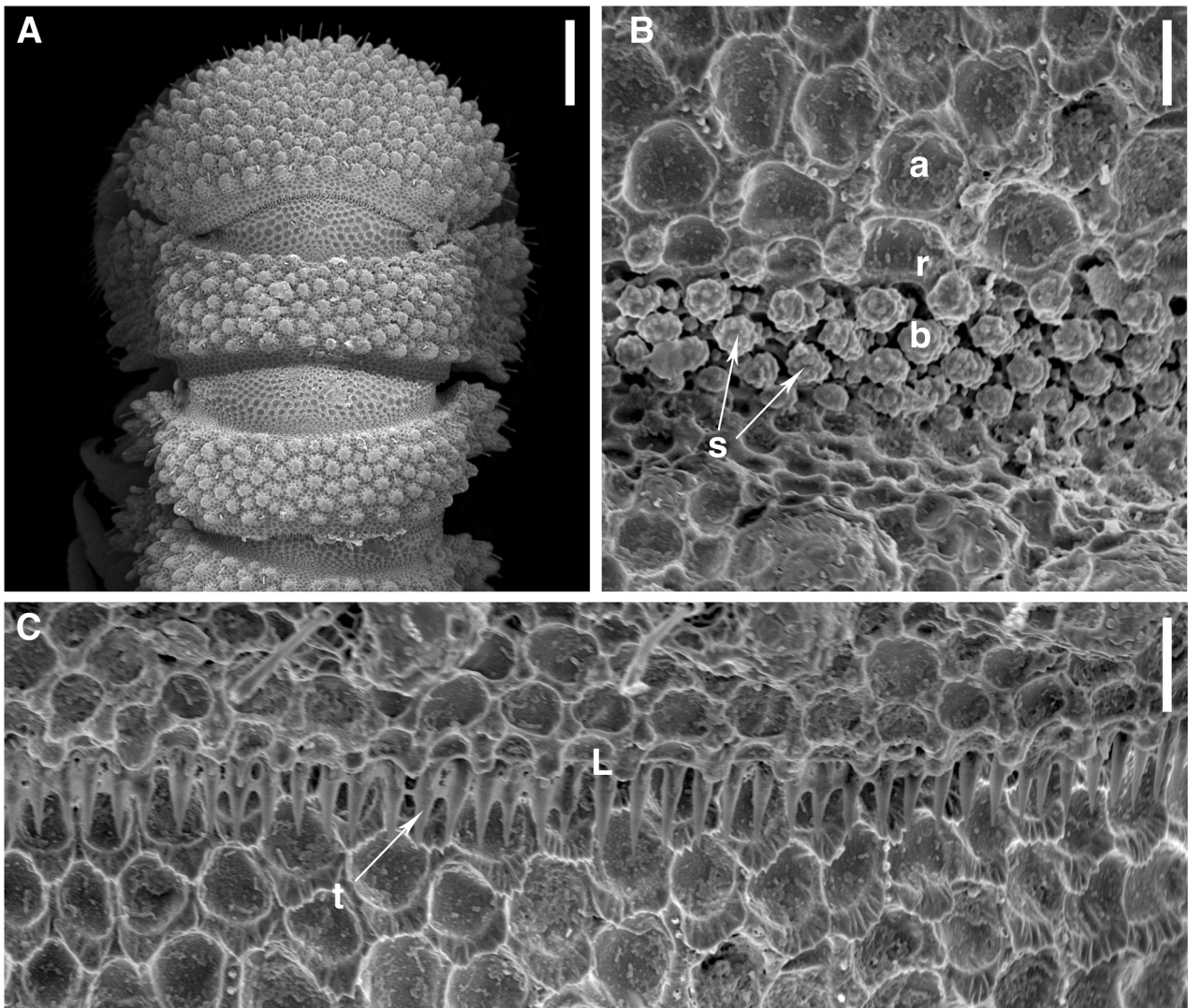


Figure 5 - *Agathodesmus urbanus* sp. nov., male paratype (KS.131508). **A.** Dorsal view of anterior. **B.** Enlargement of **A** Showing sculpture of the prozonite. **C.** Enlargement of **A** Showing the structure of the limbus. Scale bars: (A) = 0.2 mm, (B) and (C) = 0.02 mm.

with identification, facilitating collaboration between the authors for the present study, and comments as reviewer for this project. We also thank the anonymous reviewer and Dr. Mark Harvey, the editor, for their valuable comments which helped us improve this paper. Permission to collect specimens from conserved land was provided by the City of Parramatta (for Hunts Creek Reserve) and Mosman Municipal Council (for Clifton Gardens Reserve). This study was conducted by the authors without specific funding.

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