

First Record of Psolid Sea Cucumber *Psolidium* (Holothuroidea: Dendrochirotida: Psolidae) from the Brazilian Coast, with the Description of Two New Species

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Two new species, *Psolidium nanoplax* and *Psolidium lonchostinum*, are described from the southeastern Brazilian coast, from 44 and 200–258 meters deep, respectively. This is the first record of the genus *Psolidium* from Brazil. *Psolidium nanoplax* sp. nov. superficially resembles its Atlantic and Magellanic congeners, *P. disciformis* (Théel, 1886), *P. dorsipes* Ludwig, 1886, and *P. prostratum* Pawson & Valentine, 1981, but it can be readily distinguished from these by a combination of characters of the sole ossicles and by the absence of midventral tube feet. *Psolidium lonchostinum* n. sp. stands apart from all Atlantic and Southern Ocean species (Atlantic sector), including *Psolidium nanoplax* sp. nov., in having branched rods (thorn ossicles) and knobbed plates in the sole. A key and a synoptic table to all Atlantic and Southern Ocean (Atlantic sector) species of *Psolidium* is provided.

Key words: Echinodermata, Sea cucumber, Biodiversity, Atlantic Ocean, Southern Ocean.

BACKGROUND

The Holothuroidea fauna from the Brazilian coast is still poorly known, but efforts over the last 18 years have improved our knowledge of the holothuroid biodiversity (Martins et al. 2012a b 2016; Martins and Souto 2015 2018; Souto et al. 2017; Martins 2018; Martins and Tavares 2018a b c 2019a b).

In a continued effort to broaden the current knowledge of Brazil's Holothuroidea, we describe herein two new species of *Psolidium* Ludwig, 1886, from São Paulo and Rio Grande do Sul. This is the first record of the genus from the Brazilian coast.

Psolidium now includes 13 species in the regions comprising the Atlantic Ocean and the Atlantic sector of the Southern Ocean. In addition to species descriptions, we provide a dichotomous key for the *Psolidium* species occurring in these regions. Additionally, a synoptic table

of all Atlantic and Southern Ocean (Atlantic sector) *Psolidium* is provided.

MATERIALS AND METHODS

The specimens of *Psolidium lonchostinum* sp. nov. were collected from infaunal assemblages during the REVIZEE Program (Living Resources in the Exclusive Economic Zone), with the aid of a Van Veen grab and a rectangular dredge. *Psolidium nanoplax* sp. nov. was obtained from infaunal assemblages during the Campos Basin Monitoring Program with the aid of an ELOS dredge (Tommasi 1994). The infaunal samples were sieved onboard through a 1 mm mesh.

Measurements (in millimeters, mm) were taken from ethanol fixed specimens and refer to the maximum length of the smallest and of the largest specimens,

ethanol-fixed specimens and the maximum length was recorded of the smallest and largest specimens, unless otherwise stated. Dates are written in the format day.month.year, with months in lower-case Roman numerals. Labels on the calcareous ring follow Ludwig's (1889–1892) scheme.

Ossicles were extracted from the dorsal and lateral scales, tube feet and sole using household bleach, washed five times in distilled water, and then five times in absolute ethanol according to Samyn et al. (2006). Ossicle samples were mounted on slides with Entellan Merck® for permanent storage and then examined and measured under optical microscope. Micrometric data were obtained from 30 measurements for each ossicle category. Other ossicle samples were dried and mounted on metal stubs with double-sided tape, coated with gold and observed with a LEO 440 Scanning Electron Microscope (SEM).

The studied specimens were deposited in the collections of the Museu de Zoologia, Universidade de São Paulo (MZUSP): AsSO (Atlantic section of the Southern Ocean), NEA (northeastern Atlantic), SEA (southeastern Atlantic), and SWA (southwestern Atlantic).

RESULTS

TAXONOMY

Order Dendrochirotida Grube, 1840
Family PSOLIDAE Burmeister, 1837
Genus *Psolidium* Ludwig, 1886

Type species. *Psolidium dorsipes* Ludwig, 1886 [by monotypy]
 Atlantic and Southern Ocean Species (Atlantic Sector): *Psolidium prostratum* Pawson & Valentine, 1981 (NWA); *P. complanatum* Cherbonnier, 1969 (NEA); *Psolidium lonchostimum* sp. nov. (SWA); *Psolidium nanoplax* sp. nov. (SWA); *Psolidium disciformis* (Théel, 1886) (AsSO - Strait of Magellan); *Psolidium dorsipes* Ludwig, 1886 (AsSO - Argentine, Strait of Magellan); *Psolidium gaini** Vaney, 1914 (AsSO); *Psolidium incubans** Ekman, 1925 (AsSO); *Psolidium pawsoni** O'Loughlin & Ahearn, 2008 (AsSO); *Psolidium tenue** Mortensen, 1925 (AsSO); *Psolidium whittakeri** O'Loughlin & Ahearn, 2008 (AsSO); *Psolidium pulcherrimum* Thandar, 2008 (SEA); *Psolidium pseudopulcherrimum* Thandar, 2008 (SEA). (*) Species also known from outside the AsSO.

***Psolidium lonchostimum* sp. nov. Martins and Tavares**

(Figs. 1–3)

urn:lsid:zoobank.org:act:C2B17FCD-41FE-4D98-BB75-8EA7348EFDC9

Holotype: 8.3 mm (MZUSP 744), Brazil, REVIZEE, off coast of Rio Grande do Sul,

33°41'S–51°32'W, 02.iv.1998, 200 m.

Paratypes: 7 specimens, 7–7.5 mm (MZUSP 743), 8 specimens, 6–8.2 mm (MZUSP 591), Brazil, REVIZEE, off coast of São Paulo, 24°20'S, 44°09'W, 258 m, 10. i.1998.

Etymology: The specific epithet is formed by the combination of two Greek words, *lonche* (spear) and *ostinos* (bony, Latinized to *ostinum*), and refers to the thorn-shaped ossicles (branched rods) found in the sole.

Diagnosis: Body flat, oval in outline, mouth and anus covered by a variable number of small and irregular scales, lacking oral and anal valves. Dorsal and lateral body with conspicuous imbricating scales covered by inconspicuous small tube feet (up to two per scale). Calcareous ring notched only in radial plates. Tube feet arranged in two rows, lacking mid-ventral tube feet. Dorso-lateral ossicles are smooth multiperforated plates and branched rods (thorn ossicles). Sole ossicles are knobbed and perforated plate and smooth plates with slightly knobbed in edges. Dorso-lateral tube feet with perforated rods.

Description: Body flat, oval in outline, 6–8.3 mm long and 4–5.9 mm wide (Fig. 1A). Mouth and anus covered by a variable number of small and irregular scales (0.8–1 mm wide), up to two tube feet penetrate each scale dorsally and laterally (Fig. 1B), lacking oral and anal valves.

Marginal dorsolateral scales (0.1–0.3 mm) smaller than dorsal scales (Fig. 1C). Thin sole, lacking scales, tube feet arranged in a double series: inner series of large tube feet and outer peripheral series of smaller tube feet close to the ventral margin (Fig. 1D), lacking mid-ventral (sole) radial series of tube feet, except for a cluster (up to 5) posteriorly and anteriorly (Fig. 1E). Calcareous ring simple, lacking posterior processes; radial and interradial plates united only at the base, notched only at the radial plate (Fig. 1F).

Dorsal/lateral ossicles are smooth and perforated plates, irregular in outline, with undulating margins (100–120 µm long) and round holes (5–20 µm in diameter) (Fig. 2B) and branched rods (thorn ossicles) (40–60 µm long, Fig. 2C). Dorsal tube feet with perforated rods (70–130 µm long), with undulating in margins (Fig. 2D).

Sole with single-layered and elongated plates (130–150 µm long), perforated at their entire length and knobbed at center and margins (Fig. 2E–F) and smooth plate (Fig. 3A–E), slightly knobbed in the margin (70–100 µm long). Ventral tube feet with perforated rods with irregular, curved and undulating margins (80–160 µm long) (Fig. 3F) and end-plate.

Distribution: Brazil: São Paulo (~24°S) and Rio Grande do Sul (~30°S), between 200 and 258 m.

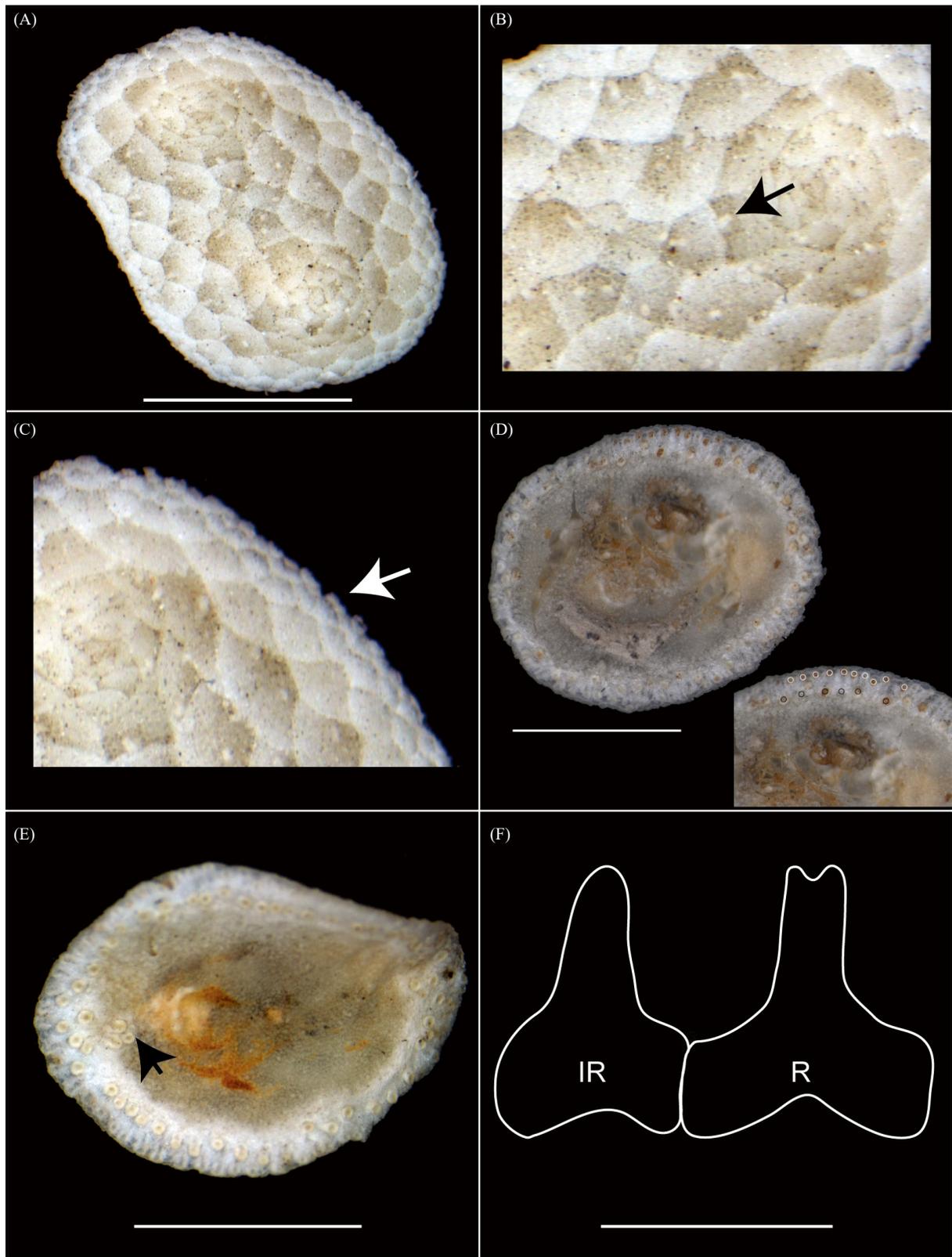


Fig. 1. (A–F) *Psolidium lonchostinum* sp. nov. (A–D) holotype (MZUSP 744). (A) upper view; (B) detail of dorsal tube feet (black arrow); (C) detail of lateral scales (white arrow); (D) ventral view; detail of ambulacral feet (note the inner and outer rows of tube feet: black and white circles, respectively); (E) paratype (MZUSP 591) detail of ventral tube feet (black arrow); (F) outline of the calcareous ring [holotype] R, radial plate. IR, interradial plate. Note in F interradial plate entire and radial plate notched. Scale bars: A = 4 mm; D = 2 mm; E = 3 mm; F = 500 μ m.

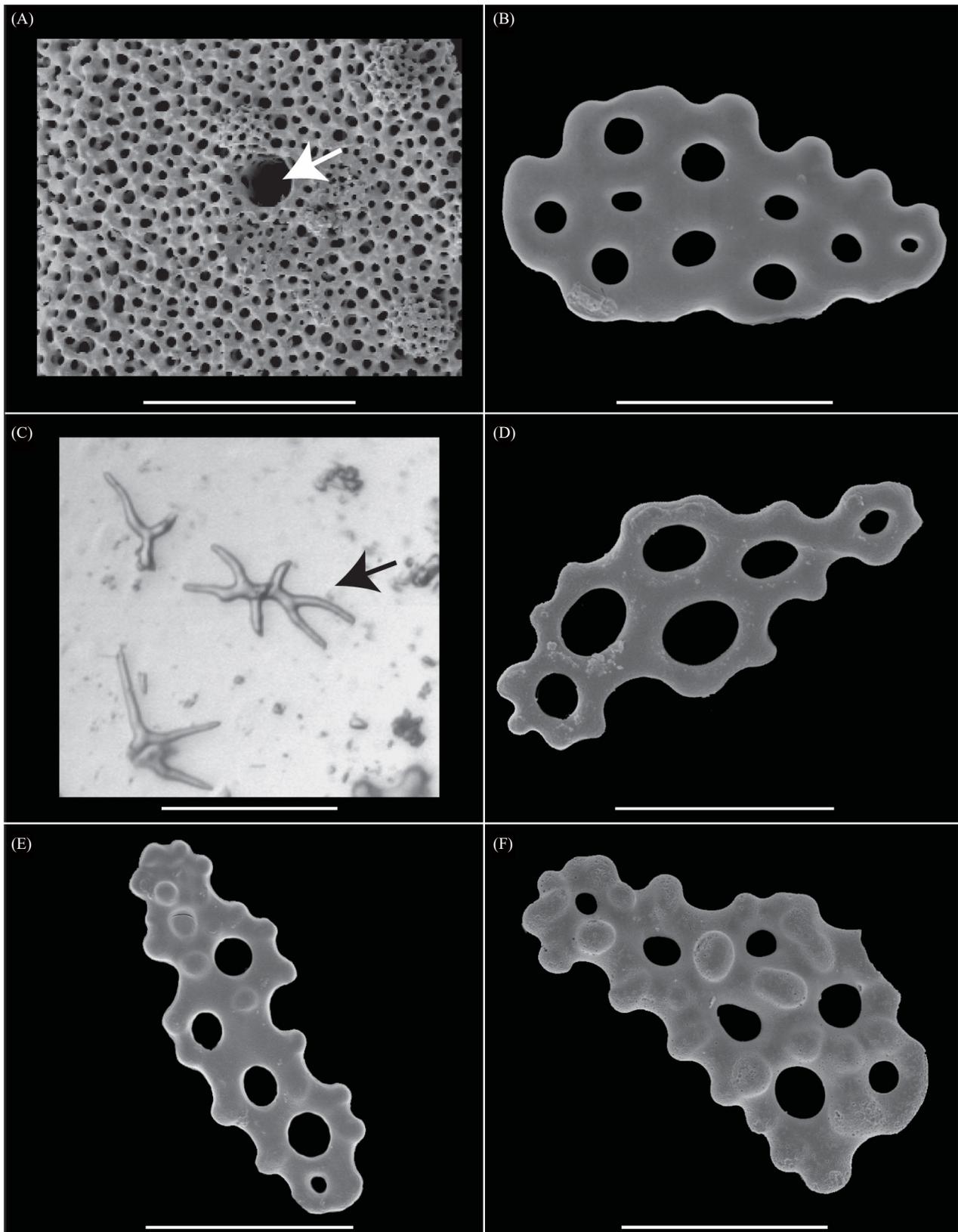


Fig. 2. (A–F) *Psolidium lonchostinum* sp. nov., holotype (MZUSP 744). SEM photomicrographs of the ossicles. (A) scale from dorsal body wall, showing canals for tube feet (white arrow); (B) smooth plate from dorsal body; (C) branched rods (thorn ossicle) (black arrow); (D) rod from dorsal tube feet; (E–F) knobbed plates from sole. Scale bars: A–B = 50 μ m; C = 40 μ m; D–F = 50 μ m.

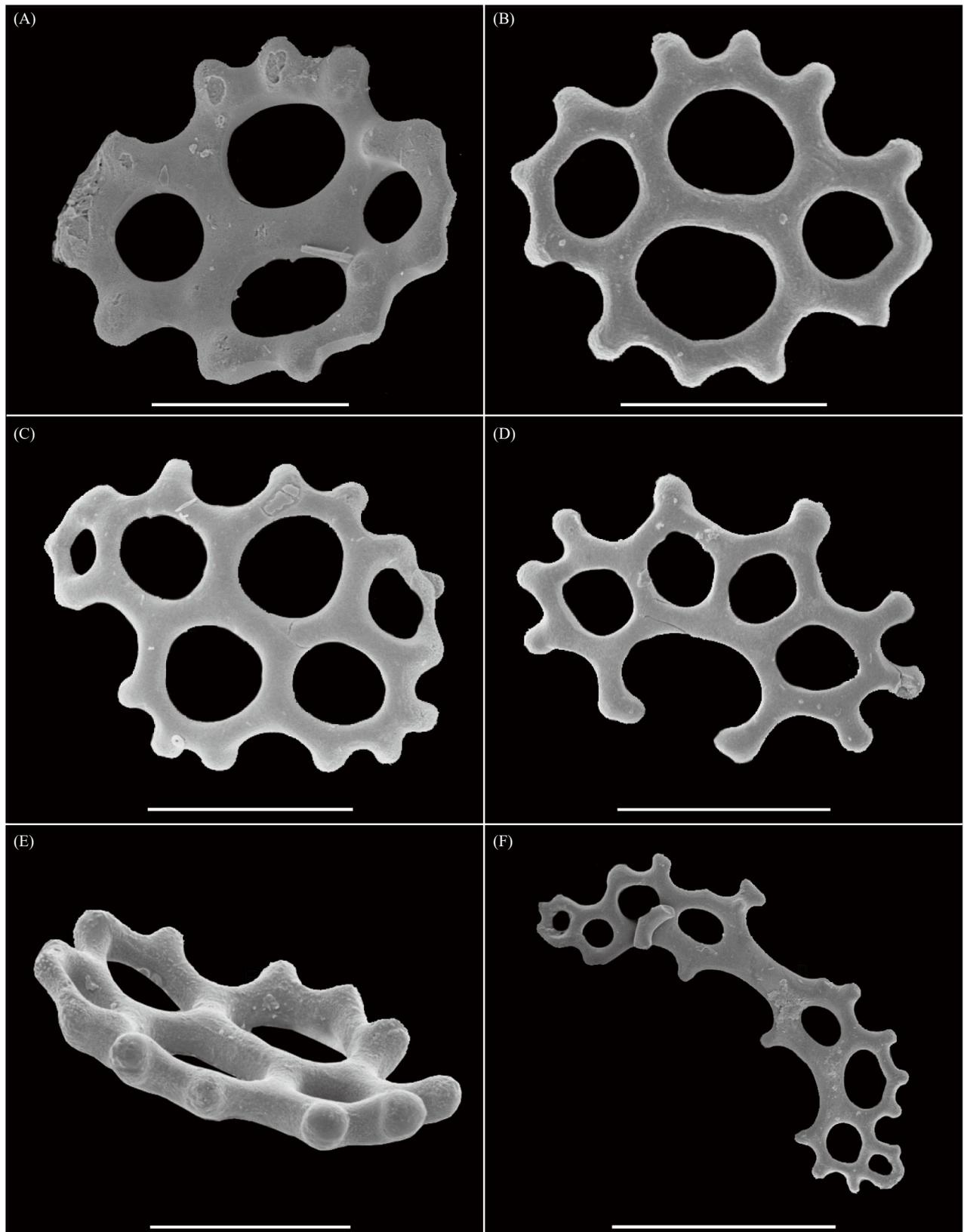


Fig. 3. (A–F) *Psolidium lonchostinum* sp. nov., holotype (MZUSP 744). SEM photomicrographs of the ossicles. (A) four-holed smooth plate from sole, ventral view; (B) four-holed smooth plate from sole, dorsal view; (C–D) multiperforated smooth plate from sole, dorsal view; (E) four-holed smooth plate from sole, lateral view; (F) rod from ventral tube feet, dorsal view. Scale bars: A–B = 30 μ m; C = 40 μ m; D–E = 50 μ m; F = 80 μ m.

***Psolidium nanoplax* sp. nov. Martins and Tavares**

(Figs. 4–5)

urn:lsid:zoobank.org:act:AC75BF38-07B5-4013-B197-DBDCDB1B6E3F

Holotype: 11 mm (MZUSP 589), Campos Basin, southeastern Brazil, 21°41'S–40°20'W, Campos Basin, Monitoring Program coll., xii.1991 to i.1992, 44 m.

Paratype: 1 specimen 8.5 mm (MZUSP 592), same data as the holotype.

Etymology: The specific name is formed by the Greek words, *nano* (little) and *plax* (plate), in reference to the reduced length of the sole plates.

Diagnosis: Body elongate in large forms (8–10 mm long; 5.5–5.9 mm wide), small forms ventrally and dorsally flattened. Dorso-lateral body covered by multi-layered imbricating scales without granules or tubercles. Lacking oral and anal valves. Calcareous ring notched only in the radial plates. Tube feet arranged in two rows, lacking mid-ventral tube feet. Dorso-lateral ossicles are knobbed multiperforated plates. Sole ossicles are knobbed perforated plates and “cup-like” perforated plates. Tube feet with perforated plates and end plate.

Description: Body elongate in large forms (10 mm long) (Fig. 4A); small forms ventrally and dorsally flattened (8 mm) (Fig. 4B).

Mouth and anus lacking valves (Fig. 4B); anal cone slightly raised (Fig. 4C). Dorsal and lateral body with conspicuous imbricating scales (0.8–1 mm) and without granules or tubercles at the surface. One inconspicuous tube foot present at each scale (Fig. 4D). Marginal dorsolateral (Fig. 4E) scales smaller than dorsal scales (0.1–0.3 mm). Ventral sole lacking scales, tube feet arranged in a double series: inner series of large tube feet and outer peripheral series of smaller tube feet close to ventral margin (Fig. 4F), mid-ventral tube feet absent. Calcareous ring simple, lacking posterior processes, radial and interradial plates united only at the base; radial plate notched (Fig. 4G–I).

Dorso-lateral ossicles are knobbed and multiperforated single plates, flat, oval in outline, heavily knobbed on one side, smooth on the other surface, knobbed edges (150–170 μ m long) and rounded holes 10–20 μ m in diameter (Fig. 5A).

Sole with knobbed and multiperforated single plates, strongly concave, oval in outline, heavily knobbed on one side, smooth on the other surface, knobbed edges (70–100 μ m long), and round holes 15–20 μ m in diameter (Fig. 5G) and “cup-like” multiperforated plates, concave, oval in outline (50–70 μ m long) 10–15 μ m in diameter (Fig. 5C–F).

Dorsal tube feet with supporting rods (Fig. 5B), curved with one central perforation and one central

apophysis (80–150 μ m). Ventral tube feet with knobbed and multiperforated plates (Fig. 5H–I; (120–150 μ m).

Distribution: Campos Basin, southeastern Brazil, between 20.5° and 23°S.

DISCUSSION

Psolidium lonchostinum sp. nov. can be distinguished from its congeners (except *P. ramum* Davey and Whitfield 2013, from New Zealand; *Psolidium parmatum* (Sluiter, 1901) and *Psolidium nigrescens* Clark, 1938, both from northwest Australia) in having branched rods (thorn ossicles) in the sole. In this regard, *P. lonchostinum* sp. nov. *P. parmatum*, *P. nigrescens* and *P. ramum* resemble one another. However, *P. lonchostinum* sp. nov. differs from *P. ramum* in having the midventral tube feet restricted to the anterior and posterior parts of the body (Fig. 1E), whereas the midventral row of tube feet is complete across the body in *P. ramum* (see also Davey and Whitfield 2013). *Psolidium lonchostinum* sp. nov. stands apart from both *P. parmatum* and *P. nigrescens* in the absence of bulbous pillars on the dorsal and lateral scales and the absence of cups in the sole, respectively *versus* bulbous pillars present in *P. parmatum* and cups present in *P. nigrescens*). *Psolidium lonchostinum* sp. nov. additionally, differs from its southwestern Atlantic and Magellanic congeners, *P. prostratum*, *P. disciformis* and *P. dorsipes*, as follows: 1) from *P. prostratum* in having smooth and knobbed plates in the sole and about 50 dorsal tube feet (*versus* knobbed plates only and about 100 dorsal tube feet in *P. prostratum*); 2) from both *P. dorsipes* and *P. disciformis* in having no cups in the sole (*versus* presence of cups in *P. dorsipes* and *P. disciformis*).

Psolidium nanoplax sp. nov. differs from *P. lonchostinum* sp. nov. in the absence of branched rods (thorn ossicles) in the sole, which are present in the latter species, and in having both knobbed and “cup-like” plates in the sole, whereas *P. lonchostinum* sp. nov. has knobbed and smooth plates in the sole. *Psolidium nanoplax* sp. nov. can be readily differentiated from its southwestern Atlantic and Magellanic congeners *P. prostratum*, *P. disciformis* and *P. dorsipes*, by the characters of the sole ossicles and the absence of midventral tube feet. It differs from *P. prostratum* in having both knobbed and “cup-like” plates in the sole, whereas the latter species only has knobbed plates. The knobbed and “cup-like” plates in the sole of *P. nanoplax* sp. nov. also allow for its distinction from *P. dorsipes*, which has cups and knobbed buttons, and *P. disciformis*, which has cups and disc like-plates. *Psolidium nanoplax* sp. nov. further stands apart in having no midventral

tube feet, whereas *P. dorsipes* and *P. disciformis* have midventral tube feet.

Key to the Atlantic and Southern Ocean (Atlantic sector) species of *Psolidium*

- 1. Mid-ventral line of tube feet complete 2
- Mid-ventral line of tube feet restricted to the anterior and posterior parts of the body..... 3
- 2. Sole ossicles include cups and perforated disc-like plates
.....*P. disciformis*
- Sole ossicles include cups and knobbed buttons.....*P. dorsipes*
- 3. Cups absent 4

- Cups present 7
- 4. Dorsal region includes plates and branched rods.....
..... *Psolidium lonchostinum* sp. nov.
- Dorsal region includes plates; branched rods absent 5
- 5. Sole ossicles include only smooth and perforated plates
.....*P. complanatum*
- Sole ossicles include “cup-like” perforated plates and knobbed plates..... 6
- 6. Sole ossicles include perforated plates “cup-like” (up to 70 μm) and knobbed plates.....
.....*P. nanoplax* sp. nov.
- Sole ossicles include only knobbed plates; “cup-like” plates absent.....*P. prostratum*
- 7. Brood-protection present..... 8
- Brood-protection absent 10

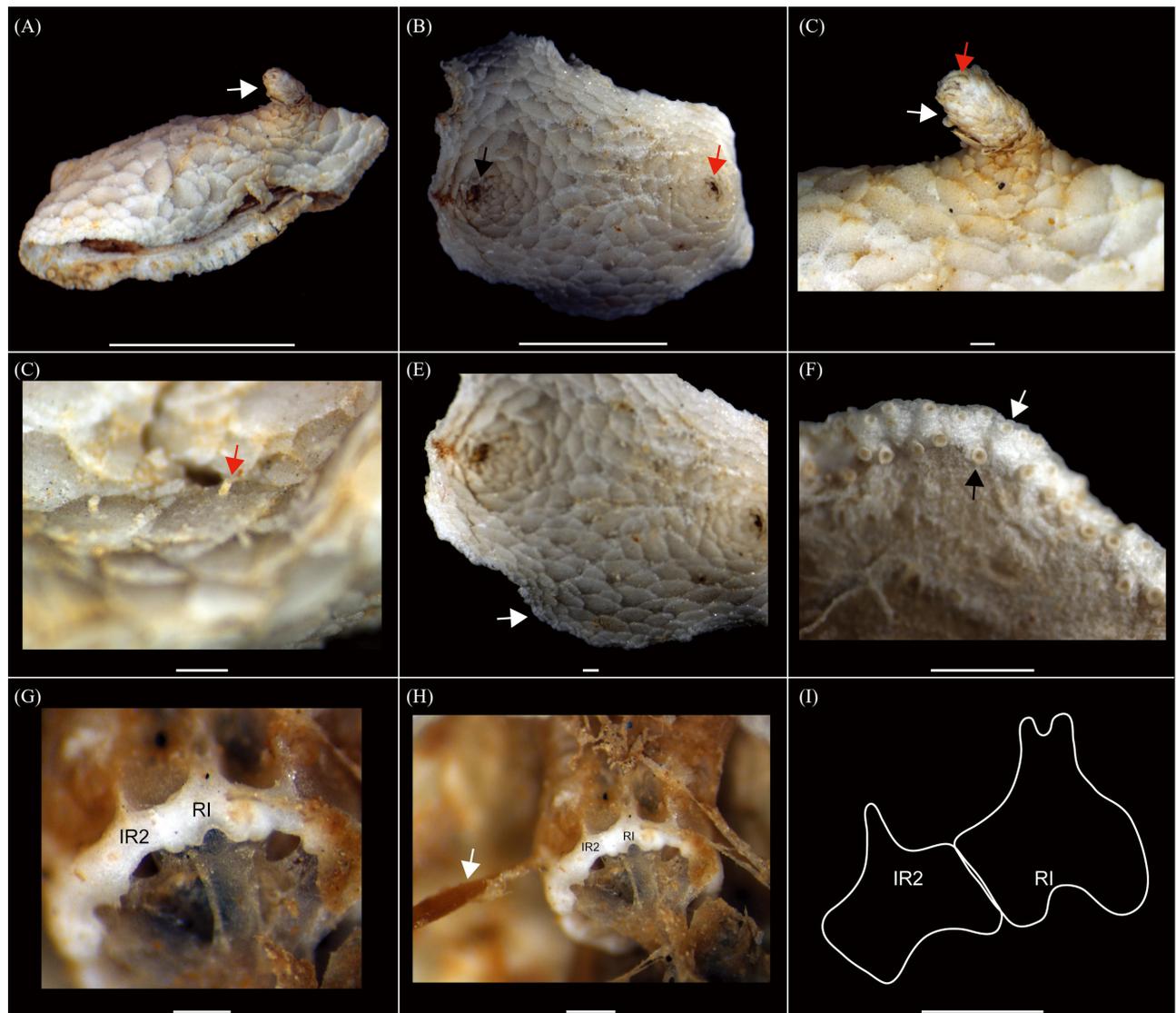


Fig. 4. (A–F) *Psolidium nanoplax* sp. nov. (MZUSP 589, 592). (A) lateral view of holotype preserved in ethanol (note anal cone in white arrow); (B) upper view of [paratype-MZUSP 592] preserved in ethanol (note mouth and anus in black and red arrows, respectively); (C) detail of anal cone [holotype-MZUSP 592] (note anal cone and papillae, in white and red arrows, respectively); (D) detail of dorsal tube feet [holotype-MZUSP 592] (red arrow); (E) detail of lateral scales [paratype-MZUSP 592]; (F) ventral view detail of ambulacral feet [paratype-MZUSP 592], (note the inner and outer rows of tube feet: black and white arrows, respectively); (G) calcareous ring (H) detail of retractor muscle (white arrow) and (I) outline of the calcareous ring [paratype-MZUSP 592]; R, radial plate. IR, interradial plate. Note, only radial plate notched. Scale bars: A = 5 mm; B = 4 mm; C = 500 μm, D = 500 μm, E = 0.5 mm; F = 2 mm; G–I = 500 μm.

- 8. Young brooded in folds of sole*P. incubans*
- Young brooded in coelomic pouches 9
- 9. Dorsal ossicles include cups and smooth plates...*P. pulcherrimum*
- Dorsal ossicles absent..... *P. pseudopulcherrimum*
- 10. Dorsal and lateral tube feet lacking support plates 11
- Dorsal and lateral tube feet with support plates 12
- 11. Dorsal scales frequently with smooth white thickening; perforations reduced, many almost closed..... *P. pawsoni*
- Dorsal scales with irregular lumpy or reticulate thickening, rarely with smooth white thickening and almost closed perforations
..... *P. whittakeri*
- 12. Sole ossicles include knobbed buttons and smooth perforated plates.....*P. gaini*
- Sole ossicles include knobbed plates and smooth perforated plates.....*P. tenue*

CONCLUSIONS

The genus *Psolidium* comprises about 50 species distributed world-wide (WoRMS 2019), most of which found in the Southern Hemisphere (SH) ($n = 40$), especially in the Antarctic region ($n = 10$). The Indo-Pacific harbors 26 *Psolidium* species, the Pacific NH harbors 8 species, and the Atlantic Ocean harbors 13 species (Table 1).

The distribution of tube feet along the midventral surface of the sole and the type of sole ossicles are diagnostic to the species level in *Psolidium*. Interestingly enough, the species with complete midventral row of tube feet across the body are confined

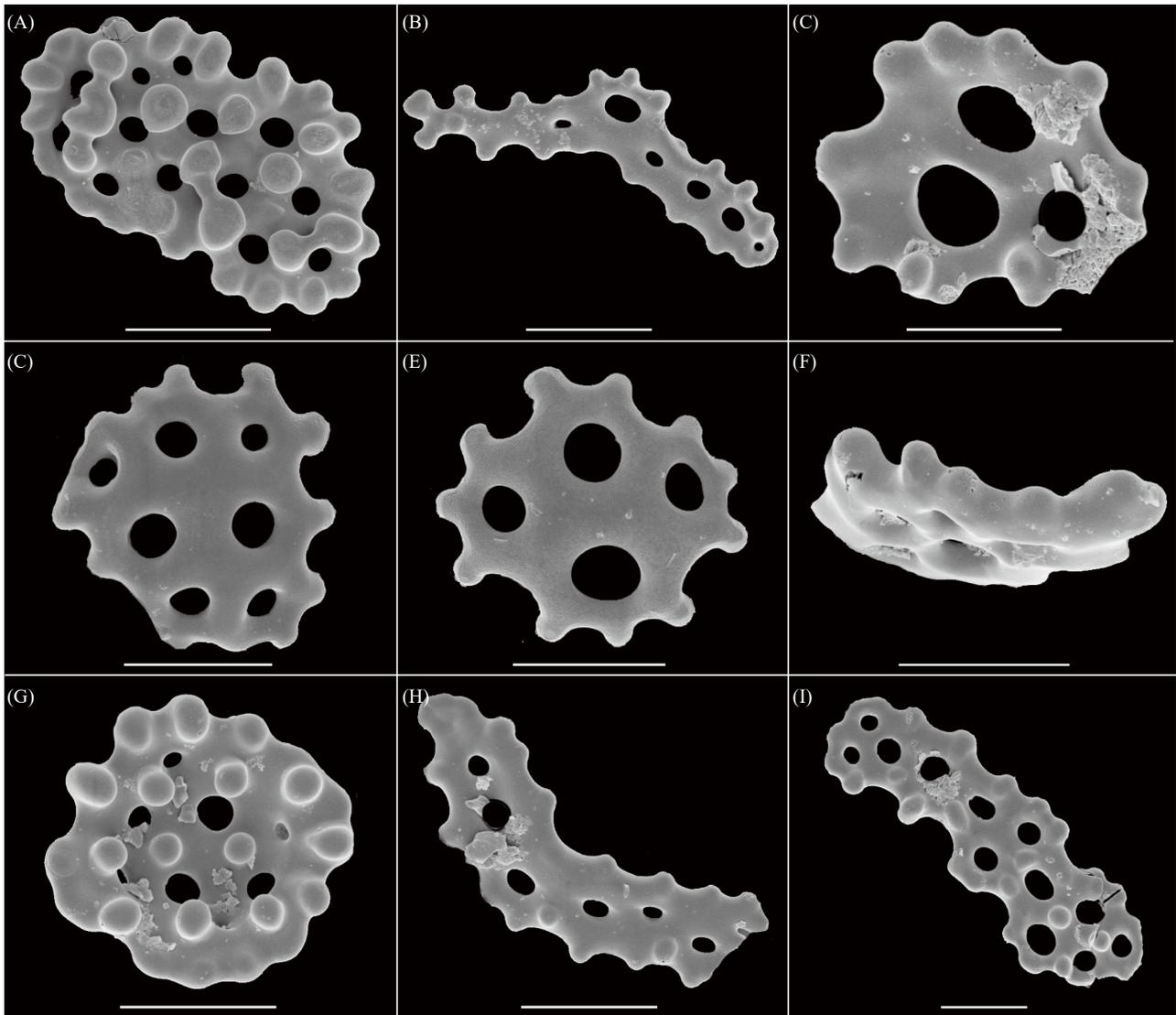


Fig. 5. (A–I) *Psolus nanoplax* sp. nov. Martins & Tavares (MZUSP 589). SEM photomicrographs of the ossicles. (A) knobbed plate from dorsal body (B) supporting rod from dorsal tube feet; (C) “cup-like” plates from sole in dorsal view; (D) “cup-like” multiperforated plates from sole in ventral view; (E) “cup-like” four-holed plates from sole in dorsal view; (F) “cup-like” plates from sole in lateral view (G) knobbed plates from sole and (H–I) knobbed plates from ventral tube feet. Scale bars: A–B = 50 μ m; C = 20 μ m; D–I =, 30 μ m.

Table 1. Synoptic table of the gross geographic and bathymetric distributions, and main morphological characters of the Atlantic and Southern Ocean (Atlantic sector) species of *Psolidium*. **ANT**, Antarctic region. **NEA**, northeastern Atlantic. **NWA**, northwestern Atlantic. **SEA**, southeastern Atlantic. **SWA**, southwestern Atlantic (including the Strait of Magellan and the Falklands/Malvinas Is.). TF, tube feet. (*) Type species of *Psolidium*. Biocorregions follow Spalding et al. (2007)

Character/species	<i>P. complanatum</i>	<i>P. prostratum</i>	<i>Psolidium nanoplax</i> sp. nov	<i>P. lonchostinum</i> sp. nov	<i>P. disciformis</i>	<i>P. dorsipes</i> *
Distribution	NEA Mediterranean	NWA North Carolina to Florida	SWA Brazil	SWA Brazil	SWA Strait of Magellan	SWA Argentina, Chile; Strait of Magellan, Tierra del Fuego
Deep (m)	480-1200	380-450	44	200-258	8-448	10-483
Complete Midventral radial TF	No	No	No	No	Yes	Yes
Dorsal/lateral ossicles	"Cup-like plates"; arched plates	Smooth plates; knobbed plates	Knobbed plates; supporting rods	Smooth perforated plates; perforated rods	?	Knobbed plates; smooth perforated plates; cups
Ventral TF ossicles	Smooth perforated plates	Endplate	Knobbed plates end plate	Rods end plate	Rod "like plates"	?
Sole ossicles	Smooth perforated plates	Knobbed perforated plates	"Cup-like plates" Knobbed perforated plates	Knobbed perforated plates; Smooth perforated plates	Perforated disc-like smooth plates, cups; X shaped bodies	Cups, Knobbed buttons; Knobbed perforated plates
Number of TF by scale	1-2	1-3	1	1-2	1-2	1-2
Branched rods (thorn ossicles)	Absent	Absent	Absent	Present	Absent	Absent
Reference(s)	Cherbonnier (1969); Fernández- Rodríguez et al. (2019)	Pawson & Valentine (1981)	Present paper	Present paper	Théel, 1886; Pawson (1969) O'loughlin & Ahearn (2008)	Ludwig, 1886; Pawson (1969) O'loughlin & Ahearn (2008)

Character/species	<i>P. pulcherrimum</i> Thandar, 2008	<i>P. pseudopulcherrimum</i> Thandar, 2008	<i>P. gaini</i> Vaney, 1914	<i>P. incubans</i> Ekman, 1925	<i>P. pawsoni</i> O'loughlin & Ahearn, 2008	<i>P. tenue</i> Mortensen, 1925	<i>P. whittakeri</i> O'loughlin & Ahearn, 2008
Distribution	SEA South Africa	SEA South Africa	ANT South Georgia, Weddell Sea, Antarctic Peninsula	ANT South Georgia	ANT Weddell Sea	ANT Antarctic Peninsula,	ANT South Sandwich, South Shetland Islands
Deep (m)	200	200	19-795	12-38	137-920	90-2100	146-759
Complete Midventral radial TF	No	No	?	No	No	No	No
Dorsal/ lateral ossicles	Cups; smooth plates	Absent	Curved tube foot support plates	Cups	Smooth plates	Tube foot support plates; endplates	Absent
Ventral TF ossicles	Perforated plates	Rods plates	?	?	Perforated rod plates	Perforated rod plates	Irregular rods and elongate perforated rod- plates
Sole ossicles	Knobbed plates; cups	Knobbed plates; cups; end plate	Knobbed buttons; smooth perforated plates	Cups; perforated plates	Smooth plates	Smooth perforated plates; knobbed plates	Shaped rods and perforated plates
Number of TF by scale	?	?	1-3	1-2	1-4	1-3	1-4
Branched rods (thorn ossicles)	Absent	Absent	Absent	Absent	Absent	Absent	Absent
Reference(s)	Thandar (2008)	Thandar (2008)	Vaney, 1914; O'loughlin & Ahearn (2008)	Ekman, 1925; O'loughlin & Ahearn (2008)	O'loughlin & Ahearn (2008)	Mortensen (1925); O'loughlin & Ahearn (2008)	O'loughlin & Ahearn (2008)

to the Argentinean province and Magellanic region (*P. disciformis* and *P. dorsipes*), whereas the species occurring elsewhere in the Atlantic have tube feet restricted to the anterior and posterior parts of the body. Martins and Tavares (2019) noticed that the Brazilian and the Argentinean/Magellanic fauna have little in common morphologically. On the other hand, the South African, the Antarctic and the Subantarctic (Atlantic sector) species are unique in having cups, whereas the remaining Western and Northeastern Atlantic species have plates only.

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Authors' contributions: LM and MT contributed equally to the manuscript.

Competing interests: LM and MT declare they have no conflict of interest.

Availability of data and materials: Type and non-type specimens are in the Museu de Zoologia, Universidade de São Paulo (MZUSP).

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Ethics approval consent to participate: Not applicable.

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