Memoirs of Museum Victoria 65: 1–22 (2008)

ISSN 1447-2546 (Print) 1447-2554 (On-line)
http://www.museum.vic.gov.au/memoirs/index.asp

Australian species of *Psolidium* Ludwig (Echinodermata: Holothuroidea: Psolidae)

P. Mark O'Loughlin[1] and Dragica Maric[2]

[1] Marine Biology Section, Museum Victoria, GPO Box 666, Melbourne 3001, Victoria, Australia (pmo@bigpond.net.au)
[2] Research Associate, Marine Biology Section, Museum Victoria, GPO Box 666, Melbourne 3001, Victoria, Australia (dragicamaric@hotmail.com)

Abstract O'Loughlin, P.M. and Maric, D. 2008. Australian species of *Psolidium* Ludwig (Echinodermata: Holothuroidea: Psolidae). *Memoirs of Museum Victoria* 65: 1–22.

Six new species of *Psolidium* Ludwig from Australia are described: *Psolidium berentsae*, *P. hutchingsae*, *P. karenae*, *P. laperousazi*, *P. marshae*, *P. mccallumae*. The species *Psolus parmatus* Sluiter and *Psolus spinuliferus* H. L. Clark are re-assigned to *Psolidium*. Diagnoses are given for *Psolidium granuliferum* H. L. Clark, *P. nigrescens* H. L. Clark, *P. minutus* (H. L. Clark), *P. parmatus* (Sluiter), *P. ravum* Hickman and *P. spinuliferus* (H. L. Clark). The family Psolidae is ascribed to Forbes as author, not Perrier. The diagnosis of the family Psolidae, assignment of genera, and status of the family are discussed. The genus *Psolidium* is revised. Keys are provided to the genera of Psolidae, and 12 known Australian species of *Psolidium*.

Keywords Echinodermata, Holothuroidea, Psolidae, *Psolidium*, taxonomy, new species, keys.

Introduction

Rowe (in Rowe and Gates, 1995) listed four species of *Psolidium* Ludwig, 1886 from Australia: *P. granuliferum* H. L. Clark, 1938 (southern Western Australia), *P. minutus* (H. L. Clark, 1938) (Lord Howe I), *P. nigrescens* H. L. Clark, 1938 (New South Wales), and *P. ravum* Hickman, 1962 (Tasmania). *Psolus spinuliferus* H. L. Clark, 1938 was described for northwestern Australia, and is re-assigned here to *Psolidium*. *Psolus parmatus* (Sluiter, 1901) was described for Indonesia, and was found recently in collections from the continental slope off Western Australia. It is also re-assigned here to *Psolidium*. In this work six new species of *Psolidium* are described for Australia.

Pawson and Fell (1965), and subsequent authors, have incorrectly nominated Perrier (1902) as the systematic author of the Psolidae. Forbes (1841) was the original author.

Materials and methods

Live colour photographs of some species were taken in the field by Karen Gowlett-Holmes, and the images lodged in the South Australia Museum with a photoindex registration prefix PK. Some specimen photographs were taken by Leon Altoff and Audrey Falconer, with Mark O'Loughlin, using a Pentax K10D digital SLR with a variety of lenses and lit using two electronic flashes. Preserved specimens were placed on or suspended above black velvet. The live photo was taken in a perspex tank with filtered sea water. Photos of ossicles were taken by Mark O'Loughlin and Chris Rowley using a Leica DM5000 B compound microscope, and Leica DC500 camera with montage software. Some specimen photographs were taken by Simon Hinkley with Dragica Maric using a Leica MZ16 stereomicroscope, Leica DC500 digital camera with montage software. Drawings of tube feet distributions were made by Dragica Maric using stereomicroscope and camera lucida.

Abbreviations: AM—Australian Museum, Sydney; MCZ—Museum of Comparative Zoology, Harvard, USA; NMV—Museum Victoria, Melbourne, Australia; SAM—South Australian Museum, Adelaide; WAM—Western Australian Museum, Perth; ZMA—Zoölogisch Museum, Amsterdam.

Specimen registration number prefixes: AM J, NMV F, SAM K, WAM Z, ZMA V.ECH.H

Dendrochirotida Grube, 1840

(restricted Pawson and Fell, 1965)

Key to genera of Psolidae Forbes

1. Dorsal and lateral scales imbricating, conspicuous, lacking calcareous towers; scales of ventro-lateral body clearly demarcated from the thin calcareous sole that lacks scales **2**

— Dorsal and lateral multilayered ossicles (scales) embedded in integument; some scales with conspicuous projecting calcareous towers; ventro-lateral body not clearly demarcated from sole ..... ***Echinopsolus*** Gutt, 1990

2. Tentacles 15; oral valves 5, radially situated ..... ***Ceto*** Gistel, 1848

— Tentacles 10; oral valves situated interradially if present **3**

3. Mid-body tube feet absent dorsally and laterally ..... ***Psolus*** Oken, 1815

— Mid-body tube feet present dorsally and laterally **4**

4. Dorsal and lateral scales covered by ossicles that include hour-glass shaped and/or tower ossicles ..... ***Lissothuria*** Verrill, 1867

— Hour-glass shaped and tower ossicles not present amongst the dorsal and lateral ossicles **5**

5. Mouth and anus lie in the plane of bilateral symmetry ..... ***Psolidium*** Ludwig, 1886

— Mouth and anus lie in a plane at right angle to the usual plane of bilateral symmetry ..... ***Ekkentropelma*** Pawson 1971b

Psolidae Forbes

(synonymy of systematic records)

Psolidae Forbes, 1841: 201–02, 206.—Agassiz, 1845: 11.—Agassiz, 1848: 905.

"Psoline sub-family" Bell, 1882: 642 (no family or other sub-family nominated).

Psolida (uncredited).—Haeckel, 1896: 380, 441, 442.

Psolinae R. Perrier, 1902: 493, 512 (sub-family of Cucumariidae, with Cucumariinae).

Psolidae Perrier, 1902.—Pawson and Fell, 1965: 4.—Pawson, 1969a: 129.—Pawson, 1968b: 19.—Pawson, 1968c: 347.—Tommasi, 1969: 8.—Pawson, 1970: 28.—Pawson, 1971a: 33–34.—Pawson, 1971b: 115, 118.—Tommasi, 1971: 3–4.—Pawson and Valentine, 1981: 450.—Carriol et Féral, 1985: 50.—Gutt, 1988: 22–23.—Gutt, 1990: 112–13.—Massin, 1992a: 317.—Massin, 1992b: 179.—Lambert, 1996: 21.—Massin, 1997: 101.

Psolidae Ed. Perrier (undated).—Thandar, 2006: 35 (R. Perrier was the author of Psolinae).

Psolidae (uncredited).—Mortensen, 1927: 413.—Deichmann, 1940: 206.—Deichmann, 1941: 73, 135–36.—H. L. Clark, 1946: 385, 412–13.—Deichmann, 1947: 336: 336.—Deichmann, 1954: 401.—Hickman, 1962: 60.—Pawson, 1964: 461–62.—Pawson, 1967: 1–2.—Baranova and Belyaev, 1968: 236.—Pawson, 1968a: 142.—Pawson, 1969b: 38, maps 3, 5.—Cherbonnier, 1974: 601, 605.—Dartnall, 1980: 13, 77.—Pawson, 1982: 815.—Cannon and Silver, 1987: 10, 11, 29.—Rowe (in Rowe and Gates), 1995: 317.

Diagnosis (most recently by Lambert, 1996, quoting Pawson, 1970). Body flattened, with well-defined ventral sole. Dorsal surface of body invested by imbricating scales. Ventral sole soft, surrounded by tube feet. Mouth and anus dorsally turned.

Type genus. *Psolus* Oken, 1815 (original designation; = *Lepidopsolus* Bronn, 1860, and *Lophothuria* Verrill, 1866; synonymy by Théel, 1886).

Other genera. *Ceto* Gistel, 1848 (= *Cuvieria* Jäger, 1833, *Callisto* Gistel, 1848, *Stolinus* Selenka, 1868, *Hypopsolus* Bell, 1882, and *Theelia* Ludwig, 1892; synonymy by Pawson, 1971a); *Lissothuria* Verrill, 1867 (= *Thyonepsolus* H. L. Clark, 1901; synonymy by Pawson, 1967); *Psolidium* Ludwig, 1886; *Ekkentropelma* Pawson, 1971b; *Echinopsolus* Gutt, 1990.

Remarks. The family Psolidae was erected by Forbes (1841), who based his family on the genus *Psolus* Oken and remarked that *Cuvieria* Peron (= *Ceto* Gistel, by Pawson, 1971a) should be included in Psolidae. The family was recognised by Agassiz (1845, 1848). Bell (1882) referred to a "Psoline sub-family", without reference to family or additional sub-family. Perrier (1902) erected 2 sub-families for Cucumariidae: Cucumariinae and Psolinae. Subsequently no author (including Perrier himself) has referred to Psolinae Perrier, 1902. Perrier (1905), Mitsukuri (1912), and Ohshima (1915) referred species of *Psolidium* Ludwig, 1886, and *Psolus* Oken, 1815, to Cucumariidae, without reference to Psolidae. Mortensen (1927) referred *Psolus* and *Psolidium* species to Psolidae, without indication of family author. Many authors followed Mortensen (1927). Pawson and Fell (1965) incorrectly nominated Perrier (1902) as the systematic author of the Psolidae. Subsequent authors incorrectly referred to Psolidae Perrier, 1902.

Within the history of holothuroid classification we note that Semper (1868) referred *Psolus* Oken to order II Pneumonophora, family Dendrochirotae, sub-family Dendrochirota Gastropoda. Théel (1886) referred *Psolus* Oken to order II Pedata, family Dendrochirotae, sub-family Gastropoda.

Forbes (1841) distinguished the family Psolidae as "having a soft circumscribed disk like the foot of a Gasteropodous Mollusc on which the suckers are placed for progression". In his diagnosis of sub-family Psolinae, Perrier (1902) continued emphasis on the distinct sole with its specialised tube feet. Mortensen (1927) added the presence of large imbricating scales dorsally, sharply delimited from the thin-walled ventral sole; dorsal mouth and anus; and 10-15 tentacles. Subsequent diagnoses by Deichmann (1941), Hickman (1962), Pawson and Fell (1965), Tommasi (1969, 1971), Pawson (1970, 1982), Carriol et Féral (1985), Cannon and Silver (1987), Gutt (1988), Rowe (in Rowe and Gates, 1995), and Lambert (1996) have generally agreed with Mortensen (1927). But none has continued to include the significant point made by Mortensen (1927) that there is a sharp demarcation between the dorsal scales and the thin-walled sole. In discussing his new genus *Psolidiella*, Mortensen (1925) noted "a distinct ventral sole, which is, however, not limited from the rest of the body by a sharp edge", one reason given by Mortensen for not referring *Psolidiella* to the Psolidae.

A second reason stated by Mortensen (1925) for not referring *Psolidiella* to the Psolidae was "the fact that the posterior part of the intestine, with its mesentery, is in the left ventral interradius". He added "the situation of the posterior part of the intestine appears to be of primary importance for the subdivision of dendrochirotes, the cucumariids and the phyllophorids having it in the left, and the psolids having it in the right ventral interradius".

Hickman (1962) noted contradictory observations by Deichmann (1941) who claimed that "Cucumariidae seem typically to have the third mesentery attached on the right side of the midventral muscle band, the Phyllophoridae seem to have it attached to the left, and the Psolidae have it either way". She explained that for *Psolidium* and *Thyonepsolus* (=*Lissothuria*) the loop is attached in the left ventral interambulacrum, while in *Psolus* it is attached in the right.

Some cucumariid species were examined in this study: *Apsolidium densum* O'Loughlin and O'Hara, 1992, *Neoamphicyclus mutans* (Joshua, 1914), *Psolidiella hickmani* O'Loughlin, 2000. In these three cucumariid genera and species the posterior intestinal mesentery is attached to the left of the midventral radial muscle, supporting Mortensen (1925) and contradicting Deichmann (1941). O'Loughlin (2000) illustrated this position for the genus *Psolidiella*. Pawson (1968a) described a right attachment for the cucumariid species *Pseudopsolus macquariensis* (Dendy, 1896), and Ludwig and Heding (1935) reported a right attachment for their cucumariid species *Pseudocholchirus mollis*, supporting Deichmann (1941). This evidence indicates that the position of posterior intestinal mesenteric attachment is variable for cucumariids as currently assigned.

Some psolid species were examined in this study: *Ceto cuvieria* (Gistel, 1848), *Echinopsolus acanthocola* Gutt, 1990, *Psolidium poriferum* (Studer, 1876) (=*incertum*), *Psolidium ravum* Hickman, 1962, *Psolus antarcticus* Philippi, 1857, *Psolus arnaudi* Cherbonnier, 1974, *Psolus charcoti* Vaney, 1906, *Psolus koehleri* Vaney, 1914, *Psolus paradubiosus* Carriol and Féral, 1985. In eight of these psolid species the posterior intestinal mesentery is attached to the right of the midventral radial muscle, supporting Mortensen (1925) and Deichmann (1941) for *Psolus* species. But in *Ceto cuvieria* it is attached to the left. This evidence indicates that the position of posterior intestinal mesenteric attachment is variable for psolids as currently assigned.

Pawson (1967) noted difficulty with the Psolidae in determining whether or not some species should be considered psolids or referred to another dendrochirotid family. The cucumariid genera *Pseudopsolus* (see Pawson, 1968a), *Apsolidium* and *Neocnus* (see O'Loughlin and O'Hara, 1992), and *Psolidiella* (see O'Loughlin, 2000) include species with a sole that is not delimited by a distinct junction of ventro-lateral body wall scales with a thin-walled sole lacking scales, and lack conspicuous imbricating dorsal and lateral scales. None has been referred to Psolidae. We support this exclusion. The genus *Echinopsolus* Gutt, 1990 was referred to Psolidae on the grounds of the species having a distinct sole. We note that *Psolus charcoti* Vaney, 1906 and *Echinopsolus acanthocola* Gutt, 1990 lack a sharply demarcated sole, and lack macroscopic imbricating scales dorsally, and should not be referred to Psolidae. Reassignment of these taxa does not belong in this revision of *Psolidium*, and will be treated elsewhere.

A comprehensive revision of the relationships amongst cucumariid and psolid species is required and should be undertaken with supportive evidence from molecular genetic data.

Table 1. Distribution of Australian species of *Psolidium* Ludwig, 1886.

***Psolidium* species**	**Distribution**
P. berentsae sp. nov.	Queensland, Lizard I, 6–18 m
P. granuliferum H. L. Clark, 1938	SW Western Australia to SE Tasmania, 4–37 m
P. hutchingsae sp. nov.	Northern New South Wales, 12–15 m
P. karenae sp. nov.	South Australia, 3–12 m
P. laperousazi sp. nov.	SE Tasmania to South Australia, 1–10 m
P. marshae sp. nov.	Western Australia to South Australia, 5–14 m
P. mccallumae sp. nov.	Western Australia, off Point Cloates, 100 m
P. minutus (H. L. Clark, 1938)	Eastern Tasman Sea, 1–10 m
P. nigrescens H. L. Clark, 1938	NSW, Broken Bay to Batemans Bay, 0–11 m
P. parmatus (Sluiter, 1901)	Indonesia to NW Western Australia, 95–487 m
P. ravum Hickman, 1962	SE Tasmania to W South Australia, 0-15 m
P. spinuliferus (H. L. Clark, 1938)	NW Australia, Darwin to Perth, 0–22 m

Key to Australian species of *Psolidium* Ludwig

1. Dorsal and lateral scales with vertical spires/pillars (not lumps) **2**

— Dorsal and lateral scales lacking spires/pillars; some species with surface lumps on the scales **3**

2. Dorsal and lateral scales each covered with slightly bulbous pillars; lacking mid-ventral radial series of tube feet; "thorn" ossicles present in body wall ..... ***P. parmatus*** (Sluiter, 1901) (NW Australia slope)

— Dorsal and lateral scales with predominantly single digitiform spires; mid-ventral radial series of tube feet present; lacking "thorn" ossicles in body wall ..... ***P. spinuliferus*** (H. L. Clark, 1938) (N and W Australia)

3. "Thorn" ossicles present in body wall; live and preserved colour "black" ..... ***P. nigrescens*** H. L. Clark, 1938 (central New South Wales)

— Body wall lacking "thorn" ossicles; live and preserved colour not "black" **4**

4. Body wall with cupped crosses and/or cups **5**

— Body wall lacking cupped crosses and/or cups **11**

5. Cupped crosses and/or cups in sole of 2 ranges of size **6**

— Cupped crosses and/or cups in sole of 1 range of size **7**

6. Rosettes present in dorsal body wall and tentacles; smaller cupped crosses and cups up to 32 μm long; sole with irregular thick perforated plates, knobbed on surface and margin ..... ***P. marshae*** sp. nov. (SW Australia)

— Rosettes absent from dorsal body wall and tentacles; smaller cupped crosses and cups up to 24 μm long; sole with smooth perforated plates ..... ***P. minutus*** (H. L. Clark, 1938) (E Tasman Sea)

7. Dorsal and lateral cups shallow, completely covered by fine spinelets, including the cross; lacking mid-ventral radial series of tube feet ..... ***P. mccallumae*** sp. nov. (Western Australia slope)

— Dorsal and lateral cups and cupped crosses not shallow; spinelets on rim of cup or distally on branches of cupped cross, not on cross; mid-ventral radial series of tube feet present **8**

8. Body wall with predominantly cups, fewer cupped crosses **9**

— Body wall with predominantly cupped crosses, fewer cups **10**

9. Knobbed plates in sole; tentacle rosettes small, up to 40 μm long; body rounded ventrally in transverse section ..... ***P. berentsae*** sp. nov. (NE Queensland)

— Perforated plates in sole predominantly smooth; tentacle rosettes large, up to 80 μm long; body flat ventrally ..... ***P. laperousazi*** sp. nov. (SE Australia)

10. Knobbed perforated plates in sole; irregular perforated plates in tentacles ..... ***P. hutchingsae*** sp. nov. (N New South Wales)

— Perforated plates in sole predominantly smooth; tentacles lack irregular perforated plates ..... ***P. ravum*** Hickman, 1962 (SE Australia)

11. Lacking series of mid-ventral radial tube feet; dorsal and lateral tube feet inconspicuous in mid-body; dorsal and lateral scales coarsely granuliform ..... ***P. granuliferum*** H. L. Clark, 1938 (southern Australia)

— Mid-ventral radial tube feet present as scattered series; dorsal and lateral tube feet conspicuous in mid-body; dorsal and lateral scales finely granuliform ..... ***P. karenae*** sp. nov. (South Australia)

Psolidium Ludwig

Figures 1e, 2d, 4b-d, 5e, 8f

Psolidium Ludwig, 1886: 9.—Mortensen, 1927: 413.—Deichmann, 1941: 141-143.—Deichmann, 1947: 336.—Lambert, 1996: 21.

Diagnosis. Dendrochirotid holothuroids; small, up to 40 mm long; mid-body arched dorsally in transverse section, flat ventrally; dorsal and lateral body covered with imbricating scales, usually macroscopically conspicuous, sometimes obscured by integument, scales irregular in size and arrangement; scales decreasing in size ventro-laterally, orally and anally; lacking large oral valves; extensible oral cone, anterior or anterior-dorsal or dorsal orientation; extensible anal cone, posterior or posterior-dorsal or dorsal orientation; tube feet dorsally and laterally in mid-body, pass through scales.

Sole distinct, oval to elongate; discrete margin created by junction of small imbricating ventro-lateral scales with thin-walled, usually calcareous sole that lacks scales; peripheral band of tube feet, may be discontinuous across the inter-radii anteriorly and posteriorly; peripheral tube feet frequently of 2 sizes, those of outer series smaller; mid-ventral radial series of tube feet present or absent.

Calcareous ring solid, plates sub-rectangular, radial and interradial plates with tapered anterior projections; radial plates with deep notch posteriorly, interradial plates with shallow concave indentation posteriorly; 10 dendritic tentacles, ventral 2 smaller.

Dorsal and lateral ossicles: multi-layered or single-layered perforated plates (scales), always some with tube foot canals; integument covering scales may have cupped crosses, cups, "thorn" ossicles (irregular branched rods pointed distally), buttons, perforated plates and rosettes; tube foot small endplates, and tube foot support ossicles that are irregular rods and plates, bent and curved, variably perforated.

Sole ossicles: inter-radii with small to large single-layered perforated plates (rarely with multi-layering), smooth to variably knobbed and thickened, sometimes with cupped crosses, cups, thorn ossicles and rosettes; radii with additional tube foot ossicles, large endplates and tube foot support ossicles that are irregular rods and plates, bent and curved, variably perforated.

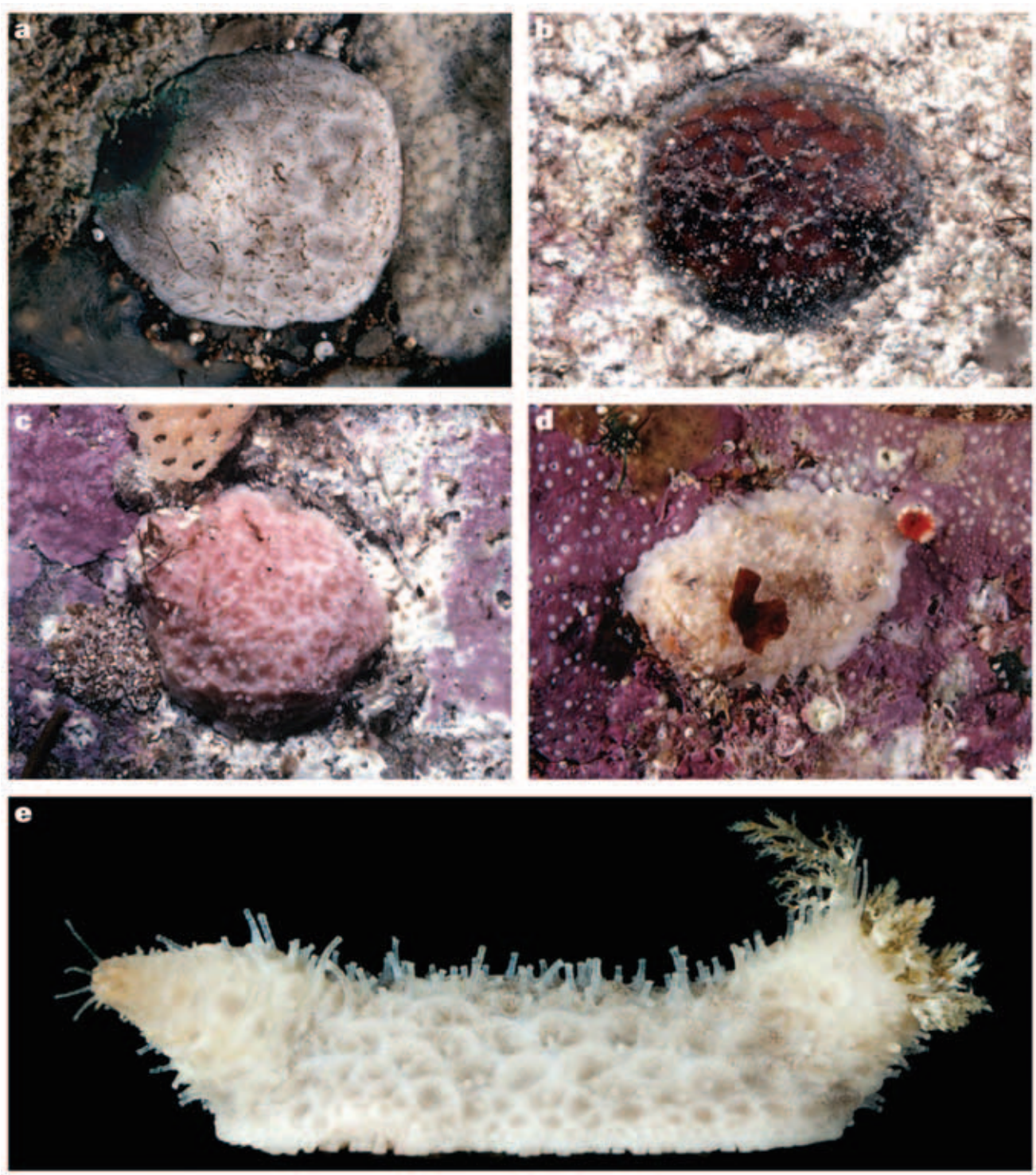

Figure 1. Photos of live specimens of *Psolidium* Ludwig, 1886 (a–d, in situ by K. Gowlett-Holmes; e, in aquarium by L. Altoff): a, *P. granuliferum* H. L. Clark, 1938, Port Davey, Tasmania (14 mm long preserved; SAM K2174, PK0259); b, *P. karenae* sp. nov., Yorke Peninsula, South Australia (17 mm long preserved; holotype SAM K2177, PK0105); c, *P. laperousazi* sp. nov., Kangaroo I, South Australia (13 mm long preserved; paratype SAM K2179, PK0253); d, *P. marshae* sp. nov., Kangaroo I (10 mm long preserved; SAM K2173, PK0273); e, *P. ravum* Hickman, 1962, Portland, Victoria (17 mm long preserved; NMV F125379).

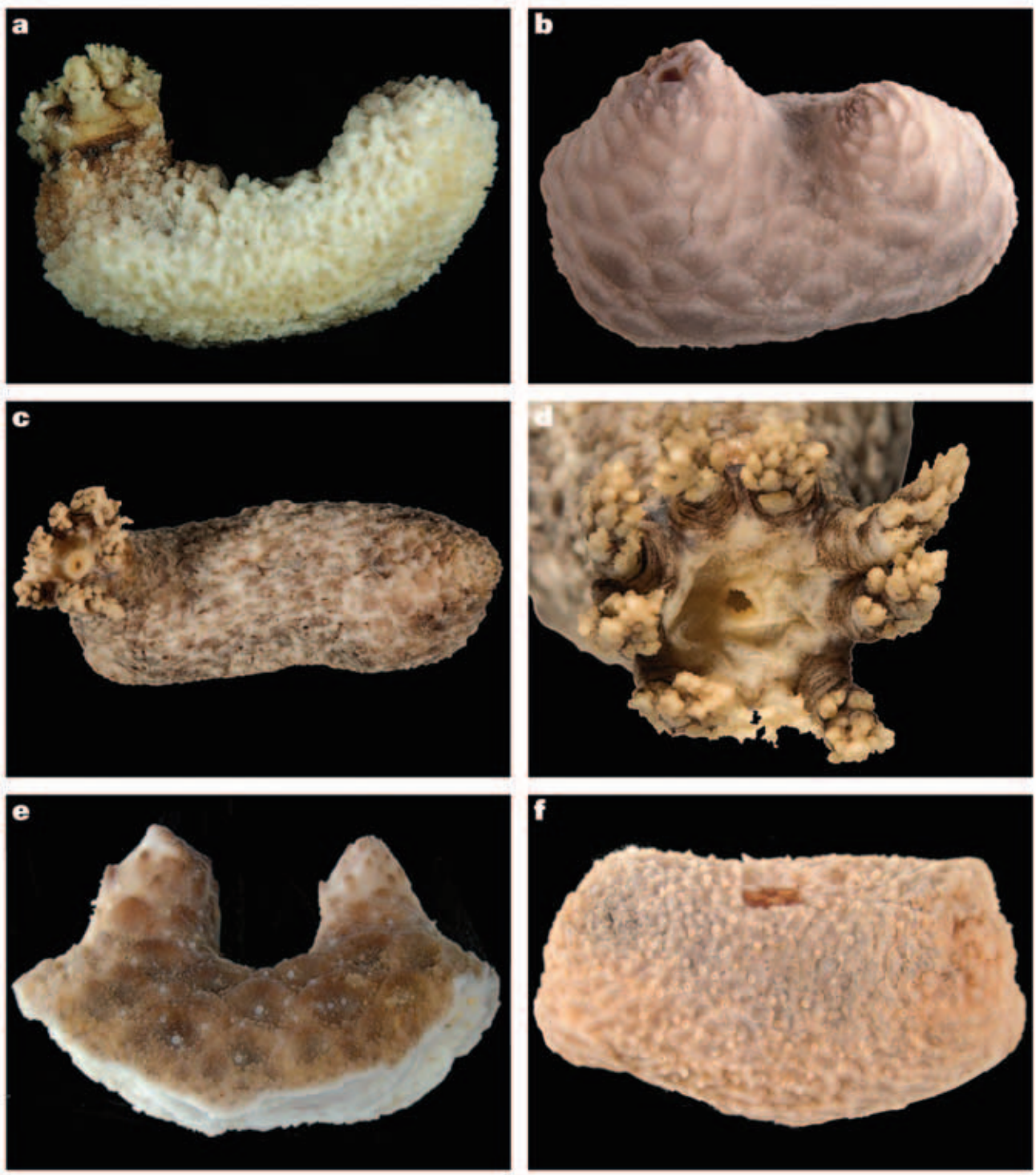

Figure 2. Photos of preserved specimens of *Psolidium* Ludwig, 1886 (a, c–d by L. Altoff; b, e–f by S. Hinkley and D. Maric): a, *P. berentsae* sp. nov., Lizard I, Queensland (lateral view; 12 mm long; holotype AM J24098); b, *P. granuliferum* H. L. Clark, 1938, Smokey Bay, South Australia (dorso-lateral view, with mouth left; 19 mm long; SAM K2176); c–d, *P. hutchingsae* sp. nov., Split Solitary I, New South Wales (20 mm long; holotype AM J24107); c, dorso-lateral view; d, 10 tentacles, with 2 small ventral ones bottom; e, *P. karenae* sp. nov., Adelaide (lateral view, mouth left; 20 mm long; paratype SAM K2185); f, *P. laperousazi* sp. nov., D'Entrecasteaux Channel, Tasmania (dorso-lateral view, mouth right; 18 mm long; paratype SAM K2339).

Figure 3. Photos of preserved specimens of *Psolidium* Ludwig, 1886 (by L. Altoff): a, *P. marshae* sp. nov., Geographe Bay, Western Australia (dorsal view; 8 mm long; holotype WAM Z31173); b, *P. mccallumae* sp. nov., slope off Point Cloates, Western Australia (lateral view; 7 mm long; holotype NMV F126891); c–d, *P. nigrescens* H. L. Clark, 1938, Gunnamatta Bay, New South Wales (40 mm long; AM J6821); c, lateral view; d, ventral view (sole); e–f, *P. parmatus* (Sluiter, 1901), Adele slope, Western Australia (9 mm long; NMV F151835); e, lateral view; f, ventral view (sole).

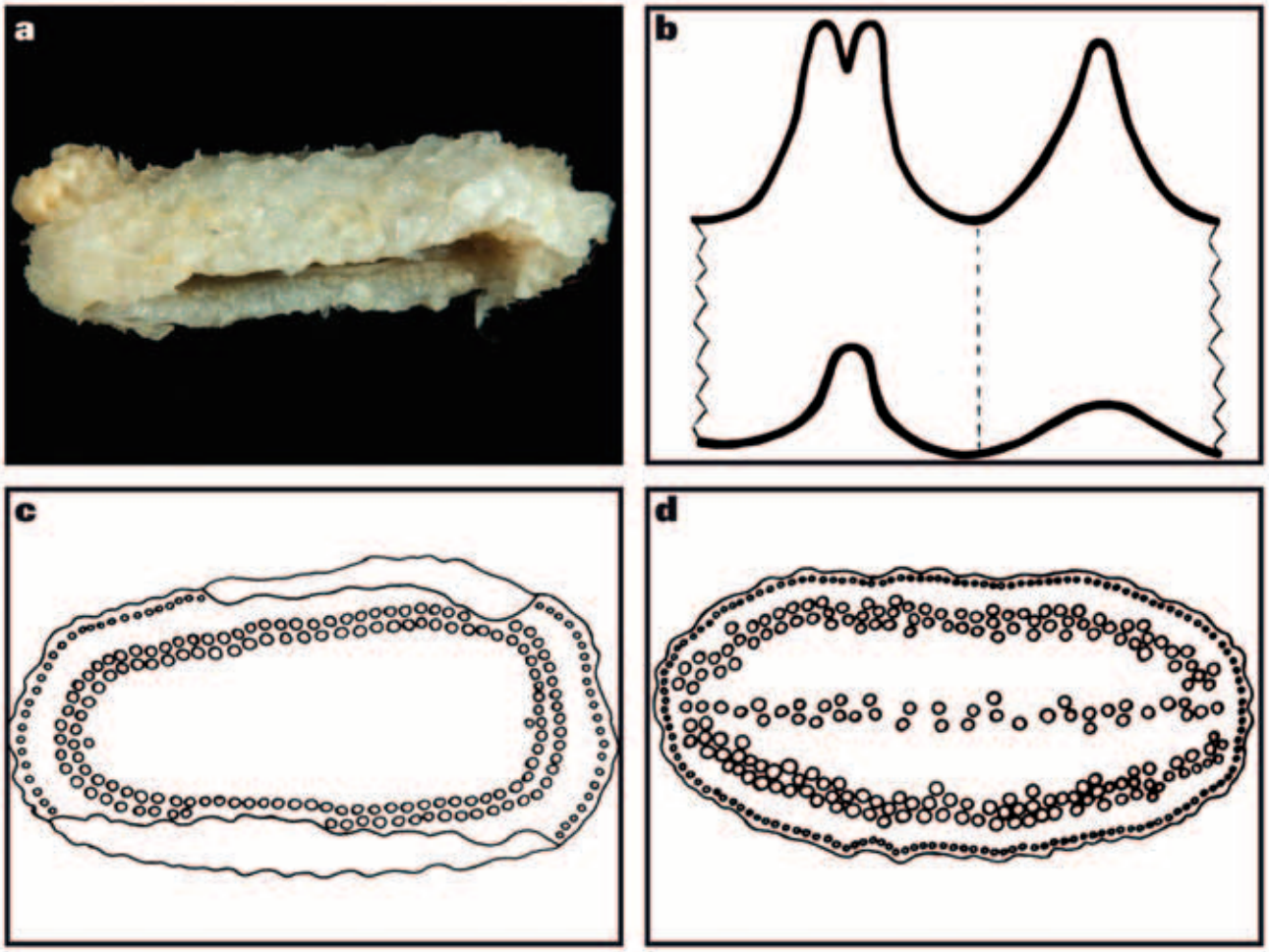

Figure 4. a, *P. spinuliferus* (H. L. Clark, 1938), Darwin (lateral view; 10 mm long; AM J24096; photo by L. Altoff); b, generalised form of radial (left) and interradial plates of the calcareous ring of *Psolidium* species (drawing by M. O'Loughlin); c–d, drawings of sole showing distribution of tube feet (by D. Maric); c, *P. granuliferum* H. L. Clark, 1938 (SAM K2176); d, *P. karenae* sp. nov. (SAM K2188).

Tentacle ossicles: rods variably perforated, thick to thin, long to short, straight or bent, flat or curved; dendritic tentacle branch endplates are small, irregular in shape, cupped, with a few large perforations and irregular margin; perforated plates may be present; densely branched rosettes may be present.

Type species. *Psolidium dorsipes* Ludwig, 1886.

Australian species. *Psolidium berentsae* sp. nov., *P. granuliferum* H. L. Clark, 1938, *P. hutchingsae* sp. nov., *P. karenae* sp. nov., *P. laperousazi* sp. nov., *P. marshae* sp. nov., *P. mccallumae* sp. nov., *P. minutus* (H. L. Clark, 1938), *P. nigrescens* H. L. Clark, 1938, *P. parmatus* (Sluiter, 1901), *P. ravum* Hickman, 1962, and *P. spinuliferus* (H. L. Clark, 1938).

Remarks. The descriptive term "thorn" ossicles is used for the body wall ossicles in the form of irregular short branched rods that are pointed distally. They occur in *Psolidium nigrescens* H. L. Clark and *P. parmatus* Sluiter. H. L. Clark (1938) referred to them as "triradiate particles/spicules". Sluiter (1901) did not report their presence. The type of *P. parmatus* was examined by one of us (PMO), and their presence noted.

Pawson and Valentine (1981) reported that their Atlantic species *Psolidium prostratum* lacked endplates in the dorsal tube feet. Thandar (2006) described *Psolidium multipes* from South Africa, and among characteristic *Psolidium* features reported that the sole was not distinct from the dorsum, the ventral tube feet were in radial series, and there were multi-layered ossicles in the sole. These characters are atypical of *Psolidium*, but may indicate juvenile form.

The Australian species of *Psolidium* are distinguished from each other in the key. The key indicates three morphological groupings of Australian *Psolidium* species: *P. parmatus* and *P. spinuliferus* and with their vertical pillars/spires on dorsal and lateral scales; species with cupped crosses and cups (as for the type species *P. dorsipes*); and species lacking cupped crosses and cups.

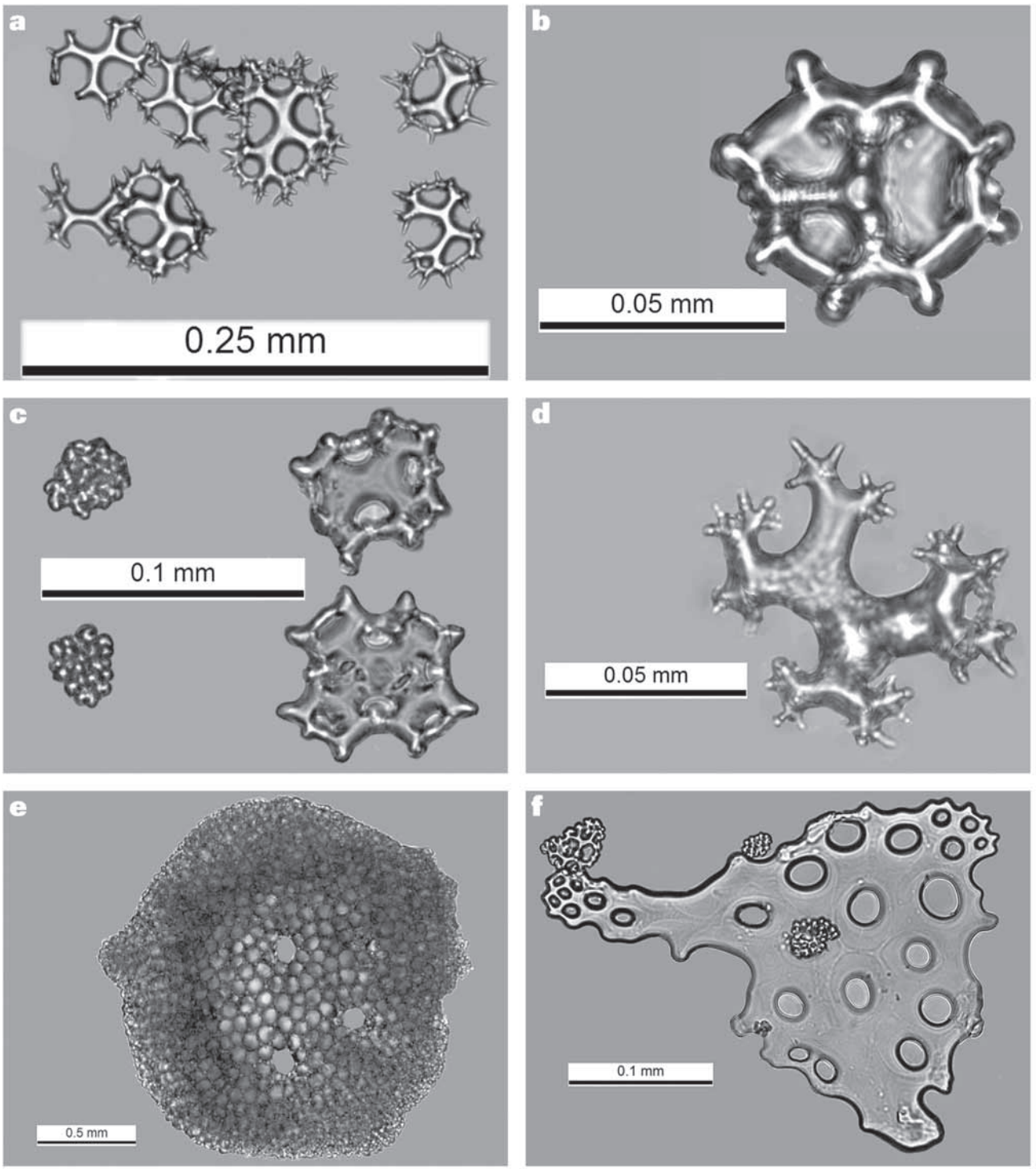

Figure 5. Photos of ossicles from Australian species of *Psolidium* Ludwig, 1886 (by Mark O'Loughlin and Chris Rowley): a–c, *P. berentsae* sp. nov.; a, dorsal cupped crosses and cups (small specimen, paratype AM J24099); b, dorsal bridged cup (holotype AM J24098); c, dorsal cups and rosettes (holotype AM J24098); d–f, *P. hutchingsae* sp. nov.; d, dorsal cupped cross (paratype AM J24108); e, dorsal multi-layered ossicle (scale) with tube foot canals (AM J19665); f, tentacle plate and rosettes (AM J19665).

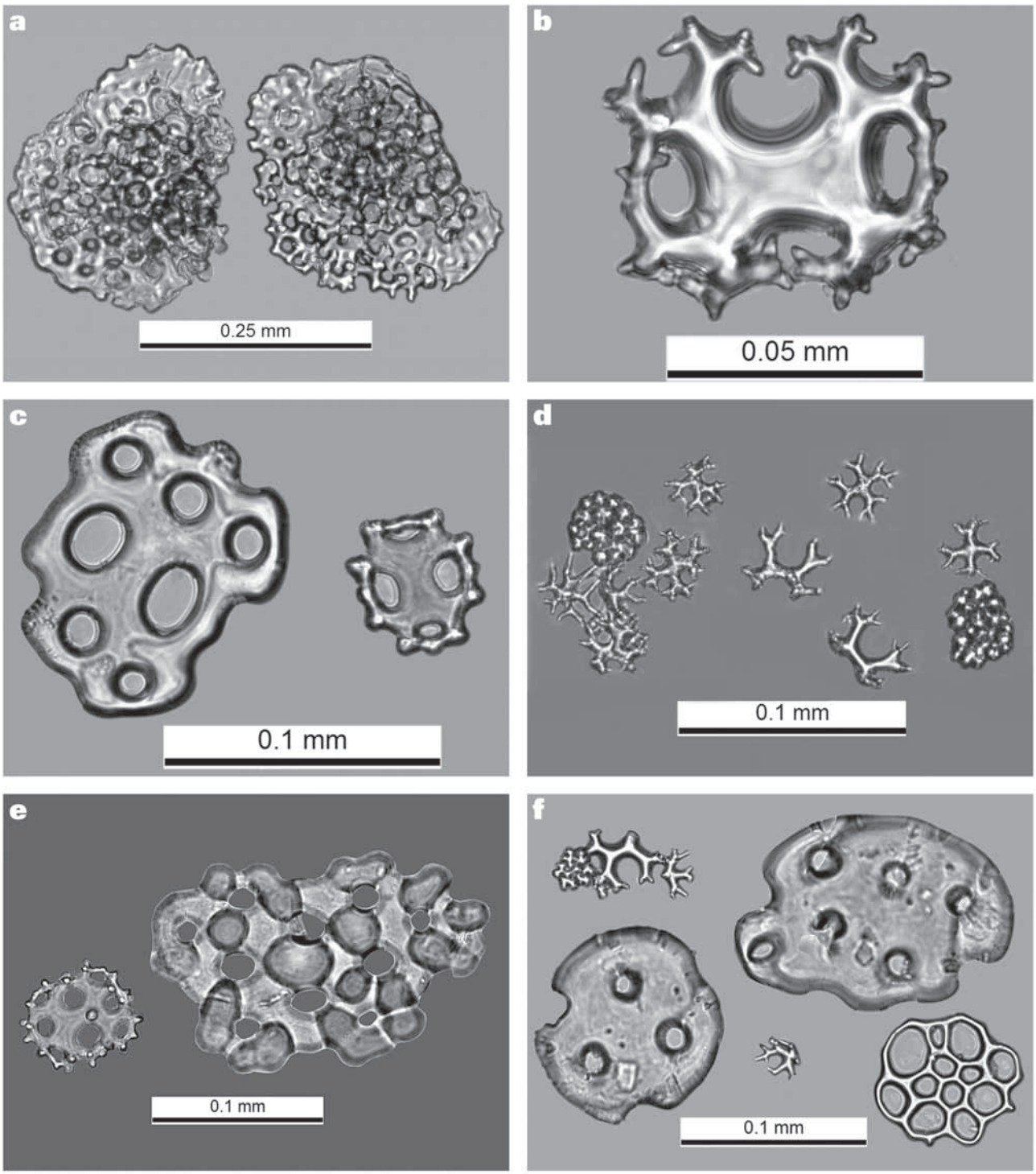

Figure 6. Photos of ossicles from Australian species of *Psolidium* Ludwig, 1886 (by Mark O'Loughlin and Chris Rowley): a, *P. granuliferum* H. L. Clark, 1938, multi-layered ossicles from the sole (SAM K2174); b–c, *P. laperousazi* sp. nov. (paratype SAM K2179); b, dorsal partly closed cup; c, cup and plate from sole; d–f, *P. marshae* sp. nov. (paratype WAM Z31165); d, dorsal small cupped crosses and rosettes; e, large cup and knobbed plate from sole; f, dorsal buttons, small endplate, large and small cupped crosses and rosette.

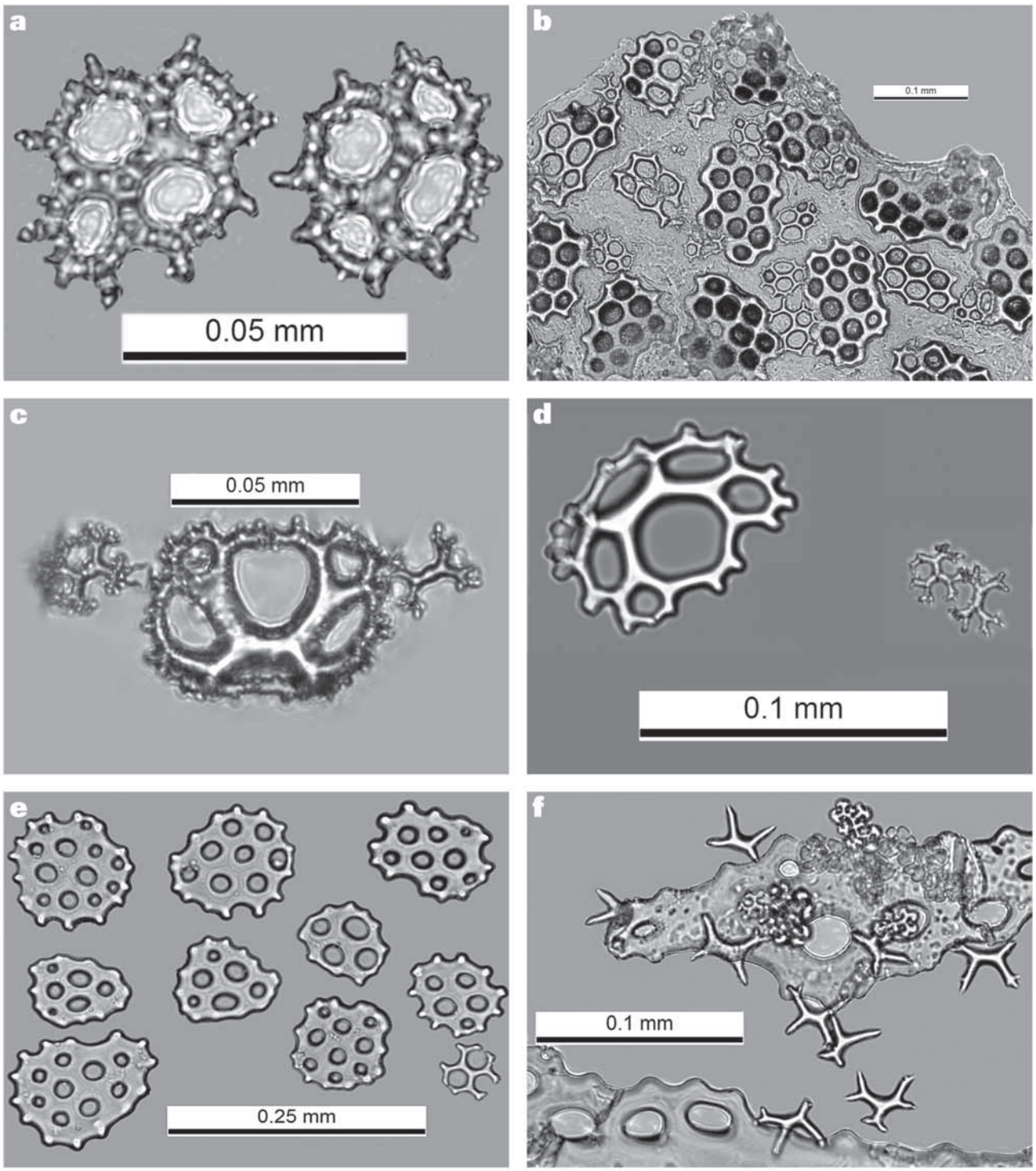

Figure 7. Photos of ossicles from Australian species of *Psolidium* Ludwig, 1886 (by Mark O'Loughlin and Chris Rowley): a–b, *P. mccallumae* sp. nov. (holotype NMV F126891); a, dorsal cups; b, mount of part of sole body wall, with plates and cups; c–d, *P. minutus* (H. L. Clark, 1938) (NMV F93176); c, dorsal large cup and small cupped crosses; d, large cup and small cupped crosses from sole; e–f, *P. nigrescens* H. L. Clark, 1938 (AM J6821); e, knobbed plates from sole; f, tentacle "thorns" and rosettes.

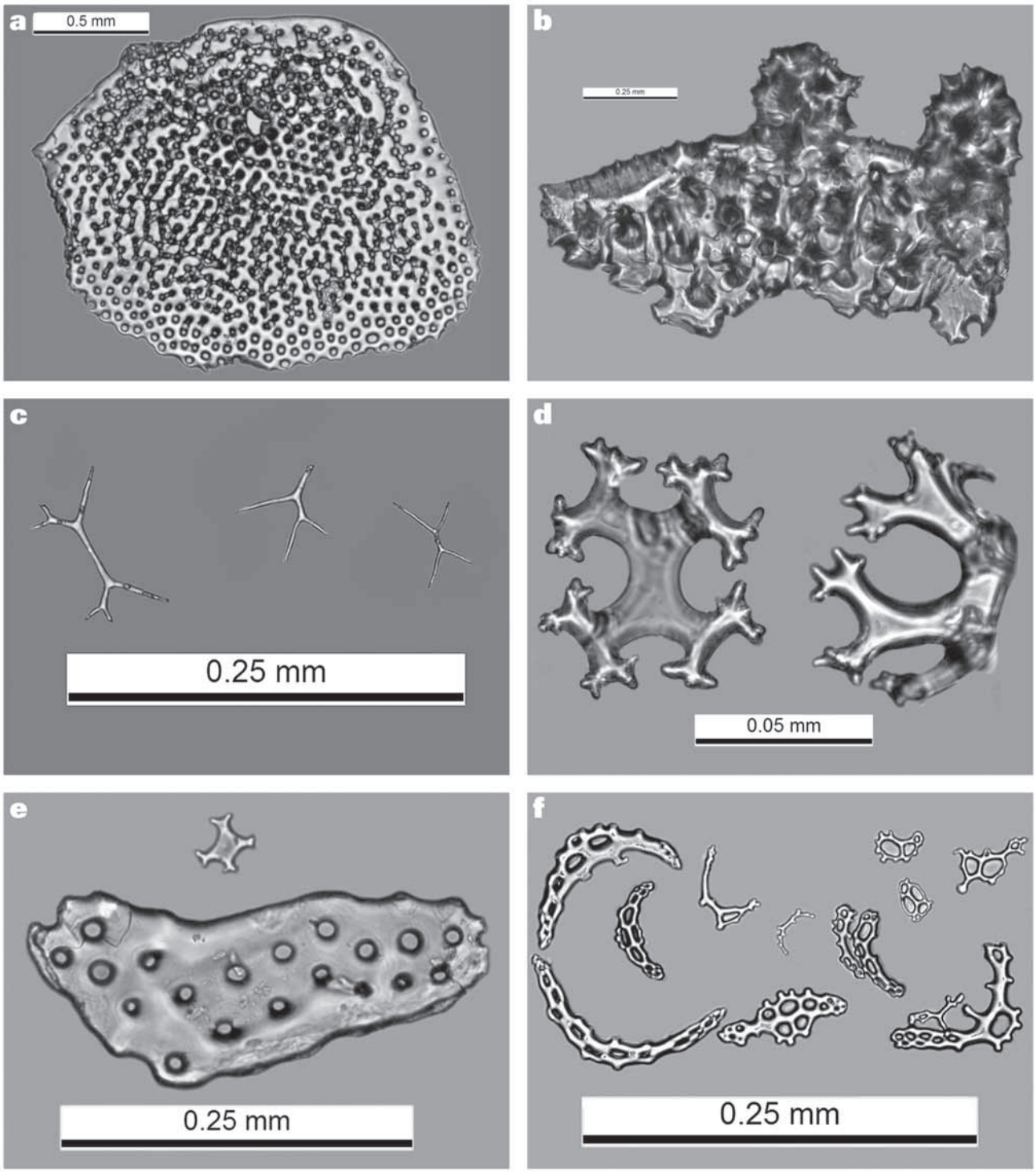

Figure 8. Photos of ossicles from Australian species of *Psolidium* Ludwig, 1886 (by Mark O'Loughlin and Chris Rowley): a–c, *P. parmatus* (Sluiter, 1901); a, dorsal scale with tube foot canal (holotype V.ECH.H1300); b, pillars on edge of part of scale (NMV F109378); c, dorsal "thorns" (holotype V.ECH.H1300); d–e, *P. ravum* Hickman, 1962 (SAM K2180); d, dorsal cupped crosses; e, cupped cross and plate from sole; f, *P. spinuliferus* (H. L. Clark, 1938), tentacle rods and dendritic branch endplates (top right) (AM J24096).

Psolidium berentsae sp. nov.

Table 1, Figures 2a, 5a–c

Material examined. Holotype: Queensland, Lizard I., off western side of Palfrey I., washings from coral blocks, 14°40'S 145°28'E, 6 m, P. B. Berents and P. A. Hutchings, 12 Jan 1976, stn 76 LIZ 16B, AM J24098.

Paratypes: type locality and date, J24099 (2); type locality and date, stn 76 LIZ 16A, J24100 (1).

Other material (up to 6 mm long; no cups detected): Chinamans Head, washings from coral blocks, 14°36'S 145°37'E, 6 m, P. A. Hutchings and P. B. Weate, 10 Jan 1976, stn 76 LIZ 15, J24101 (1); off Chinamans Head, reef rock, 14°40'S 145°28'E, 7 m, P. A. Hutchings and P. B. Weate, 27 May 1976, stn 76 LIZ B-00-03-3, J24102 (1); No Name Reef, southwest end, rubble from base of bommie, 14°40'S 145°39'E, 15 m, I. Loch, 19 Dec 1984, J24106 (1).

Other material (up to 11 mm long; no ossicles; presumably initial formalin preservation): Lizard I, off Chinamans Beach, coral block, 14°40'S 145°28'E, 7 m, P. A. Hutchings, Apr 1978, stn D15-27-1, J24104 (1); Outer Yonge Reef, 14°37'S 145°38'E, 18 m, P. A. Hutchings, 15 Jan 1977, stn 77 LIZ 47-4, J24105 (3).

Description. *Psolidium* species up to 12 mm long (preserved); body rounded in transverse section ventrally; dorsal and lateral scales thick, up to 1.3 mm wide; oral, anal and mid-body scales frequently tapering to projecting, bluntly pointed distal end, body surface very uneven.

Sole with peripheral band of tube feet, outer single series of slightly smaller tube feet, inner series 2 wide; mid-ventral radial series 2 wide; sole not discrete in very small specimens (4-6 mm long), small scales conspicuous.

Dorsal and lateral ossicles: multi-layered ossicles (scales), thick, with tube foot canals; buttons numerous, perforated, thick, irregularly oval, thickly knobbed, up to 176 μm long, up to 12 perforations, intergrade with multi-layered ossicles; in larger specimens (12 mm long) cups numerous, deeply cupped, thick cruciform base, rim bluntly spinous, cups sometimes "bridged" with transverse branches from rim joined, cups 56–96 μm long; in small specimens (4–6 mm long) numerous thin cupped crosses and cups, with elongate pointed spines on rim, cups up to 80 μm long; rosettes numerous in larger specimens, densely branched, irregularly oval in form, up to 56 μm long.

Sole ossicles: numerous knobbed plates, elongate, irregular in shape, large marginal and surface knobs, 3-12 perforations, up to 240 μm long; rare smooth elongate, perforated plates, up to 240 μm long.

Tentacle ossicles include abundant rosettes, densely branched, up to 40 μm long.

Colour (preserved). Dorsal and lateral dark to pale brown, sometimes with brown flecking; sole off-white; tentacle trunks brown, dendritic branches off-white; introvert off-white.

Distribution. Queensland, Lizard I, 14°36'–14°40'S 145°28'–145°39'E, coral rocks and rubble; 6–18 m.

Etymology. Named for Dr Penny Berents (Scientific Officer, Marine Invertebrates, Australian Museum), with appreciation of her contribution to Australian marine invertebrate research, and with gratitude for her gracious assistance with loans and research in the Australian Museum.

Remarks. Some of the paratype specimens are small, 4 mm long (J24099 (2)). In this material the cups and cupped crosses are much finer than in the larger type material. This is judged to be a developmental difference. Some of the non-type specimens assigned to the new species are small, with specimen lengths 4 mm (J24101), 5 mm (J24102) and 6 mm (J24106). No cups or cupped crosses were detected, and this was judged to be a sampling inadequacy for this very small material, since fine cups and cupped crosses were found in 4 mm long paratype. The specimens have the same appearance as the types, and are from the type locality and eco-niche. Further collecting and study might reveal the presence of an additional species. Other additional material judged to be *P. berentsae* sp. nov. has the body form and scale outlines of the species, but lacks calcareous material. The preservation history presumably included time in acidic formalin solution. Specimen lengths are 5 mm (J24104) up to 11 mm (J24105). A rounded ventrum, absence of discrete sole and presence of conspicuous scales ventrally appear to be juvenile developmental characteristics. The distinguishing characters of *P. berentsae* sp. nov. are the tapered body scales, rounded ventrum, fine cups with long pointed spines in small specimens, and thick cups with blunt spines and sometimes "bridges" in large specimens.

Psolidium granuliferum H. L. Clark

Table 1, Figures 1a, 2b, 4c, 6a

Psolidium granuliferum H. L. Clark, 1938: 503–04, fig. 49.—H. L. Clark, 1946: 415.—Rowe, 1982: 458, 464, pl. 31.4.—Rowe (in Rowe and Gates), 1995: 318.

Material examined. Holotype: Western Australia, Koombana Bay, Bunbury, 9–15 m, C-A-H Expedition, 26 Oct 1929, MCZ 1666.

Other material. Cape Nauraliste, Geographe Bay, Map Reef, near Two Rocks, limestone reef, coralline foliose algae, 31°28.365'S 115°33.634'E, 7.6 m, A. Sampey, 18 Jul 2005, WAM Z31164 (1); South Australia, W Eyre Peninsula, Smokey Bay, 37 m, N. Pearsons, 1971, SAM K2176 (2); Tasmania, Port Davey, Bramble Cove, NW end, under rock, 4–6 m, K. L. Gowlett-Holmes, 17 Mar 2003, SAM K2174 (2; live colour photo SAM PK 0259).

Description. *Psolidium* species up to 21 mm long (preserved); body height low to moderately high, dorsal and lateral scales thick, up to 3 mm wide, lumps on surface creating coarsely granuliform appearance; abundant small scales at base of larger scales; tube feet dorsally and laterally inconspicuous, sparse across mid body, usually present near base of scales.

Sole: peripheral band of tube feet, outer single series of distinctly separate smaller tube feet; series of inner larger tube feet 2 wide, series not always continuous anteriorly and posteriorly; lacking series of mid-ventral radial tube feet.

Dorsal and lateral ossicles: multi-layered perforated ossicles (scales), thick, large surface lumps, canals for tube feet, intergrade with single-layered perforated plates; lacking cups, cupped crosses, rosettes.

Ventral ossicles: small to large single-layered perforated plates, up to 22 perforations, thin to moderately thick, irregularly round to oval, up to 312 μm long, plate surfaces with abundant fine to medium knobs and rare large peripheral knobs, plate margins knobbed to bluntly spinous (fewer surface and peripheral knobs in plates from small specimens); large specimens have

perforated plates with secondary surface developments, intergrading into multi-layered ossicles.

Tentacles lack rosettes.

Colour. Live. Dorsally and laterally grey with off-white; white ventrally.

Preserved. Dorsally and laterally grey, or pale to darker brown with off-white; off-white ventrally.

Distribution. SW Western Australia (Koombana Bay) to SE Tasmania (Port Davey); 4–37 m.

Remarks. The distinguishing characteristics of *Psolidium granuliferum* H. L. Clark, 1938 are the absence of a mid-ventral radial series of tube feet on the sole, inconspicuous dorsal and lateral tube feet, coarsely granuliform dorsal and lateral scales, numerous small scales at the base of the large dorsal and lateral scales, and multi-layered ossicles in the sole of larger specimens. In the smallest specimens the sole has perforated plates with fewer knobs, and lacks perforated plates with secondary surface developments and multi-layered ossicles.

Psolidium hutchingsae sp. nov.

Table 1, Figures 2c–d, 5d–f

Material examined. Holotype: N New South Wales, 50 m west of Split Solitary I, 30°14'S 153°10'48"E, *Herdmania momus*, rocks, sponges, ascidians, 15 m, P. A. Hutchings and L. C. Rose, 7 Mar 1992, stn NSW 677, AM J24107. Paratype: Type location and date, J24108 (1).

Other material. Coffs Harbour, SE Islet, 30°19'S 153°09'E, 12 m, A. Hoggett and D. Johnson, 22 Jan 1982, J15469 (1); Port Stephens, 32°37'S 152°04'E, surface of ascidian, S. Smith, 1985, J19665 (1).

Description. *Psolidium* species up to 18 mm long (preserved); dorsal and lateral body scales thick, up to 2.2 mm wide, body surface uneven; oral and anal scales tapering to narrow rounded end distally.

Sole with peripheral irregular band of tube feet, about 4–5 wide, lacking discrete outer series of smaller tube feet; mid-ventral radial series of tube feet, about 2 wide.

Dorsal and lateral ossicles: multi-layered ossicles (scales) thick, up to 4 tube foot canals; buttons perforated, irregularly oval, thick, smallest 80 μm long with 3 perforations, intergrade with thickened and knobbed perforated plates and with multi-layered ossicles; crosses abundant, deeply cupped, arms bifurcate, arms distally finely spinous, cupped crosses 56–88 μm long; rosettes rare, up to 32 μm long.

Sole ossicles: knobbed to thickened perforated plates, marginal and surface knobs, variable shape from flat crosses to irregular plates with up to 12 perforations, up to 160 μm long; shallow concave crosses rare, arms bifurcate, arms bluntly spinous to finely knobbed distally, up to 72 μm long; shallow cups rare, knobs to short digitiform spinelets on rim, cups up to 96 μm long.

Tentacle ossicles include irregular, thick, perforated, plates, up to 320 μm long; abundant rosettes, densely branched, up to 80 μm long.

Colour. Preserved. Dorsally and laterally pale to dark grey-brown, some specimens with dark brown patches or spotting; sole off-white; tentacle trunks brown, dendritic branches off-white; introvert off-white.

Distribution. Northern New South Wales, Split Solitary I, Coffs Harbour and Port Stephens; rock, sponge, ascidians; 12–15 m.

Etymology. Named for Dr Pat Hutchings (Senior Principal Research Scientist, Australian Museum), with appreciation of her contribution to Australian marine invertebrate research and in particular for the collection and documentation of specimens described in this work.

Remarks. The distinguishing characteristics of *Psolidium hutchingsae* sp. nov. are the presence dorsally of abundant deeply cupped crosses with bifurcate arms that are distally finely spinous, and large rosettes and irregular plates in the tentacles.

Psolidium karenae sp. nov.

Table 1, Figure 1b, 2e, 4d

Material examined. Holotype: South Australia, Spencer Gulf, Yorke Peninsula, Port Victoria jetty, under rock, 5–6 m, K. L. Gowlett-Holmes and W. Zeidler, 14 Dec 1994, SAM K2177 (live colour photo SAM PK 0105).

Paratypes: St Vincent Gulf, Kemps Ground, 12 m, N. Holmes, Apr/May 1985, K2188 (1); Adelaide, Hallet Cove, R. Balfour, 1970, K2184 (3); Moana Beach, reef off S end, 10 m, K. L. Gowlett-Holmes, 4 Apr 1987, K2185 (3); Nuyts Archipelago, just N of centre of W island, Franklin I, 6–8 m, P. Aerfeldt et al., 14 Apr 1983, SAM K2187 (1); St Francis I, W end of N beach, among rocks, 3 m, W. Zeidler, 24 Jan 1982, K2181 (2).

Description. *Psolidium* species up to 32 mm long (preserved); body height low to moderately high, dorsal and lateral body scales thick, finely granuliform, large, up to 4.5 mm wide, with sparse small scales at base; dorsal and lateral tube feet conspicuous, pass through centre of scales.

Sole: peripheral band of tube feet, outer single series of distinctly separate smaller tube feet, inner series of larger tube feet, 2-3 wide, series not always continuous anteriorly and posteriorly; mid-ventral radial series of tube feet, irregularly spaced, 1-2 wide.

Dorsal and lateral ossicles: multi-layered perforated ossicles (scales), thick, fine surface lumps, canals for tube feet, intergrade with single-layered perforated plates up to 160 μm; lacking cupped crosses, cups, rosettes.

Ventral ossicles: small to large single-layered perforated plates, typically up to 24 perforations, up to 46 perforations in larger specimens, thin to moderately thick, irregularly round to oval, up to 240 μm long, plate surfaces with abundant fine to medium knobs and rare large peripheral knobs, plate margins knobbed to bluntly spinous; perforated plates from small specimens with fewer surface and peripheral knobs; large specimens lack secondary surface developments on perforated plates, and multi-layered ossicles.

Tentacles lack rosettes.

Colour. Live. Dorsally dark reddish-brown.

Preserved. Dorsally pale to dark brown to grey-brown; sole off-white to cream to pale brown.

Distribution. South Australia, St Vincent Gulf to Nuyts Archipelago; 3–12 m.

Etymology. Named for Karen Gowlett-Holmes (CSIRO Marine and Atmospheric Research; Eaglehawk Dive Centre) in appreciation of her contribution to marine invertebrate research, and with gratitude for her fieldwork and photography that contributed substantively to this work.

Remarks. The distinguishing characteristics of *Psolidium karenae* sp. nov. are the conspicuous dorsal and lateral tube feet, finely granuliform dorsal and lateral scales, sparse small scales at the base of the large dorsal and lateral scales, absence of cups, cupped crosses and rosettes, and presence of separate single outer series of smaller peripheral tube feet around the sole. In the sole of the smallest specimens the perforated plates have fewer knobs.

Psolidium laperousazi sp. nov.

Table 1, Figures 1c, 2f, 6b–c

Material examined. Holotype: SE Tasmania, D'Entrecasteaux Channel, Tinderbox, E of boat ramp, 1.5–3 m, K. L. Gowlett-Holmes, 14 Jul 1991, SAM K2172.

Paratypes: type locality and date, K2339 (2); South Australia, Kangaroo I, b/wn Western River Cove and Snug Cove, W side, 8–10 m, K. L. Gowlett-Holmes, 24 Feb 2003, K2179 (1, live colour photo SAM PK0253).

Description. *Psolidium* species up to 27 mm long (preserved); body height low to moderately high; dorsal and lateral scales thick, embedded in thick integument, imbricating, up to 1.5 mm wide; dorsal and lateral tube feet conspicuous, abundant.

Sole: peripheral band of tube feet, 3-4 wide, not always continuous anteriorly and posteriorly, lacking series of distinctly separate outer small tube feet; regular, close series of mid-ventral radial tube feet, 2 wide.

Dorsal and lateral ossicles: multi-layered perforated ossicles (scales), thick, irregular form; deeply cupped crosses and more abundant partially and fully closed cups, 40-72 μm, typical size range 56-64 μm long, cup rim densely, finely spinous; small to large buttons, up to 12 perforations, thick, smooth, irregular form, up to 264 μm long, intergrade with multi-layered ossicles.

Ventral ossicles: predominantly large single-layered perforated plates, up to 20 perforations, rarely up to 42 perforations in larger specimens, variable thickening, irregularly round to elongate, smooth, irregular margin, up to 368 μm long; perforated plates with variable surface and peripheral knobs rare; perforated plates with 4 perforations rare; moderately deep to deeply cupped crosses and more abundant partially and fully closed cups, 48–64 μm long, typical size range 48–56 μm long, cup rim bluntly spinous.

Tentacle ossicles include rosettes, irregularly oval, densely branched, up to 80 μm long in larger specimens.

Colour. Live: dark pink dorsally. Preserved: pale brown to cream dorsally and ventrally; small, discrete, dark brown spots may be present on the sole.

Distribution. SE Tasmania (D'Entrecasteaux Channel) to South Australia (Kangaroo I); 1–10 m.

Etymology. Named for Thierry Laperousaz (Collection Manager, Marine Invertebrates, South Australian Museum), with gratitude for his prompt and gracious assistance with loans.

Remarks. The distinguishing characteristics of *Psolidium laperousazi* sp. nov. are the embedding of the dorsal and lateral scales in thick integument, the abundant and conspicuous tube feet, the predominance of cups over cupped crosses dorsally and ventrally, large rosettes in the tentacles, and the presence of dark spots on the sole.

Psolidium marshae sp. nov.

Table 1, Figures 1d, 3a, 6d–f

Material examined. Holotype: Western Australia, Cape Naturaliste, Geographe Bay, Bunker Bay, granite reef, brown algae canopy, *Cystophora*, 33°32.152'S 115°01.993'E, 5.4 m, A. Sampey, 15 Apr 2005, WAM Z31173.

Paratype: Eagle Bay, granite reef, brown algae canopy, *Sargassum*, *Cystophora*, 33°33.387'S 115°04.078'E, 4.9 m, A. Sampey, 2 Feb 2005, Z31165 (1).

Other material. South Australia, Kangaroo I, b/wn Western River Cove and Snug Cove, 12–14 m, under rock, on coralline red alga or sponge, K. L. Gowlett-Holmes, 14 Mar 2004, SAM K2173 (1, live colour photo SAM PK0273).

Description. *Psolidium* species up to 10 mm long (preserved); very uneven surface; dorsal and lateral scales thick, up to 1.5 mm wide; oral and anal scales small, tapering to rounded end distally.

Sole with peripheral band of tube feet, band up to 4 wide, size variable, outermost series slightly smaller; mid-ventral radial series irregular, up to 4 wide; peripheral series of tube feet variably continuous anteriorly and posteriorly.

Dorsal and lateral ossicles: multi-layered ossicles (scales) thick, tube foot canals; buttons numerous, thick, smooth, not knobbed, irregularly oval, 3-9 perforations, up to 216 μm long; crosses small, deeply cupped, most quadri-radiate, some tri- or penta-radiate, abundant, typically 32 μm long, arms distally spinous, spinelets long, spinelets sometimes joined to close rim to form cups; rosettes abundant, oval, typically 32 μm long.

Sole ossicles: knobbed plates numerous, variable form, 4-16 perforations, thickly knobbed on surface and marginally, up to 240 μm long; cups and cupped crosses shallow concave, with digitiform spinelets marginally only; cups and cupped crosses of 2 sizes, larger typically 72 μm long, of variable form, some intergrading with knobbed plates, smaller typically 32 μm long, quadri-radiate or tri-radiate base, marginal rim closed or not.

Tentacle ossicles include abundant rosettes, oval, up to 56 μm long.

Colour. Live. Predominantly white with some brown patches.

Preserved: dorsally and laterally off-white with dark brown-black patches and flecks; sole off-white; tentacle trunks with dark brown markings.

Distribution. Western Australia, Cape Naturaliste, Geographe Bay; granite; 5 m; South Australia, Kangaroo I; 12–14 m.

Etymology. Named for Loisette Marsh (Research Associate, Marine Invertebrates Section, Department of Aquatic Zoology,

Western Australian Museum), in appreciation of her considerable contribution to echinoderm systematic and biogeographical research, and with gratitude for her gracious assistance with loans of echinoderm specimens for systematic research.

Remarks. The distinctive characters of *Psolidium marshae* sp. nov. are the presence of 2 size ranges of cupped crosses and cups in the sole, and presence of rosettes in the body wall.

Psolidium mccallumae sp. nov.

Table 1, Figures 3b, 7a–b

Material examined. Holotype: Western Australia, off Point Cloates, upper continental slope, hard substrate, *Southern Surveyor* SS10/2005 stn 139, 22.85°S 113.51°E, 100 m, 9 Dec 2005, NMV F126891.

Description. *Psolidium* species up to 7 mm long (preserved); dorsal and lateral body scales thick, up to 1.3 mm wide, oral and anal cone scales tapering to projecting angled spine; dorsal and lateral tube feet conspicuous.

Sole with peripheral band of tube feet, outer single series of slightly smaller tube feet, inner single series; lacking mid-ventral radial series of tube feet.

Dorsal and lateral ossicles: multi-layered ossicles (scales), up to 2 tube foot canals; cups shallow, 4-8 perforations, cross and rim covered with fine spinelets, cups 40–72 μm long; rosettes rare, small, up to 32 μm long.

Sole ossicles: smooth, irregular perforated plates, up to 16 perforations, up to 184 μm long; shallow cups with finely spinous rim, typically 4 perforations, typically 48 μm long; lacking rosettes.

Colour (preserved). White dorsally, laterally, ventrally.

Distribution. Central Western Australia, off Point Cloates, upper continental slope, hard substrate; 100 m.

Etymology. Named for Anna McCallum (Marine Biology Section, Museum Victoria) with appreciation of her participation in the collection of this material on the *Southern Surveyor*, and her careful curation of this holothuroid collection in Museum Victoria.

Remarks. The distinctive character of *Psolidium mccallumae* sp. nov. is the complete cover of small spinelets on the cross and rim of the shallow dorsal cups.

Psolidium minutus (H. L. Clark)

Table 1, Figures 7c–d

Psolus minutus H. L. Clark, 1938: 507–09, figs 51–52.—H. L. Clark, 1946: 414.—Pawson, 1968b: 21 (key).—Cannon and Silver, 1987: 29.

Psolidium minutus.—Rowe (in Rowe and Gates), 1995: 318.—Coleman, 2002: 65, fig.

Material examined. Paratypes: Lord Howe I, Neds Beach, under rock, Apr 1932, AM J6450 (3).

Other material. Neds Beach, under rock, N. Coleman, 20 Jul 2002, NMV F93176 (1); Middleton Reef, shallow reef front, 29°27.2'S 159°06.8'E, sandy bottom, 10 m, 4 Dec 1987, AM J20901 (1).

Description. *Psolidium* species up to 10 mm long (live); dorsal and lateral body scales thick to thin, bluntly toothed on free edge, up to 1.3 mm wide; tube feet pass through scales.

Sole with peripheral band of tube feet, outer single series of smaller tube feet, inner single series; mid-ventral radial series of tube feet 2 wide.

Dorsal and lateral ossicles: single to multi-layered ossicles (scales) with tube foot canals; large cups shallow to deep, closely finely spinous rim, large cups 48–80 μm long; small cupped crosses and cups deep, closely finely spinous distal arm branches and cup rim, small crosses and cups up to 24 μm long; lacking rosettes.

Sole ossicles: perforated plates, irregularly round to elongate, smooth, marginally slightly knobbed to bluntly spinous, up to 36 perforations, up to 360 μm long; shallow cups with finely spinous rim, typically 4 perforations, typically 48 μm long; very small deeply cupped crosses and cups, finely closely spinous on distal arm branches and rim, up to 20 μm long; lacking rosettes.

Tentacles lack rosettes.

Colour. Live colour white, tentacles yellowish (H. L. Clark, 1938; Coleman, 2002: 65, fig.).

Distribution. Tasman Sea, Lord Howe I, Middleton Reef; 1–10 m.

Remarks. The distinctive characters of *Psolidium minutus* (H. L. Clark, 1938) are the presence of 2 size ranges of cupped crosses and cups in the sole, and absence of rosettes in the body wall. H. L. Clark (1938) noted that Dr Deichmann had called his attention to the fact that the ossicles in *Psolus minutus* resembled those in some species of *Psolidium*. Rowe (1995) reassigned *Psolus minutus* to *Psolidium* on the basis of dorsal tube feet penetrating the scales.

Psolidium nigrescens H. L. Clark

Table 1, Figures 3c-d, 7e-f

Psolidium nigrescens H. L. Clark, 1938: 505-507, fig. 50.—H. L. Clark, 1946: 414–15.—Cannon and Silver, 1987: 29.—Rowe (in Rowe and Gates), 1995: 318.

Material examined. New South Wales, Broken Bay, Hawkesbury River, Yeomans Bay, Smith-MacIntyre Grab, mud sediment, G. Phillipson, Oct 1992 (specimen not lodged in museum); Port Jackson, Middle Harbour, N bank W of Spit Bridge, 33°48'S 151°15'E, steeply sloping bottom with telestacean bed, live and dead mussels, *Tethia* sp. and compound ascidians, 8 m, J. K. Lowry, 9 Jun 1981, J24097 (1); Botany Bay, off Dolls Point, dredged, 7–11 m, D. F. McMichael, Oct 1949, J6789 (4); Port Hacking, Gunnamatta Bay, 34°04'30"S 151°08'54"E, on shells of *Anadara*, I. Bennett, 2 Nov 1948, AM J6821 (6); Batemans Bay, Clyde R, edge of channel near southern bank downstream from Princes Hwy road bridge, 35°42'34"S 150°11'3"E, 5 m, clump of hairy mussels, Australian Museum party, 30 Mar 2004, J24092 (3).

Description. *Psolidium* species up to 40 mm long (preserved); body elongate; dorsal and lateral body scales thick, up to 4 mm wide, covered by fairly thick integument; scales tapered to projecting rounded point orally and anally; dorsal and lateral tube feet conspicuous, up to 5 pass through a scale.

Sole with peripheral band of tube feet, about 5 wide, outermost tube feet not smaller; mid-ventral radial series of tube feet predominantly 2 wide.

Dorsal and lateral ossicles: multi-layered ossicles (scales) with tube foot canals; thick knobbed buttons, 3-10 perforations,

up to 192 μm long, intergrade with multi-layered ossicles; branched rods with pointed ends ("thorn" ossicles), irregular form, 3-5 arms, flat to 3-dimensional, up to 56 μm long; rosettes, densely branched, up to 40 μm long.

Sole ossicles: perforated plates, slightly concave, irregularly round, knobbed marginally, up to 14 perforations, up to 152 μm long; very shallow, marginally knobbed, 4-perforation cups and cupped crosses, typically 96 μm long; rare rosettes; rare "thorn" ossicles.

Tentacle ossicles include: rosettes, up to 40 μm long; "thorn" ossicles, up to 40 μm long.

Colour (preserved). Dorsal and lateral body black to brown to dark grey, with fine white spotting over scales; tube feet off-white; sole pale brown to cream, with some fine brown flecking; tentacle trunks dark brown, tentacle dendritic ends off-white.

Distribution. Eastern Australia, central New South Wales, Broken Bay to Batemans Bay, estuarine; 0–11 m.

Remarks. The distinguishing characters of *Psolidium nigrescens* H. L. Clark, 1938 are the "thorn" ossicles in the body wall, and very dark brown to black colour.

Psolidium parmatus (Sluiter)

Table 1, Figures 3e–f, 8a–c

Psolus parmatus Sluiter, 1901: 102–03, pl. 6 fig. 14.

Material examined. Holotype (very poor condition): Indonesia, Banda Sea, *Siboga* stn 259, 5°29.2'S 132°52.5'E, coral sand, 487 m, V.ECH. H1300.

Other material. Western Australia, Ningaloo North, *Southern Surveyor* SS2005/10 stn 163, 21.94°S 113.84°E, hard substrate, 133 m, 12 Dec 2005, NMV F112156 (1); Adele, SS05/2007 stn 161, 14.5622°S 122.9182°E, hard rubble, 95 m, 4 Jul 2007, F151835 (1); Kulumburu, SS05/2007 stn 176, 13.2247°S 123.3957°E, 400 m, F151836 (1).

Arafura Sea, *Southern Surveyor* SS05/2005 stn 42, 9°7.018'S 133°24.725'E, 204 m, 18 May 2005, F109377 (1); SS05/2005 stn 43, 9°5.312'S 133°2.989'E, 226 m, 19 May 2005, F109378 (1).

Description. *Psolidium* species up to 13 mm long (preserved); dorsal and lateral scales up to 2.0 mm wide, scales each with numerous blunt calcareous vertical projections; dorsal and lateral tube feet not conspicuous amongst projections.

Sole with peripheral band of tube feet, single outer series of smaller tube feet, inner single series of larger ones; lacking mid-ventral radial series of tube feet.

Dorsal and lateral ossicles: single to multi-layered perforated plates (scales), lace-like secondary surface developments to multi-layering, tube foot canals; each scale with numerous thick, bulbous calcareous spires, constricted basally, rounded distally, about 200 μm high, 136 μm widest diameter, finely spinous surface; irregular branched pointed rod "thorn" ossicles, up to 160 μm long; shallow concave cups, perforations large, typically 4 around central cross, frequently 4 smaller corner perforations, cups knobbed around margin and on cross, cups typically 120 μm long; lacking rosettes.

Sole ossicles: shallow concave cups, perforations large, typically 4 around central cross, frequently 4 smaller corner perforations, cups knobbed around margin and on cross, cups typically 112 μm long; "thorn" ossicles up to 96 μm long; lacking rosettes.

Colour (preserved). White dorsally, laterally, ventrally.

Distribution. Indonesia (Banda Sea), Arafura Sea, to NW Western Australia (Ningaloo North); 95–487 m.

Remarks. Tube feet pass through the dorsal and lateral scales of *Psolus parmatus* Sluiter, 1901. The species is re-assigned here to *Psolidium* Ludwig. The distinctive species characteristic of *Psolidium parmatus* (Sluiter) is the presence of numerous blunt vertical calcareous projections on each of the dorsal and lateral scales. These projections resemble "shields" in profile, and hence the species name chosen by Sluiter (*parma,* Latin for "small shield").

Psolidium ravum Hickman

Table 1, Figures 1e, 8d–e

Psolidium ravum Hickman, 1962: 60-61, figs 75–86, pl. 2 fig. 7.—Dartnall, 1980: 51, 77.—Rowe, 1982: 458, 464, fig. 10.29c.—Rowe (in Rowe and Gates), 1995: 318–19.

Material examined. Syntype: SE Tasmania, Derwent Estuary, Ralphs Bay, dredged, 13 m, 28 Aug 1959, AM J7202 (1).

Other material: N point of Trial Bay, near Kettering, 3 m, under rock, 31 Mar 1991, SAM K2180 (1); Hobart, AM G248 (3); Frederick Henry Bay, Primrose Sands, Renard Point, under rock, 3–4 m, K. L. Gowlett Holmes, 25 Aug 1999, K2178 (1); Bass Strait, Lulworth, Black Rock Point, M. O'Loughlin et al., 22 Nov 1982, NMV F97439 (1); Tamar R., Greens Beach, M. O'Loughlin, 7 Mar 1981, NMV F97440 (1). Victoria, Bass Strait, Ninety Mile Beach, 10 km W of Seaspray, J. Watson, 1977, AM J11171 (1); Portland, 500 m E of Whalers Point Lighthouse, 10 m, under rocks, P. Berents and R. Springthorpe, 10 May 1988, AM J21980 (1); Saxon Reef, 10 m, J. Watson, 24 Feb 2007, NMV F125379 (1). South Australia, Spencer Gulf, Yorke Peninsula, Port Elizabeth, 7 m, K. Sheard, 23 Feb 1941, SAM K2182 (1); Pt Turton jetty, 3–4 m, N. Holmes, 31 Aug 1986, SAM K2186 (1); W Eyre Peninsula, Streaky Bay, Pt Westall, littoral, M. O'Loughlin, 15 Jan 1991, NMV F97438 (1); Nuyts Archipelago, Franklin I, 12–15 m, W. Zeidler and P. Aerfeldt, 23 Feb 1983, SAM K2183 (1).

Description. *Psolidium* species up to 40 mm long (preserved); body form oval to elongate; body height low to moderately high; dorsal and lateral scales thick, up to 2 mm wide, covered with thick integument; dorsal and lateral tube feet conspicuous, numerous.

Sole: peripheral band of tube feet, 4-5 wide, not always continuous anteriorly and posteriorly, lacking series of distinctly separate outer small tube feet; regular, close series of mid-ventral radial tube feet, 2 wide.

Dorsal and lateral ossicles: multi-layered perforated ossicles (scales), thick, irregular form; deeply cupped crosses with distal spinous to digitiform spinelets, rare partially or fully closed cups, 32–72 μm long, typical size range 40–56 μm long; small to large buttons, up to 12 perforations, thick, smooth, irregular form, up to 216 μm long, intergrade with multi-layered ossicles.

Ventral ossicles: predominantly large single-layered perforated plates, up to 16 perforations, rarely up to 38 perforations in larger specimens, variable thickening, irregularly round to elongate, smooth, irregular margin, up to 360 μm long;

perforated plates with variable surface and peripheral knobs rare; perforated plates with 4 perforations rare; moderately deep to deeply cupped crosses with distal spinous to knobbed spinelets, rare partially or fully closed cups, typical size range 40–48 μm long, rarely up to 56 μm long.

Tentacle ossicles include rosettes, irregularly oval, densely branched, up to 96 μm long in larger specimens.

Colour. Live: grey dorsally and laterally. Preserved: dark brownish-grey to off-white dorsally and laterally; sole brown to grey-brown.

Distribution. SE Tasmania (Derwent Estuary), Bass Strait, to W South Australia (Nuyts Archipelago); 0–15 m.

Remarks. Although not reported by Hickman (1962), the syntype and all of the specimens determined here to be *P. ravum* have rosettes in the tentacles. The specimen from the Eyre Peninsula (NMV F97438) ventrally has more abundant plates with 4 perforations, but the external morphology and presence of cupped crosses dorsally and ventrally are typical of *P. ravum*. The specimens from Frederick Henry Bay (SAM K2178) and Kettering (K2180) have similar morphological appearances to *P. laperousazi* sp. nov., but the dorsal and ventral ossicles are typical of *P. ravum*. Knobbed to spinous plate margins in the sole of the specimens from Port Elizabeth (SAM K2182) and Portland (NMV F125379) are similar to those of *P. karenae* sp. nov. and *P. granuliferum* H. L. Clark, but the external morphology and presence of dorsal and ventral cupped crosses and cups are typical of *P. ravum*. Small ossicles were absent from specimens from Nuyts Archipelago (SAM K2183) and Yorke Peninsula (K2186) (probably formalin preservation history), but the specimens have the typical external morphology of *P. ravum*. The distinguishing characteristics of *Psolidium ravum* Hickman, 1962 are the conspicuous dorsal and lateral tube feet, the predominance of cupped crosses over cups dorsally and ventrally, large rosettes in the tentacles, and absence of dark spots on the sole.

Psolidium spinuliferus (H. L. Clark)

Table 1, Figures 4a, 8f, 9a–d

Psolus spinuliferus H. L. Clark, 1938: 509–11, fig. 53.—H. L. Clark, 1946: 414.—Cannon and Silver, 1987: 29.—Rowe (in Rowe and Gates), 1995: 319.

Material examined. Northern Territory, Darwin Harbour, North Shell I, 12°29'48"S 130°53'12"E, coral rubble covered with sponges and some algae, 5 m, P. A. Hutchings, 16 Jul 1993, stn NT 346, AM J24096 (1). Western Australia, Perth, Cottesloe, Mudurup Rocks, c70 m S of groyne, reef flat, *Sargassum* zone, on reef flat under thin veneer of sand, 31°59'51"S 115°45'01"E, 0–1 m, J. Keesing, 6 Feb 2007, WAM Z37479 (1); Trigg I, c100 m N of 'island', inshore mixed algal zone mid-platform with thin veneer of sand overlaying reef, 31°52'29"S 115°45'04"E, 0–1 m, J. Keesing, 19 Feb 2007, Z37478 (1); Waterman, *Sargassum* zone, mid-platform, 31°51'15"S 115°45'05"E, 0–1 m, J. Keesing, 14 Feb 2007, Z37468 (5); from mixed localities, Cottesloe and Trigg I, inter-tidal platforms, on reef flat under thin veneer of sand, J. Keesing, Feb 2007, Z37469 (1).

Description. *Psolidium* species up to 20 mm long (preserved); dorsal and lateral body scales thin, single-layered, with spires, scales up to 1.5 mm wide; tube feet dorsally and laterally pass through scales, not conspicuous amongst spires.

Sole: peripheral band of tube feet, outer single series of smaller tube feet, inner single to zig-zag series; mid-ventral radial series irregular, double to zig-zag to scattered.

Dorsal and lateral ossicles: single-layered, thick, perforated plates (scales), irregularly oval, some with secondary thickening, most with vertical digitiform spire near margin; spires up to 400 μm long, 120 μm diameter, distally spinous.

Sole ossicles: knobbed plates, numerous, predominantly regular 4-holed thin plates, smooth to finely knobbed marginally, typically 80 μm long; lacking cupped crosses, cups, rosettes.

Tentacle ossicles include: thick perforated plates, elongate, variable form, some with secondary layer development, up to 352 μm long; numerous rosettes, large to small, frequently with 4 central perforations, densely branched, oval to elongate and distally rounded, up to 160 μm long, intergrade with elongate plates.

Colour(live and preserved).White, dorsally and ventrally.

Distribution. Northern Territory (Darwin), to Western Australia (Perth); 0–22 m.

Remarks. The dorsal and lateral tube feet are not conspicuous, and were not noticed by H. L. Clark (1938). *Psolus spinuliferus* H. L. Clark, 1938 is reassigned here to *Psolidium* Ludwig. The distinguishing characters of *Psolidium spinuliferus* (H. L. Clark) are the predominantly single-layered scales with vertical digitiform marginal spire. The type specimen (MCZ no. 1669) was taken off the Eighty Mile Beach near Broome in northwestern Australia, at 18–22 m.

Acknowledgments

We are most grateful to the following for their gracious assistance: Cynthia Ahearn (Smithsonian Institution; literature); Leon Altoff and Audrey Falconer (Marine Research Group, Field Naturalists Club of Victoria; photography); Ben Boonen (photoshop of images, format of figures); Mary Catherine Boyett (MCZ; loan); Karen Gowlett-Holmes (CSIRO, Hobart; live colour photos, field work); Simon Hinkley and Chris Rowley (NMV; photography); John Keesing (CSIRO, Perth; data), Thierry Laperousaz (SAM; loans); Loisette Marsh and Mark Salotti (WAM; loans and data); Stephen Keable and Roger Springthorpe (AM; loan, data); Jan Watson (Marine Research Group, Field Naturalists Club of Victoria; fieldwork). We are most appreciative of the helpful suggestions made by referees Dr D. L. Pawson and Dr F. W. E. Rowe.

References

Agassiz, L. 1845. *Nomina systematica generum echinodermatum tam viventium quam fossilium, secundum ordinem alphabeticum disposita, adjectis auctoribus, libris in quibus reperiuntur, anno editionis, etymologia et familiis, ad quas pertinent*. Jent et Gassmann: Soloduri: Switzerland.

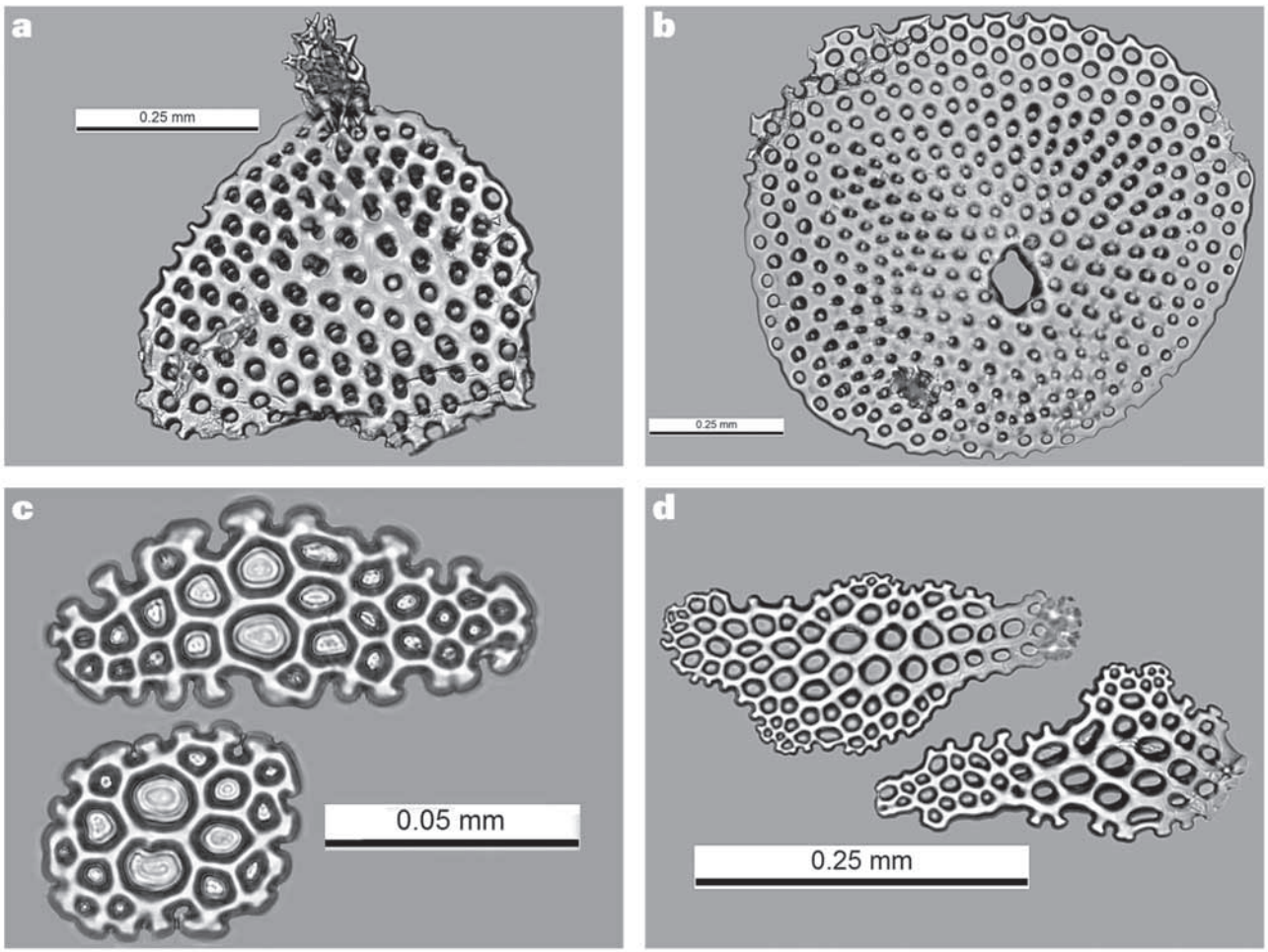

Figure 9. Photos of ossicles from Australian species of *Psolidium* Ludwig, 1886 (by Mark O'Loughlin and Chris Rowley): a–d, *P. spinuliferus* (H. L. Clark, 1938) (WAM Z37468); a, part of dorsal scale with marginal vertical spire; b, dorsal scale with tube foot canal and base of lost spire; c, tentacle rosettes; d, tentacle plates.

Agassiz, L. 1848. *Nomenclatoris zoologici index universalis, continens nomina systematica classium, ordinum, familiarum et generum animalium omnium, tam viventium quam fossilium, secundum ordinem alphabeticum unicum disposita, adjectis homonymiis plantarum*. Jent et Gassmann: Soloduri: Switzerland.

Baranova, Z.I., and Belyaev, G.M. 1968. Echinodermata. In: Zenkevich, L. A. (ed.), *La vie des animaux*. Izdatel stvo *Proveshchenic*. Moscow 2: 197–297. (in Russian)

Bell, J.F. 1882. Studies in the Holothuroidea. I. On the genus *Psolus* and the forms allied thereto. *Proceedings of the Zoological Society, London*. *1882*: 641–50, pl. 158.

Bronn, H.G. 1860. *Die klassen und ordnungen des thier-reichs, wissenschaftlich dargestellt in wort und bild*. *2*. *Aktinozoen*. C. F. Winter'sche Verlagshandlung: Leipzig and Heidelberg. 434 pp., 49 pls.

Cannon, L.R.G., and Silver, H. 1987. *Sea Cucumbers of Northern Australia*. Queensland Museum: Brisbane, Australia. i–viii, 60 pp.

Carriol, R-P., and Féral, J-P. 1985. Réexamen de quelques Psolidae (Holothurioidea, Echinodermata) antarctiques et subantarctiques. Description de deux nouvelles espèces du genre *Psolus*. *Bulletin du Muséum national d'Histoire naturelle, Paris* 4(7) A(1): 49–60.

Cherbonnier, G. 1974. Invertébrés marins des XIIème et XVème expéditions antarctiques Françaises en Terre Adélie. 15. Holothurides. *Tethys* 5(4): 601–10.

Clark, H.L. 1901. Holothurians of the Pacific Coast of North America. *Zoologischer Anzeiger* 24: 162–71.

Clark, H.L. 1938. Echinoderms from Australia. An account of collections made in 1929 and 1932. *Memoirs of the Museum of Comparative Zoology at Harvard College* 55: 1–596, 28 pls, 63 figs.

Clark, H.L. 1946. The echinoderm fauna of Australia. Its composition and its origin. *Carnegie Institution of Washington Publication 566*: 1–567.

Coleman, N. 2002. *Lord Howe Island Marine Park*. Neville Coleman's Underwater Geographic. 95 pp.

Dartnall, A. 1980. *Fauna of Tasmania Handbook* 3. *Tasmanian echinoderms*. University of Tasmania: Hobart. 82 pp., 36 figs, 5 pls, 18 maps.

Deichmann, E. 1940. Report on the Holothurians, collected by the Harvard-Havana expeditions 1938 and 1939, with a revision of the Molpadioida of the Atlantic Ocean. *Memorias Sociedad Cubana Historia Natural, Felipe Poey* 14(3): 183–240, 10 pls.

Deichmann, E. 1941. The Holothurioidea collected by the *Velero III* during the years 1932–1938. I. Dendrochirotida. *Allan Hancock Pacific Expeditions* 8(3): 61–194, pls 10–30.

Deichmann, E. 1947. Shallow water holothurians from Carbo de Hornos and adjacent waters. *Anales del Museo Argentino de Ciencias Naturales. Invertebrados Marinos* 8: 325–51.

Deichmann, E. 1954. The holothurians of the Gulf of Mexico. *Fishery Bulletin of the Fish and Wildlife Service* 89(55): 381–410.

Dendy, A. 1896. Observations on the Holothurians of New Zealand; with descriptions of four new species, and an appendix on the development of the wheels in *Chirodota*. *Journal of the Linnaean Society of London, Zoology* 26: 22–52.

Forbes, E. 1841. *A history of British starfishes and other animals of the class Echinodermata*. John van Voorst: London. 267 pp.

Gistel, T. 1848. Echinodermata. Class 11. Pp. 174–77 in: *Naturgeschichte des Thierreichs für höhere Schulen*. Stuttgart. xvi+216 pp., 32 pls.

Grube, A.E. 1840. *Aktinien, Echinodermen und Würmer des Adriatischen und Mittelmeeres*. J. H. Bon: Königsberg. 92 pp.

Gutt, J. 1988. Zur Verbreitung und Ökologie der Seegurken (Holothuroidea, Echinodermata) im Weddellmeer (Antarktis). *Berichte zur Polarforschung* 41: 1–87.

Gutt, J. 1990. New Antarctic holothurians (Echinodermata) —I. Five new species with four new genera of the order Dendrochirotida. *Zoologica Scripta* 19(1): 101–17.

Haeckel, E., 1896. Systematische Phylogenie der Echinodermen. Pp. 348–504 in: *Systematische Phylogenie der Wirbellosen Thiere (Invertebrata). Zweiter Teil des Entwurfs einer systematischen Stammesgeschichte*. Reimer: Berlin. 720 pp.

Hickman, V.V. 1962. Tasmanian sea-cucumbers (Holothuroidea). *Papers and Proceedings of the Royal Society of Tasmania* 96: 49–72, 2 pls, 186 figs.

Jäger, G.F. 1833. *De Holothuriis. Dissertatio Inauguralis*. Turici. 40 pp., 3 pls.

Joshua, E.C. 1914. Victorian Holothuroidea, with descriptions of new species. *Proceedings of the Royal Society of Victoria. New Series* 27(1): 1–11.

Lambert, P. 1996. *Psolidium bidiscum*, a new shallow-water psolid sea cucumber (Echinodermata: Holothuroidea) from the northeastern Pacific, previously misidentified as *Psolidium bullatum* Ohshima. *Canadian Journal of Zoology* 74: 20–31.

Ludwig, H. 1886. Die von G. Chierchia auf der Fahrt der Kgl. Italianische Corvette *Vettor Pisani* gesammelten Holothurien. *Zoologische Jahrbücher* 2: 1–36, 2 pls.

Ludwig, H. 1892. Echinodermen. Pp. 32–61, pls 15–17 in: Bronn,H. G., *Klassen und Ordnungen des Thier-Reichs* 2(3) 3 Das System. C. F. Winter'sche Verlagshandlung: Leipzig and Heidelberg. 460 pp., 17 pls.

Ludwig, H., and Heding, S. G. 1935. Die holothurien der Deutschen Tiefsee-Expedition. 1. Fusslose und dendrochirote formen. *Wissenschaftliche Ergebnisse der Deutschen Tiefsee-Expedition auf dem dampfer* Valdivia *1898–1899* 24: 123–214.

Massin, C. 1992a. Holothurians (Echinodermata) from Marion and Prince Edward Islands: new and little-known species. *Zoologica Scripta* 21(3): 311–24.

Massin, C. 1992b. Three new species of Dendrochirotida (Holothuroidea, Echinodermata) from the Weddell Sea (Antarctica). *Bulletin de l'Institut Royal des Sciences Naturelles de Belgique, Biologie* 62: 179–91.

Massin, C. 1997. First record of a Psolidae (Holothuroidea, Echinodermata) in the Mediterranean Sea (Sicilian Channel). *Bulletin de l'Institut Royal des Sciences Naturelles de Belgique, Biologie* 67: 101–06.

Mitsukuri, K. 1912. Studies on Actinopodous Holothurioidea. *Journal of the College of Science, Tokyo Imperial University* 29(2): 284 pp., 8 pls.

Mortensen, T. 1925. Echinoderms of New Zealand and the Auckland-Campbell Islands. 4. Holothurioidea. Pp. 322–86 in: *Papers from Dr. Th. Mortensen's Pacific Expedition 1914–1916. 29. Videnskabelige Meddelelser Dansk Naturhistorisk Forening, København 79*.

Mortensen, T. 1927. *Handbook of the Echinoderms of the British Isles*. Oxford University Press: London. 471 pp.

Ohshima, H. 1915. Report of the holothurians collected by the United States Fisheries Steamer *Albatross* in the northwestern Pacific during the summer of 1906. *Proceedings United States National Museum* 48: 213–91, pls 8–11.

Oken, L. 1815. *Lehrbuch der Naturgeschichte. 3. Zoologie*. Jena: Germany. Pp. xxxviii+850+xviii.

O'Loughlin, P.M. 2000. A review of the cucumariid genus *Psolidiella* Mortensen (Echinodermata, Holothuroidea). *Memoirs of Museum Victoria* 58: 25–37.

O'Loughlin, P.M., and O'Hara, T.D. 1992. New cucumariid holothurians (Echinodermata) from southern Australia, including two brooding and one fissiparous species. *Memoirs of the Museum of Victoria* 53: 227–66.

Pawson, D.L. 1964. The Holothuroidea collected by the Royal Society Expedition to Southern Chile, 1958–1959. *Pacific Science* 18(4): 453–70.

Pawson, D.L. 1967. The psolid genus *Lissothuria*. *Proceedings of the United States National Museum* 122(3592): 1–17.

Pawson, D.L. 1968a. Some holothurians from Macquarie Island. *Transactions of the Royal Society of New Zealand (Zoology)* 10(15): 141–50.

Pawson, D.L. 1968b. The echinozoan fauna of the New Zealand subantarctic islands, Macquarie Island, and the Chatham Rise. *Bulletin of the New Zealand Department of Scientific and Industrial Research* 187: 9–33, 3 figs, 1 pl.

Pawson, D.L. 1968c. A new psolid sea cucumber from the Virgin Islands. *Proceedings of the Biological Society of Washington* 81: 347–50.

Pawson, D.L. 1969a. Holothuroidea from Chile. Report No. 46 of the Lund University Chile Expedition 1948–1949. *Sarsia* 38: 121–45.

Pawson, D.L. 1969b. Holothuroidea. Pp. 36–38, 1 pl. in: Bushnell, V.C., and Hedgpeth, J.W. (eds), *Distribution of Selected Groups of Marine Invertebrates in Waters South of 35° S Latitude*. *Antarctic Map Folio Series (II)*. American Geographical Society: New York.

Pawson, D.L. 1970. The marine fauna of New Zealand: Sea cucumbers (Echinodermata: Holothuroidea). *Bulletin of the New Zealand Department of Scientific and Industrial Research* 201: 7–65, 10 figs, 2 pls.

Pawson, D.L. 1971a. The Western Australian psolid holothurian *Ceto cuvieria* (Cuvier). *Journal of the Royal Society of Western Australia* 54(2): 33–39.

Pawson, D.L. 1971b. *Ekkentropelma brychia* n.g., n.sp., an Antarctic psolid holothurian with a functionally lateral sole. *Proceedings of the Biological Society of Washington* 84(14): 113–18.

Pawson, D.L. 1982. Holothuroidea. Pp. 813–18; figs pp. 791, 792; pls 136, 137 in: Parker, S.P. (ed.-in-chief), *Synopsis and Classification of Living Organisms*. McGraw-Hill: New York.

Pawson, D.L., and Fell, H.B. 1965. A revised classification of the dendrochirote holothurians. *Breviora* 214: 1–7.

Pawson, D.L. and Valentine, J.F. 1981. *Psolidium prostratum*, new species, from off the east coast of the USA. (Echinodermata: Holothuroidea). *Proceedings of the Biological Society of Washington* 94(2): 450–54.

Perrier, R. 1902. Holothuries. Pp. 273–554, pls 12–22 in *Expéditions scientifiques du* Travailleur *et du* Talisman *pendant les années 1880, 1881, 1882, 1883.* Masson et Cie, Éditeurs: Paris.

Perrier, R. 1905. Holothuries antarctiques du Muséum d'Histoire Naturelle de Paris. *Annales des Sciences Naturelles. Zoologie* 1: 1–146, 5 pls.

Philippi, A. 1857. Vier neue Echinodermen des Chilenschen Meeres. *Archiv Naturgeschicht* 23: 130–34.

Rowe, F.W.E. 1982. Sea-cucumbers (class Holothurioidea). Pp. 454–76, figs 10:26-10:37, pls 29–32 in: Shepherd, S.A., and Thomas, I.M. (eds), *Marine Invertebrates of Southern Australia*. Part 1. South Australian Government Printer: Adelaide.

Rowe, F.W.E., and Gates, J. 1995. Echinodermata. In: Wells, A. (ed.), *Zoological Catalogue of Australia* 33: i–xiii, 1–510. CSIRO: Melbourne.

Selenka, E. 1868. Nachtrag zu den Beiträgen zur Anatomie und Systematik der Holothurien. *Zeitschrift Wissenschaftliche Zoologische* 18: 109–19, pl. 8.

Semper, C. 1868. Holothurien. *Reisen im Archipel der Philippinen. 2. Wissenschaftliche Resultate. Erster Band.* Engelmann: Leipzig. 288 pp., 40 pls.

Sluiter, C.P. 1901. Die Holothurien der *Siboga*-Expedition. Siboga-*Expéditie* 44: 1–142, 10 pls. Buchhandlung en Druckerei v. E. J. Brill: Leiden.

Studer, T. 1876. Über Echinodermen aus dem antarktischen Meere und zwei neue Seeigel von den Papua-Inseln, gesammelt auf der Reise SMS *Gazelle* um die Erde. *Monatsberichte der Königlich Preussichen Akademie der Wissenschaften*. Berlin. Pp. 452–65.

Thandar, A.S. 2006. New species and new records of dendrochirotid and dactylochirotid holothuroids (Echinodermata: Holothuroidea) from off the east coast of South Africa. *Zootaxa* 1245: 1–51.

Théel, H. 1886. Report on the Holothurioidea dredged by HMS *Challenger* during the years 1873–1876. *Report on the scientific results of the voyage of HMS* Challenger, *Zoology* 14(39): 1–290, 16 pls.

Tommasi, L.R. 1969. Lista dos Holothurioidea recentes do Brasil. *Contribuições Avulsas Instituto Oceanográfico, São Paulo* 15: 1–29.

Tommasi, L.R. 1971. Equinodermes do Brasil. *I. Sobre alguncas espécies novas e outras pouco conhecidas para o Brasil. Boletim Instituto Oceanográfico, São Paulo* 20(1): 1–23.

Vaney, C. 1906. Holothuries. Expédition Antarctique Française (1903–1905). *Sciences Naturelles: Documents Scientifiques*. Masson et Cie, Éditeurs: Paris. 30 pp., 2 pls, 1 map.

Vaney, C. 1914. Holothuries. Deuxième Expédition Antarctique Française (1908–10). *Sciences Naturelles: Documents Scientifiques*. Masson et Cie, Éditeurs: Paris. 54 pp., 5 pls.

Verrill, A.E. 1866. On the Polyps and Echinoderms of New England. *Proceedings of the Boston Society of Natural History* 10: 333–57.

Verrill, A.E. 1867. Notes on the echinoderms of Panama and the west coast of America, with descriptions of new genera and species. *Transactions of the Connecticut Academy of Arts and Sciences* 1(2): 251–322.