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New Australian deep-sea Goniasteridae (Asteroidea; Valvatacea)

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Abstract

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The deep-sea benthic fauna of Australia, especially asteroids found in depths greater than 1000 m, are poorly understood. Recent surveys have uncovered additional specimens that further illustrate the biodiversity of this largely understudied area. Two new genera and seven new species of Goniasteridae from deep-sea settings in Australian waters, including the South Pacific and Indian Ocean waters are described. A new genus, *Alloceramaster* was developed to accommodate not only the newly described species, but also other deep-sea species present in similar habitats from the Atlantic and the Pacific oceans. It addresses taxonomic shortcomings of *Ceramaster*, which has increasingly been used to accommodate other dissimilar species. Further occurrences of widespread deep-sea species, including *Bathyceramaster teres, Litonotaster intermedius*, *Nymphaster moebi*, and *Sibogaster nieseni* are also reported.

Keywords new species, taxonomy, deep-sea, Australia

Introduction

Australia has the third largest exclusive economic zone (EEZ) in the world, but surprisingly little is known about its deepest regions owing to a historical focus on coastal regions or settings less than 1000 m in depth. Over 70% of the EEZ, excluding Antarctic waters, is greater in depth than 1000 m, and 48% is deeper than 3000 m (Bond and Jamieson, 2022). Significant efforts have been undertaken to survey the biodiversity in this habitat, including trawl surveys of the Great Australian Bight (MacIntosh et al., 2018), the eastern coast of Australia (O'Hara et al., 2020) and video/trawl surveys of the Gascoyne Marine Park off Western Australia (Post et al., 2021).

Asteroids, popularly known as sea stars or starfishes, are members of the phylum Echinodermata whose shallow-water members demonstrate ecological significance as a keystone species, i.e. they affect ecological community structure (e.g. Paine, 1966, 1969). Relevant to taxa herein, members of the Goniasteridae have been documented as predators relevant to shallow-water systems (e.g. Birkeland, 1974). In situ observations of deep-sea Goniasteridae have shown that they are significant predators not only on deep-sea colonial octocorals such as the Isididae (the "bamboo" corals) (e.g. Mah, 2020, 2022), but also on sponges (Mah 2020). Multiple pentagonal forms comparable to those described herein were observed devouring multiple sponge types.

Ongoing efforts have begun to document the asteroid fauna of Australia in deep-sea habitats, especially those at greater than 1000 m depths. Among these taxa include poraniids (Mah 2023a), "toothless" Odontasteridae (Mah, 2023b), and Goniasteridae associated with coral predation (Mah 2024a). Primary monographs on Australian shallow-water faunas were documented principally by H.L. Clark (1914, 1916, 1921, 1946). More recent accounts of shallow-water fauna included the catalogue/checklist by Rowe and Gates (1995) and a comprehensive guide by Marsh and Fromont (2020).

Newly collected specimens studied at Museums Victoria and the Western Australian Museum motivated this report, which is part of an ongoing survey of deep-sea Goniasteridae following the overview of Hippasterinae, Circeasterinae and other taxa relevant to deep-sea corals in Mah (2024a).

Materials and Methods

Specimens referenced herein are housed at Museums Victoria in Melbourne, Australia (NMV), the Western Australian Museum in Perth (WAM), and the National Museum of Natural History in Washington, D.C. (USNM). Measurements throughout the manuscript are in centimetres except for scales on figures, which are in millimetres.

I have adopted Marsh and Fromont's (2020) format of identifying relevant characters under each diagnosis in **bold**.

Terminology (Figure 1A–D)

Taxa discussed here utilise characters that are more clearly communicated with specific definitions and as such, I have outlined and figured several commonly utilised terms for the sake of clarity.

Fasciolar groove. The space formed around the elongate shaft of tabulate plates ("tabulae") and/or paxillae which often facilitates water flow and provides aeration of the papulae located around the base of each abactinal plate. Fasciolar grooves also called "fascioles" are formed below granules and other surficial accessories on marginal and actinal plate surfaces.

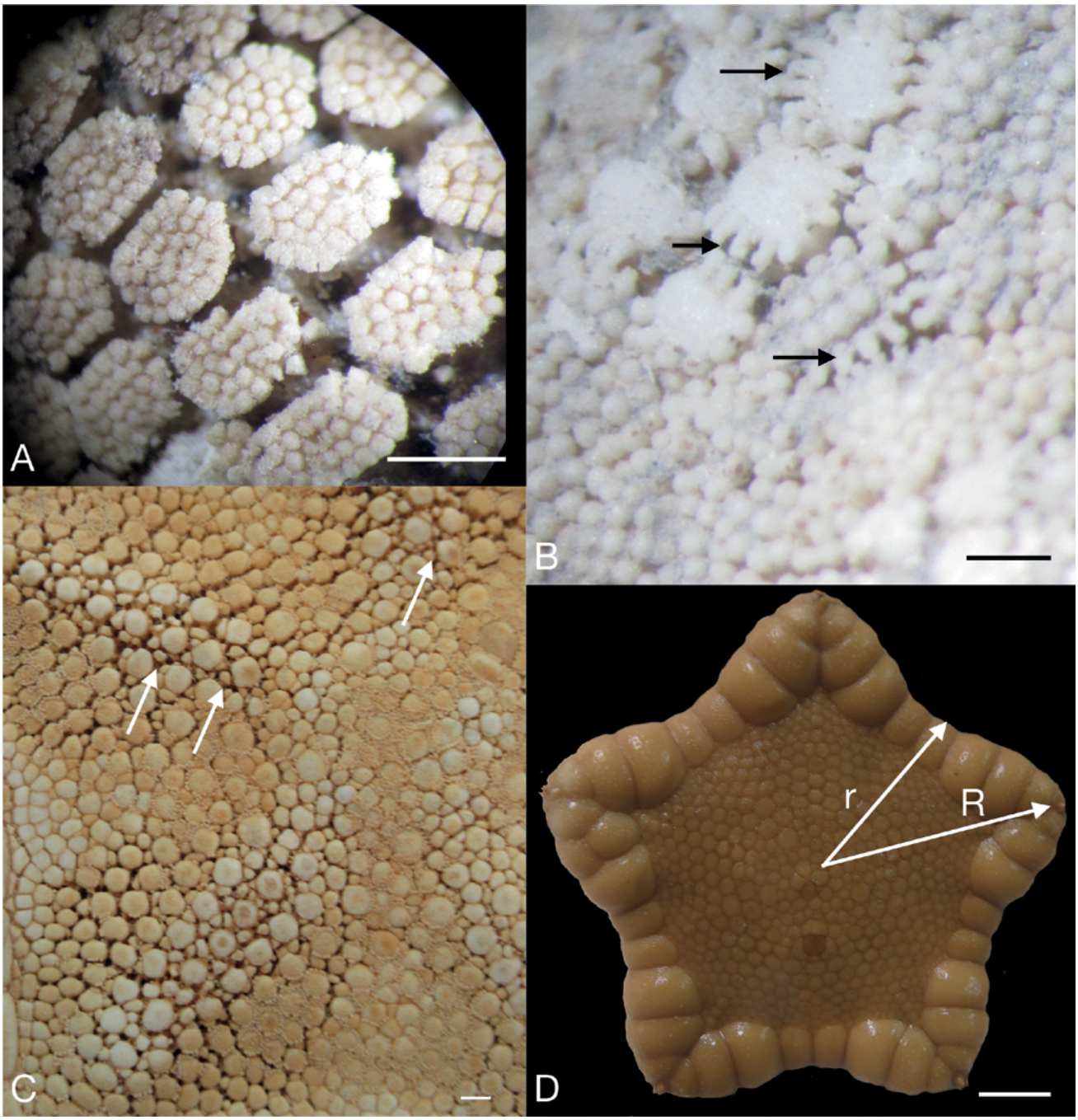

Figure 1. Morphological Terminology: a, Strongly tabulate plates with well-developed fasciolar channels, from *Ceramaster patagonicus* USNM 1123437; b, Abactinal papular plate region. Shallow/weakly tabulate plates with shallow fasciolar channels from *Alloceramaster affinis* USNM E11260. Peripheral granules indicated with black arrows; c, Secondary plates identified by white arrows, observed in *Peltaster placenta* IE-2019-4504, Mediterranean south of Crete; d, *Sphaeriodiscus ganae* Mah 2018, MNHN-IE-17139, displaying enlarged superomarginal plates. Scale bar: 1.0 mm = a, b, c; Scale bar: 10.0 mm = d.

Granules and other accessories. In many instances, plate surfaces are covered by numerous small to minute calcitic structures of various shapes and sizes. Attachment is variable, some show easily deciduous attachment and fall off easily, whereas others are strongly attached and require considerable effort to remove. In some instances, a convexity or pitting is present on the corresponding plate surface, but in others plate surfaces remain flat. These structures, also defined herein as "accessories" frequently show variable shapes. Most often, round features are termed "granules", which can range between distinctly spherical, cylindrical or round, to more polygonal or blocky in shape with angular surfaces. These features can vary in shape, such that some display points and are shaped as pointed or conical structures that are termed spinelets. Terminology can refer to both "granular spinelets" and/or "spinelet like granules" where intermediate forms are recognised.

Papular pore area. (Figures 1A–B, 2A–B). All known members of the Goniasteridae display a region where papulae emerge through pores in the abactinal surface. For the taxa at hand, this region is usually present at the base of the arm along the radius of the arm. The size and shape of this area varies, but it tends to occupy a region beginning proximally along the arm and forming a rough diamond-shaped area with an accompanying fasciolar groove, which is variably shallow to well developed. Papulae, often 6 to a plate, occur at corners along the plates of these areas.

"R" and *"r"* (Figure 1D) are used to show approximate dimensions of the body shape. R is the distance from disk centre to arm tip. r is the distance from disk center to its edge. These measurements are shown here in centimetres unless otherwise noted. Note that the ratio of R/r does not have units.

Secondary plates. (Figure 1C). Abactinal plates which are significantly smaller (approximately 10 to 25% of length/width of primary plates) than others on the abactinal surface.

Tabulate plates. (Figures 1A–B) Abactinal plates which are fundamentally taller than wide, many with a cylindrical shaft widening to a broad "table" like top surface with a variable base. Proportions and shape of the shaft and top are variable. The surface is usually adorned with granules that vary from round and spherical to large and prismatic in shape. These are consistently differentiated from paxillae which are topped by spines. Fasciolar grooves are generally formed where tabulate plates or "tabulae" are present.

Strongly tabulate. (Figure 1A) This describes tabulate plates with an elongate, cylindrical shaft such that a large and extensive fasciolar groove. Granules and surficial accessories are strongly expressed.

Weakly tabulate. (Figure1B–C) This describes more mound like or short plates forming a relatively constrained or small fasciolar groove. On plates with short plates, the negative space formed by the granules and/or spines form the fascioles around the plates.

Systematics

Goniasteridae Forbes, 1841.

The last account of Australian asteroids (Rowe and Gates, 1995) showing Goniasteridae below 1000 m included three genera and species, *Hippasteria trojana* (now *H. phrygiana*), 366–1152 m, *Mediaster arcuatus*, 630–1070 m, and *Nymphaster moebii,* 195–1655 m out of 34 species in 19 genera (Gates and Rowe, 1995). These species were present in a much shallower primary range, only extending at the lower limit below 1000 m. The Pseudarchasteridae, including *Pseudarchaster* and *Paragonaster* were removed from the Goniasteridae by Mah and Foltz (2011) since Gates and Rowe (1995).

Taxonomic Uncertainty between *Sphaeriodiscus* Fisher, 1910 and *Peltaster* Verrill, 1899

As has been discussed in other accounts (e.g. Mah, 2018) taxonomic uncertainty exists between these two genera, with *Sphaeriodiscus* possibly a synonym of *Peltaster.* The problematic aspects of this relationship are demonstrated by the Atlantic *Peltaster placenta*, which is apparently present on the Western (North American) and Eastern (European) sides of the Atlantic. Numerous synonyms, and taxonomic placements have been applied to this species, with *P. placenta* having been assigned to both *Ceramaster* and *Sphaeriodiscus* throughout its history (Clark and Downey, 1992). Downey in Clark and Downey (1992) argued that this was one highly variable, wide-ranging taxon. Accounts, such as those by A.M. Clark and Tortonese (1956) argued for placement within *Sphaeriodiscus*. Tortonese (1984) described morphological variation within this species, particularly in Mediterranean populations illustrating the close similarity in terms of enlarged penultimate superomarginals shared with typological *Sphaeriodiscus*.

Peltaster placenta from the western Atlantic display numerous secondary plates (Fig. 1C) (Verrill, 1899, Halpern, 1977, Clark and Downey, 1992), which are absent from *Sphaeriodiscus* and Mediterranean *P. placenta*. Consequently, Mediterranean *P. placenta* conform nearly exactly to *Sphaeriodiscus,* but those elsewhere – especially those displaying secondary plates – do not.

Thus, it appears that the conclusion of a single wide-ranging Atlantic *P. placenta* is premature. Based on taxonomic assessments herein, different outcomes could include the likelihood of two or more species within *P. placenta,* an outcome hinted at by the numerous synonyms listed by Clark and Downey (1992) or alternatively *Peltaster* and *Sphaeriodiscu*s are synonymous. Resolution of this issue is beyond the scope of this paper. Further tests of these concepts, especially with molecular data is desirable.

Taxonomic Diversity within *Ceramaster*.

Historically one of the largest genera within the Goniasteridae has been the genus *Ceramaster,* which currently includes 15 extant and 4 fossil species (Mah, 2024c), but has included many more species throughout its history displaying variable morphologies. In addition to taxonomic overlap with other

genera, such as *Peltaster* and *Sphaeriodiscus*, as documented in Mah (2011, 2022, among others), species within *Ceramaster* are diverse and a review suggests discrete morphological groupings, calling for further taxonomic expansion.

Most *Ceramaster* species listed in Mah (2024c) show affinities with *C. patagonicus* or the type species *C. granularis* sharing prismatic, very coarse, homogeneous granules with well-developed fasciolar grooves. This treatment disagrees with the action taken by Clark and Downey (1992) which positioned *C. patagonicus* and related species as subspecies of *C. grenadensis*. Characters uniting these species as part of a larger "*grenadensis*" group were not confirmed and comparison of *C. grenadensis* (Perrier, 1881) and related specimens with other *Ceramaster* species suggests discrete character differences that warranted distinction from the typological definition of *Ceramaster* as represented by *C. granularis*, the type species designated by Fisher (1906).

Species which are differentiated from the more typological *C. granularis* show more weakly developed tabulae, finer (non-prismatic) abactinal granules and heterogeneous granule types between the radial papular areas the other abactinal plate regions. Fasciolar grooves in *C. granularis/patagonicus*-type species are well developed on the abactinal surface whereas those in *C. grenadensis* and allied species are shallow to absent, except for the radial papular regions.

Halpern (1970) attributed many of the differences in the granulation type of the papular radial plate regions of *C. grenadensis* as variation, sometimes attributed to deeper water forms. In this respect, the presence of distinctly rhombic to elongate rectangular peripheral granules are evident in deep-water species. However, it is argued that the angular granules present on the papular areas are a consistent character present in this and related species. Some of these species, such as "*Pentagonaster*" *affinis,* had been previously synonymised with *C. grenadensis*. I was unable to arrive at Halpern's (1970) conclusion that differently sized granules demonstrated variation with intermediate forms based on the available material. It should be noted that simply demonstrating differing peripheral granules around radial/papular versus interradial regions did not signify a unique character for this group. Some *Sphaeriodiscus* species for example demonstrate heterogeneous peripheral granule types but differ in several other regards. Abactinal plates, the presence of fasciolar grooves in the papular regions, and the marginal plate shape and number were also considered significant shared characters.

Relevant species which demonstrated the distinct radial granules, included not only the Atlantic *C. grenadensis* and the re-instated *C. affinis*, but also the Pacific *C. pointsurae*. Two new Australian species demonstrating this character are also described from Australian waters. Species of *Alloceramaster* are collected primarily from below 1000 m depths.

Key to *Ceramaster* and related genera.

(0) Abactinal plates strongly tabulate. Fasciolar grooves well developed extending wide areas (40–50%) of radial and in some instances interradial regions. Granules coarse to angular (Fig. 10B). ..... *Ceramaster* (*sensu stricto, C. patagonicus* and related lineage)

(0') Abactinal plates abutted with flat or mound-like plates that are weakly tabulate. Fasciolar grooves are visible and present, but only as void space around peripheral granules (or other accessories). These present around a more restricted papular area around the proximal arm region. .. (1)

(1) Marginal plate number per interradius high, 18 to 60 (arm tip to arm tip). Marginal plates not forming dorsal-facing frame. Body strongly stellate, R/r = 1.8 to 4.0. Penultimate superomarginals not enlarged. All known species at greater than1000 m depths. .... *Bathyceramaster* Mah, 2016

(1') Marginal plate number 8 to 20 per interradius, mostly 10 to 15. Marginal plates forming dorsal facing frame, occupying 15–25% of distance r. Body tends to be pentagonal or at most, weakly stellate (1.0 to 1.8). Penultimate or adjacent superomarginals enlarged or not. Species occurring in shallow (approx. 10 m) and deep-water settings. ..... (2)

(2) Peripheral granules and abactinal plates in papular regions differing in shape from those elsewhere (especially interradially). Granules rhomboid to spinose, abactinal plates triangular or otherwise different from others. No secondary plates. ..... *Alloceramaster* nov. gen.

(2) Granules and abactinal plates on papular regions identical to those elsewhere. Abactinal plates are round to irregular in shape. Secondary plates present or absent. ..... (3)

(3) Secondary plates not present. Marginal plates per interradius number between 6 to 10, many with 8, forming broad dorsal facing periphery. Penultimate superomarginal plate and those adjacent to it enlarged, up to 3 times the size of adjacent marginal plates (this is the typological distinction). *Note: Distinctions between *Sphaeriodiscus* and *Peltaster* are inconsistent and should be regarded cautiously. See explanation herein. ..... *Sphaeriodiscus* Fisher, 1910*

(3') Secondary plates present or absent (Fig. 1C). Marginal plates 7 to 30, mostly 15 to 20. Penultimate superomarginal plates not enlarged in most, with exceptions in *P. placenta*. ..... *Peltaster* Verrill, 1899*

***Alloceramaster* nov. gen.**

Etymology. The genus name is based on the Greek "allos" for "other", alluding to the difference from the established genus *Ceramaster.*

Diagnosis. Overall body forms pentagonal or weakly stellate (R/r = 1.1–1.9) with few known adults greater in size than R = 2.0 to 5.0 cm. Arm tips blunt. Interradial arcs weakly curved to straight.

Fasciolar grooves present around radial papular regions, but shallow to absent around other abactinal plate regions. Two distinct types of abactinal accessories, the more rectangular to rhombic shaped granules forming a periphery around papular radially positioned, abactinal plates versus those forming round to polygonal granules forming periphery around the remainder of the plates.

Marginal plates per interradius (arm tip to arm tip), 10–18, most bald or with large bald region on plate surface. Actinal plates quadrate to polygonal, covered by granules. Furrow spines 2 to 9, blunt, subambulacral spines 3 to 4.

Comments. *Alloceramaster* nov. gen. is proposed to accommodate *C. grenadensis* and other related taxa with shared characters as outlined herein, including *P. affinis*, *C. pointsurae*, and two new Australian species. *Pentagonaster affinis* is designated as the type species for the genus.

Although split from *Ceramaster,* members of *Alloceramaster* share more in common morphologically with *Sphaeriodiscus*, displaying distinctly different abactinal plates present around the papular pore region. Peripheral granules (e.g. Fig. 2A–B) on radial regions differ from interradial regions and elsewhere, separate from other abactinal plates and have more weakly-developed fasciolar grooves. In conjunction with the well-developed fasciolar grooves, typological *Ceramaster* have well-developed abactinal tabulate plates (e.g. Fig. 10A–C) whereas those in *Alloceramaster* are shorter and are more weakly developed. Granules in *Alloceramaster* are smaller, rounder, and more abundant than those observed in typological *Ceramaster,* which tend to be larger and polygonal in shape. This is in stark disagreement with Clark and Downey's (1992) taxonomy which argued *C. patagonicus* as a subspecies of *C. grenadensis*. *Alloceramaster* also shares several characters with *Bathyceramaster*, showing abutted abactinal plates with papular, or proximal fasciolar grooves and demonstrating an abundance of granules present over abactinal and marginal plate surfaces. *Alloceramaster* and *Bathyceramaster* tend to occur below 1000 m depths, whereas *Ceramaster* shows a broad range between 20 and 1500 m.

As with other deep-sea Goniasteridae, such as *Bathyceramaster, Alloceramaster* is widely occurring in deep-sea settings. Although variation based on morphological data suggests multiple species, independent phylogenetic data for other widely occurring asteroid genera, such as *Hippasteria* (Foltz et al., 2013) have suggested some species do not always show morphological, taxonomic and molecular congruence.

Key to *Alloceramaster*

(0) Abactinal plates of papular region trapezoidal/triangular in shape (Fig. 2A–B). Peripheral granules elongate, rectangular in shape. Dorsal and lateral surface of superomarginal plates completely bare. Tropical Atlantic. ..... *Alloceramaster affinis* nov. gen. nov. comb.

(0') Abactinal plates of papular region polygonal to round (e.g. Fig. 6A–B, D). Peripheral granules elongate, trapezoidal or triangular. Bare region discrete, raised, but limited to a quadrate or similarly shaped region, located mostly on dorsal surface of superomarginal plates. ..... (1)

(1) Peripheral granules around abactinal plates of papular region rectangular in shape, thickened (Fig. 6B, D). North Pacific. ..... *Alloceramaster pointsurae* (Mah, 2016)

(1') Peripheral granules around abactinal plates of papular region trapezoidal to triangular in shape (e.g. Fig. 3B, 5D). ..... (2)

(2) Penultimate superomarginal plate enlarged, abutted triangular in shape (Fig. 4A, C). South Pacific and Indian Ocean. ..... *Alloceramaster leios* n. sp.

(2') Penultimate superomarginal plate not enlarged. Similar in shape to other superomarginals. ..... (3)

(3) Marginal plates 14–16 per interradius. Granular covering on plates discrete, showing clear association with underlying plates. No pedicellariae. Bare patch small occupying about 40% of total superomarginal width, round to irregular in size. Tropical Atlantic. ..... *Alloceramaster grenadensis* nov. gen. nov. comb.

(3') Marginal plates 10 per interradius. Granular covering on interradius dense, obscuring boundaries between plates. Forceps like pedicellariae present abactinal, actinal surface. Bare patch occupying approximately 50% of total superomarginal width, quadrate in shape. Indian Ocean. ..... *Alloceramaster minus* n. sp.

***Alloceramaster affinis* Perrier, 1884 nov. gen, nov. comb.**

Figures 2A–F

Pentagonaster affinis Perrier, 1884: 168, 183, 186, 243, pl.8 fig. 4; Sladen, 1889: 265, 267, 744; Perrier, 1894: 40, 390; Halpern, 1970: 216.
Tosia affinis Perrier, 1884: 183.
Pyrenaster affinis Verrill, 1899: 168, 1915: 222.

Material Examined. MCZ AST–404. Paratypes for *Pentagonaster affinis* Off Cuba, north of Navassa Island, Western Central Atlantic. 19º 5' 55" N, 74º 49' 5" W, 2194.5 m, Coll. Alexander Agassiz, USCSS *Blake* Expedition, 1877–1880, 19 December 1878. 3 dry specs. R = 1.4 r = 0.9, R = 1.3 r = 0.8, R = 1.6 r = 0.9

USNM E45324. Exuma Sound, Bahamas, North Atlantic Ocean. 23° 51' 0" N, -75° 49' 47.9994" W, 1853–1858 m. Coll. R.S. Carney, R/V *Columbus Iselin*, 3 September 1980. 6 dry specs. R = 2.7 r = 1.5, R = 3.1 r = 1.9, R = 3.1 r = 1.7., R = 2.5 r = 1.4, R = 2.6 r = 1.6, R = 2.2 r = 1.3.

USNM E53737. Serrana Bank, Nicaragua, Caribbean Sea, North Atlantic Ocean. 14° 33' 0" N, -79° 46' 11.9994" W, 2341 m. Coll. W. E. Pequegnat, 14 July 1970. 6 dry specs. R = 1.7 r = 1.0, R = 1.6 r = 0.9, R = 1.6 r = 0.9, R = 1.5 r = 0.9, R = 1.4 r = 0.9, R = 1.5 r = 0.9

USNM E11257. NW of Libreville, Gabon, Gulf of Guinea, North Atlantic. 1° 13' 0.1194" N, 7° 46' 0.12" E, 2525 m. Coll. R/V *Pillsbury*, 17 May 1965. 1 dry spec.

USNM E11260. NW of Libreville, Gabon, Gulf of Guinea, North Atlantic. 1° 13' 0.1194" N, 7° 46' 0.12" E, 2525 m. Coll. R/V *Pillsbury*, 17 May 1965. 44 dry specs.

USNM E19088. Off west coast of Jamaica, Long Bay, Caribbean Sea, North Atlantic. 18° 16' 0.12" N, 78°31' 5.8794" W, 1244–1830 m. Coll. R/V Pillsbury, 8 July 1970. 1 dry spec.

USNM E19090. West of Cape Falls, Dominican Republic, Caribbean Sea, North Atlantic. 17° 52' 59.8794" N, 71° 58' 59.8794" W, 1893–3109 m. Coll. R/V *Pillsbury,* 17 July 1970. 5 dry specs.

USNM E19091. SE of Acklins Island, Mayaguana Passage, Bahamas, North Atlantic. 21° 58' 0.012" N, -73° 41' 30.1194" W, 1650 m. Coll. R/V *Pillsbury,* 22 July 1971. 5 dry specs.

USNM E19003. NE of Cape Dame-Marie, Haiti, Caribbean Sea, North Atlantic. 18° 51' 0" N, 74° 30' 0" W, 2545 m. Coll. R/V *Pillsbury* 1 July 1970. 14 dry specs.

USNM 1664246. Exuma Sound, Bahamas, North Atlantic Ocean. 24° 0' 0" N, -75° 19' 59.988" W, 1884 m, Coll. R/V *Columbus Iselin*, 4 March 1973. 1 dry spec. R = 1.7 r = 1.0

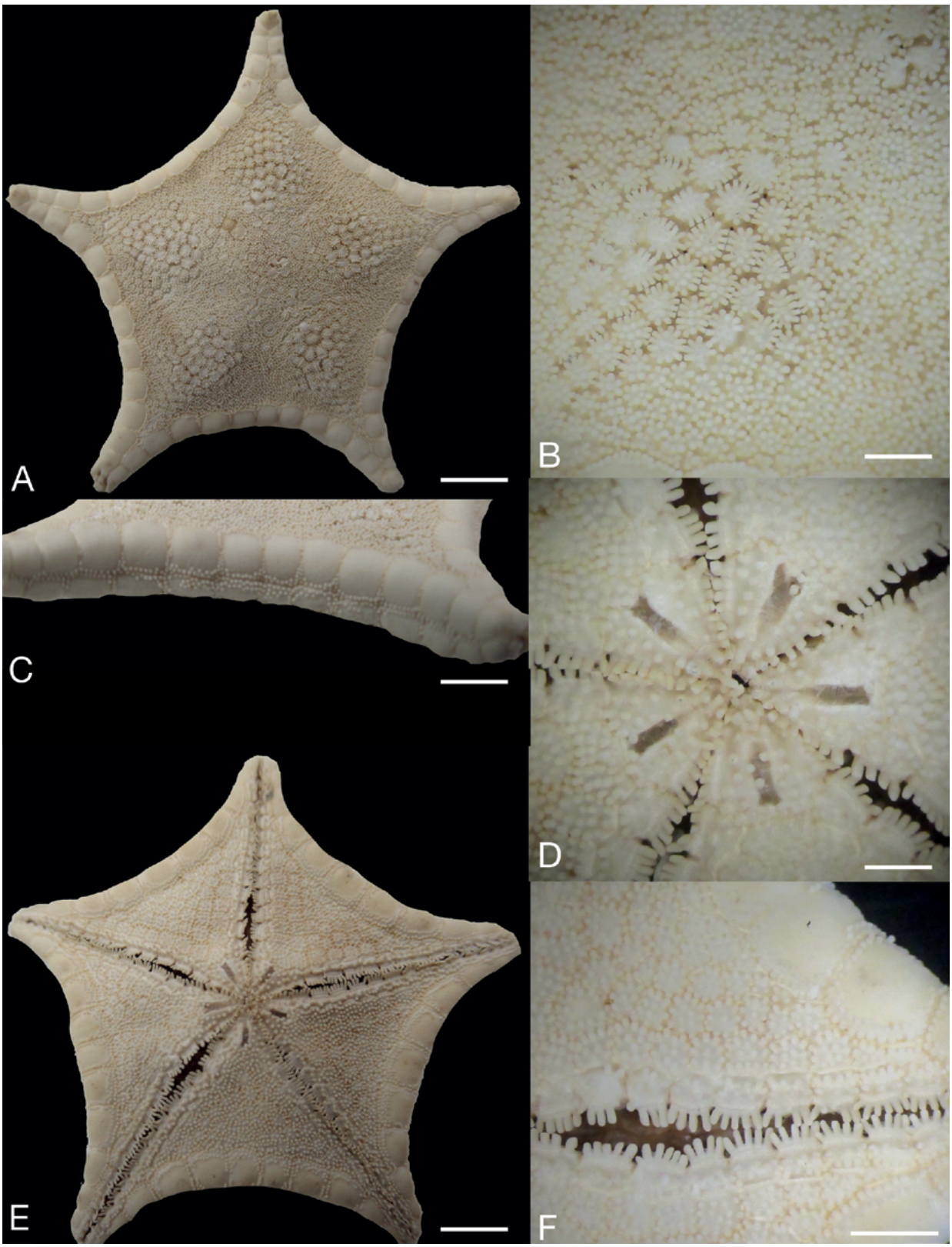

Figure 2. *Alloceramaster affinis* (Perrier 1884) USNM E11257: a, Abactinal; b, Closeup abactinal; c, Abactinal-lateral view; d, Oral region; e, Actinal; f, Adambulacral/Furrow spination. Scale bar = 5.0 mm: a, c, e; Scale bar = 2.0 mm: b, f; Scale bar = 1.0 mm: d.

USNM 1664247. Exuma Sound, Bahamas, North Atlantic Ocean. 24° 8' 59.9994" N, 75° 54' 0" W, 1842 m. Coll. R/V *Columbus Iselin* 9 Nov 1974, 3 dry specs.

USNM 1664249. NW of Great Inagua Island, Bahamas, North Atlantic. 21° 19' 12" N, 73° 45' 29.88" W, 2523 m. Coll. R/V *Pillsbury* 21 July 1971. 3 dry specs.

USNM 1607692. Caribbean Sea 12° 24' 6.0006 "N, 75° 24' 0" W, 2353–2303 m, Coll. R/V *Columbus-Iselin*, 7 September 1980. 12 dry specs.

Diagnosis. **Identified by papular regions proximally on arm with elongate, rectangular peripheral granules,** abactinal plates triangular to irregularly round, each with well-developed fasciolar grooves. Marginal plates elongate when viewed dorsally. Furrow spines 2–5 at R = 1.5 (on paratype) to 5–7 at R = 3.0, spatulate, varying from pointed and triangular to blunt, quadrate in shape. Subambulacral spinelets, 3 to 5.

Comments. Perrier's *P. affinis* should be reinstated as an accepted species, herein as *A.affinis* n. comb. Halpern (1970:216) argued that *C. affinis* (Perrier, 1884) was a synonym of *C. grenadensis* (Perrier, 1881) based on the assertion that the "only difference" was based on the granulation of the radial plates which he correctly observed as being elongate rather than being more square, as in *C. grenadensis*. Halpern further argued that these peripheral granules ran a wide spectrum of intermediate forms within *C. grenadensis* with a tendency towards elongation of these granules in deeper-water forms. The distinction between deep and shallow peripheral granules in these species is confirmed, but it is argued that this represents a distinction between species in different settings rather than simple variation. No examples of intermediate morphologies could be located which supported his claim of intermediate forms. Similarly, Halpern argued (1970: 218) that the "state of relaxation or contraction was important in the appearance of the radial plates". Examination of a range of specimens, which were consistent with the type specimens of "*P. affinis*" as well as *C. grenadensis* did not provide the same conclusion. The material examined by Halpern (1970) was also from a range of depths, most of which were shallower than those of specimens with the "*affinis*" type morphology. This species was recorded from abyssal depths: 1650–3109 m.

Although distinguished from other *Alloceramaster* based on the trapezoidal/triangular abactinal plates in the papular regions, this character is also observed in the South Pacific *Sphaeriodiscus maui*, which bears a similar appearance, but displays fewer marginal plates per interradius (n = 8 versus n = 15 in *A. affinis*), more abundant, denser abactinal granulation, and is overall less stellate, lacking the tapering distal arm tip. In comparing other tropical Atlantic *Alloceramaster*, *A. affinis* displays triangular abactinal plates on the papular region with slender, rectangular peripheral granules whereas *A. grenadensis* has round to polygonal abactinal plates on the papular region with trapezoidal to triangular peripheral granules.

Occurrence. Tropical Western Atlantic, Cuba, the Bahamas, Dominican Republic, Haiti, Nicaragua Gabon, Gulf of Guinea, 1650–3109 m.

Description. Body shape pentagonal to weakly stellate, R/r = 1.5–1.8, arms triangular, acutely tapering to pointed tip. Abactinal plates convex, mound-shaped, round to polygonal in outline. Fasciolar grooves shallow to absent around most plates save for specific radial papular regions (Fig. 2A–B), which are deeper and more well developed. Abactinal plates covered by round granules, 2 to 15 per plate, covering complete surface, evenly spaced save for those plates present radially, on proximal arm region, ranging from 4 to 10 which possess narrow rectangular peripheral granules (Fig. 2B). Central surface of these plates with round granules.

Marginal plates, 11–13 per interradius (arm tip to arm tip), but not clearly associated with size. When viewed dorsally, marginal plates elongate, forming narrow edge along periphery. Distalmost superomarginal plates abutted. Superomarginal plate surface (Fig. 2C) devoid of granules or other accessories, but with a pattern present with a wrinkled ornament on the surface. Inferomarginal plates similarly devoid of surficial accessories, covered with a pronounced wrinkle-like pattern on plate surface. Marginal plate periphery with 20 to 40 granules, round, approximately 8 to 10 per side. Superomarginals and inferomarginals slightly offset forming zigzag contact.

Actinal plates irregular to polygonal in shape, covered by granules, 6–15 similar to those on abactinal surface (Fig. 2E). Plates in 2 to 3 full series in chevron-like arrangement. Fasciolar grooves present but shallow.

Furrow spines 2–5 at R = 1.5 (on paratype) to 5–7 at R = 3.0, spatulate, varying from pointed and triangular to blunt, quadrate in shape (Fig. 2F). Adambulacral plate surface adjacent to furrow spines with a single row of short subambulacral spinelets, 3 to 5, with a distinct space separating them from both the furrow spines (and the adambulacral edge) and on the other side, contact with the actinal plates and granules. Oral plates with 9–10 furrow spines, one large spine projecting into mouth on each oral plate (two projecting into mouth per interradius). Oral plate surface with 6 jagged spines along the edge of the diastema between plates (Fig. 2D), each quadrate to polygonal in cross-section. Similar spines, 4–6 present on oral plate surface, all widely spaced to absent.

Alloceramaster grenadensis (Perrier, 1881) nov. gen. nov. comb.

Figures 3A–E

Pentagonaster grenadensis Perrier, 1881: 19; 1884: 168,181, 186, 232–233, pl. 8, fig. 2; Sladen, 1889: 265, 266, 744; Perrier, 1894: 39, 390.

Ceramaster grenadensis Verrill, 1915: 222; Halpern, 1970: 213, figs. 8–9; Downey, 1973: 49, pl. 17 figs. C, D.

Material Examined. MCZ Holotype. AST–416, Off Grenada, 12° 3' 55.0002" N -61° 49' 39.9966" W, 1053 m. Coll. Alexander Agassiz, USCSS *Blake* Expeditions, 2 March 1879. 1 dry spec. R = 2.6 r = 1.7.

USNM E12700. NW of Montserrat, Caribbean Sea, North Atlantic Ocean, 589 m. Coll. R/V *Oregon* II. 8 December 1969. 1 dry spec. R = 3.1 r = 1.8.

USNM E12702. Northeast of Honduras, Caribbean Sea, North Atlantic, 16° 31' 48" N, -83° 24' 0" W, 914 m. Coll. U.S. Fish and Wildlife Service, 24 October 1970. 3 dry specs. R = 3.7 r = 2.0, R = 3.1 r = 1.5, R = 2.6 r = 1.5.

USNM E12780. North of St. Eustatius, St. Kitts and Nevis, Caribbean Sea, North Atlantic Ocean. 17° 46' 11.9994" N, 62° 58' 47.9994" W, 649–668 m. Coll. R/V *Oregon,* 18 May 1967. 4 dry specs. R = 2.5 r = 1.3 R = 2.3 r = 1.1, R = 1.8 r = 1.1, R = 2.0 r = 1.1

USNM E12781. East of Saint Christopher, Saint Christopher and Nevis Island, Caribbean Sea, North Atlantic Ocean. 17° 15' 0" N, 62° 22' 11.9994" W, 580 m. Coll. R/V *Oregon* II, 8 December 1969. 1 dry spec. R = 3.0 r = 1.6

USNM E12782. NE of St. Kitts, St. Kitts and Nevis, Caribbean Sea, North Atlantic Ocean. 17° 23' 59.9994" N, 62° 32' 59.9994" W, 644 m. Coll. R/V *Oregon II*. 8 December 1969. 1 dry spec. R = 2.1 r = 1.3.

USNM E12783. East of Saint Christopher, Saint Christopher and Nevis Island, Caribbean Sea, North Atlantic Ocean. 17° 23' 59.9994" N, 62° 28' 11.9994" W, 629 m. Coll. R/V *Oregon* II, 8 December 1969. 2 dry specs. R = 2.2 r = 1.2, R = 3.5 r = 1.8.

USNM E13218. Honduras, Caribbean Sea, North Atlantic Ocean. 16° 43' 11.9994" N, 82° 37' 47.9994" W, 430–612 m. Coll. R/V *Alaminos*, 12 July 1970. 1 dry spec. R = 2.1 r = 1.3.

USNM E19089. West of Los Roques Islands, Caribbean Sea, North Atlantic, 11° 46' 0.12" N, 67° 5' 41.9994" W, 1098–1175 m. Coll. 24 July 1968. 1 dry spec. R = 2.7 r = 1.7.

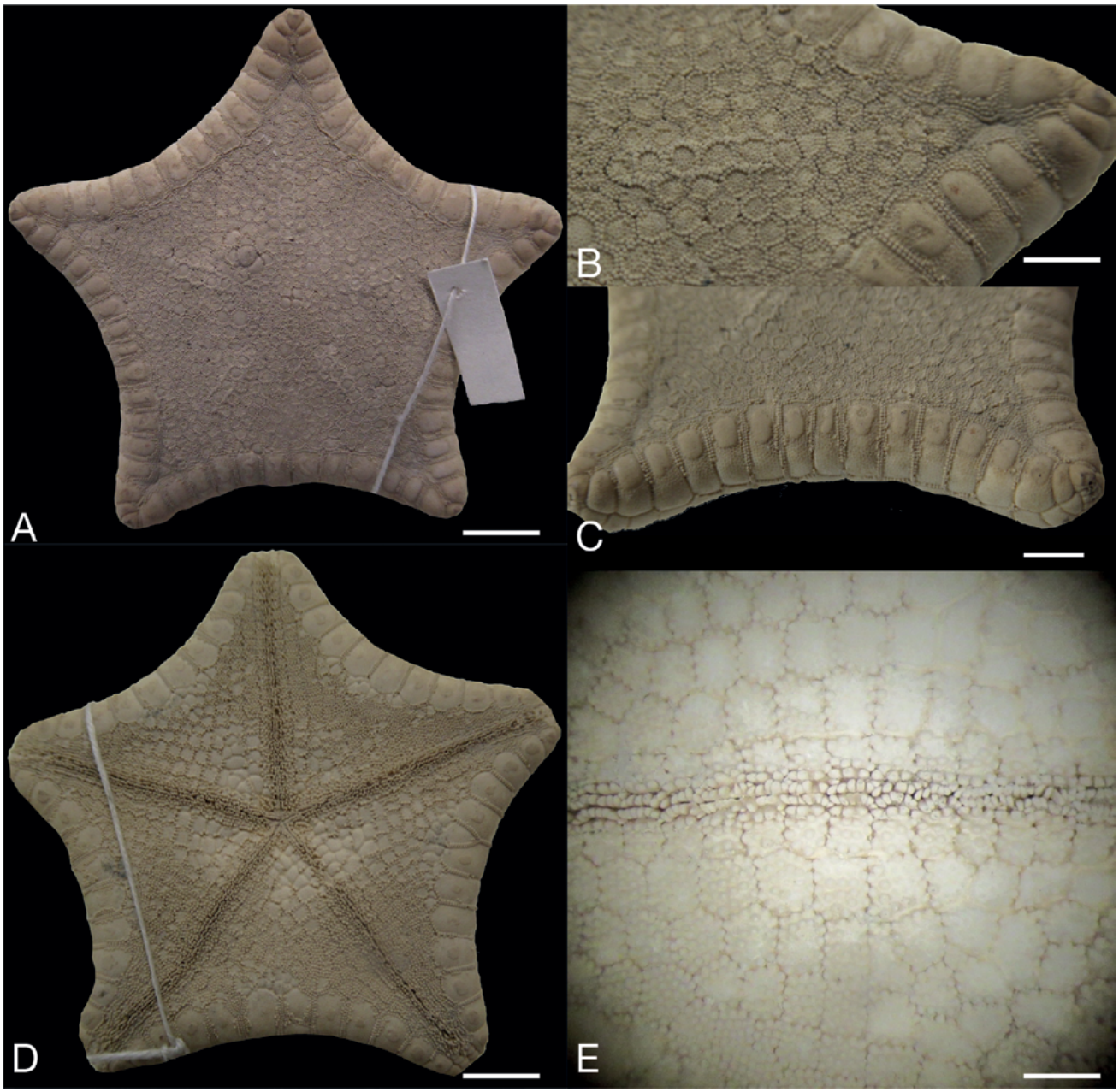

Figure 3. *Alloceramaster grenadensis* (Perrier 1881) MCZ AST-416 Holotype: a, Abactinal; b, Closeup abactinal and arm tip region; c, Abactinal-lateral view; d, Actinal; e, Adambulacral/Furrow spination. Scale bar = 5.0 mm: a, d; Scale bar = 2.0 mm: b, c, e.

USNM E19094. North of Portland Rock, Pedro Bank, Jamaica, Caribbean Sea, North Atlantic, 17° 21' 24.12" N, 77° 34' 47.9994" W, 805–1089 m. Coll. R/V *Pillsbury*, 15 July 1970. 1 dry spec. R = 1.4 r = 0.9.

USNM E22187. Off NE coast of Nicaragua, Caribbean Sea, North Atlantic Ocean. 15° 1' 47.9994" N, -81° 4' 47.9994" W, 439–631 m. Coll. R/V *Alaminos*, 13 July 1970. 1 dry spec. R = 2.3 r = 1.5.

USNM 1233808. N of Black Rocks, St. Kitts and Nevis, Caribbean Sea, North Atlantic. 17° 33' 0" N, 62° 46' 12" W, 668 m. Coll. R/V *Oregon II*, 9 December 1969. 1 dry spec. R = 3.5 r = 2.0.

USNM 1241639. East of Paraguana Peninsula, Venezuela, Caribbean Sea, North Atlantic Ocean. 11° 49' 12" N, 69° 24' 0" W, 549 m. Coll. R/V *Oregon*, 3 October 1963. 1 dry spec. R = 2.7 r = 1.7.

Diagnosis. **Abactinal plates of papular region, polygonal to round in shape, with peripheral granules distinctly trapezoidal, triangular in shape.** Superomarginal plates 12–15 per interradius. Bare patch small, irregular in shape. Furrow spines 4–9, blunt, quadrate in cross-section, mostly 7 to 8. Subambulacral spines in one or two rows, each with approximately three blunt, spines in each series, quadrate in cross-section

Comments. *Alloceramaster grenadensis* nov. comb. is considered herein a distinct species and a separate taxon from *C. patagonicus* contrary to the taxonomic conclusion outlined by Clark and Downey (1992) which concluded *C. patagonicus* was a subspecies of *C. grenadensis* with the implication of *C. grenadensis* as "the most widely distributed, as well as one of the most abundant shallow-water asteroid species in the world". (Clark and Downey, 1992: 237). This is especially disagreeable given that no members of *C. grenadensis* are known below 430 m.

The basis of *C. patagonicu*s as a subspecies seems largely tied to Clark and Downey's (1992) statement that southern hemisphere *C. patagonicus* differed only in "minor (subspecific) characters from *C. grenadensis*" which I could not confirm based on available material or descriptions. Clark and Downey (1992) do not outline characters for this conclusion. Character evidence as outlined for *Alloceramaster* supports *C. grenadensis* in a distinctly separate genus from *C. patagonicus* which, based on the larger abactinal granules, and more well-developed abactinal fasciolar grooves and marginal plate shape is more similar to the typological *C. granularis*. All known species of *Alloceramaster* also occur at much deeper depths (greater than1000 m) than *C. patagonicus* and related species.

Alloceramaster grenadensis displays characters similar to *Alloceramaster minus* n. sp., in that the abactinal plates for the papular region are round to polygonal, each with triangular to trapezoid-shaped peripheral granules. The bare spots on *A. minus* are larger, occupying much more of the superomarginal surface. *A. grenadensis* differs from the other tropical Atlantic species in that the abactinal plates on the papular region are polygonal to round with triangular to trapezoidal peripheral granules. This contrasts with those in *A. affinis* which displays triangular abactinal plates on the papular region with slender, rectangular peripheral granules.

Occurrence/Distribution. Tropical West Atlantic, Grenada, Caribbean Sea, St. Kitts and Nevis, Honduras, Nevis Island, Los Roques Island, Jamaica, Nicaragua. 430–1175 m.

Eastern Atlantic. Azores, Canary Islands, Mediterranean Sea, Corsica. 540–2220 m.

Description. Body pentagonal to stellate, R/r = 1.4 to 1.9, arms triangular, disk broad. Interradial arcs curved. Abactinal plates tabulate, plates weakly convex, mound-shaped, round to polygonal in outline, but with shallow fasciolar grooves. Fascioles around radial papular regions (Fig. 3A, B) well developed, weakly present elsewhere. Abactinal surface covered primarily by granules, round, 4 to 60, mostly 20–50, covering plate surface in ordered concentric series. Radial papular regions with distinct angular peripheral granules, variable dimensions, mostly rhombus-shaped (Fig. 3B) but with some more slender shaped in smaller individuals.

Marginal plates, 12–15, forming wide periphery when viewed from dorsal surface. Distalmost superomarginals, 1 to 3, mostly 2 abutted over midline. Superomarginal surface with a centrally bald region, which varies in size from small, discrete, raised patch (Fig. 3C), approximately 15% of complete dorsal superomarginal plate surface to covering 70–80% of plate surface. Remainder of marginal plates surface covered by variably round, evenly spaced granules, 40–400, which cover lateral and inferomarginal surface (Fig. 3C).

Actinal region in full series, 3 to 4, chevron-like formation with irregular plates present adjacent to contact with inferomarginal plates. Actinal plates covered by granules, 5–40, mostly 10–30 (Fig. 3D). When removed they leave a shallow concavity on actinal plate surface.

Furrow spines 4–9, blunt, quadrate in cross-section, mostly 7 to 8 (Fig. 3E). Subambulacral spines in one or two rows, each with approximately three blunt, spines in each series, quadrate in cross-section. Remainder of adambulacral plate covered by granules 3–8 round to rough tipped, similar to identical with those on actinal plates. Oral plates with blunt, 9 to 15, polygonal to quadrate in cross section, oral plate surface with approximately 8–10 granules, each blunt but quadrate to polygonal in cross-section, present along either side of the central diastema between paired oral plates.

Alloceramaster leios nov. gen, nov. sp.

Figures 4A–E

Material Examined. Holotype. MV F240274. Great Australian Bight. 34º 46' 30" S, 131º 43' 53" E to 34º 47' 56" S, 131º 44' 41" E, 1323–1340m, Coll. IN2015_COI GAB Chevron. 22 November 2015. 1 wet spec. R = 2.4 r = 1.5.

Paratypes. WAM Z110247. 147 km WNW of Koks Island, outside the Gascoyne Marine Park, 23º 59' 20.112" S, 111º 58 '8.4612" E, 1025 m 8 wet specs. Coll. B. Alvarez, K. M. Naughton, K. Moore, C. Unteidt, aboard RV *Investigator* CSIRO 10064562, 8 wet specs. R = 1.2 r = 0.7, R = 1.2 r = 0.7 R = 1.2 r = 0.7, R = 1.2 r = 0.7 R = 1.1 r = 0.6, R = 1.1 r = 0.6 R = 0.9 r = 0.5, R = 0.6 r = 0.4

Etymology. The species epithet is derived from the Greek *leios* for smooth or bald, alluding to the smooth, bare superomarginal plate surfaces.

Diagnosis. Body weakly stellate (R/r = 1.6), interradial arcs curved. Arms triangular. Abactinal plates weakly tabulate along papular regions, **plates rounded to polygonal in shape.**

Granules more uniform, densely arranged with less distinction between those centrally and peripherally. **Radial regions with fasciolar grooves, plates hexagonal to round, peripheral granules trapezoidal with central granules round to polygonal.** Marginal plates 14 to 16 per interradius (arm tip to arm tip), **penultimate superomarginal enlarged, abutted distally. Superomarginals with prominent bald area occupying central region.** Furrow spines, blunt, round in cross-section, 4 to 6, mostly 4 or 5 with six spines present closer to arm tip in weakly palmate arrangement. First row of subambulacral spines, primarily three but some with four, set apart from furrow spines by distinct space.

Comments. *Alloceramaster leios* n. sp. shares distinctive characters with *A. minus* sp. suggesting affinities, notably that the superomarginal plate surface is bare and smooth, either

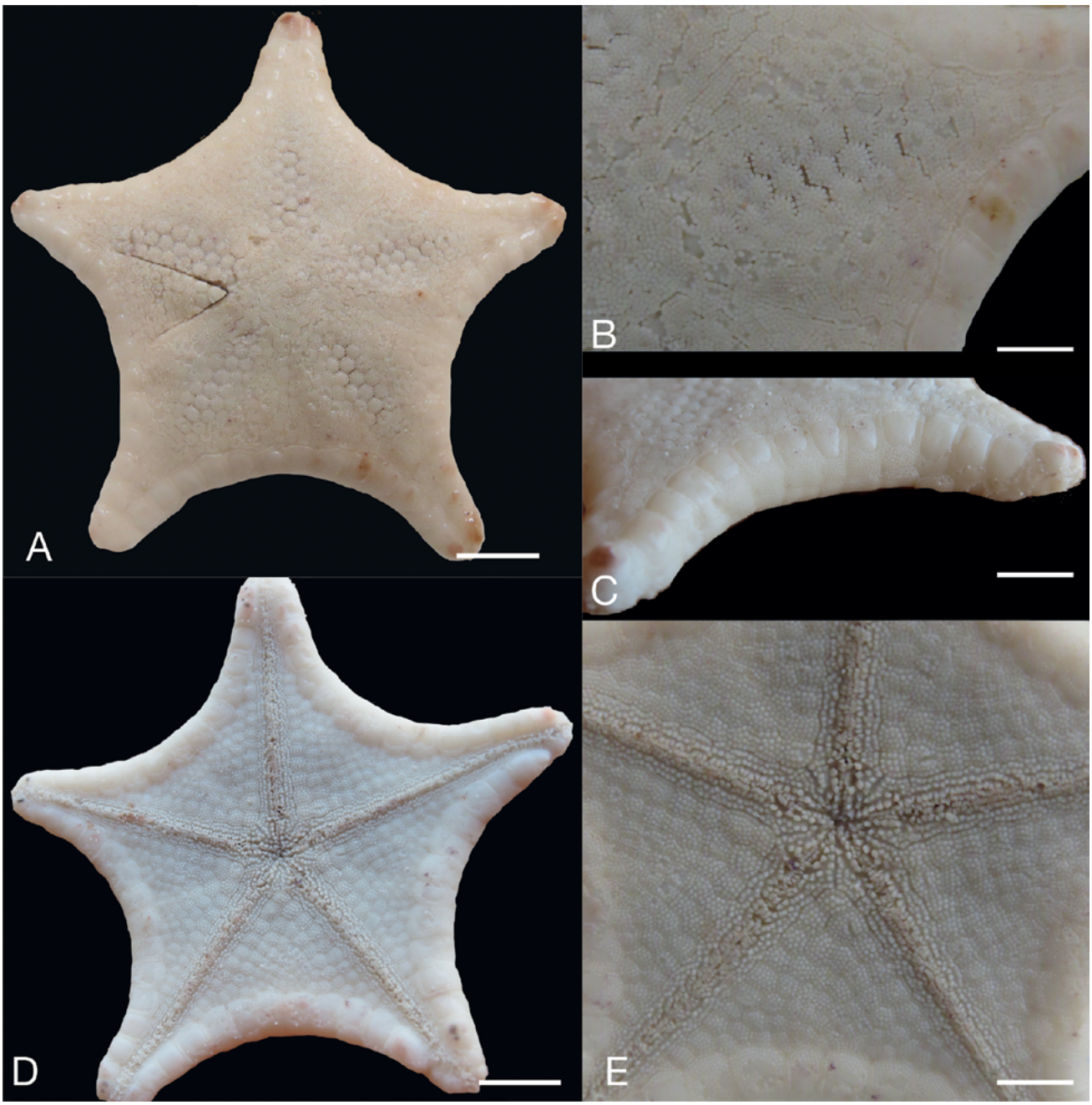

Figure 4. *Alloceramaster leios* n. sp. Holotype. NMV F240274: a, Abactinal; b, Closeup abactinal; c, Abactinal-lateral view; d, Actinal; e, Adambulacral/Furrow spination. Scale bar = 7.0 mm: a, d; Scale bar = 2.0 mm: b, c, e.

completely or as a distinct patch on the dorsal surface. The papular regions, also show plates with peripheral granules that are similar in appearance (Fig. 4B). *Alloceramaster leios* shows an enlarged, penultimate superomarginal plate distinguishing it from other known *Alloceramaster* species. Although the enlarged penultimate superomarginal invokes comparisons with *Sphaeriodiscus, Alloceramaster* displays heterogeneous peripheral granules between the radial and interradial areas and has superomarginal plates with smooth, bare dorsal areas with no granules present. Marginal plate number in *Alloceramaster,* 10 to 18, which is generally more stellate is also greater than in *Sphaeriodiscus*, 6 to 12, which is generally more pentagonal.

The small sized individuals suggest greater development of marginal plate number and granule number relative to that observed in the holotype (at R = 2.4) as well as a more stellate shape in larger individuals. If assessment of WAM Z110247 as small individuals is correct, the distribution of this species extends from the South Pacific to the Indian Ocean, suggesting widespread occurrence.

Occurrence/Distribution. Great Australian Bight, 1323–1340 m. Gascoyne Marine Reserve (1025m).

Description. Body weakly stellate (R/r = 1.6 to 1.7), interradial arcs curved. Arms triangular (Fig. 4A).

Abactinal plates weakly tabulate, extending from disk to arm tip. Fasciolar channels present primarily over radial papular regions (Fig. 4A, B), weakly present or shallow interradially. Abactinal plates polygonal to round in outline with weakly convex surface. Plates covered by 10 to 70 granules. Peripheral granules show distinct shape difference between those present radially and interradially. Those present along radial regions with peripheral granules, 10 to 30 distinctly trapezoidal in shape (Fig. 5B). Other granules, 8 to 30, present on central and interradial regions round in outline. Radial granules widely spaced. Granules interradially and within the primary circlet with more weakly differentiated peripheral and central granules. Peripheral and central granules more closely homogeneous in size and shape, and more densely arranged. Peripheral and central granules also more homogeneous, closer in shape and size relative to those on the radial regions. Radial plates include eight to nine granules across a 1.0 mm line. Superomarginal plates abutted distally, forming distinct border, approximately 10% of total distance "r" (Fig. 4A). Madreporite quadrate in shape, concave curvature, flanked by four plates. A distinct dividing contact present along each interradius between plates present on the disk. Pedicellariae not observed.

Superomarginal plates 14, inferomarginals 16 per interradius, arm tip to arm tip. Eight at R < 1.2. Penultimate superomarginal plates enlarged, oblong approximately twice the size of the adjacent superomarginal plate and completely devoid of granules. Superomarginal with prominent, round bald area occupying most of abactinal facing surface (Fig. 4C). Dense, round granules, counting approximately 50 to 70 on lateral facing of superomarginal plate (Fig. 4C). Superomarginals and inferomarginals with peripheral granules, round in shape, approximately 40 to 80. Interradially with 15 on each short side, 20 on each elongate side. Pits corresponding to tong-like pedicellariae present on bare plate surface. Superomarginal contact with abactinal plates convex. Inferomarginal oral surface with round bald spot variable in size from three to four granules wide to completely covering inferomarginal surface, otherwise covered by 20 to 100 round granules, continuous with granules on actinal surface. Terminal plates triangular, smooth surface.

Actinal surface with three full rows in chevron-like pattern with one to two irregular, incomplete rows. Plates quadrate in shape, each covered by eight to 30 round to polygonal evenly shaped granules (Fig. 4D, E).

Furrow spines, blunt, teardrop in cross-section, 4 to 6, (Fig. 4E) mostly 4 or 5 with six spines present closer to arm tip in weakly palmate arrangement. First row of subambulacral spines, primarily three, but some with four set apart from furrow spines by distinct space. This row 50–60% of furrow spine height, with each spine about twice as thick as each furrow spine. Two further rows of subambulacral granules or short spinelets present on adambulacral plate, gradually decreasing in size until becoming consistent in size with other actinal granules. Each subambulacral row with spaces between them. Oral plate furrow spines 12, blunt, more quadrate in cross-section with one distinct spine, blunt-tipped, quadrate in cross-section, from each plate directed into mouth. Oral plate surface with two paired series of six angular granules along oral plate centre contact. Approximately seven to nine other angular or quadrate in cross-section spines present on oral plate surface.

WAM Z110247 shows eight specimens with overall R <1.2 cm. These show much more weakly developed abactinal plates, and shallower fasciolar grooves around the papular regions. Coarse, angular granules, 3 to 10 per plate, with fewer on papular regions. Marginal plates 8 per interradius, superomarginal dorsal face completely bald, inferomarginal plates surface covered by quadrate shaped bald spot, surrounded by granules. Furrow spines 2 to 4, mostly 3. Subambulacral spines decreasing in size, shape from furrow to actinal intermediate surface.

Alloceramaster minus nov. gen, nov. sp.

Figures 5A–E

Material Examined. Holotype. WAM Z110126. Gascoyne Marine Reserve, 164 km NW of Kurabi Point, 20° 50' 3.4332" S, 112° 51' 52.9524" E, 1088 m. Coll. B. Alvarez, K. M. Naughton, K. Moore, C. Unteidt, aboard RV *Investigator* CSIRO barcode 10052895. 1 wet spec. R = 1.7 r = 0.9

Paratype. WAM Z110133. Gascoyne Marine Reserve, 164 km NW of Kurabi Point, 20° 50'03.4332" S 112° 51' 52.9524" E, 1088m, Coll. B. Alvarez, K. M. Naughton, K. Moore, C. Unteidt, aboard RV *Investigator* CSIRO 10052998, 1 wet spec. R = 0.8 r = 0.6.

Etymology. The species epithet *minus* refers to the Latin for bare or smooth, alluding to the absence of granules on the superomarginal plate surface.

Diagnosis. Body stout, shape pentagonal to weakly stellate, (R/r = 1.3–1.8), arms short, blunt. Interradial arcs weakly curved to straight. Abactinal surface covered by dense cover of

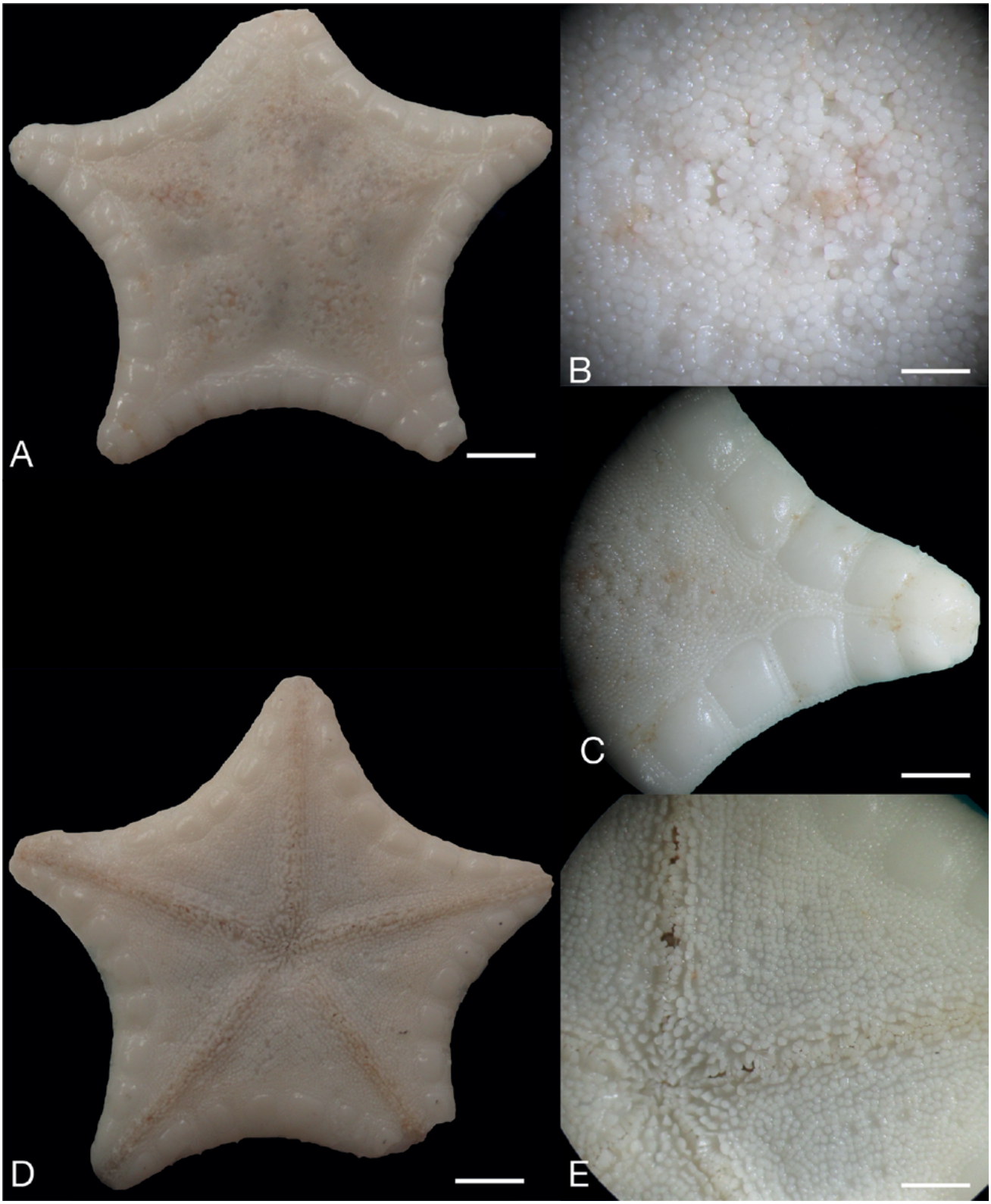

Figure 5. *Alloceramaster minus* n. sp. WAM Z 110126 Holotype: a, Abactinal; b, Closeup abactinal; c, Closeup arm tip; d, Actinal; e, Adambulacral/Furrow spination. Scale bar = 4.0 mm: a, d; Scale bar=2.0 mm: b, c; Scale bar=1.0 mm: b.

granules. **Radial areas with fasciolar grooves, bearing widely spaced rectangular to broadly trapezoidal peripheral granules versus polygonal to round central granules, these differing from those on interradial areas which show identically shaped peripheral and central granules. Superomarginal plates 10 per interradius. Penultimate superomarginals similar in size to adjacent superomarginals.** Superomarginal surface with large, bald, smooth surface. Inferomarginal plates similar overall to superomarginal plates, but with a rounded-quadrate bald patch on actinal surface, while remainder of surface covered by 20–130 granules. Furrow spines 6 to 8, mostly 6 with highest number of spines on proximalmost adambulacral plates. Subambulacral spines 3, blunt, 2 to 3 times the thickness of the furrow spines. Pedicellariae, when present with forceps-like valves present with abundance on abactinal surface.

Comments. *Alloceramaster minus* n. sp. shares with *A. leios* n. sp. the presence of a prominent bald patch or surface (Fig. 5A, C) on the superomarginal plate surfaces and marginal plate number per interradius differ, although both characters may vary based on size. There are an abundance of forceps-like pedicellariae on the abactinal surface of *A. minus*. This species also displays some resemblance with *A. grenadensis* in that it has round to polygonal abactinal plates on its papular region with triangular to trapezoidal-shaped peripheral granules.

Occurrence/Distribution. Gascoyne Marine Reserve, Western Australia, Indian Ocean, 1088 m.

Description. Body stout, shape pentagonal to weakly stellate, (R/r=1.3–1.8), arms short, blunt. Interradial arcs weakly curved (Fig. 5A, D).

Abactinal plates with low tabulate plates over radial regions where papulae are present, abutted abactinal plates centrally and interradially (Fig. 5B). Non-radial plates hexagonal to irregularly polygonal in shape, covered by granules, round to polygonal, close set, homogeneous in size and shape, but discretely separated into peripheral and central areas. Granules form continuous cover, approximately 5 to 6 counts along a 1.0 mm line, totalling 8 to 30 per plate (Fig. 5B). Radial plates, approximately 9 plates per arm with more widely spaced peripheral granules, up to 20 granules densely arranged on plate surface on a convex surface. Shallow fasciolar grooves present around these radial tabulate plate regions (Fig. 5B). Pedicellariae with narrow forcep-like valves, approximately 15–25 per interradius. Madreporite triangular in shape, on raised plate, flanked by three plates, and approximately 18–20 granules.

Marginal plates 10 per interradius, arm tip to arm tip (4 to 5 per arm side), 2 superomarginals abutted in full contact along midline at arm tip (Fig. 5C). Superomarginal plates round in cross-section with strongly convex surface along abactinal-lateral angle, quadrate in overall shape. Central surface of superomarginal plates with a large, smooth and bare quadrate region (Fig. 5A, C). Lateral surface of superomarginals covered by small, round granules, 60–70, widely spaced. Inferomarginal plates similar overall to superomarginal plates, but with a rounded-quadrate bald patch on actinal surface, while remainder of surface covered by 20–130 granules, evenly spaced. Some superomarginal plates show signs of damage and double-plate growth. No pedicellariae observed. Terminal plate round, with smooth surface.

Actinal intermediate region with two full series in chevron formation, with irregularly arranged plates adjacent to inferomarginal contact. Individual plates quadrate in shape. All plates covered by granules, 9 to 20, mostly 8–15, round to polygonal (Fig. 5E). More widely spaced proximally becoming more closely arranged distally adjacent to contact with inferomarginal plates.

Furrow spines 6 to 8, mostly 6 (Fig. 5E) with highest number of spines on proximalmost adambulacral plates. Spines blunt with rounded tips, in weakly palmate formation. Subambulacral spines 3, 2 distalmost enlarged, proximalmost spine smallest set off from furrow spines by a discrete space. Subambulacral spines thick, approximately 2 to 3 times the thickness of the furrow spines, blunt tips, similar in height, the smallest of these spines approximately 50% of the height of the other subambulacral spines. Remainder of adambulacral plate covered with blunt, thick, granules, approximately half the height of the subambulacral spines, similar in stature to granules on the actinal surface. These granules widely spaced with a single row, composed of four granules at contact with actinal plates. Oral plates with 6 furrow spines, triangular in cross-section with blunt tips and a seventh spine projecting into the mouth from the tip of each oral plate (two in each interradius). Oral plate with 6 to 8 pairs of thick granules (Fig. 5E), each triangular in cross-section with blunt tips on either side of the diastema between the paired oral plates. A single pedicellariae, forceps-like valves, on one of the proximal adambulacral plates adjacent to the oral region with narrow valves (Fig. 6E).

Alloceramaster pointsurae (Mah 2016) nov. gen, nov. comb.

Figures 6A–E

Mah 2016: 114, Fig. 4A–D

Material Examined. Holotype. USNM 1407942. President Jackson Seamount B, North Pacific, 42° 49' 59.304" N, 128° 9' 40.3914" W, 1975.7 m. Coll. D. Clague,1 wet spec. R = 1.8, r = 1.0.

Paratypes. USNM 1407943. President Jackson Seamount C, North Pacific, 42° 44' 24.0966" N 128° 5' 53.736" W, 1742.1 m. Coll. D. Clague, MBARI, D82–A3. 1 wet spec. R = 1.0, r = 0.6; USNM 1407944. President Jackson Seamount C, North Pacific, 42° 44' 23.9604" N, 128° 5' 49.776" W, 1730.1 m. Coll. D. Clague, MBARI, D82–A6, 1 wet spec. R = 1.2, r = 0.6.

Diagnosis (Based on Mah, 2016). Body shape is stellate (R/r = 1.6–2.0 at R = 1.8). Interradial arcs curved. Abactinal plates Abactinal plates round to polygonal in outline, covered by 7–30 (mostly 10–25) granules. **Six to 20 rectangular-oblong granules form discrete periphery surrounding one to eight round central granules on radial plates.** Superomarginal and inferomarginal plates, 10–16 per interradius (arm tip to arm tip) with distinct, quadrate-shaped smooth, bald surfaces. Marginal plates wide, forming distinct periphery around body, approximately 22% of "r" (5.0 /23.0 mm), **distalmost one or two pairs of superomarginal plates abutted at arm tip.** Actinal

plates covered by fine granules with angular tips, which obscure boundaries between plates. Furrow spines, 3–4, mostly 4 arranged in a straight to palmate pattern. Subambulacral spines in two rows, each with two thick but pointed subambulacral spines, approximately twice as thick as a single furrow spine, set off from furrow spines by discrete space. A second row of subambulacral

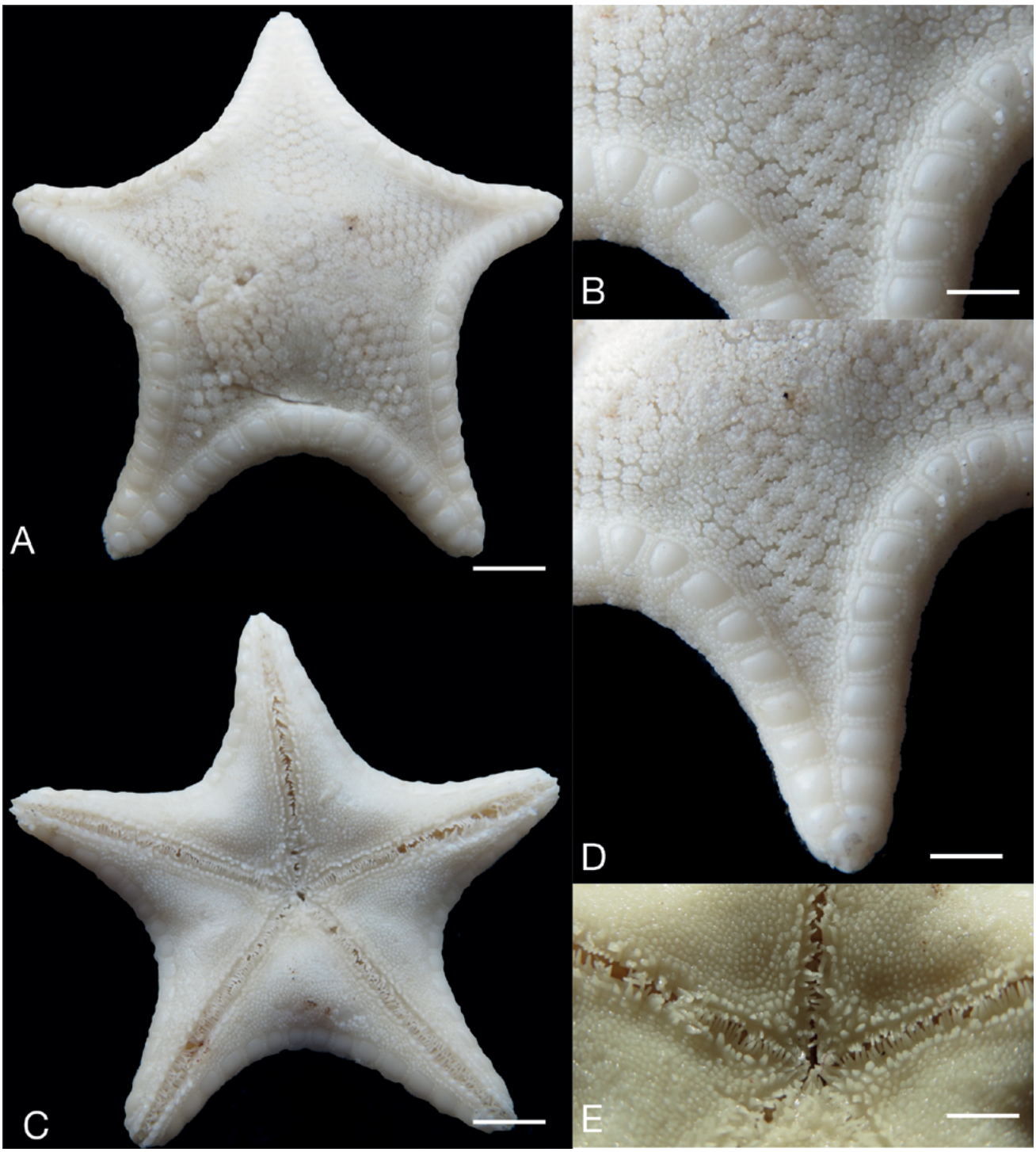

Figure 6. *Alloceramaster pointsurae* Mah, 2016 Holotype USNM 1407942: a, Abactinal: b, Closeup abactinal surface; c, : c, Abactinal-arm tip; d, Actinal; e, Adambulacral/Furrow spination. Scale bar=3.0 mm.

spines sits adjacent to the first series, less than half the height but closely resembles angular granules on actinal surface.

Comments. This species displays the angular, elongate granules as well as well-developed fasciolar grooves around proximal papular pores which are shared by species within *Alloceramaster*. This species invites comparison with *A. affinis,* but differs in having much finer and more abundant actinal spines and much coarser and less angular peripheral granules around the proximal papular regions (Fig. 6B, D). The superomarginal plates also form a much broader periphery (20% of "r") than the one in *A. affinis*, which forms a much narrower marginal border (only 11% of "r").

Occurrence/Distribution. President Jackson Seamount B and C. North Pacific. 1975–1742 m.

Bathyceramaster Mah, 2016.

Mah 2016: 105; 2022: 31

Diagnosis (modified from Mah, 2016). **Abactinal plates tabulate, low to moderate in height with fasciolar grooves, variably shallow to well-developed plates lacking stellate bases. Abactinal, marginal, actinal surfaces covered by densely arranged polygonal to round granules.** Bald patch on marginal plates present on a minority of taxa, absent on most. Body stellate, many species with well-developed arms (R/r = 1.8–4.0).

Comments. *Bathyceramaster* was designated to accommodate *"Mediaster" elegans*, which lacked the characteristic radiating internal processes present at the base of its abactinal plates that defined typological *Mediaster* (Mah 2016). *Ceramaster* is similar to *Mediaster*, but the species in question, "*Mediaster*" *elegans*, lacked characters consistent with typological *Ceramaster* species (i.e. *C. granularis* and related). Ultimately, the designation of *Bathyceramaster* not only accommodated "*Mediaster*" *elegans,* but also came to include six other species, which are also present primarily in deep-sea settings (greater than 1000 m).

Morphology in *Bathyceramaster* is, for goniasterids, very generalised, including abutted polygonal to round abactinal plates, fasciolar grooves present primarily around papular regions, widespread granular coverings on the abactinal, marginal and actinal surface, and weak stellate to stellate body shape.

Bathyceramaster species, including single species such as *Bathyceramaster teres* occur widely and have so far, been recorded from the Atlantic, Pacific, and now the Indian Ocean.

Key to Australian *Bathyceramaster*

(1) Pedicellariae, prominent, present on proximal actinal region and adambulacral plates. Arms elongate, disk pentagonal with weakly curved to straight interradii. ..... ***Bathyceramaster teres*** Mah 2022

(1') Pedicellariae absent from proximal adambulacral plates. Body more stellate, arms triangular with broad base. ..... (2)

(2) Granules densely arranged with abactinal plate outlines not evident. Fasciolar grooves weakly present or obscured by granules. 3 granule count along 1.0 mm line, peripheral granules trapezoidal. ..... ***Bathyceramaster wami*** *n. sp.*

(2') Granules widely spaced overall, plate outlines evident, show discrete shape, fasciolar grooves evident on radial regions. Greater than 5 granule count along 1.0 mm line, peripheral granules rounded to quadrate. ..... ***Bathyceramaster tasmanensis*** n. sp.

Bathyceramaster tasmanensis n. sp.

Figures 7A–E

Material Examined. Holotype. NMV F270799. Central north 1000 Tasmanian seamounts, 44º 09' 11" S, 147º 11' 42" E, 999.8–1038.4 m, Coll. A. Williams, A.A. Weber and R-L. Erickson, RV *Investigator*, 27 November 2018. 1 wet spec. R = 4.9 r = 2.7.

Paratypes. NMV F270801. Central north 1000 Tasmanian seamounts, 44º 09' 11" S, 147º 11' 42" E, 999.8–1038.4 m, Coll. A. Williams, A.A. Weber and R-L. Erickson, RV *Investigator*, 27 November 2018. 4 wet specs. R = 5.8 r = 3.3; R = 5.2 r = 3.1; R = 5.1 r = 3.0; R = 4.6 r = 2.4

Etymology. This species is named for the type collection locality in the Tasman Sea.

Diagnosis. Body weakly stellate to stellate, R/r = 1.67–1.9, arms triangular, broad at base, disk confluent with arms. Arm tips blunt. Interradial arcs weakly curved. **Abactinal plates weakly tabulate, polygonal, the largest being hexagonal, surface flat covered by polygonal granules, 4 to 30, peripheral granules more rounded overall, but weakly angular in shape along radial regions,** all widely spaced on each plate surface. No radial stellate radiating ossicles on abactinal plate bases. No pedicellariae. Marginal plates wide, 30–32 per interradius, pronounced forming 20% of distance "r". **Both series covered by granules, round, abundant but evenly spaced.** Actinal plates with granules, 4 to 15 present on each plate surface, fasciolar grooves shallow but present. Furrow spines 5 to 6, mostly 6, blunt tipped, quadrate in cross section, in straight to palmate series. Subambulacral spines short, blunt, granular in two series of 3 to 4, all widely spaced.

Comments. Placement of this species was difficult owing its generalised appearance with observed characters suggesting placement in *Mediaster* and *Ceramaster*. It lacks the internal radiating abactinal plates diagnostic for *Mediaster* and *Ceramaster,* shows better developed fasciolar grooves, and shows better developed tabulae as defined herein. Complete granule cover present on the abactinal, marginal and actinal surfaces, but widespread granules are present in several goniasterid taxa. The disparity between deeper radial fasciolar grooves versus weakly developed to absent fasciolar grooves interradially was also observed as a diagnostic character for *Bathyceramaster*, suggesting placement pending further data.

Occurrence/Distribution. Tasmanian Seamounts, South Pacific, 999.8–1038.4 m

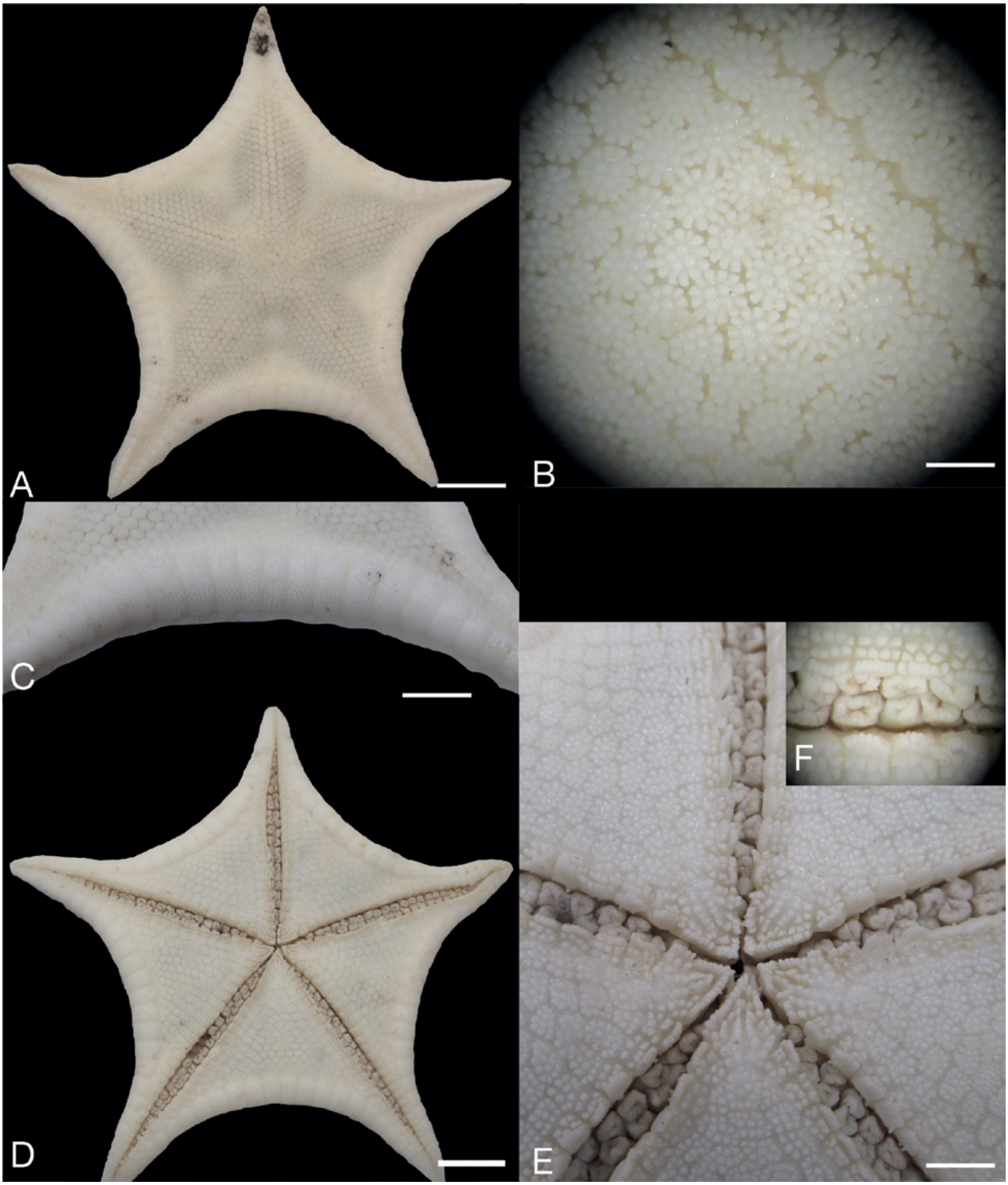

Figure 7. *Bathyceramaster tasmanensis* n. sp. NMV F270799: a, Abactinal; b, Closeup abactinal; c, Abactinal-lateral view; d, Actinal; e, Closeup oral region; f, Adambulacral/Furrow spination.

Description. Body weakly stellate to stellate, R/r = 1.67–1.9, arms triangular, broad at base, disk confluent with arms. Arm tips blunt. Interradial arcs weakly curved (Fig. 7A, D).

Abactinal plates polygonal with more strongly hexagonal shaped plates present radially (Fig. 7B). Plates smaller, densely arranged, more irregular interradially adjacent to superomarginal contact. Abactinal plate surface flattened, continuing to arm terminus. Plates covered by granules, 4 to 30, mostly 10–18, greater than 5 count along a 1.0 mm line. Peripheral granules, approximately 3 per side mostly round to polygonal, but rhomboid and narrow around radial regions. Fasciolar grooves present proximally and around radial regions, but more weakly developed to absent interradially. No radiating stellate ossicles on plate base. Superomarginal plates forming dorsal-facing boundary, approximately 20% of distance "r." Madreporite quadrate in shape, flanked by four adjacent plates. No pedicellariae observed.

Superomarginal plates wide, 30–32 per interradius, widest interradially becoming more squarish distally along arms (Fig. 7A, C). Marginal plate surface completely covered by coarse, round granules, approximately 50–90, evenly spaced. Inferomarginal plates with identical complete round granules. No pedicellariae.

Actinal region with 4 to 5 full series in chevron formation, but only adambulacral series extending along arm (Fig. 7D, E). Plates round to irregularly polygonal in shape. Fasciolar grooves present, shallow. Plates covered by granules, 4 to 15, evenly spaced. Plates smaller, more irregular with fewer granules distally, at contact with inferomarginal plates.

Furrow spines 5 to 6, mostly 6, blunt tipped, quadrate in cross section, in straight to palmate series (Fig. 7E, F). Subambulacral spines short, blunt, granular in two series of 3 to 4, all widely spaced. Oral plate furrow spines, 11 with a further spine (total of 2) projecting into mouth from each side. Spines are blunt, quadrate in cross-section. Five to six spines present on either side of central oral plate diastema (Fig. 7E), further spines on oral plate decreasing in size, shape becoming more similar to those on remainder of actinal plate surface, widely spaced.

Bathyceramaster teres Mah, 2022.

Figures 8A–E

Mah 2022:36, Fig. 12A–G

Material Examined. WAM Z100655. Ningaloo, Western Australia. 21° 50› 6» S, 112° 55› 35» E, 2535.3 m. Coll. Wilson N, Rouse, G., Kirkendale, L., Ritchie, J. aboard RV *Falkor* March 2020. 1 wet spec. R = 2.7 r = 1.7

WAM Z110275. 203 km WNW Koks Island outside of Gascoyne Marine Park, Western Australia, 24° 0' 6.336" S, 111° 19' 45.8796" E, 2014.0 m. Coll. B. Alvarez, K. M. Naughton, K. Moore, C. Untiedt, 16 December 2022. CSIRO 10064864. 1 wet spec. R = 3.3 r = 1.1.

WAM Z110010. Gascoyne, Western Australia 21° 18› 25.8732› S, 112° 17› 25.7136» E, 2010 m. Coll. B. Alvarez, K. M. Naughton, K. Moore, C. Untiedt, 29 November 2022, CSIRO 10051180. 1 wet spec. R=1.5 r=0.6.

WAM Z110274. 203 km WNW Koks Island outside of Gascoyne Marine Park, Western Australia 24°0› 6.336» S, 111°19› 45.8796" E, 2014 m. Coll. B. Alvarez, K. M. Naughton, K. Moore, C. Untiedt, 16 December 2022. CSIRO 10064863 2 wet specs. R = 1.8 r = 0.6 R = 2.2 r = 1.0

WAM Z110276. 203 km WNW Koks Island outside of Gascoyne Marine Park, Western Australia 24° 0' 6.336" S, 111° 19' 45.8796" E, 2014 m. Coll. B. Alvarez, K. M. Naughton, K. Moore, C. Untiedt, 16 December 2022. 3 wet specs. R = 3.6 r = 1.5, R = 3.3 r = 1.3 R = 3.2 r = 1.2.

NMV F241946. Off Fraser Island, Queensland, Australia, 25°19'31.1"S 154°04'04.8"E, 2342–2350 m. Coll. Tim O'Hara et al. IN2017 V03 abyss Marine Invertebrates Team, 6 Nov. 2017. 1 wet spec. R = 3.7 r = 1.5

NMV F307965. Cocos (Keeling) Islands, Indian Ocean Territory, Santa Ridge. 13° 33' 42" S to 13° 33' 10" S to 96° 22' 6" E to 96° 22' 56" E, 2418–2156 m. Coll. O'Hara et al. 25 Oct 2022, 1 wet spec. R = 3.5 r = 1.2

WAM Z110102. 147 km WNW of Koks Island, outside Gascoyne Marine Park, 22° 16› 11.6832» S, 112° 57› 46.2672» E, 2073 m. Coll. Alvarez, B., Naughton, K.M., Moore, K., Unteidt, C. CSIRO Gascoyne 10052624, 25 November 2022, 1 wet spec. R = 2.7 r = 1.0.

Diagnosis. Body thick, weakly stellate (R/r = 1.77), interradial arcs straight to weakly curved. Lateral edge is thick and rounded. **Abactinal plates tabulate, fasciolar grooves well-developed. Abactinals and marginal plates with coarse granules, abactinal plates each with four to fifty granules**, most with 8 to 35 with convex surface. **Superomarginal plates covered by continuous granular cover, but in Pacific specimens there are with variably quadrate to irregularly shaped bald spots.** Actinal plates with dense covering of coarse granules similar to those on the abactinals. Pedicellariae tong-like, prominent on proximal adambulacral and actinal plates, with two or three valves. Furrow spines, 4 to 7 with 2 to 4 subambulacrals (mostly 3).

Living individuals orange, variably with lavender to purple coloured marginal plates.

Comments. The type specimens for this species were collected from Howland Island and Sibelius Seamount in the North Pacific. New specimens from the South Pacific and the Western Australian region in the Indian Ocean indicate remarkable new occurrence for what is apparently a wide-ranging species. This apparently suggests that this species is similar to goniasterids such as *Sibogaster nieseni* (Mah 2016) and porcellanasterids such as *Hyphalaster inermis* (Madsen, 1961) which show widespread distributions throughout deep-sea settings.

There are variations. Abactinal plates on the type series are more distinctly convex whereas those here are more weakly so. The superomarginal count in the type specimens ranges from 22 to 24 at R = 3.2 whereas those herein number approximately 30 at similar R. The granules covering proximal superomarginals but absent along distal superomarginals is present in some, e.g. WZ110102, but not all specimens. Furrow and subambulacral spination shows are consistent but with pedicellariae positioned slightly further away adjacent to the subambulacral spines the adjacent to the furrow spines in the type specimens.

Occurrence/Distribution. North Pacific. Howland Island and Sibelius Seamount, North Pacific Ocean. 2175–2439 m. South Pacific. Off Fraser Island, Queensland, Australia, Tasman Sea, 2342–2350 m.

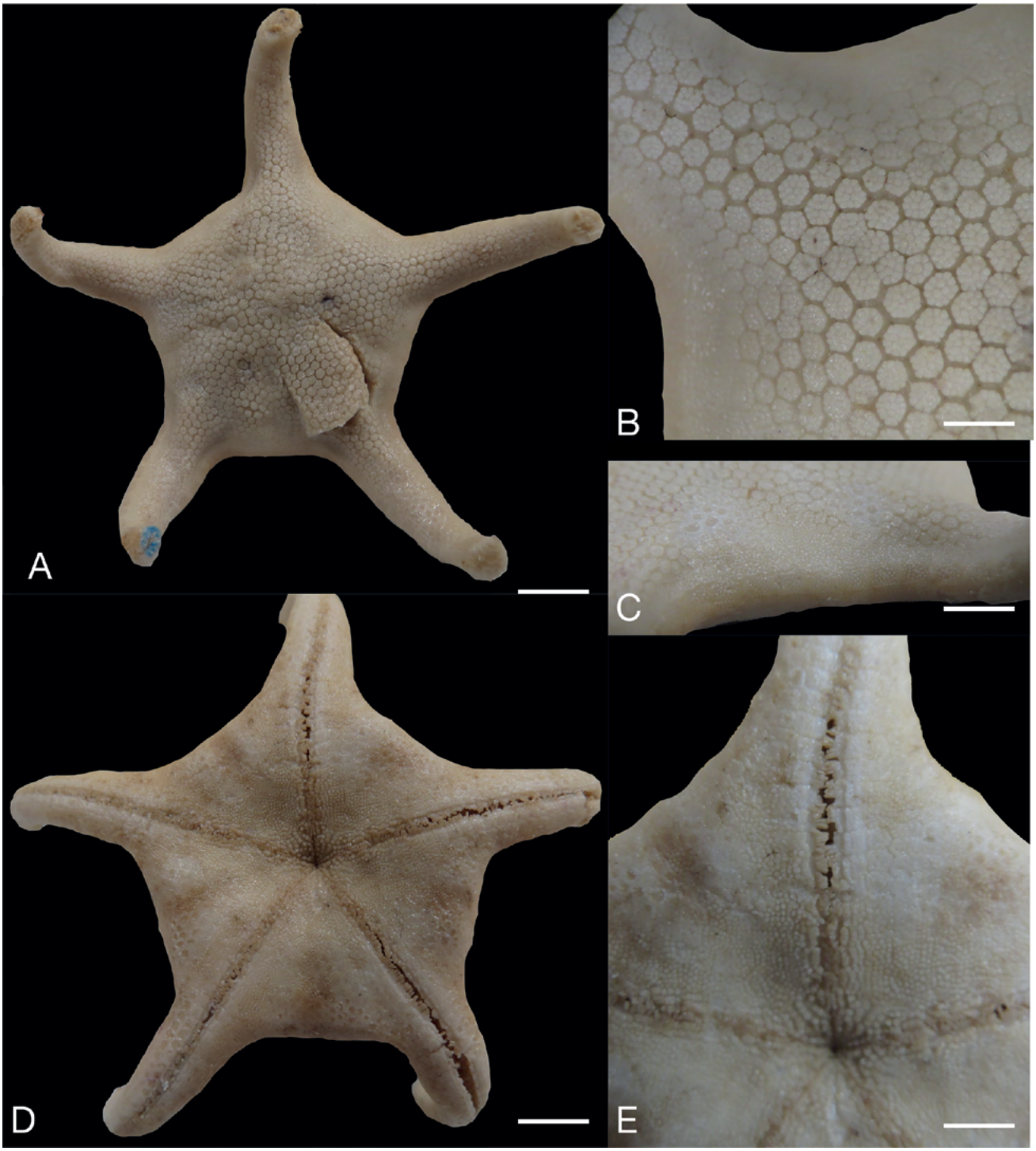

Figure 8. *Bathyceramaster teres* Mah, 2022 NMV F241946: a, Abactinal: b, Closeup abactinal; c, Abactinal-lateral view; d, Actinal; e, Adambulacral/Furrow spination. Scale bar = 5.0 mm, a, d, e; Scale Bar = 3.0 mm: c; Scale bar = 2.0 mm: b.

Indian Ocean. Ningaloo, Gascoyne Marine Park, off the coast of Western Australia, Indian Ocean. 2073 m. Western Australia and Cocos (Keeling) Islands region. 2010–2418 m.

Description. Body stellate, R/r = 1.5 to 3.0, disk with surface weakly concave, arms elongate, weakly rectangular with broad tips. Arms, quadrate with rounded edges in cross-section. Disk with straight interradial arcs (Fig. 8A, D)

Abactinal plates mostly polygonal, abutted, save for those on radial regions, composed of low tabulate plates, covered by abundant granular cover, densely packed over most of abactinal surface (Fig. 8A, B). Plate surfaces round, shallow fasciolar grooves present. Granules, round to polygonal, forming dense surface, approximately 6 granules along a 1.0 mm line count, covering obscures boundary contact between proximal adjacent plates on disk centre. Granules form distinct, close-set cover interradially on disk and along lateral sides along arms. Most abactinal plates covered by polygonal granules, 10 to 25 variably crowded to widely spaced. Abactinal plates narrow along arms from approximately five series across arm base to 2 or 3 distally Papular and radial areas extend down arm, nearly to arm tip, tips of these plates round to polygonal. Plates on papular and radial areas with angular peripheral granules, trapezoid in shape, distinctly different from peripheral granules on other plates. Weakly hexagonal plate outlines observable on proximal arm regions, these with granules, 10–30, mostly 20 evenly distributed on plate surface. Interradial regions particularly dense. Plates more evident along arms in approximately 6 to 8 series. Madreporite triangular, flanked by three adjacent plates, sulci well-developed. Small forcep-like pedicellariae with wide valves present on a minority of plates, but variably sent on some specimens (e.g. WZ110102).

Marginal plates, variably approximately 11 to 16 per arm side, 22 to 32 per interradius with lateral facing, quadrate, elongate interradially with more square-shaped plates along arm (Fig. 9A, C). Presence of granulation varies, WZ110102 with proximalmost granular cover, but subsequent marginal plates along disk and arms with a bare, irregular to quadrate region, bare, raised and surrounded by granules. These bare regions become largest distally, forming smooth, bald convex surface adjacent to terminal plate. Superomarginal and inferomarginal plate surfaces covered by granules, 20–60, widely but evenly spaced, with lateral facing (Fig. 8C). Some marginal plates lacking bare spots. Granule covering is dense and continuous from abactinal and actinal surface and obscures plate boundaries. Abactinal-lateral and actinolateral edges, rounded. No pedicellariae on marginal plates. Terminal plate round to triangular in outline, surface bare.

Actinal surface small, approximately 2 to 4 full series in chevron arrangement with irregular plates present adjacent to inferomarginals, limited to disk, absent from arms (Fig. 8D, E). Plates quadrate in shape, completely covered by granules, 8–16, mostly 12–14) per plate, variably with round to pointed surface. Granules more widely spaced proximally becoming more closely arranged forming a denser cluster closer to the actinolateral surface. Pedicellariae present, approximately 10 to 20 per interradius, paddle-shaped most with 2 valves, but exceptionally 3-valved pedicellariae present, widely spaced from one another.

Furrow spines 4 to 6, mostly 5 in palmate arrangement, each spine with blunt, round tips, round in cross-section (Fig. 8E). Subambulacral spines, 3 to 4, mostly 3 set off from furrow spines by distinct space. Second subambulacral series, 2 to 3, mostly 3, these spines approximately half the height of the preceding series with a final series of pointed granules on plate surface adjacent to actinal plate contact. All subambulacral spines and granules widely spaced from one another. A single paddle pedicellariae present adjacent to the furrow but separated by a distinct field, blunt spines present adjacent to pedicellariae. Pedicellariae with elongate forceps like valves on 1 to 4 proximal adambulacral plates adjacent to the oral plates. Oral plate with 9 to 10 furrow spines, one blunt spine enlarged, quadrate in cross-section and directed into the mouth, thus a total of two enlarged spines per interradius directed into the mouth. Oral plate with five paired spine-like granules, terminating with sharp tips present along either side of diastema between oral plates. These spines largest proximally decreasing in size adjacent to the actinal surface. Approximately 3 to 7 other short, angular granules present on oral plate surface.

Bathyceramaster wami n. sp.

Figures 9A–E

Material Examined. Holotype. WAM Z110181. Gascoyne Marine Reserve 23° 9' 21.2688" S, 112° 48' 21.654" E, 992.0 m. Coll. B. Alvarez, K.M. Naughton, K. Moore, C. Untiedt, 9 December 2022, CSIRO 10056099, 1 wet spec. R = 6.2 r = 2.3

Etymology. This species is named for the Western Australian Museum.

Diagnosis. Abactinal, marginal granules large, coarse, 3 counted along a 1.0 mm line. Marginal plates 16 per arm side, 32 total from arm tip to arm tip. **Granular cover continuous over abactinal, marginal, actinal surfaces. Abactinal granules along the plate surface of tabulae, tightly articulated, with granules in some areas forming an almost solid surface.** Furrow spines 3–5, blunt, subambulacral spines 2 to 3, in two series, each twice the thickness of the furrow spines.

Comments. A species distinguished by the large, course granules forming a relatively abundant and continuous covering on the abactinal, marginal and actinal surfaces, as well as the distinct marginal plates forming a rolled edge. The dense abactinal covering is similar to that of the North Pacific *Bathyceramaster elegans*, which differs from *Bathyceramaster wami* n. sp. in having many more furrow spines, 9 to 15, much finer and smaller granules, and a much more stellate shape (R/r=3.7 to 4.9).

Occurrence/Distribution. Gascoyne Marine Reserve, Western Australia, Indian Ocean. 992.0 m.

Description. Body stout, stellate in shape (R/r = 2.69), arms triangular in outline, thick, broadly trapezoidal in cross-section (Fig. 9A, D). Arm tips upturned.

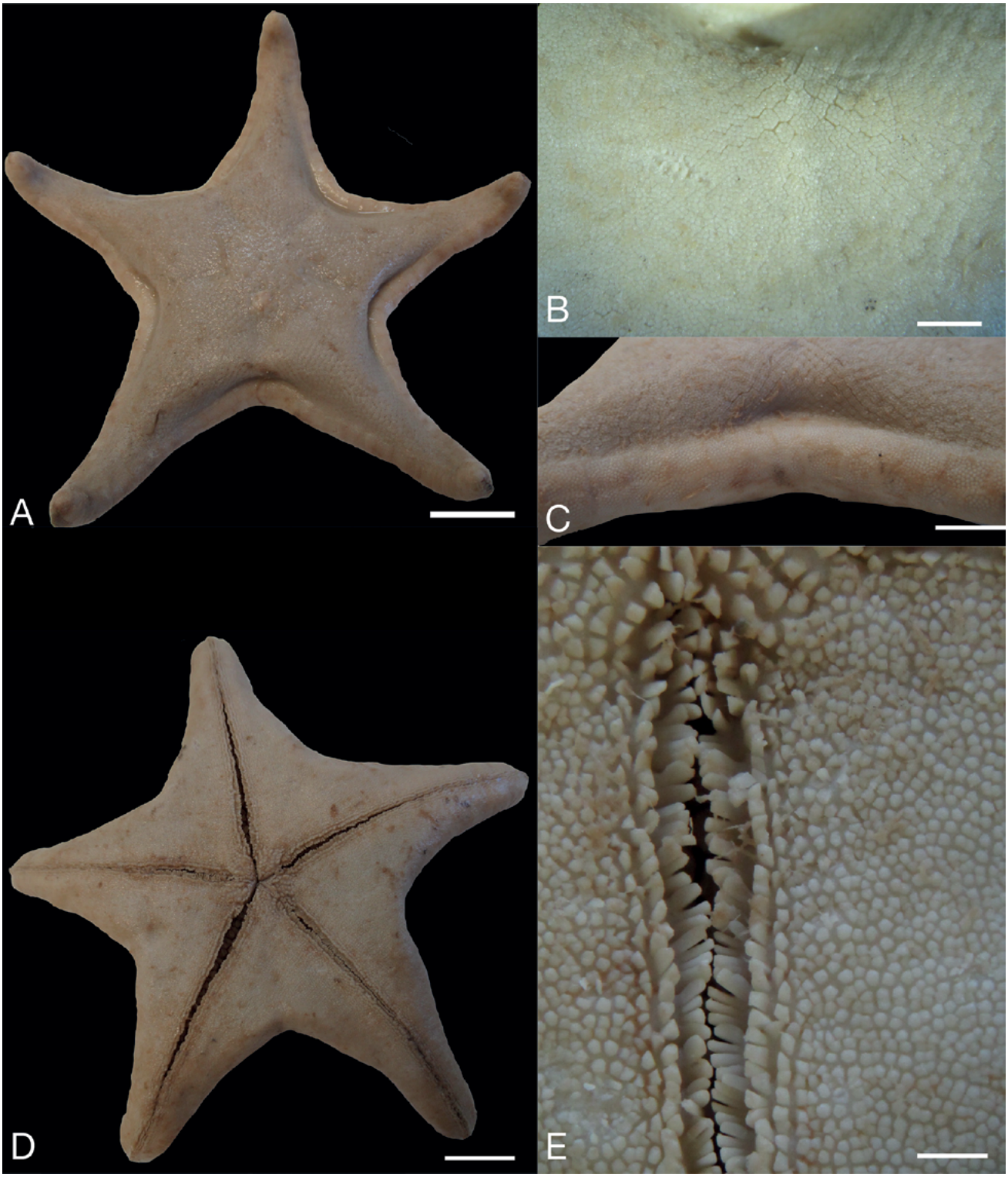

Figure 9. *Bathyceramaster wami* n. sp. WAM Z 110181 Holotype: a, Abactinal; b, Closeup abactinal; c, Abactinal-lateral view; d, Actinal; e, Adambulacral/Furrow spination. Scale bar = 10.0 mm: a, d; Scale bar = 5.0 mm: c; Scale bar = 3.0 mm: b; Scale bar = 2.0 mm: e.

Abactinal surface arched. Surface composed of closely articulated, short tabulate plates. Tabular surfaces quadrate, hexagonal to irregularly polygonal. Surface covered by coarse, polygonal-shaped granules, 4 to 12, approximately 3 present along a 1.0 mm count, ranging from a flush flat surface to a convex plate surface, each displaying a very homogeneous appearance (Fig. 9A–B). Granules along the plate surface of these tabulae, tightly articulated, with granules in some areas forming an almost solid surface. These are more prevalent centrally on the disk with more weakly articulated tabulae distally, especially interradially adjacent to the contact with the superomarginal plates. Papulae not observed. Madreporite strongly convex with polygonal granules forming a ring around the base of the plate. Pedicellariae, small, near granule-size, paddle-shaped, embedded among plates near contact with superomarginal series.

Marginal plates 16 per arm side, 32 total per interradius (arm tip to arm tip) (Fig. 9A, C). Individual plates quadrate, especially interradially becoming slightly wider distally. Overall marginal plate series round in appearance, "rolled" with lateral edges from abactinal and actinal plate series rounded where they form angular contact with the marginal plates. Superomarginal and inferomarginal plates articulated more 1:1 interradially becoming more offset and forming zigzag contact which is more prominent distally along arm. Superomarginal and inferomarginal plate surfaces covered by coarse granules, approximately 40–150, each polygonal in shape, closely but evenly spaced, forming a continuous layer with granules from the abactinal surface. Granules coarse, approximately 3 along a 1.0 mm line, covering all plate surfaces along the arm. A discrete series, slightly larger than those centrally, present around each plate surface periphery, approximately 10 to 40 per side. Inferomarginal plates wide, larger than superomarginal plates with 40–200 granules covering surface, identical in overall size, shape to those covering superomarginal plate surface. Terminal plate triangular with smooth surface, no spines. Pedicellariae absent from marginal plate surface.

Actinal surface large with three to four full series in chevron formation with a single actinal series extending onto the arm and an irregular number array of these distally adjacent to contact with inferomarginal plates (Fig. 9D). Each plate quadrate in shape, covered by coarse, round granules, widely spaced. Surficial granules 25–50, granular cover identical to those on abactinal and marginal plates, obscuring plate boundaries.

Furrow spines, 3 to 5, mostly 3 or 4, blunt-tipped, quadrate in cross-section, palmate to straight in formation, widely spaced (Fig. 9E). Two rows of subambulacral spines set off from furrow spines by distinct diastema, first row composed of mostly 2, exceptionally 3, spines, approximately twice the thickness of the furrow spines, forming a nearly straight line along the adambulacral series. The second subambulacral series composed of approximately 2 to 3 spines, shorter spines similar in size, height to granules on actinal plate surface, triangular to quadrate in cross-section. All widely spaced.

Oral plates with furrow spines, 8, quadrate in cross-section with a ninth spine directed into mouth (Fig. 9D, E). Five blunt, thick spines, each triangular in cross-section present along either side of the diastema between oral plates. Additional oral plate spines, 5 to 9 on plate surface, similar in appearance to oral furrow spines. First adambulacral plate with distinct forceps like pedicellariae.

Ceramaster Verrill, 1899.

Tosia (*Ceramaster)* Verrill, 1899: 161

Ceramaster Fisher, 1906: 1054; 1911: 162, 204; Verrill, 1914: 289; Koehler, 1924: 173; Mortensen 1927: 80; Djakonov, 1950: 38; Tortonese and A.M. Clark, 1956: 347; Halpern, 1970b: 62; 1970c: 212; 1970: 62; Downey, 1973: 49; McKnight, 1973: 178; Downey, 1973: 49; A.M. Clark and Courtman-Stock, 1976: 61; Clark and Downey, 1992: 231; Downey in Clark and Downey, 1992: 231; Mah, 2011:5, 2016: 112.

Philonaster Koehler, 1909: 78 (type species *Pentagonaster [Philonaster] mortenseni* Koehler, 1909).

Tosiaster Verrill, 1914: 1054.

Diagnosis. Body outline pentagonal in most (i.e. R/r = 1.1–1.5) with some becoming more stellate. Abactinal plates tabulate, granules present on abactinal plates, marginals, actinal plates. **Fasciolar grooves present among abactinal, marginal plates. Bare "patch" on dorsal facing of superomarginal plates on most species**

Comments. As has been summarised herein, *Ceramaster,* as historically recognised is likely paraphyletic, including multiple species whose morphology suggest distinct groupings within the nominal "*Ceramaster*" as described by Verrill (1899). Full comments on the division of *Ceramaster* into *Alloceramaster* nov. gen. are included under the Goniasteridae heading. As iterated elsewhere, *Ceramaster* herein is restricted largely to those taxa most similar to the typological *C. granularis*, which includes those species showing affinities to the wide ranging *C. patagonicus*. Fossils, which are largely based on individual ossicles were not considered.

Pseudoceramaster glasbyi (McKnight, 1993) nov. comb.

Only one species, *Ceramaster glasbyi* McKnight, 1993 was considered significantly different from other members of the *C. patagonicus/granularis* group, given its lack of well-developed fasciolar grooves and stellate shape. Review of the description suggests that placement within *Pseudoceramaster* Jangoux, 1981 is appropriate, especially given the modification of *Pseudoceramaster*'s boundaries to include shallow or weakly developed papular fasciolar channels (Mah and Fujita, 2024).

Ceramaster fortis n. sp.

Figures 10A–F

Material Examined. Holotype. WAM Z110161. Gascoyne Marine Park, Western Australia, Indian Ocean, 22° 0' 0.1656" S, 113° 44' 13.1316" E, 794.0 m. Coll. B. Alvarez, K. M. Naughton, K. Moore and C. Unteidt. 8 December 2022, Gascoyne 10055572. 1 wet spec. R = 10.8 r = 6.5

Etymology. The species epithet *fortis* is derived for the Latin for "strong", alluding to this species' particularly stout and well-developed skeleton.

Diagnosis. Body stout, thick, weakly stellate (R/r = 1.66), arms upturned, broadly triangular in shape. Disk large, interradial

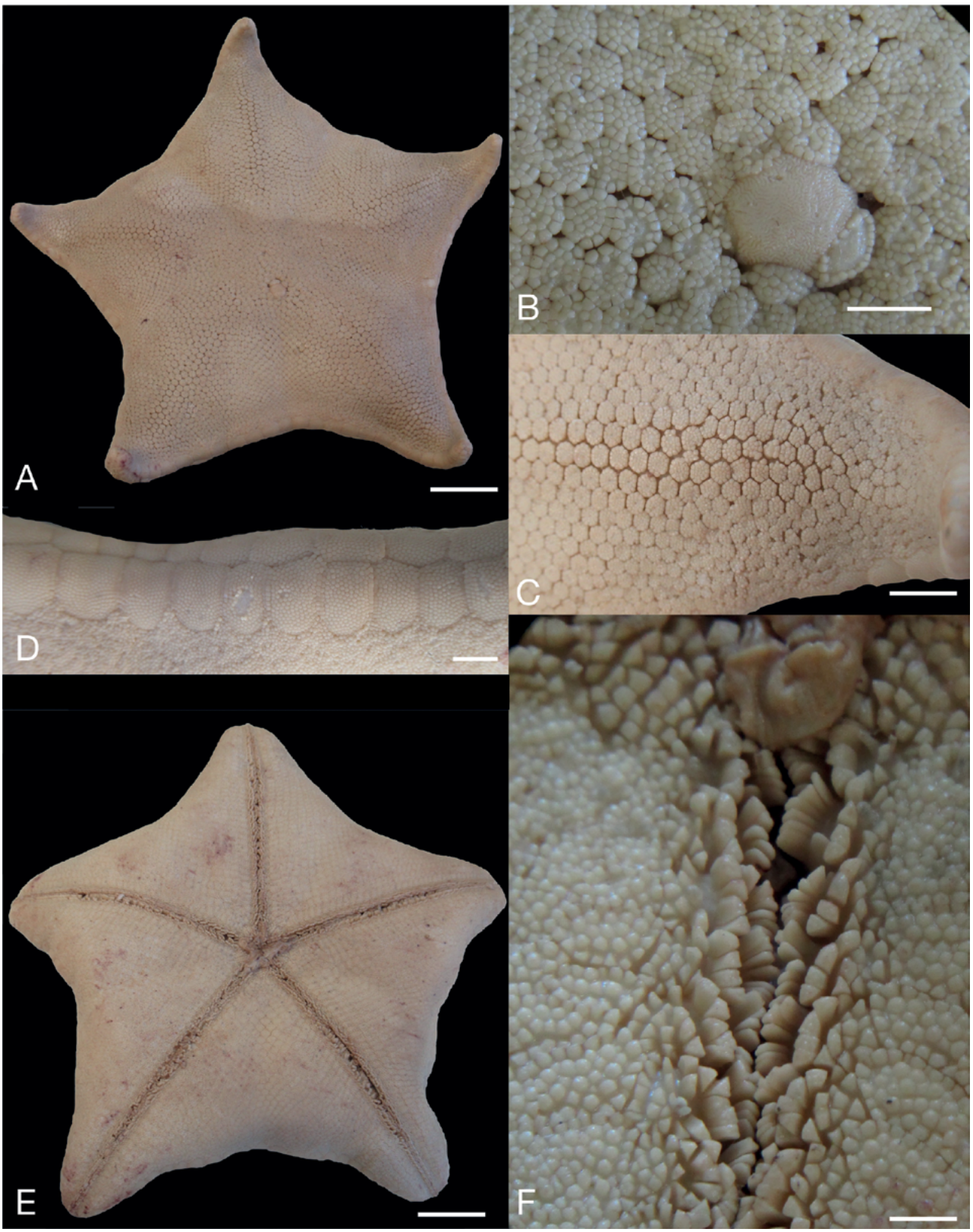

Figure 10. *Ceramaster fortis* n. sp. WAM Z 110161, Holotype: a, Abactinal; b, Closeup abactinal; c, Abactinal arm tip view; d, Abactinal-Lateral view, marginal plates; e, Actinal; f Adambulacral/Furrow spination. Scale bar = 20.0 mm: a, e; Scale bar = 5.0 mm: b, c, d; Scale bar = 2.0 mm, f.

arcs weakly curved to straight. Abactinal plates tabulate. **Each plate covered with polygonal, well-developed, coarse granules, 4–18 around periphery, angular, 3–20 present in central surface. Fasciolar grooves well developed. Superomarginal plates, 13–14 per side, 26–28 per interradius, surface covered with coarse, round granules, close-set approximately 3 count along a 1.0 mm line. Superomarginal surface completely covered with no bare region.** Actinal region large, with up to 15 full series in chevron-like arrangement. Plate surface covered by large, coarse, round to polygonal granules. Furrow spines, 5 to 9. Subambulacral spines and granules in two to three irregularly arranged series. Subambulacral spines closely arranged, 4 to 5, two to three times as thick as the furrow spines,

Comments. A species that appears to be a member of the *C. patagonicus* group within *Ceramaster* based on the coarse and strongly angular granules present on the abactinal table, the well-developed granulation present on the marginal plates and the well-developed fasciolar grooves present among the abactinal plates. The skeleton in this species is heavily developed.

This species differs from *C. patagonicus* and *Ceramaster australis* H.E.S. Clark, 2001 in that the superomarginal surface is completely covered in granules, the distinct convex to raised bare patch present on the superomarginal plate surface in other species is absent. There are large angular granules present, especially on the periphery of the tabulate plates, 4 to 18 versus the smaller granules in *C. patagonicus* with 8 to 80 total. *C. australis* further differs in showing significantly smaller and differently shaped peripheral granules and much fewer superomarginal plates per interradius (n = 19 at R = 4.2) versus 26–28 (R = 10.8) in *C. fortis* n. sp. Superomarginal plates on *C. australis* are much more tumid, strongly convex in cross-section. *C. fortis*, displays greater numbers of furrow spines, 5 to 9 versus 3 to 4 on *C. patagonicus*.

C. fortis n. sp. is most similar to the South African *Ceramaster trispinosus* with which it shares the coarse abactinal and actinal granules, the granular cover over the superomarginal and inferomarginal plates, and the stout skeletal construction. It differs in having 5 to 9 furrow spines versus 3 furrow spines in *C. trispinosus*, which are much shorter than those of *C. trispinosus*. The subambulacral spines are much thicker and blockier than those of *C. trispinosus*.

Occurrence/Distribution. Gascoyne Marine Park, Western Australia, Indian Ocean, 794 m.

Description. Body stout, thick, weakly stellate (R/r = 1.66), arms upturned, broadly triangular in shape. Disk large, interradial arcs weakly curved to straight (Fig. 10A, E).

Abactinal surface strongly tabulate, completely covered by closely abutted tabulate plates. Each plate covered with polygonal, well-developed, coarse granules, 4–18 around periphery, 3–20 present in central surface (Fig. 10B, C). Approximately 2 count along a 1.0 mm line. Granules closely arranged, but evenly distributed on plate. Radial regions arched, interradial regions with shallow valleys. Abactinal plates more densely arranged interradially than on radial arm regions. Pedicellariae, elongate paddle-shaped, present on 40–50% of plates overall but with slightly higher numbers present on radial regions. When present pedicellariae located on central surface surrounded by granules. Fasciolar areas well-developed but especially so along proximal radial regions along arms. Madreporite pentagonal, strongly convex with well-developed sulci.

Marginal plates approximately 13–14 per arm side, 26 to 28 per interradius, with predominantly lateral facing (Fig. 10A, D). Superomarginals quadrate in shape, surface flat becoming more convex distally adjacent to arm tip. Superomarginals offset with inferomarginals forming zigzag contact between them. Superomarginal plate surface covered with coarse, round granules, close-set approximately 3 counts along a 1.0 mm line (Fig. 10D). Superomarginal and inferomarginal plate surfaces with 40–60 granules, quadrate to shield-shaped present in a single series around plate periphery. Central region with 100–300 round granules, present on superomarginal plates especially those interradially with granule number decreasing with smaller plate size distally along the arm. Pedicellariae, elongate paddle-shaped, 1 to 4, similar to those on abactinal surface present on a one or two of the total number of superomarginal plates per interradius. No bald spots. Inferomarginal contact with actinal intermediate region irregularly convex, especially interradially.

Actinal intermediate areas large, approximately 15 full series of actinal plates in chevron formation with multiple irregular series present interradially adjacent to the inferomarginal plate contact (Fig. 10E). Individual plates quadrate proximally adjacent to adambulacral plate series becoming more irregularly polygonal in shape adjacent to contact with inferomarginal plates. A closely arranged cover of polygonal to round coarse granules, approximately 2 granules counted along a 1.0 mm line. Granules variably rounded to weakly pointed.

Adambulacral armature closely arranged, crowded. Furrow spines 5 to 9, proximalmost adambulacral plates with five, then increasing 7 to 9 distally then decreasing to approximately five adjacent to arm tip. Furrow spines, blunt, with quadrate tips, arranged in strongly palmate to straight series (Fig. 10F). Spines quadrate to triangular in cross-section. A large space separating furrow spines from subambulacral spines. Subambulacral spines and granules in two to three irregularly arranged series. Subambulacral spines closely arranged, 4 to 5, two to three times as thick as the furrow spines, immediately adjacent to furrow spines with club-like blunt tips. Subsequent subambulacral spine series, 3 to 4, approximately half the height of the subambulacral spines but as thick as prior series, quadrate to triangular in cross-section. Subsequent granules on adambulacral plates, polygonal but identical in size with granules on adjacent actinal surface, more widely spaced.

Oral plate furrow spines 12–14, quadrate to polygonal in cross-section, blunt tipped (Fig. 10E). Approximately 8 to 10 paired quadrate granules present along edge of each ridge adjacent to diastema. Oral plate surface with further 8–10 polygonal granules. First adambulacral plate with an elongate pedicellariae present adjacent to oral plate.

Cardiac stomach extended.

***Kokosaster* nov. gen.**

Etymology and Diagnosis. Monotypic: see below.

***Kokosaster acanthodes* nov. gen. nov. sp.**

Figures 11A–G

Material Examined. Holotype. NMV F307960. Cocos (Keeling) Islands, Indian Ocean Territory, 12º 13 ‘ 32" S, -12º 14' 21" S to 96º 57' 36" E, -96º 58' 16" E 1113–1343 m. Coll. O’Hara et al. RV *Investigator* 17 October 2022. 1 wet spec. R = 3.9 r = 2.3

Paratypes. NMV F307959. Cocos (Keeling) Islands Territory, Australia. 12º 13' 32" S, 12º 14' 21" S to 96º 57' 36" E, -96º 58' 16 “ E, 1113–1343 m. Coll. Tim O’Hara et al. IN2022 V08IOT 2, Marine Invertebrates Team, 17 October 2022. 1 wet spec. R = 3.8 r = 2.1

NMV F307961. Cocos (Keeling) Islands Territory, Australia. 12º 13' 32" S, 12º 14' 21" S to 96º 57' 36" E, -96º 58' 16" E, 1113–1343 m. Coll. Tim O’Hara et al. IN2022 V08IOT 2, Marine Invertebrates Team, 17 October 2022. 1 wet spec. R = 3.5 r = 1.8.

Etymology. The genus, *Kokosaster* is named for the type locality, the Cocos Islands (spelled *Pulu Kokos* in Cocos Malay). The species epithet *acanthodes* alludes to the numerous spines present on the actinal plates.

Diagnosis. Body stout, inflexible, weakly stellate, R/r = 1.69, arms wide at base, arm tips blunt. Interradial arcs weakly curved. **Abactinal plates flat to weakly convex covered by granules, 5 to 30, mostly 15 to 20,** Peripheral granules elongate different from round/irregularly polygonal granules elsewhere. Marginal plates 18/20 superomarginal/inferomarginal. **Superomarginal surface bare, inferomarginals bare distally, but with granules proximally.** Granules present interstitially between superomarginals and inferomarginals. **Actinal plates covered with short spinelets, 1 to 6, mostly 4 to 5 conical present centrally on each plate especially on those close to inferomarginal plates.** Furrow spines 6, with two series of 3 conical subambulacral spines, widely spaced.

Comments. Characters on *Kokosaster acanthodes* nov. gen. nov. sp. appear intermediate between other pentagonal shaped Goniasteridae, such as *Peltaster* (granular covered abactinal plates) and *Alloceramaster* (smooth superomarginal plate surface, differing peripheral granules around the abactinal plates of the papular region). The actinal spination, showing spines with blunt tips as expressed on *Kokosaster* could not be located on other goniasterid taxa, in contrast to taxa such as *Calliaster* and *Calliderma* that show distinct, pointed conical spines present on the actinal surface (Fig. 11F). However, similar types of spines are found on the actinolateral boundary of the inferomarginal plates on *Ahuastra gfoei* (Mah, 2020).

Occurrence/Distribution. Cocos Keeling Islands, Indian Ocean Territory, 1113–1343 m.

Description. Body rigid, weakly stellate, R/r = 1.69–1.8, arms wide at base, arm tips blunt. Interradial arcs weakly curved (Fig. 11A).

Abactinal plates polygonal with more plates more distinctly hexagonal along radial regions, more irregularly polygonal and smaller shaped interradially adjacent to the superomarginal plates. Abactinal plates restricted to disk, absent from distalmost arm regions where superomarginal plates are abutted. Plates flat to weakly convex, covered by granules, 5 to 30 flattened, weakly polygonal, close but evenly arranged in linear series (Fig. 11A–C). Where granules are absent, shallow concavities are present. Peripheral granules of two types, weakly polygonal granules present around interradial plates and elongate, rod-shaped granules, approximately 25–30 total, 5 per side, present around radial plates, papular regions in three series. Papulae around proximal arm regions, absent distally and interradially. Madreporite quadrate in shape, flanked by four plates. Small paddle-shaped pedicellariae, approximately 1.0 mm in length, variably present.

Superomarginal plates 16 to 18 per interradius (arm tip to arm tip) at R = 3.5, 20 inferomarginal plates (Fig. 11A, D). Superomarginal plates wide, blocky curved abactinal-lateral edge, forming approximately 13% of the total “r” distance (0.3/2.3). Distalmost four superomarginals abutted along arm midline. Superomarginal plate surface completely bare on dorsal and lateral surface. Inferomarginal plates with ventral-facing bare patch, covered by granules on lateral surface. Peripheral granules, round present in interstitial regions, forming two to four series especially at contact between superomarginal and inferomarginal plates. No pedicellariae.

Actinal plates in four, full series, chevron-like series. Plates quadrate in shape with rounded edges. Fasciolar grooves shallow. Actinal plates with spines, blunt, short, and pointed, 1 to 6 present centrally on each plate (Fig. 11F). One paratype with much shorter spines, comparable in height to adjacent granules. Peripheral granules, approximately 3 to 4 per side, 12–18 total, each quadrate to polygonal in cross-section, shorter than actinal spines. Actinal plate surface otherwise bare. No pedicellariae. Inferomarginal plates with pointed conical spinelets similar to others on actinal plate surface on surface adjacent to actinal surface. Actinal surface adjacent to inferomarginal plates with blunt spinelets. Paddle-like pedicellariae variably present on actinal plate surface, 2 to 6, per interradius.

Furrow spines 5 to 6, mostly 6, blunt, laterally flattened, subambulacral spines in two series, three spines each, conical, pointed, widely spaced with central spine most prominent (Fig. 11G). Further adambulacral granules, 4 to 8, short, irregularly pointed to rough. Oral plates with furrow spines, 12 and a single prominent spine, quadrate in shape, blunt tipped directed into the mouth (a total of 2 per interradius). Oral plate surface with 7 prominent elongate pointed spines (identical to subambulacral spines) and 7 shorter spines, quadrate in cross-section, paired on either side of the central diastema between the oral plate sides. 6 to 8 granules similar to those on actinal surface on remaining oral plate surface.

***Litonotaster* Verrill 1899.**

Litonotaster Verrill 1899: 171; Fisher 1911: 165; Halpern 1969: 129, 1970: 252; 1970b: 144; Clark and Downey 1992: 249.

Diagnosis (modified from Clark and Downey 1992). Body stellate, arms short, interradial arcs weakly curved to straight. **Abactinal plates flat, thin, covered with surficial and marginal granules. Secondary abactinal plates absent.** Papulae few in narrow regions. **Marginal plates flat, more**

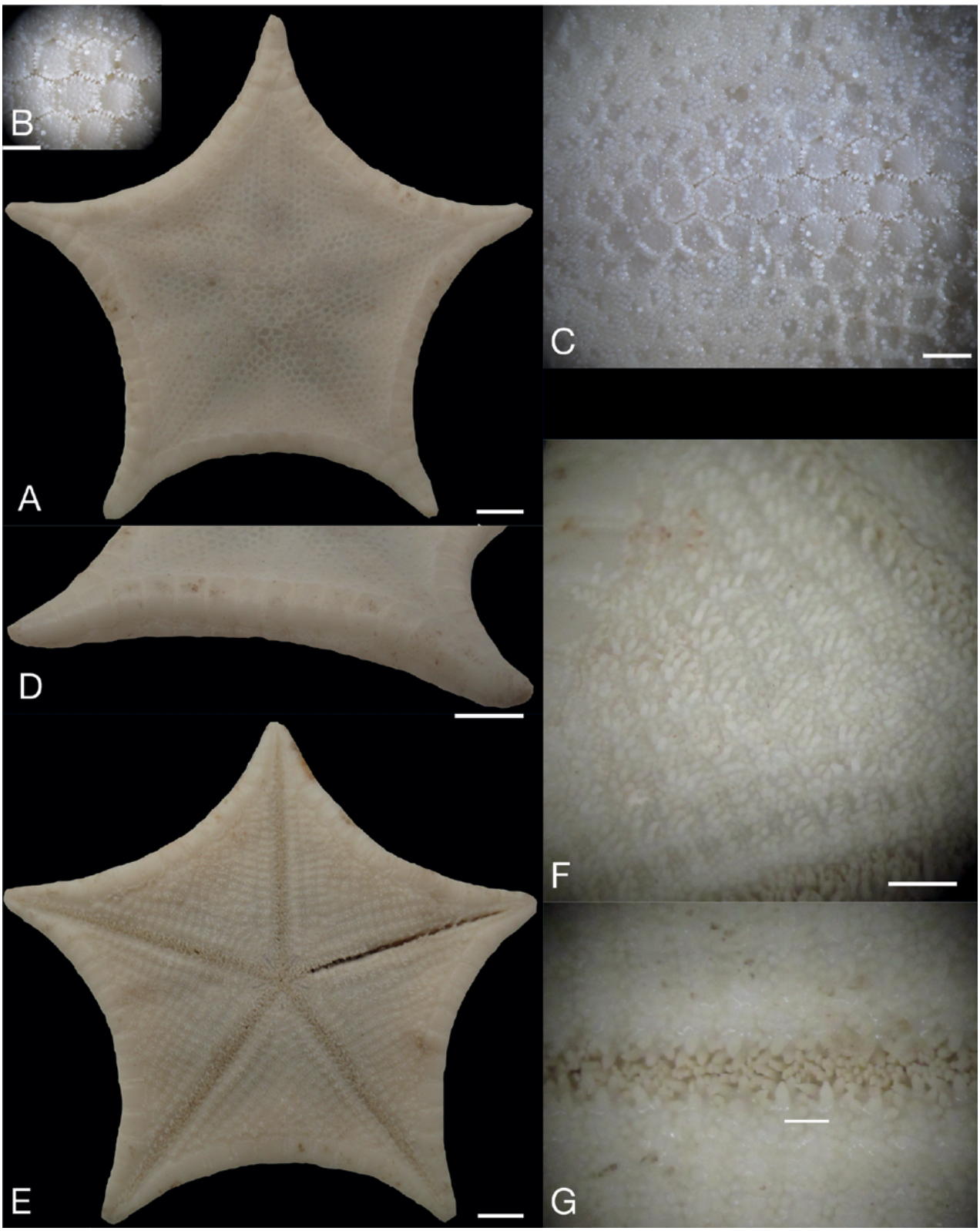

Figure 11. *Kokosaster acanthodes* n. gen. n. sp. Holotype, NMV F307959: a, Abactinal; b, Closeup tabulae; c, Closeup Abactinal surface; d, Abactinal-lateral view; e, Actinal; f, Actinal surface showing spination; g, Adambulacral/Furrow spination. Scale bar = 3.0 mm: a, d, e; Scale bar = 1.0 mm: b, c, f, g.

elongate than wide, surface largely bare. Actinal surface covered by granules, Furrow spines with short, blunt spines, 4 to 8, subambulacral spines in multiple rows. Pedicellariae when present, small, excavate.

Comments. *Litonotaster* includes 4 species, the Atlantic, *L. africanus* Halpern, 1969 and *L. intermedius* (Perrier, 1884) as well as the East Pacific *L. tumidus* H.L. Clark, 1920 and the tropical North Pacific *L. gfoei* Mah, 2022. All known species occur at bathyal to abyssal depths (1000 to 5000 m).

Litonotaster intermedius is highly variable and widely occurring throughout the Atlantic. Downey in Clark and Downey (1992: 250) remarked that *L. africanus* from the Gulf of Guinea "certainly" falls within the range of variation of *L. intermedius*.

***Litonotaster intermedius* (Perrier, 1894).**

Figures 12A–E

Pentagonaster intermedius Perrier, 1884: 243, pl. 5, figs. 5–6 (Non-*Pentagonaster intermedius* Alcock, 1893: 90)

Litonotaster intermedius Verrill, 1899: 172, pl. 28, figs 5–5b, H.L. Clark, 1941: 48; Madsen, 1951: 88; Halpern, 1969: 130, figs. 1B,2,3; 1970: 147; Clark and Downey, 1992: 250, pl. 59C, D.

Litonotaster rotundigranulum Halpern, 1969: 134, figs. 6–7; 1970: 252 figs 20–22, 1970b: 153, fig. 6.

Material Examined. NMV F240390. Great Australian Bight 35º 09' 10" S, 134º 06' 32" E to 3º 10' 56" S, 134º 06' 32" E. 965–1077 m. Coll. IN2015_C02, GAB BP. 15 wet specs. R = 2.2 r = 1.0; R = 2.6 r = 1.3; R = 2.2 r = 1.1; R = 2.0 r = 1.1; R = 3.1 r = 1.6; R = 3.2 r = 1.7; R = 2.9 r = 1.5; R = 3.4 r = 1.9; R = 3.0 r = 1.5; R = 3.6 r = 2.0; R = 4.4 r = 2.3; R = 3.9 r = 2.2; R = 4.1 r = 2.2; R = 4.3 r = 2.3; R = 4.5 r = 2.4; R = 5.0 r = 2.6.

WAM Z110120. Gascoyne Marine Reserve, 21° 2'15.99" S, 112° 38' 30.2316" E, 1534 m. Coll. Alvarez, B., Naughton, K.M., Moore, K., Unteidt, C. CSIRO Gascoyne 10052793, 27 Nov 2022. 1 wet spec. R = 5.4 r = 2.3.

WAM Z110036. Gascoyne Marine Reserve, 20°48'8.1612"S 111°36"55.5984" E, 2013 m. Coll. Alvarez, B., Naughton, K.M., Moore, K., Unteidt, C. CSIRO Gascoyne 10051556, 3 December 2022. 1 wet spec. R=3.8 r=2.0.

WAM Z110042. Gascoyne Marine Reserve, 20° 49' 41.3616" S, 111°36'12.2256" E, 2057 m. Coll. Alvarez, B., Naughton, K.M., Moore, K., Unteidt, C. CSIRO Gascoyne 10051697, 4 Dec. 2022. 2 wet specs. R = 5.2 r = 2.3 R = 4.8 r = 2.4.

WAM Z110121. Gascoyne Marine Reserve, 21° 2' 15.99" S, 112° 38' 30.2316" E, 1534 m. Coll. Alvarez, B., Naughton, K.M., Moore, K., Unteidt, C. CSIRO Gascoyne 10052794, 27 Nov. 2022.

2 wet specs. R = 2.0 r = 1.1 R = 0.9 r = 0.6

WAM Z110170.123 km WSW Ningaloo Reef. Western Australia, 22°59'12.282"S 112°28'42.3408" E, 1451 m. Coll. Alvarez, B., Naughton, K.M., Moore, K., Unteidt, C. CSIRO Gascoyne 10055923, 9 Dec. 2022. 4 wet specs. R = 2.4 r = 1.3, RE = 3.0 r = 1.6, R = 4.2 r = 3.1, R = 4.7 r = 2.4.

WAM Z110050. Gascoyne Marine Reserve, 20° 48' 12.0672" S 111° 43' 39.2088" E, 1558 m. Coll. Alvarez, B., Naughton, K.M., Moore, K., Unteidt, C. CSIRO Gascoyne 10055923, 4 December 2022.

8 wet specs. R = 1.1 r = 0.6, R = 2.1 r = 1.1, R = 1.9 r = 1.0 R = 2.8 r = 1.4 R = 2.8 r = 1.5, R = 1.5 R = 1.3 r = 0.7 R = 3.4 r = 1.5 R = 4.0 r = 1.9.

WAM Z110097. Gascoyne Marine Reserve, 22° 22' 28.0236" S, 113° 13' 28.9272" E, 1497 m. Coll. Alvarez, B., Naughton, K.M., Moore, K., Unteidt, C. CSIRO Gascoyne 10055923, 25 November 2022. 1 wet spec. R = 5.3 r = 2.3.

Diagnosis (Based on Clark and Downey, 1992). Body stout, shape weakly stellate to stellate (R/r = 1.3–2.3), arms short, triangular. Interradial angles weakly curved to straight. **Abactinal plates abutted, polygonal to quadrate, surface completely covered by round, granules, 7 to 24, variably with small central areas bare. Marginal plates 20–24, surface bare but with dense granulation around periphery and on inferomarginal surface completely covered by granules, completely covered by coarse, round granules, approximately 80–150, widely spaced.** Furrow spines 3 to 8, mostly 5 to 7 in straight series. A single clamp-like pedicellariae present proximally on the adambulacral plate, remainder of plate covered by subambulacral granules in 3 loosely linear series, evenly spaced.

Comments. Characters observed on specimens from Australian waters were consistent with those observed from the Atlantic, varying in minor respects with regard to furrow spine number and granular cover, which have already recorded as being variable among Atlantic specimens. *L. intermedius* appears to be a primarily deep-sea goniasterid species, such as *S. nieseni*, which shows widespread distribution across its range.

Occurrence/Distribution. Atlantic Ocean. Gulf of Mexico, Cuba, Straits of Florida, West Indies, 1060–3530 m.

Pacific Ocean. Great Australian Bight, 965–1077 m.

Indian Ocean. Gascoyne Marine Reserve, 1451–2057 m.

Description. Body stout, shape weakly stellate to stellate (R/r = 1.3–2.3), arms short, triangular. Interradial angles weakly curved to straight (Fig. 12A).

Abactinal plates abutted, variably polygonal to quadrate with larger plates centrally becoming smaller and more irregularly shaped distally, adjacent to superomarginal contact. Plate periphery surrounded by prominent ring of quadrate granules, 7 to 24, mostly 10–15 occupying approximately 20–25% of total plate diameter. Peripheral granules directly abutted against peripheral granules of adjacent plates forming a thick boundary between them (Fig. 12B). Further granules present on plate surface contributing up to twice or even three times a granular ring around each plate. Most central plate surfaces flat to weakly convex, bare, especially those interradially, but variably, several plates on radial regions with 4 to 10 identical close-set granules present on central region presenting a densely granular appearance when present (Fig. 12B–C). These dense granular regions are especially prominent at contact between abactinal and superomarginal plates. Pedicellariae small, paddle-like similar in size to granules on plates, present on a minority of plates, perhaps 20–30% of total irregularly distributed over abactinal surface. Papulae single, present with greatest abundance on radial regions along arms, absent interradially. Madreporite approximately 3.0 mm in length, quadrate to irregularly round, flanked by abactinal plates, 4 to 8 partially obscured by 7–10 coarse granules. Sulci well developed.

Marginal plates approximately 10–12 plates per arm side, 20–24 per interradius (arm tip to arm tip at R=5.2). Distalmost two to three pairs of superomarginals abutted along midline (Fig. 12A, C). Superomarginal plates elongate becoming squarish distally along arms. Abactinal-lateral angle rounded.

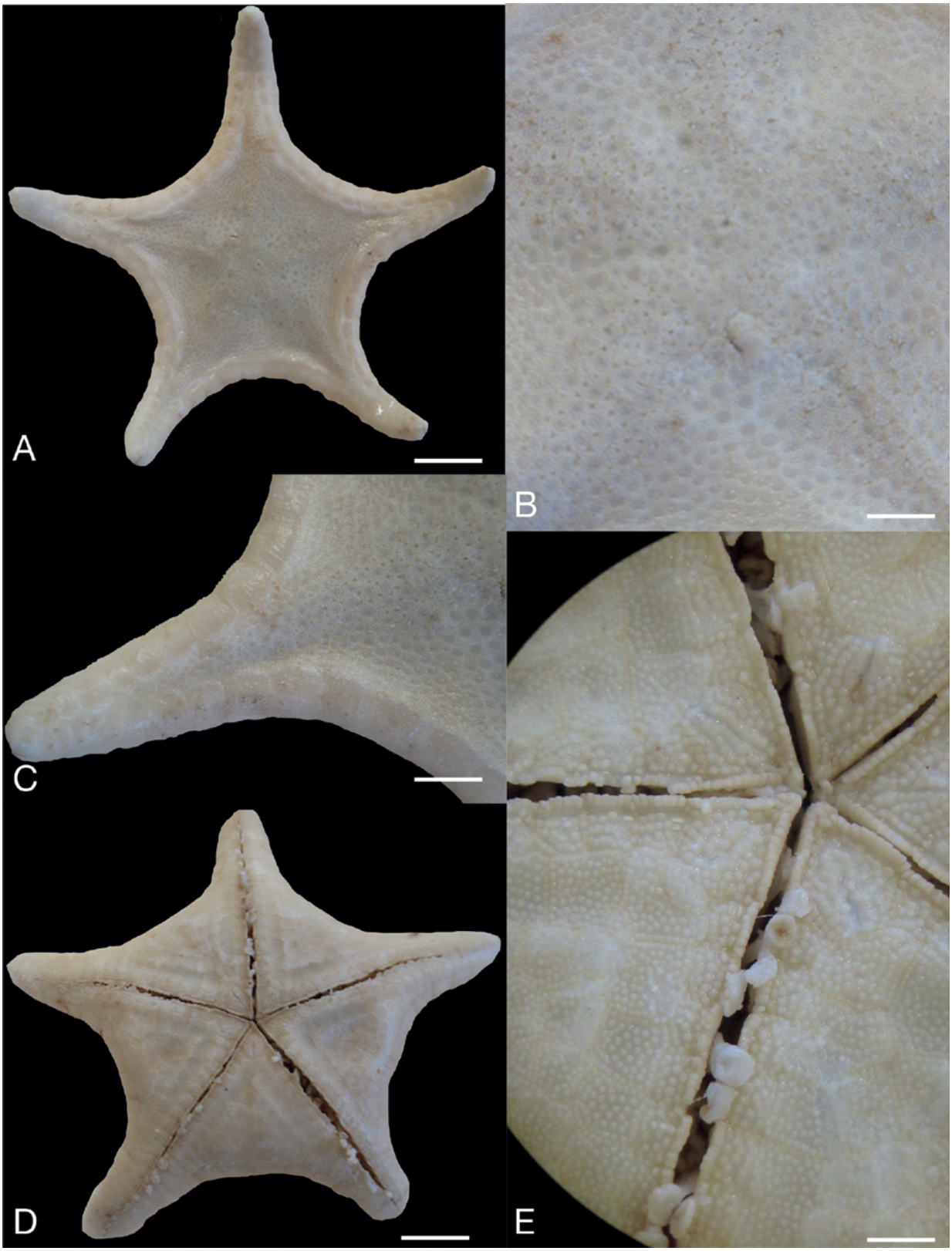

Figure 12. *Litonotaster intermedius* (Perrier, 1884) WAM Z 110097: a, Abactinal; b, Closeup abactinal; c, Abactinal-arm tip view; d, Actinal; e, Adambulacral/Furrow spination. Scale bar = 10.0 mm: a, d; Scale bar = 5.0 mm: c; Scale bar = 2.0 mm: b, e,

Inferomarginal plates larger than superomarginals especially interradially with quadrate/square shape to arm tip. Superomarginal and inferomarginal plates slightly offset forming zigzag contact between them. Superomarginal plate surface irregularly bare on abactinal surface, lateral surface covered by 10–30 coarse, round granules, widely spaced, irregularly arranged, present in 2 to 3 series covering lateral surface. Peripheral granules quadrate, approximately 10–30 per side. Inferomarginal plate surface completely covered by coarse, round granules, approximately 80–150, widely spaced. Inferomarginal plates with quadrate angles, straight line contact with superomarginal and actinal plate fields. Penultimate superomarginals compressed in size, with bare surface, terminal plate triangular with smooth surface.

Actinal plates with three complete series and incomplete irregular series adjacent to the inferomarginal plate contact (Fig. 12D–E). Plates continue from disk, attenuating to a single series approximately midway along arm. Actinal plate surface with 20–120 coarse, round granules present, widely and evenly spaced. Peripheral granules, approximately 20–50, mostly 30–40 similar to the central surface.

Furrow spines 3 to 8, mostly 5 to 7 in straight series, with decreasing number distally (Fig. 12E). Spines short, quadrate in section with blunt tips. A single clamp-like pedicellariae present proximally on the adambulacral plate, remainder of plate covered by subambulacral granules in 3 loosely linear series, widely but evenly spaced.

Oral plate furrow spines 10, forming linear series with furrow spines, quadrate in cross-section with blunt angular tips (Fig. 12D, E). Remainder of oral plate surface with approximately 10 angular. Flat granules present along either side of interradial diastema on oral plate. Remainder of oral plate surface covered by 10–20 angular granules similar to those on subambulacral surface of other plates.

Mediaster Stimpson, 1857.

Mediaster. Stimpson, 1857: 530; Sladen, 1889: 263; Perrier, 1894: 377; 1896: 45; Verrill, 1899: 178; Fisher, 1911: 196; Verrill, 1914: 295; 1915: 108; Fisher, 1919: 255; Macan, 1938: 369; H.L. Clark, 1946: 83; Bernasconi, 1963: 11; 1964: 253; Halpern, 1970: 202; 1970b: 45; Clark and Downey, 1992: 251; Mah, 2018: 53.

Diagnosis. (Based on Mah, 2018). **Body stellate, tabulate abactinal plates displaying internally radiating ossicles from base of each plate.** Abactinal tabulae plates with granules or spinelets. Abactinal plates in most, extending to arm tip, but exceptionally with distalmost superomarginals abutting. Abactinal, marginal, actinal surface covered by granules.

Comments. *Mediaster* is widely occurring and includes 1 fossil and 18 living, totalling 19 species present in the Atlantic (n=2), Pacific (n=10), Indian Oceans (n=5), 1 from South Africa and one species present in both the Indian and Pacific oceans. Most species occur across a broad depth range from intertidal to 1829 m (e.g. Mah, 2016). Mah (2018) described 3 deep-sea species from the Indian Ocean. Rowe and Gates (1995) listed 3 species recorded from Australian waters, *M. arcuatus* (Sladen, 1889), *M. australiensis* H.L. Clark, 1916, and *M. praestans* Livingstone, 1933.

Mediaster praestans Livingstone, 1933.

Figure 13 A–F

Livingstone 1933: 21; H.L. Clark 1946: 83.

Material Examined. NMV F270807. Baseline 14, Tasmanian seamounts, Tasmania, Australia. 44º 6' 22" S, 146º 12' 13" E, 940–965 m. Coll. A. Williams, A. A. Weber, and R-L. Erickson, 6 December 2018, CSIRO. 1 wet spec. R = 2.0 r = 1.0.

Diagnosis. Number of abactinal plate rows decreasing along arm, becoming single series adjacent to arm tip. **Each tabula with 10 peripheral granules, 2 to 4 centrally.** Holotype with central granules 2 to 6, peripheral angular granules, 6 to 17. Marginal plates 30 per interradius, arm tip to arm tip (15 along each arm), wide, encroaching onto abactinal region. Surface covered by granules, when removed leaving numerous convex bosses. **Adambulacral plates with blunt quadrate furrow spines, 7, subambulacral spines in two series, each composed of 3 blunt spines. Subambulacrals shorter adjacent to contact with actinal plates. Pedicellariae absent from all surfaces.**

Comments. Characters on this specimen identify it as *M. praestans* Livingstone 1933. This includes identical abactinal tabulae and adambulacral spination, similar arrangement of abactinal disk plates, and marginal plate morphology. Pedicellariae are absent. The holotype displays a more stellate shape, R/r = 2.5 versus 2.0 in the current specimen but otherwise appears consistent.

This represents the first account of this species since its description, from the northeast coast of Queensland. The holotype did not have a recorded depth, making this specimen the first to show bathymetric occurrence. Its depth, 940–965 m suggests that this species is present in deep-sea settings. This specimen was collected from Tasmanian seamounts, significantly south of the type locality off Queensland suggesting that *Mediaster praestans* is a widely occurring species.

Occurrence/Distribution. NE coast of Queensland, no depth information.

Tasmanian Seamounts, 940–965 m.

Nymphaster Sladen, 1889.

Nymphaster Sladen, 1885: 612 (*nomen nudum*; diagnosed but no species named); 1889: 294; Fisher, 1917: 167; 1919: 261; Spencer and Wright, 1966: U62; Halpern, 1970: 222; 1970: 88; Downey in Clark and Downey, 1992: 253

Dorigona Perrier, 1885: 39; 1894: 365; Koehler, 1909: 54 (Non *Dorigona* Gray 1866)

Diagnosis. A genus with strongly stellate body form, triangular arms with rapidly tapering, pointed tips. **Abactinal surface showing weakly tabulate plates with granules covering surface. Superomarginals abutted over mid-radius along entire arm length, forming prominent frame around disk.**

Comments. A widely distributed genus of Goniasteridae with 16 species in the Atlantic, Pacific, and Indian Oceans with approximately a dozen fossil species, represented primarily by ossicles from Cretaceous chalks in northern Europe (e.g. Breton,

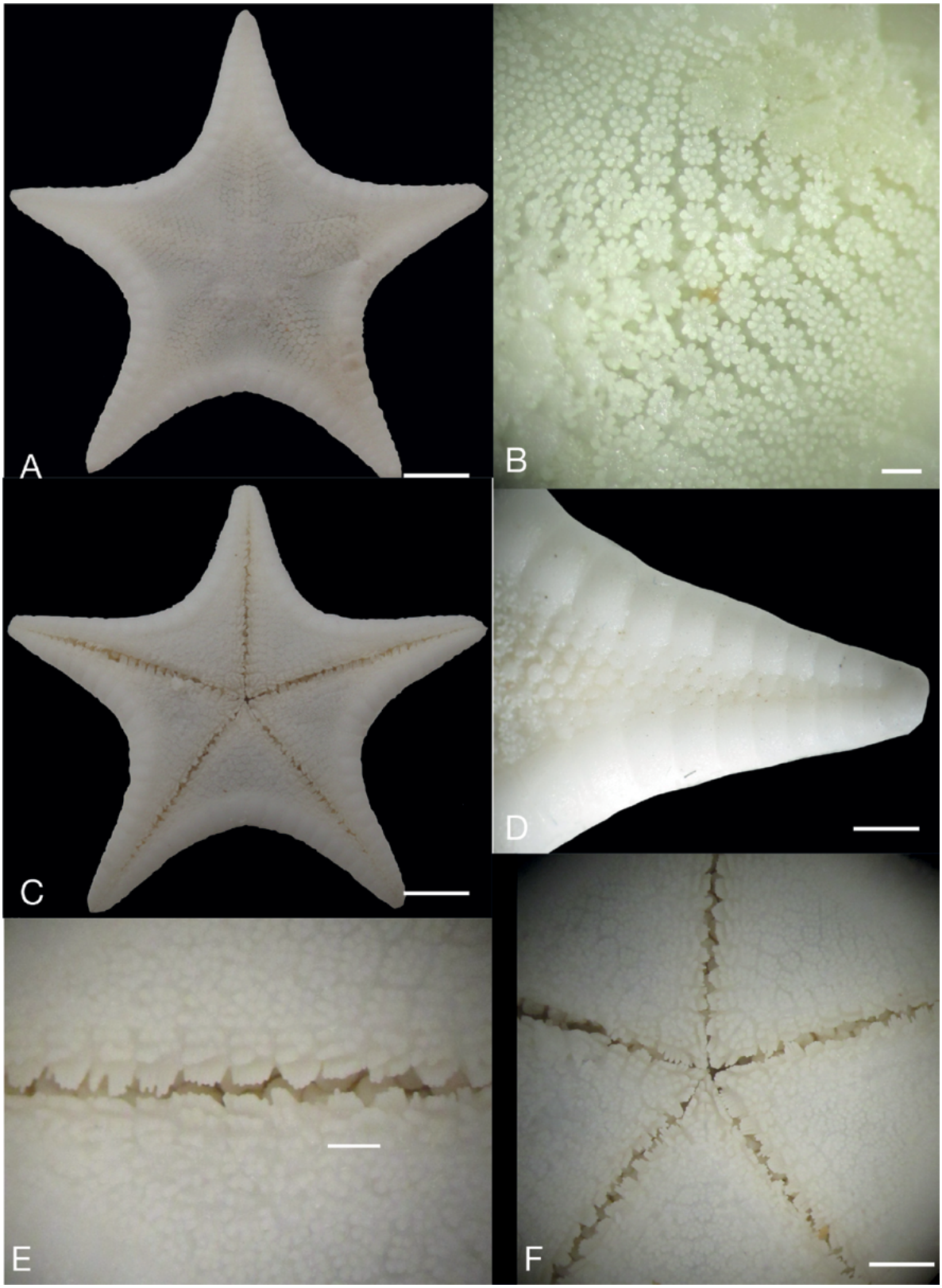

Figure 13. *Mediaster praestans* Livingstone, 1933 NMV F 270807: a, Abactinal; b, Abactianl tabulae; c, Actinal; d, Denuded abactinal arm plates, arm tip; e, Adambulacral spination; f, Oral region. Scale bar = 5.0 mm: a, c; Scale bar = 2.0 mm: d, f; Scale bar = 1.0 mm, b, e.

1988). *Nymphaster* is a genus in need of taxonomic refinement. Both the Atlantic and Indian Ocean/Australian species, *N. arenatus* and *N. moebi*, respectively, have included one or more synonyms encompassing what has been argued as variation in each as a widespread species. In contrast, Fisher (1913, 1919) described eight species of *Nymphaster* from the central Pacific which have not been reviewed. Variation among *Nymphaster* species is widespread, as has been observed in *N. moebi* (see Mah, 2018) and *N. arenatus* (Clark and Downey 1992). Further efforts to test species boundaries are desirable, especially over widely distributed species.

Nymphaster moebi (Studer, 1884).

Figures 14A–D, 15A–D

Pentagonaster (Dorigona) Studer 1884: 30, 35

Nymphaster moebi Sladen, 1889: 869; Döderlein, 1924: 55; Macan, 1938: 375; H.L. Clark, 1946: 87; A.M. Clark, 1993: 266 (checklist); Rowe and Gates, 1995: 67; A.M. Clark, 1993: 266

Nymphaster protentus Alcock, 1893: 95

Nymphaster basilicus Alcock, 1893: 95

Dorigona ternalis Koehler, 1909: 54, pl. viii, figs 5, 6

Dorigona ludwigi Koehler, 1909: 61, pl. ix, figs 5, 6

Dorigona belli Koehler, 1909: 58, pl. viii, figs. 2,3,4; James 1983: 89 (checklist)

Nymphaster pentagonus Clark, H.L., 1916: 36.

Material Examined. WAM Z105015. Off Perth, Western Australia, 31º 54' 24" S, 115º 6' 56" E, 534.3 m. Coll. A.M. Hosie, A. Hara, 22 Feb 2020.1 wet spec. R=8.2 r=2.2.

WAM Z110064. Gascoyne Marine Reserve 21º 45' 43.7976" S, 113º 40' 18.1452" E, 1104.0 m. Coll. B. Alvarez, K.M. Naughton, K. Moore, C. Untied, CSIRO 10051905, 5 December 2022. 2 wet specs. R = 7.6 r = 1.8 R = 9.2 r = 1.8.

WAM Z110082. Gascoyne Marine Reserve 22º 22' 05.9988" S, 113º 32' 04.92" E, 1075.0 m. Coll. B. Alvarez, K.M. Naughton, K. Moore, C. Untied, CSIRO, 24 November 2022. 2 wet specs. R = 6.7 r = 1.6, R = 8.2 r = 2.3.

Diagnosis (Based on Macan, 1938 and Mah, 2018). **Abactinal plates covered by coarse granules, fourteen to eighteen on carinal plates.** Eight to ten superomarginals form edge around disk, approximately 12 or more **Furrow spines seven, then eleven distally, compressed in palmate arrangement.** Mouth plates with ten or eleven furrow spines.

Comments. This species was recently reviewed by Mah (2018) as part of a survey of west Indian Ocean Goniasteridae. Rowe and Gates (1995) previously recorded this species from Australia, including New South Wales, Victoria, South Australia, and Western Australia. Specimens reported herein are new occurrences for the region. This appears to be the only known species of *Nymphaster* from Australian waters.

As touched upon by Mah (2018) distinctions between this species and the Atlantic *N. arenatus* are poorly defined and given the propensity for deep-sea goniasterids to be distributed widely (e.g. *S. nieseni*) there lies the possibility for at least one wide-ranging species.

Occurrence/Distribution. Australian. Off northwest coast of Australia, New South Wales, Victoria, South Australia, Western Australia, 534–1104 m.

Indian Ocean. Madagascar, Mozambique Channel, Mascarene Islands, Off coast of Tanzania (Zanzibar Island region). 195–1655 m.

Description. Body stout, strongly stellate (R/r = 3.0–4.4), arms elongate, sharply triangular in shape, acutely tapering. Interradial arcs curved to straight (Figs. 14A, B; 15A, B).

Abactinal plates weakly tabulate, surface outline polygonal to round, radial and adradial plates hexagonal or nearly so (Figs 15A, B). Fasciolar grooves present around radial regions, absent interradially. Abactinal plate surface covered by coarse, round granules, 4 to 20 total, fundamentally homogeneous, but forming a single-series peripheral, widely spaced from one another, approximately, 5 to 25 with a variable number and arrangement of central granules, numbering 3 to 20. Pedicellariae not observed on abactinal surface. Papulae primarily centred around radial regions, but absent interradially. Madreporite polygonal to round, variably quadrate to hexagonal, weakly convex with well-developed sulci, flanked by four to six abactinal plates.

Superomarginal plates, abutted over midline for the nearly complete arm distance (Fig 15A, B). Arm tips on nearly all specimens broken, but pointed when present. Superomarginals per interradius, (25/60) approximately 40% of superomarginals in contact. Superomarginals elongate, with variably angular to rounded lateral edges (Fig. 14A, B, 15A, B). Superomarginal and inferomarginal plates form discrete border around abactinal surface with plates forming variably wide periphery. Superomarginal and inferomarginal surface, covered by 200–500 polygonal, coarsely grained granules, evenly, and widely distributed over plate surface. Peripheral granules number about 12–15 along short edge, 20–30 along elongate edge. Actinolateral edge along inferomarginal series variably round to angular. No pedicellariae observed.

Actinal intermediate region large, approximately four full series in chevron formation with a small number of irregular plates present adjacent to inferomarginal contact. Individual plates variably quadrate to polygonal in shape. Surface covered by homogenous sized and shaped granules, 10–20, round, evenly spaced (Fig. 14C, D; 15C, D)

Furrow spines 8 to 9 in distinct angular arrangement (R=8.2). A discrete space separates the furrow spines from the subambulacral series behind it (Fig. 15C, D). Subambulacral spines in 2 to 3 irregular series, each number four to six, but mostly five, spines more granular approaching actinal granules in size, shape. Oral plate with approximately 10–12 furrow spines similar to identical with furrow spines on other plates. Single spine, triangular in cross-section present on each oral plate, two total for each interradius. Oral plate surface with approximately six to eight blunt spines present along the edge of each sulcus directed along the middle of the oral plate.

Pillsburiaster Halpern, 1970a.

Halpern, 1970a: 2; McKnight, 1973: 180; Downey in Clark and Downey, 1992: 258; Clark and McKnight, 2001: 102 (key).

Diagnosis. Body pentagonal in most species, weakly stellate in some (R/r = 1.4 to 2.0). Abactinal plates mound-like to flat,

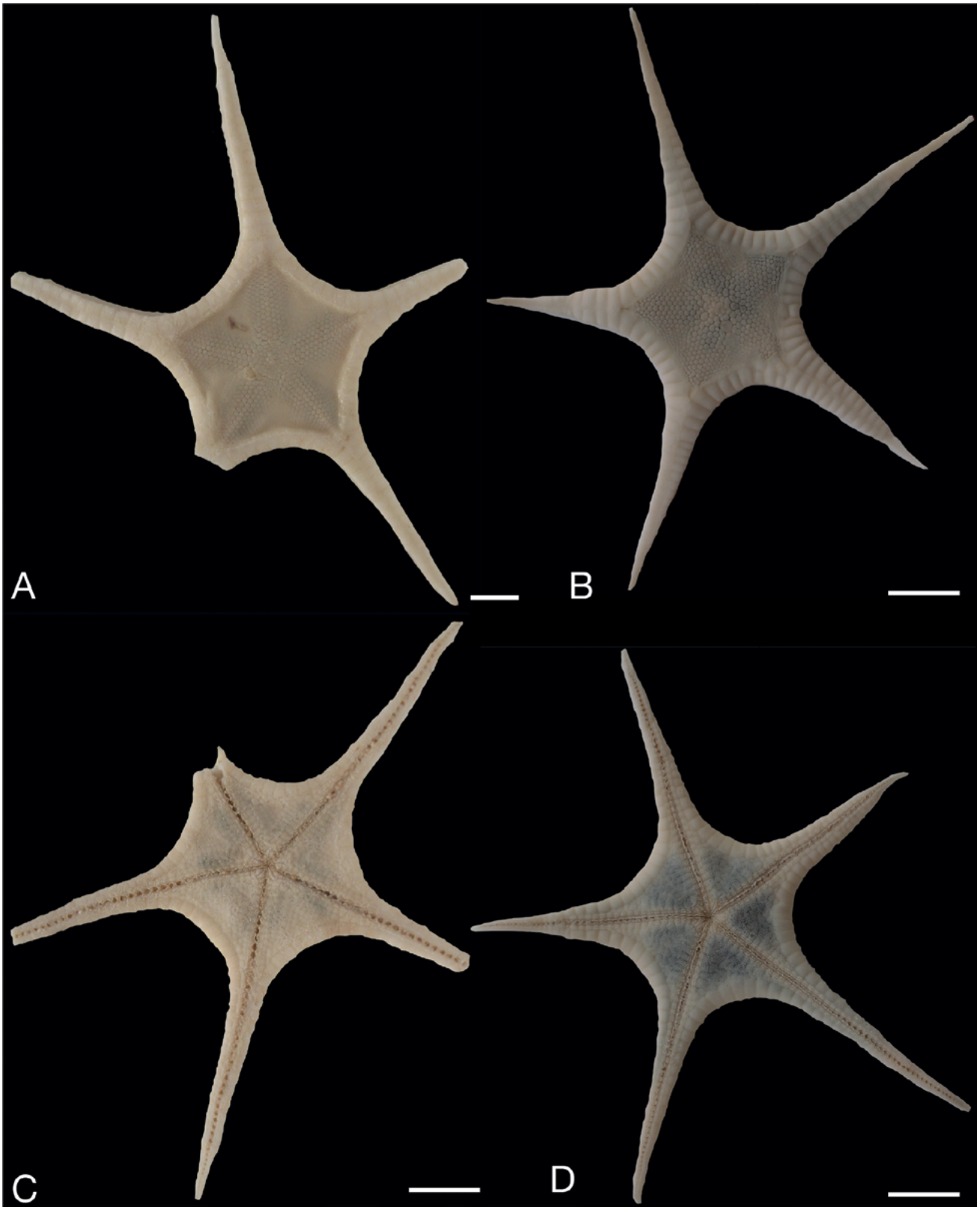

Figure 14. *Nymphaster moebi* (Studer, 1884), Specimens showing variation: Abactinal-Actinal of WAM Z 110082, WAM Z 105105. Scale bar = 10.0 mm: a-c.

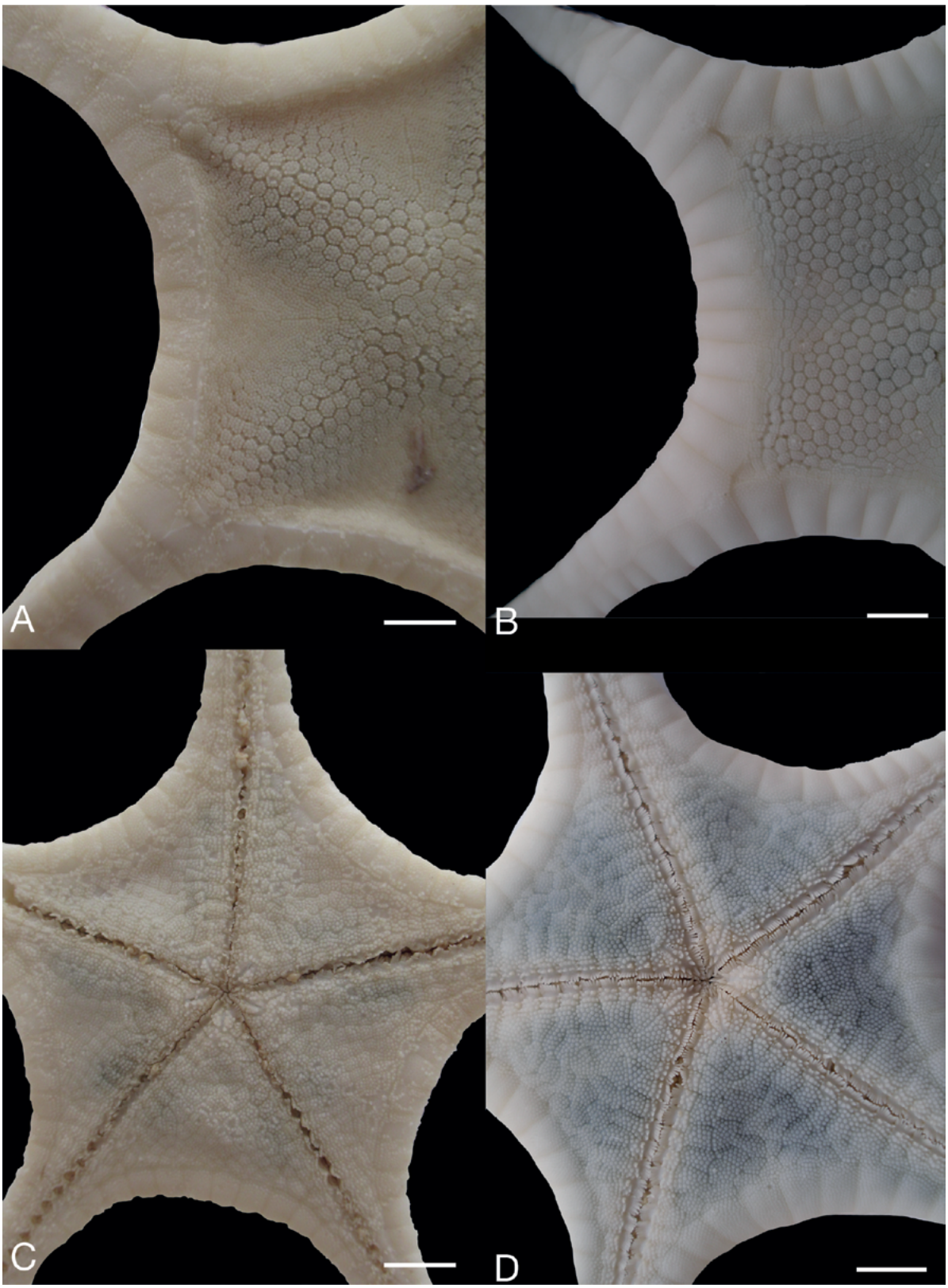

Figure 15. *Nymphaster moebi* (Studer, 1884), Specimens showing variation: a, b, Abactinal, lateral view WAM Z 110082; c, d, Actinal WAM Z 105105. Scale bar = 5.0 mm

weakly tabulate, arranged irregularly. **Abactinal surface densely covered by numerous, coarse, spherical granules forming close clusters, obscuring plate boundaries in some species. Secondary plates present.** Marginal plates numerous, 14 to 35 per interradius. Bald region, variably small to large present centrally on superomarginal plate surface, absent in one species. Furrow spines 2 to 10. Subambulacral spines 2 to 4, thick, widely spaced followed by small but coarse granules in irregular arrangement. Pedicellariae, when present, spatulate.

Comments. *Pillsburiaster* was described by Halpern (1970) from the Atlantic, but subsequent discoveries and taxonomic refinement have found subsequent taxa to be wide-ranging, including 10 species, three from the Indian Ocean and six from the Pacific, including the recently reassigned (Mah in prep) *P. micropelta* (Fisher, 1906) and the Atlantic P. *geographicus* Halpern, 1970.

Pillsburiaster aoteanus McKnight, 1973

Figures 16A–E

Pillsburiaster aoteanus McKnight, 1973: 180, fig. 5; A.M. Clark, 1993: 276; H.E.S. Clark and McKnight, 2001:100, Pl. 27; Mah, 2011: 39; MacIntosh et al., 2018: 12.

Plinthaster singletoni McKnight, 1973: 185, fig. 7; 1993: 169; A.M. Clark, 1993: 277.

Material Examined. NMV F123060. Lord Howe plateau, site 10, Tasman Sea, 34° 2' 24.7194" S, 163° 17' 13.2" E, 1976–1083 m. Coll. TAN 0308 091, 26 May 2003. 2 wet specs. R = 3.8 r = 2.3 R = 5.1 r = 2.7

NMV F246909. St. Helens flat, Tasmanian Seamounts, 41° 12' 15.48" S, 148° 47' 16.8" E, 1202–1221 m. Coll. Dr A.Williams - CSIRO, Dr. Alexandra A. Weber - Museums Victoria, Ricky-Lee Erickson - Museums Victoria, et al, 17 December 2018. 1 wet spec. R = 3.4 r = 1.7

NMV F123058. Wanganella Bank, site 13, 34° 4' 59.5194" S, 168° 55' 33.5994" E, 1000–1150 m, Coll. 6 March 2003, 1 wet specimen.

NMV F123071. Lord Howe Plateau, Tasman Sea, 32° 39' 20.1594" S, 162° 33' 7.1994" E, 864–870 m. Coll. M.F. Gomon, Museum Victoria, NORFANZ team, 25 May 2003, 1 wet specimen.

NMV F122953. Wanganella Bank, site 13, 33° 2' 26.8794" S, 167° 27' 3.5994" E, 1451–1478 m, Coll. 28 May 2003, 3 wet specs.

NMV F240377. Great Australian Bight, South Australia, 34° 36' 32.7594" S, 131° 3' 21.6"E, 1478–1507 m. Coll. Great Australian Bight, BP Expedition. 12 September 2015. 1 wet spec.

NMV F240378. Great Australian Bight, South Australia, 33° 55' 41.88" S, 131° 3' 39.6" E, 1021–1033 m, Coll. Great Australian Bight, BP Expedition. 12 September 2015. 1 wet spec.

NMV F240380. Great Australian Bight, South Australia, 33° 30' 57.96" S, 130° 15' 53.9994" E 978–1013 m, Coll. Great Australian Bight, BP Expedition. 12 September 2015. 1 wet spec.

NMV F240381. Great Australian Bight, South Australia, 34° 31' 49.44" S, 130° 40' 8.4" E, 1473–1483 m, Coll. Great Australian Bight, BP Expedition. 12 September 2015. 1 wet spec.

USNM 1098141. Cook Strait, New Zealand, South Pacific Ocean, 41° 42' 0" S, 175° 25' 30" E, 946–951 m. Coll. R/V *Eltanin*, US Antarctic Research Program 31 January 1965. 1 dry spec. R = 2.2 r = 1.3.

USNM 1100862. Campbell Plateau New Zealand, South Pacific Ocean -48° 40' 0.1194" S, 170° 48' 28.7994" E, 814 m. Coll. 20 Jan 1965. 2 dry specs. R = 5.8 r = 3.6; R = 3.3 r = 2.3.

USNM 1100852. Campbell Plateau New Zealand, South Pacific Ocean 49° 13' 30" S, 171° 30' 7.2" E, 260 m. Coll. 21 Dec. 1970, 1 dry spec., R = 6.5 r = 3.8.

Diagnosis (Modified from McKnight, 1973). Body pentagonal (R/r = 1.4–2.0), interradial arcs weakly curved to straight. **Abactinal plates with large, round spherical granules, 7–20 (at R = 6.5). Marginal plates 18 (R = 2.0) to 30 (at R = 6.5) per interradius, arm tip to arm tip.** Superomarginal surface covered by granules save for a small bald area present centrally on dorsal surface. **Furrow spines 5 to 7, flat tipped, blunt, quadrate in cross-section.** Subambulacral spines short, 4 to 6, blunt, granular in 2 to 3 irregular series, set off from furrow spines by distinct diastema. Pedicellariae present or absent.

Comments. Descriptions for *P. aoteanus* presented in McKnight (1973) and H.E.S. Clark and McKnight (2001) differed in several respects from other specimens of *P. aoteanus* in the USNM collections. These include differing counts of the abactinal granules, showing a greater range than indicated in earlier description and an accounting of superomarginal plates, up to 32 per interradius at R = 6.5 (USNM 1100852) which specifically differs from the description in Clark and McKnight (2001) which describes the species as showing 18 (possibly 20 in their plate 27) plates per interradius on a specimen at R = 6.0. The superomarginal plate and abactinal granule number are significant because these are used by McKnight to distinguish *P. aoteanus* from *P. maini*. These values show overlap suggesting that the two species are nearly indistinguishable, differing only in that *P. maini* shows a distinct "substellate" body shape (R/r = 2.7).

The Australian specimens are consistent with characters of *P. aoteanus* as outlined herein and in Clark and McKnight (2001) but show a much larger more distinct quadrate to round bald patch rather than the small, irregular patch on the dorsal surface of each superomarginal plate. Furrow spine number and adambulacral spination are consistent.

Aside from the presence of *Pillsburiaster* sp. in MacIntosh et al. (2018) from the Great Australian Bight these are the first published occurrence of *Pillsburiaster* in Australian and nearby waters.

Occurrence/Distribution. New Zealand area. Near Three Kings Rise, north of North Cape, New Zealand and from Hawkes Bay to south of Campbell Island, east to near Chatham Islands, 120–1573 m.

Australia. Tasmanian seamounts, Great Australian Bight. 1083–1507 m.

Description. Body weakly stellate to stellate, R:r = 1.6:2.0, arms broad at base, triangular. Interradial arcs weakly curved to straight (Fig. 16A, D).

Abactinal plates round to polygonal, surface of each plate with coarse, round granules, 2 to 20, mostly 15 to 15, homogeneous in size, shape (Fig. 16A, B, C). Densest aggregations distally adjacent to contact with superomarginal plates. At smaller sizes, R= 3.4, minority of distal interradial plates with bare central region. Papular regions extensive, ranging from central disk to approximately six superomarginals from terminus; individual pores single. Madreporite pentagonal, flanked by 6 plates. No pedicellariae observed.

Superomarginal plates 12 per side, 24 from arm tip to arm tip (at R=3.4 to 5.1) with rounded dorsolateral edge (Fig. 16A, C). Abactinal surface of each plate with variably sized, irregular round bald spot on dorsal to dorsolateral surface, occupying central plate surface (Fig. 16C). Remainder of superomarginal plate covered by granules, round, deciduous, approximately 100–300, forming abundant covering on lateral surface of superomarginal plate. Inferomarginal covered by granules,

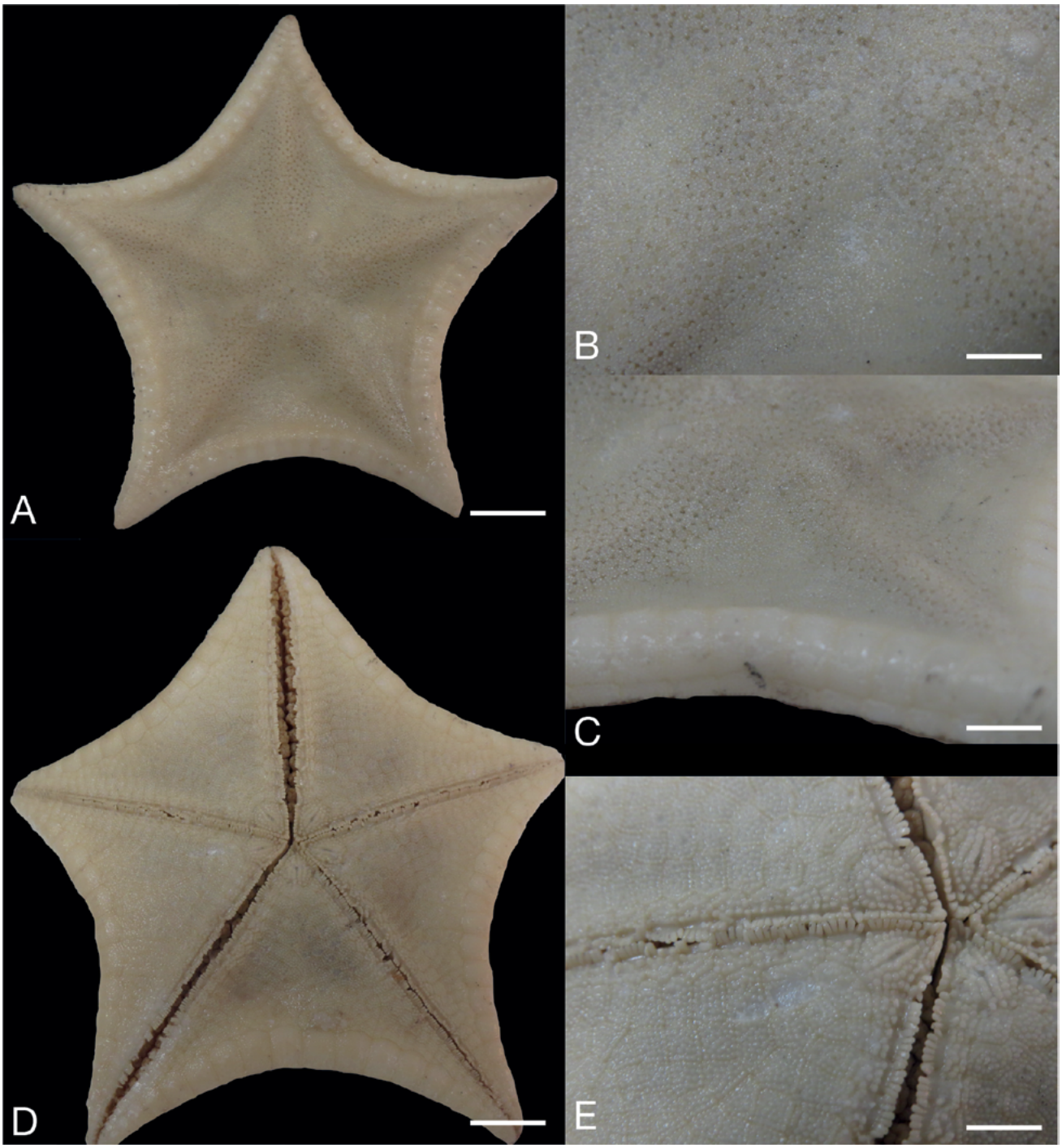

Figure 16. *Pillsburiaster aoteanus* McKnight, 1973 NMV F123060: a, Abactinal; b, Closeup abactinal; c, Abactinal lateral view; d, Actinal view; e Adambulacral/Furrow spination. Scale bar = 20.0 mm: a, d; Scale bar = 5.0 mm: b, c, d, e.

round, coarse, closely but evenly arranged. No pedicellariae. Terminal plates triangular, lacking granulation. No pedicellariae.

Actinal plate region in approximately 4 complete series in chevron-like formation. Each plate quadrate to irregularly polygonal, covered by granules, 5 to 50, evenly arranged (Fig. 16D, E). No pedicellariae.

Furrow spines 4 to 6, blunt, weakly clavate, in straight to weakly palmate arrangement on plate (Fig. 16E). Furrow spines set off from subambulacral granules by distinct diastema. Subambulacrals in approximately 3 irregular series, each composed of 2 to 5, mostly 3 or 4 blunt granules. Adambulacral accessories similar to actinal granules in overall appearance but set off by a weakly developed groove. Oral plates with furrow spines, approximately 12 with a single prominent blunt spine directed into the mouth on each plate, totalling 2 per interradius. Oral plate surface with approximately 12 paired granules on either side of central diastema. Both sides of oral plate surface covered by approximately 15–20 granules arranged in two series parallel to the central diastema.

Sibogaster Döderlein, 1924.

Sibogaster Döderlein, 1924: 63; A.M. Clark, 1993: 283 (checklist only); Mah, 2016: 129.

Diagnosis. **Abactinal plates smooth, bare (no accessories on plate surface-although embedded glassy bosses present in *S. digitatus*), weakly convex, round to polygonal in outline. Marginal plates elongate, mostly smooth, bare (*S. digitatus* has fewer than 6 granules on one or two interradial superomarginals). Inferomarginals adjacent to actinal surface covered with variably abundant granules.** Actinal plates covered by granules. Adambulacral plates rectangular in shape. Furrow spines numerous, six to 15. Subambulacral spines. thickened relative to furrow spines. Remaining granulation identical to others on actinal surface.

Comments. *Sibogaster* currently includes 3 species, the tropical Pacific *S. digitatus*, the Atlantic and Pacific *S. bathyheuretor* and the widely occurring *S. nieseni*, which have been recorded from 640 to 4175 m, but primarily from bathyal and abyssal depths (1000 to 5000 m). Specimens reported herein are the first from Australian waters.

Sibogaster nieseni Mah, 2016.

Figures 17A–D

Sibogaster nieseni Mah, 2016: 136, Figs. 10A–E.

Material Examined. **Indian Ocean. Western Australia.** WAM Z100738. Ningaloo, Western Australia. 22° 15' 59" S, 113° 0' 39" E, 2105.5 m. Coll. Wilson N, Rouse, G., Kirkendale, L., Ritchie, J. aboard RV *Falkor* March 2020. 1 wet spec. R = 6.7 r = 3.0.

WAM Z100641. Ningaloo, Western Australia. 21° 53' 9" S, 113° 0' -48" E, 2519.9 m. Coll. Wilson N, Rouse, G., Kirkendale, L., Ritchie, J. aboard RV *Falkor* March 2020. 1 wet spec. R = 4.5 r = 2.5

WAM Z110291. Gascoyne Marine Reserve, 22° 16' 11.6832" S, 112° 57' 46.2672" E, 2073 m. Coll. Alvarez, B., Naughton, K.M., Moore, K., Unteidt, C. CSIRO, barcode 10059270, 25 November 2022, 1 wet spec. R = 4.0 r = 1.6.

WAM Z110110. Site 009, Gascoyne Marine Preserve, ca 113 km WNW of Ningaloo Reef, Western Australia, 22° 14' 22.9344" S, 112° 36' 56. 3976" S, 3747 m. Coll. J. Keesing, et al. CSIRO aboard RV *Investigator*, barcode 10052707, 26 November 2022. 1 wet spec. R = 5.4 r = 2.2

NMV F241948, Off Fraser Island, Queensland, Australia. -25° 19' 31.0794" N, 154° 4' 4.8" E, 2342–2350 m. Coll. T. O' Hara et al. INV2017_V03, abyss Marine Invertebrates team, 6 Nov 2017, 1 wet spec. R = 3.8 r = 1.6

NMV F307918. Santa Ridge, Cocos (Keeling) Islands, Indian Ocean, Australia, 13° 33' 42" S, -13° 33' 10" S, 96° 22 06" E - 96° 22' 56" E, 2418–2156 m. Coll. by T. O' Hara, 22 November 2022, 1 wet spec. R = 2.1 r = 0.9.

NMV F307968. Balthazar Seamount, Christmas Island, Indian Ocean, 11° 21' 33" S 11° 22' 16" S, to 104° 02' 53" S, 104° 3' 28" E, 3510–3611 m. Coll. by T. O' Hara, 7 October 2022. 1 wet spec. R = 5.4 r = 2.3.

NMV F307970. Balthazar Seamount, Christmas Island Territory, Indian Ocean, Australia. 11° 21' 33" S to 11° 22' 16" S, 104° 02' 53" E, 3611–3510 m Coll. by T. O' Hara, 22 November 2022, 1 wet spec. R = 6.4 r = 2.6.

NMV F307971. Balthazar Seamount, Christmas Island Territory, Indian Ocean, Australia. 11° 21' 33" S to 11° 22' 16" S, 104 02' 53" E, 3611–3610m, 1 wet spec. R = 5.3 r = 2.1.

NMV F 307972. Balthazar Seamount, Christmas Island, Indian Ocean, 11° 21' 33" S, 11° 22' 16" S, to 104° 02' 53" S 104° 3' 28" E, 3611–3610 m. Coll. T. O' Hara, 7 Oct 2022. 1 wet spec. R = 3.4 r = 1.1.

Diagnosis. Body stellate (R/r = 3.1 to 6.4). Abactinal plates polygonal in shape, flat, smooth, glassy tubercles absent. **Superomarginal plate surfaces smooth to rough, bare, lacking granules. Inferomarginal and actinal plates covered by granules. Paddle-like pedicellariae present**. Furrow spines 6 to 10.

Comments. *Sibogaster nieseni* is a widely occurring species recorded from the Pacific, Atlantic, and now the Indian Ocean, observed between 2000 and 5000 m depths. Figure 17A shows an in situ image of a specimen (WAM Z 100738) of this species off Ningaloo at 2105.5 m on a soft-sediment bottom, which is consistent with other observations of this species. Other observations suggest deposit feeding and predation on sponges (Mah 2024/2025 in review).

Description. Body stellate (R/r = 1.88 to 3.0), arms elongate, triangular in shape. Interradial arcs curved to linear.

Abactinal plates round to polygonal, homogenous, flat and variably smooth to rough, with no surficial accessories (no granules, etc.). Each plate periphery surrounded by discrete ring of granules, 20–25, each oval to quadrate in outline. Peripheral granules are large, occupying 25–30% of the total width of each plate, including the peripheral granule. Glassy tubercles absent. Papulae 3–6 per plate present at plate angles.

Marginal plates 24–36 per interradius. Surface of each plate flattened, smooth, flat devoid of surficial accessories. Inferomarginal plates bare on lateral surface adjacent to superomarginals, but actinal surface covered by granules.

Actinal intermediate regions covered by granules, 8–30, hemispherical to pointed. Pedicellariae variably present or absent on abactinal, marginal and actinal plate surfaces. Pedicellariae small (~0.25 cm), tong-like with blunt, paddle-like blades, inset into a shallow pit.

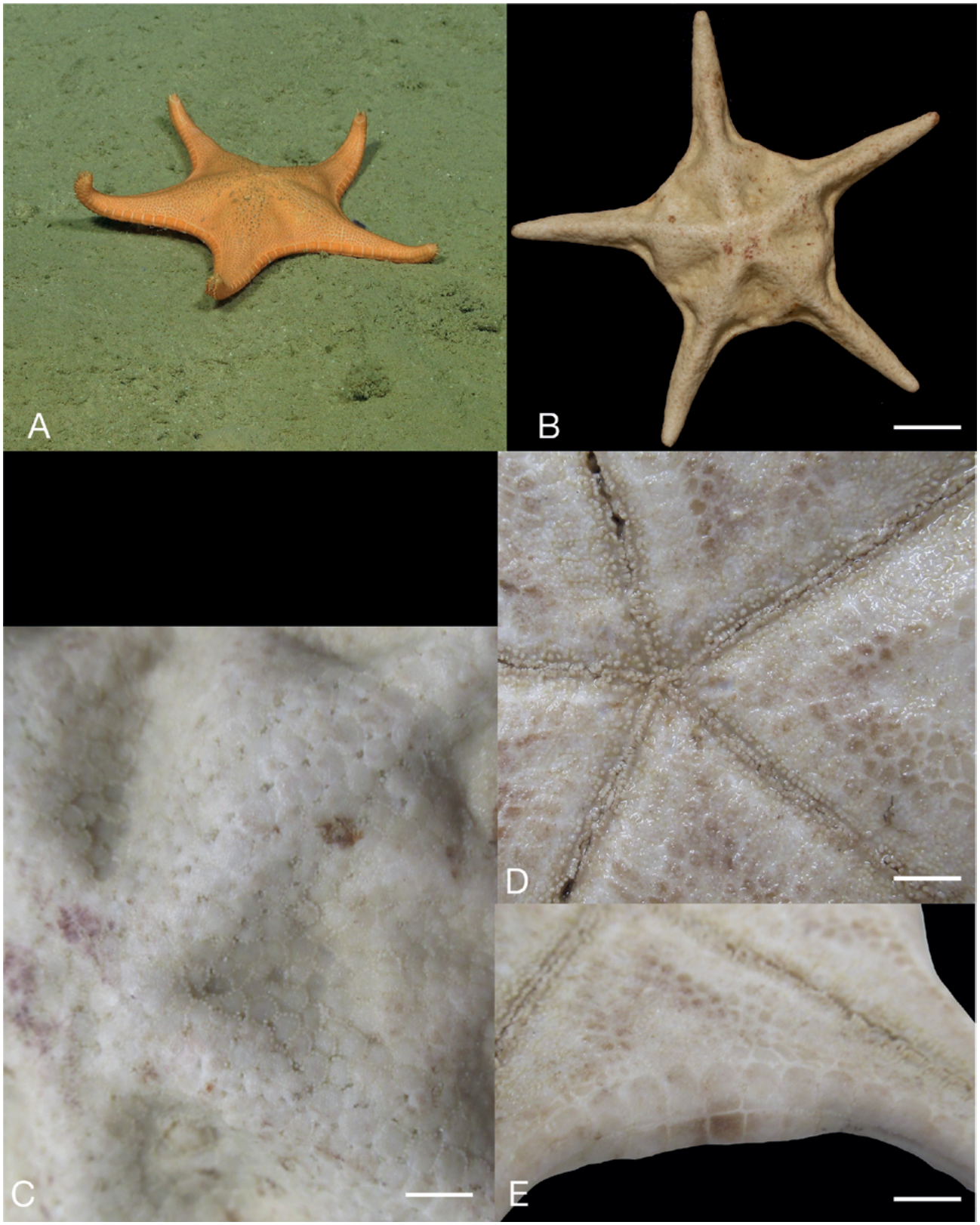

Figure 17. *Sibogaster nieseni* Mah, 2016: a, *In situ* image of WAM Z100738 off Ningaloo, Western Australia, 2105.5 m. B. NMV F307970 Balthazar Seamount, Abactinal; b, Abactinal plates close; c, Oral region close; d, Actinolateral view. Scale bar = 30.0 mm: b; Scale bar = 5.0 mm: c, d, e.

Furrow spines 6–10, mostly 7 to 8, quadrate in cross-section with blunt tips. Subambulacral spines 3–5, round to polygonal in cross-section with variable morphology in Atlantic versus Pacific individuals. Adambulacral pedicellariae one or two, elongate, tong-like in shape, thick with complementing valves, taller than furrow spines. Pedicellariae elongate valves, variably present on adambulacral plates sitting adjacent to subambulacral spines, occurring irregularly from the third adambulacral and distally along the furrow series. Oral plates with 8–10 furrow spines.

Variation in Indian Ocean (Western Australian) specimens. WAM Z100738 and WAM Z100641, from the Ningaloo region displays specimens with smooth superomarginals surfaces showing glassy tubercles on the plate surface. Actinal surface covered by rounded granules. Pedicellariae absent from adambulacral plates. Furrow spines 5 to 10 in linear series, space separates from subambulacral accessories in irregular series. Nearest with 3 blunt short spines, covered by 6–8 variably pointed short granules. Others are short, similar to actinal granules with pointed tips.

Occurrence/Distribution. Australia-Indian Ocean. Western Australia, Ningaloo, Gascoyne Marine Preserve, Balthazar Seamount off Christmas Island, off Fraser Island, Queensland. 2106–3747 m

North Pacific. Taney Seamounts B and C, "NESCA" Clam sites (North Pacific), Patton Seamount and Patton Escarpment, Cascadia Plain, west of Cortez Bank, Hawaiian Islands and Johnston Atoll regions, Musicians Seamount, Japan (2597–3450 m), Celebes Sea, Indonesia, 2100–4175 m.

East Pacific. Galapagos, 3012 m.

Tropical Atlantic. Off coast of Mauritania, 2114–3162 m

Discussion

Characterisation of Australia's Deep-sea Asteroidea: Depth and Distribution

Specimens described herein elaborates on goniasterid species present in deep-sea Australian marine settings, specifically those greater than 1000 m. The deep-sea asteroid fauna of Australia, especially at great depths (1000–5000 m) has, until recently (e.g. Mah, 2023a, b), been undocumented. Checklists, such as Rowe and Gates (1995) reported on echinoderm taxa in shallow habitats from intertidal to the continental shelf. Deep-sea taxa below 1000 m are included, but report only global occurrence rather than specific records (e.g. the Porcellanasteridae). Mah (2023a) reported Australia's deepest known asteroid to date, the poraniid *Poraniomorpha tartarus*, to 3850 m.

There are prior instances of shallow-water Asteroidea demonstrating endemism, including species in the genus *Tosia* (Mah, 2007) and members of the Stichasteridae (Mah and Foltz, 2011), such as *Uniophora*. It is argued; however, that these considerations are premature for the taxa treated herein primarily due to the absence of comprehensive taxon sampling from deep-sea habitats. Consideration of these notions is further complicated by the widespread nature of many deep-sea taxa, such as *Bathyceramaster, Sibogaster* and *Litonotaster.*

Further Goniasteridae reported herein add to our characterisation of known deep-sea asteroids in the Australian abyss, many of which are widely occurring species that show nearly cosmopolitan distribution similar to other deep-sea asteroid groups, such as the Porcellanasteridae. Widely occurring deep-sea goniasterid species include *S. nieseni,* off the Western Australian and Cocos Keeling region in the Indian Ocean at depths of 2106–3747 m. This species is known throughout its range to 4175 m depths and may yet be found in deeper Australian settings. *Bathyceramaster teres*, previously known from the tropical North Pacific (Mah 2020) is further reported herein from the Indian Ocean, notably the Ningaloo, Gascoyne regions of Western Australia and the Cocos (Keeling) Islands region at 2010–2418 m depth and *L. intermedius*, known primarily from the Atlantic was also discovered in Australian waters from the Pacific in the Great Australian Bight at 965–1077 m, and from the Indian Ocean in the Gascoyne Marine Reserve, 1451–2057 m. Mah (2024a) also found *Evoplosoma voratus*, originally described from Davidson Seamount in the North Pacific, not only off the coast of California, but also from Ningaloo Canyon off the northwest coast of Western Australia.

Widely occurring deep-sea genera, such as *Nymphaster, Bathyceramaster,* and *Pillsburiaster* invite further questions regarding whether character differences, which are often minimal, could be considered variation within a widely distributed species. This was tested with molecular data in the widely occurring goniasterid *Hippasteria* (Foltz et al., 2013; Mah et al., 2014), which resulted in the synonymy of several species that were ultimately thought to represent variation among different populations within *H. phrygiana*. In the Atlantic, Downey in Clark and Downey (1992) ultimately concluded that there was only one widely occurring species, *N. arenatus*. Distinctions between the Atlantic species, the Indian Ocean *N. moebi* and Pacific *Nymphaster* spp. are difficult and so, plausibly synonymous. Further testing is desirable.

Taxonomic Actions

1. Two new genera and 6 new species are described.
2. The new genus *Alloceramaster* was established to accommodate *Ceramaster grenadensis* and related species, including *A. affinis, A. pointsurae, A. leios* n. sp. and *A. minus* n. sp.
3. *Ceramaster glasbyi* moved to *Pseudoceramaster,* combined to *Pseudoceramaster glasbyi* (McKnight 1993)
4. *Litonotaster intermedius*, is a wide-ranging deep-sea species known previously from the tropical Atlantic, is also recorded from Australia in the South Pacific and the Indian Ocean.
5. Further occurrence data are recorded for *Nymphaster moebi* and *Pillsburiaster aoteanus*.
6. The wide-ranging *Sibogaster nieseni* is reported from the Indian Ocean, notably the Cocos Keeling Islands and the Gascoyne marine reserve off Western Australia.

List of Species

Alloceramaster nov. gen.

Alloceramaster affinis (Perrier 1884) **nov. comb.**

Alloceramaster grenadensis (Perrier 1881) **nov. comb.**

***Alloceramaster leios* n. sp.**

***Alloceramaster minus* n. sp.**

Alloceramaster pointsurae **nov. comb.**

Bathyceramaster tasmanensis n. sp.

Bathyceramaster teres Mah 2022

***Bathyceramaster wami* n. sp.**

Ceramaster patagonicus (Sladen, 1889)

***Ceramaster fortis* n. sp.**

***Kokosaster acanthodes* nov. gen. nov. sp.**

Litonotaster intermedius (Perrier 1884)

*Pseudoceramaster glasbyi (*McKnight, 1993) **nov. comb.**

Nymphaster moebi (Studer 1884)

Pillsburiaster aoteanus McKnight 1973

Sibogaster nieseni Mah 2016

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