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# Asteroidea (Echinodermata) of the South Java Deep-Sea biodiversity cruise, Indonesia

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**Abstract.** A joint Indonesia–Singapore deep-sea expedition, sampling the benthic biota of the Sunda Strait and the slopes of the Sunda Trough off south Java to a maximum depth of 1,800 metres, has recovered 37 species of Asteroidea belonging to 24 genera in 12 families. Ten of these species, including two described in a separate publication, are new records for Indonesian seas. The families Astropectinidae and Goniasteridae were the most diverse, being represented by ten and six species respectively. Most species records were based on singletons or a few specimens, but some, notably the goniasterid *Anthenoides cristatus* and the astropectinid *Astropecten timorensis*, were particularly abundant—the former at multiple sites—and in consequence probably play a significant role in deep-sea food webs in these waters.

**Key words.** deep-sea, Indian Ocean, Indonesia, Echinodermata, Asteroidea

## INTRODUCTION

During the South Java Deep-Sea Biodiversity Expedition (SJADES 2018)—the first joint Indonesia–Singapore Expedition exploring biological deep-sea resources in Indonesian waters—an extensive collection of sea stars (Asteroidea) was made from the slopes of the Sunda Trough in the Indian Ocean and from the Sunda Strait. Although a number of oceanographic/biological deep-sea expeditions have included or focused on Indonesian seas, both in earlier colonial times [e.g., Challenger (1872–1875); Siboga (1899–1900); Albatross (final cruise: 1909–1910); Snellius (1929–1930)] and subsequently, following Indonesian political independence [e.g., Corindon IV (1981); Snellius-II (1984–1985); Karubar (1991)], deep-sea habitats of the western part of the Archipelago had been little investigated prior to this Expedition.

## MATERIAL AND METHODS

The SJADES 2018 deep-sea expedition was undertaken from 23rd March to 5th April 2018 on the Indonesian Institute of Sciences Research Centre for Oceanography research vessel, RV *Baruna Jaya VIII*. A total of 53 stations were sampled by beam trawl or dredge along a cruise track from the Sunda Strait into the Indian Ocean off southwest Java as far as Cilacap, to a maximum depth of 1,800 metres. Sea stars were recovered at 26 of the stations (Fig. 1). Trawled or dredged sea stars were preserved in 70% ethanol after photography of representative living examples on board the vessel using a Nikon D800 DSLR camera equipped with a 60 mm macro lens and speedlight SU-800 flash system. Subsequent photography of dried or wet specimens was undertaken using a Canon M mirrorless camera with an EF-M 22 mm lens. Photographs through a microscope were taken using a Samsung Galaxy S4 camera phone attached to the eyepiece of an Olympus SZH10 stereomicroscope.

The sea star collection from the cruise was divided into two representative sets, one being deposited in the Zoological Reference Collection (ZRC) of the Lee Kong Chian Natural History Museum, (LKCNHM), National University of Singapore, the other in the Reference Collection of the Research Centre for Oceanography (RCO) of the Indonesian Institute of Sciences (LIPI), Jakarta, Indonesia. Taxonomic listing follows the phylogeny of Mah & Blake (2012) and a regularly updated, online Asteroidea database (Mah, 2021). A summary checklist of the species encountered is provided in Table 1.

## TAXONOMY

### Order Forcipulatida

### Family Zoroasteridae Sladen, 1889

### *Zoroaster* Wyville Thomson, 1873

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Fig. 1. Map of the South Java/Sunda Strait survey area within the Indonesian Archipelago (inset) indicating the sampling stations at which specimens of Asteroidea were recovered.

### *Zoroaster carinatus* Alcock, 1893
(Fig. 2A, B)

**Material examined.** One wet specimen (ZRC.ECH.1299), R:r = 150:10 mm (R:r ratio = 15), Stn. CP23, Sunda Strait, south of Panaitan Island, 06°46.331′S 105°08.799′E (mid-point of beam trawl), 27th March 2018, depth = 559–571 m. Substrate: gravel with some mud; One dry specimen (ZRC.ECH.1269), R:r = 35:4 mm (R:r ratio = 8.8), Stn. CP48, Indian Ocean, south of Tg. Gede, Java, 07°51.419′S 107°46.310′E (mid-point of beam trawl), 1st April 2018, depth = 689–637 m. Substrate: mud.

**Description.** 5-rayed sea star with small disc and very long narrow, tapering arms. Marked carinal ridge of enlarged, domed plates with five rows of lower profile lateral plates on each side, all in register (Fig. 2A). The first or primary carinal domed plates and intervening, slightly elevated interradial ones form a disc ring but this is not very distinct. Carinal and lateral plates densely covered with short conical granules or spinelets. Long spines present only on the lower three rows of lateral plates (Fig. 2A, B). Adambulacral plates bear a transverse series of no more than three prominent spines on the actinal surface; furrow spines associated with forcipulate pedicellariae. Quadri-serial tube foot rows with adjacent rows staggered (Fig. 2B).

**Remarks.** This species is distinguished from other Indo-Pacific *Zoroaster* taxa by the lack of central spines on both carinal and marginal plates and from the closely related subspecies, *Zoroaster carinatus philippinensis* Fisher, 1916, by the smaller number of prominent adambulacral spines.

**Distribution.** The occurrence of this species, off the south coast of Java in the Indian Ocean, is within the known Indo-West Pacific distribution range for the species (Rowe & Gates, 1995; Clark & Mah, 2001).

### *Zoroaster microporus* Fisher, 1916
(Fig. 3A, B)

**Material examined.** One wet specimen (ZRC.ECH.1298), R:r = 361:12 mm (R:r ratio = 30.1), Stn. CP23, Sunda Strait, south of Panaitan Island, 06°46.331′S 105°08.799′E (mid-point of beam trawl), 27th March 2018, depth = 559–571 m. Substrate: gravel with some mud.

**Description.** 5-rayed sea star with small disc and extremely long, narrow arms, barely wider at their base (14 mm) than the disc radius. Pronounced carinal ridge and pentagonal disc ring of domed plates (Fig. 3A). There is also a raised, rounded plate at the centre of the disc/disc ring. Carinal plates closely abut each other and consequently are somewhat squarish in profile. Well-defined sulcus between carinal ridge and a longitudinal ridge of slightly smaller, rounded abactinal plates on either side; a further four lateral rows of plates are regularly aligned, longitudinally and transversely, with the first lateral row and with each other. All five rows of lateral plates have long spines (Fig. 3A, B) and both laterals and carinals are densely covered with short spinelets. Spines of the adambulacral plate and furrow are multiple and of different sizes but, being partly obscured by protruding tube feet, are not easily counted in this specimen. Numerous forcipulate pedicellariae are associated with the furrow spines.

Table 1. Checklist of Asteroidea taxa collected during the SJADES 2018 deep-sea expedition.

| Order | Family | Taxon |
|---|---|---|
| Forcipulatida | Zorasteridae | *Zoroaster carinatus* Alcock, 1893 |
| | | *Zoroaster microporus* Fisher, 1916 |
| | | *Zoroaster* sp. |
| Brisingida | Brisingidae | – |
| Spinulosida | Echinasteridae | *Henricia arcystata* Fisher, 1917 |
| | | *Henricia* sp. |
| Valvatida | Goniasteridae | *Anthenoides cristatus* (Sladen, 1889) |
| | | *Gigantaster weberi* Döderlein, 1924 |
| | | *Iconaster vanuatuensis* Mah, 2005 |
| | | *Nymphaster euryplax* Fisher, 1913 |
| | | *Nymphaster moebii* (Studer, 1884) |
| | | *Sibogaster digitatus* Döderlein, 1924 |
| | Solasteridae | *Lophaster* sp. |
| | | *Solaster tropicus* Fisher, 1913 |
| | | *Solaster* sp. |
| Paxillosida | Astropectinidae | *Astropecten timorensis* Döderlein, 1917 |
| | | *Astropecten* sp. 1 |
| | | *Astropecten* sp. 2 |
| | | *Astropecten* sp. 3 |
| | | *Astropecten* sp. 4 |
| | | *Dipsacaster fisheri* Lane & Vimono, 2020 |
| | | *Persephonaster roulei* Koehler, 1909 |
| | | *Persephonaster suluensis* Fisher, 1913 |
| | | *Plutonaster* sp. |
| | | *Psilaster gotoi* Fisher, 1913 |
| | Ctenodiscidae | *Ctenodiscus caudatus* Döderlein, 1921 |
| | Porcellanasteridae | *Porcellanaster ceruleus* Wyville Thomson, 1878 |
| | Pseudarchasteridae | *Paragonaster ctenipes* Sladen, 1889 |
| | | *Paragonaster ctenipes hypacanthus* Fisher, 1913 |
| | | *Perissogonaster insignis* Fisher, 1913 |
| | | *Pseudarchaster pulcher* Ludwig, 1905 |
| Notomyotida | Benthopectinidae | *Benthopecten moluccanus* Fisher, 1913 |
| | | *Benthopecten semisquamatus celebensis* Döderlein, 1921 |
| | | *Pectinaster mimicus* (Sladen, 1889) |
| Velatida | Caymanostellidae | *Caymanostella* sp. |
| | Pterasteridae | *Pteraster sjadesensis* Lane & Vimono, 2020 |
| | | *Pteraster* sp. |

**Remarks.** This species is identified based on the pronounced carinal ridge of tumescent, squarish abactinal plates, a similarly prominent ring of plates on the disc, and long spines on the lateral plates.

**Distribution.** Previously known only from a single specimen from the type locality in the Moluccas (Fisher, 1916) at a depth of 1,280 m, the present locality off south Java is the second for Indonesia and represents a new record for the Indian Ocean.

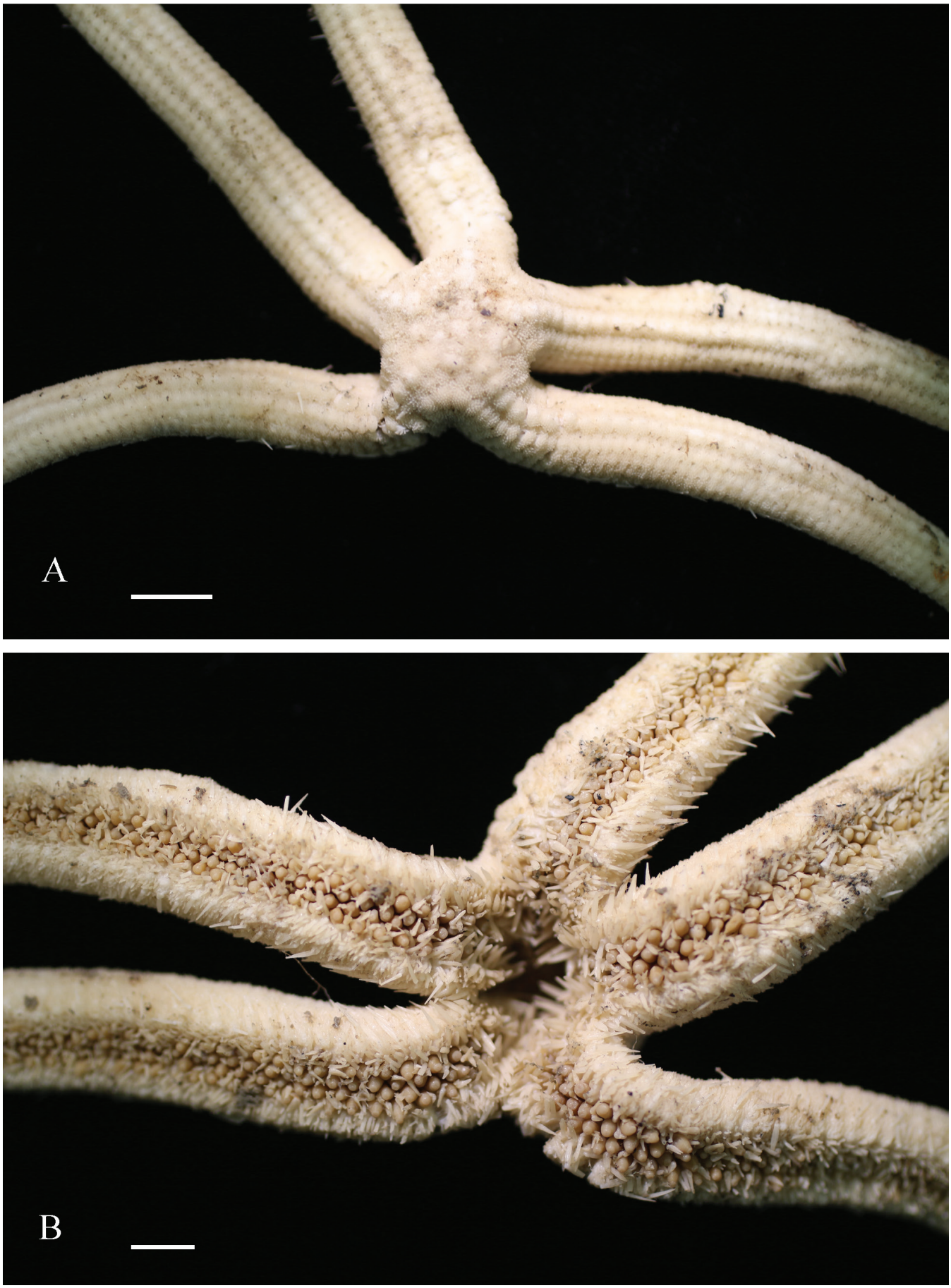


Fig. 2. *Zoroaster carinatus*, ethanol-preserved wet specimen (ZRC.ECH.1299). A, abactinal view showing prominent carinal row of abactinal plates; B, actinal view showing quadri-serial arrangement of tube feet and the spination of lateral and adambulacral plates. Scale bars: A = 10 mm; B = 5 mm.

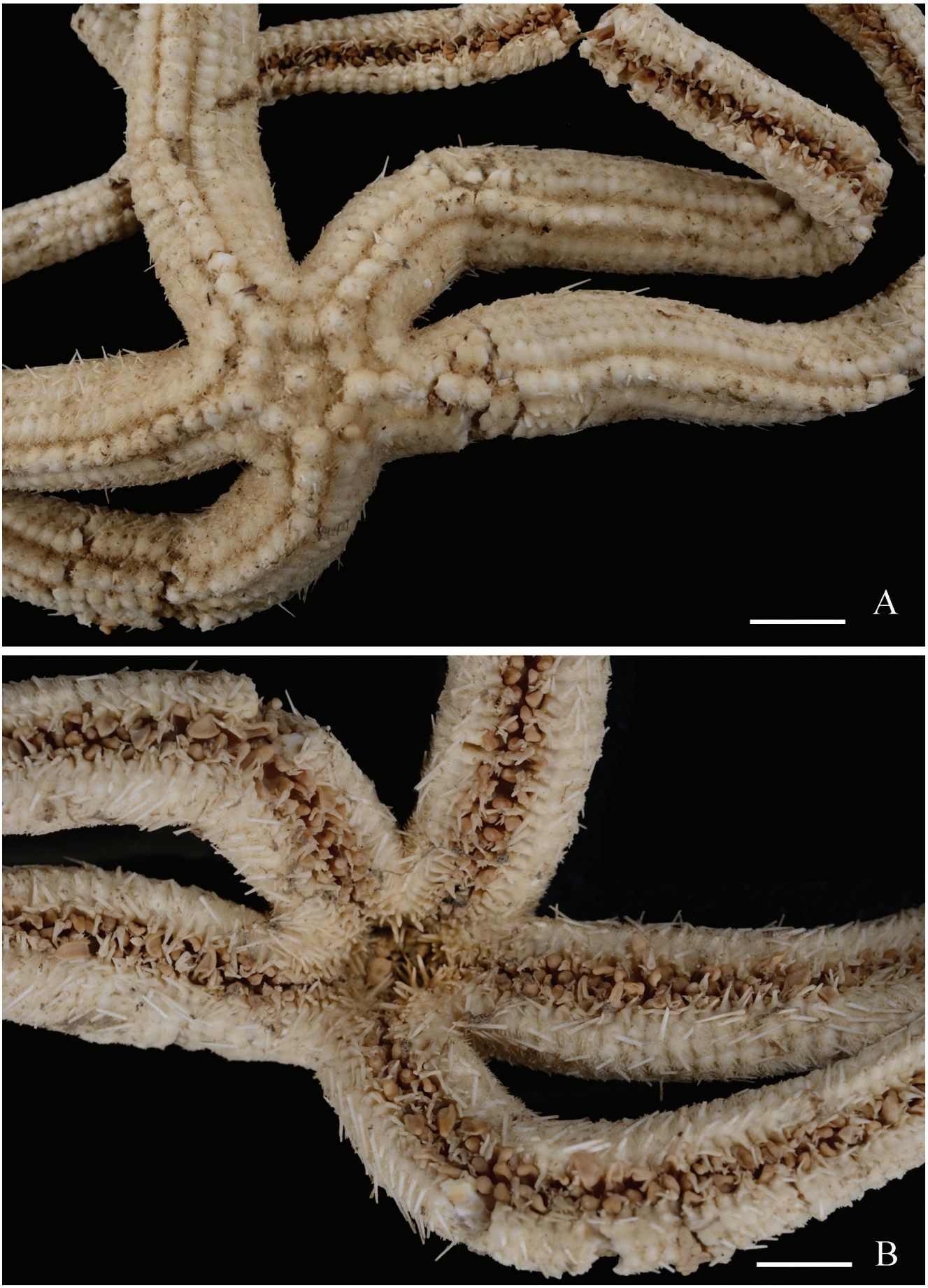


Fig. 3. *Zoroaster microporus*, ethanol-preserved specimen (ZRC.ECH.1298), temporarily air dried. A, abactinal view of prominent carinal ridge and pentagonal disc ring of domed plates; B, actinal view showing spines of lateral plates and the adambulacral plate/furrow region. Scale bars = 10 mm. Photographs by Iffah binte Iesa.

***Zoroaster* sp.**
(Fig. 4A, B)

**Material examined.** 2 wet specimens (ZRC.ECH.1588), R:r = 12:3 mm & 10:2.5 mm (R:r ratio = 4) and 1 dry specimen (ZRC.ECH.1279), R:r = 16.7:3.3 mm (R:r = 5.1), Stn. CP37, Indian Ocean, south of Cilacap, 08°07.663′S 109°06.054′E (mid-point of beam trawl), 30th March 2018, depth = 163–166 m. Substrate: fine mud with pieces of small branches.

**Description.** 5-rayed sea star with arms tapering evenly. Interbrachial arc acute. Abactinal surface characterised by domed plates that on the disc are concentrically arranged and on the arms are aligned in longitudinal rows (Fig. 4A). On the disc there is a large, rounded dorso-central plate surrounded by five smaller radial plates. An outer ring of ten disc plates consists of small interradials alternating with large radials, these being the largest on the disc. The radial series continues along each arm as a prominent ridge of slightly smaller carinal plates. Seen from above the carinal plates closely abut each other and consequently their rounded profile is slightly square. Lateral to the carinal series is a row of small, depressed plates, then a single prominent row of tumescent marginal plates (Fig. 4A). Uppermost surfaces of the prominent disc and carinal plates bear a low, rounded nodule or nodules (Fig. 4B) but the predominant abactinal plate armament consists of slightly-spaced, squamulate ossicles, some rounded but many with lanceolate, pointed ends. Terminal plate, markedly swollen and notched on its proximal border, has a pair of apical, distally projecting spines and other smaller ones, most of them broken in the present specimens. Madreporite small and located interradially adjacent to marginal plates. Inferomarginal and actinal pates each bear a slender spine plus small spinelets. Adambulacral plates are broader than long, forming a series of transverse ridges that bear three or four spines and, occasionally, additional furrow spinelets proximally. Pedicellariae absent. Tube feet biserial.

**Remarks.** The present specimens resemble *Zoroaster adami* in the number, disposition, and relative sizes of the rounded, tumescent abactinal plates on the disc. However, the identity is uncertain as small size, a low R:r ratio, and the presence of enlarged terminal arm plates indicate that the present specimens are possibly juvenile forms. Fisher (1919a) reports that small examples of Zoroasteridae are very different from adults. In juvenile asteroids generally, ontogeny often shows allometry with disproportionately enlarged structures becoming more proportional during development (Mah, 2007). Consequently it is considered that these small specimens can be assigned to genus only.

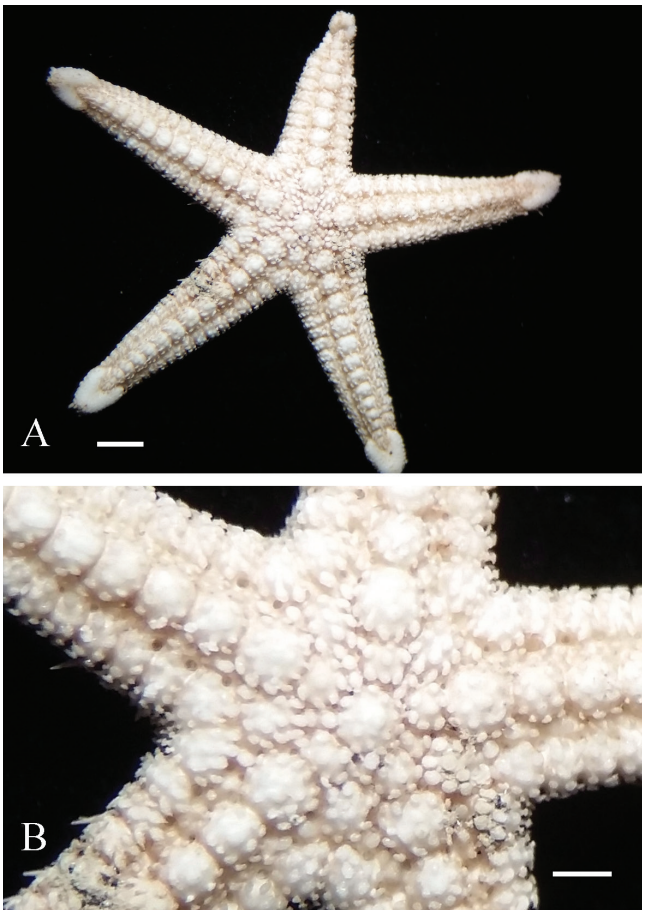


Fig. 4. *Zoroaster* sp., ethanol-preserved (ZRC.ECH.1588). A, abactinal view of whole specimen; B, abactinal close-up of disc and arm bases. Scale bars: A = 2 mm; B = 1 mm.

## Order Brisingida

### Family Brisingidae G.O. Sars, 1875
(Fig. 5)

**Material examined.** 1 wet specimen (ZRC.ECH.1608), arm fragments only, Stn. CP05, Sunda Strait, northwest of Rakata Island, 06°02.983′S 105°10.875′E (mid-point of beam trawl), 24th March 2018, depth = 928–929 m. Substrate: very fine sand-mud; 1 wet specimen (ZRC.ECH.1609), single arm only, Stn. CP28, Indian Ocean, east of Tinjil Island, 06°59.986′S 105°54.924′E (mid-point of beam trawl), 28th March 2018, depth = 957–1022 m. Substrate: coarse sand and some mud.

**Description.** Arms very long, swollen basally, tapering very gradually towards arm tip. Basal, thicker parts of arms have a regular series of transverse, calcified ridges that encircle dorsal and lateral aspects of the arm, sometimes sinuously or in zigzag fashion (Fig. 5). Transverse ridges, separated by uncalcified tissue, have occasional small spinelets; ridges align with a long spine at each end, adjacent to a long subambulacral spine and then a short, slender furrow spine that projects into the ambulacral groove between the biserial, cylindrical tube feet. Transverse ridges are less prominent on attenuated parts of the arms.

**Remarks.** Only arm fragments were found in the beam trawl; discs were missing. The undulating or zigzag transverse calcareous ridges on the arms could indicate one of a number of genera in the family (e.g., *Brisinga*, *Brisingenes*, *Hymenodiscus*), consequently the material could be identified to family only.

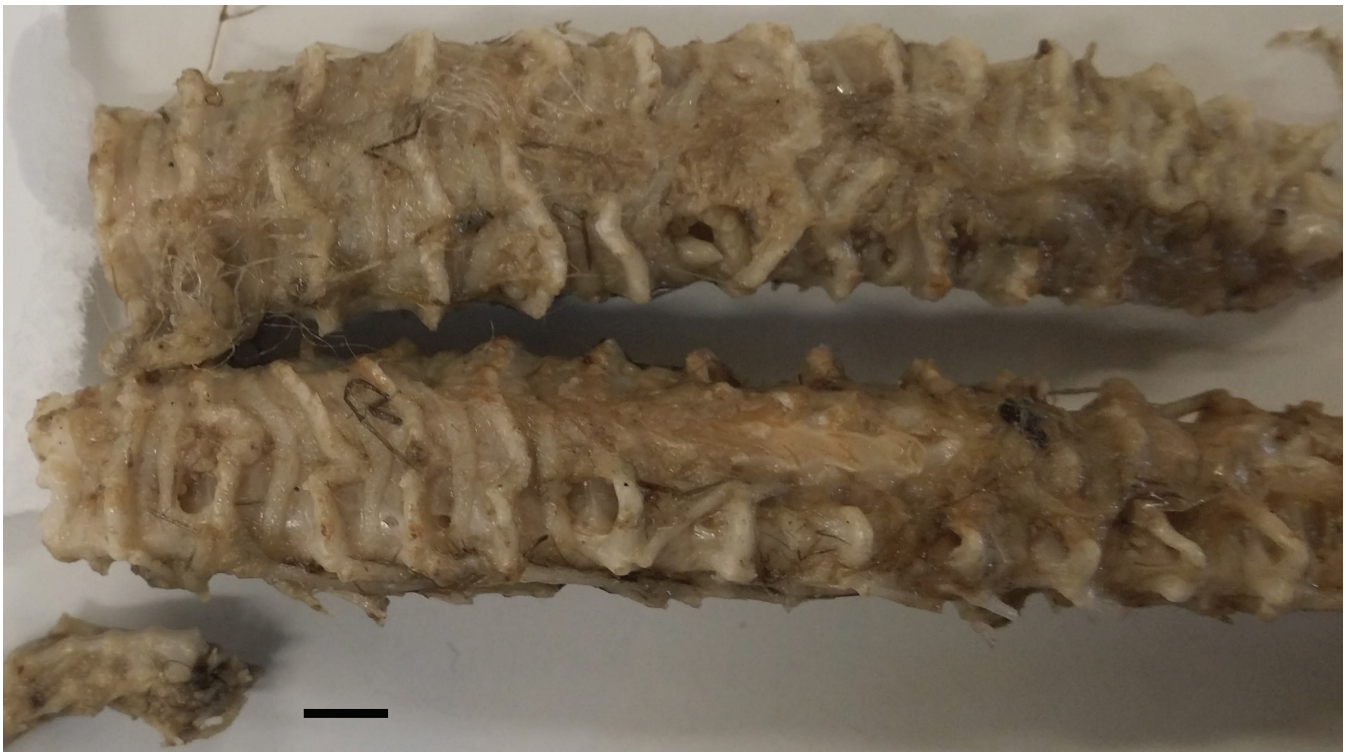

Fig. 5. Brisingidae. Ethanol-preserved specimen, proximal arm fragments (ZRC.ECH.1608). Scale bar = 5 mm.

**Order Spinulosida**

**Family Echinasteridae Verrill, 1867**

***Henricia* Gray, 1840**

***Henricia arcystata* Fisher, 1917**
(Fig. 6A–F)

**Material examined.** 1 wet specimen (ZRC.ECH.1300), R:r = 161:20 mm (R:r ratio = 8.05), Stn. CP39, Indian Ocean, south of Cilacap, 08°15.972′S 109°10.553′E (mid-point of beam trawl), 30th March 2018, depth = 528–637 m. Substrate: some mud.

**Description.** Sea star with a small disc and five long arms (Fig. 6A). Arms taper gradually to a narrow, rounded extremity but at the base some rays are noticeably swollen and then at the junction with the disc these become constricted (Fig. 6A, B). Abactinal surface shows an irregular, skeletal mesh network which is compact on the disc and more open and net-like along the ray distally (Fig. 6C, D). The skeletal mesh is composed of raised plate walls surmounted by a fencing of fine, webbed spinelets (Fig. 6D). These enclose papular areas, the larger of which include two to five papulae and occasional clusters of small spinelets (Fig. 6D). On the actinal surface network walls become transversely aligned in rows that are grid-like (Fig. 6E, F), comprising three 'cells' per row proximally, then two, then one towards the arm tip. Adambulacral plates have from one to three stout, sometimes curved, spines on the furrow face, the lowest of which is deep within the groove, and variable numbers of different-sized spines in irregular clusters projecting actinally; some of the larger ones are spatulate, grooved, or bi-lobed at the tip.

**Remarks.** This specimen closely resembles Fisher's original account (Fisher, 1917) and a subsequent more detailed description (Fisher, 1919b) for *Henricia arcystata*, in R:r ratio and in the arrangement of the body wall skeletal mesh. Basal arm swelling was not noted in Fisher's accounts, but this could be related, for example, to reproductive condition. *Henricia mutans* (Koehler, 1909) is a similar species but this has slightly shorter arms and fewer furrow-face spines than in the SJADES specimen.

**Distribution.** Previously known only from localities in the central Philippines (Fisher, 1917, 1919b) the present record is a new one for Indonesia and extends the range for this species to the Indian Ocean.

***Henricia* sp.**
(Fig. 7A, B)

**Material examined.** 1 dry specimen (ZRC.ECH.1591), R:r = 14:3 mm (R:r ratio = 4.5), Stn. CP08, Sunda Strait, between Tabuan Island and Sumatra, 05°45.175′S 104°51.395′E (mid-point of beam trawl), 25th March 2018, depth = 425–442 m. Substrate: coarse sand, gravel and rubble.

**Description.** Small 5-rayed sea star with a small disc and a flattened undersurface; rays are semi-cylindrical in cross section without any basal swelling and gradually taper to a blunt tip (Fig. 7A, B). Abactinally the plates form a regular mesh-like structure with diagonal rather than longitudinal-transverse alignment of skeletal elements and papular pore areas (Fig. 7A). Pore areas are mostly small and rounded on

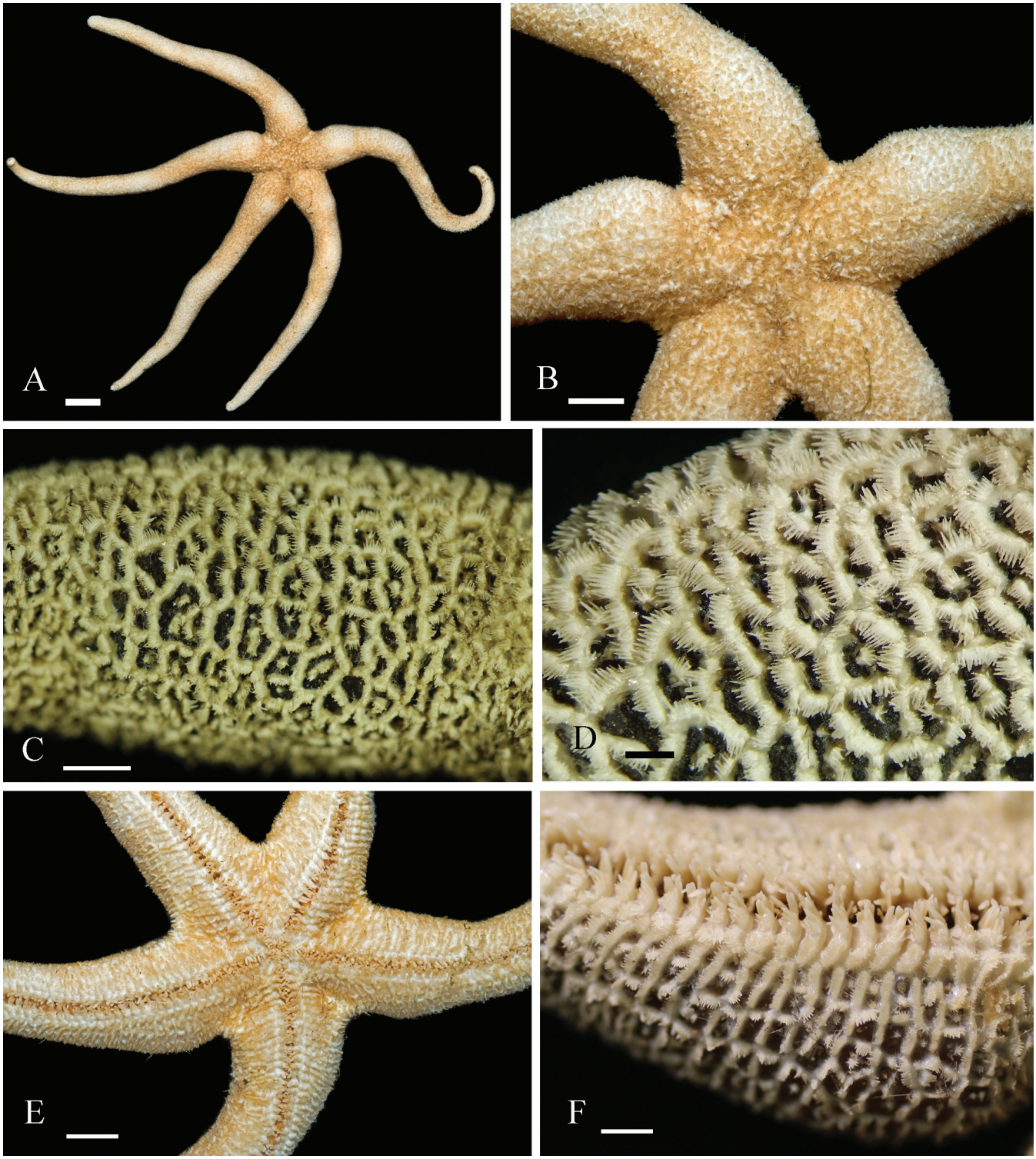


Fig. 6. *Henricia arcystata* (ZRC.ECH.1300). A, live specimen, aboral view of whole sea star; B, live specimen, abactinal view of disc and swollen arm bases constricted at their junction with the disc; C, D, specimen ethanol-preserved and dried. Abactinal skeletal mesh of proximal arm region with mesh walls surmounted by a fencing of fine spinelets, webbed at their bases; E, live specimen, actinal view of disc and proximal regions of arms; F, ethanol-preserved and dried, showing grid-like alignment of abactinal skeletal network. Scale bars: A = 20 mm; B, E = 10 mm; C, F = 5 mm; D = 2 mm.

the arms, each with a single papula, but there are often more papular pores per area on the disc and occasionally up to five per pore area basally on the arms. Abactinal plates bear paxilla-like clusters (pseudopaxillae) of up to 16 fine, multi-pointed spinelets, most with two or three points; actinal and adambulacral plates are similarly armoured. Furrow spines include a protruding cluster of two to three apically-echinate spines plus, along a ridge extending down into the furrow, a row of at least three small spinelets diminishing in size progressively. It is, however, difficult to discern and count furrow structures in this dried specimen as the ambulacral furrow is partially closed and the suckered tube feet, preserved in an expanded state, protrude from the furrow and obscure skeletal details. No pedicellariae observed.

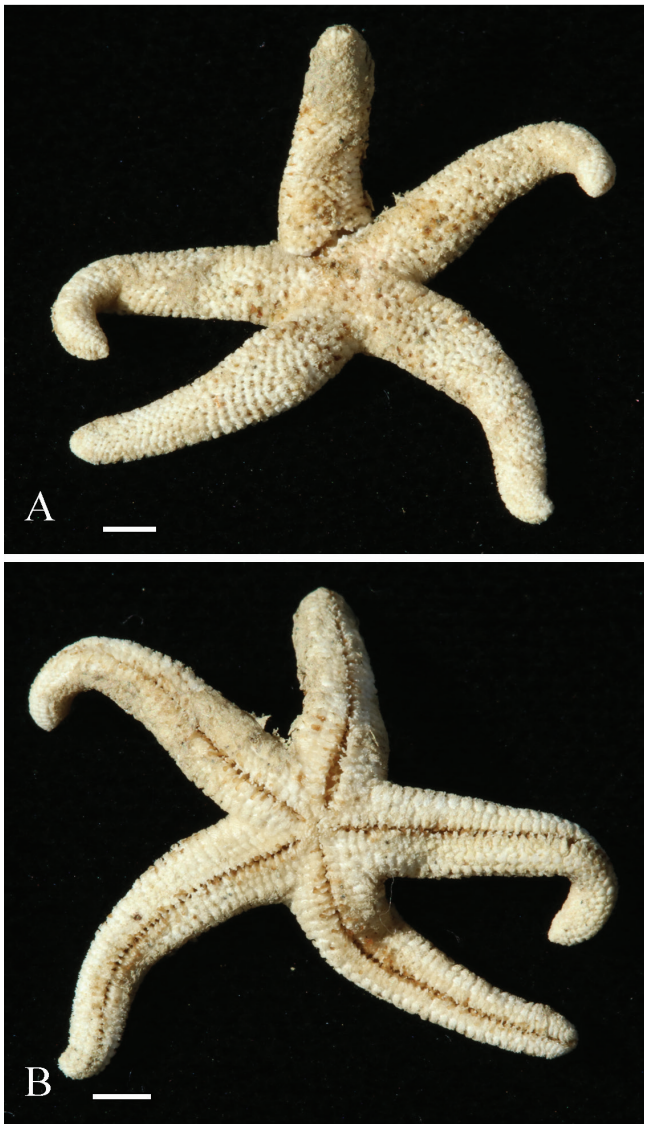


Fig. 7. *Henricia* sp. (ZRC.ECH.1591), ethanol-preserved and dried. A, abactinal view showing diagonal alignment of skeletal network; B, actinal view. Scale bars = 2 mm.

**Remarks.** The genus *Henricia* is highly speciose with some 96 valid taxa currently recognised (Mah, 2021) and although widely distributed in the world's oceans they occur predominantly in cold waters, shallow or deep, in the northern hemisphere (Chichvarkin, 2017). Identification of species is often problematic due to variation and instability of morphological characters (Madsen, 1987; Bratova & Paskerova, 2018). In tropical seas the genus is absent from shallow depths and is poorly represented in deeper waters. The affinities of this single *Henricia* sea star specimen from around 400 m deep in the Sunda Strait are unclear; the oblique alignment of the abactinal open skeletal mesh in the present specimen contrasts with the longitudinal-transverse or irregular abactinal plate arrangements characteristic of other open-mesh *Henricia* sea stars.

**Order Valvatida**

**Family Goniasteridae Forbes, 1841**

***Anthenoides* Perrier, 1881**

***Anthenoides cristatus* (Sladen, 1889)**
(Fig. 8A–F)

**Synonymy.** *Leptagonaster cristatus* Sladen, 1889; *Anthenoides sarissa* Alcock, 1893; *Antheniaster sarissa* Verrill, 1899 (assigned to *Anthenoides* by Fisher (1919b)).

**Material examined.** 2 dry specimens (ZRC.ECH.1267) R:r = 89:34 mm & 83:31 mm (R:r ratios = 2.61 & 2.68), 8 wet specimens: (ZRC.ECH.1288) R:r = 89.1:35.6 mm (R:r ratio = 2.50), (ZRC.ECH.1292) R:r = 80:32 mm (R:r ratio = 2.50), (ZRC.ECH.1293), R:r = 77:30 mm (R:r ratio = 2.57), (ZRC.ECH.1287) R:r = 70:27 mm (R:r ratio = 2.59), (ZRC.ECH.1290) R:r = 61:25 mm (R:r ratio = 2.44), (ZRC.ECH.1294) R:r = 56:24 mm (R:r ratio = 2.33), (ZRC.ECH.1291) R:r = 54:24 mm (R:r ratio = 2.25), (ZRC.ECH.1289) R:r = 52:23 mm (R:r ratio = 2.26), 2 wet specimens (RCO.ECH.3158) R:r = 57.9:26.8 mm & 57:23.9 mm (R:r ratios = 2.16 & 2.38), Stn. CP37, Indian Ocean, south of Cilacap, 08°07.663′S 109°06.054′E (mid-point of beam trawl), 30th March 2018, depth = 163–166 m. Substrate: fine mud with pieces of small branches (total number of individuals counted for CP37 trawl was 53); 1 dry specimen, (ZRC.ECH.1277) R:r = 79:32 mm. (R:r ratio = 2.47), Stn. CP38, Indian Ocean, south of Cilacap, 08°13.094′S 109°07.952′E (mid-point of beam trawl), 30th March 2018, depth = 290–295 m. Substrate not recorded.

**Description.** Disc large with rays tapering markedly to a narrow extremity (Fig. 8A–C). Available data for SJADES specimens indicate an increasing R:r ratio (2.16–2.68) with increasing body size. Interbrachial arcs broad and rounded. Abactinal plates longitudinally aligned in rows along the rays, as are papular pores between them (Fig. 8B, E). Rounded superomarginal plates, numbering 20 to 27 from interradial midline to arm extremity, are longer than wide for much of the arc, tending to become square in profile towards arm extremities when viewed from above (Fig. 8A, B). Inferomarginal plates protrude out beyond the superomarginals for much of the interbrachial arc by up to half the superomarginal width (Fig. 8B, E); towards arm extremities the protrusion diminishes and the two rows of marginals become aligned above one another. Inferomarginal plates bear from two to seven robust short spines laterally (Fig. 8E, F), reducing to a single spine for the more distal plates. Some superomarginals bear one or, rarely, two elongated, pincer-like pedicellariae. Pedicellariae of this type are also present basally on the actinal surface of adambulacrals and some adjacent actinal plates. Many abactinal plates bear shorter, bivalve-like pedicellariae but these decrease in frequency towards the arm tips. Marginals, actinals, and abactinal plates are covered with fine, spaced granules (Fig. 8E, F). Adambulacral plates bear a comb row of five to seven furrow spines (Fig. 8D, F), sometimes with

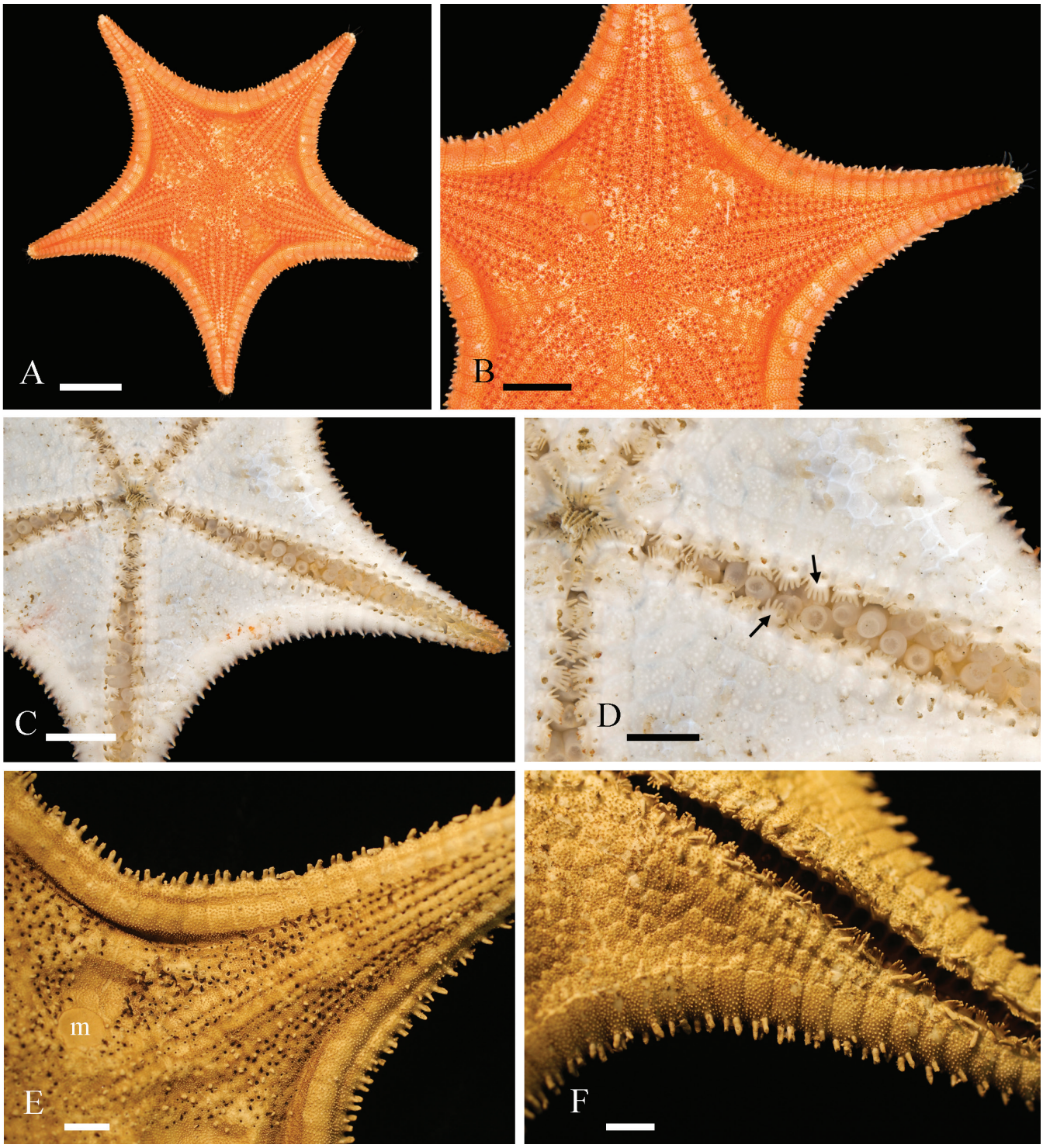


Fig. 8. *Anthenoides cristatus*. A–D, live specimen (RCO.ECH.3158); E, F, ethanol-preserved and dried specimen (ZRC.ECH.1267). A, B, overall view and close-up view of abactinal surface; C, actinal view of disc and arms; D, actinal view of part of disc and arm base showing comb rows of furrow spines (arrows) and biserial tube feet; E, abactinal view of arm base and part of disc showing madreporite (m), spination of laterally protruding inferomarginals, granulation of supero- and inferomarginals and longitudinal alignment of papulae; F, actinal view of arm base and part of disc showing inferomarginal spines, furrow spines and granulation of inferomarginals and actinals. Scale bars: A = 20 mm; B, C = 10 mm; D–F = 5 mm.

an elongated or spatulate pedicellaria aligned at the end of the row. Proximal adambulacrals also bear a pair of robust spines similar in length to the furrow spines; these reduce to a single but longer spine per plate for the outer part of the ray. Mouth spines, numbering nine to ten, are similar in size adjacent to furrow spines but they increase in length and thickness towards the mouth. Colour in life: orange abactinally (Fig. 8A, B), unpigmented actinally (Fig. 8C, D).

**Remarks.** The SJADES material closely matches Sladen's Philippine specimens over a wide range of characters, namely: pentagonal disc with narrowly tapering rays, similar R:r ratio,

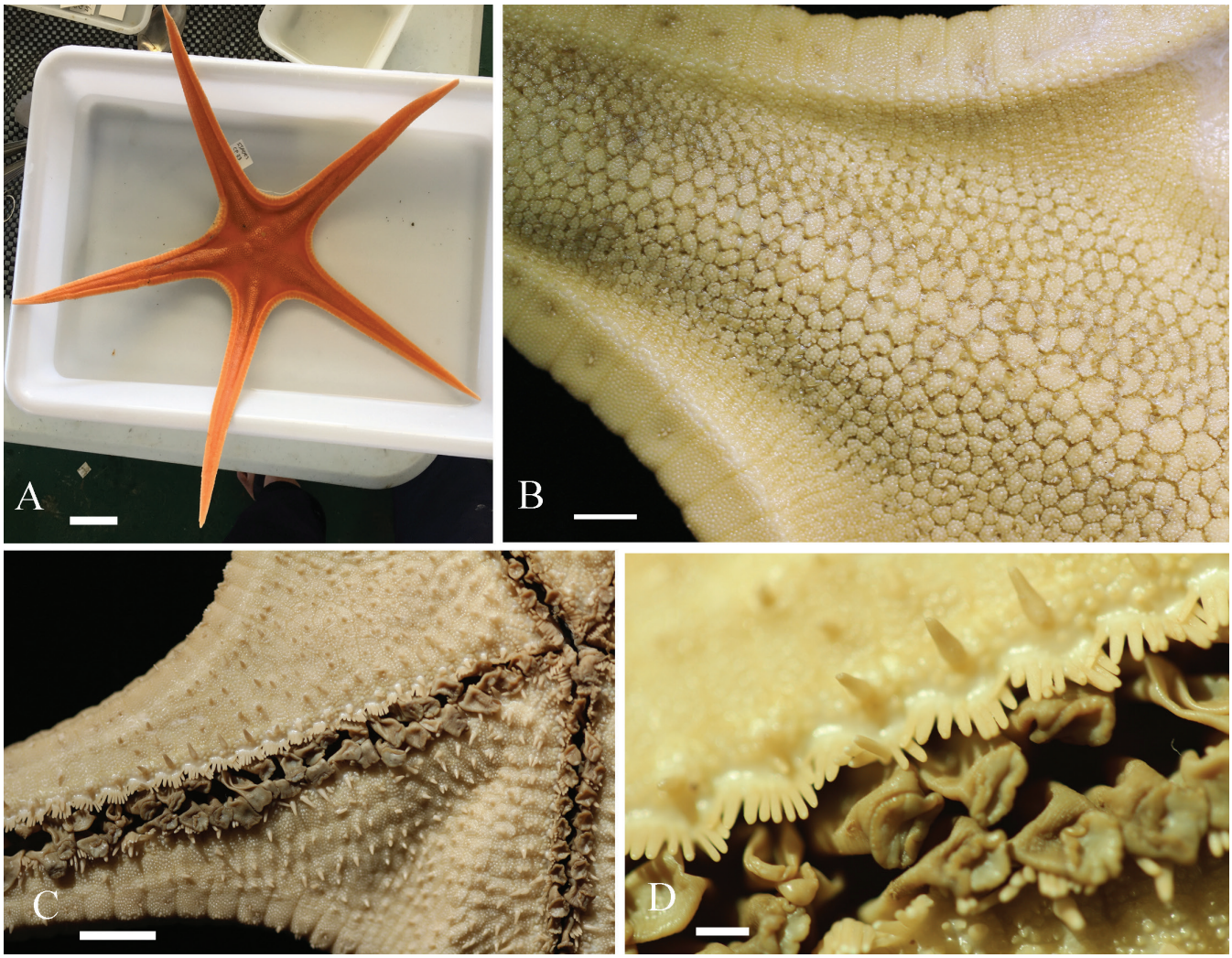


Fig. 9. *Gigantaster weberi* (ZRC.ECH.1312). A, abactinal view of live specimen; B–D, specimen preserved in ethanol and dried. B, abactinal plates of arm base. Note hexagonal carinal series of abactinal plates and two intercalated sub-hexagonal rows on either side; C, actinal view of basal part of arm/disc area. Actinal plates each bear at least one short, prominent spine; D, close-up of ambulacral groove with suckered tube feet, spatulate furrow spines in a comb row and a single subambulacral spine on each adambulacral plate. Scale bars: A = 40 mm; B = 5 mm; C = 10 mm; D = 2 mm.

interradial arcs very broad, comparable number of similarly shaped spineless superomarginals, spinose inferomarginals protruding in interbrachial region, similar granulation for all plates, adambulacral furrow spine number, presence of pedicellaria at end of furrow spine comb row, and comparable number and size distribution for mouth plate furrow spines.

A high catch number for this species, recorded during SJADES 2018 for Station CP37 south of central Java and also noted at Marinduque Island in the Philippines (Fisher, 1919b) and in the Gulf of Aden (Macan, 1938), indicates a significant role in deep-sea food webs with a diet that, for specimens at mesophotic depths off the North Island of New Zealand, is reported to include Foraminifera (Clark & McKnight, 2001).

**Distribution.** The present records for *Anthenoides cristatus* are new for Indonesian seas and they add another Indian Ocean locality to its known distribution range from the Gulf of Aden (Macan, 1938) to the Andaman Sea (Alcock, 1893), the Philippines (Sladen, 1889; Fisher, 1919b), and seas around New Zealand (Clark & McKnight, 2001).

### *Gigantaster* Döderlein, 1924

### *Gigantaster weberi* Döderlein, 1924
(Fig. 9A–D)

**Material examined.** 1 wet specimen (ZRC.ECH.1312) R:r = 235:50 mm (R:r ratio = 4.7), Stn. CP33, Indian Ocean, south of Tg Boyangkareuceng, 07°43.084′S 107°36.897′E (mid-point of beam trawl), 29th March 2018, depth = 525–312 m. Substrate: coarse sand and mud.

**Description.** Very large sea star with suckered tube feet and long arms that taper gradually towards their extremity (Fig. 9A, C, D). Prominent marginal plates (superomarginals) are broader than long basally, less so distally. Abactinal plates extend all the way to the arm tip, thus opposing marginals do not come into contact. Abactinals are aligned

radially for the hexagonal carinal series and the adjacent row of rounded-hexagonal, intercalated plates on either side (Fig. 9B). Plates of these three radial rows are larger than the others, with the carinal series being the largest of the three. Other abactinals are smaller, polygonal, and generally irregularly arranged (Fig. 9B). Madreporite is nearer the disc centre than the marginal plates. Abactinal, superomarginal, and inferomarginal plates densely covered with low, rounded granules (Fig. 9B–D). On the outer edge of the inferomarginals the granules become more pointed with some being elongated as very short spines, generally a central one being largest. Actinal plates likewise densely covered with rounded granules and each plate also bears a single or pair of short pointed spines (Fig. 9C). Forcipulate pedicellariae are present abactinally, except interradially, and on many of the marginal plates, on their respective upper, outer, and lower surfaces. Adambulacral plates densely covered with rounded granules, a single spine, occasionally two, and a row of six to eight blunt, spatulate furrow spines (Fig. 9D). Colour in life: orange abactinally.

**Remarks.** A large and rare member of the deep-sea megafauna, this monotypic sea star genus is very characteristic; its long, straight, narrow rays taper to finely pointed extremities, yet the abactinal surface extends all the way to the arm tip.

**Distribution.** Previously found only in the East Java Sea/ Flores Sea area during the 1899/1900 Siboga Expedition (Döderlein, 1924), the present record off south Java extends its known distribution to the Indian Ocean.

### *Iconaster* Sladen, 1889

### *Iconaster vanuatuensis* Mah, 2005
(Fig. 10A–F)

**Material examined.** 1 dry specimen (ZRC.ECH.1274), R:r = 61:21 mm (R:r ratio = 2.91), 1 wet specimen (ZRC. ECH.1275), R:r = 63:20 mm (R:r ratio = 3.15), 2 wet specimens (RCO.ECH.3143), R:r = 57:21 mm & 42:15 mm (R:r ratios = 2.71 & 2.8), Stn. CP37, Indian Ocean, south of Cilacap, Java, 08°07.663′S 109°06.054′E (mid-point of beam trawl), 30th March 2018, depth = 163–166 m. Substrate: fine mud.

**Description.** Stellate sea star with tapering arms. Swollen disc and arm bases give the sea star a convex profile. Radial abactinal plates comprise a carinal series of hexagonal to rounded-hexagonal plates that, with three or four radial rows of similar plates on either side, extend into the arm partially and to a diminishing extent away from the mid-radial line. Other abactinals are polygonal, the largest located centrally on the disc (together with smaller ones) and in adjacent interradial areas. The carinal series and those abactinals of the central pentagonal region of the disc are characteristically pigmented dark brown, as are some of the peripheral abactinals interradially (Fig. 10A). The pigmentation persists in alcohol-preserved specimens (Fig. 10C, D). Abactinal plates have numerous glassy tubercles. Superomarginals, numbering from 20 to 24, are wider than long, the opposing series abutting at the 10th or 11th plate about two thirds of the way along the arm length (Fig. 10A). Abactinal, actinal, and marginal plates are each bordered by accessory granules that form a double row between plates (Fig. 10D–F). Rounded, polygonal actinal plates form radially aligned rows, the row adjacent to the adambulacrals being more rectangular. Adambulacral plates generally bear a cluster of three to six short, blunt spinelets that are sometime curved or markedly flattened, other low tubercles plus a peripheral row of granules that are of similar size to the adjacent actinal accessory granules. Furrow spines, numbering five or six, are short, round-ended and quadrate or triangular in cross section (Fig. 10F). Oral plates each have four rounded oral spines with flat opposing faces, the central pair being larger (Fig. 10F). Pedicellariae are not present but some of the abactinals and actinals in one of the specimens bear clusters of two to four spinelets—possibly derived from involuted accessory granules—that resemble pedicellariae (Fig. 10D, F).

**Remarks.** This species, one of just four in the genus, is immediately recognisable by its general body form, the darkly pigmented abactinal plates of the carinal series and central pentagonal region of the disc, the large size of many of the central disc plates and, at a microscopic level, by the numerous glassy tubercles on each abactinal plate, the number and structure of the adambulacral furrow spines and by the flat-sided, hemispherical oral spines.

**Distribution.** First collected in 1994 and then described (Mah, 2005) from near Port-Vila, Vanuatu, S.W. Pacific, this species has been subsequently collected from further north in Vanuatu near Espiritu Santo in 2006 (unpublished records of the second author). The present records for this species are the first for Indonesia and the Indian Ocean where the collection depth (163–166 m) is slightly shallower than for Pacific Ocean records [294–301 m (Mah, 2005); 290–503 m (unpublished data of the second author)].

### *Nymphaster* Sladen, 1889

### *Nymphaster euryplax* Fisher, 1913
(Fig. 11A–F)

**Material examined.** 1 dry specimen (ZRC.ECH.1273), R:r = 70:17 mm (R:r ratio = 4.12), 1 wet specimen (ZRC. ECH.1305), R:r = 73:17 mm (R:r = 4.29), St. CP25, Sunda Strait, south of Panaitan Island, 06°50.554′S 105°10.564′E (mid-point of beam trawl), 27th March 2018, depth = 876–937 m. Substrate: gravel and biogenic debris.

**Description.** Stellate, 5-rayed sea star with very narrow tapering arms (Fig. 11A, B, E). Abactinal areas comprise seven rows of rounded hexagonal plates along each radial axis giving a petaloid appearance (Fig. 11A–D). Papulae are restricted to the angles of these hexagonal plates. Interradially a triangular area is formed of polygonal abactinals that have no papular spaces between them (Fig. 11C, D). The madreporite, larger than abactinal plates and rounded-pentagonal in shape, is located midway in from the

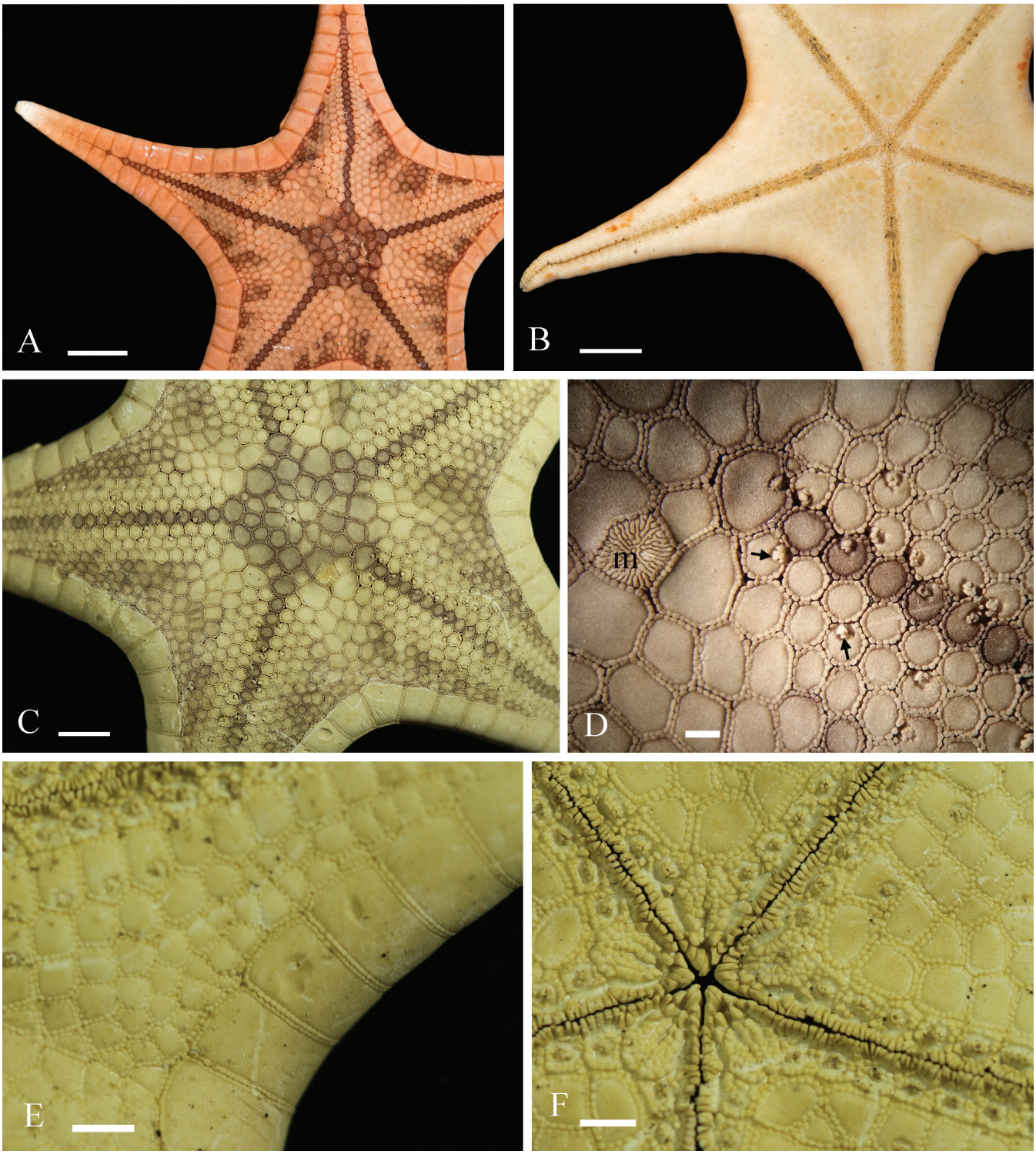


Fig. 10. *Iconaster vanuatuensis*. A, B, live specimen (RCO.ECH.3143); C–F, ethanol-preserved and dried specimen (ZRC.ECH.1274); C, dark pigmentation pattern is partially retained after ethanol preservation; D, abactinal plates bordered with row of accessory granules. m = madreporite, arrows indicate pedicellaria-like structures possibly derived from accessory granules; E, actinal and inferomarginal plates each bordered with row of accessory granules; F, oral centre of disc showing actinal plate accessory granules, furrow spine row and rounded, flat-sided oral spines. Scale bars: A, B = 10 mm; C = 5 mm; D = 1 mm; E, F = 2 mm.

disc edge. Superomarginals, numbering 32, are flat-topped and sided, giving the arms an angular, rectilinear profile abactinally (Fig. 11D). Superomarginal profile, seen from above, transitions from wider than long basally, to square at mid-arm, to longer than wide distally. For the two specimens examined, the 5$^{th}$ or 6$^{th}$ plates meet at the mid-radial line (Fig. 11D), thus there are eight or ten superomarginals to each interbrachial arc. Near the arm base the inferomarginals slightly protrude laterally beyond the superomarginals (Fig. 11B, C). Polygonal actinal plates of various sizes occur in four rows aligned in chevrons. The 4$^{th}$ row (adjacent to the adambulacral series) abuts the 4$^{th}$ inferomarginal plate (Fig. 10E, F). The entire surface of abactinals, marginals, and actinals is covered with evenly spaced, rounded granules (Fig.

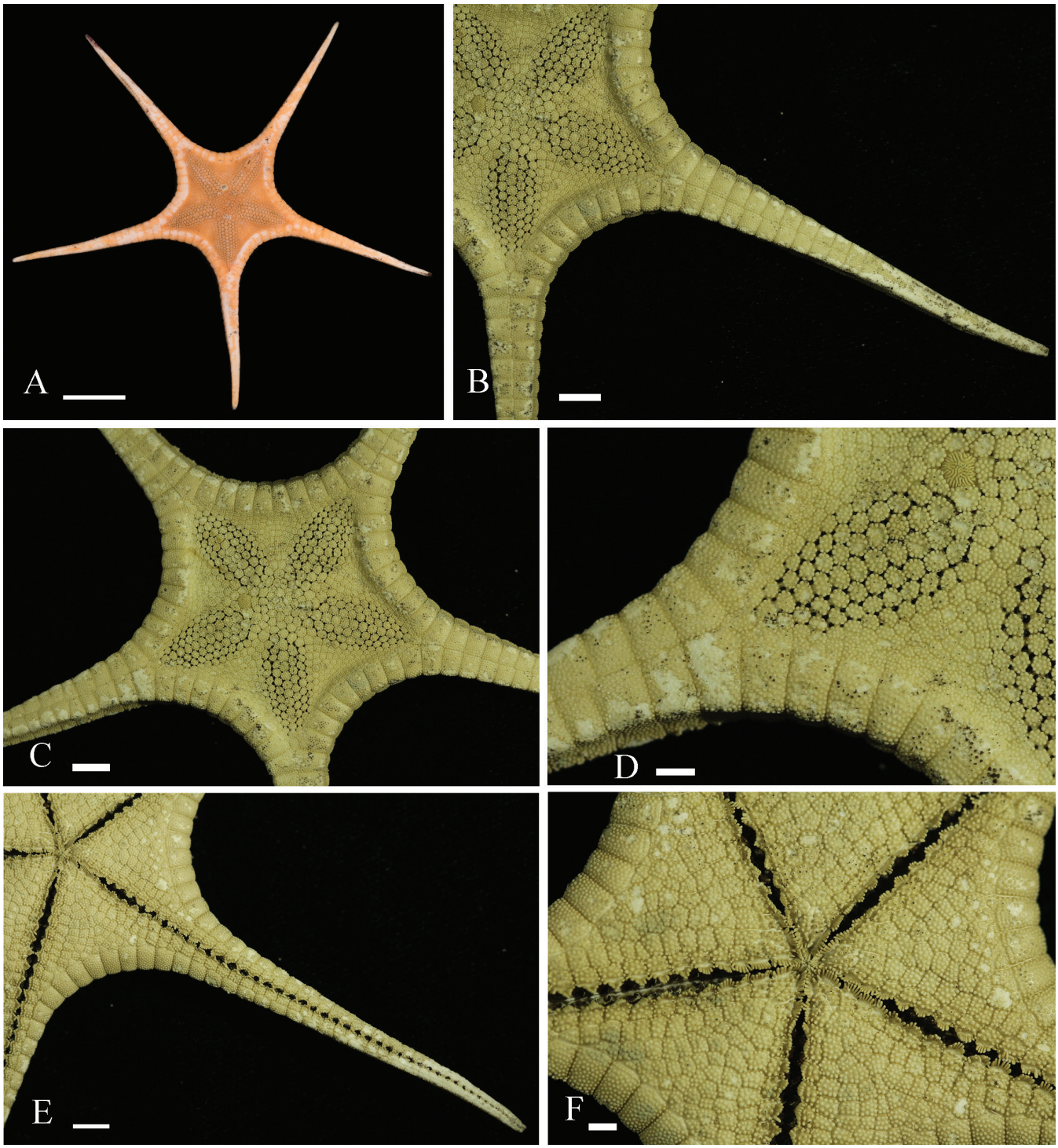


Fig. 11. *Nymphaster euryplax* (ZRC.ECH.1273). A, abactinal view of live specimen; B–F, specimen preserved with ethanol and dried. Petaloid zones on the disc (A–D) denote where papulae protrude between slightly spaced, hexagonal abactinal plates. B–D illustrate the angular profile of superomarginals. Evenly spaced, rounded granules entirely cover abactinals & superomarginals (D) and actinals & inferomarginals (F). Scale bars: A = 20 mm; B, C, E = 5 mm; D, F = 2 mm.

11D, F). Adambulacral furrow spines comprise a comb row of six to eight or nine blunt spines per plate that diminish in length from centre to either end of the row; similar oral furrow spines are nine or ten in number. Pedicellaria absent. Colour in life: orange abactinally.

**Remarks.** Very narrow, elongated rays with superomarginal plates in contact for the entire ray length indicates that this goniasterid belongs to the genus *Nymphaster*. A rectilinear profile for the upper arm edge distinguishes this species from most other members of the genus where the superomarginals are tumid or rounded. Two other species, *N. dyscritus* Fisher, 1913, and *N. meseres* Fisher, 1913, likewise possess angular superomarginals but the former, with angular inferomarinals, and the latter, with superomarginals of similar width and length interradially, contrast with the rounded inferomarginals and broad interradial superomarginals described for *N. euryplax* Fisher, 1913, and noted in the present specimen.

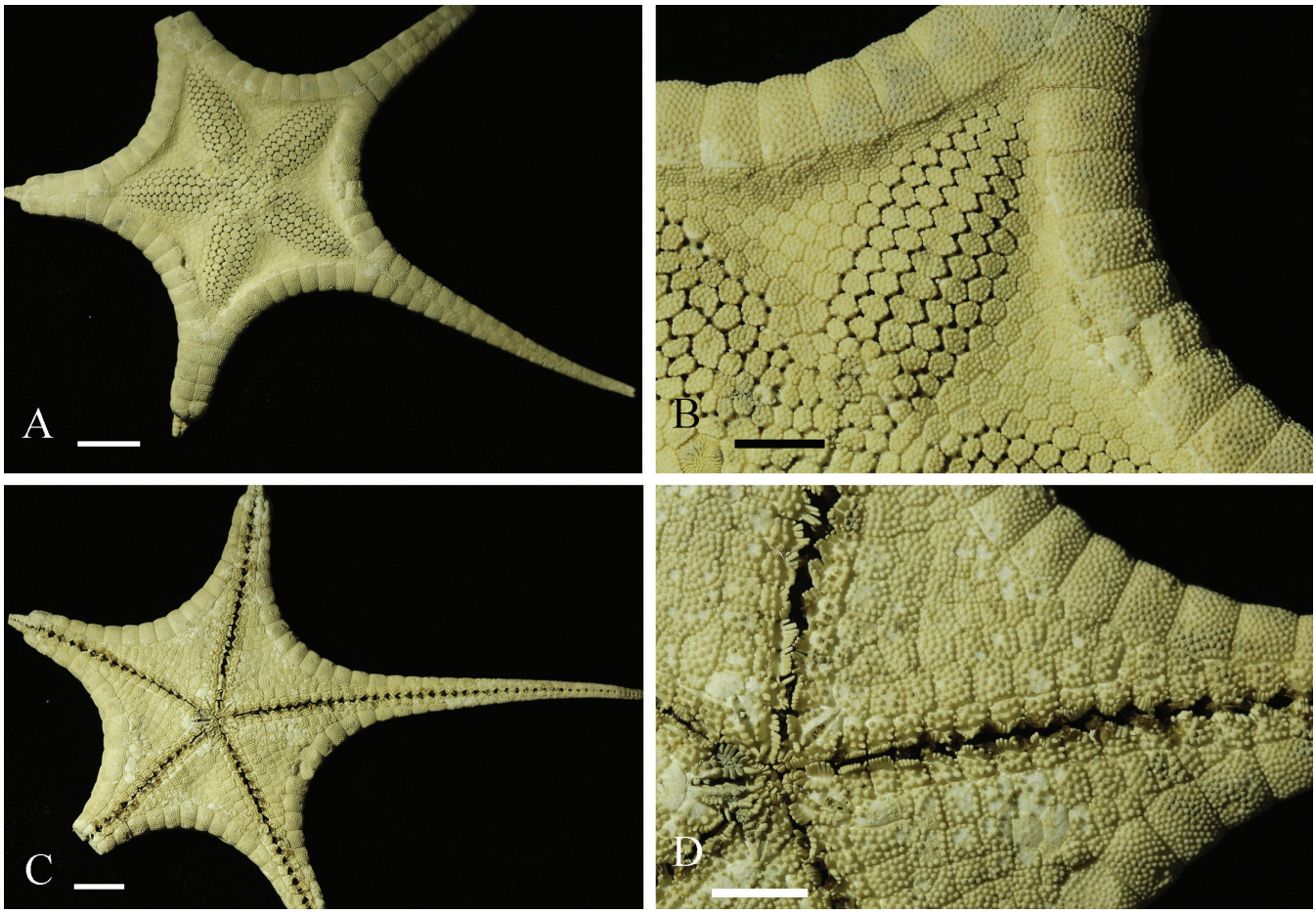


Fig. 12. *Nymphaster moebii* (ZRC.ECH.1268). Specimen ethanol-preserved and dried. A, B, tumescent petaloid areas made up of slightly spaced abactinal plates, superomarginals rounded in profile. Rounded granules densely cover abactinal & superomarginal plates (B) and actinal & inferomarginal plates (D). Scale bars: A, C = 10 mm; B, D = 5 mm.

**Distribution.** First recorded for the Mindanao Sea in the Philippines from a single specimen collected during the Albatross Expedition (Fisher, 1913a), this species had not been documented subsequently or elsewhere except for a report (unillustrated) from the East China Sea of an ascothoracidan-parasitised specimen (Saito et al., 2020). The present record off south Java is the first for Indonesian waters and the Indian Ocean.

***Nymphaster moebii* (Studer, 1884)**
(Fig. 12A–D)

**Synonymy.** *Pentagonaster moebii* Studer, 1884; *Dorigona belli* Koehler, 1909; *Dorigona ludwigi* Koehler, 1909.

**Material examined.** 1 dry specimen (ZRC.ECH.1268), R:r = 67:21 mm (R:r ratio = 3.19), Stn. CP35, Indian Ocean, south of Tg. Boyongkareuceng 07°47.679′S 107°42.190′E (mid-point of beam trawl), 29th March 2018, depth = 603–686 m. Substrate: rocks, mud, clay; 1 wet specimen (ZRC.ECH.1295), R:r = 94:23 mm (R:r ratio = 4.09), Stn. CP23, Sunda Strait, south of Panaitan Island 06°46.331′S 105°08.799′E (mid-point of beam trawl), 27th March 2018, depth = 559–571 m. Substrate: gravel and mud.

**Description.** Stellate sea star with narrowly tapering arms (Fig. 12A, C). Tumid, petaloid areas of the disc are made up of slightly spaced hexagonal abactinal plates, radially aligned in a honeycomb-like arrangement (Fig. 12B). The number of longitudinal plate rows per petaloid area peaks at seven (smaller specimen) or nine (larger specimen). Papular pores open only at the petaloid region into spaces between the plates. Carinal and adradial hexagonal plates are noticeably wider than long, except near the disc centre (Fig. 12B). Most of the interradial abactinals are rounded hexagonal or pentagonal and are tightly packed, forming smooth triangular interradial areas with no pores or spaces (Fig. 12B). Superomarginals are rounded, wider than long basally, longer than wide distally and they meet at the radial midline of the arm at plate 5 for the smaller specimen (Fig. 12A, B) or plate 6 for the larger specimen. Where they make contact, opposing superomarginal rows are either aligned or slightly out of register (up to ¼ of plate length), the midline suture appearing as a weakly zigzag line (Fig. 12A). Actinal plates tend to be square (Fig. 12D) with some being triangular, polygonal, or rounded. Abactinal, actinal and marginal plates are all covered with dense, evenly spaced arrays of rounded, nodule-like granules; on the actinal plates central granules are slightly larger than peripheral ones (Fig. 12D). No pedicellariae. Comb-like furrow spines number 6–9; curvature of comb rows maintains a series of tube feet spaces even when the furrow is almost closed (Fig. 12D). Adambulacrals bear double or triple rows of nodules (Fig. 12D). Mouth plate spines, numbering 10 per series,

are more robust than the furrow spines with the terminal ones being triangular in cross section where they bunch together. Mouth plates also bear, on each side, a ventral row of nodular tubercles that transition to larger conical spines near the mouth.

**Remarks.** *Nymphaster moebii* has been considered to be a widely variable Indian Ocean species (Macan, 1938) but the present specimen matches a recent detailed description (Mah, 2018) for this taxon in several regards, namely: similar narrow-armed stellate body form with comparable R:r ratio; 8–10 superomarginals in interbrachial arc; rounded edge for superomarginal plates, radial and adradial abactinals hexagonal with an armament of round granules in similar numbers; granulation similar for both marginals and actinals; and similar numbers of oral furrow spines. The present specimen is thus assigned to *N. moebii* pending revision of the genus (Mah, 2018).

**Distribution.** Previously reported ranging from Tanzania to the Andaman/Laccadive Islands area and northern Australia (Koehler, 1909; Clark, 1993), the present records south of Panaitan Island and the Java mainland are the first for Indonesian seas and provide additional localities for the Indian Ocean, where this taxon appears to be restricted.

### *Sibogaster* Döderlein, 1924

### *Sibogaster digitatus* Döderlein, 1924
(Fig. 13A–F)

**Synonymy.** *Eugoniaster ephemeralis* Macan, 1938; *Plinthaster ephemeralis* (*Eugoniaster* genus referred to *Plinthaster* by Halpern (1970) but subsequently synonymised with *Sibogaster* by Mah (2016, 2021)).

**Material examined.** 1 dry specimen (ZRC.ECH.1271), R:r = 71:39 mm (R:r ratio = 1.82), Stn. CP24, Sunda Strait, south of Panaitan Island, 06°47.629′S 105°06.262′E (mid-point of beam trawl), 27th March 2018, depth = 1044–1068 m. Substrate: rocks, gravel with pieces of wood.

**Description.** Sea star with relatively large pentagonal disc and short, sharply tapering rays; interradial arcs very broad with margins almost straight (Fig. 13A, B). Abactinal plates, flattened but convex at margins, are abutted tangentially leaving spaces for papular pores but there are no fasciolar grooves between plates. Plates are of various sizes, irregularly arranged, rounded or oval on the radii, more polygonal interradially (Fig. 13C) and becoming smaller towards the marginals and distally; plate surfaces bare, with no granulation, but faceted with numerous evenly spaced, low, embedded, glassy bosses. All abactinals ringed with small, slightly spaced, rounded granules numbering up to 24 for the larger plates (Fig. 13D). Papular pores occur only centrally and radially forming an abactinal petaloid zone (Fig. 13B) and are absent from triangular interradial areas (Fig. 13C), abactinal plate areas near the marginals and distal portions of the arms (Fig. 13B). Superomarginals, numbering 17 on each side of the interradius (34 for entire arc), are slightly tumid and, seen from above, are almost square in outline at the interradius but become slightly longer than wide distally. Superomarginals bordered with fine granules similar in size to those around the abactinals (Fig. 13D); upper surface generally bare but with depressions and pits; occasional granules in some of the pits; lateral surface with larger, round, densely packed granules. Inferomarginals in register with superomarginals and similarly bordered with small granules; lateral face with densely packed, large, round granules, becoming smaller and more scattered ventrally. Actinal plates, rectangular, square, or polygonal, aligned in 6–7 rows and covered with densely packed, large (and some small) rounded granules (Fig. 13F). Their counterparts on adambulacral plates are larger and slightly elongated (Fig. 13F). Furrow spines, numbering 6–7, are cylindrical or slightly spatulate. The furrow series continues on mouth plates with 8–9 similar sized oral spines, plus a 9th or 10th enlarged tooth spine. Mouth plates armoured ventrally with 19–23 large, rounded, tubercle-like granules that become more pointed near the mouth. No pedicellariae observed.

**Remarks.** A combination of characters, namely: interradial arcs almost straight, irregularly arranged, flat abactinal plates ringed with a granular border, lack of fasciolar grooves between abactinals, granules absent from upper surface of superomarginals, identify this goniasterid as a species of *Sibogaster* Döderlein, 1924. The presence of numerous glassy low bosses or tubercles embedded in the abactinals and a lower R:r ratio due to a large disc and small arms further identifies the present specimen as *Sibogaster digitatus* Döderlein, 1924. It is distinguished from the two other congeners, *Sibogaster nieseni* Mah, 2016, in which a carinal series of abactinals is evident, and the Caribbean *Sibogaster bathyheurator* Mah, 2020, that has differences in oral plate armature (absence of actinal granules and more furrow spines) and fewer actinal plate rows (3–4 as compared with 6–7). There are, however, some differences between the specimen described herein and *S. digitatus* as described by Mah (2016), namely: abutment of opposing terminal superomarginals, noted for the distalmost three to five plates (Mah, 2016), was not evident in the SJADES specimen (except perhaps for the last plate) and the row of granules bordering the abactinals are slightly spaced and not contiguous as reported previously. Whether these differences represent intraspecific variation remains to be determined.

**Distribution.** *Sibogaster digitatus*, originally described as a new genus and species from a single specimen from Indonesian waters south of Flores (Döderlein, 1924), has subsequently been recognised from the Western Indian Ocean (Macan, 1938) by updated synonymy (Mah, 2016, 2021). Records from the Philippines and Solomon Islands (Mah, 2016) have expanded its known distribution to the West Pacific. The present specimen from south of Java represents an additional Indian Ocean locality for this bathyal species.

## Family Solasteridae Viguier, 1878

### *Lophaster* Verrill, 1878

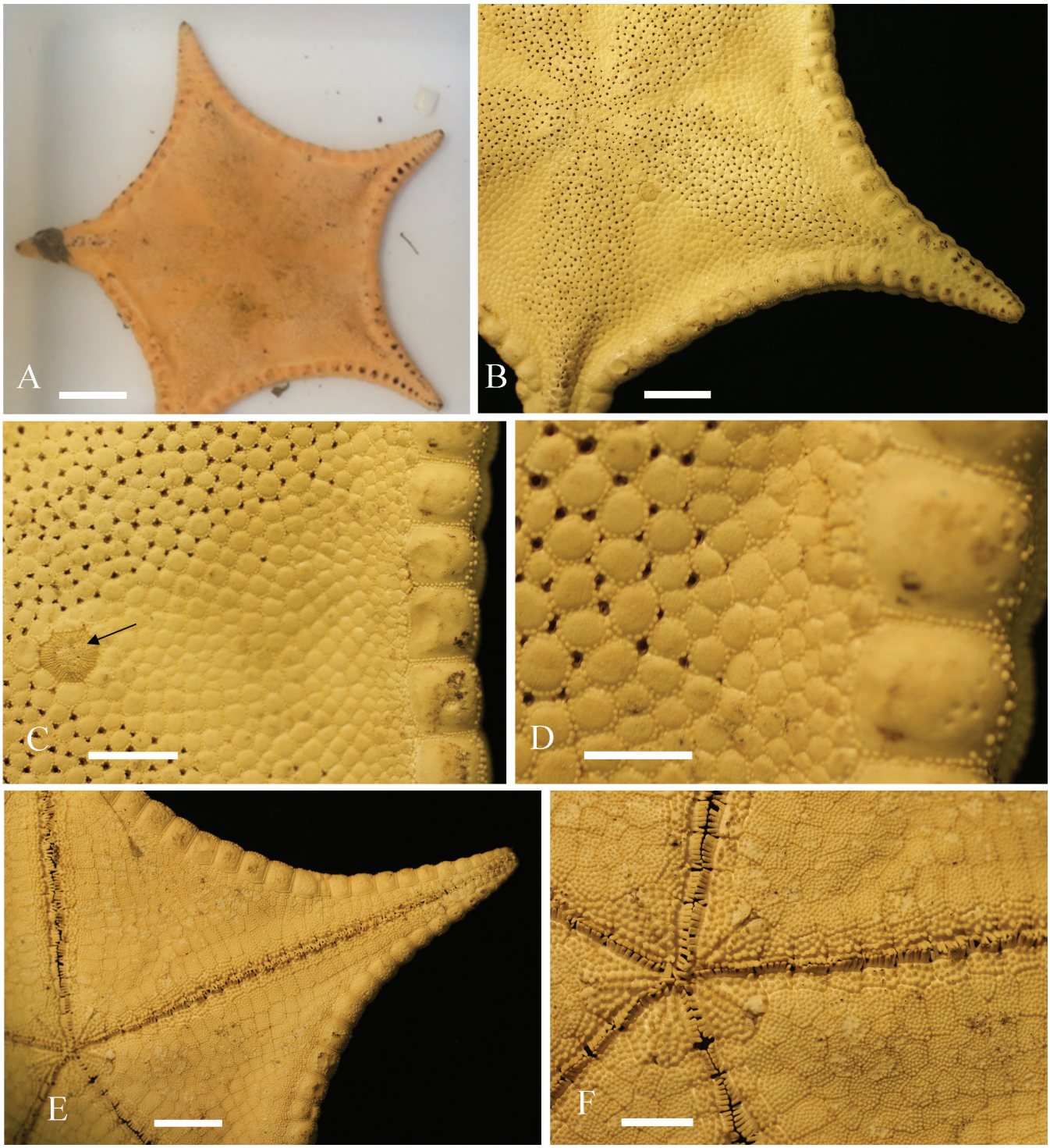


Fig. 13. *Sibogaster digitatus* (ZRC.ECH.1271). A, abactinal view of live sea star (photograph by Ismiliana Wirawati); B–F, specimen after ethanol preservation and drying. B, petaloid distribution of radial papular areas; C, interradial area lacking papular pores, arrow indicates madreporite; D, abactinal and superomarginal plates ringed with small round granules; E, actinal view of arm and part of disc; F, close view of granulated oral and actinal plates and furrow spines in comb rows. Scale bars: A = 20 mm; B, E = 10 mm; C, D, F = 5 mm.

***Lophaster* sp.**
(Fig. 14A–D)

**Material examined.** 1 dry specimen (ZRC.ECH.1383) R:r = 24:8 mm (R:r ratio = 3), 1 wet specimen (ZRC.ECH.1587) R:r = 50:16 mm (R:r ratio = 3.13), Stn. CP07, Sunda Strait, between Tabuan Island and Sumatra, 05°44.798′S 104°51.606′E (mid-point of beam trawl), 25th March 2018, depth = 379–409 m. Substrate: coarse sand, gravel, rubble and wood; 1 wet specimen (ZRC.ECH.1592) R:r = 16:4 mm (R:r ratio = 4), 1 dry specimen (ZRC.ECH.1384) R:r = 23:7 mm (R:r ratio = 3.29), 1 dry specimen (ZRC.ECH.1385) R:r = 17:5 mm (R:r ratio = 3.4), Stn. CP08, Sunda Strait, between Tabuan Island and Sumatra, 05°45.175′S 104°51.395′E (mid-point of beam trawl), 25th March 2018, depth = 425–442 m. Substrate: coarse sand, gravel and rubble.

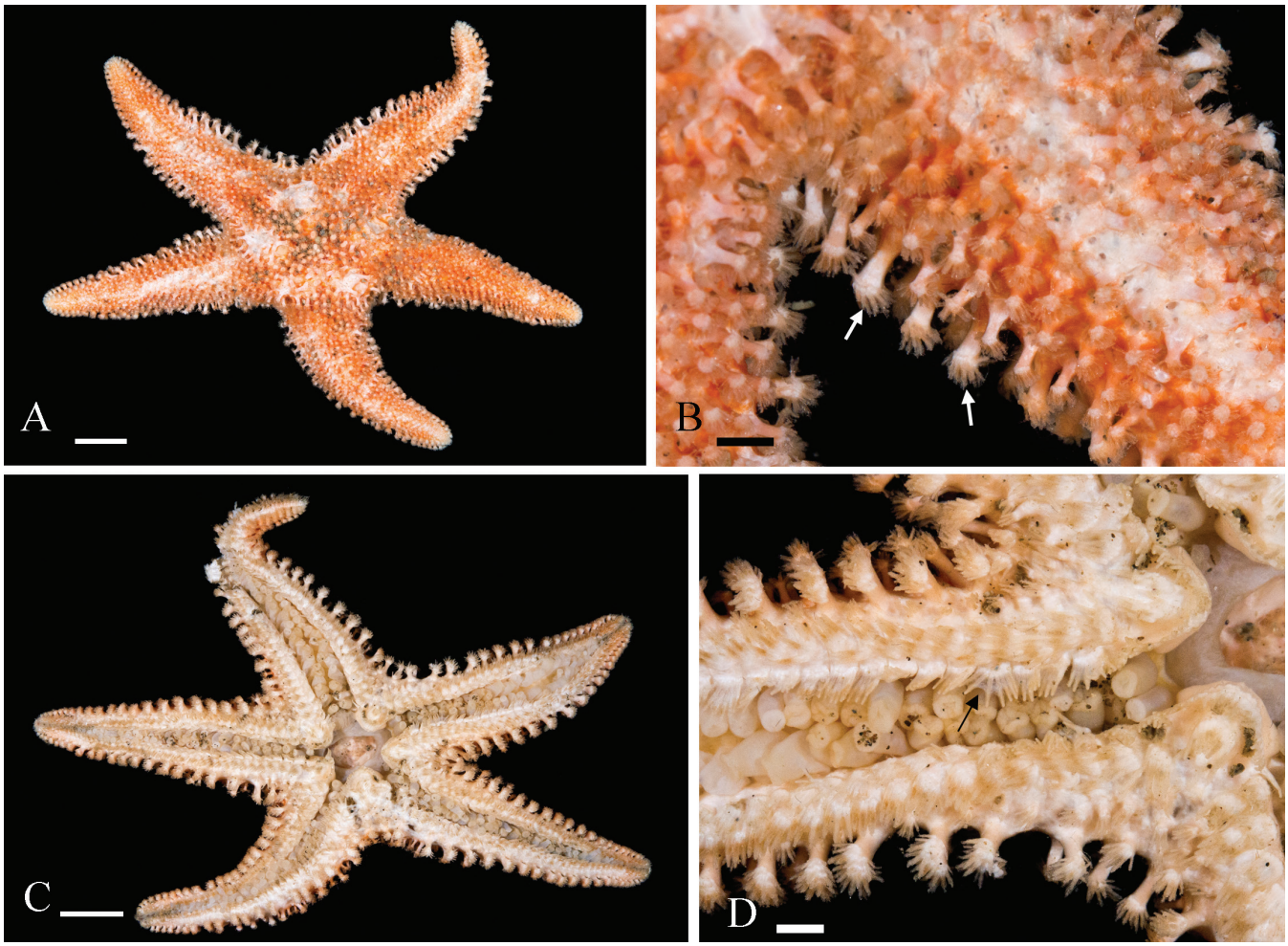


Fig. 14. *Lophaster* sp., live specimen (ZRC.ECH.1587). A, abactinal view showing the regular alignment of abactinal pedicels or pseudopaxillae on the underlying skeletal mesh; B, pedicels, crowned with spinelet clusters (arrows), are larger and more elongated laterally; C, actinal view showing biserial rows of tube feet; D, actinal view of arm base showing suckered tube feet and webbed furrow spines (arrow). Scale bars: A, C = 10 mm; B, D = 2 mm.

**Description.** Rays taper evenly to a bluntly pointed extremity (Fig. 14A, C), with the R:r ratio ranging from 3.0 to 4.0. Biserial tube feet with suckers (Fig. 14D). Abactinal plates more or less aligned in longitudinal series and forming a quadrate or polygonal mesh with papular pores in the spaces (Fig. 14A). Abactinals bear elongated well-spaced, paxilla-like pedicels that are more robust and longest for the marginal series (ca. 1 mm, smaller specimens; ca. 2 mm, larger specimen), diminishing in size and height distally and abactinally (Fig. 14B). All pedicels are densely crowned with thorny spinelets that have multi-pointed tips. The more robust marginal/basal pedicels bear more spinelets than abactinal and distal ones. Adambulacral plates bear three long subambulacral spines and 5–7 basally webbed furrow spines (Fig. 14D). Colour in life: orange abactinally, unpigmented actinally.

**Remarks.** The identity of *Lophaster* specimens from the Sunda Strait is unresolved. They resemble *L. suluensis* Fisher, 1913, from the Philippines in general pedicel arrangement, long subadambulacral spines, and a similar number of furrow spines, but the R:r ratio is less and, notably, pedicels for the SJADES material, particularly the marginal ones, are much longer. There is also resemblance to *Lophaster cactorum*, a newly described species from Japanese waters (Mah & Fujita, 2020). Both have paxillae with elongated marginal pedicels and a similar number of furrow spines, but the present material has arms that taper more markedly and evenly compared with the more parallel-sided, strap-like arms of *L. cactorum*. Additionally, the present Sunda Strait specimens have a narrower R:r ratio range (3–4) than reported for *L. cactorum* (2.7–4.7).

### ***Solaster*** **Forbes, 1839**

### ***Solaster tropicus*** **Fisher, 1913**
(Fig. 15A–D)

**Material examined.** 1 wet specimen (ZRC.ECH.1306) R:r = 130:44 mm (R:r ratio = 2.95), Stn. CP25, Sunda Strait, south of Panaitan Island, 06°50.554′S 105°10.564′E (mid-point of beam trawl), 27th March 2018, depth = 876–937 m. Substrate: gravel and biogenic debris.

**Description.** This ‘sunstar’ has a large disc with a convex upper surface and 10 arms. Arms taper gradually to their pointed extremities (Fig. 15A, B). Abactinal and actinal surfaces are densely covered with evenly spaced

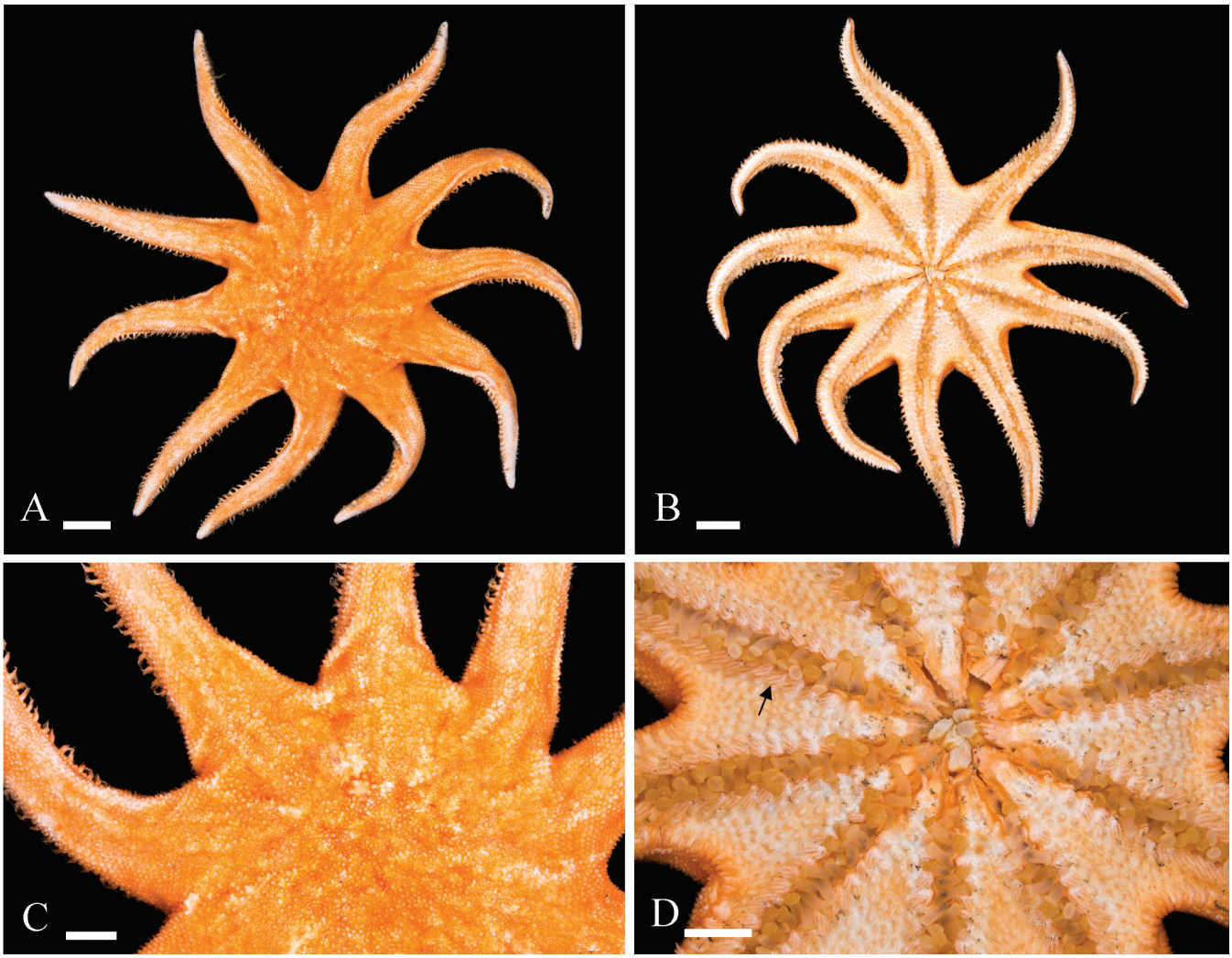


Fig. 15. *Solaster tropicus*, live specimen (ZRC.ECH.1306). A, abactinal view; B, actinal view; C, part of abactinal surface of disc and arm bases with small closely spaced pseudopaxillae partially obscured by tegument; D, actinal view of disc, arrow indicates transverse rows of adambulacral spines. Scale bars: A, B = 20 mm; C, D = 10 mm.

pseudopaxillae. Abactinal pseudopaxillae are covered in tegument but up to 10 spinelets can be discerned for some. Actinal pseudopaxillae tend to be arranged in rows parallel with the adambulacrals; although obscured by tegument they seem to have fewer spinelets. Superomarginals are inconspicuous. Inferomarginal plates have a transverse ridge formed of up to six prominent, pointed spines and low conical subunits, all united at the base. Adambulacrals bear four or five transversely aligned, stout, pointed spines united at the base. Rows of small furrow spines are entirely invested in translucent tegument and difficult to count but there are at least five spines per plate. Mouth spines are massive, pointed and are bound together with connective tissue. Bi-serial tube feet have large suckers (Fig. 15D). Colour in life: orange abactinally, paler actinally.

**Remarks.** Distinguished from the closely related *S. paxillatus* Sladen, 1889, by a larger number of rays (10 versus 9), a differing range for furrow spine count along the arm (5–6 versus 2–5) and a more prominent transverse ridge of inferomarginal spines in the former.

**Distribution.** Previously recorded only from Sulawesi and the Molucca Islands in Indonesia (Fisher, 1913b, 1919b). The present record adds another Indonesian locality and extends the distribution range of this taxon to the Indian Ocean.

***Solaster* sp.**
(Fig. 16A, B)

**Material examined.** 1 wet specimen (RCO.ECH.2704), R:r = 41.8:13.5 mm (R:r ratio = 3.1), Stn. CP35, Indian Ocean, south of Tg. Boyongkareuceng, 07°47.679′S 107°42.190′E (mid-point of beam trawl), 29th March 2018, depth = 603–686 m. Substrate: Rocks, mud and clay.

**Description.** 9-armed sea star with relatively large disc (Fig. 16A, B). Arms are almost parallel-sided proximally and taper for the outer third to blunt extremities. Abactinal ossicles form a mesh-like reticulum that shows no particular alignment on the disc and mid-radial upper surface of the arms but laterally on the arms the meshes are transversely and longitudinally aligned (Fig. 16A). Abactinal pseudopaxillae are small but on the inferomarginal plates they are large and form a single series along the lower lateral edge of the arm


Fig. 16. *Solaster* sp., live specimen (RCO.ECH.2704) in poor condition due to abrasion in trawl. A, abactinal view; B, actinal view. Scale bars: A = 10 mm; B = 5 mm.

(Fig. 16B). Coelomic cavity not partitioned by radial septa. Tube feet terminate in discs (Fig. 16B). Specimen condition when retrieved from the beam trawl was poor due to abrasion but the colour in life is tawny abactinally, paler actinally.

**Order Paxillosida**

**Family Astropectinidae Gray, 1840**

***Astropecten* Gray, 1840**

***Astropecten timorensis* Döderlein, 1917**
(Fig. 17A–C)

**Material examined.** 8 wet specimens (RCO.ECH.2695) R:r = 43.9:7.4 mm (R:r ratio = 5.9), R:r = 49:7.4 mm (R:r ratio = 6.6), R:r = 48:8.4 mm (R:r ratio = 5.7), R:r = 47.4:8.3 mm (R:r ratio = 5.7), R:r = 53.7:8.7 mm (R:r ratio = 6.2), R:r = 47:8.2 mm (R:r ratio = 5.7), R:r = 41.1:7.9 mm (R:r ratio = 5.2), R:r = 37.6:5.9 mm (R:r ratio = 6.4), Stn. CP37, Indian Ocean, south of Cilacap, Java, 08°07.663′S 109°06.054′E (mid-point of beam trawl), 30th March 2018, depth = 163–166 m. Substrate: fine mud. Including the 8 RCO specimens, a total of 35 specimens were trawled from Stn. CP37 and collectively photographed alive on the vessel.

**Description.** Narrow-rayed sea star with rays tapering evenly to arm tip (Fig. 17A). R:r ratio ranging from 6.6 to 5.2. Ray width at the arm base closely approximates to r; abactinally slightly less than half the basal arm width accounted for by superomarginal plates (Fig. 17A, B) and, actinally, half the width accounted for by inferomarginal plates (Fig. 17C). Superomarginals, numbering 35 in the largest specimen, are broader than long and lack spines. Inferomarginal plates each bear an upper, marginal, robust, conical spine of similar length to the width of its plate (Fig. 17B), with below that a secondary shorter spine, then several others much smaller (Fig. 17C). Biserial tube feet are pointed (Fig. 17C). Colour in life: dull red (Fig. 17A).

**Remarks.** The characters for this astropectinid closely match those in the original description (Döderlein, 1917) for *Astropecten timorensis*, except that the R:r ratio values for SJADES 2018 material (6.6–5.2, mean = 5.9) are higher than values (4.8–4.4) reported by Döderlein (1917). However, re-measurements taken from the photograph of one of Döderlein's specimens (Döderlein, 1917: pl. 4, fig. 12) indicate R:r ratio values (5.1–5.6) that are higher than reported in the text and in fact closer to values for the SJADES 2018 specimens.

**Distribution.** Previously known only from Timor, the present record provides an additional Indonesian/Indian Ocean locality for the species. The abundance of *A. timorensis* off the south Java coastline at Cilacap indicates a significant role in benthic food webs at this relatively shallow (163–166 m) depth zone.

***Astropecten* sp. 1**
(Fig. 18A–D)

**Material examined.** 2 wet specimens (ZRC.ECH.1379) R:r = 33:9 mm (R:r ratio = 3.67) & (ZRC.ECH.1380) R:r = 42:11 mm (R:r ratio = 3.82), Stn. CP12, southeast of Tabuan Island, 05°52.490′S 104°56.604′E (mid-point of beam trawl), 25th March 2018, depth = 615–698 m. Substrate: muddy.

**Description.** 5-rayed stellate asteroid with rays tapering evenly to pointed extremities (Fig. 18A, C). Tube feet pointed. Abactinal paxillae densely packed and aligned in transverse rows along each side of the arms (Fig. 18B, D) with the alignment transitioning to radial towards the interradius. Arrangement of paxillae is less regular on the central disc. Larger paxillae crowned with 11–14 spinelets, smaller ones with 4–9 spinelets. Central epiproctal cone cylindrical, slightly tapering, ca. 5 mm long (Fig. 18A, B, D) and covered with small paxillae. Marginal plates number 27 from interradial line to arm extremity. A pair of short, vertically aligned superomarginal spines on the upper-

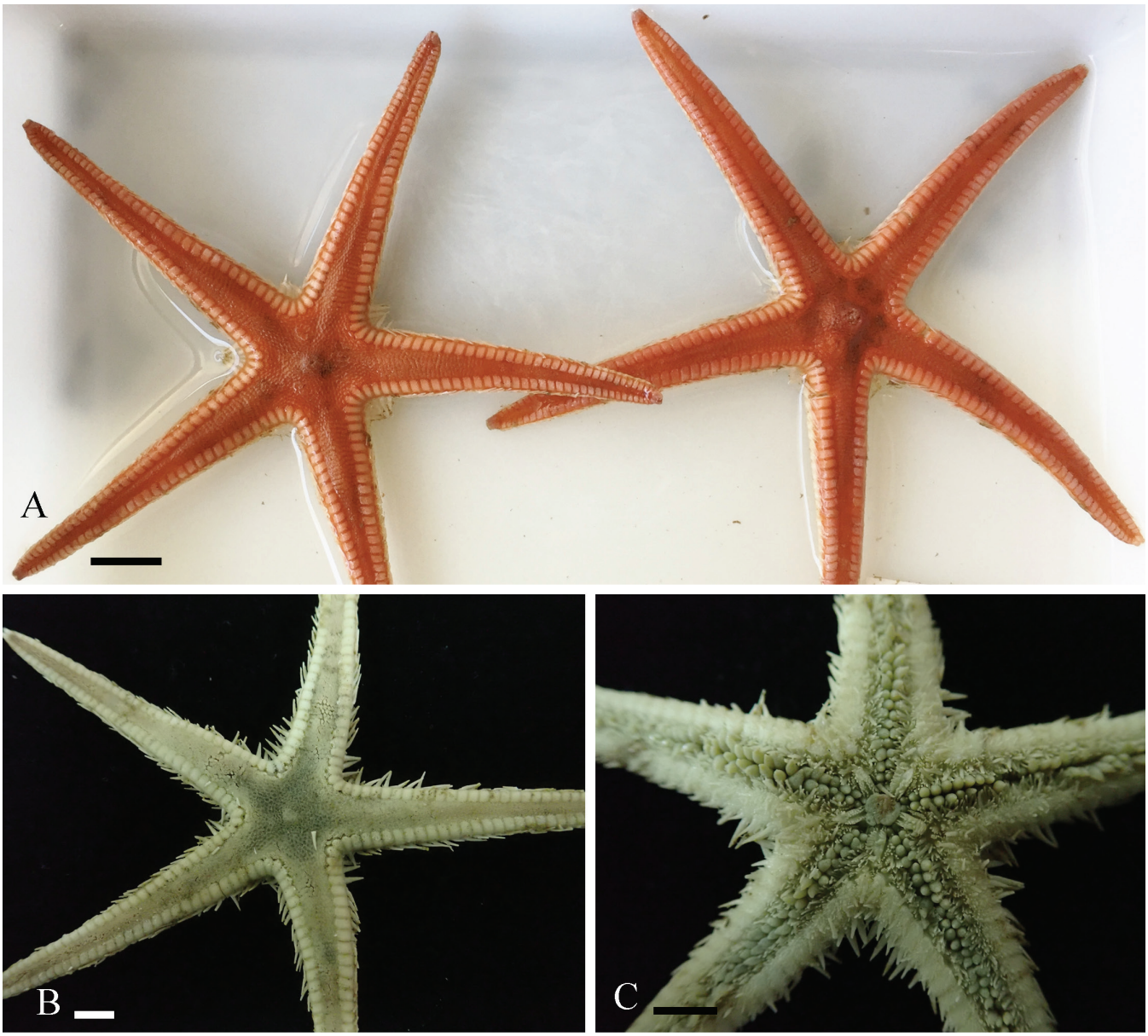


Fig. 17. *Astropecten timorensis* (RCO.ECH.2695). A, live specimens, abactinal view; B, C, specimen ethanol-preserved. B, prominent upper, larger inferomarginal spines border the rays. Spine on the disc is a detached marginal spine; C, inferomarginal spines decreasing in size actinally. Pointed tube feet are biserial. Scale bars: A = 10 mm; B, C = 5 mm.

outer part of each plate (except for the first superomarginal where they are reduced or absent) are similar in length to the finer fasciolar spinules between plates (Fig. 18D). Slender spines occur in a single series on the outer, distal edge of inferomarginals (Fig. 18B–D); they are about 1.5 mm long proximally, tend to decrease in length distally and are accompanied actinally by two shorter, subequal spines. Actinal plates number only two, or at most three, on either side of the interradius.

**Remarks.** Based on Döderlein's monograph for the genus *Astropecten* (Döderlein, 1917) a number of characters, namely: single actinal plate series of only two or three plates, narrow superomarginal profile, single large inferomarginal spine, superomarginals spinose (except the first), and Indo-Pacific geographical province, indicate that the SJADES specimens belong to the "*scoparius*" group with the closest taxon being *Astropecten scoparius* itself (Müller & Troschel, 1842). However, an epiproctal cone is lacking and the inferomarginal spines are much more robust in *A. scoparius* which, additionally, is a shallow temperate species. An epiproctal cone is not uncommon for the genus but often this is just a low conical protuberance and in some cases it may be retractable or transitory. Relatively few *Astropecten* species have a well-developed, long, cylindrical epiproctal cone—possibly a permanent rather than transitory structure—and they are all deep-water species, as is the present unresolved taxon with its distinct epiproctal cone.

### ***Astropecten* sp. 2**
(Fig. 19A, B)

**Material examined.** 1 dry specimen (ZRC.ECH.1282) R:r = 18.5:5.5 mm (R:r ratio = 3.36), 1 dry specimen (ZRC.ECH.1281) R:r = 13.8:3.8 mm (R:r ratio = 3.6), Stn. CP25, Sunda Strait, south of Panaitan Island, 06°50.554′S


Fig. 18. *Astropecten* sp. 1 (ZRC.ECH.1379). A–C, live specimen; D, specimen ethanol-preserved and dried. A, abactinal surface with central epiproctal cone on disc; B, disc and arm bases with transversely aligned paxillae, epiproctal cone and slender inferomarginal spines (arrow); C, actinal surface showing biserial, pointed tube feet; D, abactinal base of arm and part of disc showing transverse alignment of paxillae on arms, epiproctal cone covered with small paxillae, inferomarginal spines (arrowhead) and short superomarginal spines (arrow). Scale bars: A, C = 5 mm; B, D = 2 mm.

105°10.564′E (mid-point of beam trawl), 27th March 2018, depth = 876–937 m. Substrate: gravel and biogenic debris.

**Description.** Small 5-rayed sea star with narrow triangular arms tapering evenly to a pointed extremity (Fig. 19A, B). Superomarginal plates have rounded margins when viewed from above (Fig. 19A). Paxillae, low and rounded or rounded/conical, bear 4–7 spinose spinules and have papular spaces between them, except along mid-radial lines where 3–4 irregular rows of paxillae are fused together at their bases giving a whiter appearance in preserved, dried specimens (Fig. 19A). Terminal plates form a fused apical, rounded structure that has a short, robust apical spine and a midline proximal groove (Fig. 19A). Marginal plate armament difficult to quantify because of abrasion in the beam trawl but the proximal superomarginals at least bear one sometimes two very short, spinose conical spines and the inferomarginals bear at least two short, narrow spines. Furrow spines number up to five.

***Astropecten* sp. 3**
(Fig. 19C)

**Material examined.** 1 dry specimen (ZRC.ECH.1606) R:r = 21:6 mm (R:r ratio = 3.5), Stn. CP45, Indian Ocean, south of Pameungpeuk, 07°47.410′S 107°43.360′E (mid-point of beam trawl), 1st April 2018, depth = 851–684 m. Substrate: mud with small pieces of wood.

**Description.** Small 5-rayed sea star with narrow tapering arms, the taper becoming slightly convex towards their extremity (Fig. 19C). Paxillae each have a crowning circlet of 4–8 rod-like spinelets and sometimes a central, vertically direct one. Superomarginals and the spaces separating them are covered with fine spinules. There is an upper, vertically directed spine on each superomarginal plate (Fig. 19C), the size diminishing distally along the series, but many spines are missing due to abrasion in the beam trawl. Inferomarginal plates have a covering of fine spinules and each plate is

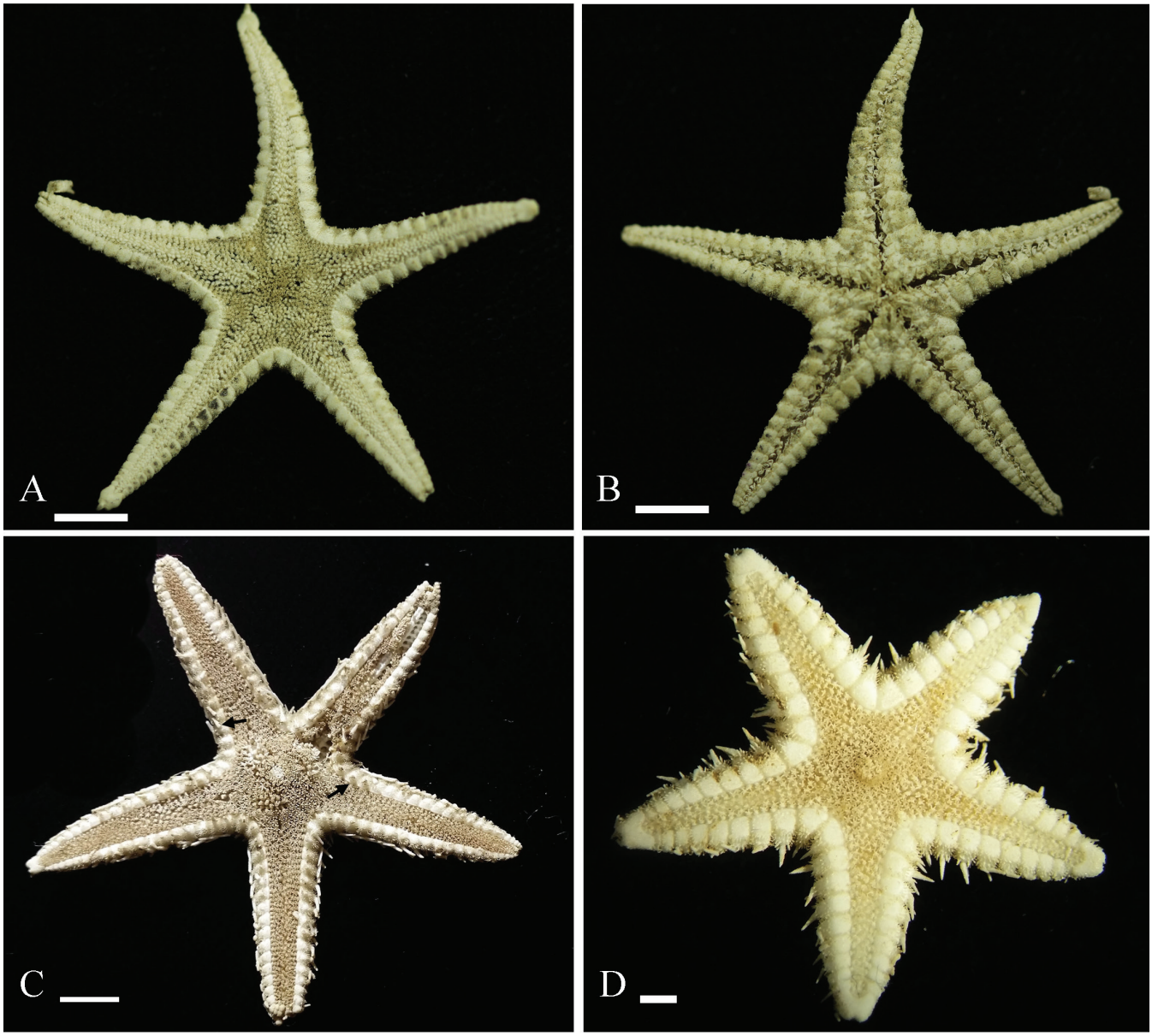


Fig. 19. A, B, *Astropecten* sp. 2 (ZRC.ECH.1282) ethanol-preserved and dried. A, abactinal view; B, actinal view; C, *Astropecten* sp. 3 (ZRC.ECH.1606) ethanol-preserved and dried, arrows indicate vertically directed superomarginal spines; D, *Astropecten* sp. 4 (ZRC. ECH.1590) ethanol-preserved and dried. Broad superomarginal plates bear spinules but lack spines which occur only on inferomarginals. Scale bars: A–C = 5 mm; D = 1 mm.

armed with two lateral, vertically aligned spines of similar size. Furrow spines of two distinct sizes number 2–3, as do the subambulacral spines.

### *Astropecten* sp. 4

(Fig. 19D)

**Material examined.** 1 dry specimen (ZRC.ECH.1590) R:r = 7:2.5 mm (R:r ratio = 2.8), Stn. CP34, Indian Ocean, south of Tg. Boyongkareuceng, 07°44.519′S 107°39.232′E (mid-point of beam trawl), 29th March 2018, depth = 243–234 m. Substrate: gravel with pieces of wood.

**Description.** Small 5-rayed sea star with short tapering arms, the taper becoming slightly convex towards the arm extremity (Fig. 19D). Abactinal paxillae are crowned with 4–6 thorny spinules. Prominent superomarginal plates account for almost two thirds of the ray width at the base of the ray (Fig. 19D); they are covered with thorny spinules but lack spines. Inferomarginal plates are likewise covered with thorny spinules that increase in size towards the lateral margin where they are accompanied by one or two large thorny spines. 2–4 furrow spines.

### *Dipsacaster* Alcock, 1893

### *Dipsacaster fisheri* Lane & Vimono, 2020

**Material examined.** 1 wet specimen (ZRC.ECH.1301) R:r = 58:26 mm (R:r ratio = 2.23), 1 small dry specimen (ZRC.ECH.1599) R:r = 27:13 mm (R:r ratio = 2.08), 2 wet specimens (RCO.ECH.3333) R:r = 61:25.3 mm (R:r ratio = 2.41) & (RCO.ECH.3332) R:r = 52.8:22.9 mm (R:r ratio = 2.31), Stn. CP07, Sunda Strait between Tabuan Island and

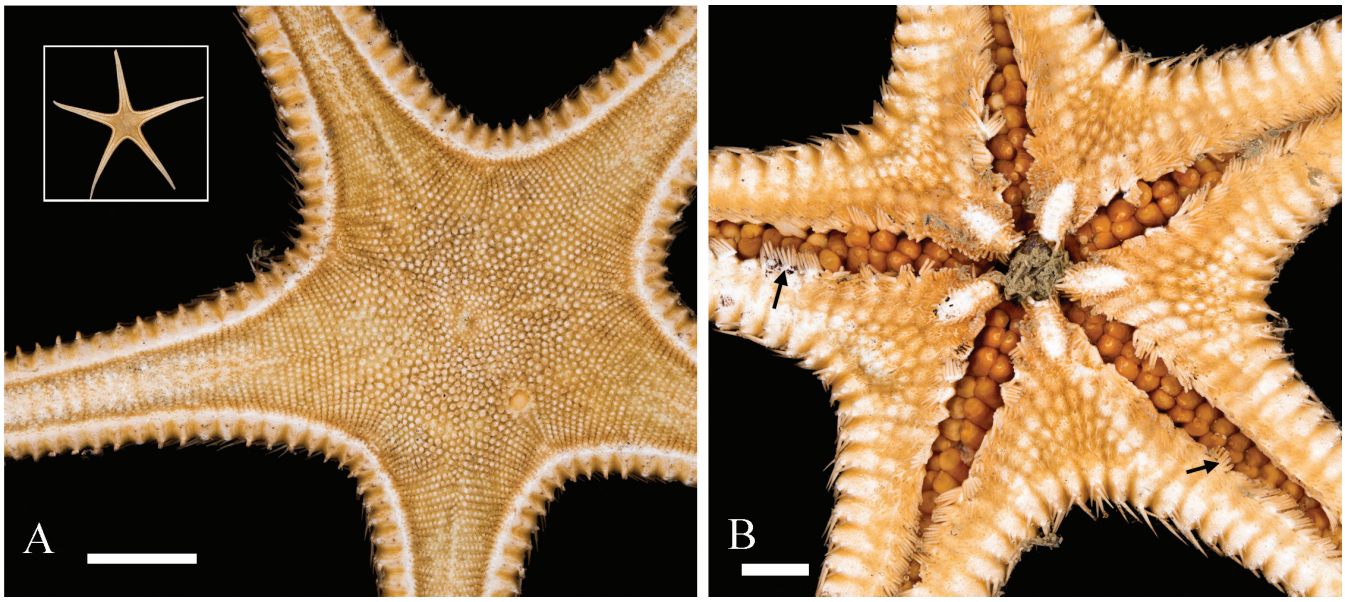


Fig. 20. *Persephonaster roulei*, live specimen (ZRC.ECH.1310). A, abactinal view of disc and proximal region of arms (whole sea star pictured in inset). Paxillae aligned in transverse rows on basal region of arms, short conical spines project laterally from superomarginals; B, actinal view of disc and proximal arms showing inferomarginal plate spination and comb-rows of furrow spines (arrows). Scale bars: A = 20 mm; B = 10 mm.

Sumatra, 05°44.798′S 104°51.606′E (mid-point of beam trawl), 25th March 2018, depth = 379–409 m. Substrate: coarse sand, gravel, rubble and wood.

**Description.** Stellate 5-rayed sea star with short, tapering bluntly rounded arms. Abactinal paxillae arranged in obliquely transverse chevrons on the arms. Inferomarginal plates project beyond superomarginals giving a spinose margin to the arms. Broad superomarginal plates number 19–20 in larger mature specimens. Their width to length ratio initially deceases peripherally along the arm but then increases before declining again near the arm apex. Actinal plate spine clusters comprise short, clavate, flat-topped spines with small spinules around and below them. Furrow spines number 6–8 and mouth plate spines number 4–5. A full description of this recently described species is given in Lane & Vimono (2020).

### *Persephonaster* Wood-Mason & Alcock, 1891

### *Persephonaster roulei* Koehler, 1909
(Fig. 20A, B)

**Material examined.** 1 wet specimen (ZRC.ECH.1311) R:r = 235:40 mm (R;r ratio = 5.88), Stn. CP23, Sunda Strait, south of Panaitan Island, 06°46.331′S 105°08.799′E (mid-point of beam trawl), 27th March 2018, depth = 559–571 m. Substrate: gravel with some mud; 1 wet specimen (ZRC.ECH.1310) R:r = 189:35 mm (R:r ratio = 5.4), Stn. CP 25, Sunda Strait, south of Panaitan Island, 06°50.554′S 105°10.564′E (mid-point of beam trawl), 27th March 2018, depth = 876–937 m. Substrate: gravel and biogenic debris; 1 wet specimen (ZRC.ECH.1302) R:r = 177:29 mm (R:r ratio = 6.1), Stn. CP22, Sunda Strait, south of Panaitan Island, 06°46.954′S 105°07.340′E (mid-point of beam trawl), 27th March 2018, depth = 864–870 m. Substrate: mud; 1 wet specimen (ZCR. ECH.1374) R:r = 115:26 mm (R:r ratio = 4.42; R and R:r values are estimates as arms are missing their extremities), Stn. CP33, Indian Ocean, south of Tg. Boyongkareuceng, 07°43.084′S 107°36.897′E (mid-point of beam trawl), 29th March 2018, depth = 525–312 m. Substrate: coarse sand and mud.

**Description.** Large sea star with long arms tapering to pointed extremities (Fig. 20A, inset). For intact specimens the R:r ratio ranges from 5.4 to 6.1. Abactinal paxillae, crowned with numerous spinelets (18–26 counted), are irregularly arranged on the disc but on the arms, at least basally, they are aligned in regular, transverse, chevron-like rows (Fig. 20A). Superomarginals are wider than long basally and maintain this shape as they diminish in size towards the arm tip. Superomarginals generally have 2–3 short conical spines along a transverse ridge, with either the central or outer being larger or both being equal in size (many spines lost however, as a consequence of abrasion in the trawl). Inferomarginal plates typically bear a pair of long spines at the distal outer edge and below that a transverse row of up to four small spines. Superomarginals are covered in fine, blunt spinules whereas inferomarginals are covered in short conical spines. Actinal plates covered in clusters of fleshy, tissue-covered spinules; some of these clusters possess a central spine. Furrow spines comprise a comb-like array of six or seven spines united by membrane at the base and tube feet are biserial (Fig. 20B).

**Remarks.** This species is readily separated from closely related forms such as *Persephonaster cingulatus* (Fisher, 1906) and the subspecies *Persephonaster cingulatus multicinctus* Fisher, 1913, by the spination of superomarginal plates (spines more conical and robust in *P. roulei*).

**Distribution.** An astropectinid species known only from the Indian Ocean (Clark, 1989), the present records add another locality off south Java and the adjacent Sunda Strait to its known range within this ocean basin.

### *Persephonaster suluensis* Fisher, 1913
(Fig. 21A–F)

**Material examined.** 1 wet specimen (RCO.ECH 2713) R:r = 131:30.9 mm (R:r ratio = 4.2), Stn. CP 34, Indian Ocean (South of Tg. Boyongkareuceng), 07°44.519′S 107°39.232′E (mid-point of beam trawl), 29th March 2018, depth = 243–234 m. Substrate: gravel with pieces of wood; 1 wet specimen (RCO.ECH.2703) R:r = 104.4:20.2 (R:r ratio = 5.2), Stn. CP35, Indian Ocean (South of Tg. Boyongkareuceng), 07°47.679′S 107°42.190′E (mid-point of beam trawl), 29th March 2018, depth = 603–686 m. Substrate: rock, mud and clay; 5 dry specimens: (ZRC.ECH.1600) R:r = 140:27 mm (R:r = 5.19), (ZRC.ECH.1601) R:r = 137:26 mm (R:r ratio = 5.27), (ZRC.ECH.1602) R:r = 133:23 mm (R:r ratio = 5.78), (ZRC.ECH.1603) R:r = 110:21 mm (R:r ratio = 5.24), (ZRC.ECH.1604) R:r = 63:13 mm (R:r ratio = 4.85), Stn. CP50, Indian Ocean, Pelabuhanratu Bay, 07°03.542′S 106°26.504′E (mid-point of beam trawl), 2nd April 2018, depth = 383–425 m. Substrate: mud.

**Description.** 5-rayed sea star with long, broad arms gradually tapering to fine pointed extremities (Fig. 21A). Paxillated abactinal surface bordered by conspicuous margin of superomarginal plates (Fig. 21A–D). Arm paxillae are regularly spaced and aligned in oblique chevrons (Fig. 21B, C), except for the distal mid-radial line where they are smaller and more irregular. Disc paxillae, except for outer interradial regions, are irregularly arranged and become more packed towards the disc centre (Fig. 21C). Paxillae crowned with 10–12 spinelets.

Superomarginal plates number 46–49 (38 for the smallest individual); they are small and almost triangular interradially (Fig. 21B, C), increasing in width and becoming rectilinear along the basal part of the arm. Interradial superomarginals have a distinct, centrally aligned transverse ridge, more noticeable when the plates are denuded; for more distal superomarginals this transverse ridge is much lower, only noticeable for denuded plates, and shifts towards the distal edge of the plate. Each superomarginal has a single, short prominent spine (Fig. 21C, D), these forming a series at the outer edge of the arm. Spines are reduced in length for the interradial pair of superomarginals (Fig. 21C) but, in common with more distal superomarginals, often bear one or two tiny accessory spines adjacent to and adradial to the primary one. Superomarginals are covered with evenly spaced, finely pointed, thorn-like spinelets (Fig. 21D).

Inferomarginal plates have up to four long spines transversely aligned on their outer edge, in addition to a covering of shorter spines and spinelets (Fig. 21E, F). Actinal plates armed with fine spinelets, with some also possessing a larger central spine. Adambulacral plates with a series of 6–7 furrow spines (Fig. 21F). Oral plates have a large pair of slightly flattened, cylindrical, bluntly pointed spines. Two rows of tube feet (Fig. 21E, F). No pedicellariae.

**Distribution.** Known previously from the Sulu Sea only (Fisher, 1913a), the present locality record off southern Java is a first for Indonesian Seas and extends the range for this species to the Indian Ocean.

### *Plutonaster* Sladen, 1889

### *Plutonaster* sp.
(Fig. 22A–D)

**Material examined.** 1 wet specimen (ZRC.ECH.1313) R:r = 91:26 mm (R:r ratio = 3.5), Stn. CP33, Indian Ocean, south of Tg. Boyangkareuceng, 07°43.084′S 107°36.897′E (mid-point of beam trawl), 29th March 2018, depth = 525–312 m. Substrate: coarse sand and mud.

**Description.** Stellate sea star with broad marginal plates and pointed tube feet in a double row. Arms taper gradually but the distal part is parallel-sided and rounded at the tip (Fig. 22A). Paxillated abactinal plates extend all the way to the arm tip. Paxillae at the sides of the arms aligned in oblique transverse series; medially along the arms and on the disc they are more irregularly packed. A large madreporic area, obscured but identifiable by paxillae that are larger and crowned with more robust spinelets than other paxillae, is discernable in one of the interradii, midway between marginal plates and disc centre (Fig. 22C). Superomarginal plates, numbering 30 or 31, form a distinct border and are about twice as wide as long in the interradial arc; they then decrease in width distally, becoming almost square three quarters of the way along the arm radius; for the outer quarter they increase in width, compensating for the narrowing abactinal width, thus giving the arm parallel sides distally before narrowing again to form the rounded arm tip (Fig. 22A). Inferomarginal plates project laterally by one quarter to one third beyond the width of the superomarginals interradially, the extent of projection declining gradually toward the arm tip (Fig. 22A, C). Superomarginals densely covered with rounded granules and edged with fine spinules but there are no spines (Fig. 22C). Inferomarginals similarly adorned with granules and spinules plus two, sometimes unequal, short spines and a cluster of very short conical spinelets on their actinolateral border (Fig. 22D). Actinal plates densely covered with short, blunt spinules. Each adambulacral plate bears numerous spines actinally and up to nine furrow spines.

**Remarks.** This sea star has a combination of features which mark it out as belonging to the genus *Plutonaster*, i.e., superomarginals devoid of spines (for most species), actinolateral spines on the inferomarginal plates and a madreporite obscured by enlarged paxillae. There are some similarities with the southwest Pacific *Plutonaster complexus* H.E.S. Clark & D.G. McKnight, 2000 (spineless superomarginals covered in granules, similar number of furrow spines) but the overall shape is quite different, the latter having more tapered, pointed arms. There are also similarities with the unillustrated account of the Chilean,

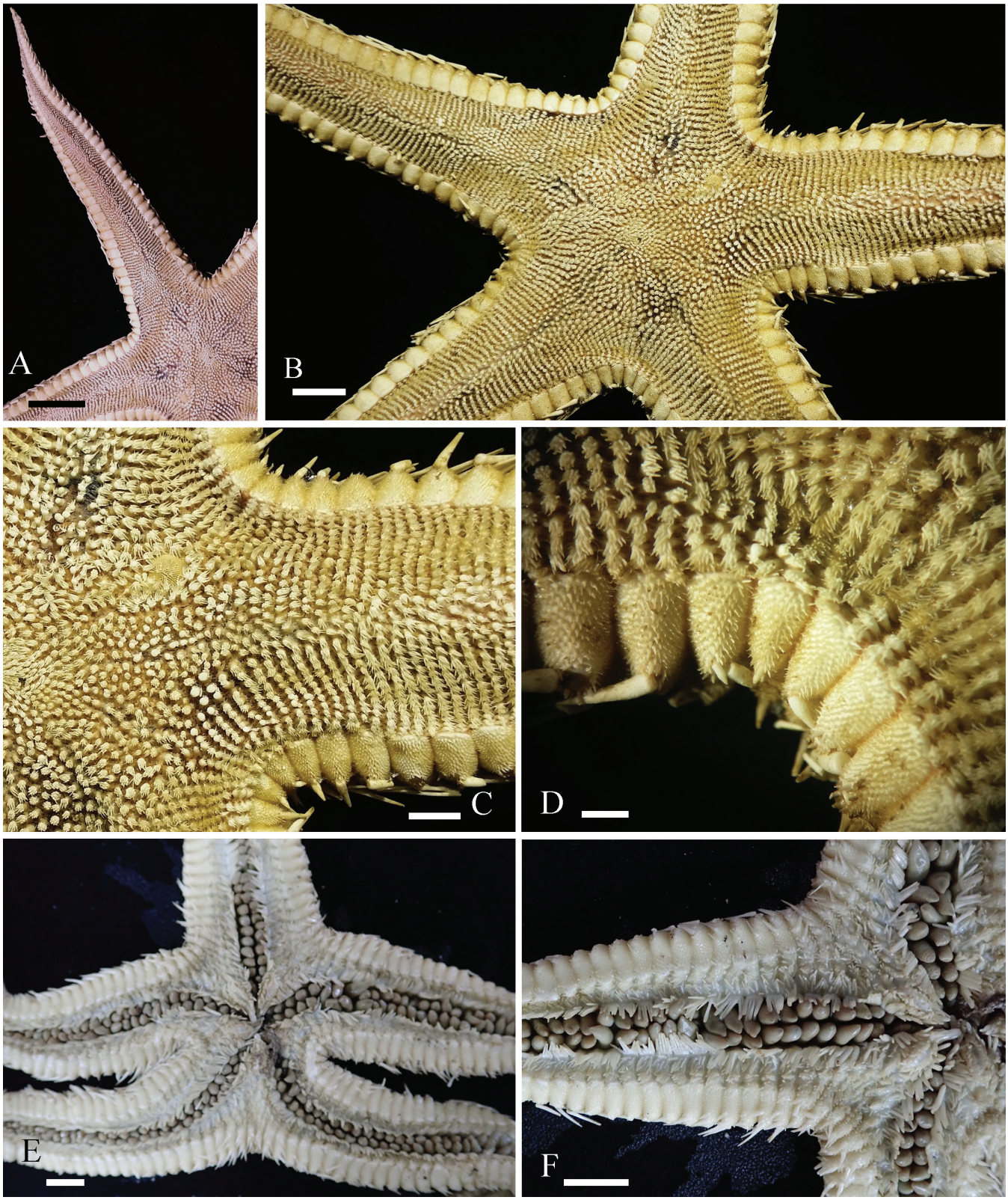


Fig. 21. *Persephonaster suluensis*. A–D, ethanol-preserved and dried specimen (ZRC.ECH.1600). A, abactinal arm-disc segment of sea star; B, C, abactinal view of disc/proximal arm area. Paxillae at sides of arms aligned in transverse chevrons; D, superomarginals each with a lateral spine, smaller accessory spines and a dense covering of spinelets; E, F, ethanol-preserved specimen (RCO.ECH.2713) showing transversely aligned inferomarginal spines, comb-rows of furrow spines and biserial, pointed tube feet. Scale bars: A = 20 mm; B, E, F = 10 mm; C = 5 mm; D = 2 mm.

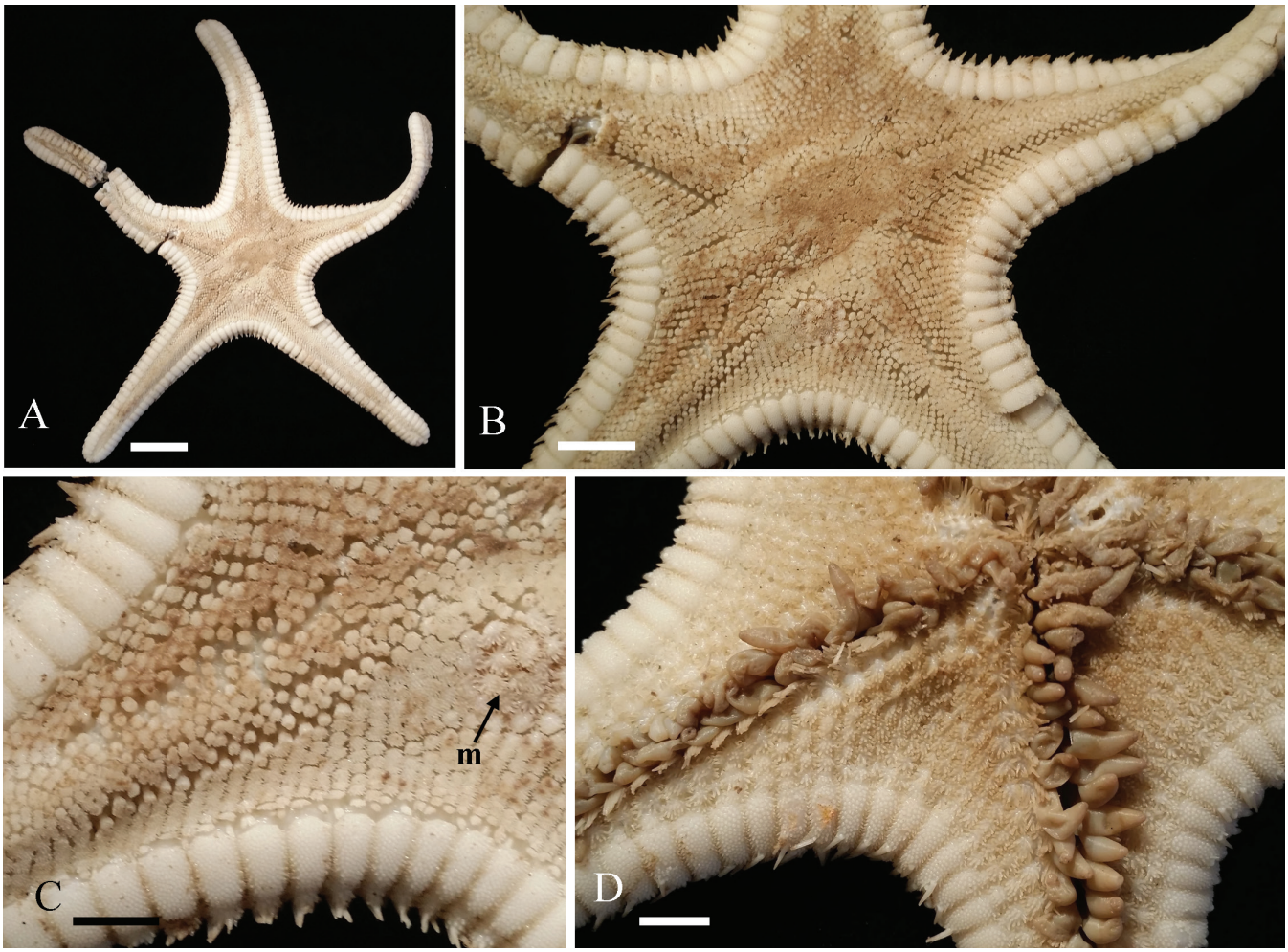


Fig. 22. *Plutonaster* sp. (ZRC.ECH.1313) ethanol-preserved. A, abactinal view of whole sea star with gradually tapering, round-ended arms; B, paxillated abactinal surface bordered by broad superomaginal plates and inferomarginals that protrude beyond the superomarginals; C, abactinal base of arm. Superomarginals lack spines but are densely adorned with granules and fine spinules. m = madreporic area obscured by enlarged paxillae; D, actinal and inferomarginal plates bear fine spinules and the latter also bear prominent spines. Scale bars: A = 20 mm; B = 10 mm; C, D = 5 mm.

southeast Pacific species, *Plutonaster sirius* A.H. Clark, 1917, i.e., paxillae at sides of arms aligned in transverse rows; more irregularly arranged on the disc centre and medial band along the arm. However, this taxon has only a single actinolateral spine and has fewer furrow spines per adambulacral plate. Thus the SJADES specimen does not closely match any of the 13 currently recognised valid species and can be identified to genus only.

### *Psilaster* Sladen, 1885

### *Psilaster gotoi* Fisher, 1913
(Fig. 23A–D)

**Material examined.** 1 wet specimen (ZRC.ECH.1594) R:r = 23:6 mm (R:r ratio = 3.8), Stn. CP12, Sunda Strait, southeast of Tabuan Island, 05°52.490′S 104°56.604′E (mid-point of beam trawl), 25th March 2018, depth = 615–698 m. Substrate: muddy.

**Description.** Stellate sea star with five short arms, wide at the base and tapering to pointed extremities (Fig. 23A, C). Interradial arcs acute or slightly rounded depending on relative disposition of the arms. Paxillate abactinal surface flat and slightly below the level of the marginals. The paxillar zone dominates the arm upper surface, accounting for about two thirds of the width at the arm base (Fig. 23B). Paxillae aligned in distinct, slightly oblique transverse rows along the outer parts of arms and interradii, less so midradially along the arms and centrally on the disc (Fig. 23B) and are surmounted by up to 11–12 or more rod-like spinelets, occasionally as many as 19 or 20, all of similar size. Prominent epiproctal cone at the disc centre, ca. 3 mm long and 2 mm wide at its base, is densely covered with small paxillae (Fig. 23A, B). Small oval madreporite, closer to marginal plates than the disc centre, is partly concealed by close-set paxillae. Terminal plate is notched on its proximal border and bears the remnants of distally projecting spines, one median and one on either side. Superomarginal plates (SMP) number 24 and viewed from above are rounded and narrow, being only slightly wider than long. SMPs and inferomarginal plates (IMP) form a high lateral edge that is not vertical but slopes inwards slightly such that the lateral aspect of the marginals is visible from above (Fig. 23A, B). At the base of the ray, SMPs and IMPs are of equal height but distally not only does the combined height diminish but the IMPs

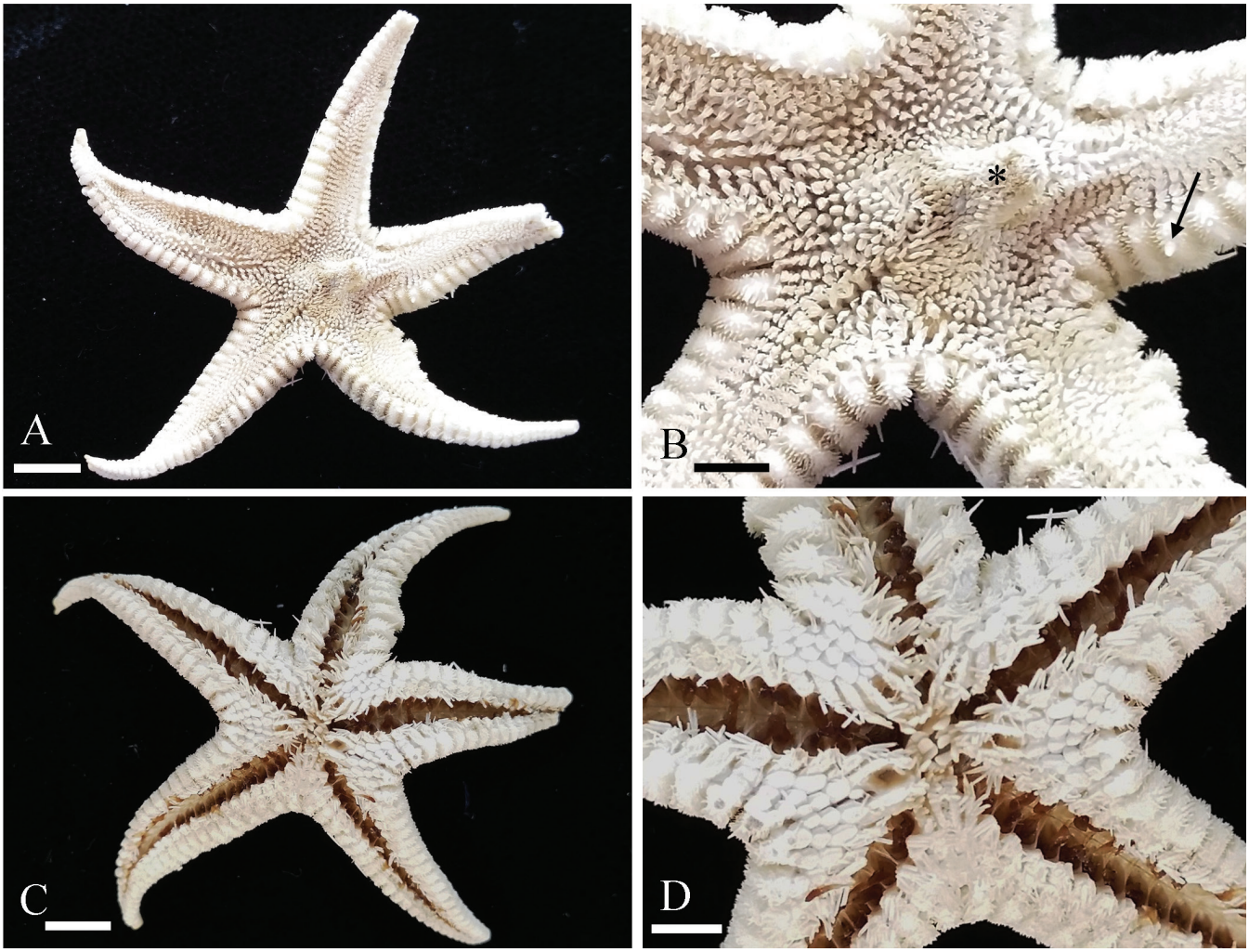


Fig. 23. *Psilaster gotoi*, ethanol-preserved specimen (ZRC.ECH.1594). A, abactinal surface, whole sea star; B, abactinal disc and arm bases. Paxillae on arms in slightly oblique transverse rows, superomarginals with short conical spine (arrow), a prominent epiproctal cone (asterisk) and a dense covering of fine spinelets; C, actinal surface, whole sea star; D, actinal surface, disc and arm bases. Scale bars: A–C = 5 mm; D = 2 mm.

become relatively less high than SMPs. SMPs are densely covered with fine spinelets and bear a short conical spine projecting upwards from the outer edge. IMPs are densely covered with spinelets that become squamulate actinally and the plates each bear a pair of ambital spines, the lower one being longer of the two and proximally longer than their distal counterparts.

Actinal plates comprise three rows (Fig. 23D). The plates in the first series extend for approximately three quarters of the arm length but become very narrow distal to the third or fourth inferomarginal; the second series extends only as far as the second superomarginal and the third only as far as the first. There is a small, unpaired oval plate near the mouth, adjacent to the first actinal plate of the primary series on each side plus a pair of small plates representing the trace of a fourth row. Actinal plates possess spinelets that narrow near their base. Where these are abraded away it is revealed that actinal plates of outer rows overlap their counterparts on inner rows. Furrow spines number 7–8 aligned in a row along a U-shaped furrow margin, alongside bunched subadambulacral spinelets that are difficult to count accurately. Mouth plate armament includes four prominent, round-ended, spatulate oral spines that are slightly curved downwards. No pedicellariae. Conical, blunt-ended tube feet are biserial (Fig. 23D).

**Remarks.** This specimen closely matches the preliminary description for *Psilaster gotoi* (Fisher, 1913a) and the more complete account in Fisher's subsequent monograph on Philippine sea stars (Fisher, 1919b). The only significant difference being the relative lengths of upper and lower ambital spines for inferomarginal plates. The lower spine is longer than the upper one for the SJADES specimen whereas the reverse was reported for Philippine material (Fisher, 1919b).

**Distribution.** This species was previously known from three specimens dredged in or near the type locality in the Philippines (Fisher, 1913a, 1919b) and from records north of Sumbawa (Jangoux et al., 1989). The present locality, bordering the Indian Ocean, represents a range extension for this taxon.

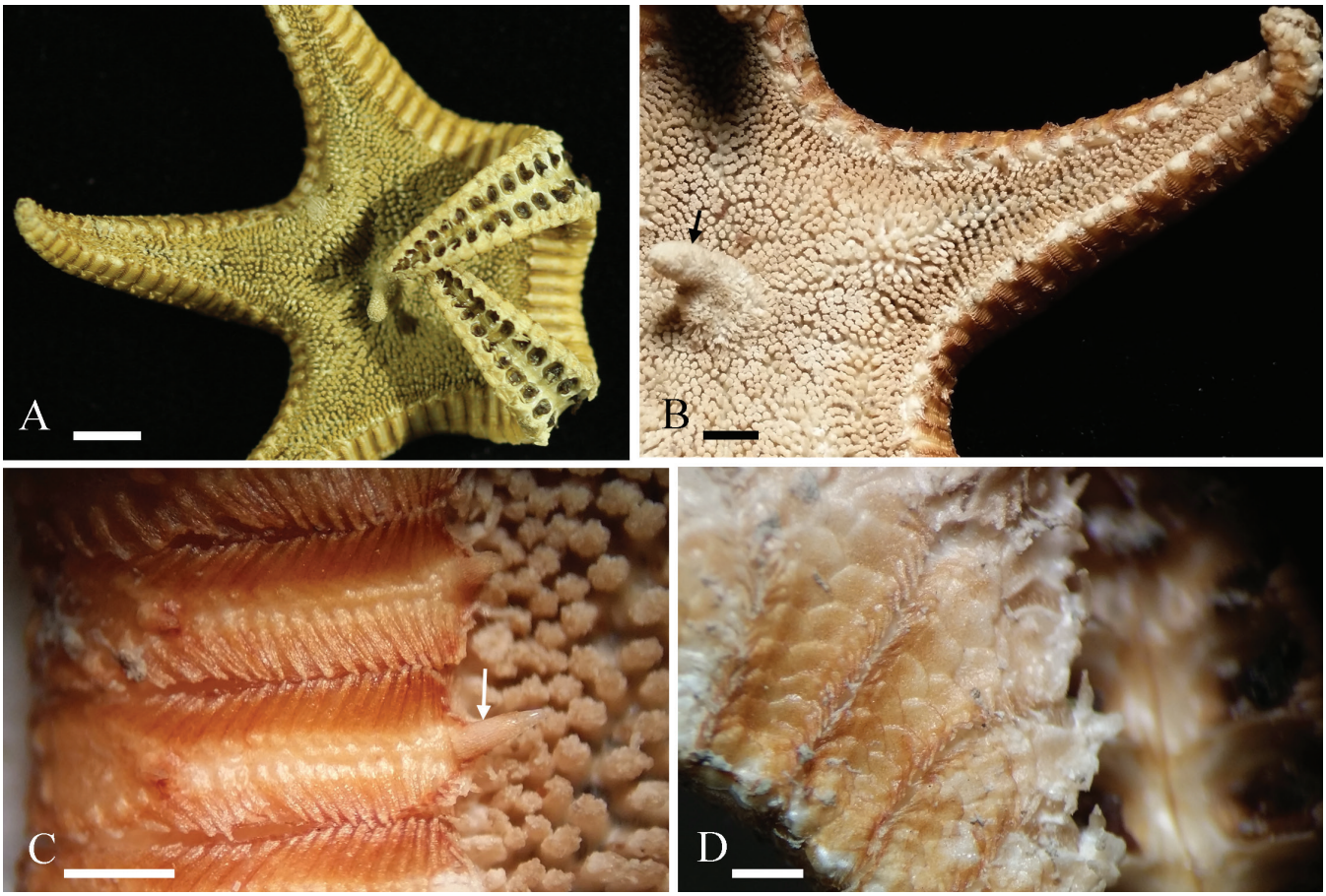


Fig. 24. *Ctenodiscus caudatus*. A, ethanol-preserved and dried (ZRC.ECH.1270), abactinal view; B–D, ethanol-preserved (ZRC.ECH.1596). B, abactinal surface of arm and part of disc. Arrow indicates epiproctal cone; C, superomarginal plates bear an upwardly directed spine (arrow) and are fringed proximally and distally by vertical rows of membrane-embedded fasciolar spinelets; D, actinal view of interradius showing imbricating actinal plates. Scale bars: A = 5 mm; B = 2 mm; C, D = 1 mm.

**Family Ctenodiscidae Sladen, 1889**

***Ctenodiscus* Müller & Troschel, 1842**

***Ctenodiscus caudatus* Döderlein, 1921**
(Fig. 24A–D)

**Material examined.** 2 wet specimens (ZRC.ECH.1595) R:r = 25:9 mm (R:r ratio = 2.78) & 25:8 mm (R:r ratio = 3.13), Stn. CP23, Sunda Strait, south of Panaitan Island, 06°46.331′S 105°08.799′E (mid-point of beam trawl), 27th March 2018, depth = 559–571 m. Substrate: gravel with some mud; 1 dry specimen (ZRC.ECH.1270) R:r = 29:9 mm (R:r ratio = 3.22), 2 wet specimens (ZRC.ECH.1596) R:r = 25:9 mm (R:r ratio = 2.78) & 19:6 mm (R:r ratio = 3.17), Stn. CP27, Indian Ocean, east of Tinjil Island, 06°58.781′S 105°53.554′E (mid-point of beam trawl), 28th March 2018, depth = 481–557 m. Substrate: gravel; 1 wet specimen (ZRC.ECH.1598) R:r 34:11 mm (R:r ratio = 3.09), CP28, Indian Ocean, east of Tinjil Island, 06°59.986′S 105°54.924′E (mid-point of beam trawl), 28th March 2018, depth = 957–1022 m. Substrate: coarse sand and some mud; individual found on arm of brisingid asteroid.

**Description.** 5-rayed asteroid with arms tapering markedly to pointed extremities (Fig. 24A). Abactinal paxillae closely packed, each crowned with 5–8 spinelets, occasionally up to 12 spinelets on the largest paxillae or as few as three or four on smaller ones close to marginal plates or on the narrow, elongated epiproctal cone (Fig. 24A, B). Superomarginal plates number 17–19 from interradius to arm tip, each bearing a prominent, upwardly-directed, pointed spine on the upper edge (Fig. 24C). Superomarginals are fringed proximally and distally by a vertical row of up to 16 fasciolar spinelets embedded in a membrane partition (Fig. 24C); spinelet fringe count decreases towards the arm tip. Membrane partitions include base of upwardly directed spine and, in the opposite direction, are continuous with similar cribiform-like partitions along the inferomarginals and either side of paired rows of imbricating actinal plates (Fig. 24D). These fasciolar fringes partition grooves leading from the abactinal surface towards the ambulacral furrow. Inferomarginals bear a single spine that, in the interradius is very short and centrally located, but further along the arm it shifts to an upper distal position and becomes slightly longer. Podia pointed.

**Remarks.** The SJADES specimens can be identified as *C. caudatus* and distinguished from three of the other four species of *Ctenodiscus* (*C. australis* Loven, in Lütken, 1871; *C. crispatus* Bruzelius, 1805; *C. procurator* Sladen, 1889) based on smaller paxillae with fewer spinelets (4–10) and a longer, more slender epiproctal cone in the former, and the

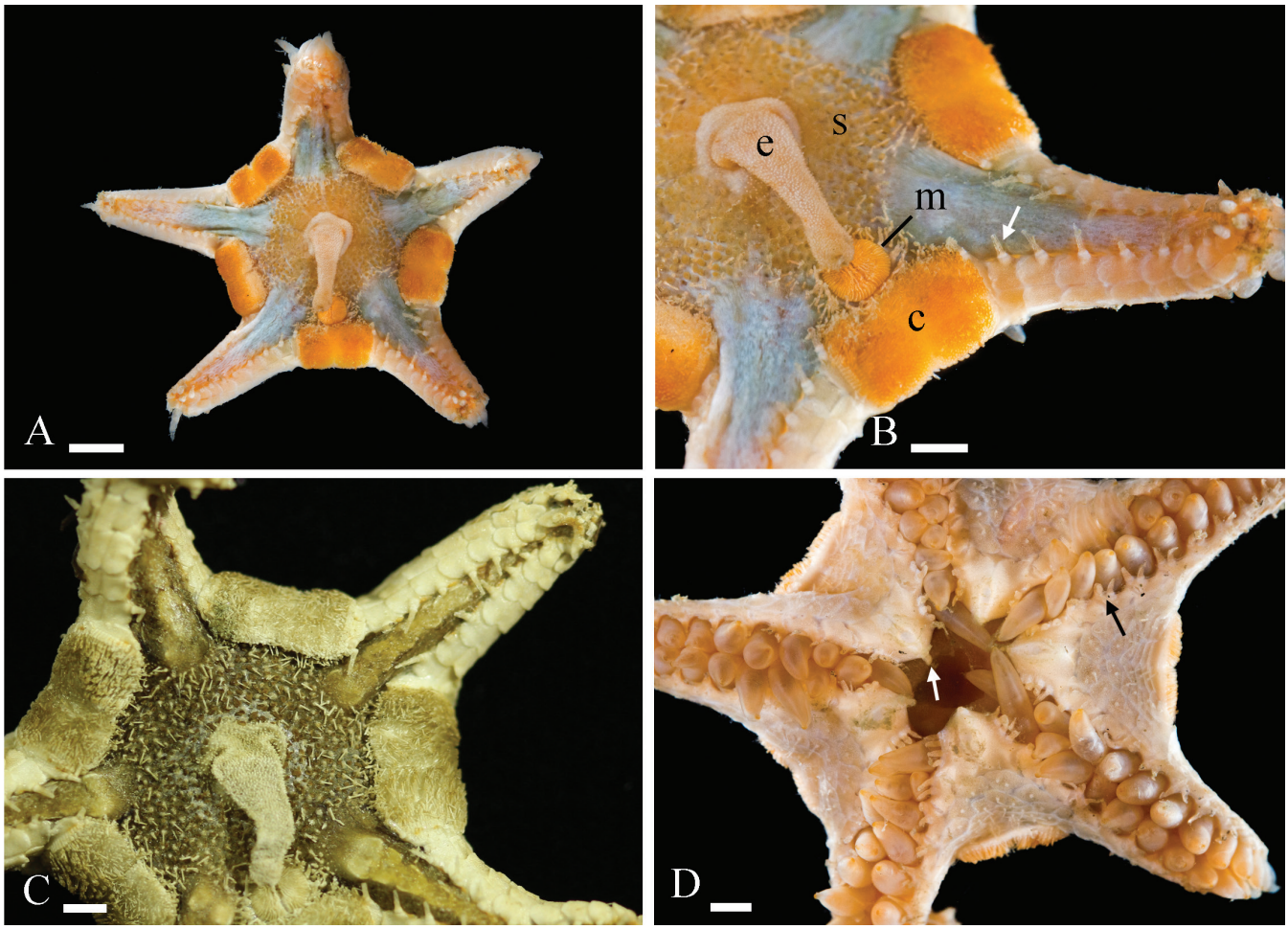


Fig. 25. *Porcellanaster ceruleus* (ZRC.ECH.1280). A, B, D, live specimen; C, specimen ethanol-preserved and dried. A, abactinal view of whole sea star; B, closer abactinal view of disc and arm showing spinose central area of disc (s), cribiform organ (c), epiproctal cone (e), madreporite (m) and upwardly directed spines (arrow) on overlapping superomarginal plates; C, abactinal microstructure of dried specimen; D, actinal view of disc and arms showing biserial, pointed tube feet, paired adambulacral spines (black arrow) and single dental spine (white arrow). Scale bars: A = 5 mm; B–D = 2 mm.

fact that these latter three species are found in other ocean realms at high latitudes. The remaining species, *C. orientalis* Fisher, 1913, is, like *C. caudatus*, tropical West Pacific in distribution but is distinguishable from the latter by longer, more slender arms with a larger R:r ratio (3.7) and a higher number of superomarginal plates (26–27).

**Distribution.** Previously collected from Eastern Indonesia only, during the 1889–1990 Dutch Siboga Expedition (Döderlein, 1921), the present records extend the range of this species further west into the Indian Ocean realm of the Archipelago.

### Family Porcellanasteridae Sladen, 1883

### *Porcellanaster* Wyville Thomson, 1878

### *Porcellanaster ceruleus* Wyville Thomson, 1878
(Fig. 25A–D)

**Synonymy.** *Caulaster pedunculatus* Perrier, 1882; *Porcellanaster caulifer* Sladen, 1883; *P. tuberosus* Sladen, 1883; *P. sladeni* Perrier, 1885; *P. granulosus* Perrier, 1885; *P. inermis* Perrier, 1885; *P. eremicus* Sladen, 1889; *Albatrossia semimarginalis* Ludwig, 1905; *A. richardi* Koehler 1909; *Caulaster dubius*, Koehler, 1909; *Porcellanaster fragilis* Döderlein, 1921.

**Material examined.** 1 dry specimen (ZRC.ECH.1280) R:r = 21:10 mm (R:r ratio = 2.1), Stn. CP14, Sunda Strait, 06°08.281′S 104°49.982′E (mid-point of beam trawl), 26th March 2018, depth = 1528–1539 m. Substrate: mud, sunken wood and plastic debris; 1 wet specimen (ZRC.ECH.1276) R:r = 29:14 mm (R:r ratio = 2.07), Stn. CP25, Sunda Strait, south of Panaitan Island, 06°50.554′S 105°10.564′E (mid-point of beam trawl), 27th March 2018, depth = 876–937 m. Substrate: gravel, biogenic debris.

**Description.** Stellate, 5-rayed sea star with triangular arms (Fig. 25A, B). Arm radius twice that of the disc. Broad, almost straight interbrachial arc formed by a pair of enlarged, slightly protruding tumescent marginal plates with a groove between them, these forming the cribiform organ (Fig. 25A–C). The disc has a pentagonal-shaped area of fine spinelets that extends furthest interradially to abut the cribiform organs (Fig. 25A–C). Disc centre bears an elongated epiproctal cone that tapers from the base, is then tubular; in an

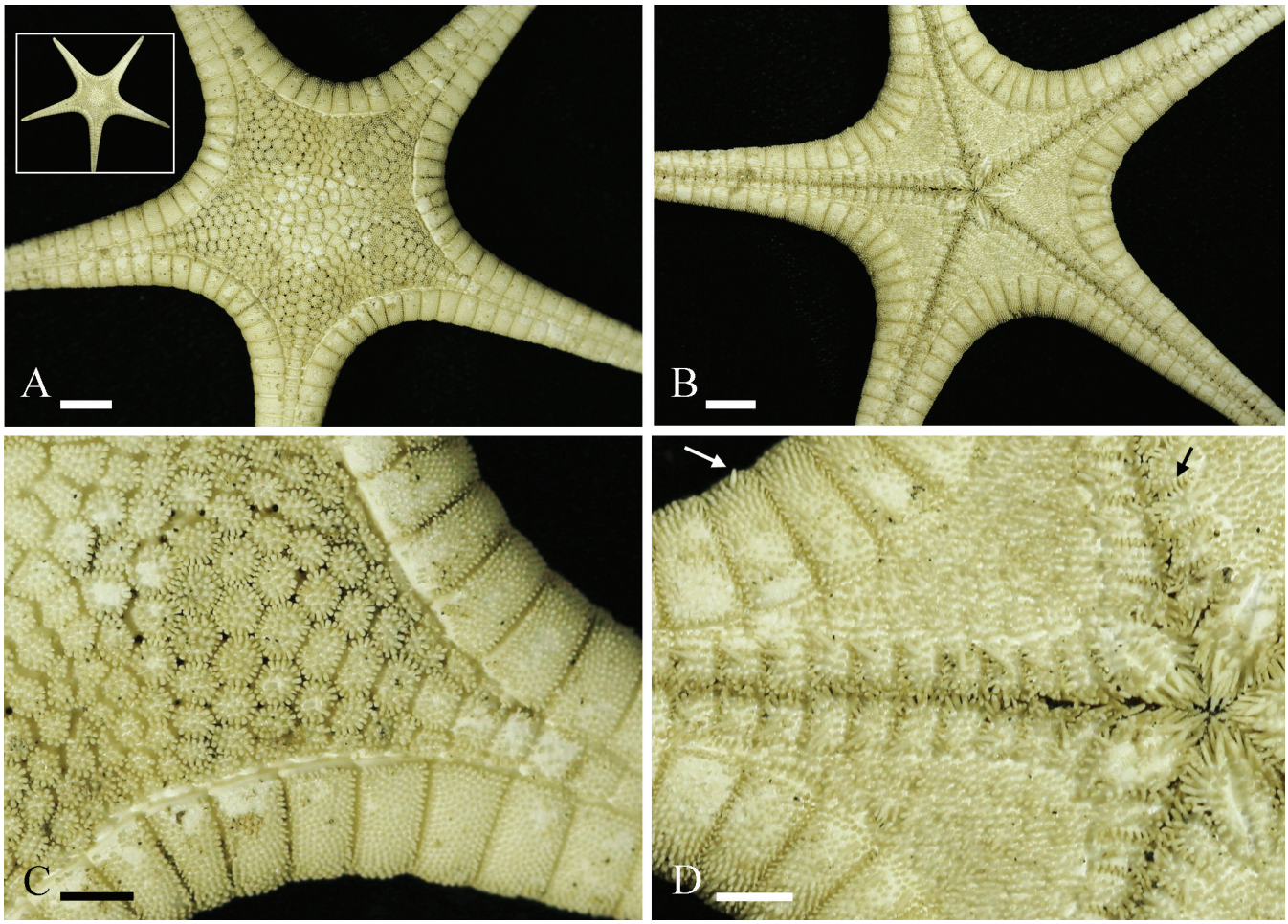


Fig. 26. *Paragonaster ctenipes*, ethanol-preserved and dried (ZRC.ECH.1272). A, abactinal view, disc and arm bases (inset, whole sea star); B, actinal view, disc and arm bases; C, abactinal base of arm. Carinal row of subhexagonal abactinal plates extend all the way to arm tip and become square distally. Superomarginals densely and evenly covered with rounded, rod-like granules; D, actinal disc and arm base. Inferomarginals densely covered with elongated granules with the occasional one being an elongated short spine (white arrow). Adambulacral plate armament includes transverse rows of spinules (black arrow). Scale bars: A, B = 5 mm; C, D = 2 mm.

extended state it approximates in length to the disc diameter (Fig. 25A–C). The large, rounded madreporite is located interradially adjacent to a cribiform organ (Fig. 25B, C). The porcellaneous supero- and inferomarginal plates are more or less in register but rounded margins of superomarginals proximally overlap adjacent plates. Superomarginals each bear a stout spine on the upper, inner edge (Fig. 25B, C). Terminal plate deeply notched abactinally; terminal plate spine ornamentation is not clear, possibly due to damage of arm tips in the trawl. Adambulacral plates each bear a pair of short conical spines, the adoral one being slightly longer (Fig. 25D). Mouth plate jaw bears a single, robust dental spine. Biserial tube feet pointed (Fig. 25D). Colour in life is striking and characteristic—abactinal areas of arms are pale blue while cribiform organs, spinose area on the disc and madreporite are orange (Fig. 25A, B).

**Distribution.** *Porcellanaster ceruleus* is a widely distributed and very distinctive deep-sea species in the world's oceans but records from Indonesian seas are few. The Challenger Expedition found it off the Aru Islands (Sladen, 1883) and it has recently been recorded in the South China Sea (Zhang et al., 2018). In addition to the present Sunda Strait sites, other known Indian Ocean locations range from the Gulf of Oman to the Andaman Sea (Wood-Mason & Alcock, 1891a, b; Koehler, 1909). The collection depth (876–937 m) for one of the Sunda Strait specimens is the first time this species has been found shallower than 1,000 m.

## Family Pseudarchasteridae Sladen, 1889

### *Paragonaster* Sladen, 1889

### *Paragonaster ctenipes* Sladen, 1889
(Fig. 26A–D)

**Material examined.** 1 dry specimen (ZRC.ECH.1272) R:r = 49:13 mm (R:r ratio = 3.78), Stn. CP37, Indian Ocean, south of Cilacap, 08°07.663′S 109°06.054′E (mid-point of beam trawl), 30th March 2018, depth = 163–166 m. Substrate: fine mud with pieces of small branches.

**Description.** Stellate sea star with narrow, gradually tapering arms (Fig. 26A, inset). Abactinal plates are polygonal centrally and rounded hexagonal elsewhere on the disc (Fig. 26A, C). A median, carinal row of abactinals extends all the way to the tip of the arm separating the opposing

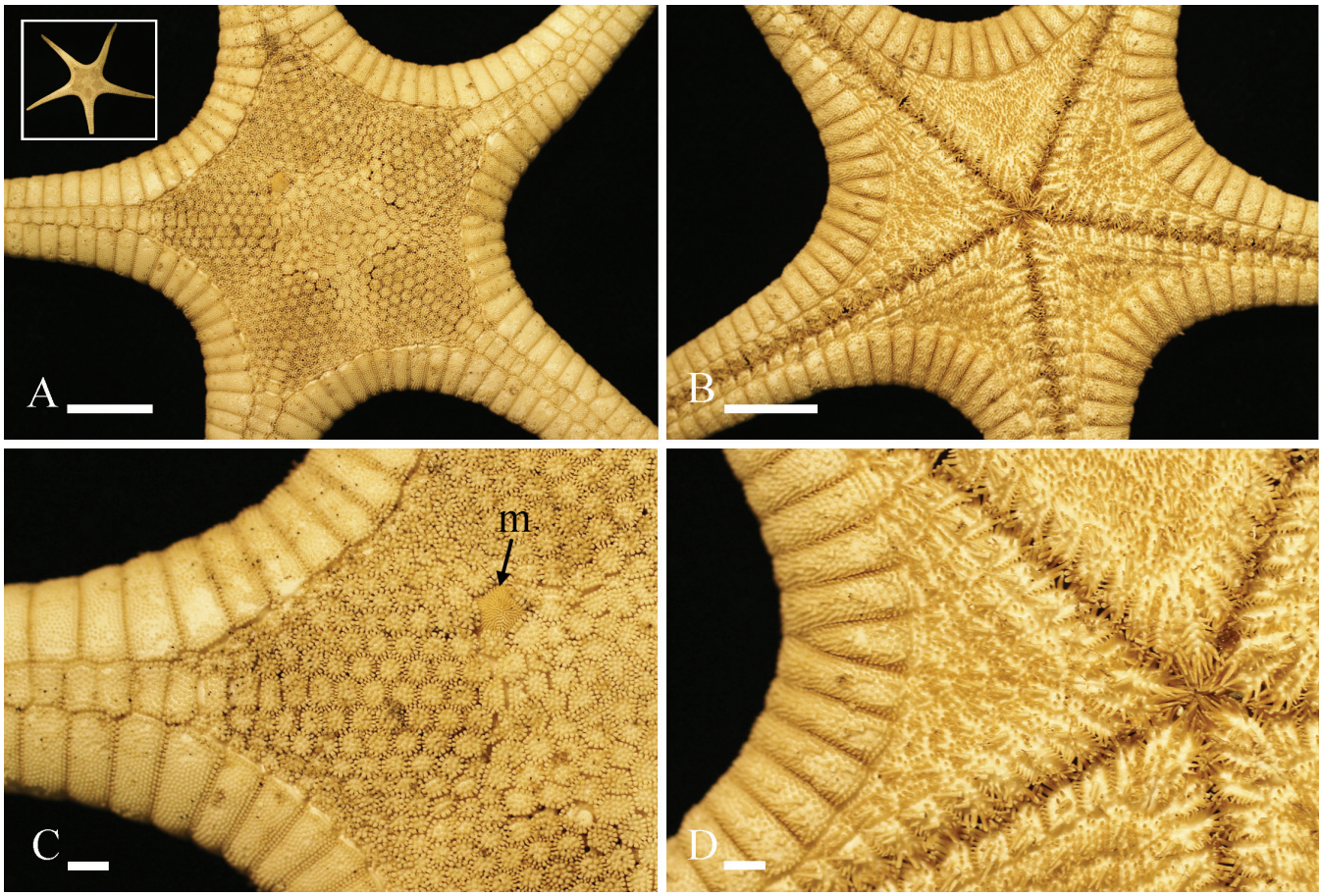


Fig. 27. *Paragonaster ctenipes hypacanthus*, ethanol-preserved and dried (ZRC.ECH.1296). A, abactinal disc and arm bases (inset, whole sea star ); B, actinal disc and arm bases; C, radial row of hexagonal abactinal plates on disc become larger and rectangular or square as the series transitions into the arm. Superomarginals densely covered with granules, m = madreporite; D, actinal view of part of disc. Scale bars: A, B = 10 mm; C, D = 2 mm.

superomarginal plates; on the disc these plates increase slightly in width towards the arm, then change to a square profile as they lead into the arm alongside just three or four increasingly small, adradial abactinals. Further out along the arm the carinal abactinals are variously square or elongated-rectangular plates; they become partially in register with the marginal series with nominally two carinals per marginal (Fig. 26A). Abactinals crowned by dense array of short, round-ended, rod-like granules giving a paxillated appearance (Fig. 26C). Superomarginals are broader than long, tending to become more nearly square in profile towards the arm extremity. Inferomarginals likewise are broader than long, particularly interradially and become more nearly square in profile distally. Superomarginals densely covered in regular arrays of granules that become more elongated actinally and there is a distinct linear series bordering each plate (Fig. 26C). Inferomarginals bear elongated conical granules with some of them becoming short conical spines, particularly on the actinal surface (Fig. 26D). Actinal plates are densely covered with short, blunt spinelets but there are no spines (Fig. 26D). Transverse edges of adambulacral plates bordered by row of short, conical spines that, on each side, grades into a comb row of slightly larger, blunt furrow spines; adambulacrals armoured actinally with one or two longer spines plus a few granule-like spinelets. Densely clustered oral spines and adambulacral furrow spines difficult to count as the ambulacral groove is closed in this preserved singleton specimen.

**Distribution.** With the type locality in the Arafura Sea in eastern Indonesia (Sladen, 1889), the species ranges to the South China Sea off the Philippines (Jangoux, 1981) and, beyond the Indo-Malay Archipelago, to Korea (Shin, 2007) and to the Indian Ocean off west and northwest Australia (Rowe & Gates, 1995). The present specimen off south Java provides an additional Indian Ocean record for this taxon.

***Paragonaster ctenipes hypacanthus* Fisher, 1913**
(Fig. 27A–D)

**Material examined.** 1 dry specimen (ZRC.ECH.1296) R:r = 70:21 mm (R:r ratio = 3.33), Stn. CP37, Indian Ocean, south of Cilacap, 08°07.663′S 109°06.054′E (mid-point of beam trawl), 30th March 2018, depth = 163–166 m. Substrate: fine mud with pieces of small branches; 1 wet specimen (ZRC.ECH.1297) R:r = 76:18 mm (R:r ratio = 4.22), same location, date, and depth.

**Description.** Stellate sea star with long tapering arms (Fig. 27A, inset). Abactinal plates hexagonal on the disc. Radial abactinals extend as a single row separating the superomarginal plates along the whole length of the arm but

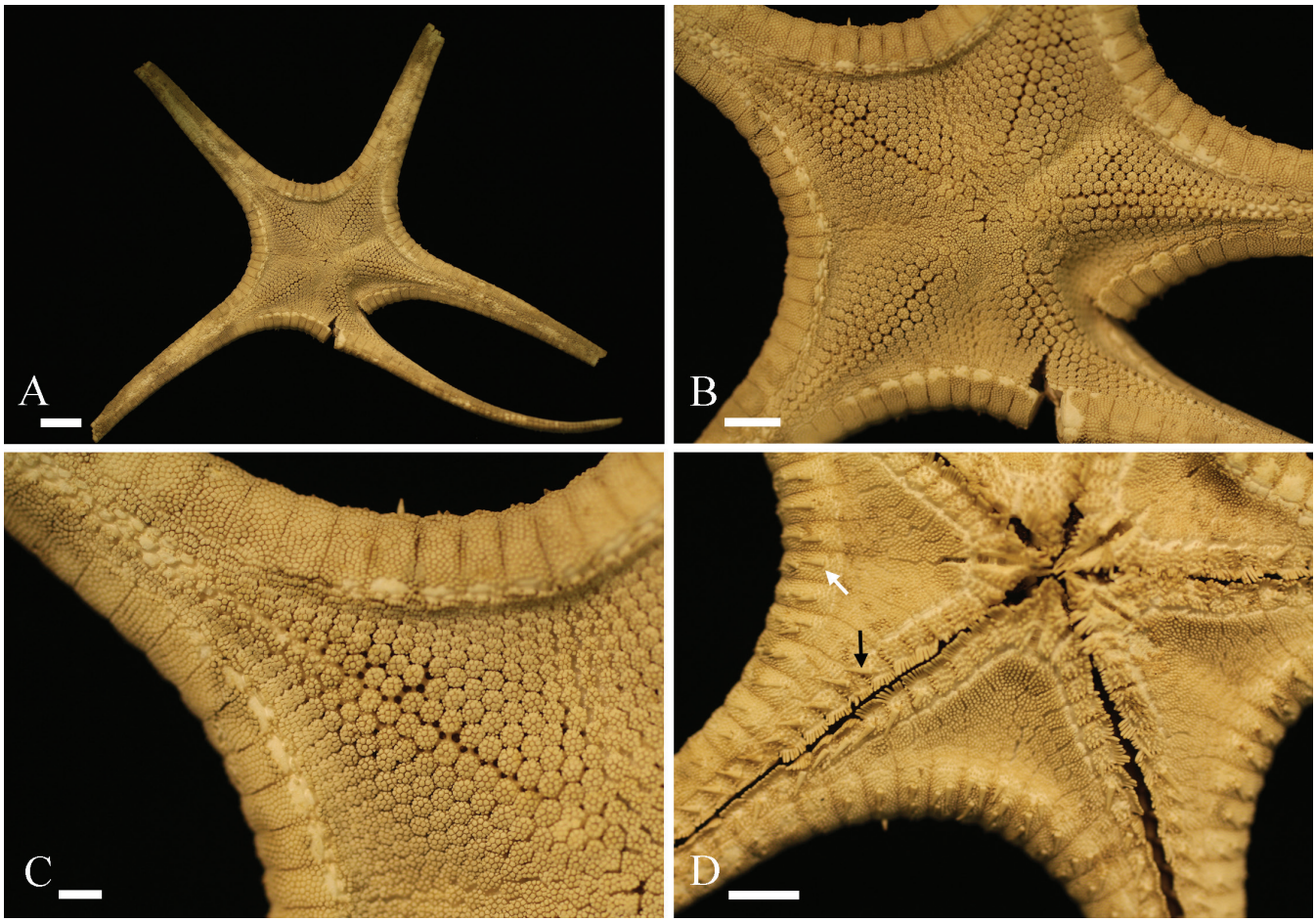


Fig. 28. *Perissogonaster insignis*, ethanol-preserved and dried (ZRC.ECH.1278). A, abactinal view of whole sea star. Arms are narrow but abactinal area extends to arm tips; B, abactinal disc and base of arms. Paxilliform abactinals rounded-hexagonal except at the margins; C, paxilliform abactinals are armoured with arrays of close-fitting granules as are the superomarginal plates; D, actinal disc and arm bases. Proximal inferomarginals bear up to three transversely aligned spines (white arrow). Prominent adambulacral spines (black arrow) first appear at the 6th or 7th plate. Scale bars: A = 10 mm; B, D = 5 mm; C = 2 mm.

the plates markedly increase in size and become rectangular as the series transitions into the arm; along the arm this series becomes more square in profile and is in and out of register with the superomarginals (Fig. 27A, C). Abactinals bear rounded granules centrally and nearly square-section granules peripherally. All but the distal superomarginals are wider than long, particularly those of the interradial arc (ratio approaching 3:1) (Fig. 27A, C). Inferomarginal plates have their greatest width-length ratio (4:1) at the interradial position (Fig. 27B, D). Superomarginals densely covered with rounded granules (Fig. 27C). Inferomarginals densely covered with conical, spine-like granules and a few short spines. Actinal plates bear clusters of spinules and one or more conical spines (Fig. 27D). Adambulacral plates bear 1–3 short spines, a few granule-like spines and a fringing row of spinelets aligned with the larger furrow spines, forming a curved comb row. Furrow spines and densely clustered oral spines are difficult to count as the mouth and ambulacral groove are closed.

**Remarks.** This subspecies of *Paragonaster* is distinguishable from *Paragonaster ctenipes* Sladen, 1889, by a marked increase in carinal plate width as the series enters the arm, broader supero- and inferomarginal plates, and by the presence of actinal plate spines in the former compared with the latter where they are absent.

**Distribution.** This subspecies has been previously recorded from several locations in the Philippines (Fisher, 1913a, 1919b), and the Makassar Strait and Solomon Islands (Mah, 2021). The present record off south Java extends the known range to the Indian Ocean.

### *Perissogonaster* Fisher, 1913

### *Perissogonaster insignis* Fisher, 1913
(Fig. 28A–D)

**Material examined.** 1 dry specimen (ZRC.ECH.1278) R:r = 88:19 mm (R:r ratio = 4.63), Stn. CP35, Indian Ocean, south of Tg. Boyongkareuceng, 07°47.679′S 107°42.190′E (mid-point of beam trawl), 29th March 2018, depth = 603–686 m. Substrate: rocks, mud, clay.

**Description.** Stellate sea star; elongated, gradually tapering rays with narrow abactinal area extending to the arm tips (Fig. 28A). Closely fitting, paxilliform abactinal plates are rounded-hexagonal, except for the ones close to the

superomarginal plates (Fig. 28B, C). Abactinals are regularly arranged, forming a radial alignment and oblique chevrons on the disc and arm bases (Fig. 28B, C) and are armoured with a pavement of closely-fitting hexagonal or pentagonal granules; most of these clusters comprise either a single or pair of flat-topped granules surrounded by a ring of 6 or 8 similar sized ones which themselves are surrounded by a ring of smaller angular granules (Fig. 28C). Superomarginal plates number 54 from interradius to arm tip and are wider than long throughout; they are densely covered in closely fitting hexagonal or polygonal flat-topped ossicles/granules similar in size to those of the abactinals. Inferomarginal plates are also densely covered in ossicles, but these become smaller and more rounded on the undersurface. Inferomarginals bear a transverse series of up to two, sometimes three, conical spines proximally (Fig. 28D), these decreasing in size and number distally until they disappear at half to two thirds along the arm length. Actinal plates are densely covered with short, cylindrical, blunt spinelets. Except for the first 6 or 7, each adambulacral plate bears a stout spine whose length diminishes towards the arm tip (Fig. 28D). Furrow spines are cylindrical and number 6–10, the number tending to increase towards the arm tip.

**Remarks.** Similar to *Paragonaster* but this monospecific taxon is distinguished by the adradial abactinals extending almost half-way along the arms and the close-fitting armament of granules on each abactinal plate.

**Distribution.** Previously known only from the Philippines (Fisher, 1913a, 1919b; Jangoux, 1981), the discovery of a single specimen off south Java is the first record for this monotypic genus in Indonesian seas and extends its range to the Indian Ocean.

### *Pseudarchaster* Sladen, 1889

### *Pseudarchaster pulcher* Ludwig, 1905
(Fig. 29A, B)

**Material examined.** 1 dry specimen (ZRC.ECH.1381) R:r = 11:4 mm (R:r ratio = 2.75), Stn. CP12, Sunda Strait, southeast of Tabuan Island, 05°52.490′S 104°56.604′E (mid-point of beam trawl), 25th March 2018, depth = 615–698 m. Substrate: muddy.

**Description.** Stellate 5-rayed sea star with triangular arms (Fig. 29A, B). Tube feet with suckers. Densely packed abactinal paxillae crowned with 3–20 short, finely spinose, club-shaped spinelets. Superomarginal plates number 10 from interradius to arm tip, are wider than long, and are covered with finely spinose, rounded granules on very short stalks. These are similar in size and appearance to paxillae spinelets. Similar granules on the lateral surface of the inferomarginals grade to smaller conical spinelets on the lower surface of these plates. Granules and spinelets readily abrade away. Terminal plate slightly enlarged and rounded, bearing a pair of short, distally projecting spines, one on either side of the end of the ambulacral furrow, plus a number of smaller spines around their bases (Fig. 29A).

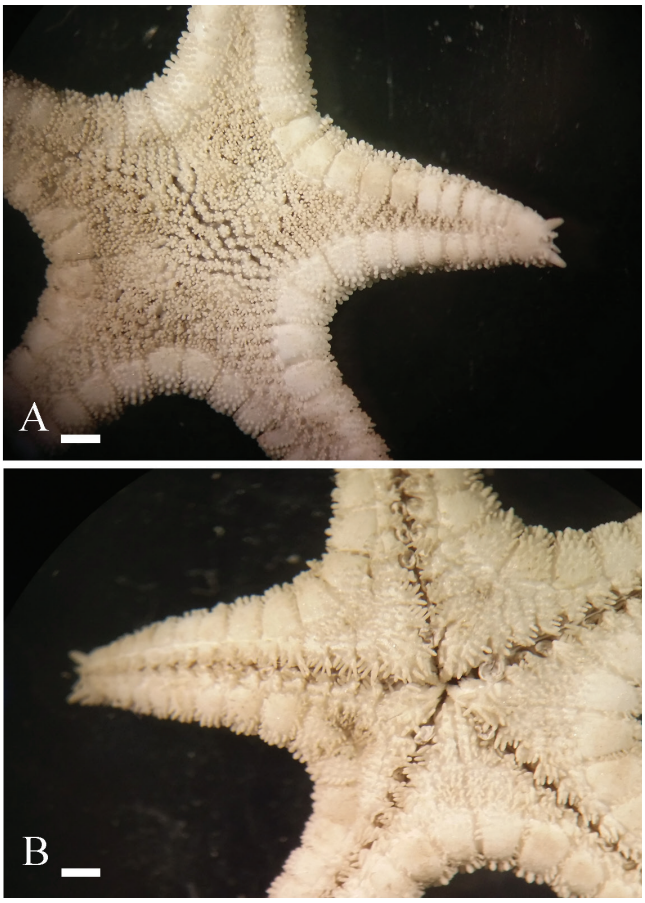


Fig. 29. *Pseudarchaster pulcher*, ethanol-preserved and dried (ZRC.ECH.1381). A, abactinal view; B, actinal view. Scale bars: A, B = 1 mm.

Madreporite is indistinct. Actinal plates have 3–7 very small, spinose spinelets. Furrow spines are spinose and number 6–7 in a curved row.

**Distribution.** Previously known only from the Galapagos and off the west coast of Mexico (Ludwig, 1905), the known range now extends to the Sunda Strait in Indonesia.

## Order Notomyotida

### Family Benthopectinidae Verrill, 1899

### *Benthopecten* Verrill, 1884

### *Benthopecten moluccanus* Fisher, 1913

**Material examined.** 1 wet specimen, (ZRC.ECH.1378) R:r undetermined as distal regions of all arms missing, Stn. CP22, Sunda Strait/Indian Ocean, south of Panaitan Island, 06°46.954′S 105°07.340′E (mid-point of beam trawl), 27th March 2018, depth = 864–870 m. Substrate: mud. Not photographed as specimen is in poor condition.

**Description.** Narrow-armed sea star (arms damaged but R:r at least 8) with small disc. Abactinal plate spines (up to 4 mm long) with distally directed thorns are numerous

Fig. 30. *Benthopecten semisquamatus celebuensis*, ethanol-preserved and dried (ZRC.ECH.1284). Enlarged interradial superomarginals each surmounted by an elongated spine (arrows) more massive than other proximal superomarginal spines. Scale bar = 5 mm.

on the disc and arm bases; more distally on the arms they become much smaller. Superomarginal plates intercalate with inferomarginals and are narrow except for an enlarged interradial superomarginal that extends onto the disc. Interradial superomarginal bears a long, robust spine (up to 9 mm long); the next two proximal superomarginals have two smaller spines each, then the more distal superomarginals each bear a single more robust spine. Inferomarginal spines, numbering one or two per plate, are up to 9 mm long and slightly thorny. Adambulacral plates bear a row of five to eight furrow spines and two to three prominent subambulacral spines.

**Distribution.** Known previously from the Molucca Islands only (Kepulauan Maluku) at depths of 762–795 m (Fisher, 1913b, 1919b), the discovery of this species at similar depths at the southwest edge of the Sunda Strait extends its known distribution range to the Indian Ocean.

### *Benthopecten semisquamatus celebensis* Döderlein, 1921
(Fig. 30)

**Material examined.** 1 dry specimen (ZRC.ECH.1284) R:r = 53:9 mm (R:r ratio = 5.9; all arm tips broken in trawl, R and R:r ratio values would be greater in life), Stn. CP22, Sunda Strait/Indian Ocean, south of Panaitan Island, 06°46.954′S 105°07.340′E (mid-point of beam trawl), 27th March 2018, depth = 864–870 m. Substrate: mud; 1 dry specimen (ZRC.ECH.1283) R:r 20:4 mm (R:r ratio = 5), Stn. CP44, Indian Ocean south of Cilicap, 08°09.934′S 108°37.292′E (mid-point of beam trawl), 31st March 2018, depth = 1013–970 m. Substrate: mud with small pieces of wood.

**Description.** Arms are narrow, evenly tapered and bordered by tumescent marginals raised above the abactinal surface (Fig. 30). Abactinal plates each with a spine or spinelet diminishing in size from disc centre (2–3 mm) to disc periphery (ca. 1 mm), then becoming increasingly small towards the limit of the papular area at superomarginal plate (SMP) 3, and tiny beyond SMP3. No papulae at disc centre. Madreporite located interradially, close to superomarginals. Twelve superomarginal plates longer than wide except for the first and very last ones. The interradial superomarginals (SMP1) at each of the five sharply angled interradii are enlarged and each is surmounted by a single, massive spine which is as long as the basal width of the arm (Fig. 30, arrows); SMP2 spine small and delicate; single spines for SMP 3–5 are enlarged and thorny; SMP spines then progressively diminish in size towards the arm tip. Inferomarginal plates (IMP) bear at least one basolateral thorny spine (length ca. 1 mm) and several other smaller ones basally. Inferomarginal plate 1 is larger than superomarginal plate 1, resulting distally in the inferomarginal and superomarginal series being out of register. The larger specimen, but not the smaller one, possesses, in the interradial actinal areas, one or two comb-like pedicellariae with 5–7 spine-like 'teeth' to each jaw ossicle. Adambulacral spines number 3–4 proximally with one or two subambulacral spines.

**Distribution.** Previously known only from Eastern Indonesia (Flores Sea, Banda Sea area; Döderlein, 1921), the present records, off south Java and the Sunda Strait, are similarly deep at up to 1,000 m or more and extend the known biogeographic range for this subspecies to Indian Ocean waters of Indonesia.

## *Pectinaster* Perrier, 1885

### *Pectinaster mimicus* (Sladen, 1889)
(Fig. 31)

**Synonymy.** *Pontaster mimicus* Sladen, 1889; *Pontaster hispidus* Wood-Mason & Alcock, 1891.

**Material examined.** 1 dry specimen (ZRC.ECH.1285) R:r = 97:14 mm (R:r ratio = 6.93) & 1 wet specimen (ZRC.ECH.1375) R:r = 111:15 mm (R:r ratio = 7.4), CP25, Sunda Strait/Indian Ocean, south of Panaitan Island, 06°50.554′S 105°10.564′E (mid-point of beam trawl), 27th March 2018, depth = 876–937 m. Substrate: gravel and biogenic debris; 1 wet specimen (ZRC.ECH.1377) R:r undetermined as all arms broken, CP22, Sunda Strait/Indian Ocean, south of Panaitan Island, 06°46.954′S 105°07.340′E (mid-point of beam trawl), 27th March 2018, depth = 864–870 m. Substrate: mud; 2 wet specimens (ZRC.ECH.1376) R:r = 103:16 mm (R:r ratio = 6.44) & 108:15 mm (R:r ratio = 7.2), CP23, Sunda Strait/Indian Ocean, south of Panaitan Island, 06°46.331′S 105°08.799′E (mid-point of beam trawl), 27th March 2018, depth = 559–571 m. Substrate: gravel with some mud; 1 wet specimen (ZRC.ECH.1593) R:r = 15:3.5 mm (R:r ratio = 4.29), CP27, Indian Ocean, east of Tinjil Island, 06°58.781′S 105°53.554′E (mid-point of beam trawl), 28th March 2018, depth = 481–557 m. Substrate: gravel.

**Description.** Stellate sea star with a small disc. Rays taper gradually to fine-pointed extremities (Fig. 31, inset). Interbrachial arcs acutely rounded. Abactinal paxillae of mixed sizes on the disc and at the bases of the arms, the

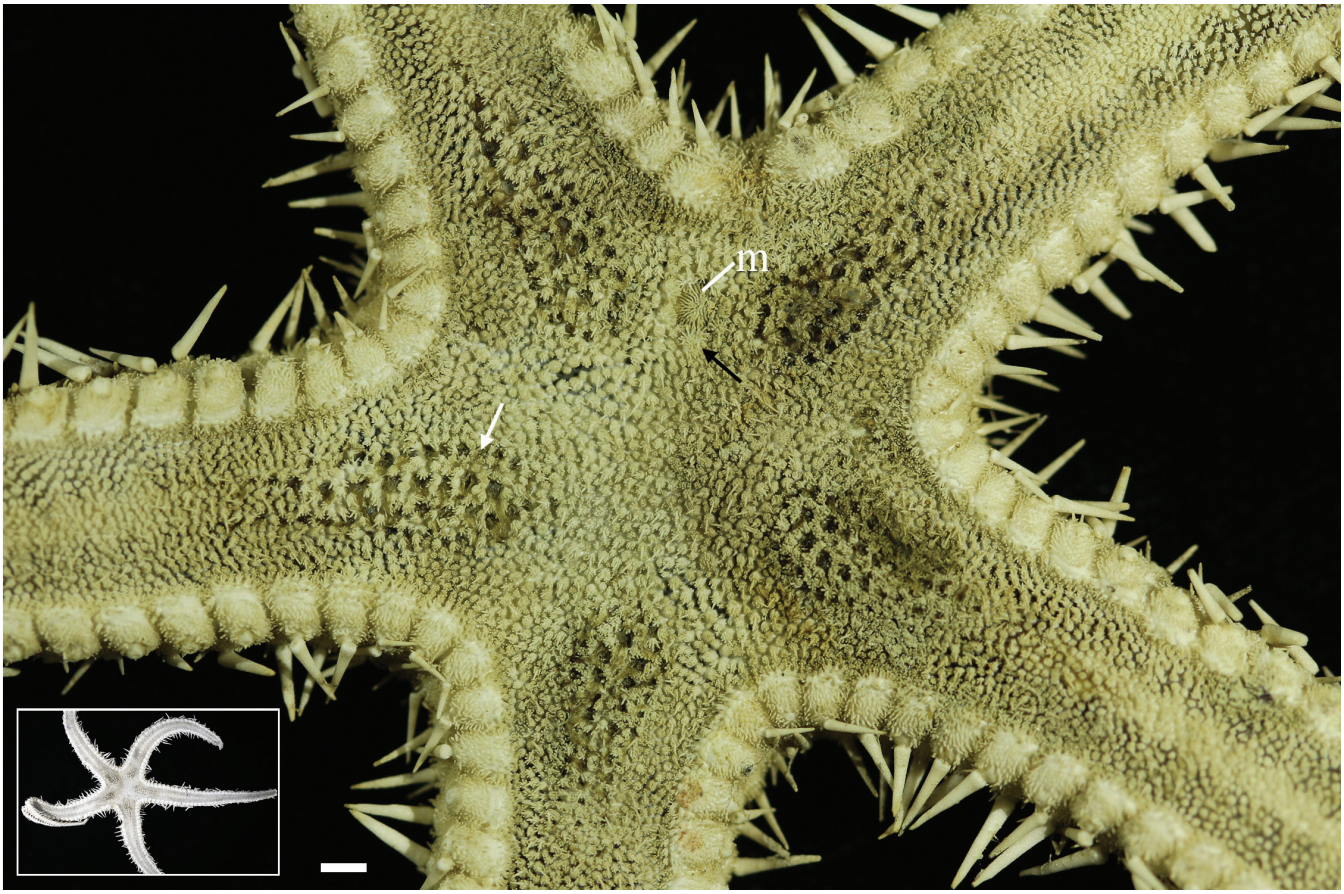


Fig. 31. *Pectinaster mimicus* (ZRC.ECH.1258), ethanol-preserved and dried (inset, whole sea star). Papular rows form a teardrop shaped papularium (white arrow) extending from disc edge into each arm base. A prominent conical spine articulates on a tubercle at the upper, outer edge of each superomarginal. Large paxillae (black arrow) border the madreporite (m). Scale bar = 2 mm.

larger ones having 20 or more crowning spinelets bunched apically. Towards the arm tips paxillae become smaller and have fewer spinelets (as few as four for some). The largest paxillae (up to 27 spinelets) border the madreporite (Fig. 31). Many of the paxillae have an elongated central spinelet up to 0.8 mm long. At the edge of the disc and extending into the base of each ray, four rows of papulae, with 10–12 papulae per row, form a distinct teardrop-shaped papularium (Fig. 31, white arrow). Distal to the papularium, the bases of the mid radial paxillae are more fused together than those either side, giving a lighter, mid-radial band along the arm (Fig. 31). The upper parts of superomarginal plates are rounded and elevated, giving a distinct raised border to the arm. Each superomarginal plate has a robust conical spine articulating on a prominent tubercle at the outer edge of the plate; these become more robust after the 2nd plate then diminish in size for the more distal plates (Fig. 31). The rest of the superomarginal surface is densely covered with short spinules plus the occasional short spine. Inferomarginal plates are slightly out of register with the superomarginals and the suture lines between them are oblique. Inferomarginals each have a large, lateral, conical spine, similar to that of the superomarginals, a smaller secondary spine below that, plus a dense covering of small spinules. Adambulacral plates bear one large conical spine centrally with a fringe of furrow spines (eight or more) around the curved margin of the plate. Mouth plate spines are largest adorally, these blunt spines often being bi-lobed at the tip.

**Distribution.** First described from the Arafura Sea, Eastern Indonesia (Sladen, 1889). Subsequently documented for the Indian Ocean in the Arabian and Laccadive Seas (Clark, 1989) and off south Australia and the Tasman Sea (Mah, 2021). The present records add further Indian Ocean localities to the known distribution range for the taxon.

## Order Velatida

### Family Caymanostellidae Belyaev, 1974

#### *Caymanostella* Belyaev, 1974

#### *Caymanostella* sp.

**Material examined.** 99 *Caymanostella* specimens recovered from sunken woody debris in beam trawls from 13 Stations (CP23, 24, 27, 28, 33, 39, 44, 47, 48, 50, 51, 58, 59) at depths ranging from 383–1,013 m off the south Java coast.

**Description.** Body outline rounded pentagonal, tending to be roughly circular; abactinally convex, actinally flattened. Superomarginal plates and peripheral inferomarginal plates form part of the discoid shape, the edge of which bears an ambital ring of club-shaped spinelets. Abactinal armament granuliform. Full specimen data, images, and a detailed

morphological/population analysis of this material are to be provided in a forthcoming publication.

### Family Pterasteridae

#### *Pteraster* Müller & Troschel, 1842

#### *Pteraster sjadesensis* Lane & Vimono, 2020

**Material examined.** 1 wet specimen (ZRC.ECH.1382) R:r = 15:6 mm (R:r ratio = 2.5), Stn. DW16, Sunda Strait (seamount reef), 06°09.803′S 104°57.976′E (drop point of dredge), 26th March 2018, depth = 103–92 m. Substrate: gravel, sand and some mud.

**Description.** 5-rayed, stellate sea star with triangular, recurved arms. Supradorsal canopy supported by paxillae, single spines and spine clusters. The chamber beneath the supradorsal membrane connects to the exterior via a central osculum embedded with at least 20 vertically oriented spines. Adambulacral plates similar in size along the furrow; each plate bears a transverse row of four small webbed spines linked by membrane to a large actinolateral spine furthest from the furrow; larger spines collectively are embedded in an actinolateral membrane that extends almost to the margins of the arms. Mouth plates each bear ten peripheral spines, the second being slightly longer than the first; the series then diminishing in size distally along the plate edge. Oral spines are webbed together, to their tips, but the webbing is independent for each oral plate. Tube feet aligned biserially. A full description of this recently described species is given in Lane & Vimono (2020).

#### *Pteraster* sp.
(Fig. 32A–D)

**Material examined.** 1 dry specimen (ZRC.ECH.1386) R:r = 12:7 mm (R:r = 1.7), Stn. CP08, Sunda Strait, between Tabuan Island and Sumatra, 05°45.175′S 104°51.395′E (mid-point of beam trawl), 25th March 2018, depth = 425–442 m. Substrate: coarse sand, gravel and rubble.

**Description.** Stellate sea star with very short triangular arms that tend to have convex edges defined by the webbed extremities of the actinolateral spines (Fig. 32A–D). Supradorsal membrane supported by paxillar spines each with a radiating array of up to nine spinelets that have a stellate appearance when the supradorsal membrane is fully inflated (Fig. 32C). Adambulacral plates all similar, not alternating in size; each has a series of six webbed spines, the peripheral ones united in a marginal, actinolateral webbed fringe that extends just beyond the lateral margin of the arms (Fig. 32B, D). Six spines for each oral plate, increasing in size towards the mouth, and with all 12 embedded in a membrane extending across the jaw angle (Fig. 32D). Two rows of tube feet.

## DISCUSSION

A total of 37 species of Asteroidea from 12 families and 24 genera was recovered in benthic trawls from the Indian Ocean south of Java and from the Sunda Strait during the SAJDES 2018 Deep-Sea Expedition. Of these, two taxa, *Dipsacaster fisheri* and *Pteraster sjadesensis* have been newly described (Lane & Vimono, 2020) and a further eight species (i.e., *Henricia arcystata*, *Anthenoides cristatus*, *Iconaster vanuatuensis*, *Nymphaster euryplax*, *Nymphaster moebii*, *Persephonaster suluensis*, *Perissogonaster insignis*, and *Pseudarchaster pulcher*), documented here, are new records for both Indonesian Seas and, except for *N. moebii* and *A. cristatus*, the Indian Ocean. Many of the taxa newly recorded for the Indian Ocean have been recorded elsewhere within the Indo-Malay Archipelago but some have more distant records. In particular the recently described goniasterid, *Iconaster vanuatuensis*, had been recorded previously only from Vanuatu in the southwest Pacific (Mah, 2005), and its discovery in the Indian Ocean off the south coast of Java represents a considerable range extension for the species. A further seven species, namely *Zoroaster microporus*, *Gigantaster weberi*, *Solaster tropicus*, *Psilaster gotoi*, *Benthopecten moluccanus*, *Benthopecten semisquamatus celebensis*, and *Paragonaster ctenipes hypacanthus*, previously known from Indonesia, are newly recorded for the Indian Ocean.

Most asteroid species records were either singletons or a few in number, possibly indicating low population density or rarity, but two species, the goniasterid *Anthenoides cristatus* and the astropectinid *Astropecten timorensis*, were locally abundant at a relatively shallow epipelagic depth zone (163–166 m) close to the Java coastline off Cilacap. The abundance of these sea stars at this locality indicates a significant role in food webs, and for *A. cristatus* the diet possibly includes foraminifera, as reported for this species at similar mesophotic depths off the North Island of New Zealand (Clark & McKnight, 2001). A third species, an as yet undetermined species of *Caymanostella*, was commonly encountered at numerous sites associated with sunken woody debris, a natural seabed substrate that, not unexpectedly, is prevalent given the proximity of deep bathymetry to the forested Javan mainland.

It is notable that in addition to the discovery of new species (Lane & Vimono, 2020), many of the deep-sea species of Asteroidea encountered during this exploratory expedition, some of them large and spectacular, had not been recorded since their original discovery during 19th-century/early 20th-century deep-sea expeditions of more than 100 years ago. These include *Zoroaster microporus*, *Henricia arcystata*, *Solaster tropicus*, *Persephonaster suluensis*, and *Benthopecten moloccanus* from the Albatross Expedition (Fisher, 1913a, b, 1916, 1917); *Gigantaster weberi*, *Astropecten timorensis*, *Benthopecten semisquamatus celebensis*, and *Ctenodiscus caudatus* from the Siboga Expedition (Döderlein, 1917, 1921, 1924); and *Persephonaster roulei* from the Investigator Expedition (Koehler, 1909). This strongly suggests that Indonesian deep seas have much to reveal in terms of

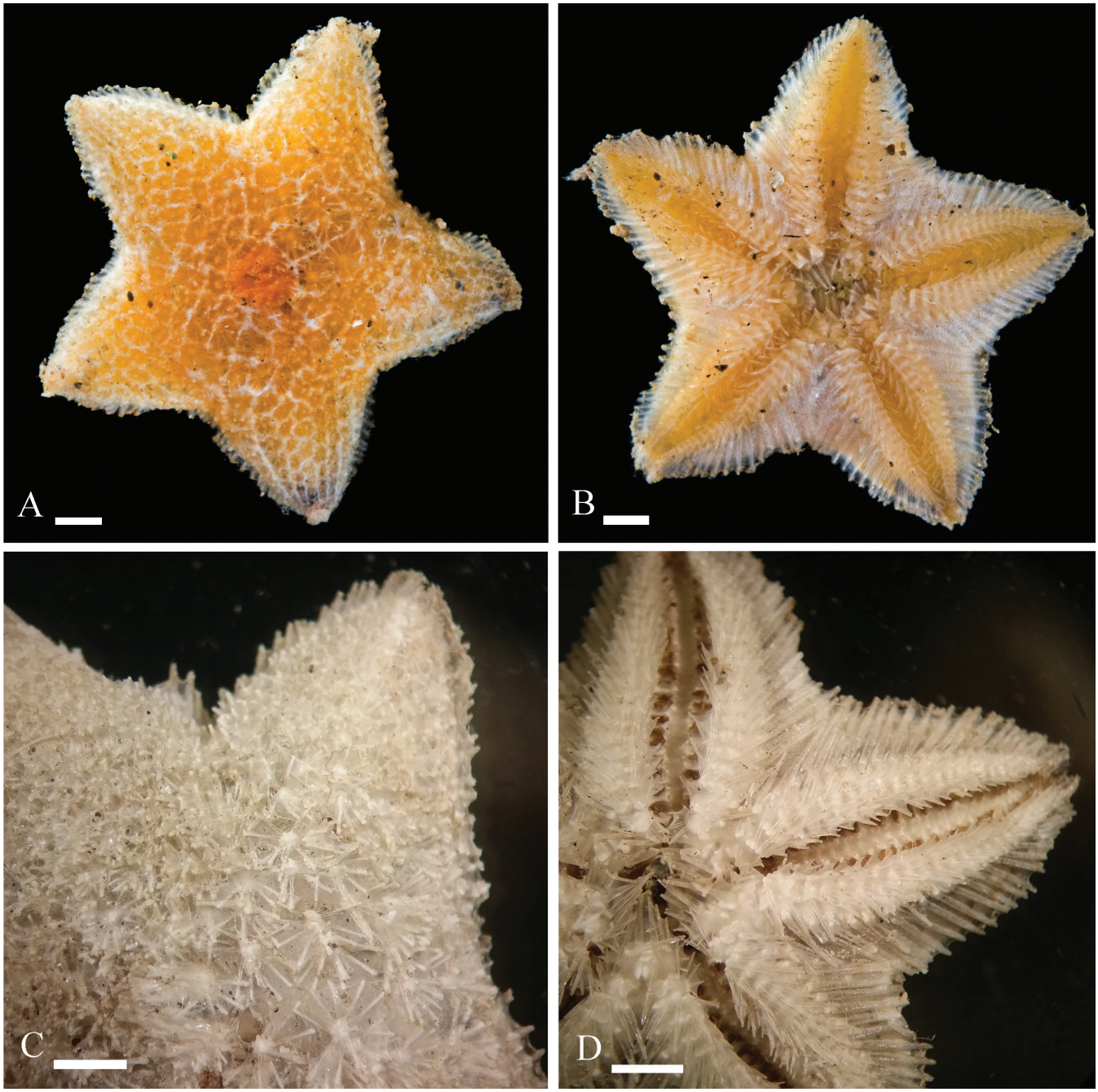


Fig. 32. *Pteraster* sp. (ZRC.ECH.1386). Abactinal view (A) and actinal view (B) of live sea star. Webbed actinolateral spines project beyond convex margin of arms; C, D, specimen ethanol-preserved and dried. C, paxillar spines and radiating spinelets support supradorsal membrane; D, actinal view showing webbed actinolateral spine fringe and membrane-embedded oral spines. Scale bars: A–D = 2 mm.

biodiversity for sea stars and probably for other echinoderms and other faunal groups too.

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## LITERATURE CITED


Alcock A (1893) Natural history notes from the HM Indian Marine Survey Steamer Investigator. 7. An account of the collection of the deep sea Asteroidea. Annals of the Magazine of Natural History, 11(6): 73–121.

Belyaev GM (1974) A new family of abyssal starfishes. Zoologischeskii Zhurnal, 53(10): 1502–1508.

Bratova OA & Paskerova GG (2018) *Henricia* spp. (Echinodermata: Asteroidea: Echinasteridae) of the White Sea: morphology, morphometry and synonymy. Canadian Journal of Zoology, 96: 341–355.

Bruzelius N (1805) Dissertatio sistens species cognitas asteriarum, quamr. sub praesidio A.J. Retzil. exhibet N. Bruzelius. Lundae, pp. 1–37.

Chichvarkhin A (2017) *Henricia djakonovi* sp. nov. (Echinodermata, Echinasteridae): a new sea star species from the Sea of Japan. PeerJ, 5: e2863. doi: 10.7717/peerj.2863

Clark AM (1989) An index of names of recent Asteroidea – Part 1: Paxillosida and Notomyotida. In: Jangoux M & Lawrence JM (eds.) Echinoderm Studies, 3: 225–347.

Clark AM (1993) An index of names of recent Asteroidea – Part 2: Valvatida. In: Jangoux M & Lawrence JM (eds.) Echinoderm Studies, 4: 187–366.

Clark AM & Mah C (2001) An index of names of recent Asteroidea – Part 4: Forcipulatida and Brisingida. In: Jangoux M & Lawrence JM (eds.) Echinoderm Studies, 6: 229–347.

Clark HES & McKnight DG (2001) The Marine Fauna of New Zealand: Echinodermata: Asteroidea (Sea Stars). Order Valvatida. NIWA Biodiversity Memoir, 117: 1–269.

Döderlein L (1917) Die Asteriden der Siboga-Expedition. 1. Die Gattung *Astropecten* und ihre Stammesgeschischte. Siboga-Expedition, 46a: 1–190, pls. 1–17.

Döderlein L (1921) Die Asteriden der Siboga-Expedition. I. Porcellanasteridae, Astropectenidae, Benthopectinidae. Siboga-Expedition, 46(1): 1–47, pls. 1–13.

Döderlein L (1924) Die Asteriden der Siboga-Expedition. II. Pentagonasteridae. Siboga-Expedition, 46(2): 49–69, pls. 14–19.

Fisher WK (1906) The starfishes of the Hawaiian Islands. Bulletin of the United States Fish Commission, 23: 987–1130.

Fisher WK (1913a) Four new genera and fifty-eight new species of starfishes from the Philippine Islands, Celebes, and the Moluccas. Proceedings of the US National Museum, 43: 599–648.

Fisher WK (1913b) New starfishes from the Philippine Islands, Celebes and the Moluccas. Proceedings of the US National Museum, 46: 201–224.

Fisher WK (1916) New east Indian starfishes. Proceedings of the Biological Society of Washington, 29: 27–36.

Fisher WK (1917) New starfishes from the Philippines and Celebes. Proceedings of the Biological Society of Washington, 30: 89–93.

Fisher WK (1919a) North Pacific Zoroasteridae. Annals and Magazine of Natural History, 3(a): 353–387.

Fisher WK (1919b) Starfishes of the Philippine seas and adjacent waters. Bulletin of the United States National Museum, 3(100): 1–547, 165 pls.

Forbes E (1839) On the Asteriadae of the Irish Sea. Memoirs of the Wernerian Natural History Society of Edinburgh, 8: 114–129.

Forbes E (1841) A history of British Starfishes and other animals of the of the class Echinodermata. John Van Voorst, London, 267 pp.

Gray JE (1840) XXII. A synopsis of the genera and species of the class Hypostoma (Asterias, Linnaeus). Annals and Magazine of Natural History, 6: 175–184.

Gray JE (1840) XXXII. A synopsis of the genera and species of the class Hypostoma (Asterias, Linnaeus). Annals and Magazine of Natural History, 6: 275–290.

Halpern JA (1970) Goniasteridae (Echinodermata; Asteroidea) of the Straits of Florida. Bulletin of Marine Science, 20(1): 193–286.

Jangoux M (1981) Echinoderms: Astéroides. In: Forest J (ed.) Résultats des campagnes MUSORSTOM: 1. Philippines (18-28 Mars 1976). Mémoires du Muséum national d'Histoire naturelle, Série A, Zoologie, 91: 457–476.

Jangoux M, De Ridder C, Massin C & Darsono P (1989) The holothuroids, echinoids and asteroids (Echinodermata) collected by the Snellius-II Expedition. Netherlands Journal of Sea Research, 23(2): 161–170.

Koehler R (1909) Astéries recueillies par l'Investigator dans l'océan Indien. I. Les Astéries de Mer profonde. Echinoderma of the Indian Museum, 5: 1–143, 13 pls.

Lane DJW & Vimono IB (2020) Two new species of sea star (Asteroidea, Echinodermata) from mesopelagic depths in the Sunda Strait, Indonesia. Raffles Bulletin of Zoology, 68: 662–669.

Ludwig H (1905) Asteroidea. Memoirs of the Museum of Comparative Zoology at Harvard, 32: vii–xii + 1–292.

Lütken C (1871) Fortasatte kritiske og beskrivende Bidrag til Kundskab om Sostjernerne (Asteriderne). Videnskabelige Meddelelser fra Dansk Naturhistorisk Forening, 1871: 227–304.

Macan TT (1938) Asteroidea. Scientific Reports, John Murray Expedition 1933-1934, 4(9): 323–435, pls. 1–6.

Madsen FJ (1987) The *Henricia sanguinolenta* complex (Echinodermata, Asteroidea) of the Norwegian Sea and adjacent waters. A re-evaluation with notes on species. Steenstrupia, 13(5): 201–268.

Mah CL (2005) A phylogeny of *Iconaster* and *Glyphodiscus* (Goniasteridae; Valvatida; Asteroidea) with descriptions of four new species. Zoosystema, 27(1): 131–167.

Mah CL (2007) Phylogeny of the Zoroasteridae (Zorocallina; Forcipulatida): evolutionary events in deep-sea Asteroidea displaying Palaeozoic features. Zoological Journal of the Linnaean Society, 150: 177–210.

Mah CL (2016) Deep-sea (>1000m) Goniasteridae (Valvatida: Asteroidea) from the North Pacific, including an overview of *Sibogaster, Bathyceramaster* n. gen. and three new species. Zootaxa, 4175(2): 101–141.

Mah CL (2018) New genera, species and occurrence records of Goniasteridae (Asteroidea; Echinodermata) from the Indian Ocean. Zootaxa, 4539(1): 1–116.

Mah CL (2020) New species, occurrence records and observations of predation by deep-sea Asteroidea (Echinodermata) from the North Atlantic by NOAA ship *Okeanos Explorer*. Zootaxa, 4766(2): 201–260.

Mah CL (2021) World Asteroidea Database. http://www.marinespecies.org/asteroidea/index.php (Accessed 20 February 2021).

Mah CL & Blake DB (2012) Global diversity and phylogeny of the Asteroidea (Echinodermata). PLoS ONE, 7(4): e35644. doi: 10.1371/journal.pone.035644

Mah CL & Fujita T (2020) New species and occurrence records of Japanese Solasteridae and Ganeriidae including a new species of *Paralophaster* from the North Pacific with an overview of *Hyalinothrix*. Zootaxa, 4750(1): 67–100.

Müller J & Troschel FH (1842) System der Asteriden. 1. Asteriae. 2. Ophiurae. Vieweg, Braunschweig (= Brunswick), xxx + 134 pp., 12 pls.

Perrier E (1881) Report on the results of dredging in the Gulf of Mexico and in the Caribbean Sea, 1877–79, by the United States coastal survey steamer Blake. 14. Description sommaire des espèces nouvelles d'Astéries. Bulletin of the Museum of Comparative Zoology, 9: 1–31.

Perrier E (1882) Sur une Asterie des grand profundeurs de l'Atlantique, pourvue d'un peduncle dorsale. Comptes rendus

hebdomadaires des séances de l'Académie des sciences, 95: 1379–1381.

Perrier E (1885) Première note préliminaire des les Echinodermes, recueillis durant les campagnes de dragages sous-marines du Travailleur et du Talisman. Annales des sciences naturelles, Zoologie, 22(8): 1–72.

Rowe FEW & Gates J (1995) Echinodermata. In: Wells A (ed.) Zoological Catalogue of Australia, Volume 33. CSIRO Australia, Melbourne, xiii + 510 pp.

Saito N, Wakabayashi K & Moritake T (2020) Three new species of *Dendrogaster* (Crustacea: Ascothoracida) infecting goniasterid sea stars (Echinodermata: Asteroidea) from Japan. Species Diversity, 25: 75–87.

Sars GO (1875) On some remarkable forms of animal life from the Great Deeps off the Norwegian coast. II. Researches on the structure and affinity of the genus *Brisinga* based on the study of a new species, *Brisinga coronata*. Christiania University, Christiania, 112 pp., 7 pls.

Shin S (2007) A new record of sea star (Asteroidea: Phanerozonia) from Jejudo Island, Korea. Korean Journal of Systematic Zoology, 23(2): 251–253.

Sladen WP (1883) The Asteroidea of H.M.S. Challenger Expedition, pt. 2. Astropectinidae. Journal of the Linnean Society of London, 17: 214–269.

Sladen WP (1885) Report of the scientific results of the voyage of H.M.S. Challenger. Narrative of the Cruise. Volume 1, Part 2, pp. 604–617.

Sladen WP (1889) Report on the Asteroidea. Report on the Scientific Results of the Voyage of H.M.S. Challenger during the years 1873-1876. Zoology. Volume 30, Part 51. Published by Order of Her Majesty's Government, London, Edinburgh and Dublin, xiii + 893 pp., 118 pls.

Studer T (1884) Verzeichnis der wärend der Reise S.M.S. "Gazelle" um die Erde, 1874-76 gesammelten Asteriden und Euryaliden. Abhandlungen der Preussischen Akademie der Wissenschaften, 2: 1–64.

Verrill AE (1867) Notes on the Radiata in the Museum of Yale College, with descriptions of new genera and species. No. 3. On the geographical distribution of the echinoderms of the west coast of America. Transactions of the Connecticut Academy of Arts and Sciences, 1(2): 323–351.

Verrill AE (1878) Art. XX. Notice of recent additions to the marine fauna of the eastern coast of North America. No. 1. American Journal of Science and Arts, 3(16): 207–215.

Verrill AE (1884) Art. XXIX.—Notice of the remarkable marine fauna occupying the outer banks off the southern coast of New England, No. 9. American Journal of Science, S3-28(165): 213–220.

Verrill AE (1899) Revision of certain genera and species of starfishes, with descriptions of new forms. Transactions of the Connecticut Academy of Arts and Sciences, 10(1): 145–234.

Viguier C (1878) Classification des Stellerides. Compte Rendue hebdomadaires des séances de l'Académie des Sciences, 86(1878): 681–683.

Wood-Mason J & Alcock A (1891a) Natural history notes from H.M. Indian marine survey steamer 'Investigator', Commander R.F. Hoskyn, R.N., commanding. No. 21. Note on the results of the last season's deep-sea dredging. Annals and Magazine of Natural History, Series 6, 7(37): 1–19.

Wood-Mason J & Alcock A (1891b) Natural history notes from H.M. Indian marine survey steamer 'Investigator', Commander R.F. Hoskyn, R.N., commanding. Series II, No. 1. On the results of deep-sea dredging during the season 1890-1891. Annals and Magazine of Natural History, Series 6, 8(48): 427–452, pl. XVII.

Wyville Thomson C (1873) The depths of the sea. Macmillan, London, 527 pp.

Wyville Thomson C (1878) The voyage of the "Challenger": the Atlantic. Macmillan, London. Volume 1: pp. 1–424; Volume 2: pp. 1–396.

Zhang R, Wang X, Zhou Y & Wang C (2018) The first record of *Porcellanaster ceruleus* (Echinodermata: Porcellanasteridae) in the South China Sea. Acta Oceanologica Sinica, 37: 185–189.