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ORIGINAL ARTICLE



Nine new records of brittle stars (Echinodermata: Ophiuroidea) from Indian waters

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ABSTRACT

This paper presents nine new records of brittle stars for the Indian waters, collected between 49 and 957 m depths in the Arabian Sea, Bay of Bengal and Andaman Sea. Of these, *Ophiolepis cardioplax* and *Ophiopsammus aequalis* are being reported for the first time from the Indian Ocean, while *Astrothorax waitei*, *Amphiophiura insolita*, *Ophialcaea tuberculosa* and *Ophioplocus declinans* are new records for the northern Indian Ocean. Three other species – *Amphiura* (*Amphiura*) *dejectoides*, *Amphiura* (*Amphiura*) *uncinata* and *Ophiopeza spinosa* are recorded from nearby areas but are being reported for the first time from the Indian waters. *Indophioderma ganapatii*, described from Agatti Island, Lakshadweep is synonymized with *Ophiopeza spinosa*. The nine species described in this paper include several that have not been adequately described in literature or have rarely been documented at all.

ARTICLE HISTORY

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KEYWORDS

Echinoderms; biodiversity; India; Arabian Sea; Bay of Bengal; Andaman and Nicobar Islands

Introduction

Studies on brittle star (Echinodermata: Ophiuroidea) diversity in the seas around India began in the late nineteenth century, with documentation of intertidal and littoral species (Lütken 1872; Bell 1882, 1887a, 1887b, 1888, 1889, 1902; Duncan 1887; Döderlein 1888; Thurston 1895; Herdman and Herdman 1904; Gravely 1927). The most important contributions were made through the surveys of the Royal Indian Marine Survey Steamer *Investigator*, which recorded deep-sea species for the first time from the region (Koehler 1897, 1899, 1910; Bomford 1913; Sastry 1981, 1987) along with shallow water taxa (Alcock 1893; Koehler 1898). The German deep-sea (Valdivia) expedition also described some species from around the Nicobar Islands (Hertz 1927; Döderlein 1930). All subsequent documentation of brittle stars during the twentieth century was confined to the intertidal and shallow-water areas (Sane and Chhapgar 1962; James 1970a, 1970b, 1981, 1982a, 1982b; Sastry 1991, 1999, 2004). A comprehensive and annotated checklist of echinoderms of India was published by Sastry (2007), which included 151 species of brittle stars.

In the last decade, new deep-sea species (Parameswaran and Abdul Jaleel 2012; Stöhr et al. 2012a), as well as several new records (Parameswaran et al.

2013, 2016, 2018, 2020) were described among brittle stars, from various parts of the Indian exclusive economic zone (EEZ). Most of these were the results of intensive biodiversity surveys of the Fishery Oceanographic Research Vessel *Sagar Sampada* (FORVSS), undertaken as part of the Marine Living Resources programme of the Ministry of Earth Sciences, Government of India. With these additions, the total number of brittle star species known from the Indian waters stands at ~180. This paper reports nine further new records of brittle stars for the Indian waters, collected during the surveys of FORV *Sagar Sampada* between 2009 and 2019. Several of these species have not been adequately described (and/or figured) in literature or have rarely been documented at all.

Materials and methods

All specimens described in this paper were collected during biodiversity surveys of Fishery Oceanographic Research Vessel *Sagar Sampada* (FORVSS) using a modified naturalist dredge, a Smith–McIntyre grab or a high-speed demersal trawl (crustacean version) net (Figure 1). They were preserved in ethanol and species identification was carried out following taxonomic keys and references (e.g. Clark and Rowe 1971;

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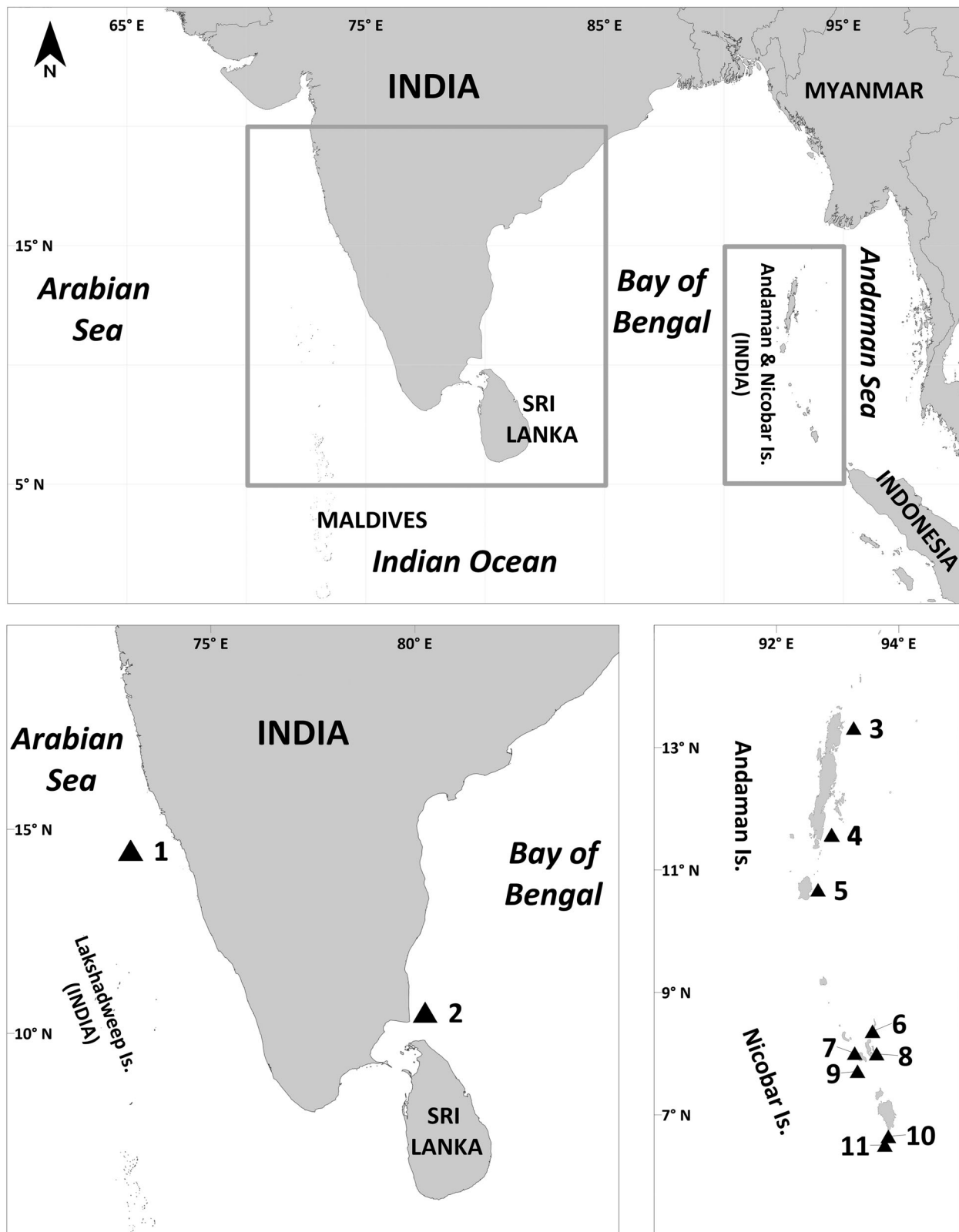


Figure 1. Map of the northern Indian Ocean, showing the collection locations of *Astrothorax waitei* (Benham, 1909) [1], *Amphiura* (*Amphiura*) *dejectoides* H.L. Clark, 1939 [2], *Ophialcaea tuberculosa* (Lyman, 1878) [3, 9], *Amphiura* (*Amphiura*) *uncinata* Koehler, 1904 [4], *Ophiopoeza spinosa* (Ljungman, 1867) [5, 8, 10], *Ophioplocus declinans* (Koehler, 1904) [6], *Amphiophiura insolita* (Koehler, 1904) [7], *Ophiopsammus aequalis* (Lyman, 1880) [7], and *Ophiolepis cardioplax* Murakami, 1943 [10, 11].

Vail and Rowe 1989; O'Hara and Stöhr 2006; O'Hara et al. 2018). Specimens were photographed using a Leica M80 stereo-zoom microscope fitted with a Leica MC170 HD camera. For species with sufficient material to sacrifice a specimen, individual ossicles were isolated by immersing whole organisms or parts in sodium hypochlorite to remove tissue, followed by cleaning with distilled water. A Jeol JSM-IT500 scanning electron microscope (SEM) at the National Institute of Ocean Technology, Chennai was used to obtain SEM images of the ossicles. Descriptive terminology in this paper follows Stöhr et al. (2012b) for general morphological features, Martynov (2010) and Thuy and Stöhr (2011) for lateral arm plate morphology and Hendler (2018) for buccal armature. Diameter of the disc is abbreviated as 'd.d.'. Distribution ranges of species are based on cited literature, as well as records in the Ocean Biodiversity Information System (OBIS 2021). All specimens are deposited in ethanol or as dried material, at the Referral Centre, Centre for Marine Living Resources & Ecology, Kochi and the accession numbers are given below.

Taxonomic account

Class Ophiuroidea Gray, 1840

Superorder Euryophiurida O'Hara, Hugall, Thuy, Stöhr & Martynov, 2017

Order Euryalida Lamarck, 1816

Family Gorgonocephalidae Ljungman, 1867

Genus *Astrothorax* Döderlein, 1911

Astrothorax waitei (Benham, 1909)

(Figure 2)

Astrothorax waitei Benham, 1909: 101–104; pl. 9. — Mortensen 1924: 104, fig. 3, pl. 4(2). — Fell 1952: 13–14.

Astrothamnus rugosus H. L. Clark, 1916: 85–86, pl. 35(1–2). — H. L. Clark 1946: 177.

Astrothamnus papillatus H. L. Clark, 1923: 316–318, pl. 20(5–6).

Astrocrius waitei — Döderlein 1927: 21.

Astrothamnus furtivus Koehler, 1930: 6–9, pl. 1(1–2). — Mortensen 1933a: 22–23, fig. 13, pl. 5(33). — H. L. Clark 1946: 177.

Astrothorax waitei — Döderlein 1930: 380–381, fig. 11, 14(k), pl. 2(2; 2a). — Fell 1958: 21; 1960: 67. — Baker 1980: 30–32, fig. 8; 31. — McKnight 2000: 61–63, pl. 29.

Astrothorax papillata — Mortensen 1933b: 279–280, fig. 15.

Astrothorax furtivus — McKnight 1975: 61.

Material examined

Eastern Arabian Sea–Off Karwar, 14°29.02'N, 73°02.28'E, 957 m (FORVSS372, St. 05), 28.02.2018,

demersal trawl, 1 specimen (IO/SS/ECD/00257); 14°29.02'N, 73°01.52'E, 953 m (FORVSS374, St. 10), 09.04.2018, demersal trawl, 5 specimens (IO/SS/ECD/00258, 00259).

Description

IO/SS/ECD/00258: Disc margin excavate interradially; d.d. 15 mm; arms simple, 4–6 times d.d., strongly arched dorsally, with strong tendency for vertical coiling. Disc scales on the dorsal side composed of small, polygonal and flattened scales interspersed with larger, tumid, flat-topped or conical tubercles, usually bearing short spinules on the apex; the tumid tubercles more densely packed on the radial shields. Density and combination of the two types of ossicles varying widely among the specimens. One specimen (IO/SS/ECD/00257, d.d. 25 mm) with more numerous flattened scales and with taller, stouter tubercles. Radial shields multi-layered, comprised of a long, stout, bar-like ossicle distally and numerous long, thin, scale-like ossicles proximally; the entire structure visible beneath the disc scales as raised bars running from the centre of the disc to the arm base. Lateral interradii composed of skin embedded with small, rounded scales; genital slits wide, more or less vertical. Ventral surface of the disc, including the jaws paved with small, rounded scales; the arrangement denser in some specimens and spaced in others. Ventral teeth long, pointed and numerous, arranged in a cluster; long, pointed papillae along the latero-ventral margin of the jaw. Girdle bands on arms beginning at the disc margin, extending down the lateral sides of the arms; inter-girdle area not markedly sunken, covered densely with rounded, tumid scales. Girdle hooklets with a secondary tooth; up to nine hooklets borne on flat, polygonal scales. Ventral surface of arms skin-covered, with dense or spaced paving of polygonal plates of varying sizes. Articulation of arm vertebrae zygospondylous. Lateral arm plates elongated along the lateral axis; very stout, densest around the middle, with a well-marked ventral projection; abradial margin widened ventrally, with a narrow, elevated ridge into which the large, oval muscle openings of spine articulations are sunken; smaller nerve openings located outside the ridge; dorso-distal margin of lateral arm plates with 4–6 elevated tubercles bearing muscle openings for girdle hooklets. Ventral projections of lateral arm plates clearly visible externally as raised transverse bars along the arm. Arm spines absent on first segment, 2–3 subequal, cylindrical spines with numerous glassy points on second segment, subsequently increasing to about 6; arm spines on distal segments reduced to ~2 flat

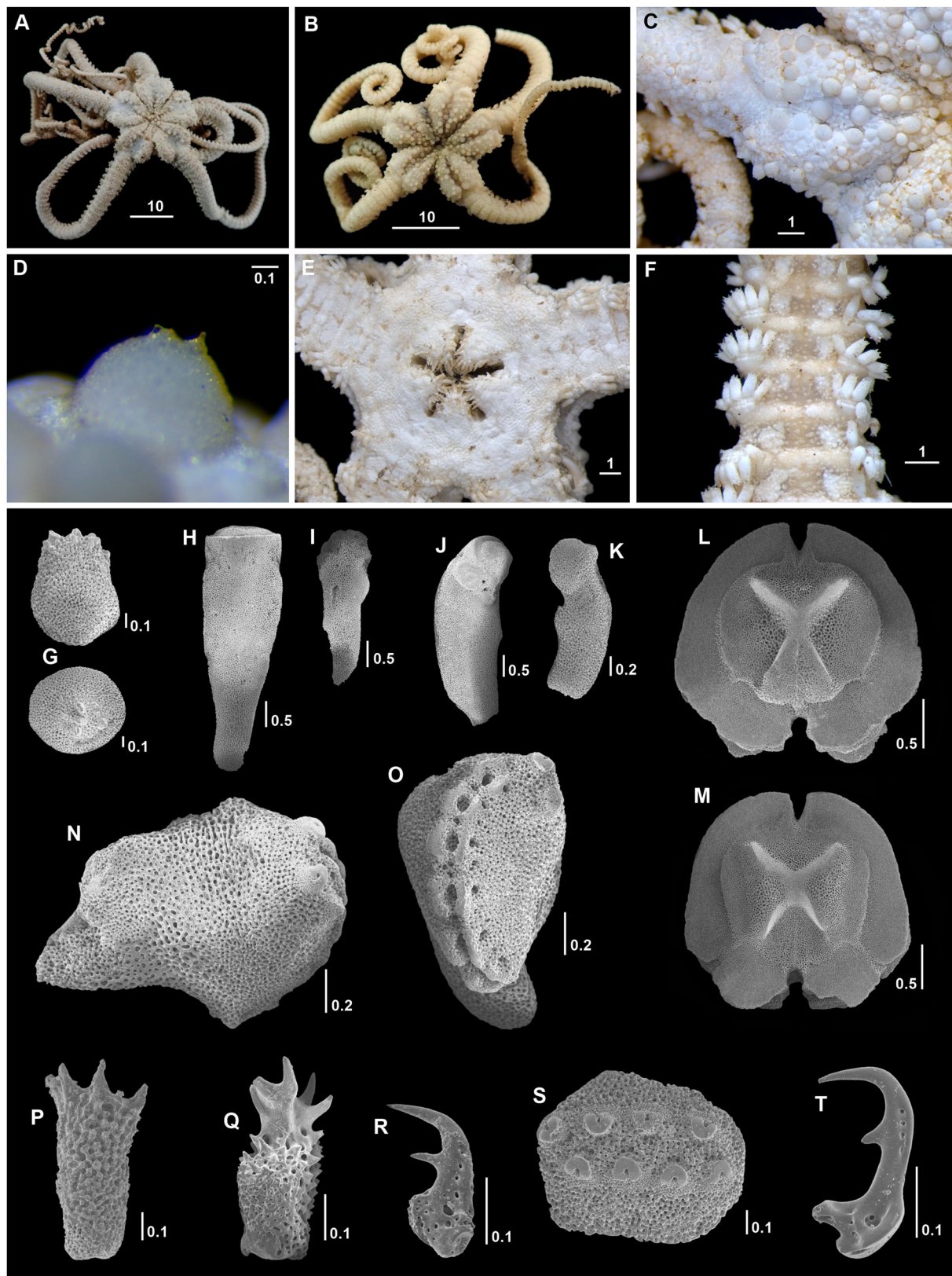


Figure 2. *Astrothorax waitei* (Benham, 1909), A: IO/SS/ECD/00257, B–F: IO/SS/ECD/00258, G–T: IO/SS/ECD/00259 SEM images. A, B, entire organism, dorsal view; C, disc margin and arm base; D, enlarged tubercle of the dorsal disc, showing spinules at the apex; E, disc, ventral view; F, proximal part of arm, ventral view; G, dorsal disc tubercles; H, distal ossicle of radial shield, dorsal view; I, proximal scale-like ossicle of radial shield, dorsal view; J, adradial genital plate; K, abradial genital plate; L, proximal arm vertebra, proximal view; M, same, distal view; N, lateral arm plate from proximal arm, distal view; O, lateral arm plate from proximal arm, abradial view; P, arm spine from proximal segment; Q, arm spine from middle segment; R, arm spine from distal segment; S, plate bearing girdle hooklets; T, girdle hooklet. Scale bars in mm.

hooks with a strong primary tooth and short secondary tooth.

Colour

Off-white throughout, in live and preserved specimens.

Distribution

South Africa (H. L. Clark 1923; Baker 1980), India: eastern Arabian Sea, Australia (H. L. Clark 1916, 1946; Koehler 1930; Baker 1980), Indonesia (OBIS 2021), Solomon Islands (OBIS 2021), New Caledonia (OBIS 2021), Norfolk Ridge (Baker 1980), New Zealand (Benham 1909; Fell 1952, 1958, 1960; McKnight 1975; Baker 1980, 2000); 70–1700 m.

Remarks

Baker (1980) observed significant variation in the shape, size and arrangement of disc scales in *Astrothorax waitei*, and thus synonymized *Astrothamnus rugosus* H. L. Clark, 1916, *Astrothorax papillatus* (H. L. Clark, 1923) and *Astrothorax furtivus* (Koehler, 1930) with *A. waitei*. However, Olbers et al. (2019) consider *A. papillatus* described from South Africa to be a distinct species, based on preliminary molecular evidence. The present specimens from the eastern Arabian Sea accord well with the description of Baker (1980), including the wide variations in shape and arrangement of disc scales, and are therefore assigned to *A. waitei*. According to Baker (1980), *A. waitei* is a hermaphrodite which broods juveniles in its bursae. No evidence of brooding was observed in the present specimens.

Astrothorax waitei has previously been recorded in the south-western and south-eastern Indian Ocean, around the Malay Archipelago and the south-western Pacific Ocean; it is being recorded for the first time from the northern Indian Ocean based on samples from the eastern Arabian Sea.

Order Ophiurida Müller & Troschel, 1840 sensu O'Hara et al., 2017

Family Ophiopyrgidae Perrier, 1893

Genus *Amphiophiura* Matsumoto, 1915

Amphiophiura insolita (Koehler, 1904)

(Figure 3)

Ophioglypha insolita Koehler, 1904: 47–48, pl. 7(4–6).

Amphiophiura insolita — Matsumoto 1915: 77. — Koehler 1922: 362–363, pl. 84(8–9); 1930: 225. — Stöhr 2011: 27, fig. 11.

Material examined

Andaman & Nicobar Islands – Off Katchall Island, 8° 00.45'N, 93°16.82'E, 94 m (FORVSS261, St. 35B), 24.01.2009, dredge, 1 specimen (IO/SS/ECD/000247).

Description

IO/SS/ECD/000247: Disc circular, high; d.d. 8 mm, disc height 2.5 mm; arms about 1.5–2 times d.d., gradually tapering, about as wide as high basally. Disc scales thin, polygonal and imbricating; centrodorsal distinct. Radial shields pentagonal with rounded distal margin; the pairs separated proximally by a large, hexagonal disc scale. Interradial space between radial shields occupied by a single, large hexagonal plate, distal to which is a thick, broad and bulging marginal plate. Ventral interradii occupied entirely by the large, pentagonal and distally bulging oral shield, which is separated from the dorsal marginal plate by a single rectangular plate. Genital slits well developed, bordered by the oral shield, abradial genital plate modified into an arm comb in the lateral disc margin. Adoral shields longer than broad, placed proximal to the oral shield and contiguous throughout their length. Teeth conical, pointed; ventral-most tooth smaller. Five papillae along each side of the jaw – corresponding to two conical tooth papillae, a broader secondary infradental papilla, followed by an infradental papilla and a buccal scale, which are much broader. Dorsal arm plates broader than long, hexagonal and tumid, broadly contiguous basally. Ventral arm plates broader than long, bulging, widely separated from each other; with proximal and distal margins concave. Lateral arm plate of second segment somewhat enlarged and conspicuously bulging distally; distal margin bearing a row of flattened and pointed papillae, which continue onto the dorsal side and form an opposing row to the main arm comb. Lateral arm plates of free segments oval, bearing eight arm spines basally in a single row; a few dorsal and the ventral-most spines shorter than the rest, which are shorter than the corresponding segment. Up to 10 tentacle scales basally, borne on the lateral and ventral arm plates. Marginal plates of the disc, radial shields, plates of the oral apparatus and arms all conspicuously beaded.

Colour

Off-white with orange patches along the proximal margins of disc plates and lateral margins of dorsal arm plates, these markings are more extensive on

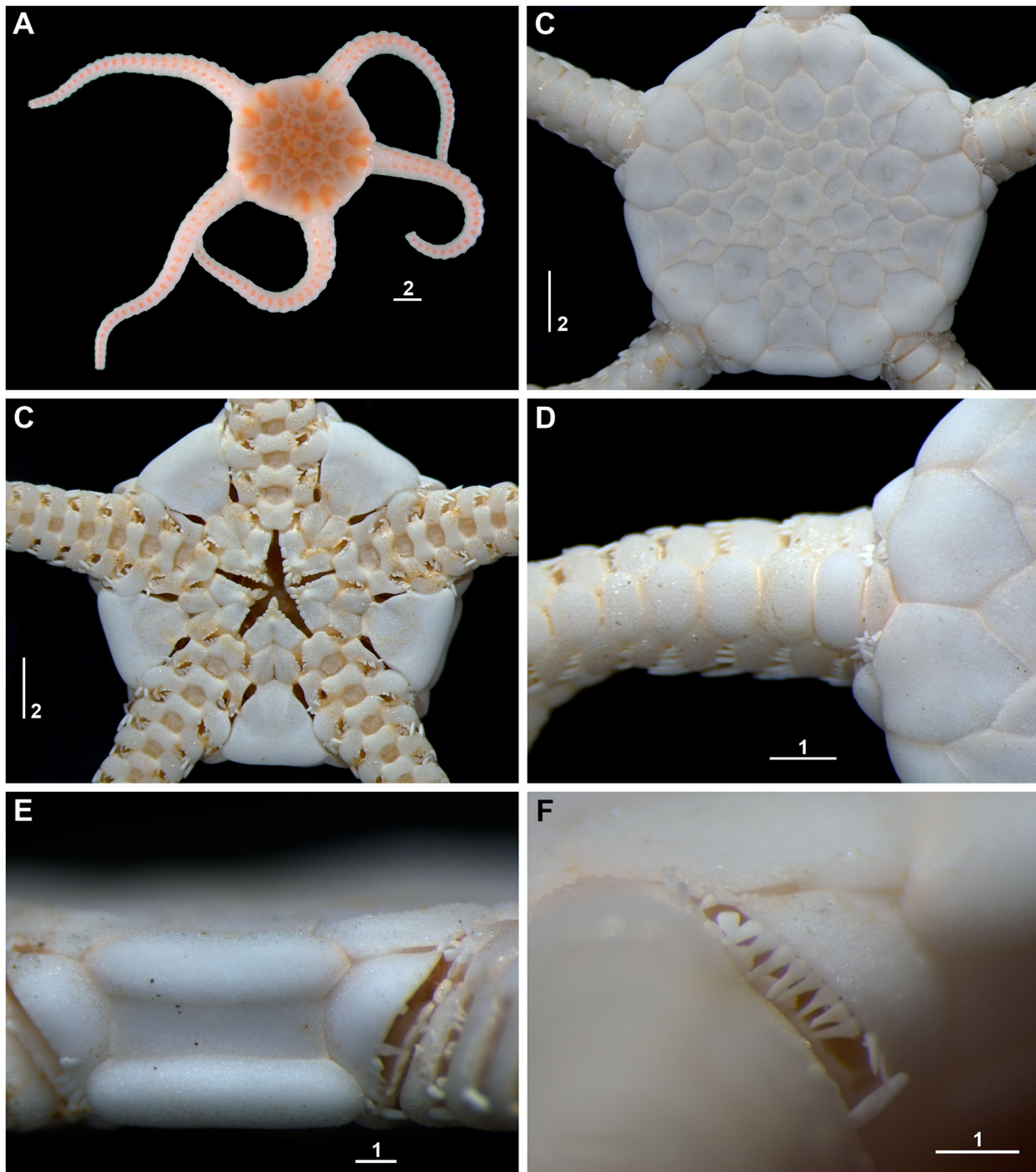


Figure 3. *Amphiophiura insolita* (Koehler, 1904), IO/SS/ECD/00247. A, live specimen, dorsal view; B, disc, dorsal view; C, disc, ventral view; D, arm base, dorsal view; E, arrangement of plates in the interradius; F, arm comb, lateral view. Scale bars in mm.

radial shields; preserved specimen off-white throughout.

Distribution

Reunion (OBIS 2021), India: Andaman & Nicobar Islands, western Australia (OBIS 2021), Indonesia (Koehler 1904, 1930), Philippines (Koehler 1922),

Taiwan (OBIS 2021), Papua New Guinea (OBIS 2021), Vanuatu (OBIS 2021), New Caledonia (Stöhr 2011), New Zealand (OBIS 2021); 94–1500 m.

Remarks

Amphiophiura insolita is previously recorded from the south-western and south-eastern Indian Ocean, as

well as the western Pacific Ocean. The present specimens from the Andaman & Nicobar Islands represent its first record in the northern Indian Ocean.

Superorder Ophintegrida O'Hara, Hugall, Thuy, Stöhr & Martynov, 2017

Order Amphilepidida O'Hara, Hugall, Thuy, Stöhr & Martynov, 2017

Family Amphiuridae Matsumoto, 1915

Genus Amphiura Ljungman, 1867

Amphiura (Amphiura) dejectoides H. L. Clark, 1939 (Figure 4)

Amphiura dejectoides H. L. Clark, 1939: 62–64, fig. 18–19. — A. M. Clark 1967: 47. — A. M. Clark & Rowe 1971: 97. — Cherbonnier & Guille 1978: 33–34; fig. 9. — Guille & Ribes 1981: 82. — Price & Rowe 1996: 73.

Amphiura inhacaensis Balinsky 1957: 6–7; fig. 2. — A. M. Clark & Rowe 1971: 97. — A. M. Clark & Courtman-Stock 1976: 117, 156.

Material examined

South-western Bay of Bengal – Off Point Calimere, 10° 31.08'N, 80°15.00'E, 114 m (FORVSS391, St. 02), 06.11.2019, dredge, 27 specimens (IO/SS/ECD/00051, 00052).

Description

IO/SS/ECD/00052: Disc with scalloped margins, d.d. 4.5 mm, arms up to ~10 times d.d. Disc scales small, fine, imbricating; covering dorsal and ventral disc surface completely; primary rosette not distinguishable. Radial shields long, curved, length about one fourth of d.d., about three times longer than wide; separated by 1–2 rows of disc scales, distally in contact. Oral shields wider than long, quadrangular, with rounded angles. Adoral shields wide, but not meeting radially or interrally. Teeth oblong with rounded distal margins. Infradental papillae thick, conical; one thin, ovate distal papilla corresponding to an adoral shield spine, which is usually erect, and easily lost. A broad, pointed buccal scale positioned on the adradial surface of the oral plate; visible in the diastema between the infradental papilla and adoral shield spine. Dorsal arm plates wider than long, narrowly in contact; with short, straight proximal margin and broadly rounded distal margin. Ventral arm plates longer than wide, squarish; with proximal margin straight, lateral margins convex and distal margin straight or notched. Arm spines stout with blunt tips which are sometimes widened or have

microscopic spinose projections; numbering up to five basally; dorsal-most minute, with spinose projections at the tip; ventral-most spine longest and stoutest, about 1.5 times as long as the corresponding segment; remaining spines about as long as corresponding segment. One long, flat, ovate tentacle scale.

Colour

Off-white throughout, in live and preserved specimens.

Distribution

Mozambique (Balinsky 1957), Madagascar (Cherbonnier and Guille 1978), Red Sea (H. L. Clark 1939; A. M. Clark 1967), India: western Bay of Bengal, Indonesia (Price and Rowe 1996), Western Australia (OBIS 2021); 0–114 m.

Remarks

Amphiura (Amphiura) dejectoides is known from the western and south-eastern Indian Ocean as well as the Malay Archipelago; it is being reported for the first time from the Indian exclusive economic zone (EEZ).

Amphiura (Amphiura) uncinata Koehler, 1904 (Figure 4)

Amphiura uncinata Koehler, 1904: 76–77, pl. 14(3–4). — Koehler 1922: 160, pl. 65(6–8), pl. 96(4). — Mortensen 1933b: 358–359, figs 65–66. — H. L. Clark 1939: 58.

Amphiura (Amphiura) uncinata — A. M. Clark & Courtman-Stock 1976: 103, 115, 158; fig. 125. — Olbers et al. 2019: 273–238, fig. 239.

Material examined

Andaman & Nicobar Islands – Off Port Blair, 11°34.72'N, 92°54.09'E, 485 m (FORVSS367I, St. 21), 18.11.2017, dredge, 1 specimen (IO/SS/ECD/00314); 11°34.20'N, 92°54.60'E, 469 m (FORVSS388, St. 01), 09.08.2019, dredge, 1 specimen (IO/SS/ECD/00304).

Description

IO/SS/ECD/00314: Disc with scalloped margins, d.d. 7 mm, arms 11–12 times d.d. Disc scales small, fine, imbricating; covering dorsal and ventral disc surface completely; primary rosette more or less distinct. Radial shields long and wide, length about one third of d.d., about twice as long as wide; separated by a rows of large disc scales, sometimes also a few small

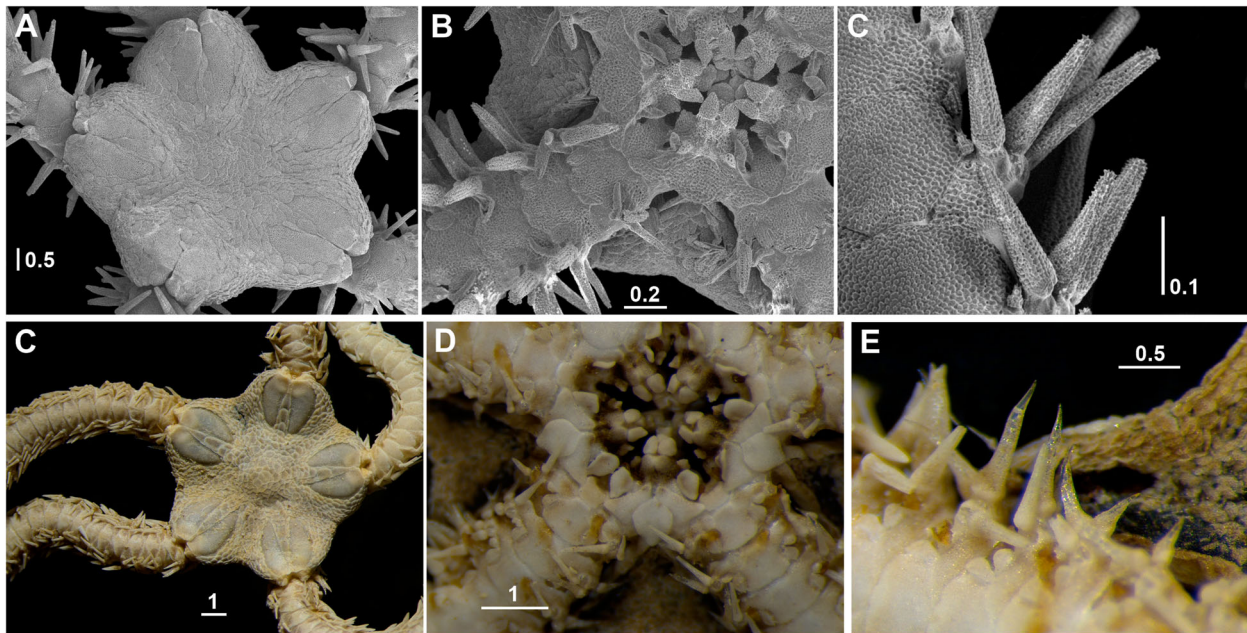


Figure 4. A–C, *Amphiura* (*Amphiura*) *dejectoides* H.L. Clark, 1939, IO/SS/ECD/00052; D–F, *Amphiura* (*Amphiura*) *uncinata* Koehler, 1904, IO/SS/ECD/00314. A, D, disc, dorsal view; B, E, disc, ventral view; C, F, basal arm spines. Scale bars in mm.

scales, distally in contact. Oral shields longer than wide, with an acute proximal angle, rounded lateral angles and a broad distal lobe. Adoral shields wide, meeting interradially but not radially. Teeth oblong

with squared-off distal margins. Infradental papillae thick, with broadly squared-off distal margins; one large, flat papilla distally, corresponding to an adoral shield spine, broad at the base with a semi-circular or

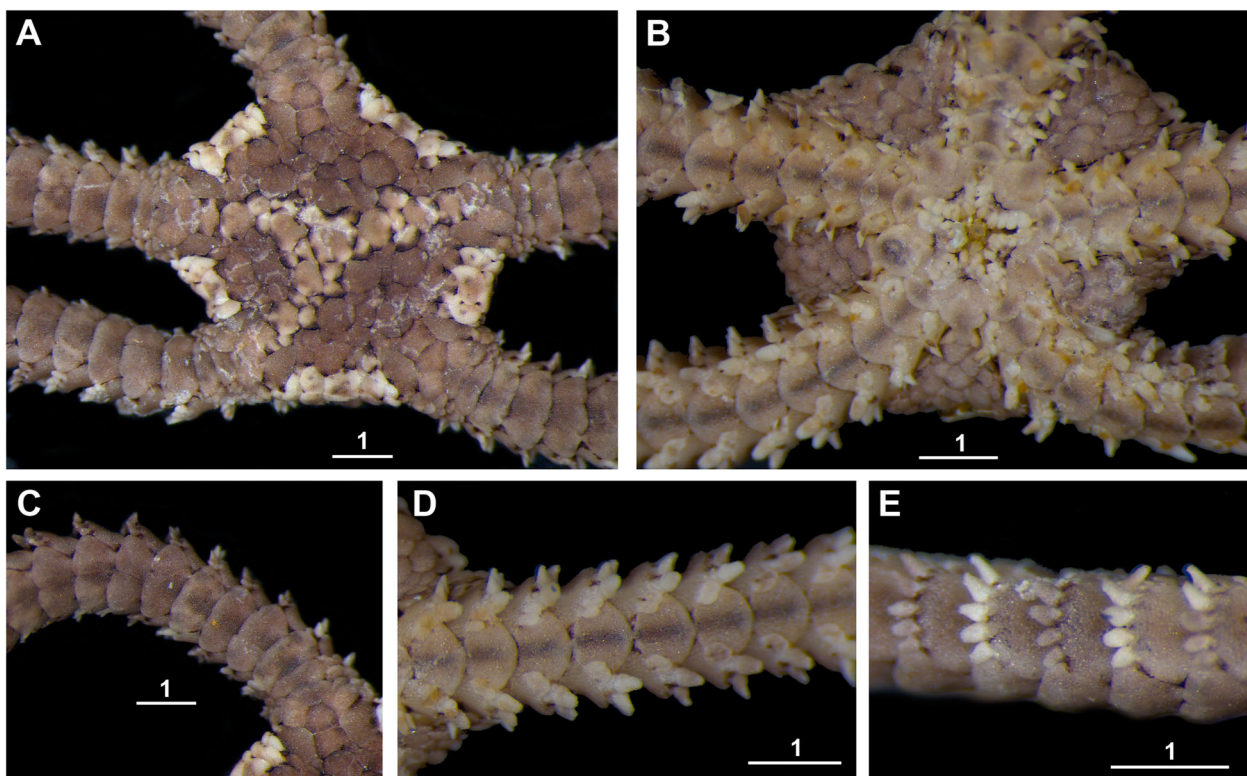


Figure 5. *Ophioplocus declinans* (Koehler, 1904), IO/SS/ECD/00244. A, disc, dorsal view; B, disc, ventral view; C, arm, dorsal view; D, arm, ventral view; E, arm, lateral view showing arrangement of arm spines. Scale bars in mm.

triangular outer margin. A broad, triangular buccal scale positioned on the adradial surface of the oral plate; visible in the diastema between the infradental papilla and adoral shield spine. Dorsal arm plates twice as wide as long at the arm base, narrowly in contact, largely separated by dorsal extensions of lateral arm plates; with broadly rounded proximal distal margins. First ventral arm plate as long as wide, subsequent plates wider than long; rectangular with straight margins. Lateral arm plates prominent, extending dorsally between consecutive dorsal arm plates; with prominent spine ridges. Arm spines numbering three in proximal segments, increasing to six; middle spines longest, length just exceeding the corresponding arm segment; ventral most and dorsal most spines shorter than corresponding arm segment. In the first 5–7 arm segments, the middle arm spines conspicuously modified as recurved, hook-like structures ending in sharp, glassy points; all other spines bluntly conical. Two flat, semi-circular tentacle scales, of which the inner one is larger.

Colour

Disc dark, almost black, arms off-white in live and preserved specimens.

Distribution

South Africa (Clark and Courtman-Stock 1976; Olbers et al. 2019), Mozambique (H. L. Clark 1939), Madagascar (OBIS 2021), Oman (H. L. Clark 1939), India: Andaman & Nicobar Islands, Indonesia (Koehler 1904), Philippines (Koehler 1930), Taiwan (OBIS 2021); 100–1415 m.

Remarks

Amphiura (*Amphiura*) *uncinata* is known from the western Indian Ocean, the Malay Archipelago and the western Pacific Ocean; it is being reported for the first time from the Indian EEZ.

Family Hemieuryalidae Verrill, 1899

Genus *Ophioplocus* Lyman, 1861

Ophioplocus declinans (Koehler, 1904)

(Figure 5)

Ophioceramis declinans Koehler, 1904: 15–16, pl. 3(8–9). — H. L. Clark 1915: 337. — Koehler 1922: 421–422; 1930: 262.

Ophioplocus declinans — Thomas 1975: 237–239, fig. 2(g).

Material examined

Andaman & Nicobar Islands – Off Kamorta Island, 8° 21.91'N, 93°34.37'E, 71 m (FORVSS388, St. 12), 13.08.2019, dredge, 1 specimen (IO/SS/ECD/00244).

Description

IO/SS/ECD/00244: Disc pentagonal; d.d. 5.5 mm, arms 4–5 times d.d. Disc scales large, polygonal or rounded, arranged irregularly; centrodorsal and primary plates distinct. Disc scales, oral shield, adoral shield and oral plate, as well as dorsal, ventral and lateral arm plates strongly beaded. Radial shields small, triangular to oval, separated by a row of 2–3 transversely wide disc scales; a pair of rounded disc scales distal to the radial shields, between which the first dorsal arm plate is wedged. Ventral disc scales similar to dorsal side, with imbricating arrangement. Genital slits long, genital scales not discernible. Oral shields triangular proximally, with a prominent distal lobe; adoral shields crescent-shaped, meeting interradially. Teeth not discernible. Four conical, pointed papillae on each side of the jaw. Dorsal arm plates intact and trapezoid basally, broadly in contact; distally a few extensively fragmented and most partially fragmented. Ventral arm plates with convex distal margin and concave lateral margins. Arm spines numbering four; conical, short, less than half the segment in length; subequal, the ventral-most slightly longer and stouter. Three tentacle scales on basal segments, two on remaining segments.

Colour

Preserved specimen grey overall with darker and lighter patches on the disc dorsally; ventral side lighter grey, with a continuous dark (black) longitudinal stripe along the entire length of the arm.

Distribution

India: Andaman & Nicobar Islands, Indonesia (Koehler 1904), north-western Australia (OBIS 2021), Philippines (Koehler 1922, 1930), Papua New Guinea (OBIS 2021); 30–400 m.

Remarks

The single specimen collected from the Nicobar Islands is a juvenile, judging by the smaller size and arrangement as well as relative development of skeletal elements.

Ophioplocus declinans is previously recorded only around the Malay Archipelago and from north-western Australia; this is the first report of this species from the northern Indian Ocean.

Family Ophiolepididae Ljungman, 1867

Genus *Ophiolepis* Müller & Troschel, 1840

Ophiolepis cardioplax Murakami, 1943

(Figure 6)

Ophiolepis cardioplax Murakami, 1943: 181–183; fig. 7. — A. M. Clark & Rowe 1971: 129.

Material examined

Andaman & Nicobar Islands – Off Great Nicobar Island, 6°30.44'N, 93°46.26'E, 88 m (FORVSS367I, St. 1), 13.11.2017, Smith-McIntyre grab, 1 specimen (IO/SS/ECD/00245); 6°38.84'N, 93°49.70'E, 56 m (FORVSS388, St. 18), 16.08.2019, dredge, 1 specimen (IO/SS/ECD/00246).

Description

IO/SS/ECD/00246: Disc pentagonal; d.d. 8 mm, arms slender, 4–5 times d.d. Disc scales large, thick, rounded; arrangement of scales regular and imbricating, with more or less sunken proximal margins and elevated distal margins. Each large scale surrounded by a ring of smaller scales. Imbricating arrangement of disc scales giving the disc a distinctly rough appearance. Centrodorsal and primary plates distinct. Radial shields small, triangular, with a convex abradial lobe; having a flat external surface, sunken below the disc scales; pairs separated by a single row of disc scales radially and three rows interradially. Ventral interradii covered by larger scales interspersed with smaller ones. Genital slits long; bordered by one long, distal genital plate and three short genital scales proximally. Oral shield thick, longer than wide; somewhat pentagonal, with an acute proximal angle and prominently U-shaped distal margin. Adoral shield crescent-shaped, meeting interradially, having an additional distal lobe which runs along the abradial edge of the first lateral arm plate. Teeth with squared tips, ventral-most slightly more rounded. Five papillae along each side of the jaw – corresponding to an infra-dental papilla, a buccal scale, a primary and secondary adoral shield spine, followed by a Lyman's ossicle; the primary adoral shield spine is twice as broad as the preceding papillae, which are more or less pointed; Lyman's ossicle conspicuously long. Proximal five arm segments located within the disc. Articulation of vertebrae streptospondylous. Dorsal arm plates wider

than long, broader distally; broadly in contact; with straight proximal and rounded distal margins; a single, small accessory dorsal arm plate inserted in the notch between dorsal and lateral arm plates. Ventral arm plates broader than long, broadly in contact; with convex distal margin and concave lateral margins; the first ventral arm plate conspicuously smaller. Lateral arm plates stout; external surface with horizontal striations and two prominent spurs on the proximal third, remaining surface with minute thorns on the tubercles; internal surface with prominent knob on the ventro-proximal edge, ridge restricted to the ventral side and one perforation. Spine articulations sunken into the distal margins of lateral arm plates; muscle and nerve openings of equal size, framed by very weak dorsal and ventral lobes. Arm spines numbering five; conical, very short, about one fourth of the segment in length; subequal with the ventral-most slightly longer and stouter. Two subequal tentacle scales, together forming an oval operculum; basal segments with 1–2 small, additional tentacle scales borne on the ventral arm plates.

Colour

Cream overall, with peach to light brown spots or patches which are denser on the dorsal side; dorsal surface of the disc with bigger patches of the same colours; transverse black annulations on the arms dorsally. Preserved specimens retaining similar colour, but paler.

Distribution

India: Andaman & Nicobar Islands, Philippines (OBIS 2021), Japan (Murakami 1943); 0–190 m.

Remarks

Though Cherbonnier and Guille (1978) synonymized *Ophiolepis cardioplax* with *O. irregularis* Brock, 1888, the two species are distinct and valid according to Pineda-Enríquez et al. (2018). A complete revision of genus *Ophiolepis* is underway (Pineda-Enríquez et al. 2018), which will shed light on the limits between species. In the interim, the present specimens, which match exactly with the type description of Murakami (1943), are assigned to *O. cardioplax*, in consultation with T. Pineda-Enríquez (pers. comm.).

Ophiolepis cardioplax has been previously recorded only in the western Pacific, and this is the first report of the species in the Indian Ocean.

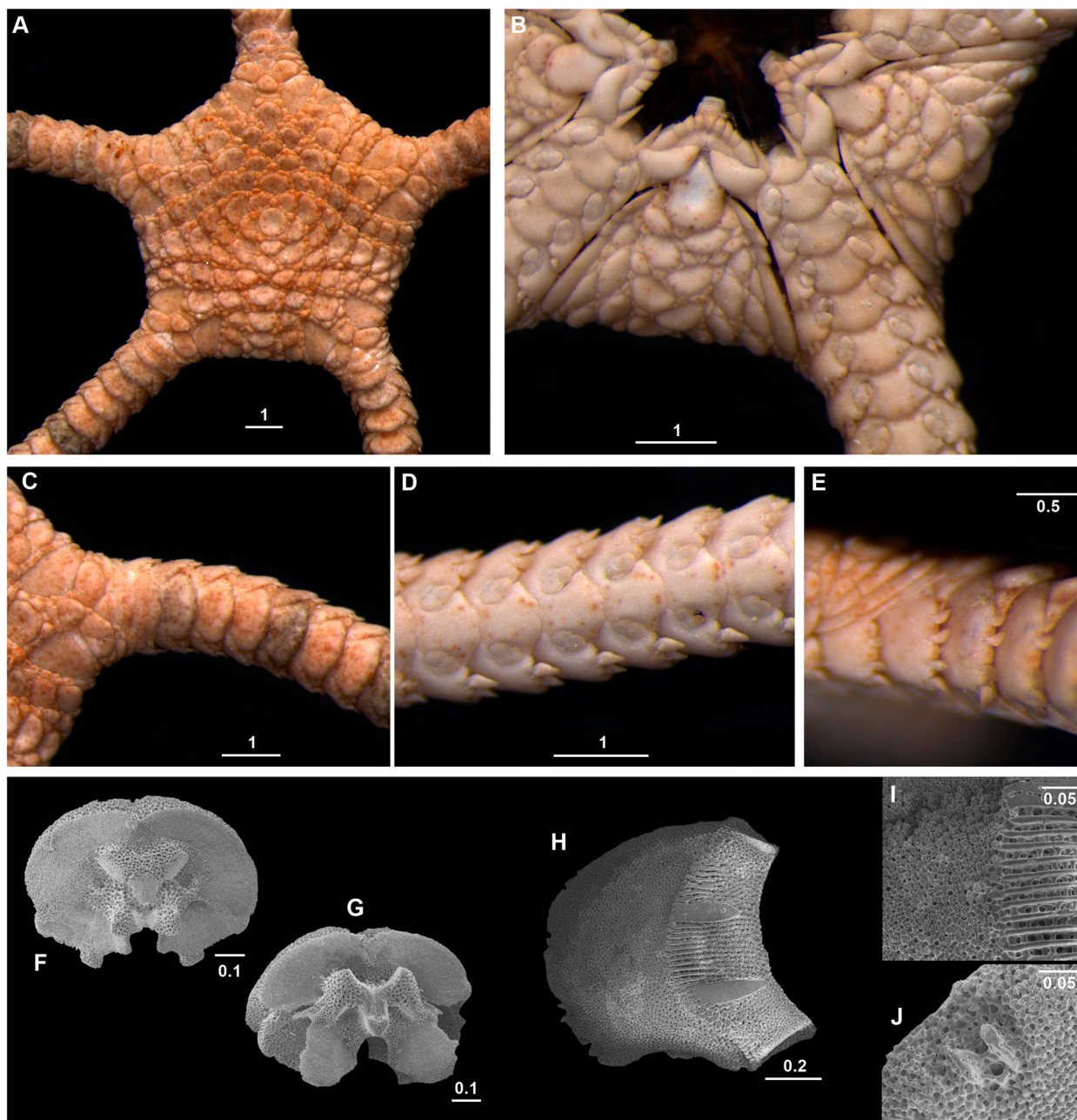


Figure 6. *Ophiolepis cardioplax* Murakami, 1943, A–E: IO/SS/ECD/00246, F–J: IO/SS/ECD/00245 SEM images. A, disc, dorsal view; B, disc, ventral view; C, arm, dorsal view; D, arm, ventral view; E, arm base, lateral view showing arrangement of arm spines; F, proximal arm vertebra, proximal view; G, same, distal view; H–J, lateral arm plate from proximal arm; H, entire plate, external view; I, enlarged external view showing thorns on the tubercles; J, distal view showing arm spine articulation. Scale bars in mm.

Order Ophiacanthida O'Hara, Hugall, Thuy, Stöhr & Martynov, 2017

Family Ophiacanthidae Ljungman, 1867

Genus Ophialcaea Verrill, 1899

Ophialcaea tuberculosa (Lyman, 1878)

(Figure 7)

Ophiacantha tuberculosa Lyman, 1878: 137, pl. 8(204–205). — Lyman 1882: 181, pl. 10(1–3).

Ophiacantha congesta Koehler, 1904: 103–104, pl. 24 (1–2).

Ophialcaea congesta — H. L. Clark 1915: 217. — A. M. Clark 1965: 41–42. — Guille 1981: 424.

Ophialcoea congesta — Koehler 1922: 85, fig. 15 (6–7).

Ophialcaea tuberculosa — H. L. Clark 1915: 217. — O'Hara & Stöhr 2006: 63–64.

Material examined

Andaman & Nicobar Islands – Off Great Nicobar Island, 7°42.68'N, 93°19.64'E, 395 m (FORVSS292, St. 90),

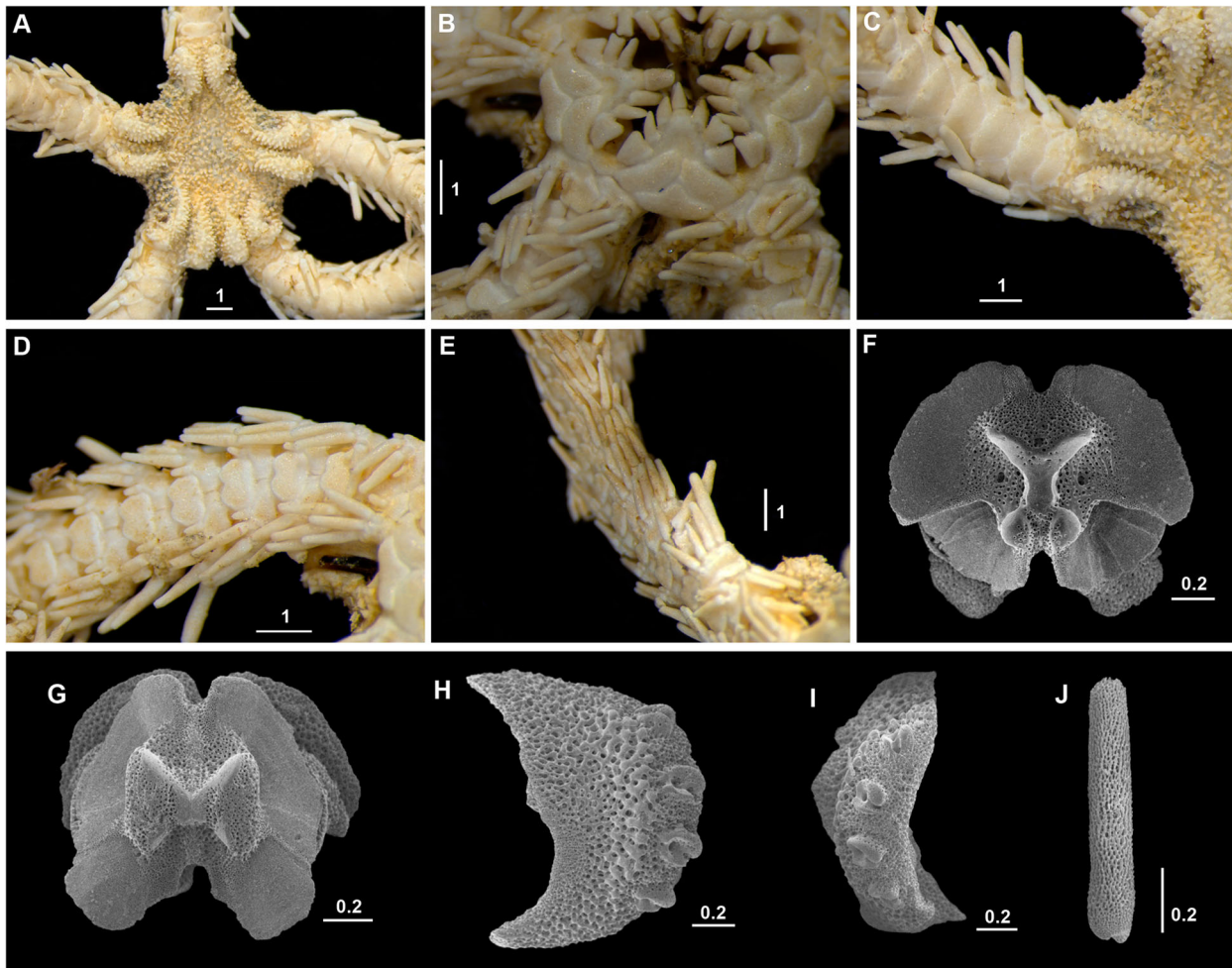


Figure 7. *Ophialcaea tuberculosa* (Lyman, 1878), A–E, IO/SS/ECD/000254, F–J, IO/SS/ECD/000255 SEM images. A, disc, dorsal view; B, disc, ventral view; C, arm base, dorsal view; D, arm base, ventral view; E, same, lateral view showing arm spines; F, proximal arm vertebra, proximal view; G, same, distal view; H, lateral arm plate from proximal arm, external view; I, lateral arm plate from proximal arm, distal view showing spine articulations; J, arm spine. Scale bars in mm.

13.12.2011, demersal trawl, 1 specimen (IO/SS/ECD/000253); 13°19.19'N, 93°15.72'E, 635 m (FORVSS367II, St. 08), 26.11.2017, demersal trawl, 6 specimens (IO/SS/ECD/000254, 000255).

Description

IO/SS/ECD/000254: Disc excavate interradially; d.d. 9 mm, arms about 3–4 times d.d. Disc scaling obscured by skin, which bears spaced, low conical tubercles on the dorsal and ventral surface; radial shields separated throughout their length; visible as narrow, raised bars underneath the tuberculated skin, with length about one fourth of d.d. Genital slits short, nearly vertical. Oral shields twice as wide as long; with an acute proximal angle, concave lateral margins and a wide, straight distal margin. Adoral shields crescent-shaped, meeting interradially but not radially. Oral

and adoral shields, as well as lateral and ventral arm plates conspicuously beaded. Teeth, including ventral-most conical, pointed. Three papillae along each side of the jaw – corresponding to an infra-dental papilla, a lateral oral papilla and an adoral shield spine; the former two conical, pointed, the latter broad and scale like, sometimes with a notch along the distal margin. Articulation of vertebrae intermediate between strepto- and zygospondylous. Dorsal arm plates broader than long, trapezoid and broadly in contact; some plates extensively fragmented, particularly in the distal part of the arm. Ventral arm plates wider than long, with a straight proximal margin and conspicuously concave distal margin. Lateral arm plate prominently arched; external side with broad, elevated ridge distally, on which spine articulations are placed; internal face with an oblique, continuous ridge, a low, rounded knob and a single perforation.

Spine articulations large, prominent and ear-shaped; proximally open with strong sigmoidal fold; large, round muscular opening and smaller, oval nerve opening. Arm spines stout and blunt, slightly longer than the corresponding segment in length; numbering 4–5 basally, of which the dorsal-most is slightly stouter and longer. Tentacle scale lanceolate, approximating the length of the ventral arm plate.

Colour

Cream to off-white throughout in live and preserved specimens.

Distribution

India: Andaman & Nicobar Islands, Indonesia (Koehler 1904; Clark 1965), western Australia (OBIS 2021), Philippines (Lyman 1878, 1882; Koehler 1922; Clark 1965; Guille 1981), Papua New Guinea (OBIS 2021); 640–970 m.

Remarks

This species was collected with the cidarid urchin *Histocidaris denticulata* Koehler, 1927 on both occasions, and in one case (FORVSS292, St. 90), the specimen was entangled with the urchin's spines; it is possibly associated with *H. denticulata* as an epibiont.

Ophialcaea tuberculosa is reported from the south-eastern Indian Ocean, the Malay Archipelago and the western Pacific Ocean; it is being recorded for the first time from the northern Indian Ocean.

Family Ophiidermatidae Ljungman, 1867

Genus Ophiopsammus Lütken, 1869

Ophiopsammus aequalis (Lyman, 1880)

(Figure 8)

Ophiopeza aequalis Lyman, 1880: 9–10, pl. 2(23–25). — Lyman 1882: 12–13, pl. 27(7–9) — Koehler 1904: 10. — A. M. Clark 1968: 313.

Pectinura aequalis — H. L. Clark 1909: 118; 1915: 303. — Koehler 1922: 337, pl. 77(16–17).

Ophiopsammus aequalis — Vail & Rowe 1989: 278–280, fig. 6.

Material examined

Andaman & Nicobar Islands – Off Katchall Island, 8° 00.45'N, 93°16.82'E, 94 m (FORVSS261, St. 35B), 24.01.2009, dredge, 1 specimen (IO/SS/ECD/000256).

Description

IO/SS/ECD/000256: Disc pentagonal, d.d. 20 mm, arms long and delicate, about 6 times d.d. Disc with interradii slightly excavate, giving it a somewhat stellate outline; disc scales flat and thin; entire disc, except oral shields, covered by rounded granules. Radial shields small, 1.5–2 mm, ovate; pairs separated widely by disc scales. Marginal disc scales distinguishable, but not convex; numbering 9–11 in each interradius; middle scale largest. A conspicuous notch at the junction of arms and disc. Genital slits long and entire. Oral shields sub-triangular, with straight or rounded distal margins; supplementary oral shields not observed. Adoral shields crescent shaped, much smaller than oral shield; not meeting radially or interradially. Oral plates as well as distal half of adoral shields obscured by granules, which are larger than disc granules. Up to eight papillae along each side of the jaw – corresponding to a conical tooth papilla, an infra-dental papilla and three lateral oral papillae, followed by broad scale-like primary and secondary adoral shield spines, as well as a Lyman's ossicle; the adoral shield spine widest and overlapping the last. Dorsal arm plates much wider than long, strongly carinate, with straight proximal and ventral margins. Ventral arm plates wider than long, hexagonal. Arms spines short and pointed, less than half the length of lateral arm plate; numbering 7–8; the dorsal-most spine shorter than the rest, the ventral-most is longer and broader. Two ovate tentacle scales; adradial one larger, the abradial scale overlapping the base of the ventral-most arm spine.

Colour

Reticulate markings of pale and dark salmon on the dorsal disc; broad, transverse light and dark salmon markings on the arms dorsally; ventral side uniformly off-white. Preserved specimens entirely off-white.

Distribution

India: Andaman & Nicobar Islands, Indonesia (Koehler 1904), Australia (Vail and Rowe 1989), Philippines (Koehler 1922), Papua New Guinea (Lyman 1880, 1882), New Caledonia (OBIS 2021), Vanuatu (OBIS 2021); 94–401 m.

Remarks

The material from the Nicobar Islands is assigned to *Ophiopsammus aequalis* based on the long, delicate

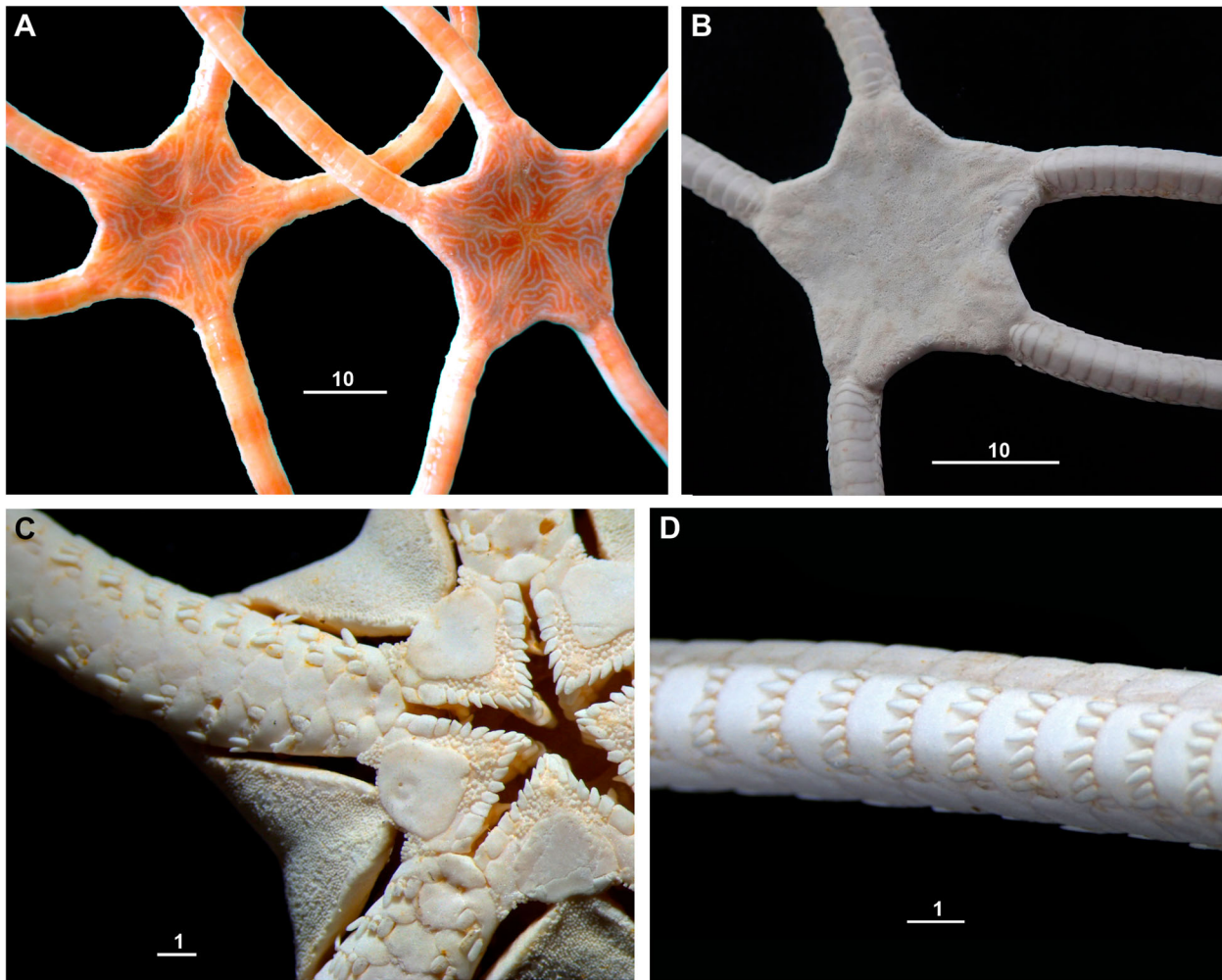


Figure 8. *Ophiopsammus aequalis* (Lyman, 1880), IO/SS/ECD/000256. A, live specimens, dorsal view; B, disc of preserved specimen, dorsal view; C, disc, ventral view; D, arm, lateral view showing arrangement of arm spines. Scale bars in mm.

arms with strongly carinate dorsal arm plates, the number, size and arrangement of arm spines as well as the jaw structure. These characters clearly distinguish it from the only other species of *Ophiopsammus* reported from Indian waters – *O. yoldii* (Lütken, 1856). Previous works mostly describe decolourized

specimens of *O. aequalis*, while Koehler (1922) noted a pink colour on the dorsal surface, with darker red annulations on the arms. The live photographs of the Nicobar specimens show a salmon colour, with light reticulate markings on the dorsal disc and broad transverse annulations on the arms dorsally.

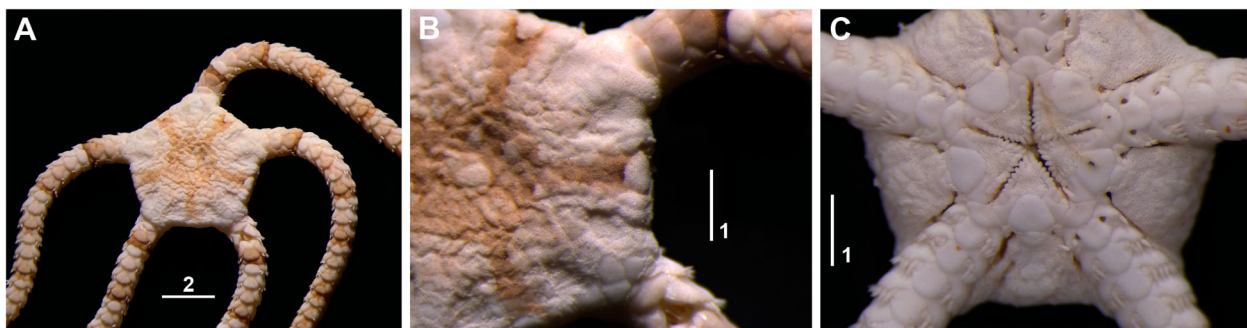


Figure 9. *Ophiopeza spinosa* (Ljungman, 1867), IO/SS/ECD/00250. A, disc, dorsal view; B, interradius, dorsal view showing the marginal plates; C, disc, ventral view. Scale bars in mm.

Ophiopsammus aequalis has been previously recorded from the Malay Archipelago and the south-western Pacific Ocean; it is being recorded for the first time from the Indian Ocean.

Family Ophiopozidae O'Hara, Stöhr, Hugall, Thuy & Martynov, 2018

Genus Ophiopeza Peters, 1851

Ophiopeza spinosa (Ljungman, 1867)

(Figure 9)

Ophiarachna spinosa Ljungman, 1867: 305–306.

Ophiopeza fallax Lütken, 1869: 35. [non *fallax* Peters, 1851]

Pectinura spinosa — Lyman 1874: 221; 1882: 17.

Ophiopozella spinosa — H. L. Clark 1909: 120; 1915: 304; 1921: 141; 1946: 258. — Koehler 1922: 338–339.

Ophiopozella lütkeni de Loriol, 1893a: 392–394, pl. 13 (1a–e).

Ophiopozella dubiosa de Loriol, 1893b: 7–9, pl. 23(2a–f). — H. L. Clark 1909: 120; 1915: 304.

Distichophis clarki Ely, 1942: 47–48, fig. 12.

Ophiopeza dubiosa — A. M. Clark 1968: 313. — A. M. Clark & Rowe 1971: 127.

Ophiopeza spinosa — A. M. Clark 1968: 313; 1980: 545–546. — A. M. Clark & Rowe 1971: 127; fig. 44e. — Devaney 1974: 184–186. — Gibbs et al. 1976: 130. — Tortonese 1977: 285, fig. 7; 1980: 129, fig. 7(C). — Cherbonnier & Guille 1978: 227–228, pl. 17(3–4). — Kingston 1980: 145. — Vail & Rowe 1989: 273–275; fig. 3. — Marsh et al. 1993: 62. — Fujita et al. 2008: 8, fig. 4(Q–R). — Boissin et al. 2016: 288, fig. 5(b). — Olbers et al. 2019: 148–150, fig. 139.

Indophioderma ganapatii Sastry, Marimuthu & Rajan, 2019: 361–362, figs 8–9.

Material examined

Andaman & Nicobar Islands – Off Little Andaman, 10° 40.57'N, 92°40.87'E, 49 m (FORVSS292, St. 50), 04.12.2011, dredge, 1 specimen (IO/SS/ECD/000248). – Off Nancowry Island, 7°59.84'N, 93°38.29'E, 58 m (FORVSS292, St. 70), 08.12.2011, dredge, 2 specimens (IO/SS/ECD/000249). – Off Great Nicobar Island, 6°38.84'N, 93°49.70'E, 56 m (FORVSS388, St. 18), 16.08.2019, dredge, 1 specimen (IO/SS/ECD/000250).

Description

IO/SS/ECD/00250: Disc pentagonal; d.d. 5 mm, arms up to 5 times d.d. Disc scales coarse dorsally and ventrally, covered entirely by flat-topped granules. Radial shields small, slightly sunken and completely obscured by granules; separated from each other by a single row

of scales. Marginal disc scales 5–7 in number, prominently convex under the disc granules. Genital slits long and entire. Oral shield longer than or as long as wide; sub-triangular with rounded margins and straight distal edge. Supplementary oral shield present, obscured completely or partially by disc granulation. Adoral shields triangular, much smaller than oral shield; not meeting radially or interradially. Oral plates obscured by granules. Teeth rounded, ventral-most tooth conical, pointed. Up to nine papillae along each side of the jaw – corresponding to a tooth papilla, an infra-dental papilla, 3–4 lateral oral papillae, a primary and secondary adoral shield spine, as well as a Lyman's ossicle; the proximal papillae pointed conical and distal papillae becoming broader and scale-like; adoral shield spines widest and overlapping the Lyman's ossicle. Dorsal arm plates fan-shaped, as wide as long and in contact in the proximal third of the arm; becoming smaller and separated distally. Ventral arm plates more or less hexagonal, longer than wide proximally, with a rounded distal margin. Arm spines less than half the lateral arm plate in length, pointed, adpressed; numbering 8–12; the ventral spines slightly longer, if at all. Two ovate tentacle scales; adradial one larger, the abradial one overlapping the base of the ventral-most arm spine.

Colour

Dull cream colour with brown blotches on the disc and dark brown banding on the arms dorsally.

Distribution

South Africa (Olbers et al. 2019), Mozambique (Ljungman 1867), Mayotte (OBIS 2021), Madagascar (Cherbonnier and Guille 1978), Reunion (Boissin et al. 2016), Mauritius (Loriol 1893b) Seychelles (A. M. Clark 1980), Somalia (Tortonese 1980), Red Sea (Tortonese 1977; Clark 1980), Oman (OBIS 2021), Maldives (OBIS 2021), India: Lakshadweep Islands (Sastry et al. 2019) and Andaman & Nicobar Islands, Sri Lanka (OBIS 2021), Malaysia (Fujita et al. 2008), Cocos Islands (OBIS 2021), Indonesia (Loriol 1893a; Clark 1909), Australia (H. L. Clark 1921, 1946; Gibbs et al. 1976; Kingston 1980; Vail and Rowe 1989; Marsh et al. 1993), Japan (OBIS 2021), Philippines (Koehler 1922), Guam (OBIS 2021), Papua New Guinea (OBIS 2021), Solomon Islands (OBIS 2021), Fiji (H. L. Clark 1909), Tonga (Lyman 1882), French Polynesia (H. L. Clark 1909; Devaney 1974), Kiribati (OBIS 2021), Hawaii Archipelago (Ely 1942); 0–110 m.

Remarks

The present specimens seem to have fewer marginal disc scales than other known materials (e.g. see Vail and Rowe 1989). This is attributed to their relatively small size.

Indophioderma ganapatii Sastry, Marimuthu & Rajan, 2019 was described as a new species of Ophiidermatidae based on a single specimen from Agatti Island, Lakshadweep. Parameswaran et al. (2020) discussed the validity of this species, suggesting it to be a misidentification of *Ophiopeza spinosa*, based on the 'the enlarged and completely granule-covered marginal disc plates, the shape of the dorsal and ventral arm plates as well as plates of the oral apparatus, the numbers and shape of arm spines, oral papillae, colour of the specimen etc.' This is confirmed by comparing the type photographs of *I. ganapatii* with the present specimens from the Andaman and Nicobar Islands. The only character distinguishing the two species appears to be the lack of granules on the ventral surface of the oral plate in *I. ganapatii*, which could have been lost during collection or preservation. Therefore, *I. ganapatii* is herein synonymized with *O. spinosa*. Since this was the type and only species under genus *Indophioderma*, this genus name is rendered invalid, and herein synonymized with genus *Ophiopeza*.

Despite being common in the Indo-west Pacific, this species is being recorded for the first time from the Indian EEZ, based on the present specimens from the Andaman & Nicobar Islands and the specimens described (as *I. ganapatii*) by Sastry et al. (2019) from the Lakshadweep.

Discussion

Documentation of ophiuroid biodiversity in the northern Indian Ocean, particularly beyond coastal waters has gained momentum in recent years, after a gap of nearly a century, especially through the Marine Living Resources Program of the Ministry of Earth Sciences. This has led to the addition of many species (Parameswaran and Abdul Jaleel 2012; Stöhr et al. 2012a; Parameswaran et al. 2013, 2016, 2018, 2020). This paper describes nine further new records for India based on collections from the eastern Arabian Sea, western Bay of Bengal and around the Andaman & Nicobar Islands. Of these, two species – *Ophiolepis cardioplax* Murakami, 1943 and *Ophiopsammus aequalis* (Lyman, 1880) are being reported for the first time from the Indian Ocean, and four others – *Astrothorax waitei* (Benham, 1909), *Amphiophiura insolita* (Koehler, 1904), *Ophialcaea tuberculosa* (Lyman,

1878) and *Ophioplocus declinans* (Koehler, 1904) are new records for the northern Indian Ocean. The three remaining species – *Amphiura* (*Amphiura*) *dejectoides* H.L. Clark, 1939, *Amphiura* (*Amphiura*) *uncinata* Koehler, 1904 and *Ophiopeza spinosa* (Ljungman, 1867), which are recorded elsewhere in the Indian Ocean, are being reported for the first time from Indian waters. Among these species, several (such as *Amphiophiura insolita*, *Ophiopsammus aequalis* and *Ophioplocus declinans*) have been collected and documented very rarely. The descriptive accounts in this paper, therefore, provide new information on the taxonomic characters of these species, including colouration of live specimens. This paper also presents the first descriptive account of *Ophiolepis cardioplax* since its original description by Murakami (1943), and it presents much more detailed photographs of external and internal characteristics.

The distribution ranges of *Ophiolepis cardioplax*, *Ophiopsammus aequalis*, *Ophialcaea tuberculosa* and *Ophioplocus declinans* are being extended from the western Pacific Ocean and Malay Archipelago to the Andaman & Nicobar Islands in the north-eastern Indian Ocean. This is indicative of continuity in faunal distribution between these regions, and extension of coral triangle fauna across the Malacca Strait towards the coral reefs of the Andaman Sea (Stöhr et al. 2012b). The high-diversity region for brittle stars according to Stöhr et al. (2012b), the 'Indo-Pacific' region, included the waters around the Andaman & Nicobar archipelago as well. A similar extension of 'coral triangle fauna' to the Andaman & Nicobar Islands is also reported in the case of macrobenthic polychaetes (Gopal et al. 2020). Based on collections from the eastern Arabian Sea, the distribution range of *Astrothorax waitei* is being extended across the equator into the northern Indian Ocean. Intensified sampling efforts in the Indian Ocean are not only adding to regional biodiversity inventories but also filling gaps in knowledge of global faunal distribution. The present findings highlight the need for continuing biodiversity surveys in the region, with emphasis on the deep-sea (>200 m).

Data availability statement

The authors confirm that the data supporting the findings of this study are available within the article itself.

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Disclosure statement

No potential conflict of interest was reported by the author(s).

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