



***Asteroschema sampadae* (Ophiuroidea: Asteroschematinae), a new deep-sea brittle star from the continental slope off the southern tip of India**

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Abstract

A new species of deep-sea euryalid ophiuroid, *Asteroschema sampadae* is described from the continental margin off the southern tip of India. This species is distinguished from others in having scattered, distinctly conical epidermal ossicles throughout the aboral surface of the disc and arms and minute, scattered granular ossicles on the oral side. This is the fourth report of the genus *Asteroschema* from Indian waters (including Andaman & Nicobar Islands) and the first report of this genus from around the Indian peninsula since the report of *Asteroschema flosculus* from a coral bank off Nellore, Andhra Pradesh by Alcock in 1893.

Key words: Ophiuroidea, Asteroschematinae, *Asteroschema*, India, continental slope

Introduction

The genus *Asteroschema* Örsted and Lutken, 1856 under the subfamily Asteroschematinae in family Euryalidae falls in order Euryalida of class Ophiuroidea. The characters of this order include the presence of thick skin over the disc and arms, below which regularly arranged plates are absent. The skin may also be variously ornamented with tubercles, granules or spines. The disc is usually small with a rounded or scalloped edge, and the arms are slender and long or may be branched. The arms roll in vertical coils, the lateral arm plates are located on the oral side of arms, with the arm spines borne at the ventro-lateral margin of the arms and oriented downwards. The jaws are simple and comprised of an unpaired oral plate, paired adoral shields and oral plates. The oral plates, which extend into the mouth, are often, but not always bordered with oral papillae on the sides and always bear tooth papillae at the apex (Mortensen, 1933; Baker, 1980; Smith *et al.*, 1995; Martynov, 2010; Okanishi *et al.*, 2011b).

The subfamily Asteroschematinae Verrill, 1899, sensu Okanishi *et al.*, 2011b is composed of two genera: *Asteroschema* Örsted and Lutken, 1856 and *Ophiocreas* Lyman, 1879, both with body covered by naked or tuberculated skin, simple arms, gonads extending into the proximal part of the arm, ventral groove of the vertebrae open, lateral arm plates in contact along the entire length of the arm (Okanishi & Fujita, 2011b), and presence of two arm spines throughout the arm, which in the distal end of the arm are represented as hook-shaped spines without regularly arranged perforations. The genus *Asteroschema*, comprising 34 species, is differentiated from *Ophiocreas* by the presence of conical (cone-shaped), granular (granule shaped) or plate-like (plate-shaped) epidermal ossicles embedded in the skin. Fifteen species of *Asteroschema* were described before 1900 (Pallas, 1788; Lyman 1872, 1875, 1878, 1879; Ljungman 1872; Alcock 1893; Verrill 1894, 1899; Lütken & Mortensen 1899), from the Gulf of Mexico, Bay of Bengal, the Atlantic and Pacific oceans; and 14 species were described between 1904 and 1949 (Koehler 1904, 1907, 1914; Matsumoto 1915; A. H. Clark, 1917; Mortensen, 1925; H. L. Clark, 1939; Murakami, 1944; A. H. Clark, 1949), from the Gulf of Mexico, the Indo-west Pacific, Pacific and Atlantic Oceans. Since then, four new species have been described, 3 from around New Zealand (Baker, 1980; McKnight, 2000) and one from off Amami-oshima Island, south of Japan (Okanishi & Fujita, 2009). A subsequent re-evaluation has led to the transfer of the species collected from Amami-oshima Island to a new genus *Squamophis* (Okanishi *et al.*, 2011a). The systematics of the order Euryalida has been subjected to recent revision based on molecular phylogenetics of mitochondrial and nuclear ribosomal genes (Okanishi *et al.*, 2011b).

The genus is reported widely from the Atlantic, Pacific and Indian Oceans, usually at depths greater than 200m. The first report of this genus around India was made by Alcock (1893), who described a new species, *Asteroschema flosculus* from a coral bank off Nellore, Andhra Pradesh. Ludwig Doderlein (1930) described a new species, *Asteroschema subfastosum* from the west of Nicobar Islands and also noted the occurrence of *A. fastosum* Koehler, 1904 in this region. Another species, *A. lissum* was described from the Maldives area, collected during the John Murray Expedition, 1933–34 (H. L. Clark, 1939). The reports of *A. flosculus*, *A. subfastosum*, *A. fastosum*, and *A. lissum* are the only records of the genus *Asteroschema* around Indian waters.

The species of *Asteroschema* are differentiated based on the shape and arrangement of the epidermal ossicles, the relative size and shape of arm spines and the number of arm segments proximal to the appearance of the second arm spine. A comparison carried out by Okanishi & Fujita (2009), based on examination of several type specimens and from literature found that 19 species possessed only granular ossicles embedded in the skin while 13 species possessed conical ossicles, either unaccompanied or in combination with granular ossicles. Additionally, 3 species were found to bear flat, polygonal plate-shaped ossicles along with rounded granular ossicles (Table 1).

TABLE 1. Shape of epidermal ossicles of all species of *Asteroschema*, based on Okanishi & Fujita, 2009.

Species with granular epidermal ossicles only	Species with granular and conical epidermal ossicles
<i>A. ajax</i> A. H. Clark, 1949	<i>A. edmondsoni</i> A. H. Clark, 1949
<i>A. arenosum</i> Lyman, 1878	<i>A. flosculus</i> Alcock, 1893 †*
<i>A. bidwillae</i> McKnight, 2000	<i>A. horridum</i> Lyman, 1879
<i>A. brachiatum</i> Lyman, 1879	<i>A. migrator</i> Koehler, 1904
<i>A. clavigerum</i> Verrill, 1894	<i>A. monobactrum</i> H. L. Clark, 1917 †
<i>A. elongatum</i> Koehler, 1914	<i>A. nuttingii</i> Verrill, 1899 †
<i>A. glaucum</i> Matsumoto, 1915	<i>A. oligactes</i> (Pallas, 1788)
<i>A. hemigymnum</i> Matsumoto, 1915	<i>A. rubrum</i> Lyman, 1879 †
<i>A. inornatum</i> Koehler, 1906	<i>A. subfastosum</i> Doderlein, 1930*
<i>A. intectum</i> Lyman, 1878	<i>A. tumidum</i> Lyman, 1879
<i>A. laeve</i> (Lyman, 1872)	<i>A. yaeyamense</i> Murakami, 1944
<i>A. lissum</i> H. L. Clark, 1939	<i>A. fastosum</i> Koehler, 1904 accepted as <i>A. horridum</i> Lyman, 1879*
<i>A. salix</i> Lyman, 1879	<i>A. ferox</i> Koehler, 1904 accepted as <i>A. tumidum</i> Lyman, 1879
<i>A. sublaeve</i> Lutken & Mortensen, 1899	
<i>A. sulcata</i> Ljungman, 1872	Species with plate-like and granular epidermal ossicles
<i>A. tenue</i> Lyman, 1875	<i>A. capense</i> Mortensen, 1925
<i>A. tubiferum</i> Matsumoto, 1915	<i>A. igloo</i> Baker, 1980
<i>A. vicinum</i> Koehler, 1907	<i>A. amamiense</i> Okanishi & Fujita, 2009 accepted as <i>Squamophis amamiense</i> (Okanishi <i>et al.</i> , 2009)
<i>A. wrighti</i> McKnight, 2000	

* Species previously reported from Indian waters.

† Presence of conical ossicles is not directly evident in the written description of these species, but examination of illustrative figures indicates that the ‘coarse’ or ‘rough’ granules described in these species are in fact ‘conical epidermal ossicles’ of some sort (confirmed by personal communication with Mr. M. Okanishi)

In the present paper, a new species, *Asteroschema sampadae* is described from off the southern tip of the Indian peninsula, which possesses well-spaced conical epidermal ossicles embedded in the skin of the aboral side of the disc and arms and minute, scattered, granular epidermal ossicles on the oral side. A table comparing the new species with the 13 species of *Asteroschema* that are described as having conical epidermal ossicles is presented, based on literature. The characters considered for this comparison are: size, epidermal ornamentation on the disc and arms, the size and shape of the arm spines and the position at which the first and second arm spines appear. Validity of certain other characters, such as the swelling of the arms at the base, for identification has been questioned in recent works (Okanishi & Fujita, 2011a; Stohr, 2011).

The specimens were collected on-board Fishery Oceanographic Research Vessel *Sagar Sampada* during a survey on the marine benthos in the continental slope of southwest India in May, 2007 (FORV SS Cr. 254). The organisms were found entangled in the frame of the modified Smith-McIntyre grab, after it was deployed at 454m (Fig. 1). The specimens were photographed and preserved in 5% neutral buffered formaldehyde. A portion of the arm of one specimen was preserved in alcohol. Taxonomic identification was carried out in the shore lab using a stereo-zoom microscope (Leica EZ4) and compound phase contrast microscope (Leica DME). The specimen were dissected to observe the vertebrae of the arms, and the skin was dissolved using 5% sodium hypochlorite solution to isolate ossicles and arm spines for Scanning Electron Microscopy (SEM). The type material is deposited in the FORV Referral Centre at the Centre for Marine Living Resources & Ecology (CMLRE), Kochi.

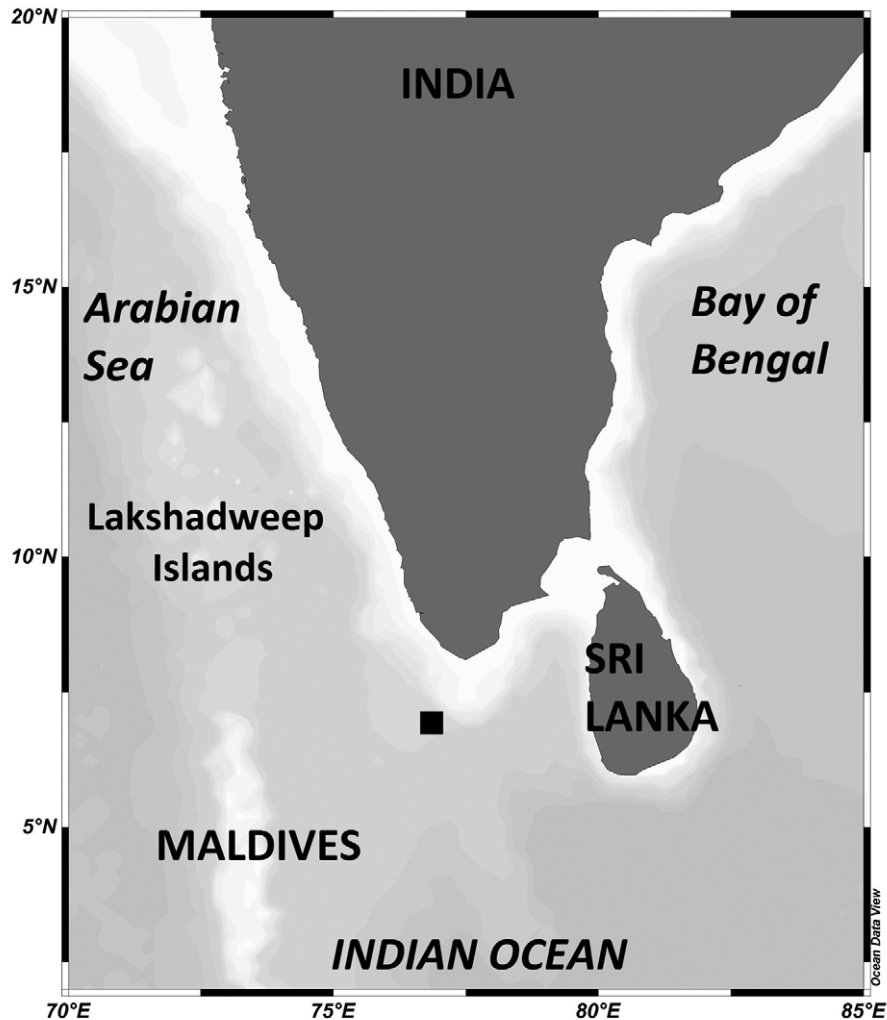


FIGURE 1. Map of the Indian Peninsula indicating the collection site.

Taxonomic account

Order Euryalida Lamarck, 1816

Family Euryalidae Lamarck, 1816, sensu Okanishi *et al.* (2011b)

Subfamily Asteroschematinae Verrill, 1899, sensu Okaniahi *et al.* (2011b)

Genus *Asteroschema* Örsted and Lutken, 1856 in Lutken, 1856

Type species: *Asterias oligactes* Pallas, 1788

Asteroschema sampadae sp. nov.

Materials examined. Holotype and paratype [CMLRE IO/SS/ECD/00021] collected on 20th May, 2007 from 454m (Lat. 7° 10'N Long. 77° 19'E) during FORV *Sagar Sampada* Cruise No. 254.

Diagnosis. Disc diameter (d.d.) about 18mm, arms about 380–450mm (21–23 times d.d.) Disc and arms covered by skin with small, scattered, distinctly conical epidermal ossicles on aboral side and minute spherical granular ossicles on oral side. Conical ossicles bearing a crown of minute spinous terminal projections. Dorsal ornamentation not closely packed anywhere on the body so that large parts of the disc and arms are overlaid by naked skin; but epidermal ossicles somewhat more dense on radial shields and at base of arms. Two arm spines from fourth arm segment; inner spine larger and approximately one third of the arm segment length, becoming twice the length of the arm segment in the middle of arm and bearing distinct thorny projections on the inner edge. The arm spines at the distal end of the arm are represented as small hook-shaped spines.

Etymology. The species is named after the vessel FORV *Sagar Sampada*, on which it was collected.

Type locality. Continental slope off the southern tip of India.

Description of holotype. Disc diameter 18.8 mm; arms between 380 mm and 450 mm long (about 21–23 times d. d.); moderately excavate inter-radially and covered by skin which bears conical epidermal ossicles aborally (Fig. 2B). Radial shields as narrow, elongate paired structures at base of arm; the shields widely separated running more or less parallel and extending a short distance beyond the disc proper; appearing to converge but not meeting centrally (Fig. 2B). Genital slits wide and vertical (Fig. 2C). Ossicles on aboral side of disc and around the genital slits are short and conical with a terminal projections at the tips (Fig. 2F); distributed more densely on radial shields than the rest of the disc, but not very closely packed anywhere, so that large parts of the disc and arms are overlaid by naked skin (Fig. 2A, B, D). Oral shield and oral plate covered by skin; embedded with minute spherical granular ossicles which are only visible when the dried skin is observed under a microscope. Oral plates elongate and extending into the mouth; bearing scattered, stout, domed granules on its vertical edge. Several, blunt and chisel shaped teeth; the lowermost tooth fragmented (Fig. 2C).

Arms not enlarged at the base; square in cross section, higher than wide at base (width 4.6 mm; height 4.9 mm); becoming more or less cylindrical and tapering distally. Aboral and lateral faces of the arm bearing conical epidermal ossicles similar to those on aboral side of the disc (Fig. 2D). Ossicles more numerous towards the base of the arms (2–3 granules in 1mm) and becoming scarce at the tip of the arms. They decrease in size towards the ventro-lateral margins; being represented on the oral side of the arm, as microscopic spherical granular ossicles, as on oral face of the disc (Fig. 2E).

Dorsal arm plates absent. Lateral arm plates small and ventro-lateral in position; the plates of each side meeting mid-ventrally, but not fused together. Tentacles of the basal arm joints covered by a hollow sheath which projects from the tentacle pore. Second tentacle pore without any arm spines, a single spine present in the next two arm segments and two spines thereafter. Arm spines bluntly tapering, covered by a thin layer of skin and bearing minute thorny projections on the inner edge (Fig. 3A, C, D). The inner arm spine always longer than the outer (Fig. 3A). Arm spines increase in size along the arm; at about a third of the arm length, the inner arm spine attains a length of 5mm (as long as the arm width and twice as long as the arm joint), becoming distinctly cylindrical with well-defined thorny projections on the inner edge (Fig. 3C, E). A mass of soft tissue adheres to the terminal projections, making the spine appear club-shaped (Fig. 3A). The outer one reaching a maximum length of about 3 mm and remaining bluntly tapering (Fig. 2D, F). Towards the distal third of the arm, both spines become progressively smaller and are represented as hooks, which do not have a lamina or regularly arranged perforations (Fig. 3B, G).

Colour in life, fawn; the disc relatively darker than arms with a greyish tinge; skin over the ossicles, tube-feet and tips of arm spines dark brown. Disc greyish and arms pale wheat in preserved specimen.

Description of paratype. Disc diameter 17.6 mm; arms about 19–22 times d. d., arm width at base 4.2mm, height 5.2 mm. Disc is slightly more excavate than the holotype, with the central part of the disc a bit concave. This difference is likely to be because the mouth of the paratype is gaping open. Similar to holotype in all other characters.

Biological association. *Asteroschema sampadae* was found in association with a gorgonacean of the family Primnoidae.

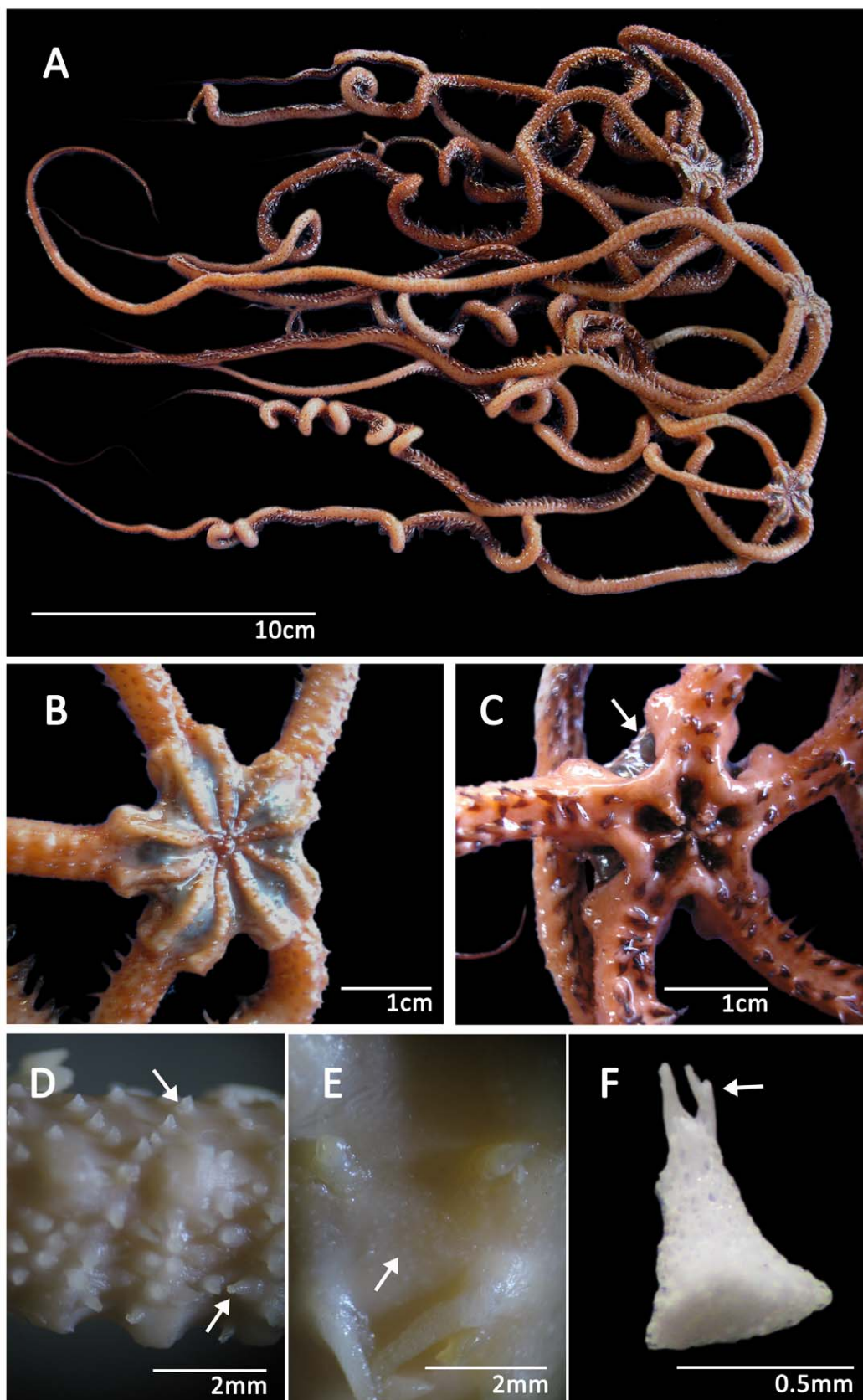


FIGURE 2. *Asteroschema sampadae* sp. nov., A–C. live specimens, D–F. Holotype (CMLRE IO/SS/ECD/00021). A. entire organism, B. aboral view of disc, C. oral side of disc showing genital slits (arrow), D. holotype (CMLRE) conical epidermal ossicles on the aboral side of the arm (arrows), E. oral side of arm base, showing minute granular epidermal ossicles (arrow), F. conical epidermal ossicle from the aboral side of the arm, with terminal projections (arrow).

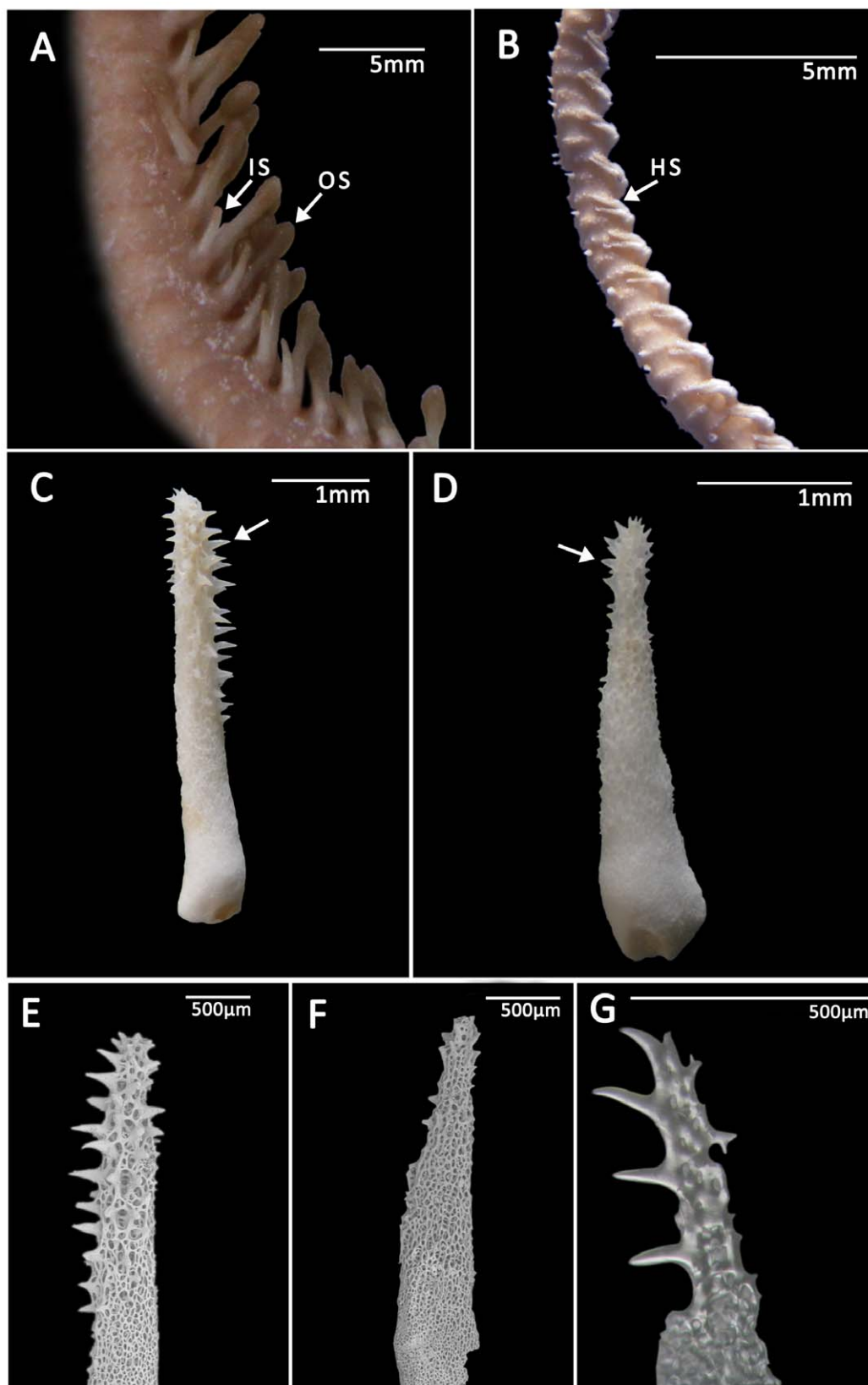


FIGURE 3. *Asteroschema sampadae* sp.nov., holotype (CMLRE IO/SS/ECD/00021). A. arm in lateral view, middle of arm showing arm spines (left=dorsal, right=ventral), B. arm in lateral view, distal end of arm (left=dorsal, right=ventral), C. inner arm spine from middle of arm, showing terminal projections on inner edge (arrow), D. outer arm spine from middle of arm, showing terminal projections on inner edge (arrow), E. SEM image of tip of inner arm spine from middle of arm, F. SEM image of outer arm spine from middle of arm spine, G. hook-shaped arm spine from distal end of arm. Abbreviations: IS, inner arm spine; OS, outer arm spine; HS, hooked spines.

TABLE 2. Comparison of species of *Asteroschema* having conical as well as granular epidermal ossicles, based on literature

Species	Disc Diameter	Arm Length	Epidermal ossicles of disc	Epidermal ossicles of arms	Arm Spine Size	Arm Spine Shape	Arm Spines appearing at		References
							First spine	Second spine	
<i>A. edmondsoni</i> A. H. Clark, 1949	13mm	290mm	Aboral: dense GO in proximal half of RS; larger CO with TP in distal half of RS Oral: dense rounded GO	Aboral: dense PO, swollen in the middle with TP; TP absent in distal end of arm Oral: same as on oral side of disc, but smaller	-	-	-	-	A. H. Clark, 1949
<i>A. flosculus</i> Alcock, 1893*	-	-	Aboral: GO & CO, scattered amongst uniform microscopic GO Oral: uniform microscopic GO	Aboral: PO, larger on arm base than on disc; 4 ossicles in 1mm at arm base; arms appearing weakly annulated owing to difference in size of ossicles Oral: plate-like ossicles & CO which are lower & thinner margin	Spines large	-	3	3	Alcock, 1893
<i>A. horridum</i> Lyman, 1879	10-12.5mm	160-195mm	Aboral: tumid polygonal PO; most with tall CO having terminal projections Oral: PO & CO which are higher & thinner at disc margin	Aboral: tumid polygonal PO; most with tall CO having terminal projections Oral: plate-like ossicles & CO which are lower & thinner margin	Inner $\approx$ 2x outer; inner > arm width	Cylindrical with TP, inner slightly swollen	1	1-6	Lyman, 1879; Lyman, 1882; Baker, 1980; McKnight, 2000
<i>A. fastosum</i> Koehler, 1904 accepted as <i>A. horridum</i> Lyman, 1879*	11mm	280mm	Aboral: long, CO on RS Oral: small CO; more rounded, close-set at disc margin Aboral: skin-covered with sparse domed CO with terminal projections, ossicles dense on RS & disc margin Oral: skin covered with few small CO	Aboral: small CO, more close-set than on disc Oral: flattened CO	Inner > outer; inner up to 4mm	Bluntly conical at arm base; inner strongly club-shaped with TP	2	4	Koehler, 1904; Doderlein, 1930
<i>A. migrator</i> Koehler, 1904	11mm	200-300mm	Aboral: skin-covered with sparse domed CO with terminal projections, ossicles dense on RS & disc margin Oral: skin covered with few small CO	Aboral: close-set small tumid GO Oral: few GO or CO	Inner $\approx$ 2x Outer; inner > arm width	Inner spine with swollen tip; outer with pointed tip; both with TP	3	6-8	Koehler, 1904; Baker, 1980; McKnight, 2000
<i>A. monobactrum</i> H.L. Clark, 1917	8mm	80-90mm	GO/CO	GO; sparse distally	Inner $\approx$ 2x Outer; inner > arm segment, up to 1mm	-	2	11-16	H. L. Clark, 1917

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TABLE 2. (continued)

Species	Disc Diameter	Arm Length	Epidermal ossicles of disc	Epidermal ossicles of arms	Arm Spine Size	Arm Spine Shape	Arm Spines appearing at		References
							First Spine	Second Spine	
<i>A. nuttingii</i> Verrill, 1899	7mm	50mm	Aboral: minute rough GO/CO, close-set on RS Oral: few grains near GS, minute rough GO/CO	Aboral: minute GO/CO, distinct distally Oral: minute rough GO/CO	Inner > Outer	Slender, tapering at arm base; inner cylindrical, blunt, swollen distally, with TP	1	1-2	Verrill, 1899
<i>A. oligactes</i> (Pallas, 1788)	-	17x d.d.	CO on disc & throughout arms; 4-5 ossicles in 1mm on aboral arm base		-	Scarcely clubbed	-	-	Lyman, 1882
<i>A. rubrum</i> Lyman, 1879	12mm	160mm	Fine close-set GO; 6-7 grains in 1mm on disc & arm base; RS faintly indicated as flat ridges		Inner with max. length of 1.4mm	Small spiniform at arm base; inner growing cylindrical, distally swollen with TP	2	5-6	Lyman, 1879; Lyman, 1882
<i>A. subfastosum</i> Doderlein, 1930*	8mm	9x d.d.	Aboral: pointed CO, blunt at disc margin, 4-5 ossicles in 1mm Oral: smooth hemispherical GO	Aboral: pointed CO	-	-	-	-	Doderlein, 1930
<i>A. tumidum</i> Lyman, 1879	8mm	135mm	Regularly spaced pointed CO	Regularly spaced pointed CO; 5 in 1mm, rarely touching each other; GO in distal end of arm	Inner > Outer; outer upto 1 1/2x arm segment (2mm) at 1/3 arm length	Rough, slightly clubbed	2	3	Lyman, 1879; Lyman, 1882
<i>A. ferox</i> Koehler, 1904 accepted as <i>A. tumidum</i> Lyman, 1879	9-13mm	120-180mm	Aboral: close-set rounded GO proximally, CO at disc margin Oral: Similar to aboral but lower	Aboral: pointed CO at arm base & close-set GO elsewhere	Inner > Outer; inner up to 2mm	Inner swollen at tip, with TP	2	4	Koehler, 1904
<i>A. yacayamense</i> Murakami, 1944	7mm	150mm	Aboral: compact, coarse CO Oral: rounded GO	Regularly spaced CO; distally swollen GO	Inner > Outer	Long, cylindrical with TP	2	3-6	Murakami, 1944
<i>A. sampaduae</i> sp. nov.	18mm	380-450mm	Aboral: spaced CO with terminal projections Oral: minute, spaced granular ossicles	Aboral: spaced CO with terminal projections; more dense at arm base	Inner ≈ 2x Outer; inner up to 2x arm segment (5mm) at 1/3 arm length	Bluntly conical at arm base; at 1/3 arm length inner cylindrical, with TP on inner edge	2	4	-

GO: granular ossicles, CO: conical ossicles, PO: plate-like ossicles, TP: terminal projections, RS: radial shields, GS: genital slits

* Species previously reported from Indian waters

Comparisons. *Asteroschema sampadae* resembles *A. oligactes* (Pallas, 1788) and *A. tumidum* Lyman, 1879 in the shape of the epidermal ossicles of the aboral side, but differs in the distribution of these ossicles, which is regular and close-set in these species but rather irregular and scattered in *A. sampadae*. The inner arm spines of *A. oligactes* is not much longer than the outer, whereas the inner arm spines of *A. sampadae* become twice as long as the outer towards the middle of the arm. In *A. tumidum*, the inner spine attains a length equaling one-third of the arm segment (2mm) and becomes rough ended and clubbed. While the shape of the inner spine of *A. sampadae* is similar to that of *A. tumidum*, the spines of *A. sampadae* are much longer, attaining twice the length of an arm segment (5mm). Moreover, *A. sampadae* is much larger than the type specimen of *A. tumidum* (8mm d. d., arms upto 135mm).

While the minute granular epidermal ossicles on the oral side of *A. sampadae* are similar to those of *A. flosculus* Alcock, 1893 and *A. nuttingii* Verrill, 1899, the ossicles on the aboral side of these two species are close-set granular ossicles unlike *A. sampadae*. The arm spines of *A. sampadae* are similar in description to those of *A. nuttingii*, in which the inner spine is longest and largest, cylindrical and blunt, enlarged at the end with minute projections at the tip. *A. nuttingii* is the only other species to be described as having claw-like distal arm spines.

A. sampadae is similar to *A. tubiferum* Matsumoto, 1915 with respect to the maximum size attained by the inner arm spines as well as the presence of a sheath around the basal tentacles. However, *A. tubiferum* possesses only coarse granular epidermal ossicles on the aboral side, while the aboral ossicles of *A. sampadae* are all distinctly conical. *A. hemigymnum* Matsumoto, 1915 also possesses a sheath around the basal tentacles, but the aboral ossicles of this species are close-set, fine, smooth granular ossicles, unlike the spaced conical ossicles of *A. sampadae*.

A. sampadae differs greatly from *A. lissum* H. L. Clark, 1939 which has been reported from the nearby Maldives region, in its size as well as the shape of epidermal ossicles; *A. lissum* (8mm d.d., arms about 110mm) possesses only close-set, fine, low granular ossicles (40–60 in 1mm) on the aboral side. While both *A. fastosum* Koehler, 1904 and *A. subfastosum* Döderlein, 1930 have conical ossicles embedded in the aboral skin, *A. sampadae* differs from both in the nature of ossicles on the oral side, which are small, flattened conical ossicles in *A. fastosum* and close-set, smooth, hemispherical granular ossicles on *A. subfastosum*. In addition, the arm base of *A. fastosum* is distinctly enlarged, while that of *A. sampadae* is not. A comparison of *A. sampadae* with all species of *Asteroschema* having conical as well as granular epidermal ossicles, based on literature is presented in Table 2.

Some species of the genus *Ophiocreas* Lyman, 1879 also have epidermal ossicles of various kinds and of these, *Ophiocreas spinulosus* Lyman, 1883 bears prominent blunt ‘spines’ or conical ossicles on the aboral skin. However, these are restricted to the radial shields and arm bases in *O. sibogae*, whereupon they are distributed evenly—a pair to each arm joint; while in the case of *A. sampadae*, the ossicles are irregularly scattered all over the aboral side of the disc and arms.

Remarks. The most distinctive features of *A. sampadae* which separates it from other species are the shape and nature of the epidermal ossicles on the aboral and oral sides along with the large inner arm spines in the middle of the arms that are represented as hook-shaped structures at the distal part of the arm. The characteristic shape of the conical epidermal ossicles of the aboral side, crowned with short terminal projections is of significance.

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References

- Alcock, A. (1893) Natural history notes from H. M. Indian Marine Survey Steamer, 'Investigator,' Commander C. F. Oldham, R. N., Commanding. Series II, No. 9. An account of the deep sea collection made during the season of 1892–93. *Journal of the Asiatic Society of Bengal. Part II. Natural Science*, 92, 169–184.
- Baker, A.N. (1980) Euryalinid Ophiuroidea (Echinodermata) from Australia, New Zealand, and the south-west Pacific Ocean. *New Zealand Journal of Zoology*, 7, 11–83.
- Clark, A.H. (1949) Ophiuroidea of the Hawaiian Islands. *Bulletin of the Bernice P. Bishop Museum*, 195, 3–133.
- Clark, H.L. (1917) Reports on the Scientific Results of the Albatross Expedition to the Tropical Pacific, 1899–1900 (Part 18). Reports on the Scientific results of the Albatross Expedition to the Eastern Tropical Pacific, 1904–1905 (Part 30). Ophiuroidea. *Bulletin of the Museum of Comparative Zoology at Harvard*, 61(12), 428–453.
- Clark, H.L. (1939) Ophiuroidea. *The John Murray Expedition 1933–1934 Scientific Reports*, 6, 29–136.
- Döderlein, L. (1927) Indopacifische Euryalae. *Abhandlungen der Bayerischen Akademie der Wissenschaften*, 31, 1–105.
- Döderlein, L. (1930) Die Ophiuroiden der deutschen Tiefsee-Expedition. 2. Euryalae. *Deutsche Tiefsee-Expedition 1898–1899*, 22, 347–396.
- Fell, H.B. (1960) Synoptic keys to the genera of Ophiuroidea. *Zoology Publication from Victoria University of Wellington*, 26, 1–44.
- Koehler, R. (1904) Ophiures de l'Expédition du Siboga. Part I. Ophiures de merprofonde. *Siboga-Expeditie*, 45a, 1–238.
- Koehler, R. (1907) Revision de la collection des ophiures du Muséum d'Histoire Naturelle de Paris. *Bulletin Scientifique de la France et la Belgique*, 41, 279–351.
- Koehler, R. (1914) A contribution to the study of the ophiurans of the United States National Museum. *Bulletin of the United States National Museum*, 84, 1–146.
- Ljungman, A.V. (1871) Förteckning öfver uti Vestindien af Dr A. Goëssamt under korvetten Josefinas expedition i Atlantiska Oceanen samlade Ophiurider. *Öfversigt af Kongliga Vetenskaps-Akademiens Förhandlingar*, Stockholm, 6, 615–658.
- Lütken, C.F. (1856) Bidrag til Kundskabom Slangestjernerne. II. Oversigt over de vestindiske Ophiurer. *Vedenskabelige Meddelelser fra Dansk Naturhistorisk Forening i Kjøbenhavn*, 7, 1–19.
- Lütken, C.F. and Mortensen, T. (1899) The Ophiuridae. *Memoirs of the Museum of Comparative Zoology at Harvard College* 23: 97–208.
- Lyman, T. (1872) *Annales des Sciences Naturelles*, series 5, Zoologie, 16(4).
- Lyman, T. (1875) Zoölogical results of the Hassler Expedition, II. Ophiuridae and Astrophytidae. *Illustrated Catalogue of the Museum of Comparative Zoology, at Harvard College*, 8, 3–34.
- Lyman, T. (1878) Report on the dredging operations of the United States Coast Survey Steamer 'Blake'. Part II. Ophiurans and astrophytons. *Bulletin of the Museum of Comparative Zoology at Harvard College, Cambridge*, 5, 217–238.
- Lyman, T. (1879) Ophiuridae and Astrophytidae of the exploring voyage of H. M. S. "Challenger", under Prof. Sir. Wyville Thompson, F. R. S. Part II. *Bulletin of the Museum of Comparative Zoology at Harvard College* Vol 5. No. 7 6 (2), 65–168.
- Lyman, T. (1882) Report on the Ophiuroidea dredged by H. M. S. Challenger during the years 1873–1876. *Report of the Scientific Results of the Voyage of H. M. S. Challenger during 1873–1876, Zoology*, 5, 1–386.
- Lyman, T. (1883) Reports on the results of dredging, under the supervision of Alexander Agassiz, in the Carribean Sea (1878–79), and on the east coast of the United States, during the summer of 1880, by the U.S. coast survey steamer "Blake", commander J.R. Bartlett, U.S.N., commanding. XX.- Report on the Ophiuroidea. *Bulletin of the Museum of Comparative Zoology at Harvard*, 10(6), 227–287.
- Matsumoto, H. (1915) A new classification of the Ophiuroidea: with descriptions of new genera and species. *Proceedings of the Academy of Natural Sciences of Philadelphia*, 67, 43–92.
- McKnight, D. G. (2000) The marine fauna of New Zealand: basket-stars and snake-stars (Echinodermata: Ophiuroidea: Euryalinea). *National Institute of Water and Atmospheric Research Biodiversity Memoir*, 115, 1–79.
- Mortensen, T. (1925) On some echinoderms from South Africa. *Annals and Magazine of Natural History Including Zoology, Botany, and Geology*, Ninth Series, 16, 146–155.
- Murakami, S. (1944) Report on the ophiurans from off Ogasawara Islands and from off the Yaéyama group, Nippon. *Journal of the Department of Agriculture, Kyushu Imperial University*, 7, 235–257.
- Okanishi, M. & Fujita, T. (2009) A new species of *Asteroschema* (Echinodermata: Ophiuroidea: Asteroschematidae) from southwestern Japan. *Species Diversity*, 14, 115–129.
- Okanishi, M., O'Hara, T.D., Fujita, T. (2011a) A new genus *Squamophis* of Asteroschematidae (Echinodermata, Ophiuroidea, Euryalida) from Australia. *ZooKeys*, 129, 1–15.
- Okanishi, M., O'Hara, T.D., Fujita, T. (2011b) Molecular phylogeny of the order Euryalida (Echinodermata: Ophiuroidea), based on mitochondrial and nuclear ribosomal genes. *Molecular Phylogenetics and Evolution*, 61, 392–399.
- Pallas, P. S. (1788) Marina varia nova et rariora - *Nova Acta Academiae Scientiarum Imperialis Petropolitanae* 2: 229–240.
- Stöhr, S. & O'Hara, T. (2007) World Ophiuroidea database. Available online at <<http://www.marinespecies.org/ophiuroidea>>. Consulted on 2012-02-03.
- Verrill, A. E. (1894) Descriptions of new starfishes and Ophiurans, with a revision of certain species formerly described; mostly from the collections made by the United States Commission of Fish and Fisheries. *Proceedings US National Museum*, 17, 245–297.
- Verrill, A. E. (1899) Report on the Ophiuroidea collected by the Bahama Expedition in 1893. *Bulletin from the Laboratories of Natural History of the State University of Iowa*, 5, 1–86.