

An updated checklist of echinoderms of the southeastern Arabian Sea

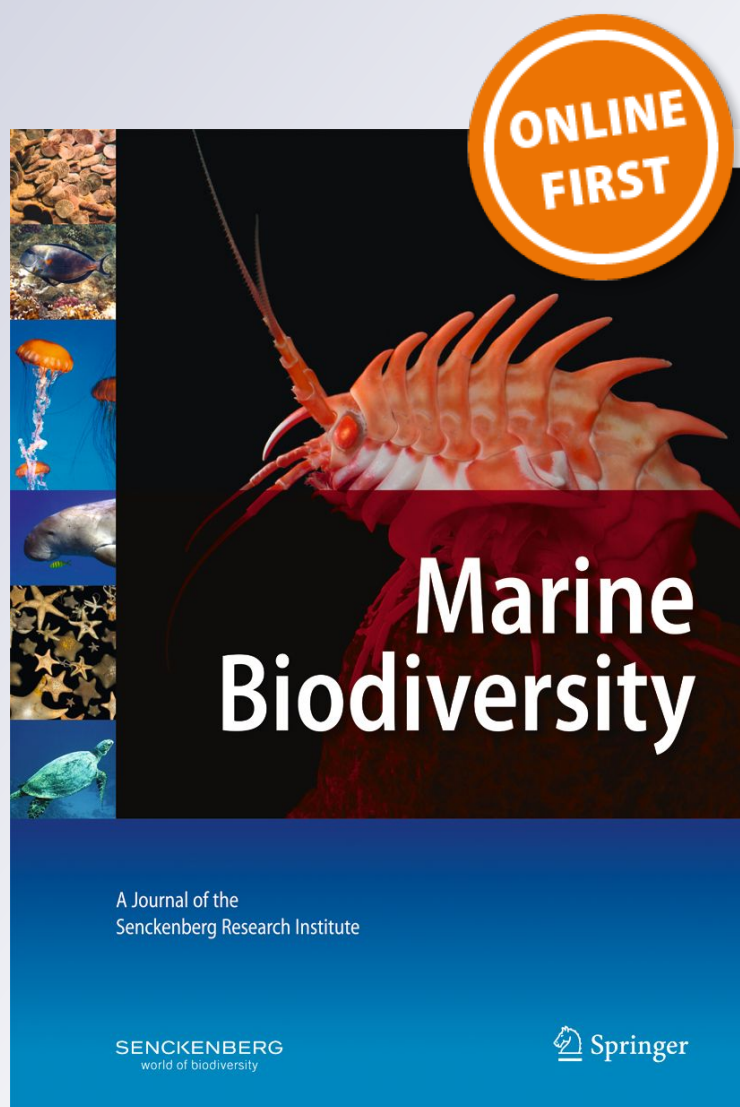
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An updated checklist of echinoderms of the southeastern Arabian Sea

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Abstract The southeastern Arabian Sea (SEAS) is a distinct ecosystem within the northern Indian Ocean, with unique physical, chemical and biological attributes. This paper provides comprehensive documentation on echinoderm diversity in the SEAS at depths of 20 to 1500 m, based on systematic surveys of over 300 sites. A total of 76 species were recorded in the surveys, which included one new species, seven new records for Indian waters and 39 species previously known from nearby areas and recorded for the first time from SEAS. With the addition of the new records from the present study to the 133 species previously reported from the SEAS, the species richness of echinoderms in the SEAS stands at 180 species. Updated checklists of echinoderms in the SEAS are provided.

Keywords Echinoderms · Southeastern Arabian Sea · Species · Checklist · Biodiversity

Introduction

The Indo-west Pacific is a region of high echinoderm diversity, as demonstrated for classes Asteroidea (Mah and Blake 2012) and Ophiuroidea (Stöhr et al. 2012). Clark and Rowe (1971) recorded 345 species of shallow-water echinoderms from the

seas around India, while Sastry (2007) published a comprehensive annotated checklist which recorded a total of 651 species from the entire Indian exclusive economic zone (EEZ). More recent works place the number of echinoderms in Indian waters at 765 species (Wafer et al. 2011; Sanjeevan et al. 2014) and 777 species (Venkatraman et al. 2015). A detailed literature survey reveals that most of the studies on Indian echinoderm diversity have been localised and focused on intertidal and shallow-water regions. In particular, there have been no efforts to document the diversity of this group in Indian waters beyond a depth of ~25 m since the surveys of Royal Indian Marine Survey (RIMS) *Investigator* (1888–1892).

The Southeastern Arabian Sea (SEAS), off the southwest coast of India is a tropical Eastern Boundary Upwelling System (EBUS), with physical, chemical and biological attributes distinct from the rest of the northern Indian Ocean (Madhupratap et al. 2001; Sanjeevan et al. 2009). The echinoderms of this region were first described through the surveys of the RIMS *Investigator* (1888–1892), and subsequently through the works of Kurian (1953), James (1969, 1971), Price and Reid (1985) and Jayakumari (2004). While the *Investigator* surveys covered both the shelf (Koehler 1898, 1910, 1914, 1922, 1927; Koehler and Vaney 1908) and slope areas (Wood-Mason and Alcock 1891; Walsh 1891; Alcock 1893; Anderson 1894; Koehler 1897, 1899, 1909, 1922, 1927; Koehler and Vaney 1905), later surveys were mostly restricted to intertidal and nearshore areas (<20 m depth). Echinoderms of the coral reefs and associated habitats of the Lakshadweep Archipelago, in the southwestern part of the SEAS, have also been documented to some extent (Anderson 1894; Koehler 1898, 1922, 1927; Bell 1902; James 1969; Mukhopadhyay and Samanta 1983; Mukhopadhyay 1991; Sastry 1991, 2007). Sastry (2007) provided a bibliographic list of echinoderms known from Indian waters, which includes historic records from SEAS. The

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aforementioned surveys recorded a total of 133 species of echinoderms from the SEAS, comprising 52 shallow-water and 81 deep-sea species. Recent surveys of the Fishery Oceanographic Research Vessel (FORV) *Sagar Sampada* have also resulted in the description of a new species, *Asteroschema sampadae* Parameswaran & Abdul Jaleel, 2012, from this region and the first record of a unique, sexually dimorphic brittle star *Ophiodaphne scripta* Koehler, 1904, from the Indian EEZ (Parameswaran et al. 2013).

Considering the threat of biodiversity loss through climate change, global warming and ocean acidification, there is an urgent need for documentation of marine biodiversity, particularly in regions that have been poorly studied. This paper provides an updated checklist of echinoderms in the SEAS as a whole, based on comprehensive surveys of the shelf and slope areas (20–1500 m isobaths).

Materials and methods

Echinoderms collected from 26 systematic surveys for FORV *Sagar Sampada* (FORVSS) were utilised for the present study. The surveys were undertaken between 2003 and 2015, covering the continental shelf and upper slope (~20 m to 1500 m) of the SEAS (7°–15° N, 73°–78° E). Naturalist dredges (100 cm × 30 cm, 1 cm mesh bag) and Smith McIntyre Grabs (0.1 and 0.2 m² bite area) were used for collections from the shelf (up to 200 m) and the slope (200–1500 m), while high-speed demersal trawls (HSDT) were also used in the slope region. While the aforementioned 26 surveys covered over 270 sampling sites, only 142 of these yielded echinoderm samples (Fig. 1), and these are listed in Table 1.

Taxonomic identification of the echinoderms was carried out following the RIMS *Investigator* expeditions (Walsh 1891; Wood-Mason and Alcock 1891; Alcock 1893; Anderson 1894; Koehler 1897, 1898, 1909, 1910, 1914, 1922; Koehler and Vaney 1905, 1908; H. L. Clark 1909b, A. H. 1912a, b), comprehensive keys (Fell 1960; Clark and Rowe 1971) and other relevant taxonomic works (Madsen 1961; James 1968, 1971, 1987, 1997; A. M. Clark 1970; Cherbonnier and Guille 1978; O'Hara and Stöhr 2006; Mah 2007 etc.). The status and validity of all taxa were checked and updated using the World Register of Marine Species (WoRMS Editorial Board 2016). Voucher specimens are deposited in the FORV Referral Centre at the Centre for Marine Living Resources & Ecology, Kochi.

In order to test the sufficiency of sampling, species accumulation curves were plotted separately for the continental shelf (20–200 m) and slope (200–1500 m) using PRIMER 6 (Clark and Gorley 2006), and species estimators (Chao 2, Jackknife 1 and 2) were calculated to determine the number of species likely to be encountered within these depths with unlimited sampling. Species

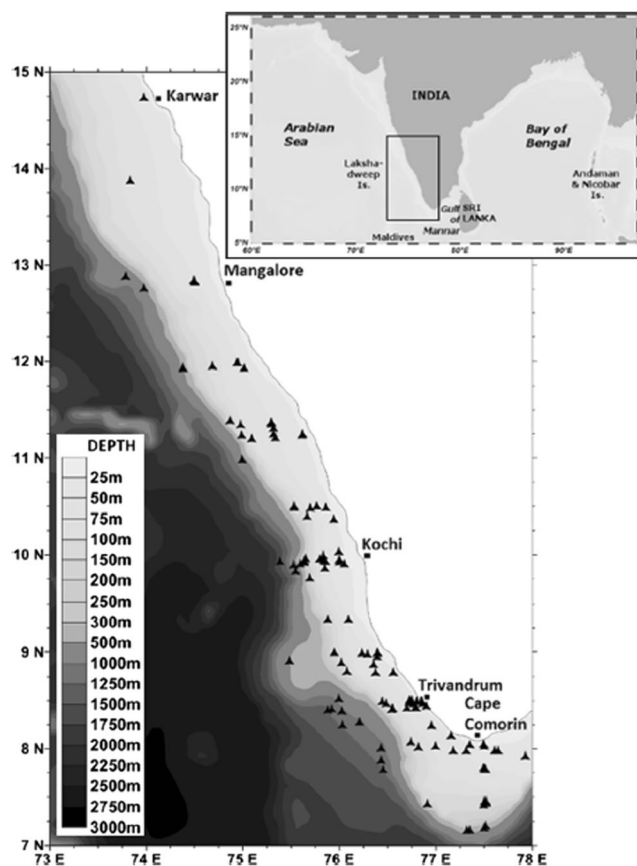


Fig. 1 Map of the northern Indian Ocean indicating the location of the study area in the Southeastern Arabian Sea (inset) and bathymetric map of the SEAS showing the sampling sites

checklists for each class of echinoderms in the SEAS continental margin (Tables 2, 3, 4, 5 and 6, Figs. 2, 3, 4 and 5) were updated based on the present surveys and by re-validation of all previous records from the region. The latter includes records from nearshore (<20 m depth) and deep-sea areas (>1500 m depth). Table 7 summarises the status of knowledge of species diversity for each class from the SEAS continental shelf and slope prior to and following the present survey, including the numbers of new records. A brief description is provided for species recorded for the first time in Indian waters through the present surveys.

Systematic account

Class Ophiuroidea Grey, 1840

Order Ophiurida Müller & Troschel, 1840

Family Amphiuridae Ljungman, 1867

Genus *Amphiura* Forbes, 1843

Amphiura (*Amphiura*) *constricta* Lyman, 1879

Figure 2l.

Table 1 Station locations of FORV *Sagar Sampada* surveys

Site No.	Cruise/ Station	Latitude (N)	Longitude (E)	Depth (m)	Date
1	219/12	9° 50.16'	75° 32.86'	988	19.12.'03
2	219/17	11° 55.93'	74° 23.13'	525	21.12.'03
3	219/21	12° 46.14'	73° 58.39'	991	22.12.'03
4	225/1	7° 10.27'	77° 20.86'	245	14.05.'04
5	225/8	8° 55.30'	75° 29.03'	454	12.05.'04
6	233/11	9° 56.28'	75° 82.99'	500	23.04.'05
7	233/15	10° 59.29'	74° 59.52'	992	14.04.'05
8	233/17	11° 56.54'	74° 22.66'	523	17.04.'05
9	233/21	12° 53.45'	73° 47.00'	1000	18.04.'05
10	254/1	7° 10.02'	77° 19.21'	454	20.05.'07
11	254/12	9° 50.16'	75° 32.87'	835	03.05.'07
12	236/10	9° 52.20'	75° 51.00'	48	03.08.'05
13	236/16	8° 54.00'	76° 01.20'	95	04.08.'05
14	236/19	8° 25.80'	76° 42.00'	58	05.08.'05
15	236/21	8° 3.00'	77° 21.00'	32	05.08.'05
16	236/22	7° 55.80'	77° 55.80'	50	05.08.'05
17	260/56	7° 25.98'	77° 29.68'	108	25.12.'08
18	260/58	8° 28.89'	76° 43.46'	52	25.12.'08
19	260/64	8° 57.90'	76° 23.33'	32	26.12.'08
20	260/65	10° 2.34'	75° 59.77'	32	26.12.'08
21	267I/1	7° 59.28'	77° 38.70'	30	30.05.'09
22	267I/2	7° 47.64'	77° 30.26'	52	30.05.'09
23	267I/15	9° 00.08'	76° 23.52'	31	03.06.'09
24	267II/8	11° 13.25'	75° 20.30'	50	10.06.'09
25	267II/9	11° 14.84'	75° 36.80'	32	09.06.'09
26	267II/10	11° 14.79'	74° 59.30'	101	10.06.'09
27	267II/22	9° 56.39'	75° 38.30'	98	13.06.'09
28	267II/23	9° 56.33'	75° 51.16'	49	13.06.'09
29	270I/17	11° 15.35'	75° 18.88'	53	07.08.'09
30	270I/18	11° 15.29'	75° 37.19'	30	07.08.'09
31	270I/22	9° 56.68'	75° 38.12'	106	08.08.'09
32	270I/23	9° 56.18'	75° 50.57'	52	08.08.'09
33	270I/24	9° 55.94'	76° 00.04'	33	08.08.'09
34	270II/1	9° 00.28'	76° 23.75'	30	14.08.'09
35	270II/9	8° 30.34'	76° 51.25'	31	16.08.'09
36	270II/10	8° 29.69'	76° 43.68'	53	16.08.'09
37	270II/19	7° 59.26'	77° 36.64'	32	18.08.'09
38	270II/20	7° 47.42'	77° 30.83'	52	18.08.'09
39	270II/21	7° 27.83'	77° 30.09'	100	18.08.'09
40	275/2	9° 54.54'	75° 35.49'	116	13.05.'10
41	275/4	9° 54.56'	76° 02.95'	33	14.05.'10
42	275/7	9° 20.97'	75° 52.84'	111	14.05.'10
43	275/8	9° 20.84'	76° 05.75'	53	14.05.'10
44	275/12	8° 28.71'	76° 28.99'	102	15.05.'10
45	275/15	8° 03.41'	77° 29.81'	24	16.05.'10
46	275/16	8° 02.20'	77° 29.95'	31	16.05.'10
47	275/17	7° 48.58'	77° 29.61'	51	16.05.'10
48	275/18	7° 27.92'	77° 31.14'	100	16.05.'10

Table 1 (continued)

Site No.	Cruise/ Station	Latitude (N)	Longitude (E)	Depth (m)	Date
49	278/2	9° 54.00'	75° 31.44'	1120	08.08.'10
50	281/3	8° 24.15'	76° 1.64'	995	12.10.'10
51	282/7	8° 01.55'	76° 49.14'	86	15.11.'10
52	282/8	7° 59.2'	77° 10.76'	49	15.11.'10
53	282/10	8° 26.01'	76° 47.94'	53	20.11.'10
54	282/12	8° 59.38'	76° 17.33'	49	21.11.'10
55	288/1	10° 30.73'	75° 45.85'	41	04.08.'11
56	288/3	10° 30.53'	75° 31.67'	84	04.08.'11
57	288/6	11° 12.42'	75° 05.55'	81	07.08.'11
58	288/10	11° 57.52'	74° 41.16'	83	08.08.'11
59	289/2	9° 56.54'	75° 51.07'	50	26.08.'11
60	289/3	9° 55.49'	75° 38.05'	109	26.08.'11
61	289/9	9° 00.12'	75° 56.80'	155	28.08.'11
62	289/11	8° 59.92'	76° 13.91'	53	28.08.'11
63	289/16	8° 24.98'	76° 32.46'	106	30.08.'11
64	289/17	8° 26.30'	76° 47.16'	52	30.08.'11
65	289/18	8° 27.05'	76° 53.96'	38	30.08.'11
66	289/20	8° 30.00'	76° 48'.00'	50	31.08.'11
67	289/21	8° 30.00'	76° 48'.00'	51	31.08.'11
68	289/22	8° 30.00'	76° 48'.00'	50	31.08.'11
69	289/29	8° 30.00'	76° 48'.00'	51	02.09.'11
70	289/33	8° 30.00'	76° 48'.00'	52	03.09.'11
71	289/37	8° 30.00'	76° 48'.00'	52	04.09.'11
72	289/38	8° 30.00'	76° 48'.00'	51	04.09.'11
73	289/40	8° 30.00'	76° 48'.00'	51	05.09.'11
74	289/41	8° 30.00'	76° 48'.00'	52	05.09.'11
75	289/44	8° 30.00'	76° 48'.00'	54	06.09.'11
76	289/45	8° 30.00'	76° 48'.00'	52	06.09.'11
77	289/49	8° 30.00'	76° 48'.00'	52	07.09.'11
78	289/50	8° 30.00'	76° 48'.00'	51	07.09.'11
79	289/52	8° 30.00'	76° 48'.00'	53	08.09.'11
80	289/53	8° 30.00'	76° 48'.00'	51	08.09.'11
81	295/3	11° 19.17'	75° 18.90'	52	22.02.'12
82	295/6	11° 56.19'	75° 00.76'	51	23.02.'12
83	295/20	9° 46.07'	75° 41.43'	98	27.02.'12
84	305/1	8° 17.13'	76° 12.42'	1069	19.10.'12
85	315/6	10° 24.50'	75° 39.90'	60	08.07.'13
86	316/1	8° 17.19'	76° 12.34'	1032	14.07.'13
87	316/2	7° 47.48'	76° 27.31'	1324	15.07.'13
88	316/4	8° 30.91'	76° 45.06'	49	16.07.'13
89	316/5	8° 25.44'	76° 33.08'	84	16.07.'13
90	316/9	8° 24.61'	75° 52.71'	1245	17.07.'13
91	316/13	8° 52.97'	76° 21.38'	52	18.07.'13
92	316/24	9° 58.10'	75° 49.62'	55	20.07.'13
93	317/2	9° 58.35'	75° 49.66'	54	30.07.'13
94	317/3	9° 58.13'	75° 39.15'	100	31.07.'13
95	317/9	10° 22.53'	75° 56.67'	30	02.08.'13

Table 1 (continued)

Site No.	Cruise/ Station	Latitude (N)	Longitude (E)	Depth (m)	Date
96	317/14	11° 59.40'	74° 56.33'	53	08.08.'13
97	317/28	13° 52.78'	73° 49.83'	65	15.08.'13
98	317/42	14° 44.91'	73° 58.30'	33	18.08.'13
99	319/1	8° 15.04'	76° 57.08'	51	07.09.'13
100	319/2	8° 04.48'	76° 44.47'	113	07.09.'13
101	319/6	7° 48.10'	77° 30.70'	53	08.09.'13
102	319/8	7° 53.24'	76° 25.77'	1262	09.08.'13
103	319/9	8° 15.28'	76° 01.89'	1338	10.08.'13
104	319/10	8° 28.56'	76° 51.50'	37	11.09.'13
105	319/11	8° 28.43'	76° 45.86'	50	11.09.'13
106	321/11	7° 26.44'	76° 54.75'	124	08.12.'13
107	321/12	7° 59.37'	77° 18.76'	48	09.12.'13
108	321/13	8° 08.63'	77° 09.40'	49	09.12.'13
109	321/14	8° 02.04'	76° 59.83'	56	09.12.'13
110	321/16	8° 00.85'	76° 25.91'	1154	10.12.'13
111	321/18	8° 25.12'	75° 55.18'	1241	11.12.'13
112	321/20	8° 31.78'	75° 59.74'	1047	12.12.'13
113	329/33	12° 51.02'	74° 29.71'	53	27.09.'14
114	330/2	12° 50.32'	74° 30.26'	51	04.10.'14
115	330/13	11° 59.52'	74° 57.18'	52	08.10.'14
116	330/16	11° 22.70'	75° 17.71'	53	09.10.'14
117	330/17	11° 23.64'	74° 52.12'	101	09.10.'14
118	330/26	10° 29.57'	75° 31.70'	88	12.10.'14
119	330/27	10° 29.33'	75° 41.98'	51	12.10.'14
120	330/28	10° 29.82'	75° 51.40'	30	12.10.'14
121	330/30	9° 57.63'	75° 50.12'	51	13.10.'14
122	330/77	8° 30.88'	76° 43.50'	50	24.10.'14
123	330/78	8° 30.36'	76° 50.62'	34	24.10.'14
124	330/79	8° 48.02'	76° 33.58'	33	25.10.'14
125	330/80	8° 48.19'	76° 22.33'	52	25.10.'14
126	330/81	8° 48.71'	76° 04.57'	96	25.10.'14
127	333/1	9° 57.48'	76° 00.12'	33	13.12.'14
128	333/2	10° 00.08'	75° 49.99'	52	13.12.'14
129	333/8	12° 49.75'	74° 30.35'	52	15.12.'14
130	340/7	12° 49.70'	74° 30.30'	52	24.05.'15
131	340/14	11° 21.57'	75° 17.67'	54	25.05.'15
132	340/17	9° 56.31'	75° 50.97'	52	26.05.'15
133	340/21	8° 29.93'	76° 50.88'	35	28.05.'15
134	340/22	8° 29.45'	76° 43.77'	52	28.05.'15
135	340/27	7° 26.93'	77° 31.69'	109	30.05.'15
136	343/16	11° 22.39'	75° 17.38'	55	13.08.'15
137	343/17	11° 21.12'	74° 58.55'	115	13.08.'15
138	343/24	9° 57.76'	75° 47.69'	31	15.08.'15
139	343/26	8° 29.71'	76° 43.48'	54	16.08.'15
140	343/27	8° 30.07'	76° 26.43'	110	16.08.'15
141	343/30	7° 12.71'	77° 31.02'	204	18.08.'15
142	343/32	7° 47.52'	77° 30.01'	55	18.08.'15

Table 2 Updated checklist of Asteroidea of the SE Arabian Sea

No.	Species	Distribution in Indian & adjacent waters*	Record in SEAS		FORVSS survey sites (See Table 1)	CMLRE voucher no. (IO/SS/ ECD/#)
			Region	References		
Order Paxillosida Perrier, 1884						
Family Astropectinidae Grey, 1840						
1.	<i>Astropecten griegi</i> Koehler, 1909	SEAS, ANI	Slope	Koehler 1909		
2.	<i>Astropecten hemprichi</i> Müller & Troschel, 1842	SEAS, GoM, WBoB	Shelf	Present study	38	00075
3.	<i>Astropecten indicus</i> Perrier, 1878	NEAS, SEAS, GoM, WBoB	Shelf	Koehler 1910; Jayakumari 2004		
4.	<i>Astropecten inutilis</i> Koehler, 1910	SEAS	Shelf	Koehler 1910; Kurian 1953		
5.	<i>Astropecten pobacanthus</i> Müller & Troschel, 1842	SEAS, GoM, ANI	Shelf	Present study	22, 76, 99	00073
6.	<i>Astropecten vappa</i> Müller & Troschel, 1843	NEAS, SEAS, WBoB, ANI	Shelf	Present study	18, 28, 32, 35, 40, 44, 45, 83, 107, 122, 128, 130–133, 136, 137	00074
7.	<i>Persephonaster croceus</i> Wood-Mason & Alcock, 1891	SEAS, GoM	Slope	Wood-Mason and Alcock 1891		
8.	<i>Persephonaster rhodopeplus</i> Wood-Mason & Alcock, 1891	SEAS, GoM	Slope	Wood-Mason and Alcock 1891; Alcock 1893, present study	50, 87, 103	
9.	<i>Psilaster agassizi</i> (Koehler, 1909)	SEAS, WBoB, ANI	Slope	Koehler 1909		
Family Luidiidae Sladen, 1889						
10.	<i>Luidia denudata</i> Koehler 1910	SEAS, WBoB	Shelf	Present study	100, 101	00077
11.	<i>Luidia hardwicki</i> (Grey, 1840)	NEAS, SEAS, GoM, WBoB	Shelf	Present study	10, 22, 29, 42, 47, 52, 56, 57, 58, 64, 65, 69, 71, 74, 76, 77, 80, 83, 85, 93, 99, 109, 122, 127, 131, 132, 134, 136–138, 141	00076
Family Porcellanasteridae Sladen, 1883						
12.	<i>Sidonaster vaneyi</i> Koehler, 1909	SEAS, ANI	Slope	Koehler 1909, present study	1, 49, 90, 110	00013
Family Pseudarchasteridae Sladen, 1889						
13.	<i>Pseudarchaster jordani</i> Fisher, 1906	SEAS	Slope	Koehler 1909		
14.	<i>Pseudarchaster roseus</i> (Alcock, 1893)	SEAS	Slope	Alcock 1893		
Order Notomyotida Ludwig, 1910						
Family Benthopectinidae Verrill, 1894						
15.	<i>Benthopecten violaceus</i> (Alcock, 1893)	SEAS	Slope	Alcock 1893		
16.	<i>Cheiraster (Cheiraster) pilosus</i> (Alcock, 1893)	SEAS	Slope	Koehler 1909		
17.	<i>Cheiraster cribellum</i> (Alcock, 1893)	SEAS	Slope	Alcock 1893		
18.	<i>Pectinaster mimicus</i> (Sladen, 1889)	SEAS, WBoB	Slope	Wood-Mason and Alcock 1891; Alcock 1893; Koehler 1909		
Order Valvatida Perrier, 1884						
Family Asterinidae Grey, 1840						
19.	<i>Anseropoda ludovici</i> (Koehler, 1909)	SEAS	Slope	Koehler 1909, present study	5	
Family Goniasteridae Forbes, 1841						

Table 2 (continued)

No.	Species	Distribution in Indian & adjacent waters*	Record in SEAS		FORVSS survey sites (See Table 1)	CMLRE voucher no. (IO/SS/ ECD/#)
			Region	References		
20.	<i>Astroceramus fisheri</i> Koehler, 1909	SEAS, ANI	Slope	Koehler 1909		
21.	<i>Ceramaster cuenoti</i> (Koehler, 1909)	SEAS	Slope	Koehler 1909, present study	50, 84, 86, 87, 90, 102, 110, 111	00080
22.	<i>Circeaster marcelli</i> Koehler, 1909	SEAS	Slope	Koehler 1909		
23.	<i>Johannaster superbus</i> Koehler, 1909	NEAS, SEAS	Slope	Present study	87, 103, 111	00079
24.	<i>Nymphaster moebii</i> (Studer, 1884)	SEAS, GoM, ANI	Slope	Alcock 1893; Koehler 1909, present study	87, 90, 111	00081
25.	<i>Stellaster childreni</i> Grey, 1840	SEAS, GoM, WBoB, ANI	Shelf	Jayakumari 2004, present study	25, 26, 52, 64, 74, 76, 80, 109, 122, 139	00018
Family Ophiasteridae Verrill, 1870						
26.	<i>Certonardoa semiregularis</i> (Müller & Troschel, 1842)	SEAS	Shelf	Sastry 2007		
27.	<i>Heteronardoa carinata</i> (Koehler, 1910)	SEAS, ANI	Shelf	Present study	59	00082
Family Oreasteridae Fisher, 1911						
28.	<i>Gontiodiscaster forficulatus</i> (Perrier, 1875)	SEAS, GoM, WBoB	Shelf	Jayakumari 2004, present study	18, 44, 106, 122	00083
Order Forcipulatida Perrier, 1884						
Family Zoroasteridae Sladen, 1889						
29.	<i>Cnemidaster squameus</i> (Alcock, 1893)	SEAS	Slope	Alcock 1893		
30.	<i>Cnemidaster zea</i> (Alcock, 1893)	SEAS	Slope	Alcock 1893, present study	50, 84, 86, 87, 90, 102, 103	00084
31.	<i>Zoroaster alfredi</i> Alcock, 1893	SEAS, WBoB	Slope	Present study	84, 86, 87, 90, 110	00085
32.	<i>Zoroaster angulatus</i> Alcock, 1893	SEAS, GoM	Slope	Alcock 1893		
33.	<i>Zoroaster planus</i> Alcock, 1893	SEAS	Slope	Alcock 1893, present study	7, 84, 86, 87, 90, 102, 103	00086
Order Brisingida Fisher, 1928						
Family Brisingidae G. O. Sars, 1875						
34.	<i>Brisinga gunnii</i> Alcock, 1893	SEAS	Slope	Alcock 1893		
35.	<i>Brisinga insularum</i> Wood-Mason & Alcock, 1891	SEAS	Slope	Wood-Mason and Alcock 1891, present study	87	00087

*Sources: Jayakumari (2004), Sastry (2007)

NEAS = Northeastern Arabian Sea, SEAS = Southeastern Arabian Sea, LI = Lakshadweep Islands, GoM = Gulf of Mannar, WBoB = Western Bay of Bengal, ANI = Andaman & Nicobar Islands

Table 3 Updated checklist of Ophiuroidea of the SE Arabian Sea

No.	Species	Distribution in Indian & adjacent waters*	Record in SEAS	FORVSS survey sites (see Table 1)	CMLRE voucher no. (IO/SS/ ECD/#)
Region References					
Order Euryalida Lamarck, 1816					
Family Asteronychidae Verrill, 1899					
1.	<i>Asteronyx loveni</i> Müller & Troschel, 1842	SEAS	Slope	Koehler 1897, 1899	
Family Asterochematidae Verrill, 1899					
2.	<i>Asteroschema sampadai</i> Parameswaran & Jaleel, 2012	SEAS	Slope	Parameswaran and Abdul Jaleel 2012 (Present surveys)	00021
Order Ophiurida Müller & Troschel, 1840					
Family Amphiuridae Ljungman, 1867					
3.	<i>Amphioplus (Lymanella) depressus</i> (Ljungman, 1867)	SEAS, WBoB, ANI	Shelf	James 1969, present study	27, 45, 47, 66, 76, 77, 80, 89, 93, 94, 95, 96, 101, 104, 113, 114, 115, 116, 120, 124, 125, 129, 136, 142
4.	<i>Amphipholis misera</i> (Koehler, 1899)	SEAS, ANI	Shelf	Present study	22, 40, 72, 79, 80, 118
5.	<i>Amphioplus dispar</i> (Koehler, 1897)	SEAS, WBoB, ANI	Slope	Koehler 1897, 1899	00089
6.	<i>Amphiura (Amphiura) ambigua</i> Koehler, 1905	NEAS, SEAS	Shelf	Present study	13, 37, 48, 135
7.	<i>Amphiura (Amphiura) constricta</i> Lyman, 1879 ^a	SEAS	Shelf	Present study	63, 115
8.	<i>Amphiura (Amphiura) duncani</i> Lyman, 1882	SEAS, GoM, WBoB ^b	Shelf	Present study	60, 81, 94
9.	<i>Amphiura (Amphiura) lorioli</i> (Koehler, 1897)	SEAS, WBoB	Slope	Koehler 1897, 1899	00091
10.	<i>Amphiura (Amphiura) micra</i> H.L. Clark, 1938	WBoB	Shelf	Present study	45
11.	<i>Amphiura (Fellaria) heptacantha</i> (Mortensen, 1940) ^a	SEAS	Shelf	Present study	46
12.	<i>Amphiura (Ophiopeltis) tenuis</i> (H.L. Clark, 1938)	SEAS, WBoB	Shelf	Present study	45, 101
13.	<i>Amphiura crispata</i> Mortensen, 1940	NEAS, SEAS	Shelf	Present study	45
14.	<i>Histampica duplicata</i> (Lyman, 1875)	SEAS	Slope	Koehler 1897, 1899	
15.	<i>Dougaloplus echinatus</i> (Ljungman, 1867)	SEAS, GoM, WBoB	Shelf	Present study	88
16.	<i>Ophiodaphne scripta</i> (Koehler, 1904) ^a	SEAS, WBoB	Shelf	Parameswaran et al. 2013 (FORVSS Surveys)	22, 42, 53, 65, 69, 71, 72, 74, 76, 77, 131
17.	<i>Ophiosphaera insignis</i> Brock, 1888 ^a	SEAS	Shelf	Present study	52
Family Ophiacanthidae Ljungman, 1867					
18.	<i>Ophiacantha dallastii</i> Duncan, 1879 ^a	SEAS	Shelf	Present study	108
19.	<i>Ophiacantha vorax</i> Koehler, 1897	SEAS	Slope	Koehler 1897, 1899	
20.	<i>Ophiomoeris tenera</i> (Koehler, 1897)	SEAS, ANI	Slope	Koehler 1897, 1899, present study	110, 111
21.	<i>Ophioplinthaca rudis</i> (Koehler, 1897)	SEAS, MI, ANI	Slope	Koehler 1897, 1899	00095
22.	<i>Ophiotreta matura</i> (Koehler, 1904)	SEAS	Slope	Sastry 2007	
Family Ophiactidae Matsumoto, 1915					

Table 3 (continued)

No.	Species	Distribution in Indian & adjacent waters*	Record in SEAS		FORVSS survey sites (see Table 1)	CMLRE voucher no. (IO/SS/ ECD/#)
			Region	References		
23.	<i>Ophiactis flexulosa</i> Koehler, 1897	SEAS	Slope	Koehler 1897, 1899		
24.	<i>Ophiactis macrolepidota</i> Marktanner-Turneretscher, 1887	SEAS	Shelf	Sastry 2007		
25.	<i>Ophiactis savignyi</i> (Müller & Troschel, 1842)	SEAS, GoM, WBoB, ANI	Shelf	Jayakumari 2004		
Family Ophiichitonidae Matsumoto, 1915						
26.	<i>Ophiichiton ambulador</i> Koehler, 1897	NEAS, SEAS, WBoB	Slope	Koehler 1897, 1899, present study	2, 7, 8, 9, 110, 111	00096
Family Ophiocomidae Ljungman, 1867						
27.	<i>Ophiocoma (Breviturna) brevipes</i> Peters, 1851	SEAS, LI, GoM, ANI	Shelf	Present study	52	00097
28.	<i>Ophiopsila pantherina</i> Koehler, 1898	SEAS, ANI	Shelf	Present study	108	
Family Ophiidermatidae Ljungman, 1867						
29.	<i>Bathypectinura heros</i> (Lyman, 1879)	SEAS, WBoB	Slope	Koehler 1897, 1899, present study	6, 49, 111	00098
30.	<i>Ophiarachnella infernalis</i> (Müller & Troschel, 1842)	SEAS, GoM, ANI	Shelf	Present study	99	00099
31.	<i>Ophiocoris cupida</i> Koehler, 1905 ^a	SEAS	Shelf	Present study	52, 108	00100
Family Ophiolepididae Ljungman, 1867						
32.	<i>Ophiomusium familiare</i> Koehler, 1897	SEAS	Slope	Koehler 1897, 1899		
33.	<i>Ophiophthalma elegans</i> (Koehler, 1897)	SEAS, ANI	Slope	Koehler 1897, 1899		
34.	<i>Ophiotrochus panniculatus</i> Lyman, 1878	SEAS	Slope	Koehler 1897, 1899		
35.	<i>Ophiozonella molestus</i> (Koehler, 1904)	SEAS, ANI	Slope	Koehler 1897, 1899		
Family Ophiotrichidae Ljungman, 1867						
36.	<i>Macrophiothrix aspidota</i> (Müller & Troschel, 1842)	NEAS, SEAS, GoM, WBoB, ANI	Shelf	Jayakumari 2004		
37.	<i>Ophiocnemis marmorata</i> (Lamarek, 1816)	SEAS, GoM, WBoB, ANI	Shelf	Jayakumari 2004, present study	52, 77, 80	00101
38.	<i>Ophiopoteran elegans</i> Ludwig, 1888	SEAS, ANI	Shelf	Present study	108	000102
39.	<i>Ophiiothrix (Acanthophiothrix) proteus</i> Koehler, 1905	SEAS, GoM, ANI	Shelf	Present study	64, 77	00105
40.	<i>Ophiiothrix (Acanthophiothrix) purpurea</i> von Martens, 1867	SEAS, LI, GoM, ANI	Shelf	Present study	22, 99	00144
41.	<i>Ophiiothrix (Ophiiothrix) aristulata</i> Lyman, 1879	SEAS, WBoB, ANI	Slope	Present study	6	00103
42.	<i>Ophiiothrix (Ophiiothrix) foveolata</i> Marktanner-Turneretscher, 1887	NEAS, SEAS, ANI	Shelf	Present study	108	00122
43.	<i>Ophiiothrix (Ophiiothrix) savignyi</i> (Müller & Troschel, 1842)	SEAS	Shelf	Koehler 1898, Present study	22, 46	000145
Family Ophiuridae Müller & Troschel, 1840						
44.	<i>Amphiophiura paupera</i> (Koehler, 1897)	SEAS	Slope	Koehler 1897, 1899		
45.	<i>Amphiophiura radiata</i> (Koehler, 1897)	SEAS	Slope	Koehler 1897, 1899		
46.	<i>Amphiophiura sordida</i> (Koehler, 1897)	SEAS, ANI	Slope	Present study	1	
47.	<i>Ophiura (Ophiuroglypha) irrorata</i> (Lyman, 1878)	SEAS, WBoB	Slope	Koehler 1897		
48.	<i>Ophiura kinbergi</i> Ljungman, 1866	SEAS, WBoB, ANI	Shelf	Koehler 1898, present study		00022

Table 3 (continued)

No.	Species	Distribution in Indian & adjacent waters*	Record in SEAS		FORVSS survey sites (see Table 1)	CMLRE voucher no. (IO/SS/ECD/#)
			Region	References		
49.	<i>Ophiura aequalis</i> (Lyman, 1878)	SEAS, ANI	Slope	Koehler 1897, 1899	12, 15, 20, 21, 22, 30, 32, 33, 39, 40, 42, 44, 46, 47, 52, 56, 57, 58, 61, 76, 77, 78, 79, 80, 81, 82, 83, 85, 93, 94, 99, 108, 109, 107, 118, 128, 129, 136, 137, 140–142	
50.	<i>Ophiura undulata</i> (Lyman, 1878)	SEAS, GoM	Slope	Koehler 1899		

*Sources: Jayakumari (2004), Sastry (2007), Parameswaran and Abdul Jaleel (2012), Parameswaran et al. (2013)

^a First report from Indian waters

^b A. H. Clark (1915) reports this species from 'Sri Lanka', but the exact collection location is not provided

NEAS = Northeastern Arabian Sea, SEAS = Southeastern Arabian Sea, LI = Lakshadweep Islands, MI = Maldives, GoM = Gulf of Mannar, WBoB = Western Bay of Bengal, ANI = Andaman & Nicobar Islands

Note: A revised classification of the Ophiuroidea is pending, as evidenced in the recent works on the higher taxonomy of this group (O'Hara et al. 2014, 2017; Thuy and Stöhr 2016). The classification adopted in this paper (following Stöhr et al. 2012 and Okanishi and Fujita 2013) is liable to be obsolete with the publication of the new classification

Collection locations: Stn. 63, 115. Naturalist dredge and Smith-McIntyre grab.

Diagnosis: Disc diameter 3–5 mm, arms about 7–8 times this length, disc covered entirely with small imbricating scales; radial shields narrow, elongate, over three times as long as wide; primary rosettes distinct. Oral shields spearhead-shaped, with a small distal prolongation; one long, spine-like distal oral papilla on each side. One tentacle scale. Six arm spines at the base of the arm, the second ventral-most spine with a small, glassy, distally directed hook; dorsal spine larger than the rest. Colour white.

Distribution: SE Arabian Sea, North Australia, Philippines.

Amphiura (*Fellaria*) *heptacantha* (Mortensen, 1940)

Figure 3a, b.

Collection locations: Stn. 46, 142. Smith-McIntyre grab.

Diagnosis: Disc diameter 2 mm; scales present only around the radial shields, which are long and bar-like, with a small gap between them, rest of the disc naked, highly contorted; arms very long, all broken. Distal oral papillae not present on all jaws (possibly lost), scale-like with a rounded distal edge. Tentacle scales absent. Arm spines number 7, all flattened, and most with a rugose edge. Colour white.

Distribution: SE Africa (Mozambique), SE Arabian Sea, Persian Gulf, W Australia.

Genus *Ophiosphaera* Brock, 1888

Ophiosphaera insignis Brock, 1888

Figure 3c–e.

Collection locations: Stn. 52. Naturalist dredge.

Diagnosis: Disc diameter 2–3 mm, arms about 2–3 times this length. Disc distinctly domed and composed of a mosaic of small, hard scale-like plates; radial shields small, twice as long as wide, contiguous; outer edge of disc demarcated by a row of erect scales. Oral apparatus small; three glassy apical oral papillae, separated from two minute scale-like distal oral papillae by a wide diastema. Arm spines number 3 at the base of the arm, increasing to 6 at segment 4–5, decreasing beyond proximal part of the arm; lowermost arm spine conspicuously enlarged, about twice the corresponding segment length, club-like and hollow, spines decreasing in length towards the dorsal side. Colour cream.

Distribution: Seychelles, SE Arabian Sea, Malay Archipelago, Philippines, New Caledonia, Fiji.

Remarks: Specimen was collected in association with echinoid *Salmaciella dussumieri* L. Agassiz in L. Agassiz & Desor, 1846, and the species is known to be epibiont on echinoids (e.g. Koehler 1930; Cherbonnier and Guille 1978). This species is also known to show sexual dimorphism, with a dwarf male being attached to the oral side of a larger female (Koehler 1930). Only two females were collected during the present surveys, without any epibiont males.

Table 4 Updated checklist of Echinoidea of the SE Arabian Sea

No.	Species	Distribution in Indian & adjacent waters*	Record in SEAS	FORVSS survey sites (See Table 1)	CMLRE voucher no. (IO/SS/ ECD/ #)
			Region	References	
Order Cidaroida Claus, 1880					
Family Cidaridae Lambert, 1900					
1.	<i>Phyllacanthus imperialis</i> (Lamarck, 1816)	SEAS, GoM, ANI	Shelf	James 1969	
2.	<i>Prionocidaris baculosa</i> (Lamarck, 1816)	SEAS, GoM, WBoB	Shelf	Jayakumari 2004	
3.	<i>Stereocidaris alcocki</i> (Anderson, 1894)	SEAS, WBoB, ANI	Shelf & Slope ^a	Anderson 1894, present study	00106
4.	<i>Stylocidaris tiara</i> (Anderson, 1894)	SEAS, LI, GoM, ANI	Slope	Koehler 1927	
Family Histocidaridae Lambert, 1900					
5.	<i>Histocidaris denticulata</i> Koehler, 1927	SEAS, ANI ^b	Slope	Koehler 1927, present study	00107
Order Echinothurioida Claus, 1880					
Family Echinothuriidae Thomson, 1872					
6.	<i>Sperosoma biserialatum</i> Döderlein, 1901	SEAS, ANI	Slope	Koehler 1927	
Family Phormosomatidae Moretensen, 1934					
7.	<i>Hygrosoma luculentum</i> (A. Agassiz, 1879)	SEAS, ANI	Slope	Koehler 1927	
8.	<i>Phormosoma bursarium</i> A. Agassiz, 1881	SEAS, GoM, WBoB, ANI	Slope	Anderson 1894; Koehler 1927	
9.	<i>Phormosoma verticillatum</i> Mortensen, 1904	SEAS, ANI	Slope	Koehler 1927	
Order Camarodonta Jackson, 1912					
Family Echinometridae Grey, 1855					
10.	<i>Echinometra mathaei</i> (Blainville, 1852)	SEAS, LI, GoM, ANI	Shelf	Jayakumari 2004	
11.	<i>Heterocentrotus mamillatus</i> (Linnaeus, 1758)	SEAS, LI, GoM	Shelf	Jayakumari 2004	
Family Temnopleuridae A. Agassiz, 1872					
12.	<i>Paratrema doederleini</i> L. Agassiz in L. Agassiz & Desor, 1846	SEAS, ANI	Shelf	Present study	00108
13.	<i>Salmaciella dussumieri</i> L. Agassiz in L. Agassiz & Desor, 1846	SEAS, GoM, WBoB	Shelf	Present study	00109
14.	<i>Salmacis bicolor</i> L. Agassiz in L. Agassiz & Desor, 1846	SEAS, GoM, WBoB, ANI	Shelf	Koehler 1927; Sastry 2007; Jayakumari 2004	
15.	<i>Salmacis virgulata</i> Leske, 1778	SEAS, LI, GoM, WBoB,	Shelf	Jayakumari 2004, present study	00017
16.	<i>Temnopleurus toreumaticus</i> (Leske, 1778)	NEAS, SEAS, GoM, WBoB, ANI	Shelf	Jayakumari 2004; Sastry 2007	
Family Toxopneustidae Troschel, 1872					
17.	<i>Triploneustes gratilla</i> (Linnaeus, 1758)	SEAS, LI, GoM, WBoB, ANI	Shelf	Jayakumari 2004	
Order Diadematoidea Duncan, 1889					
Family Diademataidae Grey, 1855					
18.	<i>Echinothrix calamaris</i> (Pallas, 1774)	SEAS, LI, MI, WBoB, ANI	Shelf	Jayakumari 2004	
Order Salenioida Delage & Hérouard, 1903					
Family Saleniidae L. Agassiz, 1838					

Table 4 (continued)

No.	Species	Distribution in Indian & adjacent waters*	Record in SEAS		FORVSS survey sites (See Table 1)	CMLRE voucher no. (IO/SS/ ECD/ #)
			Region	References		
19.	<i>Salenocidaris miliaris indica</i> Mortensen, 1939 Order Stomopneustoida Kroh & Smith, 2010 Family Stomopneustidae Mortensen, 1903	SEAS	Slope	Mortensen 1939		
20.	<i>Stomopneustes variolaris</i> (Lamarek, 1816) Order Echinoneoidea H. L. Clark, 1925 Family Echinoneidae L. Agassiz & Desor, 1847	SEAS, LI, GoM, WBoB, ANI	Shelf	Jayakumari 2004		
21.	<i>Echinoneus cyclostomus</i> (Leske, 1778) Order Clypeasteroidea A. Agassiz, 1872 Family Astriclypeidae Stefanini, 1912	SEAS, LI, GoM, ANI	Shelf	Present study	21, 47	00119
22.	<i>Scupsitechinus auritus</i> (Leske, 1778) Family Clypeasteridae L. Agassiz, 1835	SEAS, GoM, WBoB, ANI	Shelf	Koehler 1922; Kurian 1953; James 1969; Jayakumari 2004, present study	11, 18, 54, 58, 65, 69, 70, 74, 77, 108, 125	00063
23.	<i>Clypeaster annandalei</i> Koehler, 1922	SEAS, WBoB	Slope	Koehler 1922		
24.	<i>Clypeaster fervens</i> (Linnaeus, 1758)	SEAS, WBoB	Shelf	Present study	22	00014
25.	<i>Clypeaster humilis</i> (Leske, 1778)	SEAS, GoM, WBoB	Shelf	James 1969		
26.	<i>Clypeaster varispinus</i> de Meijere, 1903	NEAS, SEAS, GoM, WBoB	Shelf	Koehler 1922; Sastry 2007; Jayakumari 2004, present study	10, 13, 18–20, 24, 29, 31, 36, 41–44, 47, 51, 54, 55, 58, 62–80, 85, 93, 101, 105, 107, 108, 113, 114, 118, 119, 121, 125–128, 131, 132, 134, 136, 138, 139, 142	00042
27.	<i>Clypeaster reitculatus</i> de Meijere, 1903 Family Echinocyamidae Lambert & Thiéry, 1914	SEAS, LI, WBoB, ANI	Shelf	Koehler 1922, present study	22	00019
28.	<i>Echinocyamus solters</i> Koehler, 1922 Family Laganidae Desor, 1858	SEAS, GoM	Slope	Koehler 1922		
29.	<i>Jacksonaster depressum</i> (L. Agassiz, 1841)	SEAS, LI, GoM, ANI	Shelf	Kurian 1953		
30.	<i>Peronella lesueuri</i> (L. Agassiz, 1841)	SEAS, LI	Shelf	Koehler 1922		
31.	<i>Peronella macroproctes</i> Koehler, 1922 Order Echinolampadoida Kroh & Smith, 2010 Family Echinolampadidae Grey, 1851	SEAS, GoM, ANI	Shelf	Koehler 1922; Sastry 2007		
32.	<i>Echinolampas alexandri</i> (Grey, 1845) Order Pedinoidea Mortensen, 1939 Family Pedinidae Pomel, 1883	SEAS, GoM,	Shelf	Present study	21, 122	00110
33.	<i>Caenopedina</i> sp. ^c Order Spatangoida L. Agassiz, 1840	SEAS	Slope	Koehler 1927		

Table 4 (continued)

No.	Species	Distribution in Indian & adjacent waters*	Record in SEAS		FORVSS survey sites (See Table 1)	CMLRE voucher no. (IO/SS/ ECD/ #)
			Region	References		
Family Brissidae Grey 1855						
34.	<i>Brissopsis luzonica</i> (Grey, 1851)	SEAS, WBoB, ANI	Shelf	Koehler 1914		
35.	<i>Brissopsis oldhami</i> Alcock, 1893	SEAS, WBoB, ANI	Slope	Koehler 1914		
Family Eurypatagidae Kroh, 2007						
36.	<i>Elipneustes denudatus</i> (Koehler, 1914)	SEAS	Slope	Koehler 1914		
37.	<i>Elipneustes rubens</i> (Koehler, 1914)	SEAS, GoM	Slope	Koehler 1914		
38.	<i>Linopneustes spectabilis</i> (de Meijere, 1904)	SEAS, MI	Slope	Koehler 1914		
Family Hemiasteridae H. L. Clark, 1917						
39.	<i>Holanthus vanus</i> (Koehler, 1914)	SEAS, WBoB	Slope	Koehler 1914		
Family Loveniidae Lambert, 1905						
40.	<i>Lovenia elongata</i> (A. Agassiz, 1864)	SEAS, GoM, WBoB, ANI	Shelf	Present study	14, 22, 88, 97, 98, 99, 138, 139, 142	00016
Family Maretidae Lambert, 1905						
41.	<i>Nacospatangus alta</i> (A. Agassiz, 1864)	SEAS, GoM, WBoB, ANI	Shelf	Koehler 1914, present study	21, 22, 134, 142	00026
Family Schizasteridae Lambert, 1905						
42.	<i>Hypselastra kempi</i> (Koehler, 1914)	SEAS, WBoB	Slope	Koehler 1914		
Incertae sedis						
43.	<i>Heterobrissus hemingi</i> (Anderson, 1902)	SEAS	Slope	Anderson 1902; Koehler 1914		

*Sources: Jayakumari (2004), Sastry (2007), Arachchige (2017)

^a Treated as a slope species

^b Recorded from ~400–450 m in 'Bay of Bengal' by Koehler (1927), but exact location of collection is not known. Also collected from 400 to 700 m depths around Nicobar Islands in recent surveys of FORVSS

^c SEAS is the type locality of *Caenopedina depressa* Koehler, 1927 nomen dubium, considered as possible juvenile of *C. superba* H. L. Clark, 1925 by Mortensen (1940). The report in Koehler (1927) is treated as positive record of the genus *Caenopedina* in SEAS

NEAS = Northeastern Arabian Sea, SEAS = Southeastern Arabian Sea, LI = Lakshadweep Islands, MI = Maldives, GoM = Gulf of Mannar, WBoB = Western Bay of Bengal, ANI = Andaman & Nicobar Islands

Table 5 Updated checklist of Holothuroidea of the SE Arabian Sea

No.	Species	Distribution in Indian & adjacent waters*	Records in SEAS		FORVSS survey sites (see Table 1)	CMLRE voucher no. (IO/SS/ECD/#)
			Region	References		
Order Apodida Brandt, 1835						
Family Synaptidae Burmeister, 1837						
1.	<i>Synaptula recta</i> (Semper, 1867)	SEAS, LI, GoM, WBoB, ANI	Shelf	Present study	23, 69	
Order Aspidochirofida Grube, 1840						
Family Holothuriidae Burmeister, 1837						
2.	<i>Holothuria (Mertensiothuria) leucospilota</i> (Brandt, 1835)	SEAS, GoM, ANI	Shelf	James 1969; Jayakumari 2004		
3.	<i>Holothuria (Platyperona) difficilis</i> Semper, 1868	SEAS, LI, ANI	Shelf	Jayakumari 2004		
4.	<i>Holothuria (Selenkothuria) moebii</i> Ludwig, 1883	SEAS, GoM, ANI	Shelf	James 1969		
5.	<i>Holothuria (Semperothuria) cinerascens</i> (Brandt, 1835)	SEAS, LI, GoM, ANI	Shelf	James 1969; Jayakumari 2004		
6.	<i>Holothuria (Semperothuria) imitans</i> Ludwig, 1875	SEAS	Shelf	Jayakumari 2004		
7.	<i>Holothuria (Theelothuria) kurti</i> Ludwig, 1891	NEAS, SEAS, LI, GoM	Shelf	Koehler and Vaney 1908		
8.	<i>Holothuria (Vaneyothuria) integra</i> Koehler & Vaney, 1908	SEAS	Shelf	Koehler and Vaney 1908		
Family Mesothuriidae Smirnov, 2012						
9.	<i>Mesothuria incerta</i> Koehler & Vaney, 1905	SEAS	Slope	Koehler and Vaney 1905		
10.	<i>Mesothuria multipes</i> (Ludwig, 1893)	SEAS	Slope	Koehler and Vaney 1905		
Family Stichopodidae Haeckel, 1896						
11.	<i>Stichopus hermanni</i> Semper, 1868	SEAS, LI, GoM, ANI	Shelf	Jayakumari 2004		
Family Synallactidae Ludwig, 1894						
12.	<i>Bathyploetes natans</i> (M. Sars, 1868)	SEAS	Slope	Koehler and Vaney 1905		
13.	<i>Bathyzona incerta</i> Koehler & Vaney, 1905	SEAS	Slope	Koehler and Vaney 1905		
14.	<i>Dendrothuria similis</i> Koehler & Vaney, 1905	SEAS	Slope	Koehler and Vaney 1905		
15.	<i>Perizona magna</i> Koehler & Vaney, 1905	SEAS	Slope	Koehler and Vaney 1905, present study	87	
Order Dendrochirofida Grube, 1840						
Family Cucumariidae Ludwig, 1894						
16.	<i>Aslia forbesi</i> (Bell, 1886)	NEAS, SEAS, ANI	Shelf	Jayakumari 2004		
17.	<i>Havelockia ariana</i> (Koehler & Vaney, 1908)	SEAS, LI	Shelf	Koehler and Vaney 1908		
18.	<i>Leptopentacta imbricata</i> (Semper, 1867)	SEAS, GoM, WBoB	Shelf	James 1969, 1983; Price and Reid 1985; Jayakumari 2004, present study	10, 17, 23, 64, 67, 69, 71, 74, 76, 92, 107, 113	00078
19.	<i>Pseudocnus echinatus</i> (von Marenzeller, 1881)	SEAS, WBoB	Shelf	Present study	45	
20.	<i>Staurothyone rosacea</i> (Semper, 1869)	SEAS	Shelf	Jayakumari 2004		
21.	<i>Trachasina crucifera</i> (Semper, 1869)	SEAS	Shelf	Jayakumari 2004		
Family Phyllophoridae Östergren, 1907						
22.	<i>Neothyonidium intermedium</i> (Koehler & Vaney, 1908)	SEAS	Slope	Koehler and Vaney 1905		
23.	<i>Phyllophorus (Phyllothuria) cebuensis</i> (Semper, 1867)	SEAS, GoM	Shelf	Jayakumari 2004		
24.	<i>Stolus buccalis</i> Koehler & Vaney, 1908		Shelf	Jayakumari 2004, Present study	34, 64, 74, 76, 77, 107, 108	00111

Table 5 (continued)

No.	Species	Distribution in Indian & adjacent waters*	Records in SEAS		FORVSS survey sites (see Table 1)	CMLRE voucher no. (IO/SS/ECD/#)
			Region	References		
25.	<i>Thyone dura</i> Koehler & Vaney, 1908	NEAS, SEAS, GoM, WBoB, ANI	Shelf	Present study	45, 60, 64, 67, 69–74, 77, 80, 88, 91, 93, 117, 119	00112
	Family Psolidae Koehler & Vaney, 1905					
26.	<i>Psolidum rugosum</i> Koehler & Vaney, 1905	SEAS	Shelf	Koehler and Vaney 1905		
27.	<i>Psolus levis</i> Koehler & Vaney, 1905	SEAS	Shelf	Koehler and Vaney 1905		
28.	<i>Psolus membranaceus</i> Koehler & Vaney, 1905	SEAS	Shelf	Koehler and Vaney 1905		
	Family Ypsilothuridae Heding, 1842					
29.	<i>Ypsilothuria bitentaculata</i> (Ludwig, 1893)	SEAS, ANI	Slope	Koehler and Vaney 1905		
	Order Elapsipodida Théel, 1882					
	Family Deimatidae Théel, 1882					
30.	<i>Deima validum validum</i> Théel, 1879	SEAS, WBoB, ANI	Slope	Koehler and Vaney 1905		
31.	<i>Oneirophanta conservata</i> Koehler & Vaney, 1905	SEAS	Slope	Koehler and Vaney 1905		
	Family Lactmogonidae Ekman, 1926					
32.	<i>Laetmogone violacea</i> Théel, 1879	SEAS	Slope	Koehler and Vaney 1905		
	Family Psychropotidae Théel, 1882					
33.	<i>Benthodytes typica</i> Koehler & Vaney, 1905	SEAS, ANI	Slope	Present study	49, 50, 84, 86, 87, 102, 110, 112	00114
34.	<i>Psychropotes minuta</i> Koehler & Vaney, 1905	SEAS	Slope	Koehler and Vaney 1905		
	Order Molpadida Haeckel, 1896					
	Family Eupyrigidae Semper, 1867					
35.	<i>Eupyrigus scaber</i> Lütken, 1857	SEAS, ANI	Slope	Walsh 1891		
	Family Molpadidae Müller, 1850					
36.	<i>Molpadia musculus</i> Risso, 1826	SEAS, WBoB, ANI	Slope	Koehler and Vaney 1905, present study	49, 111	00113

*Sources: Jayakumari (2004), Sastry (2007)

NEAS = Northeastern Arabian Sea, SEAS = Southeastern Arabian Sea, LI = Lakshadweep Islands, GoM = Gulf of Mannar, WBoB = Western Bay of Bengal, ANI = Andaman & Nicobar Islands

Table 6 Updated checklist of Crinoidea of the SE Arabian Sea

No.	Species	Distribution in Indian & adjacent waters*	Records in SEAS		FORVSS survey sites (see Table 1)	CMLRE voucher no. (IO/SS/ECD/#)
			Region	References		
Order Isocrinida Sieverts-Doreck, 1952						
Family Cainocrinidae Simms, 1988						
1.	<i>Teliocrinus springeri springeri</i> (A. H. Clark, 1909)	SEAS, ANI	Slope	A. H. Clark 1909, 1912a present study	3	00118
Order Comatulida						
Family Antedonidae Norman, 1865						
2.	<i>Antedon?</i> <i>parviflora</i> (A. H. Clark, 1912)	SEAS, MI	Shelf	Present study	108	00129
3.	<i>Athrypsometra mira</i> (A. H. Clark, 1909)	SEAS, ANI	Slope	Clark 1912a		
4.	<i>Fariometra obscura</i> (A. H. Clark, 1909)	SEAS	Slope	Clark 1912a, b		
5.	<i>Mastigometra micropoda</i> A. H. Clark, 1909	SEAS, GoM ^a	Shelf	Present study	47	
6.	<i>Thaumatometra plana</i> (A. H. Clark, 1912)	SEAS	Slope	A. H. Clark 1912a		
Family Charitometridae A. H. Clark, 1909						
7.	<i>Glyptometra macilenta</i> (A. H. Clark, 1909)	SEAS	Slope	A. H. Clark 1909, 1912a		
Family Colobometridae A. H. Clark, 1909						
8.	<i>Cenometra bella</i> (Hartlaub, 1890)	SEAS, WBoB	Shelf	Present study	47	00116
9.	<i>Petasometra helianthoides</i> A. H. Clark, 1912 ^b	SEAS	Shelf	Present study	52	
Family Comatulidae Fleming, 1828						
10.	<i>Comaster schlegelii</i> (Carpenter, 1881)	SEAS, GoM, ANI	Shelf	Jayakumari 2004		
Family Himerometridae A. H. Clark, 1907						
11.	<i>Heterometra africana</i> (Hartlaub, 1890)	NEAS, SEAS	Shelf	Present study	52, 108	
12.	<i>Himerometra robustipinna</i> (Carpenter, 1881)	SEAS, ANI	Shelf	Present study	37	00117
Family Mariametridae A. H. Clark, 1909						
13.	<i>Lamprometra palmata</i> Müller, 1841	SEAS, GoM, WBoB	Shelf	A. H. Clark 1932, Jayakumari 2004		
Family Pentametrocrinidae A. H. Clark, 1908						
14.	<i>Thaumatocrinus investigatoris</i> AH Clark (in A. H. Clark & A. M. Clark, 1967)	SEAS, MI	Slope	A. H. Clark 1912a		
Family Thalassometridae A. H. Clark, 1908						
15.	<i>Stiremetra carinifera</i> A. H. Clark, 1912	SEAS	Slope	A. H. Clark 1912a		
Family Tropiometridae A. H. Clark, 1908						
16.	<i>Tropiometra carinata</i> (Lamarck, 1816)	SEAS, GoM, WBoB	Shelf	A. H. Clark 1932, Jayakumari 2004		

*Sources: Jayakumari (2004), Sastry (2007), Clark (1912a, b)

^aType locality is 'India' (A. H. Clark 1909), subsequently reported from Gulf of Mannar (A. H. Clark 1912b).

^bFirst report from Indian waters

NEAS = Northeastern Arabian Sea, SEAS = Southeastern Arabian Sea, LI = Lakshadweep Islands, MI = Maldives, GoM = Gulf of Mannar, WBoB = Western Bay of Bengal, ANI = Andaman & Nicobar Islands

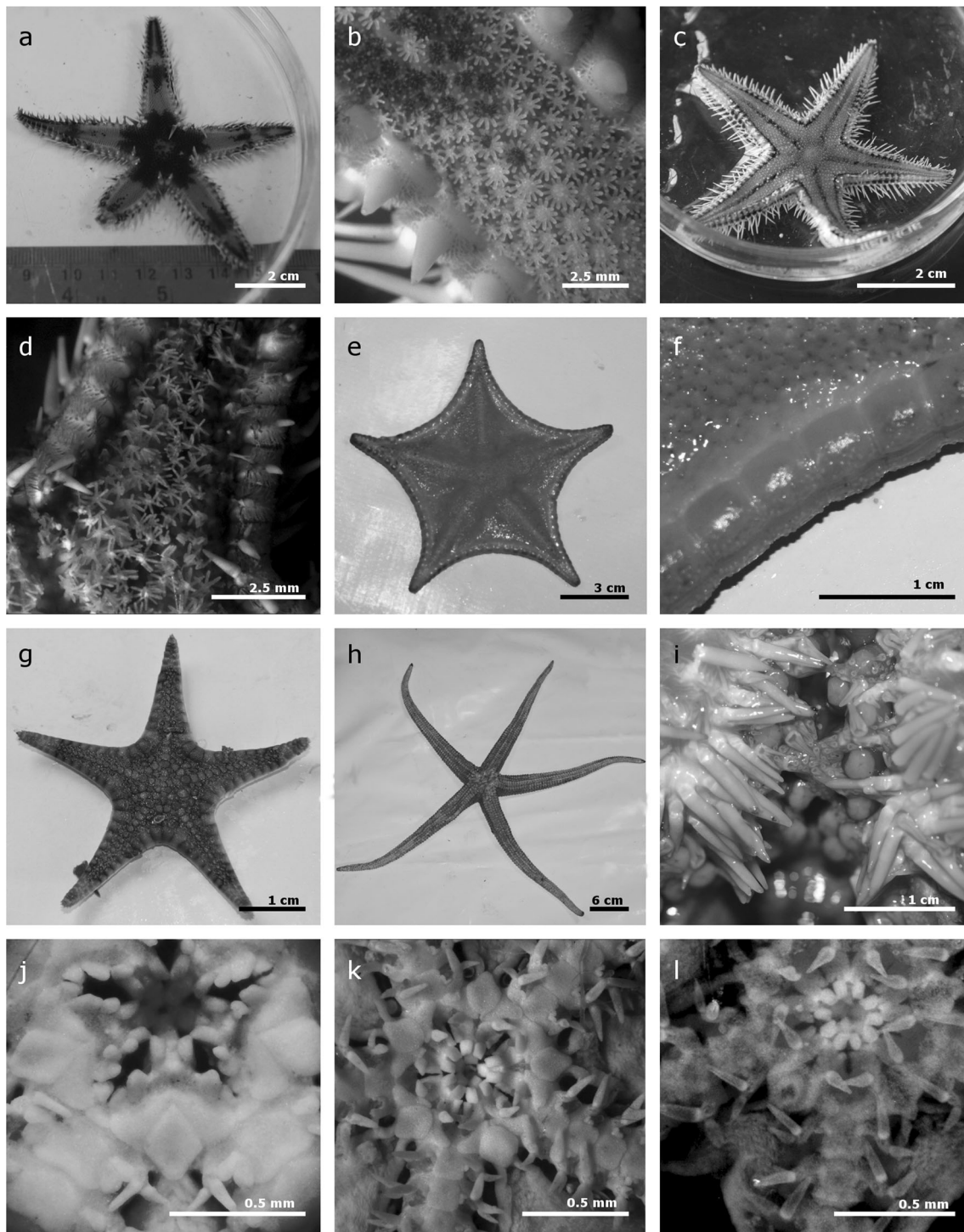


Fig. 2 **a, b** *Astropecten polyacanthus*, **a** aboral view showing spines on first supero-marginals and two subsequent supero-marginals reduced and spineless, **b** paxillae and supero-marginals on middle part of arm; **c, d** *Astropecten vappa*, **c** aboral view, **d** paxillae and supero-marginals of arm base; **e, f** *Ceramaster cuenoti*, **e** aboral view, **f** marginal plates, almost naked, with a well-defined row of granules along their edges; **g** *Goniodiscaster forficulatus*, aboral view; **h, i** *Zoroaster alfredi*, **h** aboral

view, **i** proximal part of ambulacrum showing large bivalve pedicellariae attached to the spines and bunches of small pedicellariae attached to their base; **j** *Amphiplus (Lymanella) depressus*, oral apparatus showing contiguous row of 4 oral papillae; **k** *Amphiura ambigua*, oral view showing spearhead-shaped oral shield and single distal oral papilla; **l** *Amphiura constricta*, oral view showing spine-like distal oral papillae

Family Ophiacanthidae Ljungman, 1867
Genus Ophiacantha Müller & Troschel, 1842

Ophiacantha dallasii Duncan, 1879
Figure 3f, g.

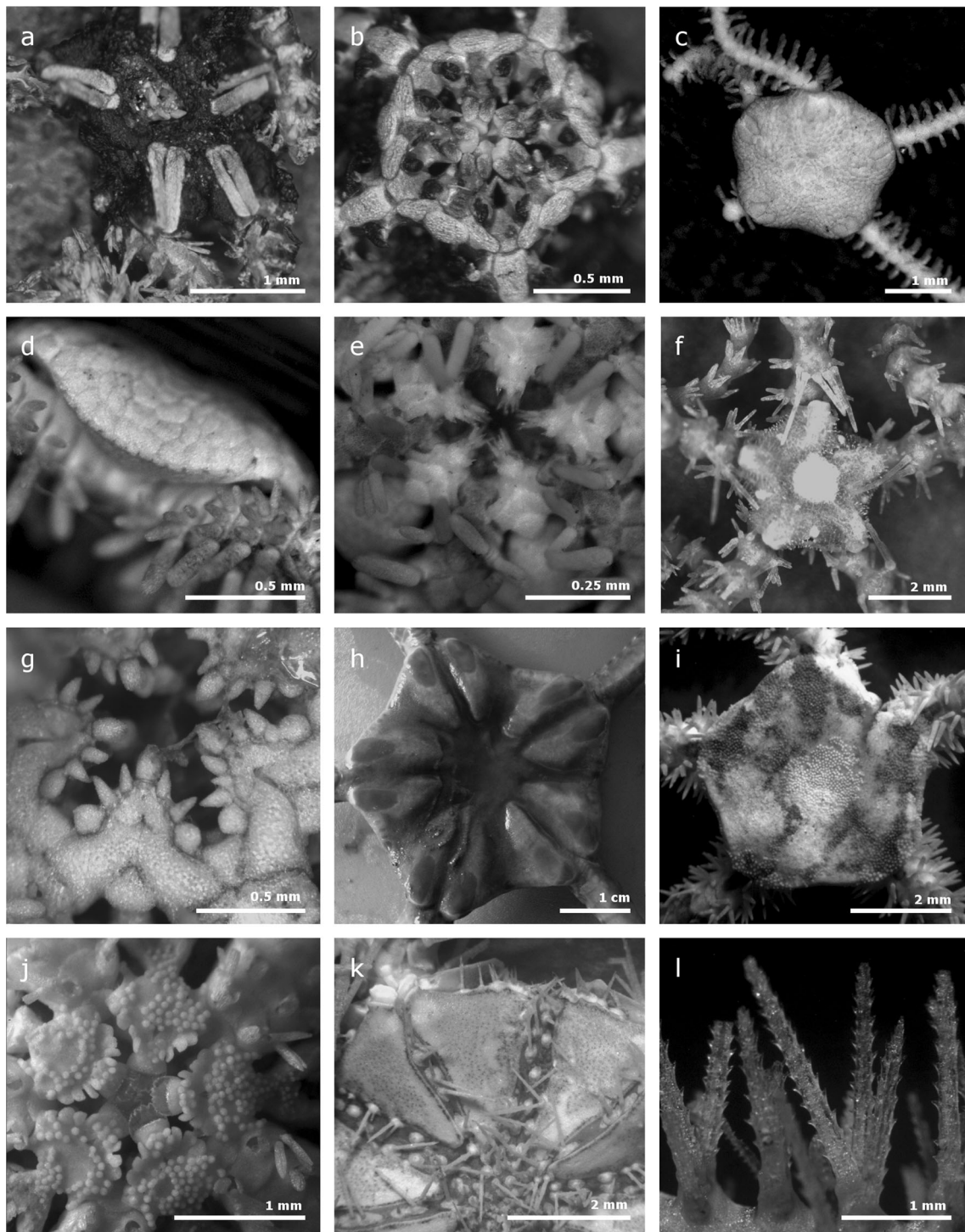


Fig. 3 **a, b** *Amphiura* (*Fellaria*) *heptacantha*, **a** aboral view, **b** oral view. **c–e** *Ophiosphaera insignis*, **c** dorsal view, **d** disc margin showing the high disc and row of erect marginal scales, **e** oral apparatus; **f, g** *Ophiacantha*

dallasii, **f** aboral view, **g** oral apparatus; **h** *Bathypectinura heros*, aboral view; **i, j** *Ophioconis cupida*, **i** aboral view, **j** oral apparatus; **k, l** *Ophiothrix* (*Ophiothrix*) *aristulata*, **k** aboral disc spines, **l** arm spines

Collection locations: Stn. 108. Naturalist dredge.

Diagnosis: Disc diameter 3 mm, disc covered above and below by short trifid stumps, more or less obscuring radial shields. Oral shields roughly triangular with a rounded distal margin; adoral shields larger than oral shields, with distal

prolongations which extend beyond the lateral margins of the oral shields; three oral papillae on each side, the outer one larger, but less than twice as wide as long. Arm distinctly moniliform. Small spiniform tentacle scales on basal arm segments. Up to seven arm spines; on the second free arm

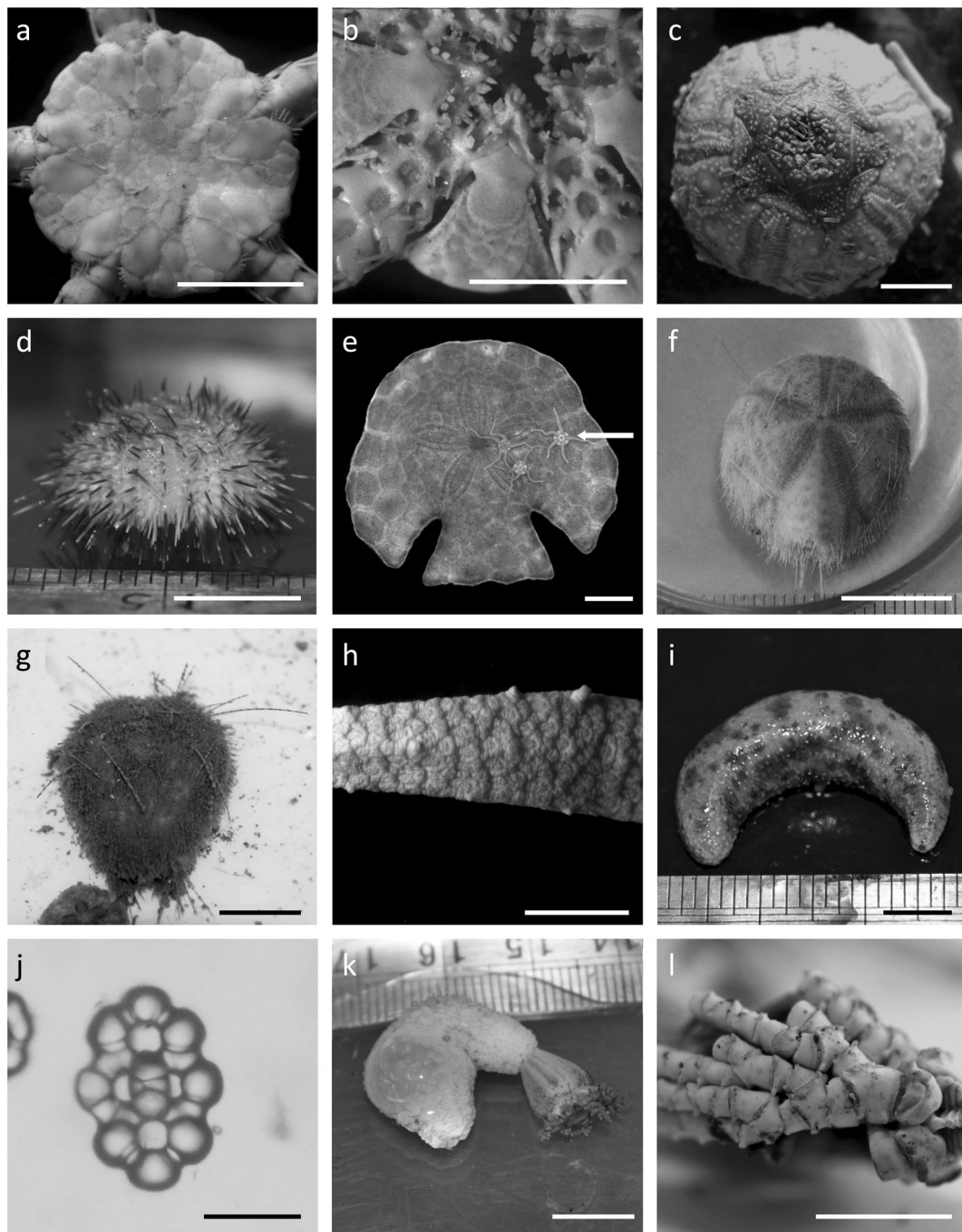


Fig. 4 **a, b** *Ophiura kinbergi*, **a** aboral view, **b** oral view; **c** *Stereocidaris alcocki*, apical system; **d** *Salmacis virgulata*, entire organism; **e** *Sculpsitechinus auritus*, aboral view with epibionts *Ophiodaphne scripta* (arrow); **f** *Echinolampas alexandri*, entire organism; **g** *Lovenia elongata*, entire organism; **h** *Leptopentacta imbricata*, middle portion

showing imbricating, plate-like arrangement of skin; **i, j** *Stelus buccalis*, **i** entire organism with tentacles everted, **j** nodose button from skin; **k** *Thyone dura*, entire organism; **l** *Teliocrinus springeri springeri*, base of crown showing first two brachitaxes

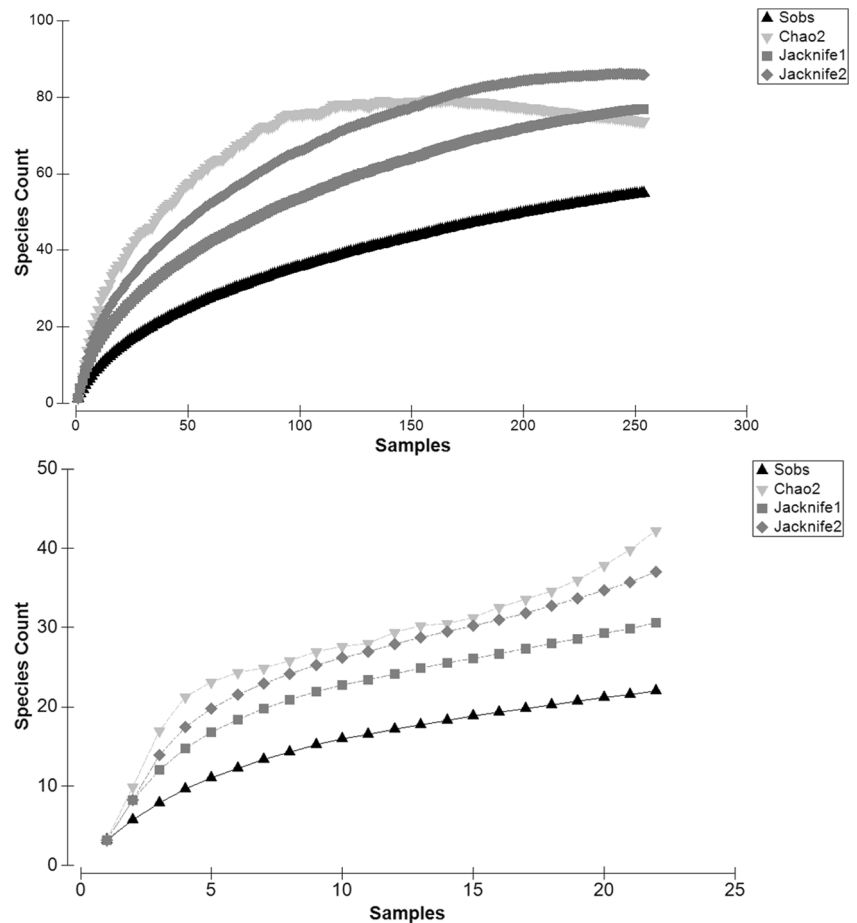
segment, spines from either side contiguous, and dorsal row of spines more than twice as long as other spines. Colour greyish white.

Distribution: SW Africa (Mozambique), SE Arabian Sea, N & NW Australia, Malay Archipelago, South China Sea,

Philippines, New Caledonia, Fiji. Also collected from Nicobar Islands during FORVSS surveys (50 m depth off Car Nicobar, Catchall & Nancowry Islands).

Remarks: Specimens collected in association with a gorgonid.

Fig. 5 Species accumulation curves of echinoderms from the SE Arabian Sea continental shelf (a) and slope (b)



Family Ophiodermatidae Ljungman, 1867

Genus *Ophioconis* Lütken, 1869

Ophioconis cupida Koehler, 1905

Figure 3i, j.

Collection locations: Stn. 52, 108. Naturalist dredge.

Diagnosis: Disc diameter 5 mm, arms 2–3 times this length; disc with a well-defined dorsolateral margin, and wholly covered with uniform rounded granulation, which is dislodged easily to reveal thin imbricating scales underneath; radial shields indistinct. Oral shields rounded or sub-triangular, covered partly by granulation, as are the adoral shield and oral plates; apical oral papillae indistinguishable from these granules; a row of three oral papillae along the edge of the jaw. Teeth extremely wide, with a rounded, serrated and hyaline edge. Arm spines numbering 7–9, flattened, as long as the corresponding segment. Colour white to light grey with dark mottling.

Distribution: Red Sea, Gulf of Aden, SE Arabian Sea, Solomon Islands, New Caledonia, Wallis & Futuna Islands.

Class Crinoidea

Order Comatulida

Family Colobometridae A. H. Clark, 1909

Genus *Petasometra* A. H. Clark, 1912

Petasometra helianthoides A. H. Clark, 1912

Collection locations: Stn. 52. Naturalist dredge.

Diagnosis: Colobometrid with 10 arms; IB₂, first syzygy between segments 3 and 4, second between 9 and 10. Pinnules simple; first inner pinnule lacking; first and second exterior pinnules of the same size. Cirri with 12 segments, bearing aboral transverse ridges on all and an opposing spine on the last. Colour white with dark blotches on the arms.

Distribution: *Petasometra helianthoides* is known from northern Australia and SE Arabian Sea. The only other known species in the genus, *P. clarae*, is reported from the Malay Archipelago.

Remarks: Only two species—*P. helianthoides* and *P. clarae* (Hartlaub, 1890)—are known in the genus (both from very few specimens), and these are suspected to be synonymous (Clark and Rowe 1971). Only character distinguishing the species is the number of arms (10–14 in *P. helianthoides* and 15–31 in *P. clarae*).

Results and discussion

In the present surveys, a total of 76 species of echinoderms were recorded from SEAS, including 29 species previously

Table 7 Updated species richness of echinoderms in the SEAS

			Species recorded in the present surveys			Total species recorded from the SEAS (re-validated)
Previous records from the SEAS*			Recorded in present surveys & previously known from SEAS	New records for the SEAS ^a	Total species recorded during the present surveys	
<i>Class Asteroidea</i>	<i>Shelf</i>	5	2	6	8	11
	<i>Slope</i>	22	8	2	10	24
	<i>Total</i>	27	10	8	18	35
<i>Class Ophiuroidea</i>	<i>Shelf</i>	7	4	20 (6)	24	27
	<i>Slope</i>	20	3	3	6	23
	<i>Total</i>	27	7	23	30	50
<i>Class Echinoidea</i>	<i>Shelf</i>	19	5	6	11	25
	<i>Slope</i>	18	2	0	2	18
	<i>Total</i>	37	7	6	13	43
<i>Class Holothuroidea</i>	<i>Shelf</i>	18	2	3	5	21
	<i>Slope</i>	14	2	1	3	15
	<i>Total</i>	32	4	4	8	36
<i>Class Crinoidea</i>	<i>Shelf</i>	3	0	6 (1)	6	9
	<i>Slope</i>	7	1	0	1	7
	<i>Total</i>	10	1	6	7	16
<i>Total Echinodermata</i>	<i>Shelf</i>	52	13	41	54	93
	<i>Slope</i>	81	16	6	22	87
	<i>Total</i>	133	29	47	76	180

Shelf refers to the continental shelf (including near shore areas) up to 250 m depth

Slope indicates the continental slope (and continental rise), at depths from 250 m to ~2200 m

*Includes species recorded outside the depth range surveyed in the present study (<20 m or >1500 m)

^a Numbers in parenthesis indicate species that are new records for the Indian EEZ

known from SEAS, 38 species previously known from other parts of the Indian EEZ (i.e. NE Arabian Sea, Lakshadweep Islands, Gulf of Mannar, W Bay of Bengal or Andaman & Nicobar Islands) or adjacent areas (e.g. Maldives), seven new records for Indian waters and one new species, *Asteroschema sampadae*. Of these 76 species, 54 species were collected from the continental shelf of the SEAS (20–200 m). The Ophiuroidea were represented by 24, Asteroidea by eight, Holothuroidea by five and Crinoidea by six species. The seven new records for the Indian EEZ were collected from the shelf region, and included six species of ophiuroids and one species of crinoid. Among these, a detailed description of one ophiuroid, *Ophiodaphne scripta* (Koehler, 1904), which exhibits sexual dimorphism and an epibiotic life habit, is published separately (Parameswaran et al. 2013). The remaining six species are briefly described above. Photographic plates (Figs. 2, 3 and 4) depict the diagnostic characters of the new records as well as other common species collected in the present surveys, and these are arranged in order of appearance in the checklists. From the slope region (200–1500 m), 22 species in 18 families were recorded, representing 10 species of Asteroidea, six of Ophiuroidea, two of Echinoidea, three of

Holothuroidea and one species of Crinoidea. Nearly all the records for the slope region represented rediscoveries of species collected and described through the RIMS *Investigator* surveys. The predominantly deep-sea echinoid species, *Stereocidaris alcocki* (Cidaridae), was recorded at one site in the shelf (at 51 m depth). Apart from this, the species composition of echinoderms in the shelf and slope were entirely distinct. Although the validity of the deep-sea cucumber *Perizona magna* Koehler & Vaney, 1909, was doubted by Sastry (2007), specimens matching well with the original description were collected in the present surveys.

Species estimators for the continental shelf (Fig. 5a) and slope (Fig. 5b) predicted the occurrence of up to 86 species in the shelf between depths of 20 and 200 m (Chao 2 estimator: 74 ± 10 ; Jackknife 1 estimator: 77; Jackknife 2 estimator: 86 species) and 62 species in the slope between depths of 200 and 1500 m (Chao 2 estimator: 42 ± 20 ; Jackknife 1 estimator: 31; Jackknife 2 estimator: 37 species). The present surveys at these depths were able to record 64% of the highest estimated diversity in the shelf and 54% in the slope region. Notably, only 48 to 72% of estimated species could be collected in the Cape Comorin region (~7–8° N), as the hard bottom and

uneven contours restricted intensive sampling, while the observed number of species nearly equalled the estimator values in the region north of Kochi (10–15° N). While previous studies report only 54 species from the SEAS shelf, the present study provides an additional 41 new records in the SEAS. With relatively limited observations in the slope, the present study recorded 22 species, of which five were new to the SEAS and one was a new species.

With the findings of the present survey, the total number of echinoderm species in the SEAS is now re-validated as 180, comprising 93 species from the continental shelf (Tables 2, 3, 4, 5, 6 and 7) and 87 species from the slope (Tables 2, 3, 4, 5, 6 and 7), as against the previous record of 133 species (Table 7). From the updated checklists, it is evident that for the SEAS continental margin as a whole (Table 7), the Ophiuroidea were the most diverse (50 species), followed by the Echinoidea (43 species), Holothuroidea (36 species) and Asteroidea (35 species), while the Crinoidea were relatively less diverse (16 species).

Echinoderms are known to be highly vulnerable to climate change, ocean acidification, oxygen depletion and bottom trawling. Within the SEAS, the intense seasonal hypoxia in the shelf (Naqvi et al. 2006) and the perennial Arabian Sea oxygen minimum zone (Helly and Levin 2004), as well as intense bottom trawling (Abdul Jaleel et al. 2015), significantly impact benthic fauna (Ingole et al. 2010; Abdul Jaleel et al. 2014, 2015) and can alter the diversity and distribution of the echinoderms. In this context, the present paper provides comprehensive species inventory of the phylum Echinodermata in the sizeable area of the SEAS, which can serve as a baseline document, for example, for impact assessment studies or formulation of conservation strategies.

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