

Annotated checklist of Echinoderms from Araçá Bay, Southeastern Brazil

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Abstract: We present a species list of echinoderms from Araçá Bay, state of São Paulo. Altogether, 863 specimens belonging to 25 species, 19 genera, and 13 families were exhaustively collected during three years in consolidated and non-consolidated substrate. Ophiuroidea was the most representative taxon with 16 species, follow by Asteroidea with four species, Echinoidea with three, and Holothuroidea with two species. The brittle stars *Amphiura kinbergi* and *Ophiothela* cf. *mirabilis* are new records for Araçá Bay. We confirm that Araçá Bay is one of the best known area of echinoderm diversity in Brazil considering that the perimeter (3 km) of the bay corresponds to only 0.03% of the Brazilian coastline (8500 km). This work complements the knowledge of Araçá Bay biodiversity and supports future interventions, management and maintaining the diversity of this wonderful group of marine animals.

Key words: Echinodermata; marine biodiversity; benthos; inventory

INTRODUCTION

Echinoderms are benthic and exclusively marine animals with broad diversity inhabiting rocky shores, beach, bays and subtidal zones including the deep-sea (Pawson 2007). All of them are free-living and present a huge variety of food strategies and ways of life (Hickman 1998; Lawrence 2012). The phylum consists of approximately 7,000 living species and 13,000 extinct species, comprising five monophyletic classes: Ophiuroidea (2136 species), Asteroidea (1800), Holothuroidea (1400), Echinoidea (1000) and Crinoidea (700) (Alvarado and Solís-Marín 2013; Kroh and Mooi 2015; Mah 2015; Stöhr et al. 2015).

The echinoderm fauna in Brazilian waters is composed of 340 species (Ventura et al. 2013). In the state

of São Paulo, southeastern Brazil, 120 echinoderm species have been reported (Hadel et al. 1999; Borges et al. 2006; Borges and Amaral 2007). In São Sebastião, in northeastern São Paulo state, 38 species are known (1 Crinoidea, 9 Asteroidea, 13 Ophiuroidea, 9 Echinoidea, and 6 Holothuroidea) (Netto et al. 2005). In Araçá Bay, a compilation of studies (Amaral et al. 2010), reported 18 species (1 Crinoidea, 5 Asteroidea, 5 Ophiuroidea, 4 Echinoidea, and 3 Holothuroidea).

The present work integrates the Project Biota/FAPESP – Araçá “Biodiversity and functioning of a subtropical coastal ecosystem: a contribution to integrated management,” which considers Araçá Bay as a model to develop proposals for sustainability of the locality. Despite of the small relict mangrove stands, this bay is ecologically and economically important, because of very diverse marine habitats and a high human impact on the environment, with substrates continuously modified by several environmental factors (Netto et al. 2005; Amaral et al. 2015). In order to create a baseline for future works in ecology, monitoring and management of Araçá Bay, we present the first comprehensive inventory of echinoderms from this location.

MATERIALS AND METHODS

Study site

Araçá Bay is located on the northeastern coast of the state of São Paulo (23°49' S, 045°24' W), Brazil. This locality is a wide (≈ 240 m) tidal flat (< 1% slope), comprising one of the richest coastal environments in southeastern Brazil, with more than 1,300 species recorded (Amaral et al. 2015). The bay is a highly complex environment, surrounded by three beaches: Pernambuco (Figure 1A), Germano and Topo; two islets: Pernambuco (Figure 1B) and Pedroso; three main stands of mangrove, rocky shores (Figure 1C), and an extensive muddy sand flat (Figure 1D) extending to the subtidal zone.

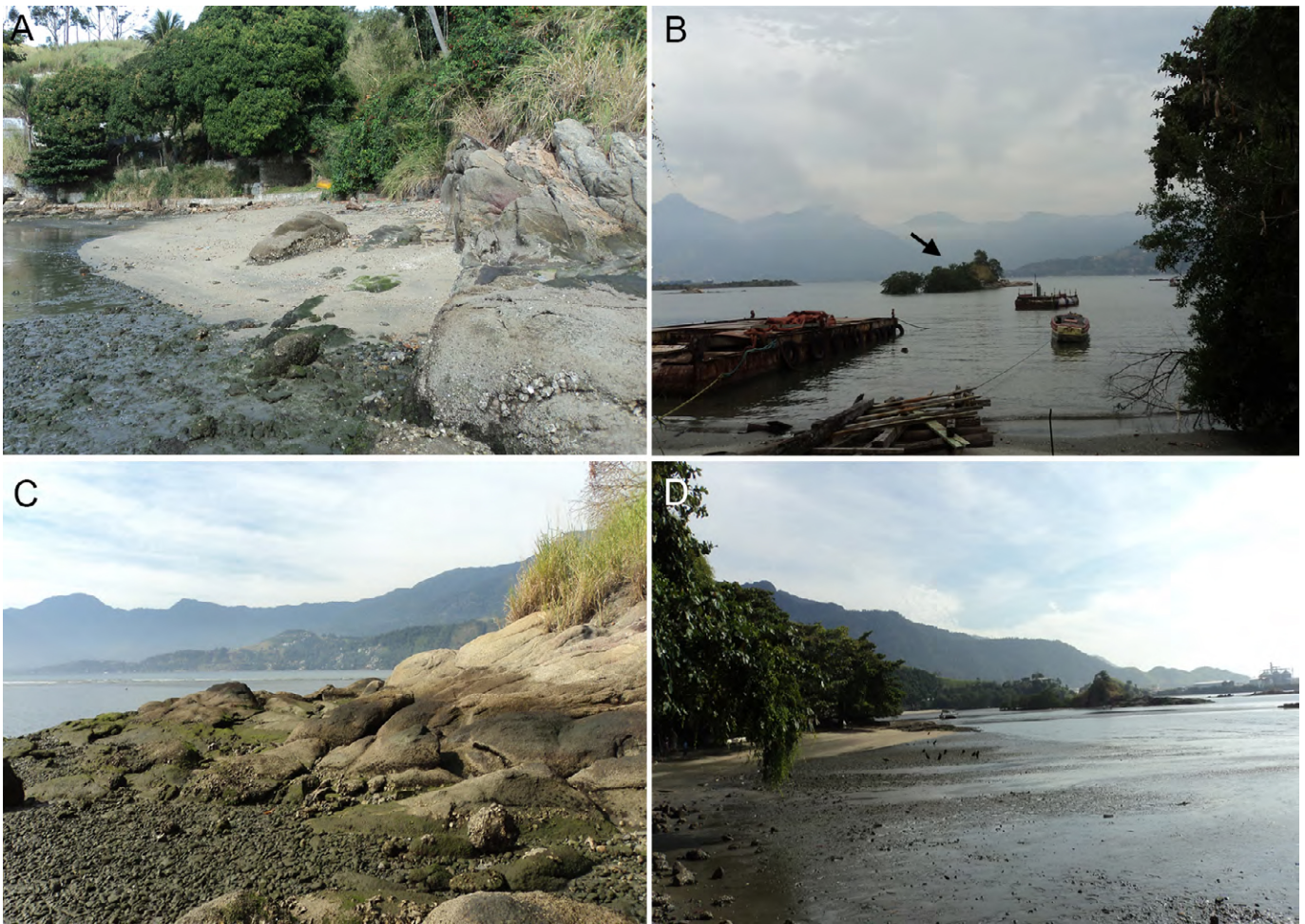


Figure 1. Araçá Bay. **A)** Pernambuco Beach; **B)** Mangrove (arrow) located near Pernambuco Island; **C)** Rocky shore; **D)** Intertidal zone with muddy sand flat.

Data collection

Different sampling strategies were adopted for each type of substrate: (i) non-consolidated up to 20 m deep and (ii) consolidated.

In non-consolidated substrate, 37 sampling stations were collected (Figure 2) during the years 2012 (October), 2013 (February, June, September, and October), and 2014 (March, June, and July). For sampling the intertidal zone we used a corer with 0.16 m² of area. In the subtidal zones a multicorer, a van Veen grab (0.25 m² base area) (Table 1), a dredge (40 × 80 cm, 5 mm conical internodes) (Table 2), and bottom trawls (9.5 m opening, 6.7 m bagger, 10 mm internodes) were used. Samples were screened with overlapping 1.0 and 0.5 mm mesh sieves.

In consolidated substrate and all biological substrate: algae, mangrove, rhizophores, pneumatophores and banks of mussels, sponges, cnidarians, bryozoans, polychaetes and barnacles, active searching was used. The samples were taken in 2012 (October), 2013 (February, July, November), and 2014 (June). All specimens collected in this study were fixed and preserved in 70% or 90% ethanol.

Taxonomic identifications were based in the works of: Tommasi (1970), Hendler et al. (1995), Borges et al. (2002), Borges and Amaral (2005), Pomory (2007) and Gondim et al. (2013) for Ophiuroidea; Clark and Downey (1992), Ventura et al. (2007), Benavides-Serrato et al. (2011), and Gondim et al. (2014) for Asteroidea; Bernasconi (1955), Tommasi (1966), Borrero-Pérez et al. (2002), and Farias (2012) for Echinoidea and Tommasi (1969), Pawson et al. (2010), Martins (2012), Prata et al. (2014) and Martins and Souto (2015) for Holothuroidea. Taxonomic list is organized systematically according to Clark and Downey (1992), Kroh and Smith (2010), Appeltans et al. (2012) and Stöhr et al. (2015). Photos of the specimens were made with a ZEISS TK 1270U video camera coupled to a stereomicroscope and a Canon EOS 7D still camera.

All specimens are deposited in the Museum of Zoology of the University of Campinas (ZUEC), and identified by the abbreviation ZUEC OPH for Ophiuroidea, ZUEC AST for Asteroidea, ZUEC ECH for Echinoidea and ZUEC HOL for Holothuroidea.

Abbreviations: st – sampling station.

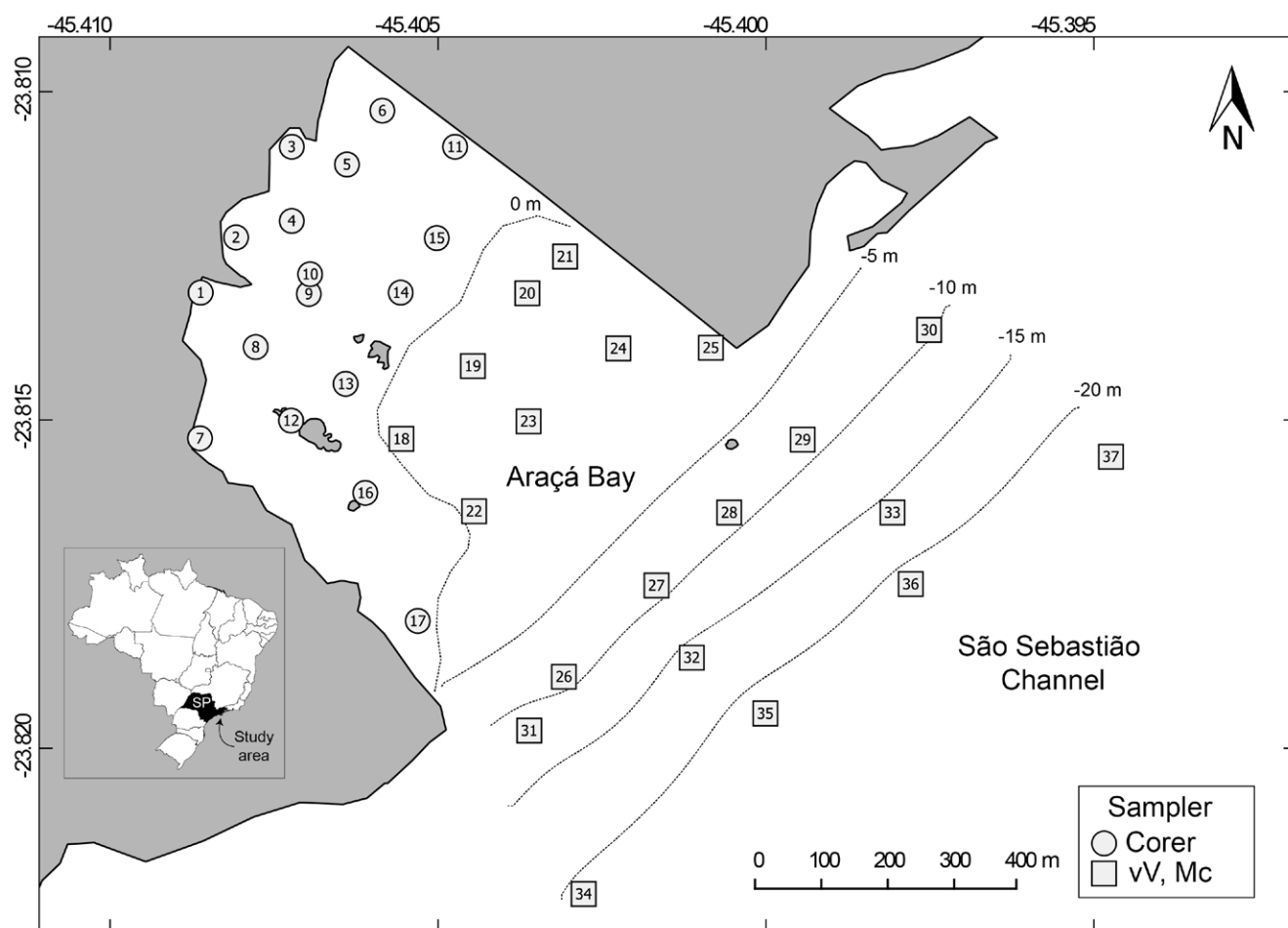


Figure 2. Sampling stations in non-consolidated substrate of Araçá Bay. Circles represent corer used in intertidal zone. Squares represent van Veen (vV) and multicorer (Mc) used in subtidal. Dashed lines represent bathymetry.

Table 1. Sampling stations carried out in intertidal zone with corer (1 to 17) and subtidal with multicorer and van Veen (18 to 37). Feb = February, Jul = July, Jun = June, Mar = March, Oct = October, Sep = September.

Stations	Oct 2012	Feb 2013	Jun 2013	Sep 2013	Mar 2014	Jun 2014	Jul 2014	Geographic Coordinates
1	1	38	75	112				23°48'47" S, 045°24'31" W
2	2	39	76	113				23°48'44" S, 045°24'29" W
3	3	40	77	114				23°48'39" S, 045°24'29" W
4	4	41	78	115				23°48'43" S, 045°24'26" W
5	5	42	79	116				23°48'40" S, 045°24'23" W
6	6	43	80	117				23°48'37" S, 045°24'21" W
7	7	44	81	118				23°48'55" S, 045°24'31" W
8	8	45	82	119				23°48'50" S, 045°24'28" W
9	9	46	83	120				23°48'47" S, 045°24'26" W
10	10	47	84	121				23°48'46" S, 045°24'25" W
11	11	48	85	122				23°48'39" S, 045°24'17" W
12	12	49	86	123				23°48'54" S, 045°24'26" W
13	13	50	87	124				23°48'52" S, 045°24'23" W
14	14	51	88	125				23°48'47" S, 045°24'20" W
15	15	52	89	126				23°48'44" S, 045°24'18" W
16	16	53	90	127				23°48'58" S, 045°24'22" W
17	17	54	91	128				23°49'05" S, 045°24'19" W
18	18	55	92	129				23°48'55" S, 045°24'20" W
19	19	56	93	130	1H	12H	23H	23°48'51" S, 045°24'16" W
20	20	57	94	131				23°48'47" S, 045°24'13" W
21	21	58	95	132	2H	13H	24H	23°48'45" S, 045°24'11" W
22	22	59	96	133	3H	14H	25H	23°48'59" S, 045°24'16" W
23	23	60	97	134				23°48'54" S, 045°24'13" W

Continued

Table 1. Continued.

Stations	Oct 2012	Feb 2013	Jun 2013	Sep 2013	Mar 2014	Jun 2014	Jul 2014	Geographic Coordinates
24	24	61	98	135	4H	15H	26H	23°48'50" S, 045°24'09" W
25	25	62	99	136				23°48'50" S, 045°24'03" W
26	26	63	100	137	5H	16H	27H	23°49'08" S, 045°24'11" W
27	27	64	101	138				23°49'03" S, 045°24'06" W
28	28	65	102	139	6H	17H	28H	23°48'59" S, 045°24'02" W
29	29	66	103	140				23°49'55" S, 045°23'58" W
30	30	67	104	141	7H	18H	29H	23°48'49" S, 045°23'51" W
31	31	68	105	142				23°49'11" S, 045°24'13" W
32	32	69	106	143	8H	19H	30H	23°49'07" S, 045°24'47" W
33	33	70	107	144				23°48'59" S, 045°23'53" W
34	34	71	108	145	9H	20H	31H	23°49'20" S, 045°24'10" W
35	35	72	109	146				23°49'10" S, 045°24'00" W
36	36	73	110	147	10H	21H	32H	23°49'03" S, 045°23'52" W
37	37	74	111	148	11H	22H	33H	23°49'03" S, 045°23'52" W

Table 2. Sampling stations carried out in subtidal with dredge. Feb = February, Jul = July, Jun = June, Mar = March, Oct = October, Sep = September.

Oct 2012	Feb 2013	Jun 2013	Sep 2013	Mar 2014	Jun 2014	Jul 2014	Geographic Coordinates
I	VI	XIV	XXI				23°49'01" S – 23°48'58" S, 045°24'09" W – 45°24'07" W
II	VII	XV	XXII				23°49'02" S – 23°49'00" S, 045°24'04" W – 45°24'02" W
III	VII	XVI	XXIII				23°49'07" S – 23°49'05" S, 045°24'05" W – 45°24'01" W
IV	IX	XVII	XXIV				23°49'11" S – 23°49'07" S, 045°24'01" W – 45°23'58" W
V	X	XVIII	XXV		XXXIV		23°49'02" S – 23°49'05" S, 045°23'54" W – 45°23'59" W
	XI	XIX	XXVI				23°49'20" S – 23°49'16" S, 045°24'10" W – 45°24'03" W
	XII	XX	XXVII				23°49'20" S – 23°49'21" S, 045°24'10" W – 45°24'15" W
	XIII						23°48'50" S – 23°48'54" S, 045°23'51" W – 45°23'56" W

RESULTS

A total of 863 echinoderms were inventoried, in four classes, 13 families, 19 genera, and 25 species, as listed below.

Class Ophiuroidea Gray, 1840

Order Ophiurida Müller & Troschel, 1940

Family Amphiuridae Ljungman, 1867

Amphiodia pulchella (Lyman, 1869)

Figures 3A and 3B.

Examined material. 17 specimens in subtidal: ZUEC OPH 2132, St. 34, 1 specimen; ZUEC OPH 2176, St. XII, 1 specimen; ZUEC OPH 2205, St. XII, 4 specimens; ZUEC OPH 2214, St. 71, 1 specimen; ZUEC OPH 2276, St. XXVI, 8 specimens; ZUEC OPH 2286, St. 147, 1 specimen; ZUEC OPH 2347, St. 20H, 1 specimen.

Amphipholis januarii Ljungman, 1866

Figures 3C and 3D.

Examined material. 20 specimens in subtidal: ZUEC OPH 2197, St. VII, 1 specimen; ZUEC OPH 2210, St. 71, 1 specimen; ZUEC OPH 2245, St. XIX, 1 specimen; ZUEC OPH 2249, St. XIX, 1 specimen; ZUEC OPH 2268, St. 145, 3 specimens; ZUEC OPH 2272, St. XXVI, 6 specimens; ZUEC OPH 2327, St. 9H, 2 specimens; ZUEC OPH 2340, St. 20H, 2 specimens; ZUEC OPH 2352, St. XXXIV, 3 specimens.

Amphipholis squamata (Delle Chiaje, 1828)

Figures 3E and 3F.

Examined material. 34 specimens. From intertidal zone and subtidal: ZUEC OPH 2121, St. 26, 2 specimens; ZUEC OPH 2122, St. III, 1 specimen; ZUEC OPH 2124, St. 32, 1 specimen; ZUEC OPH

2179, St. XII, 1 specimen; ZUEC OPH 2187, St. XI, 7 specimens; ZUEC OPH 2201, St. 68, 1 specimen; ZUEC OPH 2209, St. 71, 1 specimen; ZUEC OPH 2250, St. XIX, 2 specimens; ZUEC OPH 2293, St. 119, 1 specimen; ZUEC OPH 2330, St. 9H, 1 specimen; ZUEC OPH 2331, St. 10H, 1 specimen; ZUEC OPH 2336, St. 11H, 1 specimen. From rocky shore in sponge: ZUEC OPH 2150, St. Ofio05, 23°48'56" S, 045°24'24" W, 2 specimens; ZUEC OPH 2151, St. Ofio06, 23°49'08" S, 045°24'20" W, X.1.2012, 1 specimen; ZUEC OPH 2152, St. Ofio07, 23°49'09" S, 045°24'19" W, X.1.2012, 1 specimen; ZUEC OPH 2154, St. Ofio09, 23°49'10" S, 045°24'18" W, II.2013, 9 specimens.

Amphiura joubini Koehler, 1912

Figures 3G and 3H.

Examined material. 3 specimens in subtidal. ZUEC OPH 2211, St. 71, 1 specimen; ZUEC OPH 2277, St. XXVI, 1 specimen; ZUEC OPH 2353, St. XXXIV, 1 specimen.

Amphiura kinbergi Ljungman, 1872

Figures 4A and 4B.

Examined material. 4 specimens in subtidal: ZUEC OPH 2129, St. 34, 1 specimen; ZUEC OPH 2212, St. 71, 1 specimen; ZUEC OPH 2274, St. XXVI, 1 specimen; ZUEC OPH 2341, St. 20H, 1 specimen.

Microphipholis atra (Stimpson, 1852)

Figures 4C and 4D.

Examined material. 70 specimens in intertidal zone and subtidal: ZUEC OPH 2112, St. 16, 1 specimen; ZUEC OPH 2113, St. 34, 3 specimens; ZUEC OPH 2115, St. 28, 1 specimen; ZUEC OPH 2116, St. 21, 1 specimen; ZUEC OPH 2117, St. 11, 1 specimen; ZUEC OPH 2119, St. 26, 1 specimen; ZUEC OPH 2181, St. 71, 1 specimen; ZUEC OPH 2182, St. 68, 4 specimens; ZUEC OPH 2192, St. 68, 1 specimen; ZUEC OPH 2196, St. VII, 3 specimens; ZUEC OPH 2200, St. 68, 5 specimens;

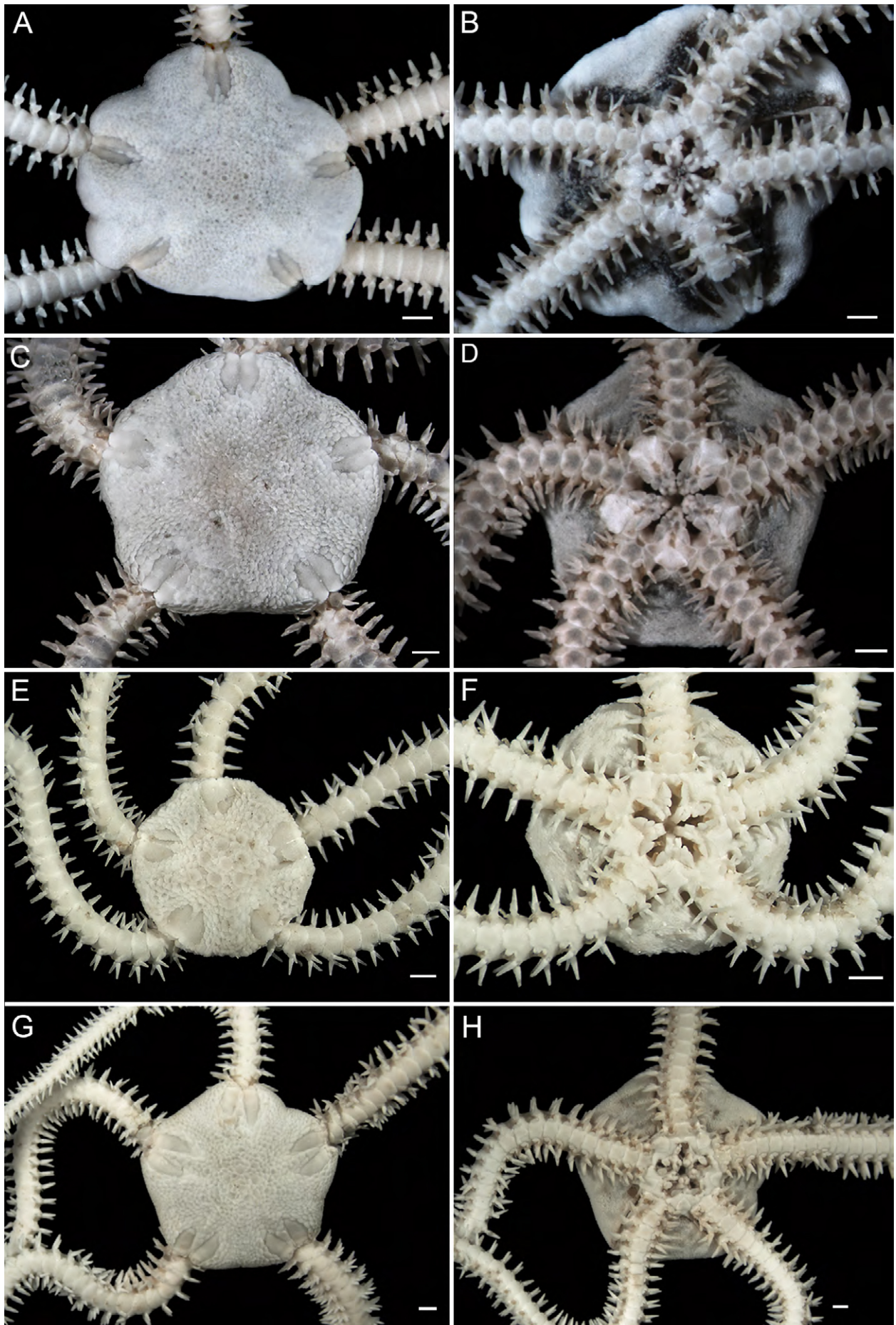


Figure 3. Ophiuroidea: **A)** *Amphiodia pulchella* dorsal view and **B)** ventral view; **C)** *Amphipholis januarii* dorsal view and **D)** ventral view; **E)** *Amphipholis squamata* dorsal view and **F)** ventral view; **G)** *Amphiura joubini* dorsal view and **H)** ventral view. Scale bar: 0.5 mm.

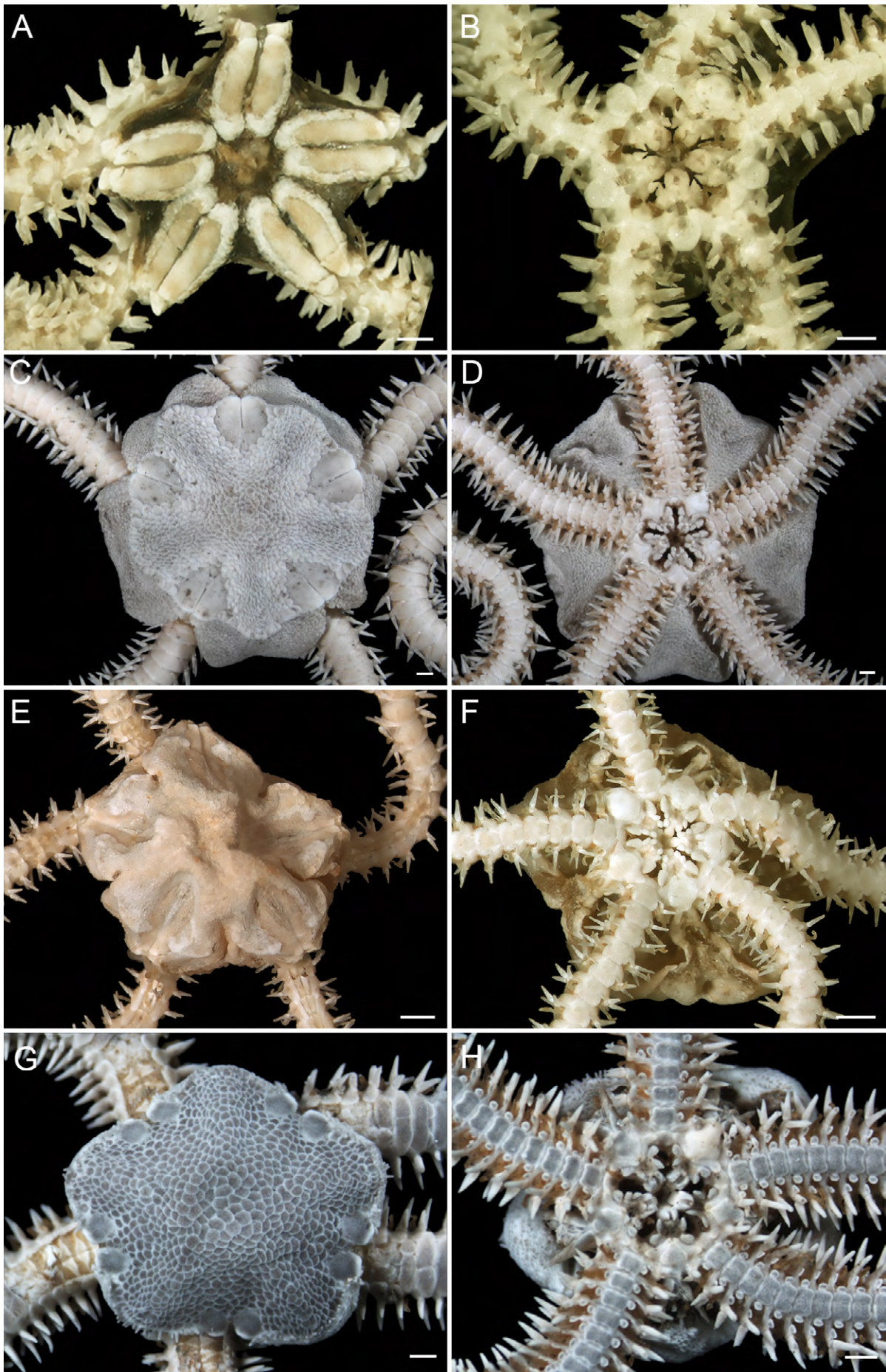


Figure 4. Ophiuroidea: **A)** *Amphiura kinbergi* dorsal view and **B)** ventral view; **C)** *Microphiopholis atra* dorsal view and **D)** ventral view; **E)** *Microphiopholis subtilis* dorsal view and **F)** ventral view; **G)** *Ophiophragmus luetkeni* dorsal view and **H)** ventral view. Scale bar: 0.5 mm.

ZUEC OPH 2208, St. 71, 5 specimens; ZUEC OPH 2213, St. 71, 3 specimens; ZUEC OPH 2242, St. 108, 1 specimen; ZUEC OPH 2244, St. XIX, 1 specimen; ZUEC OPH 2247, St. 105, 3 specimens; ZUEC OPH 2261, St. XIV, 1 specimen; ZUEC OPH 2275, St. XXVI, 7 specimens; ZUEC OPH 2283, St. XXVI, 1 specimen; ZUEC OPH 2285, St. 145, 3 specimens; ZUEC OPH 2290, St. 132, 1 specimen; ZUEC OPH 2296, St. 147, 1 specimen; ZUEC OPH 2326, St. 9H, 10 specimens; ZUEC OPH 2339, St. 20H, 2 specimens; ZUEC OPH 2351, St. XXXIV, 9 specimens.

Microphiopholis subtilis (Ljungman, 1867)

Figures 4E and 4F.

Examined material. 105 specimens in subtidal: ZUEC OPH 2120, St. 27, 7 specimens; ZUEC OPH 2134, St. I, 6 specimens; ZUEC OPH 2135, St. 26, 3 specimens; ZUEC OPH 2136, St. 35, 1 specimen; ZUEC OPH 2137, St. 31, 1 specimen; ZUEC OPH 2138, St. 33, 1 specimen; ZUEC OPH 2139, St. 30, 1 specimen; ZUEC OPH 2140, St. 32, 1 specimen; ZUEC OPH 2141, St. III, 5 specimens; ZUEC OPH 2142, St. 36, 1 specimen; ZUEC OPH 2143, St. 32, 1 specimen; ZUEC OPH 2144, St. 37, 1 specimen; ZUEC OPH 2145, St. 37, 1 specimen; ZUEC OPH 2157, St. 65, 1 specimen; ZUEC OPH 2159, St. 70, 1 specimen; ZUEC OPH 2160, St. 74, 1 specimen; ZUEC OPH 2161, St. 74, 1 specimen; ZUEC OPH 2162, St. VII, 2 specimens; ZUEC OPH 2163, St. 68, 1 specimen; ZUEC OPH 2165, St. 64, 1 specimen; ZUEC OPH 2167, St. 74, 1 specimen; ZUEC OPH 2168, St. 73, 2 specimens; ZUEC OPH 2169, St. 71, 1 specimen; ZUEC OPH 2170, St. 74, 3 specimens; ZUEC OPH 2171, St. 72, 2 specimens; ZUEC OPH 2173, St. 63, 2 specimens; ZUEC OPH 2174, St. 66, 1 specimen; ZUEC OPH 2180, St. VIII, 1 specimen; ZUEC OPH 2184, St. 69, 2 specimens; ZUEC OPH 2255, St. XVIII, 3 specimens; ZUEC OPH 2256, St. XX, 2 specimens; ZUEC OPH 2257, St. XV, 4 specimens; ZUEC OPH 2259, St. 111, 1 specimen; ZUEC OPH 2260, St. 103, 1 specimen; ZUEC OPH 2262, St. XXVIII, 1 specimen; ZUEC OPH 2263, St. 101, 1 specimen; ZUEC OPH 2264, St. 104, 1 specimen; ZUEC OPH 2265, St. XV, 1 specimen; ZUEC OPH 2281, St. XXVI, 3 specimens; ZUEC OPH 2284, St. XXVII, 9 specimens; ZUEC OPH 2287, St. 147, 1 specimen; ZUEC OPH 2289, St. XXII, 1 specimen; ZUEC OPH 2294, St. 137, 1 specimen; ZUEC OPH 2295, St. 148, 1 specimen; ZUEC OPH 2297, St. 139, 1 specimen; ZUEC OPH 2299, St. 148, 1 specimen; ZUEC OPH 2300, St. 137, 1 specimen; ZUEC OPH 2301, St. 143, 1 specimen; ZUEC OPH 2302, St. 141, 1 specimen; ZUEC OPH 2303, St. 143, 1 specimen; ZUEC OPH 2304, St. 144, 1 specimen; ZUEC OPH 2333, St. 5H, 1 specimen; ZUEC OPH 2334, St. 6H, 1 specimen; ZUEC OPH 2335, St. 11H, 1 specimen; ZUEC OPH 2337, St. 8H, 2 specimens; ZUEC OPH 2342, St. 7H, 1 specimen; ZUEC OPH 2343, St. 29H, 1 specimen; ZUEC OPH 2344, St. 16H, 1 specimen; ZUEC OPH 2345, St. 16H, 4 specimens; ZUEC OPH 2349, St. 27H, 1 specimen; ZUEC OPH 2350, St. 17H, 1 specimen.

Ophiophragmus luetkeni (Ljungman, 1872)

Figures 4G and 4H.

Examined material. 2 specimens in intertidal zone and subtidal: ZUEC OPH 2164, St. 48, 1 specimen; ZUEC OPH 2346, St. 13H, 1 specimen.

Ophiophragmus riisei (Lütken in Lyman, 1860)

Figures 5A and 5B.

Examined material. 3 specimens in subtidal: ZUEC OPH 2252, St. 15, 1 specimen; ZUEC OPH 2253, St. XVI, 1 specimen; ZUEC OPH 2357, St. 34, 1 specimen.

Family Ophiactidae Matsumoto, 1915

Hemipholis cordifera (Say, 1825)

Figures 5C and 5D.

Examined material. 61 specimens in subtidal: ZUEC OPH 2106, St. 34, 1 specimen; ZUEC OPH 2107, St. 32, 1 specimen; ZUEC OPH 2109,

St. 34, 1 specimen; ZUEC OPH 2191, St. 71, 1 specimen; ZUEC OPH 2195, St. VII, 2 specimens; ZUEC OPH 2203, St. XXII, 1 specimen; ZUEC OPH 2215, St. XXI, 1 specimen; ZUEC OPH 2246, St. XIX, 1 specimen; ZUEC OPH 2251, St. XIX, 1 specimen; ZUEC OPH 2266, St. 145, 13 specimens; ZUEC OPH 2271, St. XXVI, 20 specimens; ZUEC OPH 2329, St. 9H, 3 specimens; ZUEC OPH 2338, St. 20H, 2 specimens; ZUEC OPH 2355, St. XXXIV, 13 specimens.

Ophiactis lymani Ljungman, 1872

Figures 5E and 5F.

Examined material. 182 specimens in subtidal: ZUEC OPH 2156, St. XXII, 3 specimens; ZUEC OPH 2175, St. 71, 3 specimens; ZUEC OPH 2178, St. XXII, 15 specimens; ZUEC OPH 2183, St. 71, 10 specimens; ZUEC OPH 2185, St. XXI, 31 specimens; ZUEC OPH 2188, St. XXII, 1 specimen; ZUEC OPH 2204, St. XXII, 52 specimens; ZUEC OPH 2254, St. XXVII, 2 specimens; ZUEC OPH 2258, St. XIX, 12 specimens; ZUEC OPH 2267, St. 145, 3 specimens; ZUEC OPH 2279, St. XXVI, 35 specimens; ZUEC OPH 2291, St. 145, 6 specimens; ZUEC OPH 2292, St. XVII, 1 specimen; ZUEC OPH 2328, St. 9H, 1 specimen; ZUEC OPH 2348, St. 20H, 5 specimens; ZUEC OPH 2354, St. XXXIV, 2 specimens.

Ophiactis savignyi (Müller & Troschel, 1842)

Figures 5G and 5H.

Examined material. 26 specimens. From subtidal: ZUEC OPH 2186, St. XXI, 5 specimens; ZUEC OPH 2206, St. XXII, 1 specimen; ZUEC OPH 2273, St. XXVI, 2 specimens; ZUEC OPH 2306, St. XIX, 1 specimen. From rocky shore in sponge: ZUEC OPH 2288, St. Poro26, 23°49'07" S, 045°24'19" W, X.2.2012, 1 specimen; ZUEC OPH 2146, St. Of1001, 23°48'54" S, 045°24'24" W, X.1.2012, 3 specimens; ZUEC OPH 2147, St. Of1002, 23°48'54" S, 045°24'24" W, X.1.2012, 3 specimens; ZUEC OPH 2148, St. Of1003, 23°48'60" S, 045°24'24" W, X.1.2012, 5 specimens; ZUEC OPH 2153, St. Of1008, 23°49'09" S, 045°24'18" W, II.2013, 4 specimens; ZUEC OPH 2155, St. Of1010, 23°49'10" S, 045°24'18" W, X.2012, 1 specimen.

Family Ophiodermatidae Ljungman, 1867

Ophioderma januarii Lütken, 1856

Figures 6A and 6B.

Examined material. 89 specimens in subtidal: ZUEC OPH 2199, St. XII, 3 specimens; ZUEC OPH 2202, St. XII, 4 specimens; ZUEC OPH 2216, St. XI, 13 specimens; ZUEC OPH 2239, St. XVIII, 6 specimens; ZUEC OPH 2240, St. XIX, 8 specimens; ZUEC OPH 2241, St. XVII, 1 specimen; ZUEC OPH 2243, St. XIX, 3 specimens; ZUEC OPH 2248, St. XIX, 1 specimen; ZUEC OPH 2270, St. XXIV, 30 specimens; ZUEC OPH 2280, St. XXVI, 1 specimen. ZUEC OPH 2358, St. 21H, 2 specimens; ZUEC OPH 2359, St. XXXIV, 3 specimens; ZUEC OPH 2360, St. XXXIV, 14 specimens.

Family Ophiolepididae Ljungman, 1867

Ophioplocus januarii (Lütken, 1856)

Figures 6C, 6D and 6E.

Examined material. 1 specimen in subtidal: ZUEC OPH 2207, St. XXII, 1 specimen.

Family Ophiotrichidae Ljungman, 1867

Ophiothela cf. mirabilis Verrill, 1867

Figures 6F, 6G and 6H.

Examined material. 27 specimens in subtidal: ZUEC OPH 2189, St. IX, 1 specimen; ZUEC OPH 2190, St. XI, 1 specimen; ZUEC OPH

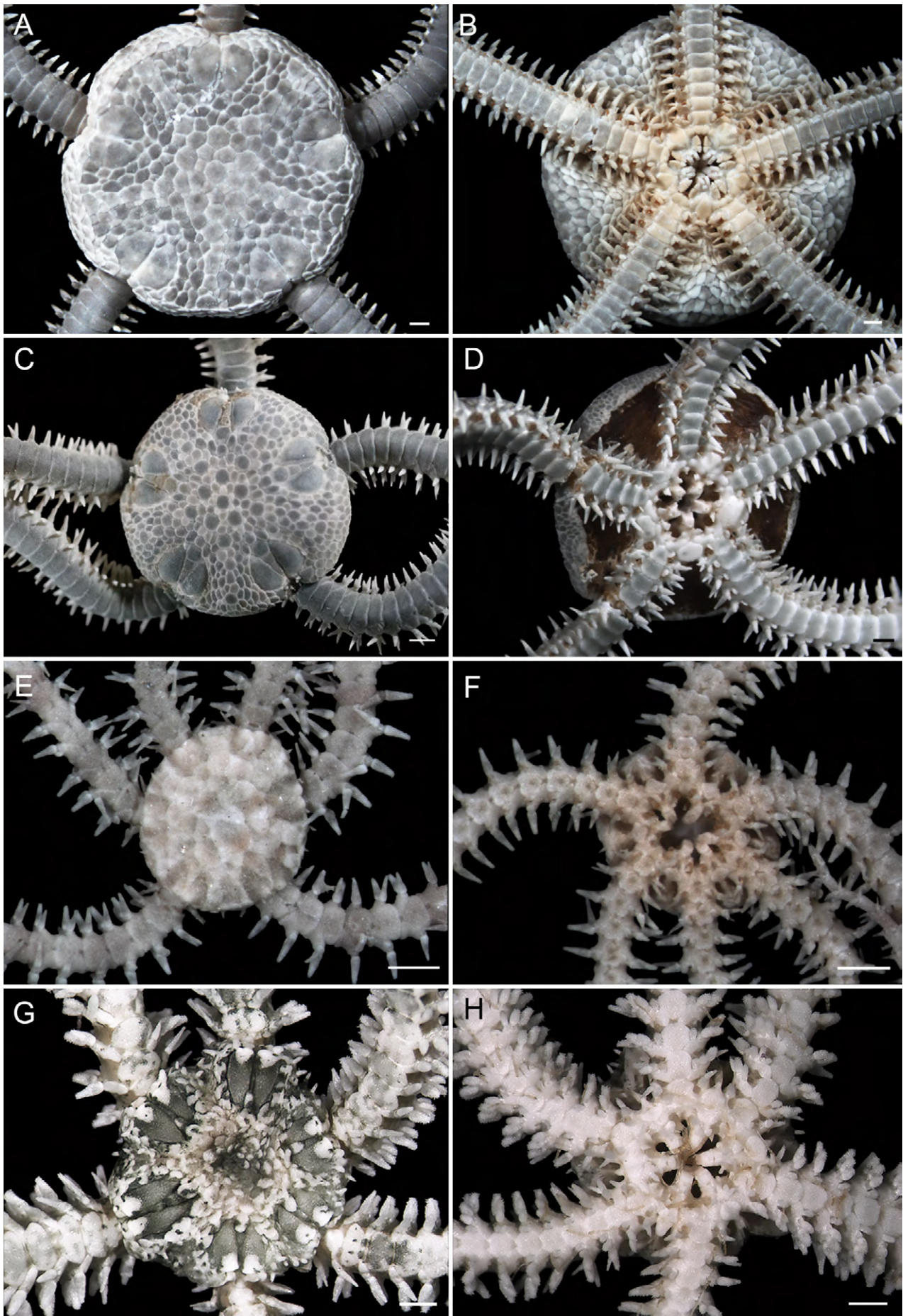


Figure 5. Ophiuroidea: **A)** *Ophiophragmus riisei* dorsal view and **B)** ventral view; **C)** *Hemipholis cordifera* dorsal view and **D)** ventral view; **E)** *Ophiactis lymani* dorsal view and **F)** ventral view; **G)** *Ophiactis savignyi* dorsal view and **H)** ventral view. Scale bar: 0.5 mm.

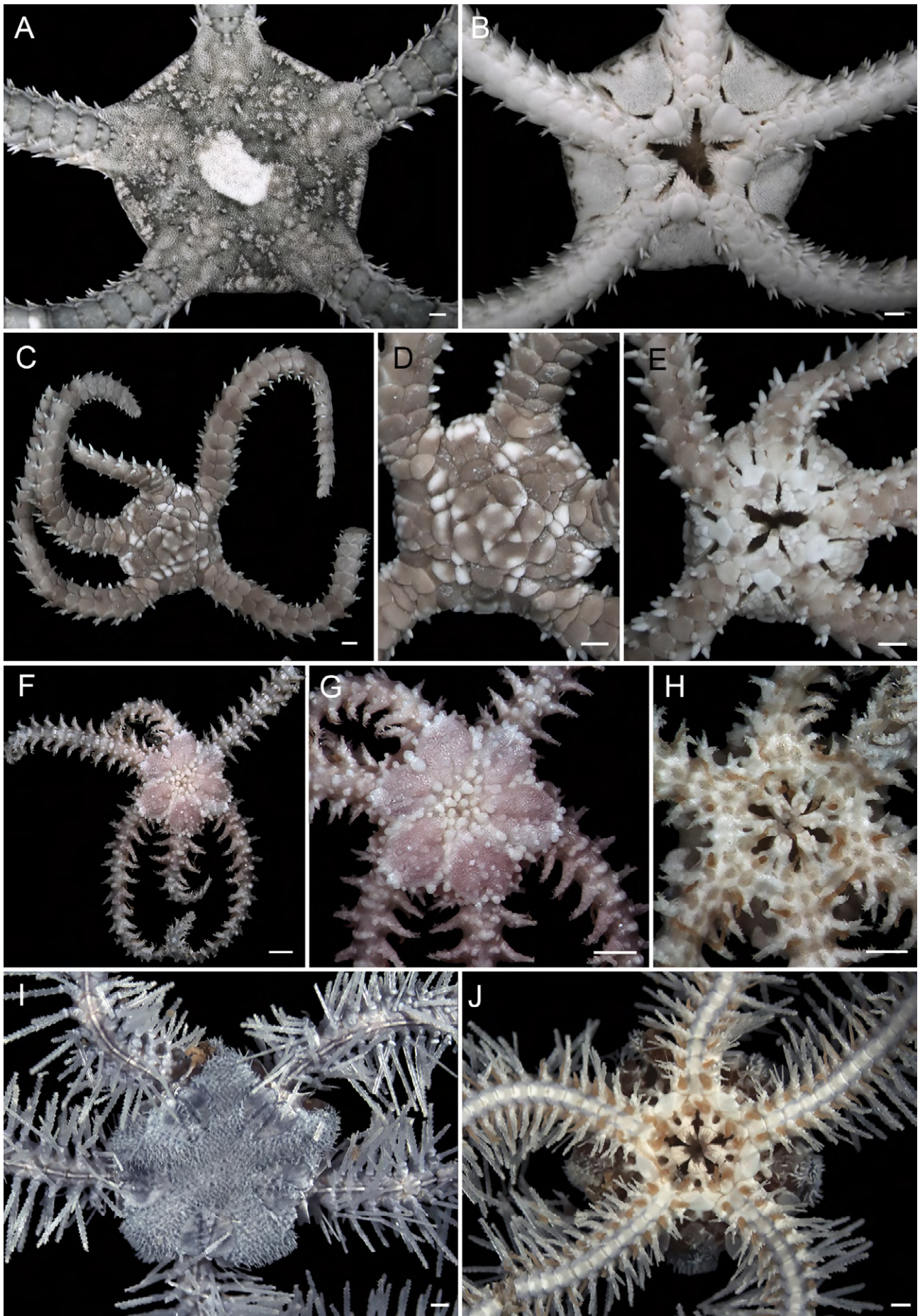


Figure 6. Ophiuroidea: **A)** *Ophioderma januarii* dorsal view and **B)** ventral view; **C)** and **D)** *Ophioplocus januarii* dorsal view and **E)** ventral view; **F)** and **G)** *Ophiothela cf. mirabilis* dorsal view and **H)** ventral view; **I)** *Ophiothrix (Ophiothrix) angulata* dorsal view and **J)** ventral view. Scale bar: 0.5 mm.

2193, St. XI, 1 specimen; ZUEC OPH 2278, St. XXVI, 13 specimens; ZUEC OPH 2298, St. 136, 10 specimens; ZUEC OPH 2332, St. XXXIV, 1 specimen.

Ophiothrix (Ophiothrix) angulata (Say, 1825)

Figures 6I and 6J.

Examined material. 16 specimens. From subtidal: ZUEC OPH 2172, St. VI, 1 specimen; ZUEC OPH 2177, St. XII, 1 specimen; ZUEC OPH 2194, St. XI, 4 specimens; ZUEC OPH 2282, St. XXVI, 6 specimens; ZUEC OPH 2356, St. XXXIV, 1 specimen. From rocky shore in sponge: ZUEC OPH 2149, St. Ofio04, 23°48'55" S, 045°24'24" W, X.1.2012, 3 specimens.

Class Asteroidea de Blainville, 1830

Order Paxillosida Perrier, 1884

Family Astropectinidae Gray, 1840

Astropecten brasiliensis Müller & Troschel, 1842

Figures 7A and 7B.

Examined material. 1 specimen from subtidal. ZUEC AST 49, St. II, 1 specimen.

Family Luidiidae Sladen, 1889

Luidia alternata alternata (Say, 1825)

Figures 7C and 7D.

Examined material. 1 specimen in subtidal. ZUEC AST 57, St. XII, 1 specimen.

Luidia senegalensis (Lamarck, 1816)

Figures 7E and 7F.

Examined material. 50 specimens. Subtidal with dredge: ZUEC AST 50, St. II, 1 specimen; ZUEC AST 55, St. XI, 2 specimens; ZUEC AST 62, St. XXIV, 1 specimen. From subtidal with bottom trawls: ZUEC AST 51, 23°48'80" S, 045°24'13" W, 1 specimen; ZUEC AST 52, 23°48'59" S, 045°24'14" W, 1 specimen; ZUEC AST 53, 23°48'47" S, 045°24'09" W, 1 specimen; ZUEC AST 54, 23°48'47" S, 045°24'09" W, 1 specimen; ZUEC AST 56, 23°48'52" S, 045°24'01" W, 5 specimens; ZUEC AST 63, 23°49'12" S, 045°24'17" W, 6 specimens; ZUEC AST 64, 23°49'03" S, 045°24'05" W, 4 specimens; ZUEC AST 65, 23°49'06" S, 045°24'02" W, 3 specimens; ZUEC AST 66, 23°49'05" S, 045°24'05" W, 5 specimens; ZUEC AST 67, 23°49'07" S, 045°24'07" W, 1 specimen; ZUEC AST 68, 23°49'04" S, 045°23'59" W, 1 specimen; ZUEC AST 69, 23°49'07" S, 045°24'10" W, 1 specimen; ZUEC AST 70, 23°48'56" S, 045°24'08" W, 2 specimens; ZUEC AST 71, 23°49'08" S, 045°24'09" W, 1 specimen; ZUEC AST 72, 23°48'49" S, 045°24'09" W, 2 specimens; ZUEC AST 73, 23°48'55" S, 045°24'14" W, 1 specimen; ZUEC AST 74, 23°49'05" S, 045°24'07" W, 1 specimen; ZUEC AST 75, 23°49'11" S, 045°24'05" W, 7 specimens; ZUEC AST 76, 23°49'07" S, 045°24'10" W, 1 specimen; ZUEC AST 77, 23°49'20" S, 045°24'10" W, 1 specimen.

Order Spinulosida Perrier, 1884

Family Echinasteridae Verrill, 1870

Echinaster (Othilia) brasiliensis Müller & Troschel, 1842

Figures 7G and 7H.

Examined material. 1 specimen on rocky shore. ZUEC AST 78, 23°48'54" S, 045°24'24" W, 1 specimen.

Class Echinoidea Leske, 1778

Order Arbacioida Gregory, 1900

Family Arbaciidae Gray, 1855

Arbacia lixula (Linnaeus, 1758)

Figures 8A and 8B.

Examined material. 3 specimens. From subtidal with bottom trawls: ZUEC ECH 19, 23°49'06" S, 045°24'19" W, 1 specimen. From rocky shore: ZUEC ECH 20, 23°49'07" S, 045°24'19" W, 1 specimen; ZUEC ECH 21, 23°49'07" S, 045°24'19" W, 1 specimen.

Order Camarodonta Jackson, 1912

Family Toxopneustidae Troschel, 1872

Lytechinus variegatus (Lamarck, 1816)

Figures 8C and 8D.

Examined material. 1 specimen on rocky shore. ZUEC ECH 34, 23°49'09" S, 045°24'18" W, 1 specimen.

Order Clypeasteroidea A. Agassiz, 1872

Family Mellitidae Stefanini, 1912

Encope emarginata (Leske, 1778)

Figures 8E and 8F.

Examined material. 2 specimens in intertidal zone collected with bottom trawls: ZUEC ECH 25, 23°49'02" S, 045°24'19" W, 1 specimen; ZUEC ECH 26, 23°48'55" S, 045°24'14" W, 1 specimen.

Class Holothuroidea de Blainville, 1834

Order Apodida Brandt, 1835

Family Synaptidae Burmeister, 1837

Protankyra benedeni (Ludwig, 1881)

Figure 8G.

Examined material. 141 specimens in subtidal. ZUEC HOL 4, St. 74, 4 specimens; ZUEC HOL 5, St. 27, 4 specimens; ZUEC HOL 6, St. 71, 3 specimens; ZUEC HOL 7, St. 30, 3 specimens; ZUEC HOL 8, St. 35, 3 specimens; ZUEC HOL 10, St. 66, 1 specimen; ZUEC HOL 11, St. 33, 5 specimens; ZUEC HOL 12, St. 29, 1 specimen; ZUEC HOL 13, St. 33, 2 specimens; ZUEC HOL 14, St. 72, 1 specimen; ZUEC HOL 15, St. 32, 3 specimens; ZUEC HOL 16, St. 65, 1 specimen; ZUEC HOL 17, St. 74, 2 specimens; ZUEC HOL 18, St. 30, 1 specimen; ZUEC HOL 19, St. 70, 1 specimen; ZUEC HOL 20, St. 69, 1 specimen; ZUEC HOL 23, St. 110, 1 specimen; ZUEC HOL 24, St. 110, 5 specimens; ZUEC HOL 25, St. 109, 2 specimens; ZUEC HOL 26, St. 105, 1 specimen; ZUEC HOL 27, St. 108, 2 specimens; ZUEC HOL 28, St. XVIII, 1 specimen; ZUEC HOL 29, St. 111, 1 specimen; ZUEC HOL 30, St. 111, 1 specimen; ZUEC HOL 31, St. 111, 8 specimens; ZUEC HOL 32, St. 106, 3 specimens; ZUEC HOL 34, St. 103, 3 specimens; ZUEC HOL 35, St. 110, 3 specimens; ZUEC HOL 36, St. 103, 2 specimens; ZUEC HOL 37, St. XIII, 1 specimen; ZUEC HOL 41, St. I, 1 specimen; ZUEC HOL 42, St. 68, 2 specimens; ZUEC HOL 43, St. 31, 1 specimen; ZUEC HOL 44, St. 73, 4 specimens; ZUEC HOL 45, St. VIII, 2 specimens; ZUEC HOL 46, St. 69, 1 specimen; ZUEC HOL 58, St. 148, 1 specimen; ZUEC HOL 59, St. 148, 3 specimens; ZUEC HOL 60, St. 148, 1 specimen; ZUEC HOL 61, St. 148, 2 specimens; ZUEC HOL 62, St. 148, 1 specimen; ZUEC HOL 63, St. 148, 1 specimen; ZUEC HOL 64, St. 146, 5 specimens; ZUEC HOL 65, St. 147, 2 specimens; ZUEC HOL 66, St. 140, 1 specimen; ZUEC HOL 67, St. XXVII, 2 specimens; ZUEC HOL 68, St. 139, 1 specimen; ZUEC HOL 69, St. 148, 8 specimens; ZUEC HOL 70, St. 139, 4 specimens; ZUEC HOL 71, St. 11H, 2 specimens; ZUEC HOL 72, St. 10H, 2 specimens; ZUEC HOL 73, St. 11H, 1 specimen; ZUEC HOL 74, St. 10H, 3 specimens; ZUEC HOL 75, St. 8H, 4 specimens; ZUEC HOL 76, St. 11H, 4 specimens; ZUEC HOL 77, St. 10H, 4

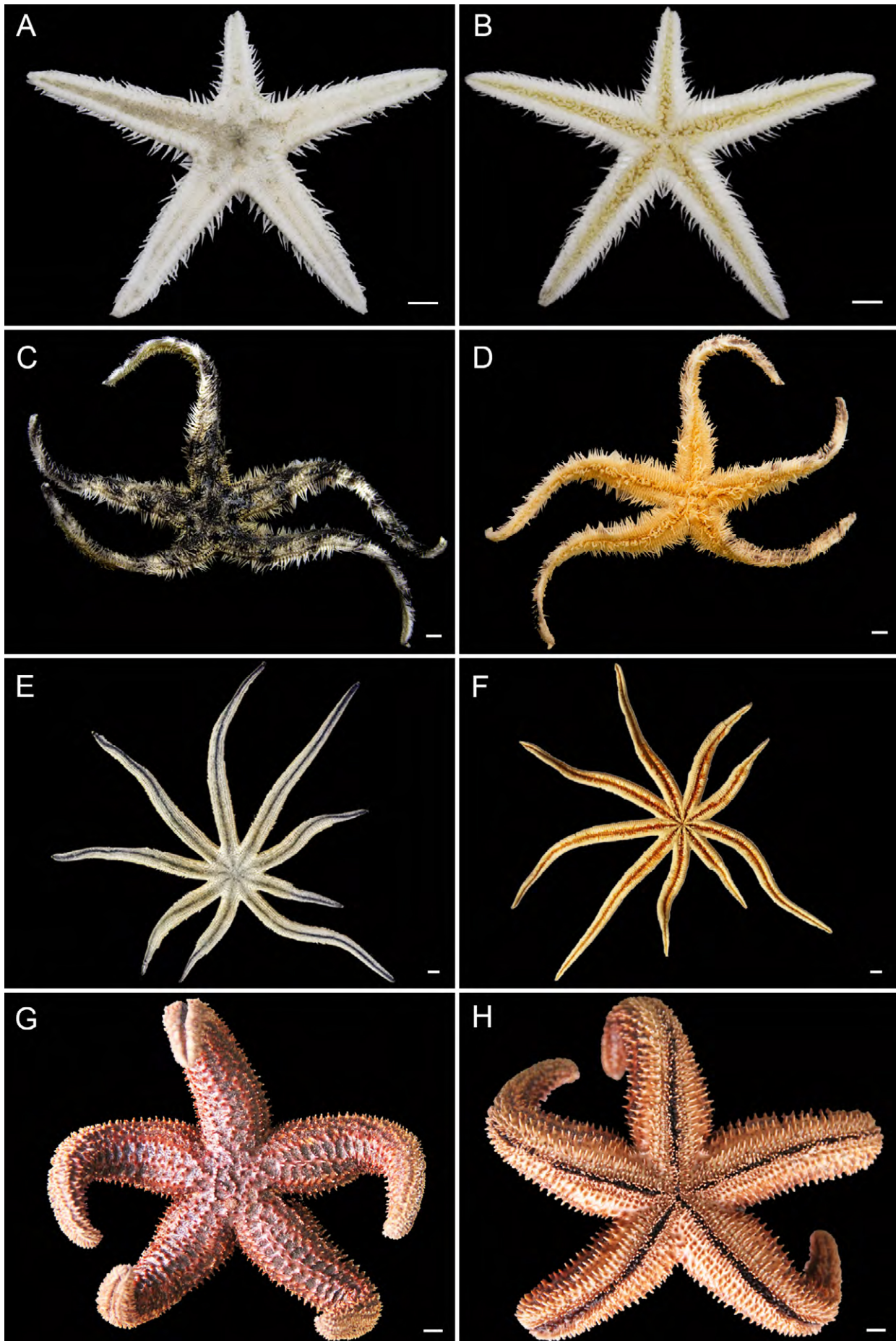


Figure 7. Asteroidea: **A)** *Astropecten brasiliensis* abactinal view and **B)** actinal view; **C)** *Luidia alternata alternata* abactinal view and **D)** actinal view; **E)** *Luidia senegalensis* abactinal view and **F)** actinal view; **G)** *Echinaster (Othilia) brasiliensis* abactinal view and **H)** actinal view. Scale bar: 5 mm.

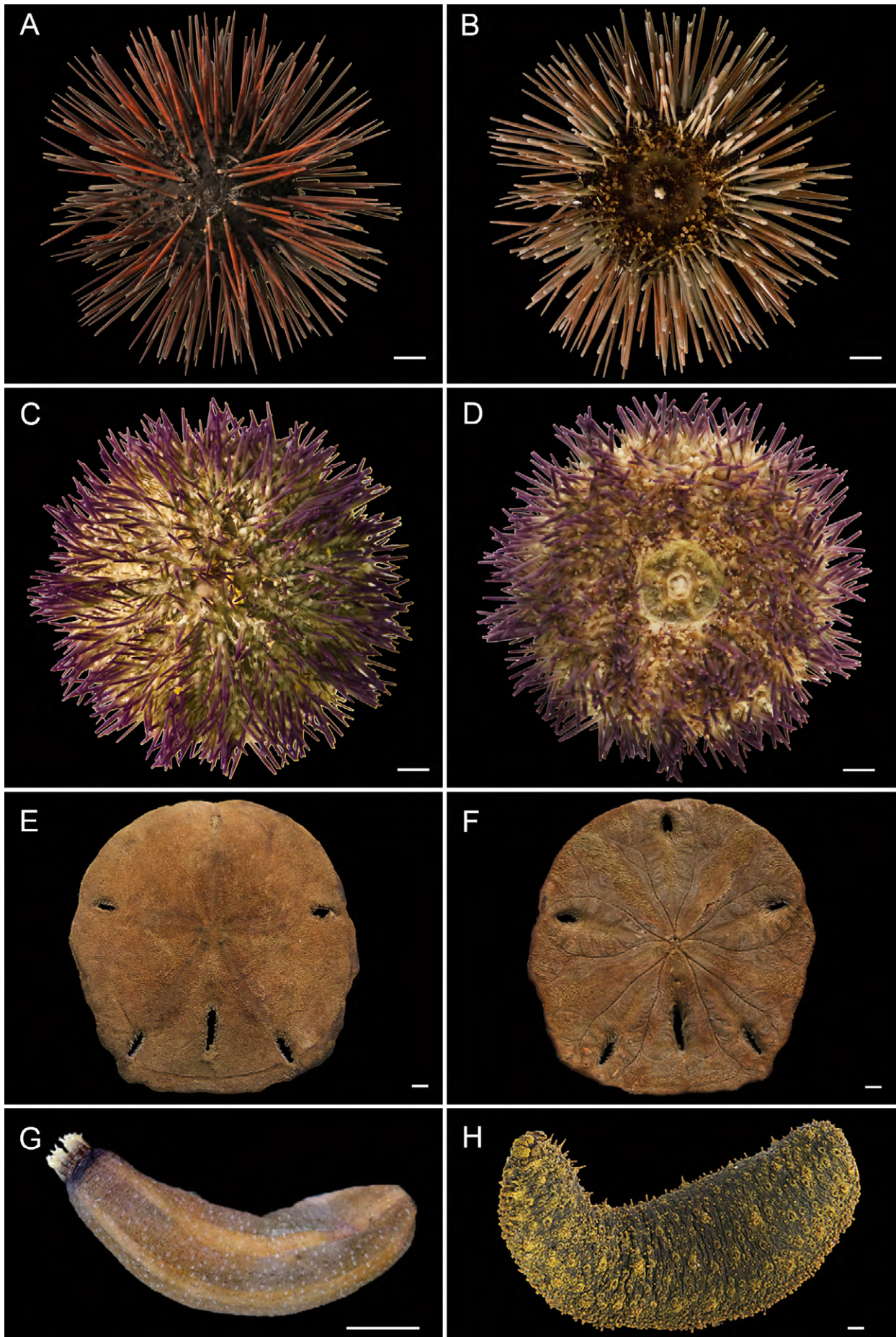


Figure 8. Echinoidea: **A)** *Arbacia lixula* aboral view and **B)** oral view; **C)** *Lytechinus variegatus* aboral view and **D)** oral view; **E)** *Encope emarginata* aboral view and **F)** oral view. Holothuroidea: **G)** *Protankyra benedeni*; **H)** *Holothuria (Halodeima) grisea*. Scale bar: 5 mm.

specimens; ZUEC HOL 78, St. 11H, 1 specimen; ZUEC HOL 92, St. 19H, 1 specimen; ZUEC HOL 93, St. XXXIV, 1 specimen; ZUEC HOL 94, St. 22H, 2 specimens; ZUEC HOL 95, St. 21H, 1 specimen; ZUEC HOL 96, St. 22H, 1 specimen; ZUEC HOL 97, St. 21H, 1 specimen.

Order ASPIDOCHIROTIDA Grube, 1840

Family Holothuriidae Burmeister, 1837

Holothuria (Halodeima) grisea Selenka, 1867

Figure 8H.

Examined material. 2 specimens on rocky shore: ZUEC HOL 2, 23°49'09" S, 045°24'19" W, 1 specimen; ZUEC HOL 3, 23°49'07" S, 045°24'19" W, 1 specimen.

Comments

Ophiuroidea was the most abundant and diverse taxon (661 specimens), mainly found in the intertidal and subtidal zones up to 20 m depth. Amphiuroidae was the most diverse family recorded (9 species) and Ophiactidae the most abundant, accounting for approximately 50% of the total Ophiuroidea. The most abundant species were *Ophiactis lymani* (182 specimens), *Microphiopholis subtilis* (105 specimens), *Ophioderma januarii* (89 specimens), *Microphiopholis atra* (71 specimens), and *Hemipholis cordifera* (61 specimens). *Microphiopholis subtilis* was collected mainly on the muddy bottom. One fourth of *Microphiopholis atra* specimens were with mature gonads and without the dorsal half of the disc. About three-quarters of the *Hemipholis cordifera* were collected with *Microphiopholis atra* and *Amphipholis januarii*. On the rocky shore *Amphipholis squamata*, *Ophiactis savignyi* and *Ophiothrix (Ophiothrix) angulata* were associated with the sponge *Amphimedon viridis* (Duchassaing & Michelotti, 1864).

Luidia senegalensis was the most abundant Asteroidea species, with 50 specimens collected in intertidal and subtidal zones. *Astropecten brasiliensis* and *Luidia alternata alternata* were in the intertidal zone and only one specimen of *Echinaster (Othilia) brasiliensis* was on rocky shore.

Three Echinoidea species were collected, *Arbacia lixula* (3 specimens) and *Lytechinus variegatus* (1 specimen) on rocky shore and *Encope emarginata* (2 specimens) in the intertidal zone.

Protankyra benedeni was the most frequently Holothuroidea, with 141 specimens collected in intertidal and subtidal zones. On rocky shore we found 2 specimens of *Holothuria (Halodeima) grisea*.

DISCUSSION

The diversity of echinoderms recorded in Araçá Bay represents 8.3% of the species known in Brazil and 26% of those in the state of São Paulo. This group, especially Ophiuroidea, was diverse, common and abundant in the area, whose perimeter (3 km) represents only 0.03% of the Brazilian coastline (8500 km).

Amphiuroidae and Ophiactidae were the richest and most abundant families of Ophiuroidea and this may be related to the wide bathymetric distribution and variety of environments (e.g., soft bottoms, rocky shores and biological substrates) where these families are found (Borges and Amaral 2005; Gondim et al. 2008; Gondim et al. 2011). The majority (80%) of *Ophiactis lymani* were with arms and discs of different sizes, due to their high degree of fission and regenerating (Hendler et al. 1995). The high fission of *O. lymani* may be an alternate reproduction strategy, when low salinity slows gonadal maturation (Lima et al. 2013). This could explain the high number of specimens regenerating disc and arms in Araçá Bay. However, this hypothesis needs to be tested based on data of salinity and rainfall patterns of the region.

Three of the four sea stars listed in this checklist are on the Brazilian Red List (Machado et al. 2008): *Astropecten brasiliensis*, *Luidia senegalensis* and *Echinaster (Othilia) brasiliensis*. They are included in the Red List because of habitat destruction or alteration, landfills, oil spills, discharge of domestic or industrial sewage and accidental by-catch by shrimp trawlers (Machado et al. 2008). Unfortunately, some of these factors are present in Araçá Bay (Amaral et al. 2010), and therefore, the exclusion or, at least, decrease of these factors is fundamental to the maintenance of the area as a refuge for sea stars.

Among Echinoidea, the black sea urchin *Arbacia lixula* was visually the most abundant in study area and was sampled only on rocky shores. This species has the potential to greatly influence benthic communities of the bay with its grazing activity, because it can feed on algae and sessile animals (Wangensteen et al. 2012). In contrast, *Lytechinus variegatus* is seemingly rare in Araçá Bay, since it was observed only once. This may be related to the decrease or absence of their food preferences, such as algae *Caulerpa* sp. and *Sargassum* sp. (Ventura et al. 2013). Echinoids exhibit two main criteria that define them as an indicator of environmental quality: a high sensitivity to environmental changes and a sedentary way of life (Guillou et al. 2000; Pinsino and Matranga 2015). Therefore, the conservation and future studies of development of sea urchins in Araçá Bay should be required and will give a clear image of the environmental conditions.

Protankyra benedeni was the Holothuroidea species with the highest number of records in Araçá Bay. This species is endemic to Brazil, from the northeast to the southeast (Martins 2012), commonly found buried in muddy sediment and low hydrodynamic, as in Araçá Bay. We considered *P. benedeni* a useful model to study a spatial distribution, growth patterns and biomonitoring because of the following reasons: i) they cycle and provide organic matter in the water column (Uthicke

1999; Ginger et al. 2001) and ii) few studies have been conducted on the population dynamics and structure of sea cucumbers in Brazil.

Seven species reported in earlier studies (Dolder 1973; Nalesso et al. 1995; Milanelli 2003; Netto et al. 2005) were not found in our study: *Asterina stellifera*, *Astropecten marginatus*, *Luidia clathrata*, *Echinometra lucunter*, *Pentacta peterseni*, *Synaptula hidriformis* and *Tropiometra carinata*. This may be a consequence of the sampling methods that we used or a possible decrease of these species. It is worth pointing out that the sea stars *Asterina stellifera*, *Astropecten marginatus* and *Luidia clathrata* are endangered (Machado et al. 2008).

The Echinodermata database created and systematized in this work is available for reference in ZUEC and for access in *speciesLink* (CRIA). These data will be the basis for future monitoring of anthropogenic impact on Araçá Bay and its surrounding areas. Although the number of echinoderms recorded has increased in recent years, studies with the group are still insufficient. Therefore, there is an imperative need to improve our biological knowledge to ensure that the diversity of this amazing group of marine animals be maintained. This annotated list was an effort to accomplish these needs.

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