

Sea cucumbers (Echinodermata: Holothuroidea) collected from the Singapore Strait

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Abstract. Thirty-one species of sea cucumbers (holothuroids) were recorded from the Singapore Strait based on specimens collected during a marine biodiversity workshop held from 21 May to 7 June 2013. Specimens were collected by hand during low tides, by snorkelling and scuba diving at subtidal sites, and by trawling and dredging on the seabed. A total of 92 specimens in 75 lots were examined, which comprised 31 species from seven families and 18 genera distributed in four taxonomic orders. Of these, eight are new records for Singapore and 10 are undetermined species including species possibly new to science. Species descriptions, accompanied by photographs of living specimens and drawings of ossicles, are provided for most species. The eight new records are: *Hemithyone semperi* (Bell), *Holothuria* (*Lessonothuria*) *pardalis* Selenka, *Holothuria* (*Metriatyla*) *martensi* Semper, *Holothuria* (*Platyperona*) *crosnieri* Cherbonnier, *Paracaudina chilensis* (Müller), *Phyllophorella kohkutiensis* Heding & Panning, *Protankyra bidentata* (Woodward & Barrett) and *Synaptula minima* Heding. The potential new species are from the genera *Holothuria* Linnaeus, *Colochirus* Troschel, *Havelockia* Pearson and *Thorsonia* Heding. These new records and possible new species attest to the still poorly documented state of biodiversity in the Malayan archipelago. The holothuroid fauna of the Singapore is surprisingly diverse. We hope that the results provide a better basis for further investigations on the taxonomy and ecology of sea cucumbers in Singapore waters.

Key words. Indo-West Pacific, holothuroids, new records, Comprehensive Marine Biodiversity Survey (CMBS), Singapore

INTRODUCTION

The Singapore Strait biodiversity workshop was conducted as a component of the Comprehensive Marine Biodiversity Survey (CMBS) project in May 2013. A similar workshop to survey the flora and fauna of the Johor Straits, Singapore was held earlier in October 2012, and the results were published in 2015 (see Tan & Goh, 2015). Ong & Wong (2015) reported 29 species of sea cucumbers from the Johor Straits, the majority being soft bottom, non-reefal holothuroids. The dominant order there was the Dendrochirotida. Two new species, *Protankyra scaphia* O’Loughlin & Ong, 2015 (Synaptidae) and *Acaudina rosettis* O’Loughlin & Ong, 2015 (Molpadidae) were described.

Singapore is located centrally in the Indo-Pacific region, surrounded by large land masses including the Malay

Peninsula, Borneo, and Sumatra. Its waters connect to the South China Sea in the east, Java Sea to the south and Malacca Straits to the west. The island state comprises the main island of Singapore and more than 50 small islands, with 193 km of coastline encompassing a total land area of ca. 716.1 km² (Department of Statistics Singapore, 2014). The narrow Johor Straits separate Singapore Island from Johor (Malaysia) to the north. In the south, the Singapore Strait is one of the world’s busiest shipping lanes. With freshwater inflow from several rivers, the salinity fluctuates between 19–33 ppt in the Johor Straits (Hajisamae & Chou, 2003; Wood et al., 1997). Such wide salinity fluctuations are not observed in the Singapore Strait where the salinity has a narrow range between 29–33 ppt. The depths of the Johor Straits range between 5–25 m, whereas the average depth of the Singapore Straits is 40 m with a few areas more than 100 m deep.

While no previous systematic survey has been done on the holothuroids of Singapore waters, most of the adjacent regions of Singapore have been relatively well-documented for holothuroids. Australia (H. L. Clark, 1938, 1946; Rowe & Gates, 1995) and South China Sea (Lane et al., 2000; Liao, 1997; Liao & Pawson, 2001; Massin et al., 2002) each has more than 200 species recorded. Indonesia has around 350 species (Wirawati & Purwati, 2012). Some 52 species were documented from Malaysia (Forbes et al., 2009; Kamarudin et al., 2010; Kamarudin 2011).

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The main objective of this study is to provide a taxonomic baseline of holothuroids for Singapore. It is hoped that together with the results from the Johor Straits workshop (Ong & Wong, 2015; O’Loughlin & Ong, 2015), a better picture of the holothuroid diversity in Singapore is obtained.

MATERIAL AND METHODS

Surveys were carried out over three weeks between 21 May and 7 June 2013 in the Singapore Strait with the involvement of volunteers. Localities where sea cucumbers were collected are shown in Fig. 1. Collection of intertidal holothuroid specimens was done on foot during low tide. Subtidal collection involved snorkelling and scuba diving (which included manual collection and coral brushing) at depths of up to 19.1 m. A naturalist dredge and a beam trawl were also used to collect sea cucumbers from the seabed at 26 sites in the Singapore Strait from depths between 10 m and 150 m.

Specimens collected were anaesthetised in 7.5% magnesium chloride solution and living colours were noted whenever possible prior to fixing and preserving in 70% denatured ethanol. Selected specimens were tissue sampled prior to preservation and/or photographed live and examined under an Olympus stereo microscope SZX10. Small sections of tissues from the body wall/tube feet/papillae/tentacles/introvert were dissolved in household bleach, washed three times with distilled water and once with alcohol, dispensed on microscope slides, air-dried, mounted with DePex® mounting

medium. Ossicle examination and drawings were done using an Olympus compound microscope BX43 equipped with a camera lucida. Specimens reported here are deposited in the Zoological Reference Collection (ZRC) and Cryogenic Collection of Lee Kong Chian Natural History Museum (LKCNC, formerly Raffles Museum of Biodiversity Research), National University of Singapore (NUS).

As far as possible, reference to original descriptions of the species was made during identification. Supplementary references for identifying the collected material included A. M. Clark & Rowe (1971), H. L. Clark (1938), Heding & Panning (1954), Heding (1928), Liao (1997), Rowe (1969), Cherbonnier (1988), Massin (1996, 1999), Samyn (2003a, b), Samyn & Massin (2003) and Thandar (1989); for the classification and descriptions of calcareous rings.

RESULTS

A total of 75 lots of 92 specimens were collected and examined, representing 31 species from the Singapore Strait. The holothuroids represent 18 genera (*Synaptula*, *Protankyra*, *Acaudina*, *Paracaudina*, *Actinopyga*, *Holothuria*, *Stichopus*, *Actinocucumis*, *Colochirus*, *Mensamaria*, *Pseudocolochirus*, *Thorsonia*, *Hemithyone*, *Phyllophorella*, *Stolus*, *Afrocucumis*, *Cladolabes*, *Havelockia*) in seven families (Synaptidae, Holothuriidae, Stichopodidae, Cucumariidae, Phyllophoridae, Sclerodactylidae, and Caudinidae) belonging to four orders (Apodida, Molpadida, Aspidochirotida, and Dendrochirotida). A list of the species is given in Table 1.

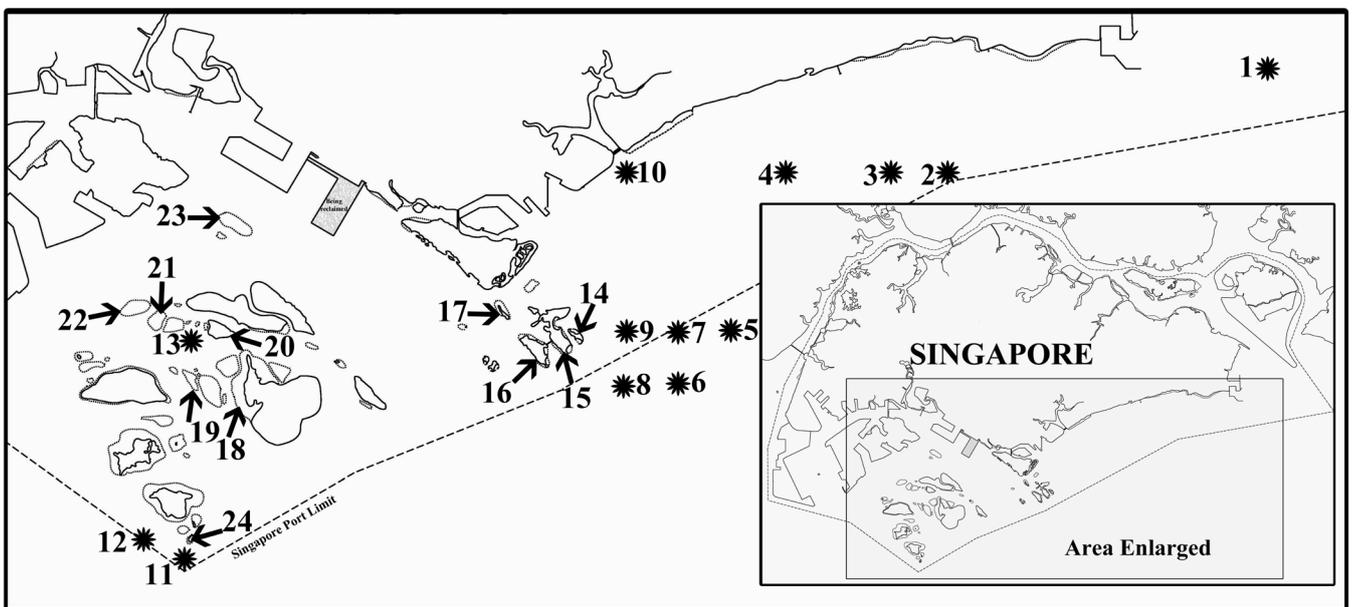


Fig. 1. Sea cucumber collection sites in the Singapore Strait. 1–13: subtidal benthos; 14–24: intertidal reefs, at the following locations—14, Kusu Island; 15, Pulau Sakijang Pelepah (Lazarus Island); 16, Pulau Sakijang Bendera (St John’s Island); 17, Pulau Tekukor; 18, Pulau Semakau; 19, Terumbu Bemban; 20, Pulau Hantu; 21, Terumbu Pempang Tengah; 22, Terumbu Pempang Laut; 23, Terumbu Pandan (Cyrene Reef); 24, Pulau Satumu (Raffles Lighthouse).

Table 1. Sea cucumbers from the Singapore Strait, collected during the Singapore Strait Biodiversity Workshop held from 21 May to 7 June 2013.

Family	Species	Remarks	Collection Site (see Table 2 and Fig. 1)	Material Examined (ZRC.ECH.)
Order Aspidochirotida Grube, 1840				
Holothuriidae	<i>Actinopyga lecanora</i> (Jaeger, 1833)	Indo-West Pacific species	IT87, IT80, IT124	0536–0538
	<i>Holothuria</i> (<i>Lessonothuria</i>) <i>pardalis</i> Selenka, 1867	Indo- and Eastern Pacific species; new record for Singapore	IT140	0539
	<i>Holothuria</i> (<i>Mertensiothuria</i>) <i>leucospilota</i> Brandt, 1835	Indo-Pacific species	IT95	0540
	<i>Holothuria</i> (<i>Mertensiothuria</i>) sp.	Undetermined species	IT95, IT108	0541, 0545
	<i>Holothuria</i> (<i>Metriatyla</i>) <i>martensi</i> Semper, 1868	Indo-West Pacific species; new record for Singapore	TB29, SW23, DR174	0542–0544, 0546, 0547, 0602
	<i>Holothuria</i> (<i>Metriatyla</i>) <i>scabra</i> Jaeger, 1933	Indo-Pacific species	IT94	0548
	<i>Holothuria</i> (<i>Platyperona</i>) <i>croisnieri</i> Cherbonnier, 1988	Madagascar, Red Sea; new record for Singapore	DR174	0549
	<i>Holothuria</i> (<i>Thymiosycia</i>) <i>impatiens</i> (Forskål, 1775)	Indo- and Eastern Pacific species	IT140	0550
Stichopodidae	<i>Stichopus</i> aff. <i>monotuberculatus</i> (Quoy & Gaimard, 1833)	Undetermined species	SW13	0551
Order Dendrochirotida Grube, 1840				
Cucumariidae	<i>Actinocucumis</i> sp.	Undetermined species	SW13, TB29, DR57, TB97, TB185	0552, 0554–0557
	<i>Colochirus</i> sp.	Undetermined species	SW77, DR111, SB67, DR174	0578–0580, 0603
	<i>Mensamaria intercedens</i> (Lampert, 1885)	South China Sea, Indonesia, Australia, Singapore	TB58	0576
	<i>Pseudocolochirus</i> <i>violaceus</i> (Théel, 1886)	Indo-West Pacific species	DR127	0604
Phylloporidae	<i>Hemithyone semperi</i> (Bell, 1884)	Indian Ocean, South China Sea, Australia; new record for Singapore	TB16, SW13, DR70, DR127	0564–0567
	<i>Phyllophorella spiculata</i> (Chang, 1935)	South China Sea	DR57	0582
	<i>Phyllophorella</i> <i>kohkutiensis</i> (Heding & Panning, 1954)	South China Sea; new record for Singapore	TB58	0581
	<i>Stolus buccalis</i> (Stimpson, 1856)	Indo-West Pacific species	SD34, SW77, IT140	0583–0587
	<i>Thorsonia</i> sp.	Undetermined species	TB15	0605

Family	Species	Remarks	Collection Site (see Table 2 and Fig. 1)	Material Examined (ZRC.ECH.)
Sclerodactylidae	<i>Afroccumis africana</i> (Semper, 1867)	Indo-West Pacific species	SW32, SW44, SW48, IT140	0558–0563, 0606, 0607
	<i>Cladolabes hamatus</i> (Sluiter, 1914)	Rarely reported Indo- West Pacific species	DR31	0608
	<i>Havelockia</i> sp.	Undetermined species	TB17, TB16, TB58, TB29, SD34, DR111, DR127, SD25, SD166, DR184	0568, 0569, 0572–0575, 0609–0612
Order Synaptida Cuénot, 1891 (sensu Smirnov 2012)				
Synaptidae	<i>Protankyra bidentata</i> (Woodward & Barrett, 1858)	Indo-West Pacific species; new record for Singapore	DR57	0596
	<i>Protankyra pseudodigitata</i> (Semper, 1867)	Indo-West Pacific species	DR57	0597
	<i>Synaptula</i> cf. <i>recta</i> (Semper, 1952)	Indo-West Pacific species	IT86, IT94	0598, 0592, 0601
	<i>Synaptula minima</i> Heding, 1928	Indo-West Pacific species; new record for Singapore	SD133	0594
	<i>Synaptula reticulata</i> (Semper, 1868)	Indo-West Pacific species	SD54, SD133	0588–0600
	<i>Synaptula</i> sp. 1	Undetermined species	SD145	0593
	<i>Synaptula</i> sp. 2	Undetermined species	SD133	0590, 0591
	<i>Synaptula</i> sp. 3	Undetermined species	SD178	0595
Order Molpadida Haeckel, 1896				
Caudinidae	<i>Acaudina</i> sp.	Undetermined species	TB96	0613
	<i>Paracaudina chilensis</i> (Müller, 1850)	Indo-West Pacific species; new record for Singapore	DR57	0614

SYSTEMATIC ACCOUNT

Order Aspidochirotida Grube, 1840

Family Holothuriidae Burmeister, 1837

Genus *Actinopyga* Bronn, 1860

***Actinopyga lecanora* (Jaeger, 1833)
(Figs. 2A, 6)**

Mülleria lecanora Jaeger, 1833: 18, pl. 2 figs. 2, 2b, pl. 3 fig. 8.
Mülleria lecanora—Semper, 1868: 75, pl. 30 fig. 7, pl. 35 fig. 2.
Holothuria (Actinopyga) lecanora—Panning, 1929: 127, fig. 9.
Actinopyga lecanora—Pearson, 1914: 182, pl. 29 fig. 9.—H. L. Clark, 1921: 156, 158, 188.—H. L. Clark, 1938: 538.—Panning, 1941: 1, figs. 1–2.—Panning, 1944: 46, figs. 14–15.—H. L. Clark, 1946: 441.—Cannon & Silver, 1986: 20, text fig.—Cherbonnier, 1988: 20, figs. 4A–I.—Conand, 1989: 17.—Rowe & Gates, 1995: 287.—Massin, 1996a: 8, figs. 2A–B.—Liao,

1997: 84, figs. 47a–b.—Massin, 1999: 8–10, figs. 3a–j, 4, 110a.—Samyn & Berghe, 2000: 4.—Samyn, 2003a: 198, figs. 3A–E, 51C.

Material examined. ZRC.ECH.0536 (1 ex.), CMBS spec. no. SS-2282, stn. IT87, Pulau Semakau, intertidal, hand collection, coll. Dwi Listyo Rahayu et al., 27 May 2013; ZRC.ECH.0537 (1 ex.), CMBS spec. no. SS-2384, stn. IT80, Terumbu Bemban, intertidal rocky reef, hand collection, coll. Tan Chia Sing et al., 26 May 2013; ZRC.ECH.0538 (1 ex.), CMBS spec. no. SS-2870, stn. IT124, Terumbu Pempang Laut, N01°13.912', E103°43.402', intertidal, hand collection, coll. Lee Yen-Ling et al., 30 May 2013.

Description. Specimens (in alcohol) 165 × 65 mm, 70 × 30 mm, and 64 × 22 mm in size, respectively. Two of three specimens were uniformly brown with white patches dorsally including a white area surrounding the anus, ventral sole uniformly beige when alive; in alcohol, the two specimens

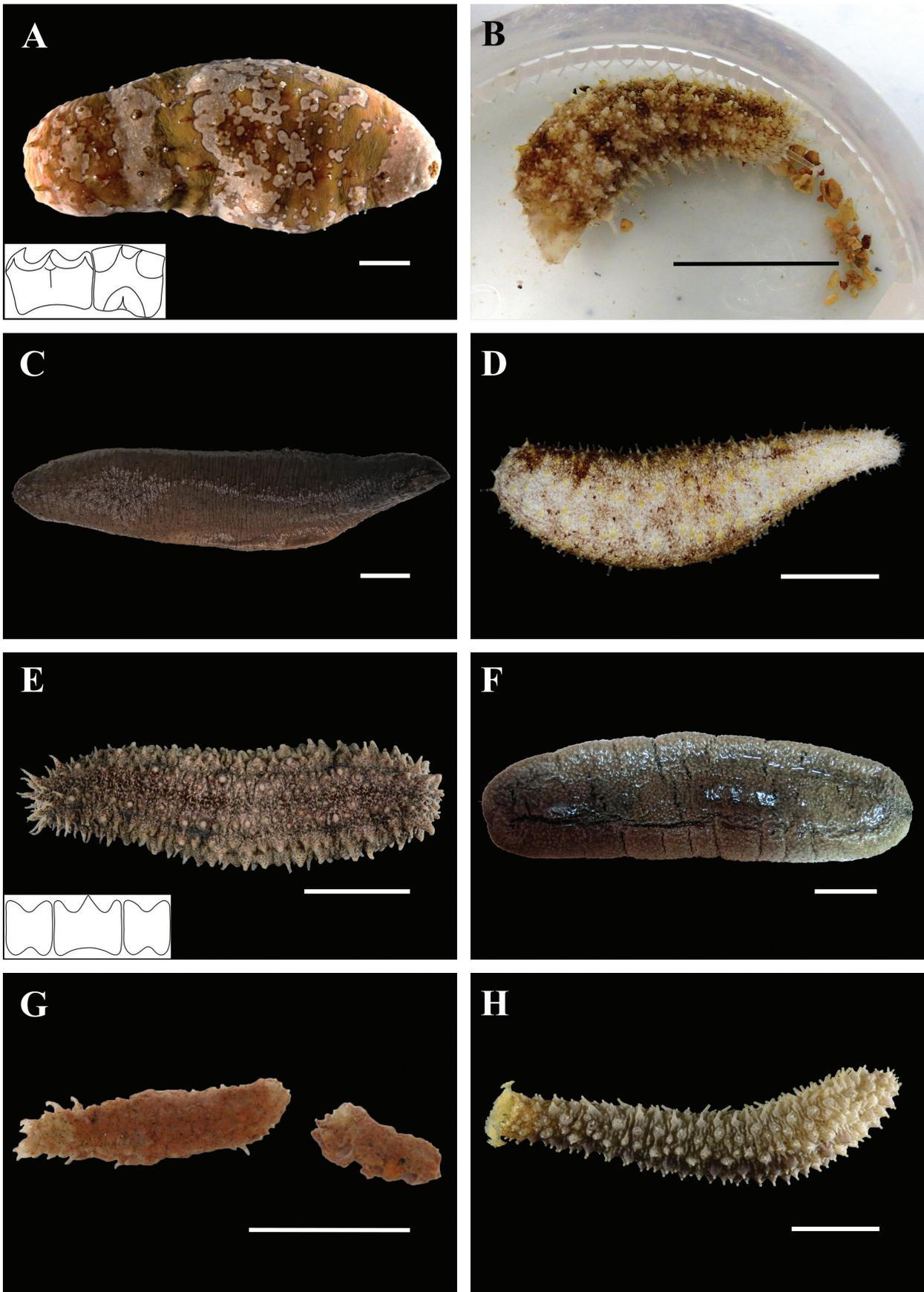


Fig. 2. Living (A, B, D, G, H) and preserved (C, F) specimens of holothuroids from the Singapore Strait: A, *Actinopyga lecanora* (Jaeger, 1833), ZRC.ECH.0537; B, *Holothuria (Lessonothuria) pardalis* Selenka, 1867, ZRC.ECH.0539; C, *Holothuria (Mertensiothuria) leucospilota* (Brandt, 1835), ZRC.ECH.0540; D, *Holothuria (Mertensiothuria) sp.*, ZRC.ECH.0541; E, *Holothuria (Metriatyla) martensi* Semper, 1868, ZRC.ECH.0544; F, *Holothuria (Metriatyla) scabra* Jaeger, 1833, ZRC.ECH.0548; G, *Holothuria (Platyperona) crosnieri* Cherbonnier, 1988, ZRC.ECH.0549; H, *Holothuria (Thymiosycia) impatiens* (Forskål, 1775), ZRC.ECH.0550. A and E with inserts of calcareous ring drawings. Scale bars = 2 cm [A, C, D, E, G], 1 cm [B, H], 4 cm [F].

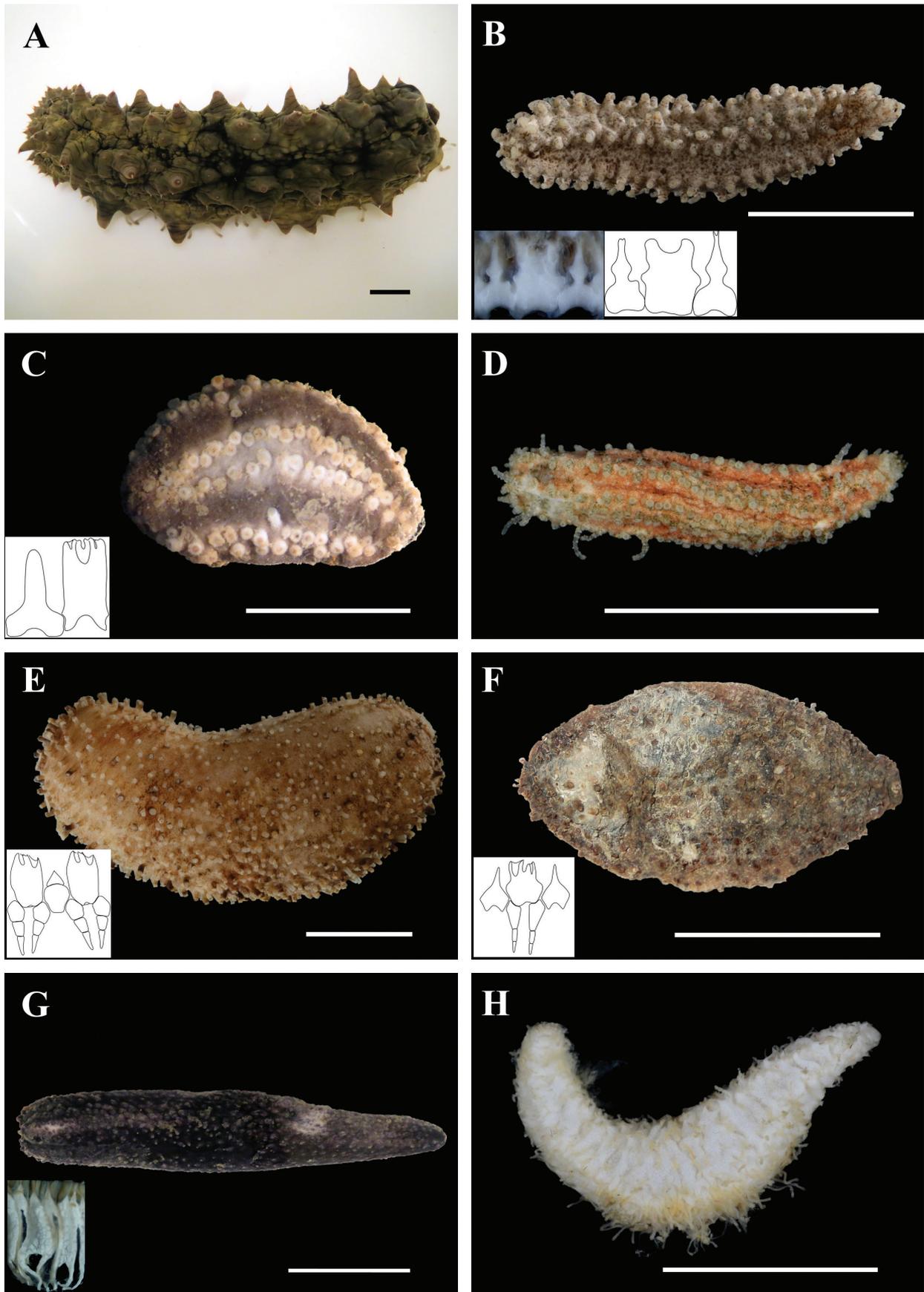


Fig. 3. Living (A, B, D, E, G, H) and preserved (C, F) specimens of holothuroids from the Singapore Strait: A, *Stichopus* aff. *monotuberculatus* (Quoy & Gaimard, 1833), ZRC.ECH.0551; B, *Actinocucumis* sp., ZRC.ECH.0555; C, *Mensamaria intercedens* (Lampert, 1885), ZRC.ECH.0576; D, *Hemithyone semperi* (Bell, 1884), ZRC.ECH.0564; E, *Phyllophorella kohkutiensis* (Heding & Panning, 1954), ZRC.ECH.0581; F, *Phyllophorella spiculata* (Chang, 1935), ZRC.ECH.0582; G, *Stolus buccalis* (Stimpson, 1856), ZRC.ECH.0584; H, *Thorsonia* sp., ZRC.ECH.0605. B, C, E and F with inserts of calcareous ring drawings. B and E with inserts of photos preserved calcareous rings. Scale bars = 1 cm [A, B, D–F, H], 0.5 cm [C], 2 cm [G].

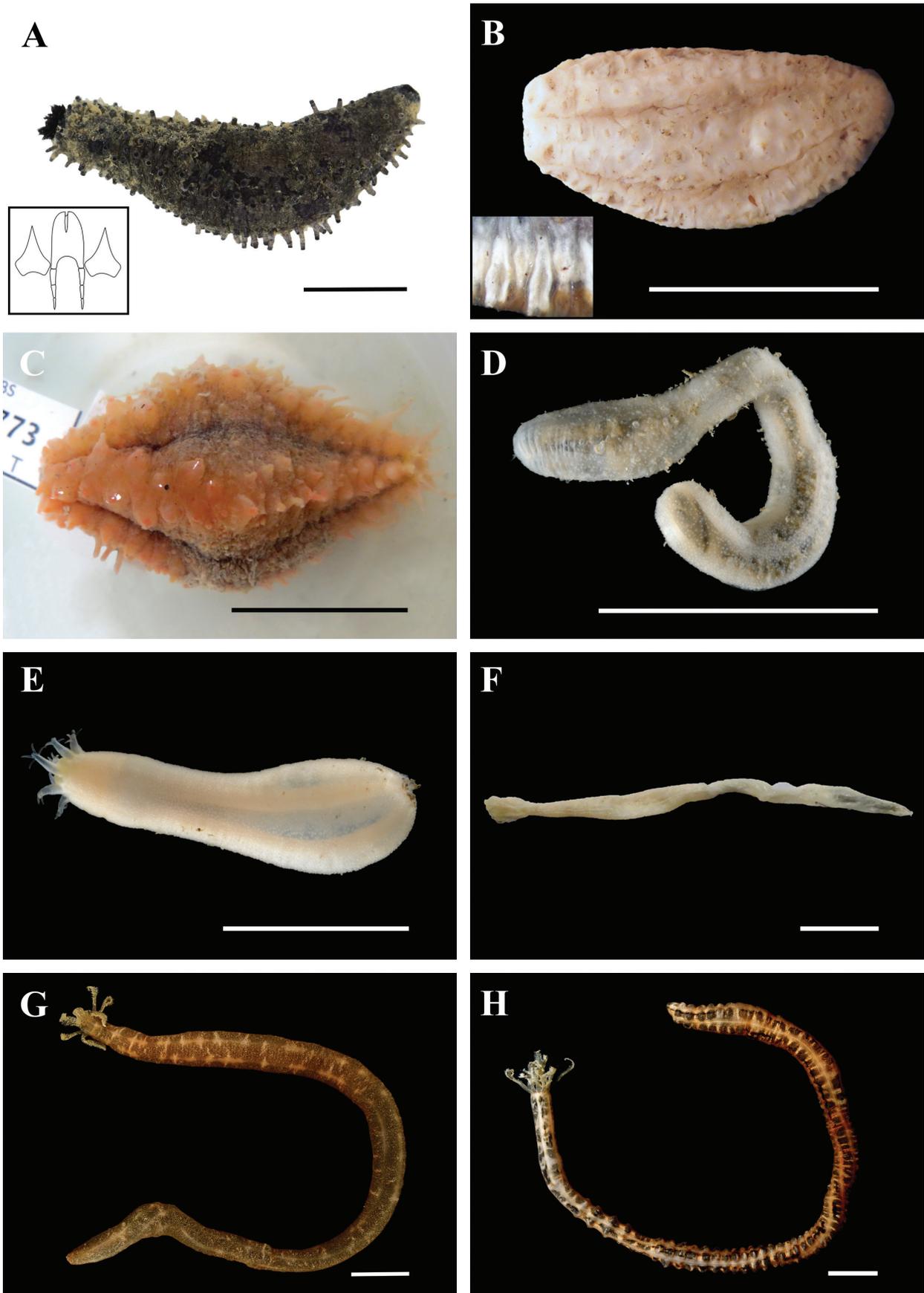


Fig. 4. Living (A, C–E, G, H) and preserved (B, F) specimens of holothuroids from the Singapore Strait: A, *Afrocucumis africana* (Semper, 1868), ZRC.ECH.0561; B, *Cladolabes hamatus* (Sluiter, 1914), ZRC.ECH.0608; C, *Havelockia* sp., ZRC.ECH.0572; D, *Protankyra pseudodigitata* (Semper, 1867), ZRC.ECH.0597; E, *Protankyra bidentata* (Woodward & Barrett, 1858), ZRC.ECH.0596; F, *Synaptula minima* Hedding, 1928, ZRC.ECH.0594; G, *Synaptula cf. recta* (Semper, 1868), ZRC.ECH.0592; H, *Synaptula cf. recta* (Semper, 1868), ZRC.ECH.0601; A and B with inserts of drawing and photograph of calcareous rings respectively. Scale bars= 1 cm [A, B, D–F], 2 cm [C, G, H].

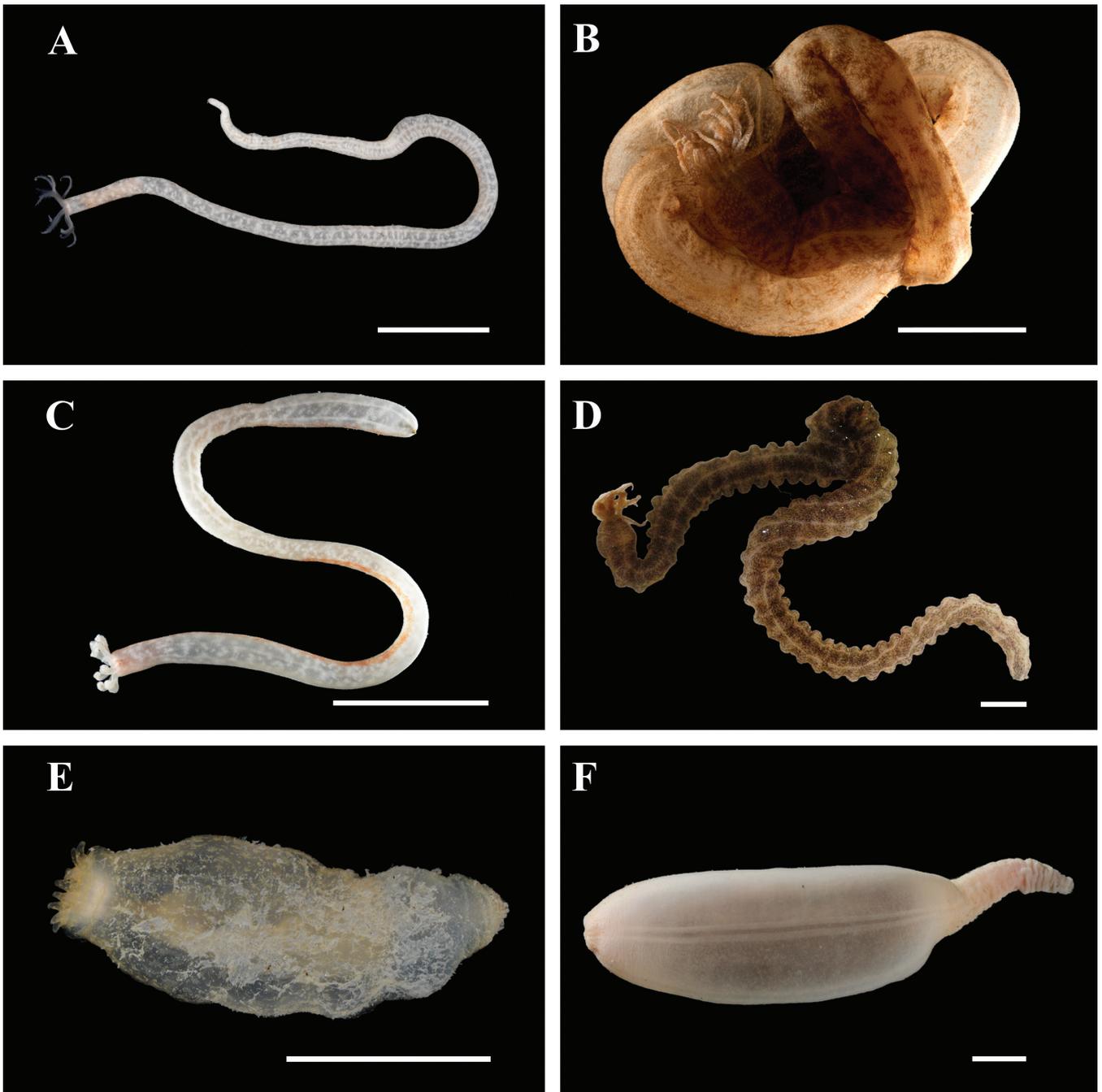


Fig. 5. Living (A–D, F) and preserved (E) specimens of holothuroids from the Singapore Strait: A, *Synaptula reticulata* (Semper, 1868), ZRC.ECH.0600; B, *Synaptula* sp. 1, ZRC.ECH.0593; C, *Synaptula* sp. 2; D, *Synaptula* sp. 3, ZRC.ECH.0590; E, *Acaudina* sp., ZRC.ECH.0613; F, *Paracaudina chilensis* (Müller, 1850), ZRC.ECH.0614. Scale bars = 2 cm [A–D], 1 cm [E, F].

are dark brown with lighter brown patches dorsally and yellowish brown ventrally. The other specimen is light brown with dark brown spots dorsally in alcohol (colour in life was not observed). In all three specimens examined, five yellow anal teeth are present on the rim of the anus. Body wall very thick. Ventral sole flat, dorsal surface arched. Mouth ventral, anus terminal. Dorsal tube feet sparse, long and scattered over the surface; ventral tube feet long and restricted to ambulacra. Calcareous ring simple, lacking posterior processes; radial plates with a slit on central anterior. Tentacles 18, peltate, yellow.

Ossicles. Ossicles of the body wall consist of small rosettes 18–32 μm in size. Rosettes have simple branches with each tip wider; sizes and shapes of rosettes from dorsal body wall similar with those from ventral body wall. Tentacles with large rods (ca. 300 μm in length), spiny at the extremities and a few smaller, smooth rods (ca. 50 μm in length).

Distribution. Somalia, Kenya, Madagascar, Mauritius, Sri Lanka, Maldives Islands, India, Myanmar, Malaysia, Indonesia, Australia, Philippines, Vietnam, China, Japan, Papua New Guinea, Solomon Islands, Loyalty Islands, New Caledonia, Fiji, and Singapore.

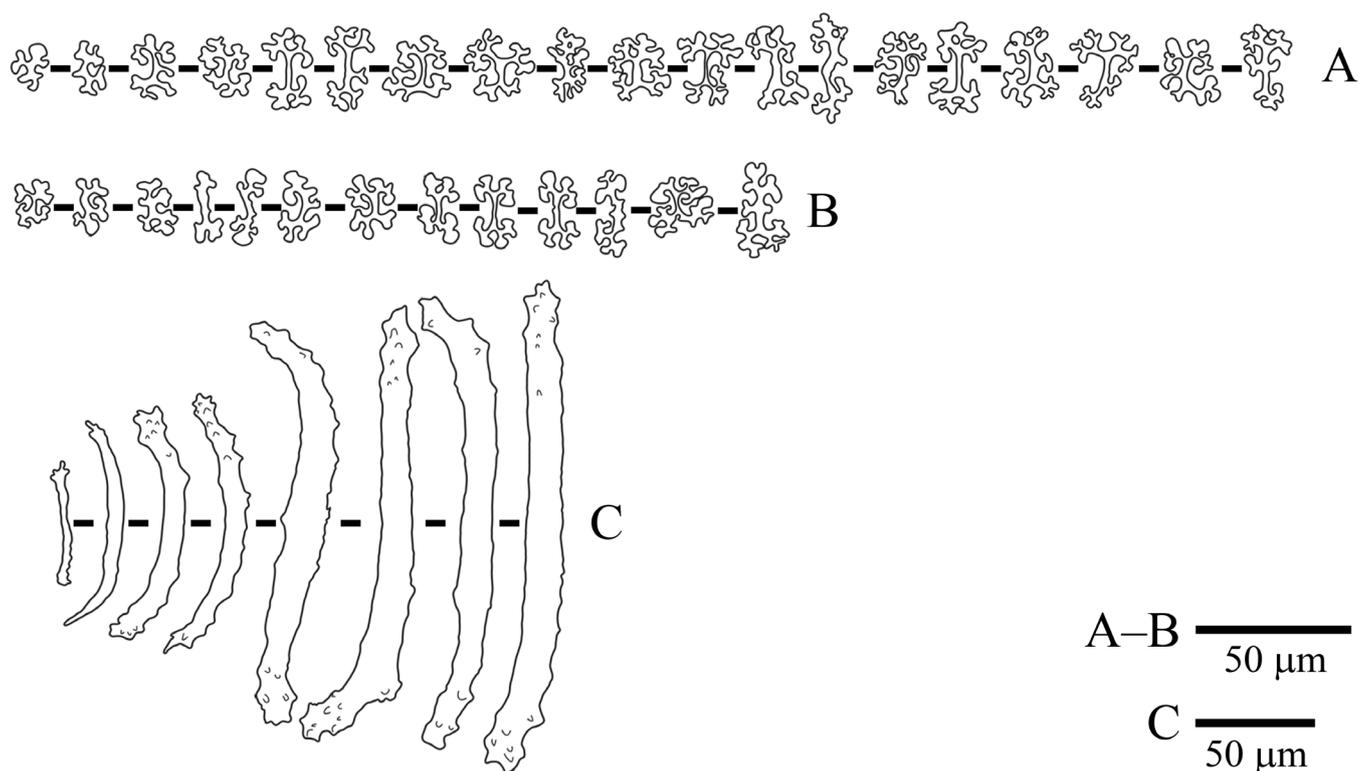


Fig. 6. *Actinopyga lecanora* (Jaeger, 1833). ZRC.ECH.0536. A, rosettes from dorsal body wall; B, rosettes from ventral body wall; C, tentacle rods.

Remarks. Two of three specimens possess similar colouration, but the third specimen was considerably lighter coloured with dark, instead of white spots when alive. No ossicle variation was observed between the three specimens.

Genus *Holothuria* Linnaeus, 1767

Subgenus *Lessonothuria* Deichmann, 1958

Holothuria (Lessonothuria) pardalis Selenka, 1867 (Figs. 2B, 7)

Holothuria pardalis Selenka, 1867: 336, pl.19 fig. 85
Holothuria pardalis—Lampert, 1896: 52.—Endean, 1957: 254.—
 Ludwig, 1899: 559.—Cherbonnier, 1955: 150, pl. 36 figs. a–p.
Halodeima pardalis—Heding, 1934: 23.
Holothuria (Holothuria) pardalis—Panning, 1935b: 3, figs. 106a–x.
Holothuria (Lessonothuria) pardalis—Rowe, 1969: 122, 149–150,
 figs. 15a–c.—Rowe & Doty, 1977: 233, fig. 4e.—Levin, 1979:
 21.—Rowe, 1983: 156.—Reyes-Leonardo, 1984: 148, pl. 4
 figs. 3a–f.—Liao, 1984: 222.—Price & Reid, 1985: 4.—Reyes-
 Leonardo et al., 1985: 274.—Cannon & Silver, 1986: 22, figs
 3g, 6e.—Cherbonnier, 1988: 117, figs. 47A–O.—James, 1989:
 127.—Levin & Dao Tan Ho, 1989: 55.—Rowe & Gates, 1995:
 292.—James, 1995: 191, figs. 3D–E.—Massin, 1996a: 19,
 figs. 12A–D, 13A–E.—Liao, 1997: 105, figs. 59a–c.—Massin,
 1999: 25–27, figs. 18a–j, 19.—Samyn et al., 2006: 72–73, figs.
 61A–D.—Samyn & Berghe, 2000: 5, 17, 23.—Samyn, 2003a:
 174, 216, pl. 2G figs. 16A–F, 52G.—Purwati & Wirawati,
 2009: 7–8, figs. 7a–7b.

Material examined. ZRC.ECH.0539 (1 ex.), CMBS spec. no. SS-3913, stn. IT140, Tekukor, N01°13.899', E103°50.265', intertidal, hand collection, coll. Lee Yen-Ling et al., 31 May 2013.

Description. Preserved specimen 15 × 7 mm in size. Living animal dorsal colour beige with brown spots horizontally, papillae white, scattered with yellow at the base; ventral darker in colour than dorsal, tube feet long and white, scattered. Body cylindrical, posterior wider than anterior. Body wall thin and smooth. Mouth ventral, anus terminal. Tentacles 18, peltate, yellow.

Ossicles. Ossicles consist of tables, buttons, rods and plates. Dorsal tables short, disc diameter 20–40 μm; margin of disc undulated; disc with four central holes and zero to eight peripheral holes; spire short, ended with rounded and spinous crown. Ventral tables similar with those in dorsal body wall but relatively smaller and sometimes reduced to disc only. Dorsal buttons nodulous, 25–45 μm long; with two to four pairs of holes often reduced to irregular number of holes and sometimes to one row of holes. Ventral buttons similar in shape with those in dorsal body wall but relatively smaller, 25–35 μm in length. Rods longer and slimmer in dorsal body wall, 75–140 μm in length; perforated by three holes at the extremities, sometimes more than three holes. Ventral rods stouter than dorsal rods, button-like, with a single hole at the extremities and four holes at the centre, ca. 80 μm in length. Ventral plates ca. 160 μm in length with a spiny edge and perforated with small holes. Ventral rod-like plates ca. 180 μm in length. Tentacles with slim and small spiny rods, 20–60 μm in length; sometimes large rods also present, spiny at the extremities, ca. 100 μm in length.

Distribution. Red Sea, Somalia, Republic of Yemen, Kenya, Zanzibar, Mazambique, Seychelles, Madagascar, Mauritius, Pakistan, Maldiv Islands, Chagos Archipelago, Sri Langka, India, Myanmar, Malaysia, Cocos Keeling Islands, Indonesia,

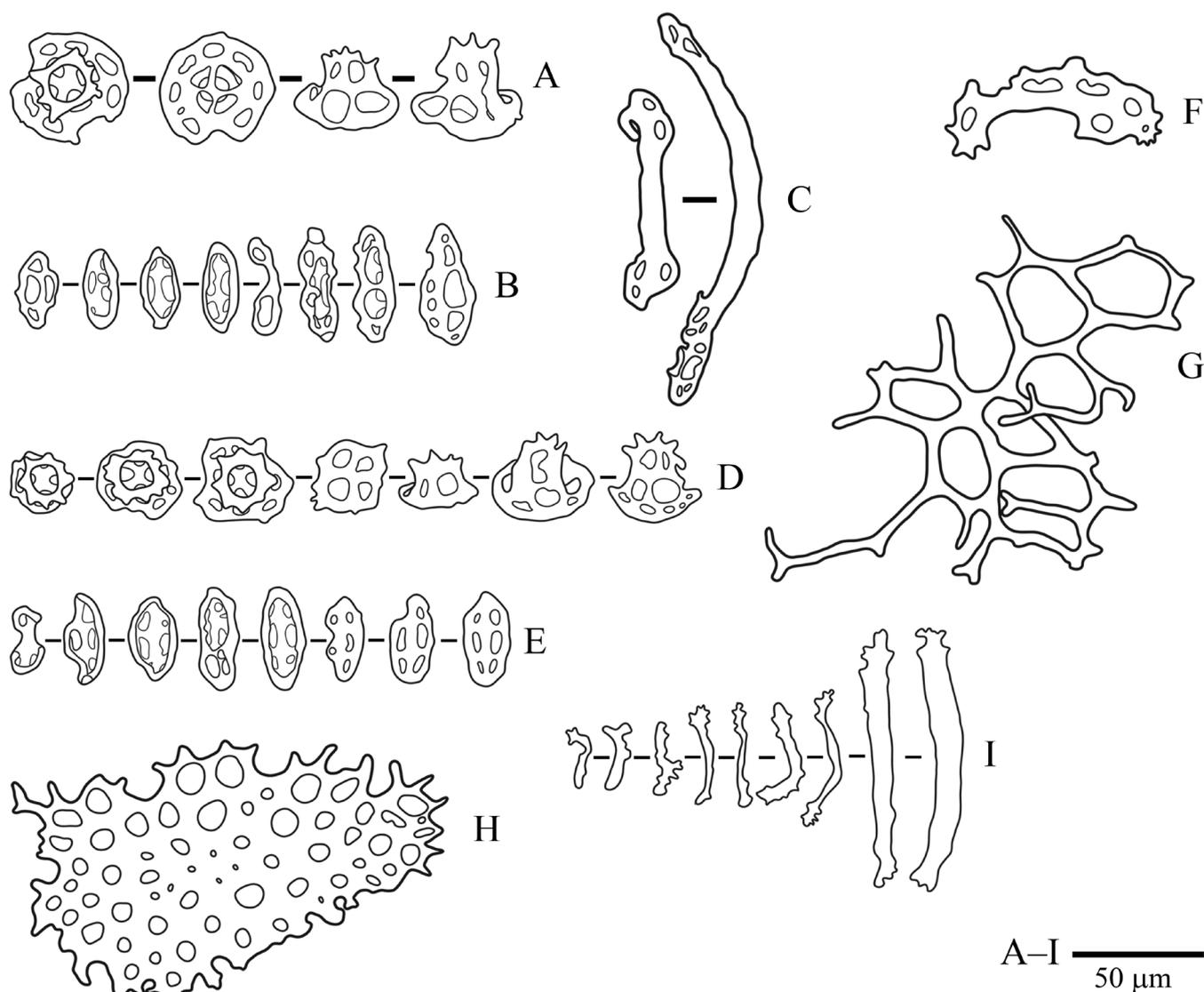


Fig. 7. *Holothuria (Lessonothuria) pardalis* Selenka, 1867. ZRC.ECH.0539. A, tables from dorsal body wall; B, buttons from dorsal body wall; C, rods from dorsal body wall; D, tables from ventral body wall; E, buttons from ventral body wall; F, rod from ventral body wall; G, rod-like plate from ventral body wall; H, plate from ventral body wall; I, tentacle rods.

Philippines, Vietnam, Taiwan, China, Japan, Korea, Mariana Island, Papua New Guinea, Australia, New Caledonia, Ellice Islands, Samoa, Gulf of California, Mexico, island off Panama, Columbia, Cocos Islands, Galapagos Islands and Singapore.

Remarks. Table ossicles in the specimen from Singapore are different from those described from Madagascar (Cherbonnier, 1988) and West Lombok, Indonesia (Purwati & Wirawati, 2009). Ossicles from the Singapore specimen consist of table discs with mostly undulated margins, whereas those from Madagascar and Indonesia possess spiny margins. Table ossicles with undulated margins were also reported by Massin (1999) from small specimens collected in the Spermonde Archipelago in Indonesia. Massin (1994) had earlier observed that ossicles become more spiny with advancing age in other holothurians. Mitsukuri (1912) also previously described table ossicles with smooth crenulate discs in small specimens of this species. Given the small size of specimens from Japan (Mitsukuri, 1912), the Spermonde

Archipelago (Massin, 1999) and Singapore (this study), we conclude that these are juveniles.

Subgenus *Mertensiothuria* Deichmann, 1958

Holothuria (Mertensiothuria) leucospilota (Brandt, 1835)

(Figs. 2C, 8)

- Stichopus (Gymnochirota) leucospilota* Brandt, 1835: 51
Stichopus (Gymnochirota) leucospilota—Ludwig, 1881: 595.
Holothuria leucospilota—H. L. Clark, 1921: 179.—Endean, 1957: 253.—James, 1983: 92, 100, 101.—Massin & Doumen, 1986: 188.
Holothuria vagabunda—Selenka, 1867: 334, pl. 19 figs. 75–76.—Panning, 1944: 66, fig. 33.
Holothuria (Holothuria) vagabunda—Panning, 1934: 67, fig. 45.—Heding, 1940a: 114.—Cherbonnier, 1955: 145, pl. 31 figs. p–s.
Holothuria (Mertensiothuria) leucospilota—Rowe, 1969: 148, fig. 14.—A. M. Clark & Rowe, 1971: 176, fig. 87, i–i', pl. 19 fig. 19.—Liao, 1975: 215.—Rowe & Doty, 1977: 233, figs. 4f, 7g.—Levin, 1979: 21.—Tan Tiu, 1981: 77, pl. 19 figs. 1–2,

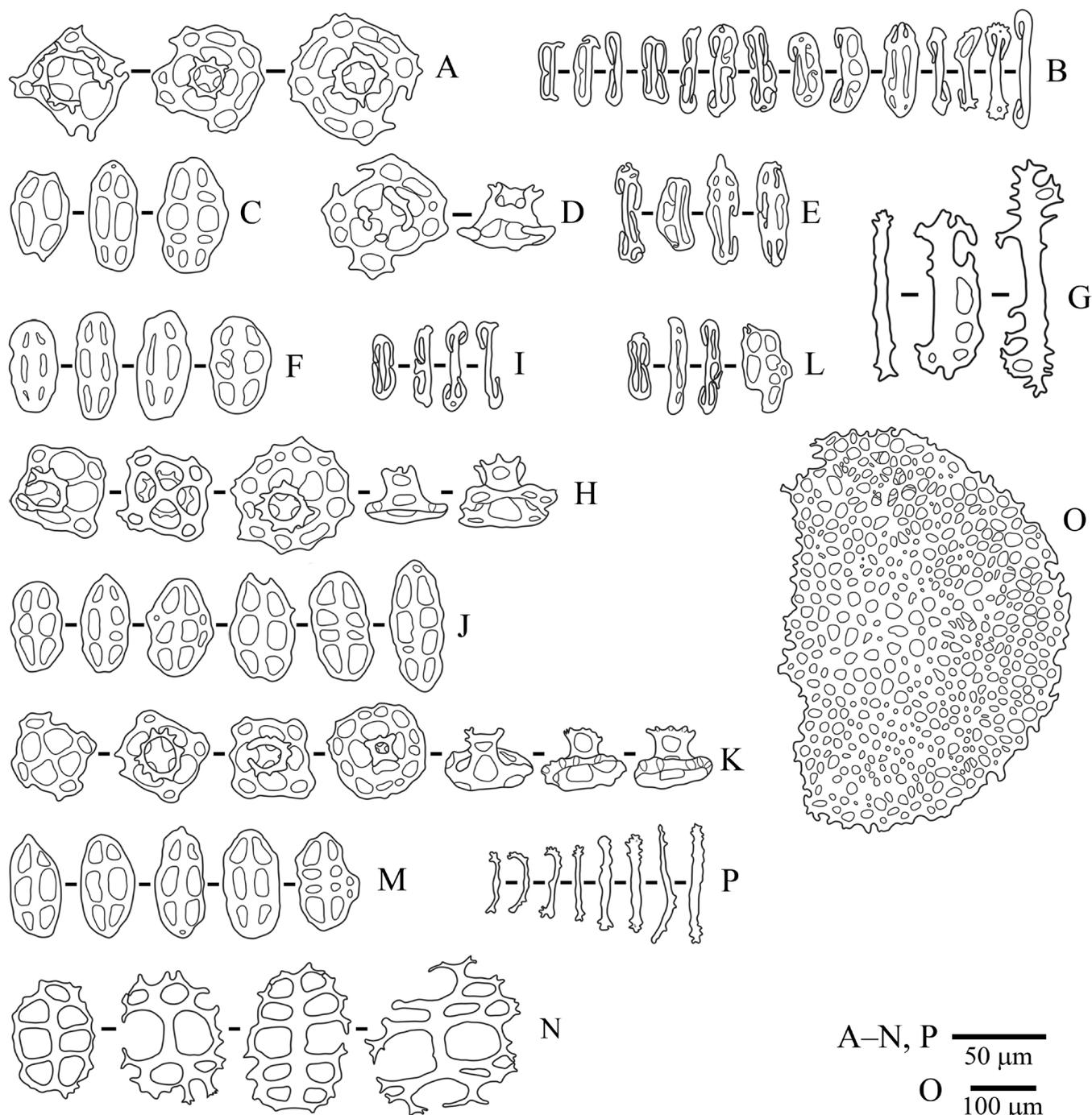


Fig. 8. *Holothuria (Mertensiothuria) leucospilota* (Brandt, 1835). ZRC.ECH.0540. A, tables from dorsal body wall; B, reduced buttons from dorsal body wall; C, regular buttons from dorsal body wall; D, tables from dorsal papillae; E, reduced buttons from dorsal papillae; F, regular buttons from dorsal papillae; G, rods from dorsal papillae; H, tables from ventral body wall; I, reduced buttons from ventral body wall; J, regular buttons from ventral body wall; K, tables from tube feet; L, reduced buttons from tube feet; M, regular buttons from tube feet; N, pseudo-plates from tube feet; O, large end-plate from tube feet; P, tentacle rods.

pl. 29 figs. 1, 2d.—Liao, 1984: 222.—Cherbonnier & Féral, 1984: 682, figs. 11A–M.—Cannon & Silver, 1986: 23, figs. 3h, 6g.—Conand, 1989: 24.—James, 1989: 126.—Levin & Dao Tan Ho, 1989: 56.—Kerr, 1994: 168.—Cherbonnier, 1988: 112, figs. 45A–P.—Marsh, 1994: 11.—Rowe & Gates, 1995: 293.—James, 1995: 190, figs. 3A–C, pl. 2A.—Liao, 1997: 109, figs. 62a–c.—Massin, 1999: 27–30, figs. 20a–g, 21.—Samyn & Massin, 2003: 2502, figs. 6A–P, 11D, 12G.—Samyn, 2003a: 220, fig. 53b.—Samyn et al., 2006: 78, figs. 64A–H.—Purwati & Wirawati, 2009: 11, figs. 9a–b.

Material examined. ZRC.ECH.0540 (2 exx.), CMBS spec. no. SS-3911, stn. IT95, Raffles Light House, N01°13.899', E103°50.265', intertidal, hand collection, coll. Tan Chia Sing et al., 28 May 2013.

Description. Preserved specimens 90 × 30 mm, 180 × 50 mm. Colour in alcohol uniformly dark brown dorsally and lighter brown ventrally. Body cylindrical, posterior wider than anterior; body wall thick. Mouth ventral and anus terminal. Dorsal papillae small, dense and scattered; tube feet long, also dense and scattered. Tentacles 20, peltate and black.

Ossicles. Ossicles consist of tables, buttons, rods, plates and pseudo-plates. Tables in the body wall short, with disc diameter 40–60 µm; disc usually rounded with spiny margin, sometimes rectangular with undulated margin; disc perforated by four central holes and 4–11 peripheral holes; crown rounded spiny. Tables in the dorsal papillae and tube feet are in general similar to those in the body wall but with reduced crown. Buttons are similar in the body wall, dorsal papillae and tube feet. Regular buttons smooth, 50–70 µm in length, perforated by three to four pairs of holes. Reduced buttons smooth, asymmetric, 30–50 µm in length, perforated by one to four holes. Rods present in the dorsal papillae and tentacles. Dorsal papillae rods spiny, 75–120 µm in length, irregularly perforated by two to five holes, sometimes without holes and slim. Tentacle rods slim, small and spiny; 30–60 µm in length. Pseudo-plates and large plates present in the tube feet; large plates diameter 540 µm, perforated by numerous small holes; pseudo-plates 50–70 µm in length, perforated by a few relatively large holes.

Distribution. Red Sea, Aden, Somalia, Kenya, Zanzibar, Mozambique, Comoros Islands, South Africa, Madagascar, Mauritius, Seychelles, Maldive Islands, Chagos Archipelago, Oman, Persian Gulf, Pakistan, India, Sri Lanka, Myanmar, Cocos Keeling Islands, Indonesia, Malaysia, Vietnam, Philippines, Taiwan, China, Japan, Mariana Islands, Papua New Guinea, Australia, New Caledonia, Loyalty Islands, Caroline Islands, Marshall Islands, Vanuatu, Ellice Islands, Phoenix Islands, Cook Islands, Samoa, Tonga Islands, Fiji, Hawaiian Islands, Line Islands, Cook Islands, Society Islands, Mexico, Clipperton Islands, Cocos Islands, Galapagos Islands, Peru; and Singapore.

Remarks. Singapore specimens possess reduced buttons in the dorsal papillae, ventral body wall and tube feet. These buttons are also present in specimens from Madagascar (Cherbonnier, 1988), but absent in animals examined from Spermonde Islands (Massin, 1999) and Solomon Islands (Samyn & Massin, 2003). This species is one of the most common intertidal species in Singapore (pers. obs.), often seen hiding underneath rocks or boulders.

Holothuria (Mertensiothuria) sp.
(Fig. 2D)

Material examined. ZRC.ECH.0541 (1 ex.), CMBS spec. no. SS-2836, stn. IT108, Raffles Light House, intertidal, hand collection, coll. Lee Yen-Ling et al., 29 May 2013; ZRC.ECH.0545 (1 ex.), CMBS spec. no. SS-3302, stn. IT95, Raffles Light House, intertidal, hand collection, coll. Tan Chia Sing et al., 28 May 2013.

Description. Specimens 52 × 17 mm, and 24 × 12 mm in size; body strongly tapers towards the anterior end. Living animals beige, with few brown patches and white small spots present on dorsal surface. Dorsal papillae white with yellow area encircling the base of each papilla, scattered on the entire dorsal surface.

Ossicles. Body wall ossicles consist of tables, buttons and rods. Tables short, disc rounded; rim of disc spinous; disc perforated by four central holes and usually 8–12 peripheral holes; some smaller discs not perforated by peripheral holes; crown rounded and spiny. Regular buttons smooth but not flat, perforated by two to four pairs of holes; irregular buttons slightly twist and knobbed, perforated by three to four holes. Rods long and slim, perforated by one hole at the extremities. Tentacle ossicles branched, slim and spiny rods.

Remarks. The types of ossicles in these specimens are similar to those of *Holothuria (Mertensiothuria) leucospilota*. However their external morphologies are different. The body of *H. leucospilota* is cylindrical in shape, and is uniformly dark brown (Samyn, 2003a). Specimens of this undetermined species possess a beige cylindrical body with dark brown spots, strongly tapers towards the anterior end. The ossicles of these specimens are regular smooth buttons and irregular knobbed buttons with a slight twist. These do not seem to correspond to ossicles from any known member of the subgenus *Mertensiothuria* (see Samyn, 2003a).

Subgenus *Metriatyla* Rowe, 1969

Holothuria (Metriatyla) martensi Semper, 1868
(Figs. 2E, 9, 10)

Holothuria martensii Semper 1868: 86, 277, pl. 30 fig. 1.
Holothuria martensii—Ludwig, 1882: 136.—Lampert, 1885: 74.—Théel, 1886a: 177, 237, pl. 7 fig. 12, pl. 16 fig. 2.—Koehler, 1895: 383.—Pearson, 1910: 179, 1913: 92, pl. XIV fig. 25.—H. L. Clark, 1932: 233.—H. L. Clark, 1946: 431.—Cherbonnier, 1955: 159, pl. 42 figs. a–l.
Holothuria subverta—H. L. Clark, 1921: 182, pl. 38 figs. 25–32.
Holothuria (Holothuria) martensii—Panning 1935a: 96, fig. 85.
Holothuria (Metriatyla) martensi—Rowe, 1969: 160.—A. M. Clark & Rowe, 1971: 178.—Liao, 1984: 238, figs. 18a–4.—Cherbonnier, 1988: 137, figs. 56A–P.

Material examined. ZRC.ECH.0542 (2 exx.), CMBS spec. no. SS-0117, stn. TB29, Singapore Port Limit, near Eastern Boarding Ground A, N01°13'036, E103°52'820, 103–98.0 m depth, gravel, rocky, beam trawl, coll. Lim Swee Cheng et al., 22 May 2013; ZRC.ECH.0543 (2 exx.), CMBS spec. no. SS-0118, stn. TB29, Singapore Port Limit, near Eastern Boarding Ground A, N01°13'036, E103°52'820, 103–98.0 m depth, gravel, rocky, beam trawl, coll. Lim Swee Cheng et al., 22 May 2013; ZRC.ECH.0544 (1 ex.), CMBS spec. no. SS-1768, stn. SW23, St. John Island, DRTech, south lagoon, N01°13'1.20, E103°51'4.17, hand collection, coll. Tan Heok Hui et al., 21 May 2013; ZRC.ECH.0546 (1 ex.), CMBS spec. no. SS-4684, stn. DR174, next to Eastern Boarding Ground A, near Kusu Island, N01°12'202, E103°52'178, 135–79.6 m depth, reddish marine clay, gravel, dead shells, rectangular dredge, coll. Lim Swee Cheng et al., 4 June 2013; ZRC.ECH.0547 (1 ex.), CMBS spec. no. SS-4692, stn. DR174, next to Eastern Boarding Ground A, near Kusu Island, N01°12'202, E103°52'178, 135–79.6 m depth, reddish marine clay, gravels and dead shells, rectangular dredge, coll. Lim Swee Cheng et al., 4 June 2013; ZRC.ECH.0602 (1 ex.), CMBS spec. no. SS-1770, stn. TB58, around Tanah

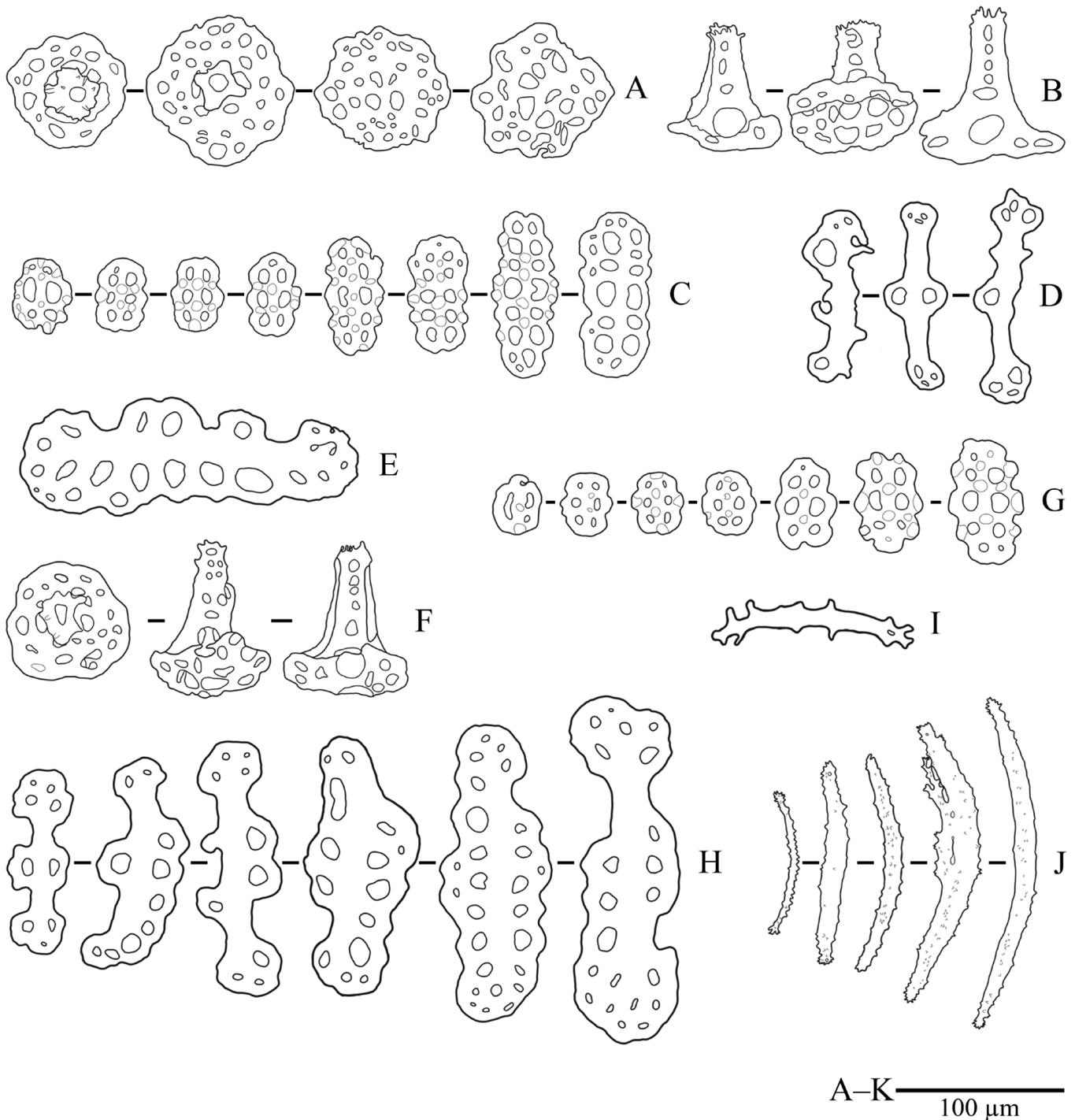


Fig. 9. *Holothuria (Metriatyla) martensi* Semper, 1868. ZRC.ECH.0544. A, tables from dorsal body wall (top view); B, tables from dorsal body wall (side view); C, buttons from dorsal body wall; D, rods from dorsal body wall; E, button-like rods from dorsal body wall; F, tables from dorsal papillae; G, buttons from dorsal papillae; H, button-like rods from dorsal papillae; I, rod from dorsal papillae; J, tentacle rods.

Merah, N01°16'808, E 103°58'246, 38.7–39.9 m depth, mud, beam trawl, coll. Lim Swee Cheng et al., 24 May 2013.

Description. Preserved specimens with sizes range from 110 × 25 mm to 47 × 21 mm. Living colours of specimens varied slightly from pale brown, yellowish brown to beige brown, all with dark brown fleckings of uneven density; fleckings forming larger dark spots on the dorsal wall of specimens ZRC.ECH.0542 and ZRC.ECH.0546. Specimen ZRC.ECH.0544 has darker body colour with denser fleckings, denser papillae and thin black lines along ambulacra (Fig.

2E). Body slightly rectangular, body wall thick and rugose. Papillae scattered on the dorsal surface, denser and evenly arranged on the ventral surface. Lateral papillae enlarged, forming wing-like shape. Mouth ventral, anus terminal. Calcareous ring simple, lacking posterior processes; radial plates as long as broad, interradial plates half as long as broad. Tentacles 20, peltate, light brown.

Ossicles. Ossicles consist of tables, buttons, rods and rod-like buttons. Body wall tables with discs 20–100 µm in diameter; margin of disc undulated; disc perforated by more than four

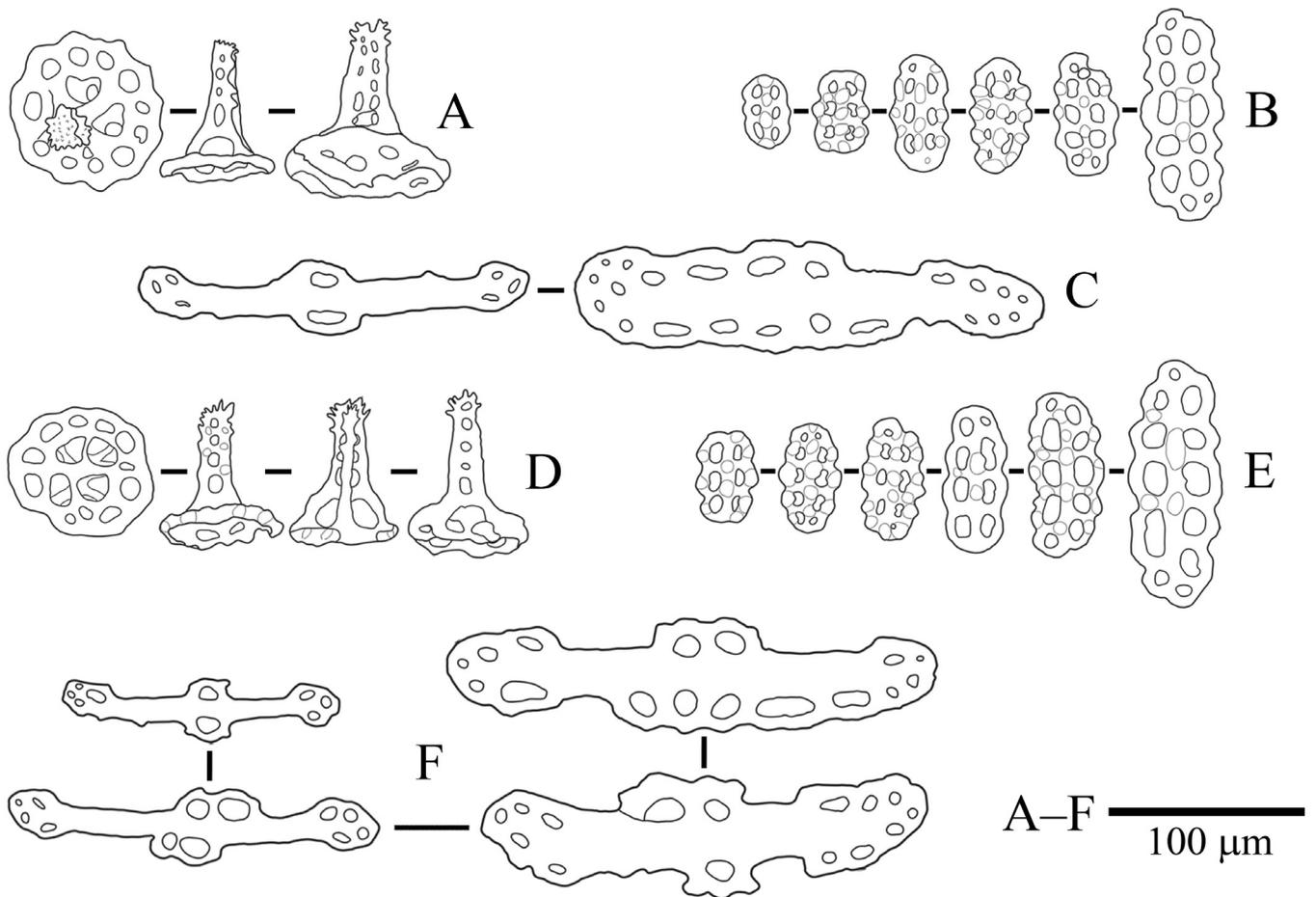


Fig. 10. *Holothuria (Metriatyla) martensi* Semper, 1868. ZRC.ECH.0544. A, tables from ventral body wall; B, buttons from ventral body wall; C, rods and button-like rods from ventral body wall; D, tables from tube feet; E, buttons from tube feet; F, rods and button-like rods from tube feet.

central holes and numerous peripheral holes; spire high (ca. 80 μm in height) and on the top generally carries several small spines; crown relatively small and spinous. Tables in the dorsal papillae are similar to those in the body wall. Tube feet tables are smaller than those in the body wall and dorsal papillae. Buttons numerous, knobbed with undulated rim; 45–100 μm in length, perforated by three to seven pairs of holes. Buttons in the body wall, dorsal papillae and tube feet are similar in shape. Dorsal papillae buttons relatively shorter than those from body wall; larger buttons sometimes present in tube feet. Rods 100–180 μm in length, perforated at the extremities and the centre, present in the body wall, dorsal papillae and tube feet. Large rod-like buttons, 100–210 μm in length, present in body wall, dorsal papillae and tube feet. Tentacle rods curved or straight, spinous, 100–200 μm in length.

Distribution. Red Sea, Africa, Madagascar, Maldiv Islands, Indo-China, Indonesia, north of Australia, Philippines, China, Japan and Singapore.

Remarks. The body colours and ossicles of Singapore specimens generally agree with the original descriptions provided by Semper (1867–1868) and by Théel (1886a). Théel (1886a) referred to a specimen where “its colour is darker from a greater abundance of slightly larger brownish

specks” and “the odd ambulacrum is marked out by a narrow dark line”; which has a similar colour pattern with the specimen ZRC.ECH.0544. Specimen ZRC.ECH.0546 has smaller and less dense dorsal papillae than the others. Specimen ZRC.ECH.0602 is of a lighter colour than ZRC.ECH.0544. The tables and buttons of all of these specimens are similar to those described in Semper (1867–1868), Théel (1886a), Pearson (1913), Panning (1935a) and Cherbonnier (1955), but without the large tables described by Liao (1984) and Cherbonnier (1988). Liao (1984) concluded that the shape and size of tables and buttons varied with the body size of specimens: large specimens have smaller, less perforated buttons with more knobs and shorter tables with smaller, thicker, less perforated discs, as compared to those from small specimens (ca. 50 mm in length). The relatively rare rod-like buttons (Liao, 1984; Théel, 1886a) are also present in these specimens.

***Holothuria (Metriatyla) scabra* Jaeger, 1833**
(Figs. 2F, 11)

Holothuria scabra Jaeger, 1833: 23

Holothuria scabra—Selenka, 1867: 341.—Semper, 1868: 79, 247, 277.—Haacke, 1880: 46.—Ludwig, 1881: 559.—Ludwig, 1882: 135.—Ludwig, 1883: 168; Lampert, 1885: 69.—Théel, 1886a: 234.—Ludwig, 1887: 31.—Sluiter, 1887: 193.—Ludwig, 1888: 807.—Ludwig, 1889–1892: 330.—Sluiter, 1894: 103.—

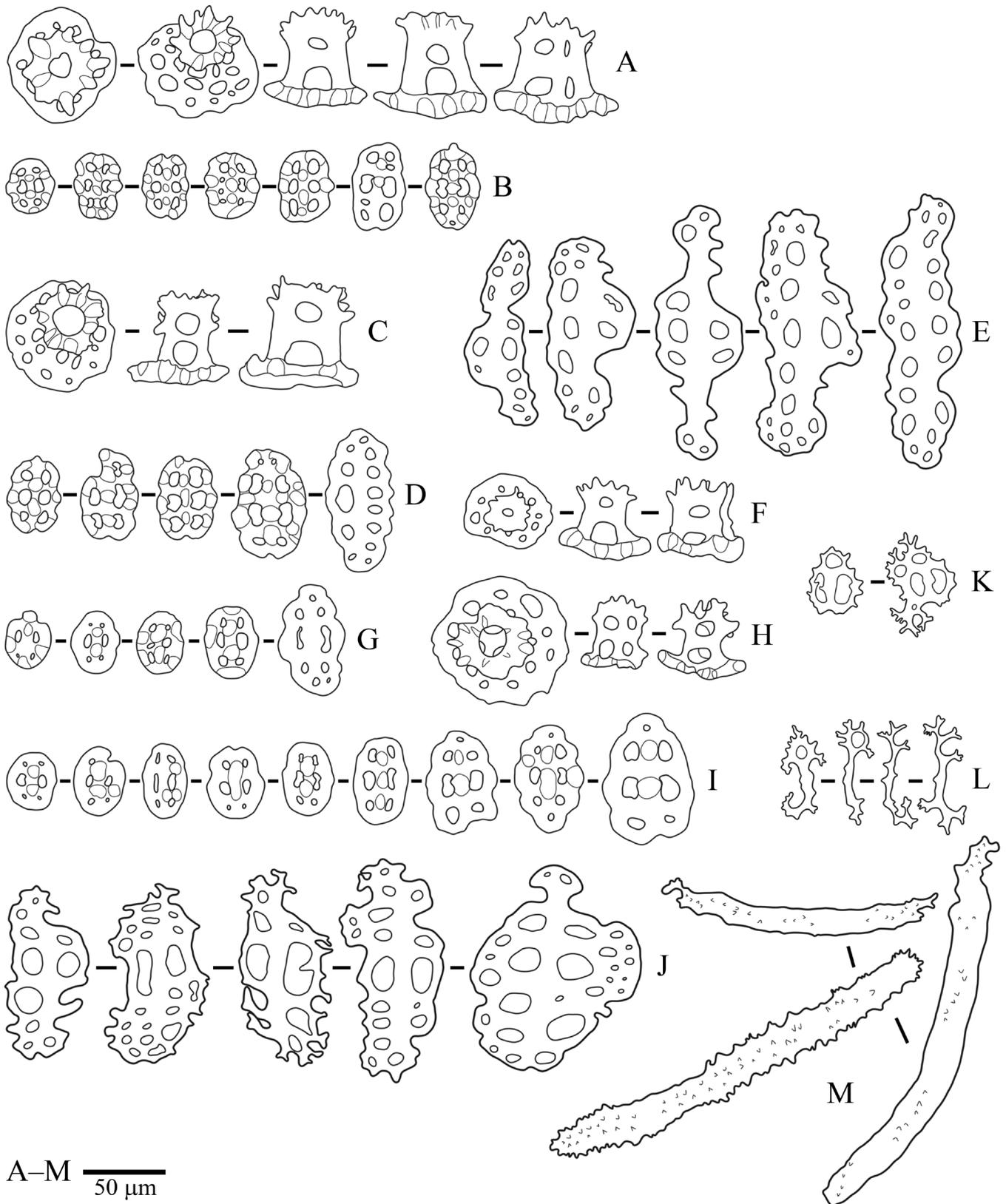


Fig. 11. *Holothuria (Metriatyla) scabra* Jaeger, 1833. ZRC.ECH.0548. A, tables from dorsal body wall; B, buttons from dorsal body wall; C, tables from dorsal papillae; D, buttons from dorsal papillae; E, rods from ventral body wall; F, tables from ventral body wall; G, buttons from ventral body wall; H, tables from tube feet; I, buttons from tube feet; J, plates from tube feet; K, plates from tentacles; L, small rods from tentacles; M, large rods from tentacles.

Lampert, 1896: 54.—Ludwig, 1899: 557.—Koehler & Vaney, 1908: 16.—Pearson, 1910: 180.—Mitsukuri, 1912: 135, textfig. 24.—Pearson, 1913: 87, pl. 13 fig. 22.—H. L. Clark, 1920: 150.—H. L. Clark, 1921: 181.—H. L. Clark, 1923: 424.—H. L. Clark, 1932: 235.—Panning, 1941: 13, figs. 9–10.—Panning, 1944: 67, figs. 34–35.—Cherbonnier, 1955: 145, pl. 32 figs. a–e.—James, 1983: 94, pl. 2C.

Holothuria tigris—Selenka, 1867: 333, pl. 19 figs. 70–72.

Holothuria cadelli—Bell, 1887a: 144, pl. 16 fig. 7.

Holothuria gallensis—Pearson, 1903: 203, pl. 3 figs. 46–50.

Holothuria (Holothuria) scabra—Panning, 1934: 80, figs. 66a–f.

Holothuria (Metriatyla) scabra—Cherbonnier, 1980: 647, figs. 16 A–L.—Rowe, 1969: 160, fig. 80.—A. M. Clark & Rowe, 1971: 178, fig. 87(l), pl. 15 fig. 15.—Liao, 1984: 237.—Reyes-Leonardo, 1984: 149, pl. 6 fig. 1a–g.—Reyes-Leonardo et al., 1985: 275.—Cannon & Silver, 1986: 23, figs 4a, 6i.—Cherbonnier, 1988: 135, figs. 55A–O.—Conand, 1989: 24, fig. 1.—Levin & Dao Tan Ho, 1989: 56.—Kerr, 1994: 168, fig. 4c.—Marsh, 1994: 11.—Rowe & Gates, 1995: 294.—James, 1995: 196–199, figs. 4B–C, pl. 2C.—Massin, 1996a: 25, figs. 16A–F, 17A–D.—Liao, 1997: 115, figs. 66a–c.—Samyn & Berghe, 2000: 24.—Samyn, 2003a: 175, 223, pl. 3A, figs. 19A–E, 53D.—Purwati & Wirawati, 2009: 11, figs. 10a, b.—Ong & Wong, 2015: 275.

Material examined. ZRC.ECH.0548 (1 ex.), CMBS spec. no. SS-3893, stn. IT94, Cyrene Reef, N01°15.374', E103°44.816', intertidal, hand collection, coll. Koh Kwan Siong et al., 28 May 2013.

Description. Preserved specimen 230 × 65 mm. Colour of living animal grey with black transverse lines on the dorsal area; ventral uniformly beige. Dorsal papillae dark brown, small and scattered on the dorsal surface; light brown circle present at the base of papillae. Tube feet dark brown, scattered on the ventral surface. Body wall very thick and hard. Mouth ventral, anus terminal. Tentacles 20, peltate.

Ossicles. Ossicles consist of tables, buttons, rods and plates. Tables in the body wall stout, disc diameter 50–80 µm, rim undulating with more than four central holes and more than one circle of peripheral holes; spire short, ended with rounded and spinous crown. Tables in the dorsal papillae and tube feet are similar with those in the body wall. Buttons in the body wall, dorsal papillae and tube feet are numerous, 25–60 µm in length, knobbed with three to five pairs of holes. Perforated rods present in the dorsal papillae, 100–125 µm in length. Plates in the tube feet elongate, 100–110 µm in length. Small and spiny plates and rods (45–50 µm) present in the tentacles. Large and spiny rods also present in the tentacles.

Distribution. Red Sea, Somalia, Kenya, Zanzibar, Mozambique, South Africa, Madagascar, Seychelles, Mauritius, Maldive Islands, Sri Lanka, India, Myanmar, Cocos Keeling Islands, Indonesia, Philippines, Vietnam, Japan, Hong Kong, Australia, Papua New Guinea, Solomon Islands, Palau Islands, Caroline Islands, New Caledonia, Vanuatu, Fiji, Tonga, Cook Islands and Singapore.

Remarks. Massin et al. (2000) noted that the ossicles of *H. scabra* varied with increasing body size. The specimen at hand is relatively large, possibly accounting for the ossicles comprising short and stout tables and nodose buttons.

Subgenus *Platyperona* Rowe, 1969

Holothuria (Platyperona) crosnieri Cherbonnier, 1988 (Figs. 2G, 12)

Holothuria (Platyperona) crosnieri Cherbonnier, 1988: 103, figs. 42, A–Q. —Hellal et al., 2002: 32.

Material examined. ZRC.ECH.0549 (1 ex.), CMBS spec. no. SS-4695, stn. DR174, next to Eastern Boarding Ground A, near Kusu Island, N01°12'202, E103°52'178, 135–79.6 m depth, reddish marine clay, gravel, dead shells, rectangular dredge, coll. Lim Swee Cheng et al., 4 June 2013.

Description. Preserved specimen 30 × 7 mm, cylindrical and slim body. Colour in life dull white covered with orange patches especially at the mid-region of the specimen; colour in alcohol slightly duller. Body wall thin and rough because of large papillae. Dorsal papillae and tube feet white, large, scattered on the dorsal surface. Mouth ventral, anus terminal. Tentacles 18, peltate, yellow.

Ossicles. Ossicles consist of tables, buttons and rods. Dorsal body wall tables with disc ca. 200 µm in diameter; very high spire, 120–140 µm in length; disc perforated by one large central hole and more than one circle of peripheral holes; spire with five to eight cross beams and surrounded by small spines; crown small and spinose. Ventral body wall tables similar in shape but smaller than dorsal body wall tables, with disc 50–150 µm in diameter; spire 80–100 µm in height. Buttons of the dorsal body wall large, 170–250 µm in length, smooth but not flat, rim undulating, with six to nine pairs of holes. Buttons of the ventral body wall similar to those in the dorsal body wall but smaller in size, 100–200 µm in length. Rods of the dorsal body wall perforated at the extremities and also at the central region, 150–330 µm in length. Ventral rods similar with the dorsal rods. Elongate plates in the ventral body wall 200–210 µm in length. Branched and spinous small rods (50–90 µm) and spinous large rods (150–200 µm) present in the tentacles.

Distribution. Madagascar, Red Sea and Singapore.

Remarks. The ossicles of the Singapore specimen agree well with those of the type specimen described by Cherbonnier (1988), i.e., tables with a large central perforation on disc and very high spire, large button with five or six pairs of holes and short, spinous tentacle rods. However, the specimen at hand differs from the type in having elongate plates present in the ventral instead of the dorsal body wall. The difference in ossicle distribution may be a case of intraspecific variation.

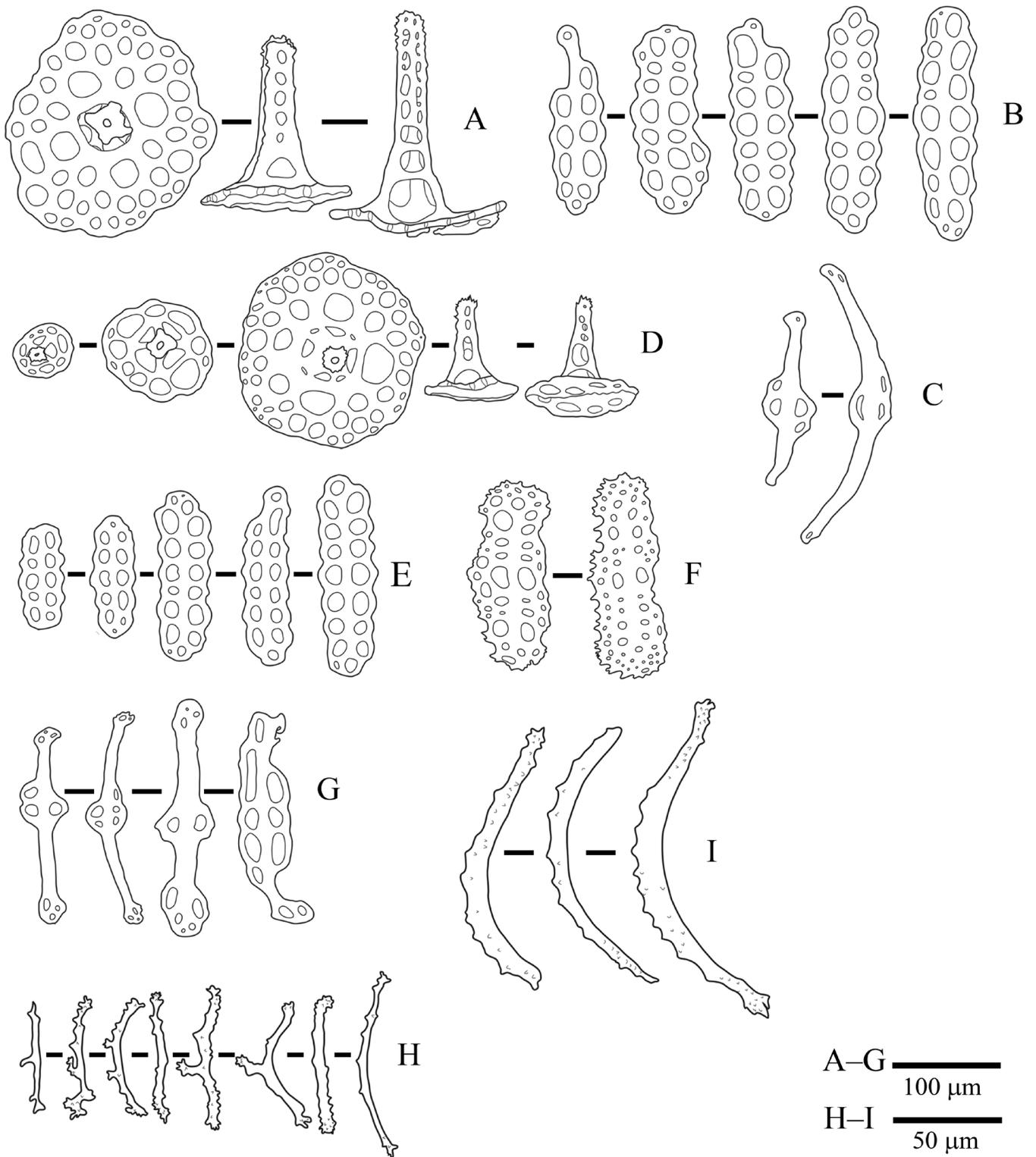


Fig. 12. *Holothuria (Platyperona) crosnieri* Cherbonnier, 1988. ZRC.ECH.0549. A, tables from dorsal body wall; B, buttons from dorsal body wall; C, rods from dorsal body wall; D, tables from ventral body wall; E, buttons from ventral body wall; F, elongate plates from ventral body wall; G, rods from ventral body wall; H, small rods from tentacles; I, large rods from tentacles.

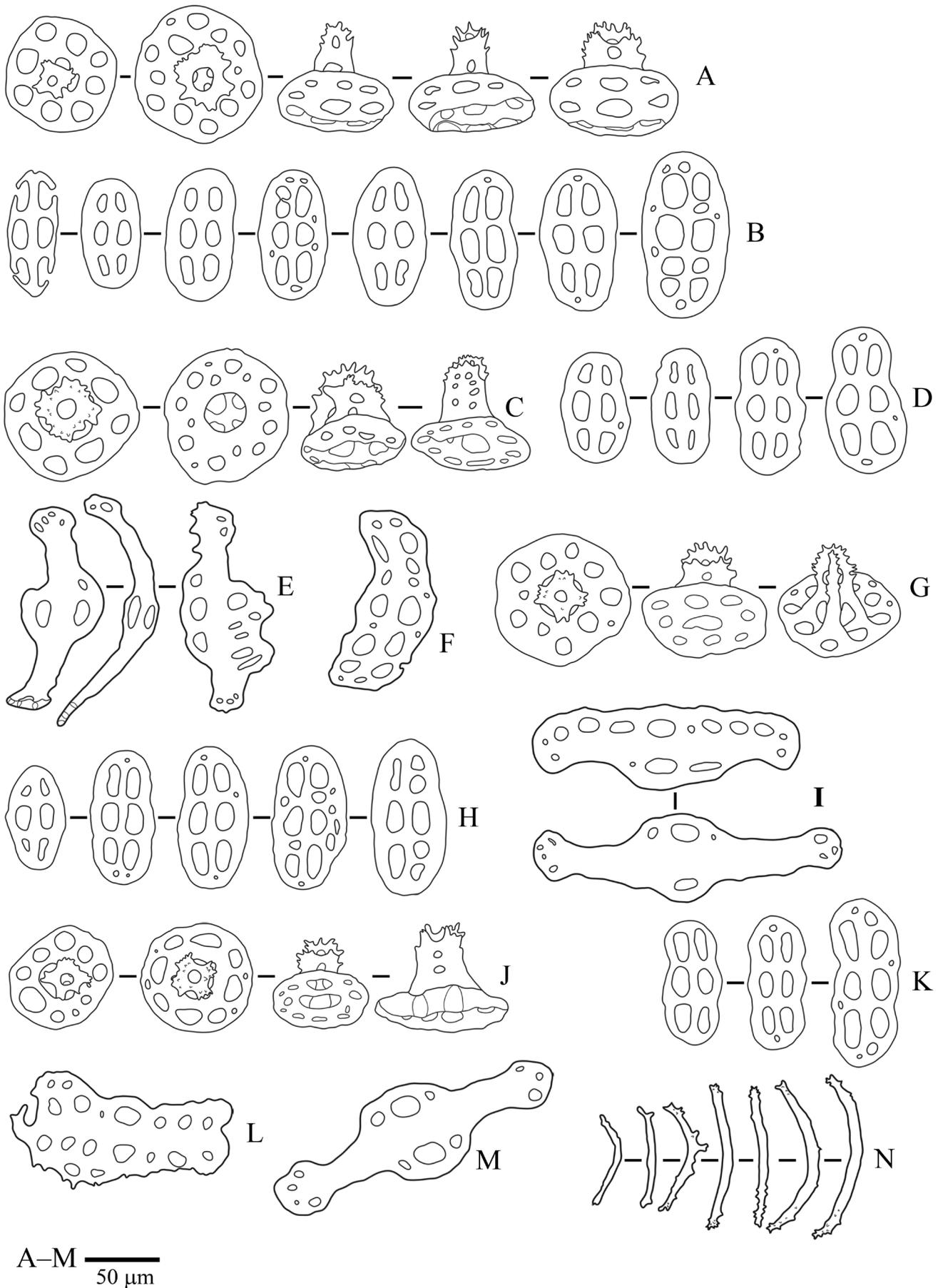


Fig. 13. *Holothuria (Thymiosycia) impatiens* (Forskål, 1775). ZRC.ECH.0550. A, tables from dorsal body wall; B, buttons from dorsal body wall; C, tables from dorsal papillae; D, buttons from dorsal papillae; E, rods from dorsal papillae; F, elongate perforated plate from dorsal papillae; G, tables from ventral body wall; H, buttons from ventral body wall; I, rods from ventral body wall; J, tables from tube wall; K, buttons from tube feet; L, elongate perforated plate from tube feet; M, rod from tube feet; N, rods from tentacles.

Subgenus *Thymiosycia* Pearson, 1914***Holothuria (Thymiosycia) impatiens* (Forskål, 1775)**

(Figs. 2H, 13)

- Fistularia impatiens* Forskål, 1775: 121, pl. 39 fig. B.
Holothuria ophidiana—Quoy & Gaimard, 1833: 134.—Cherbonnier, 1952: 31, pl. 3 fig. 5, textfigs. 11d–e.
Holothuria fulva—Quoy & Gaimard, 1833: 135.—Cherbonnier, 1952: 32, pl. 3 fig. 2, textfigs. 11a–c.
Holothuria impatiens—Selenka, 1867: 340.—Semper, 1868: 82, 277.—Semper, 1869: 120.—Ludwig, 1879.—Haacke, 1880: 46.—Ludwig, 1882: 136.—Ludwig, 1883: 169.—Lampert, 1885: 65.—Théel, 1886a: 179, 233, pl. 7 fig. 9.—Théel, 1886b: 7.—Bell, 1887a: 140.—Bell, 1887b: 654.—Ludwig, 1887: 31.—Sluiter, 1887: 193.—Ludwig, 1888: 806.—Lampert, 1889: 812.—Ludwig, 1889–1892: 329.—Herouard, 1893: 134.—Saville-Kent, 1893: 233, 237.—Koehler, 1895a: 282.—Lampert, 1896: 54.—Ludwig, 1899: 558.—Bedford, 1899: 145.—Sluiter, 1901: 9.—Fisher, 1907: 666, pl. 69 figs. 4a–d.—Koehler & Vaney, 1908: 8.—Pearson, 1910: 178.—Sluiter, 1910: 333.—Mitsukuri, 1912: 80, textfig. 17.—Pearson, 1913: 85, pl. 13 fig. 21.—Erwe, 1913: 369.—H. L. Clark, 1920: 149.—H. L. Clark, 1921: 178.—Koehler, 1921: 173, fig. 129.—H. L. Clark, 1923: 423.—Mortensen, 1926: 117.—Deichmann, 1926: 11.—Deichmann, 1930: 84–85, pl. 3 figs. 17–18.—H. L. Clark, 1932: 232.—Domantay, 1933: 66, pl. 2 fig. 4.—Heding, 1940a: 121.—Cherbonnier, 1955: 148, pl. 35, figs. a–d.—Edean, 1957: 253.
Holothuria bottelus—Selenka, 1867: 335, pl. 19, figs. 82–84.—Semper, 1868: 82, 248.—Selenka, 1868: 117.—Saville-Kent, 1893: 234, 238.
Holothuria aphanes—Lampert, 1885: 242.—Sluiter, 1901: 16.
Holothuria (Holothuria) impatiens—Panning, 1935a: 86, figs. 72a–u.
Holothuria (Thymiosycia) impatiens—Pearson, 1914: 171.—Rowe, 1969: 145, fig. 13.—A. M. Clark & Rowe, 1971: 178, pl. 78, fig. 8.—Liao, 1975: 214, fig. 14 (1–3).—Rowe & Doty, 1977: 233, figs 4c, 7e.—Levin, 1979: 22.—Cherbonnier, 1980: 642, fig. 14A–H.—Tan Tiu, 1981: 75, 76, pl. 18 figs 1–2.—Rowe, 1983: 159.—Reyes-Leonardo, 1984: 147, pl. 4 fig. 1a–d.—Liao, 1984: 222.—Reyes-Leonardo et al., 1985: 273.—Cannon & Silver, 1986: 25, figs 4g, 7f.—Cherbonnier, 1988: 89, fig. 35A–K.—Conand, 1989: 28.—James, 1989: 125.—Levin & Dao Tan Ho, 1989: 57; Marsh, 1994: 11.—Rowe & Gates, 1995: 303.—Massin, 1996a: 30–33, fig 21A–E.—Liao, 1997: 144, fig. 84a–c.—Massin, 1999: 57.—Lane et al., 2000: 489.—Samyn & Vanden Berghe, 2000: 5, 18, 28.—Samyn, 2003a: 178, 243–244, pl. 3G, fig. 33A–E, 54H.—Samyn et al., 2006: 100, fig. 75A–F.—Purwati & Wirawati, 2009: 21, fig. 17a, b.

Material examined. ZRC.ECH.0550 (1 ex.), CMBS spec. no. SS-3894, stn. IT140, Tekukor, N01°13.899', E103°50.265', intertidal, hand collection, coll. Lee Yen-Ling et al., 31 May 2013.

Description. Preserved specimen 40 × 20 mm; cylindrical body, slightly tapers towards both ends. Colour beige-yellow with numerous small dark brown dots scattered on the entire dorsal and ventral surfaces; ventral uniformly beige, series of dull brown-purplish large dots present on the dorsal lengthwise in two rows. Tube feet arranged irregularly in rows; on the dorsal region, the tube feet exist as papillae with yellow tips. Mouth ventral, anus terminal. Tentacles 20, yellow and peltate.

Ossicles. Ossicles comprise tables, buttons, rods and plates. Body wall tables with disc diameter 80–90 µm; disc rounded and smooth, perforated by a central hole and 8–16 peripheral holes; spire moderate, ended with squarish spinous crown. Tables in the dorsal papillae and ventral tube feet similar to those in the body wall. Tube feet tables relatively smaller in size, with disc diameter 60–70 µm. Buttons numerous in the body wall, dorsal papillae and tube feet; these buttons are smooth but not flat with three to four pairs of holes, 60–100 µm in length; sometimes irregular number of holes present, 100–120 µm in length. Rods in the body wall stout, 150–172 µm in length, perforated by holes at the extremities and centre. Rods in the dorsal papillae and tube feet similar in shape with those in the body wall, but slightly larger, ca. 175 µm in length. Elongate perforated plates present in the dorsal papillae and tube feet, ca. 180 µm in length. Tentacles with rods that are slim and spinous, 60–160 µm in length.

Distribution. Red Sea, Somalia, Kenya, Zanzibar, Mozambique, South Africa, Madagascar, Mauritius, Seychelles, Persian Gulf, Maldives Islands, Chagos Archipelago, Sri Lanka, India, Cocos Keeling Islands, Myanmar, Malaysia, Indonesia, Philippines, Vietnam, Taiwan, China, Japan, Mariana Islands, Caroline Islands, Palau Islands, Australia, New Caledonia, Loyalty Islands, Fiji, Samoa, Tonga Islands, Cook Island, Phoenix Islands, Line Islands, Hawaiian Islands, Marquesas Islands, Society Islands, Mexico, Gulf of California, Cocos Islands, Panama, Ecuador, Galapagos Islands and Singapore.

Remarks. The morphology of our specimen from Singapore generally agrees with Pearson's (1913) description. However, the table ossicles in this specimen differ slightly from those described in Pearson (1913) and Massin (1996a). Table discs are smoother and more rounded in the Singapore specimen unlike those shown in Pearson (1913) and Massin (1996a), which are angular and square-like. In addition, perforated plates are present in both dorsal papillae and tube feet in the Singapore specimen, instead of tube feet only as stated in Massin (1996a).

Family Stichopodidae Haeckel, 1896**Genus *Stichopus* Brandt, 1835*****Stichopus aff. monotuberculatus* (Quoy & Gaimard, 1833)**

(Figs. 3A, 14)

Holothuria monotuberculata Quoy & Gaimard, 1833: 131, pl. 432 fig. 1.

Stichopus unituberculatus—Selenka, 1867: 320.

Holothuria lutea—Quoy & Gaimard, 1833: 130.

Stichopus variegatus.—Semper, 1868: 73, pl. 16, pl. 30 figs. 1, 6, pl. 35 figs. 1, 11–13.—Koehler & Vaney, 1908: 23.—Pearson, 1903: 205.—Mitsukuri, 1912: 178, fig. 32.—Ludwig, 1882: 134.—Bell, 1884: 151.—Lampert, 1885: 105.—Théel, 1886a: 162, 191, pl. VII, fig. 7.—Bell, 1887a: 140.—Sluiter, 1887: 196.—Ludwig, 1888: 118.—Lampert, 1889: 814.—Koehler, 1895b: 384.—Lampert, 1896: 59.—Ludwig, 1899: 561.—Sluiter, 1901: 31.—H. L. Clark, 1920: 147.—H. L. Clark,

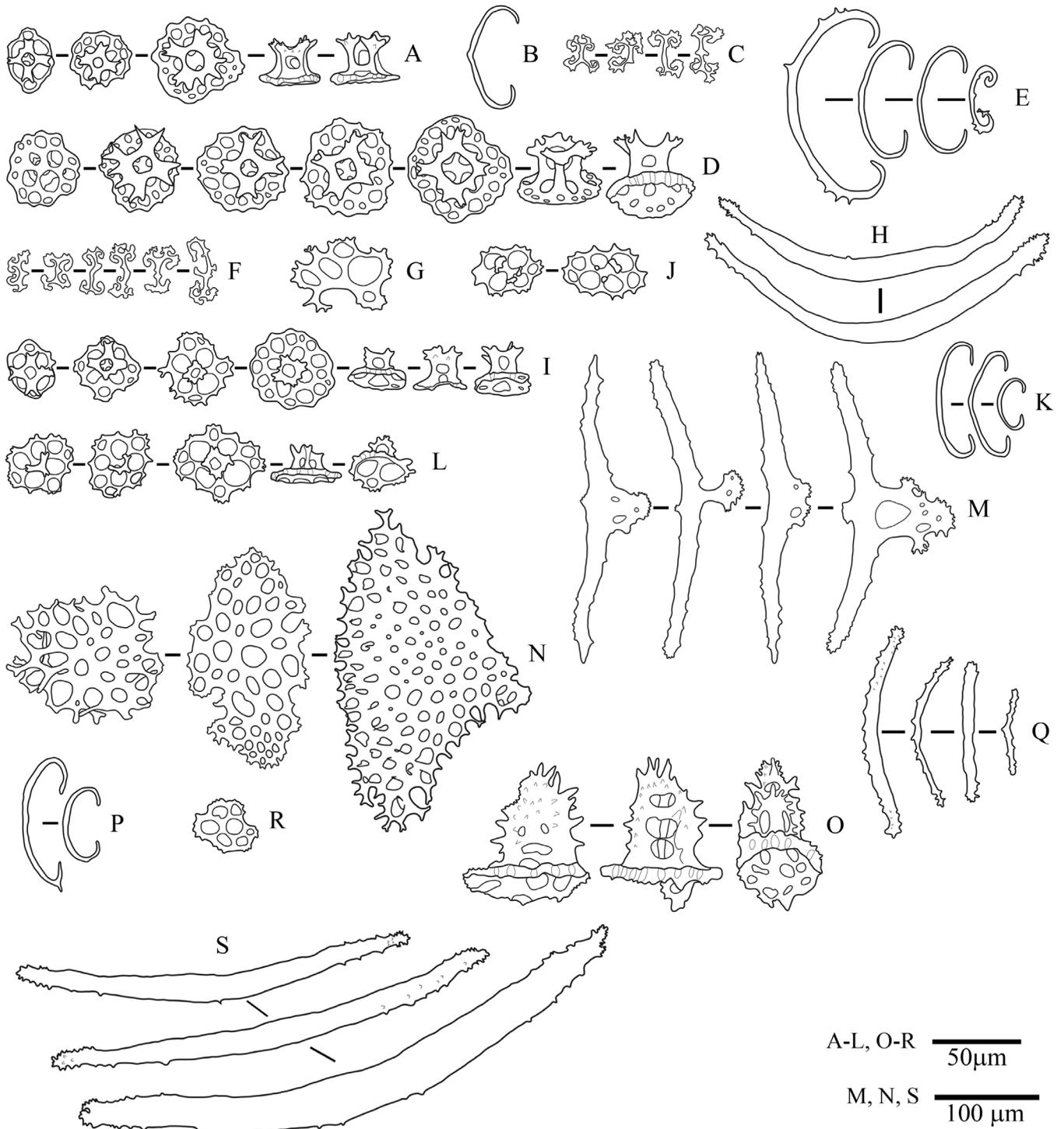


Fig. 14. *Stichopus* aff. *monotuberculatus* (Quoy & Gaimard, 1833). ZRC.ECH.0551. A, tables from dorsal body wall; B, C-shaped rod from dorsal body wall; C, rosettes from dorsal body wall; D, tables from dorsal papillae; E, C-shaped rods from dorsal papillae; F, rosettes from dorsal papillae; G, small plate from dorsal papillae; H, rods from dorsal papillae; I, tables from ventral body wall; J, reduced tables from ventral body wall; K, C-shaped rods from ventral body wall; L, tables from tube feet; M, rods from tube feet; N, plates from tube feet; O, massive tables from tentacles; P, C-shaped rods from tentacles; Q, small rods from tentacles; R, small plate from tentacles; S, large rods from tentacles.

1921: 187.—H. L. Clark, 1938: 513.—Heding, 1940a: 124.—Heding, 1940b: 330.—Panning, 1944: 31, fig. 4.—A. M. Clark & Rowe, 1971: 178, pl. 27, fig. 20.—Liao, 1975: 204.—Tan Tiu, 1981: 66 (partim), pl. 8 figs. 1–2.—Reyes-Leonardo, 1984: 152 (partim), pl. 9 fig. Za–g, pl. 10 fig. la–e.—Cherbonnier, 1988: 151, fig. 62A–S.

Stichopus luteus—Lampert, 1885: 109.—Théel, 1886a: 197.—Cherbonnier, 1952: 21.

Stichopus monotuberculatus—Cherbonnier, 1955: 161.—James, 1969: 61.—Cherbonnier, 1967: 57.—James & Pearse, 1969: 102.—A. M. Clark & Rowe, 1971: 178.—Rowe & Gates, 1995: 325.

?*Stichopus monotuberculatus*—Massin, 1996b: 163, pl. 1C, D, fig. 9, 10.

Stichopus cf. *monotuberculatus*—Samyn & Vanden Berghe, 2000: 5 (tab. 2), 18 (tab. 4), 31, pl. 2E.—Samyn, 2003a: 179, pl. 2F–H, 249, fig. 37A–K, 55D, Pl. 4C.—Samyn, 2003b: 92, fig. 37A–K, fig. 55D, pl. 4C.

Material examined. ZRC.ECH.0551 (1 ex.), CMBS spec. no. SS-0107, stn. SW13, St John's Island, DRTech, north lagoon, N01°13.116', E103°51.079', 0–1 m depth, sandy bottom with rocks, hand collection (snorkelling), coll. Nathaniel Evan, 21 May 2013.

Description. Preserved specimen 100 × 30 mm, trapezoidal body in transversal section. In life, body colour is dirty green with black patches between dorsal papillae. Dorsal and lateral papillae whitish at top half, orange-red at the apex, with black lines spiraling from the bottom to the top. Trivium flattened, with translucent white and long tube feet densely arranged in rows in the ambulacral areas. Mouth ventral, surrounded by small papillae with red tip. Anus terminal. Tentacles peltate.

Ossicles. Ossicles consist of tables, massive tables, rosettes, C-shaped rods, rods and plates. Body wall tables with disc diameter 25–50 µm; disc quadrangular, seldom elongate, with four central holes and 2–16 peripheral holes; rim of the disc spiny, sometimes undulated; crown forming a maltese cross and spinous; quadrangular crowns with small spines occasionally found in the ventral body wall. Tables in the dorsal papillae similar with those in the body wall; 5–25 peripheral holes on the disc; disc diameter 40–70 µm. Tables in the tube feet with disc 30–50 µm in diameter; edge of disc spiny; disc perforated by four central holes and two to six peripheral holes; crown quadrangular with small spines, sometimes with reduced crown and spire. Massive tables present in tentacles, stout and very spiny; spire and crown with small and large spines; discs spinous, 50–80 µm in diameter. Rosettes present in the dorsal body wall and dorsal papillae, slender and curling at the extremities and spiny on the rim. C-shaped rods in the body wall 25–70 µm in length; C-shaped rods in the dorsal papillae relatively larger (45–150 µm) and spiny. Rods present in the dorsal papillae, tube feet and tentacles. Rods in dorsal papillae slender with spines at the extremities, ca. 200 µm in length. Large tentacle rods similar shape with dorsal papillae rods, 230–500 µm in length; small tentacle rods spiny, 50–100 µm in length. Rods in tube feet large (ca. 300 µm), with spiny rim and an enlarged central process. Perforated plates present in tube feet with spiny rim and 150–300 µm in length.

Distribution. Gulf of Suez, Wadi el Dom, Gulf of Aqaba, Eilat, Aqaba, Red Sea, Entedebir, Arabian Sea, Kenya, Kiunga Marine Reserve, Tanzania, Fundu, Mauritius, Mascarene Islands and Singapore.

Remarks. The original description by Quoy & Gaimard (1833) lacks information on the ossicles of *Stichopus monotuberculatus*. Massin et al. (2002) noted the similarities and differences between *S. monotuberculatus* and *S. rubermaculosus*. The table discs of *S. rubermaculosus* are smooth, unlike those of *S. monotuberculatus* which possessed spines as observed in this study and by other authors (Cherbonnier, 1988; Théel, 1886a). However, the table ossicles of the Singapore specimen are different from those of typical *S. monotuberculatus* in terms of the shape of discs, and the size of the four central perforations on discs, i.e., discs are more angular, and the central perforation is larger in ratio in *S. monotuberculatus*. In addition, the massive tables in the tentacles of the Singapore specimen have never been recorded for *S. monotuberculatus*. We have hence tentatively identified this specimen as *Stichopus* aff. *monotuberculatus*.

Order Dendrochirotida Grube, 1840

Family Cucumariidae Ludwig, 1894

Genus *Actinocucumis* Ludwig, 1875

Actinocucumis sp.

(Figs. 3B, 15)

Material examined. ZRC.ECH.0552 (1 ex.), CMBS spec. no. SS-0108, stn. SW13, St John's Island (north lagoon), N01°13.116' E103°51.079', 0–1 m depth, sandy bottom with rocks, hand collection (snorkeling), coll. Nathaniel Evan, 21 May 2013; ZRC.ECH.0554 (1 ex.), CMBS spec. no. SS-0119, stn. TB29, Singapore Port Limit (near Eastern Boarding Ground A), (Start) N01°13.036', E103°52.820', (End) N01°12.968', E103°52.636', 103–98 m depth, gravels and rocky, beam trawl, coll. Bertrand Richer de Forges et al., 22 May 2013; ZRC.ECH.0555 (1 ex.), CMBS spec. no. SS-1775, stn. DR57, (Start) N01°16.297', E103°57.677', (End) N01°16.212', E103°57.458', 46.2 m depth, rectangular dredge, coll. Bertrand Richer de Forges et al., 24 May 2013; ZRC.ECH.0556 (1 ex.), CMBS spec. no. SS-3300, stn. TB97, near Eastern Bunkering A, (Start) N01°18.425', E104°04.607', (End) N01°18.502', E104°04.844', 22.7–22.4 m, clay, coll. Bertrand Richer de Forges et al., 28 May 2013; ZRC.ECH.0557 (1 ex.), CMBS spec. no. SS-4742, stn. TB185, off Pulau Senang (Start) N01°09.942', E103°43.458', (End) N01°09.949', E103°43.471', 24.5–24.3 m depth, mud, laterite rocks and gravels, coll. Bertrand Richer de Forges et al., 5 June 2013.

Description. Preserved specimens with sizes range from 22 × 7 mm to 45 × 14 mm. Body colour and pattern are similar in life and in alcohol, i.e., brown with dark brown freckles. Body form cylindrical, slightly tapers at mouth and

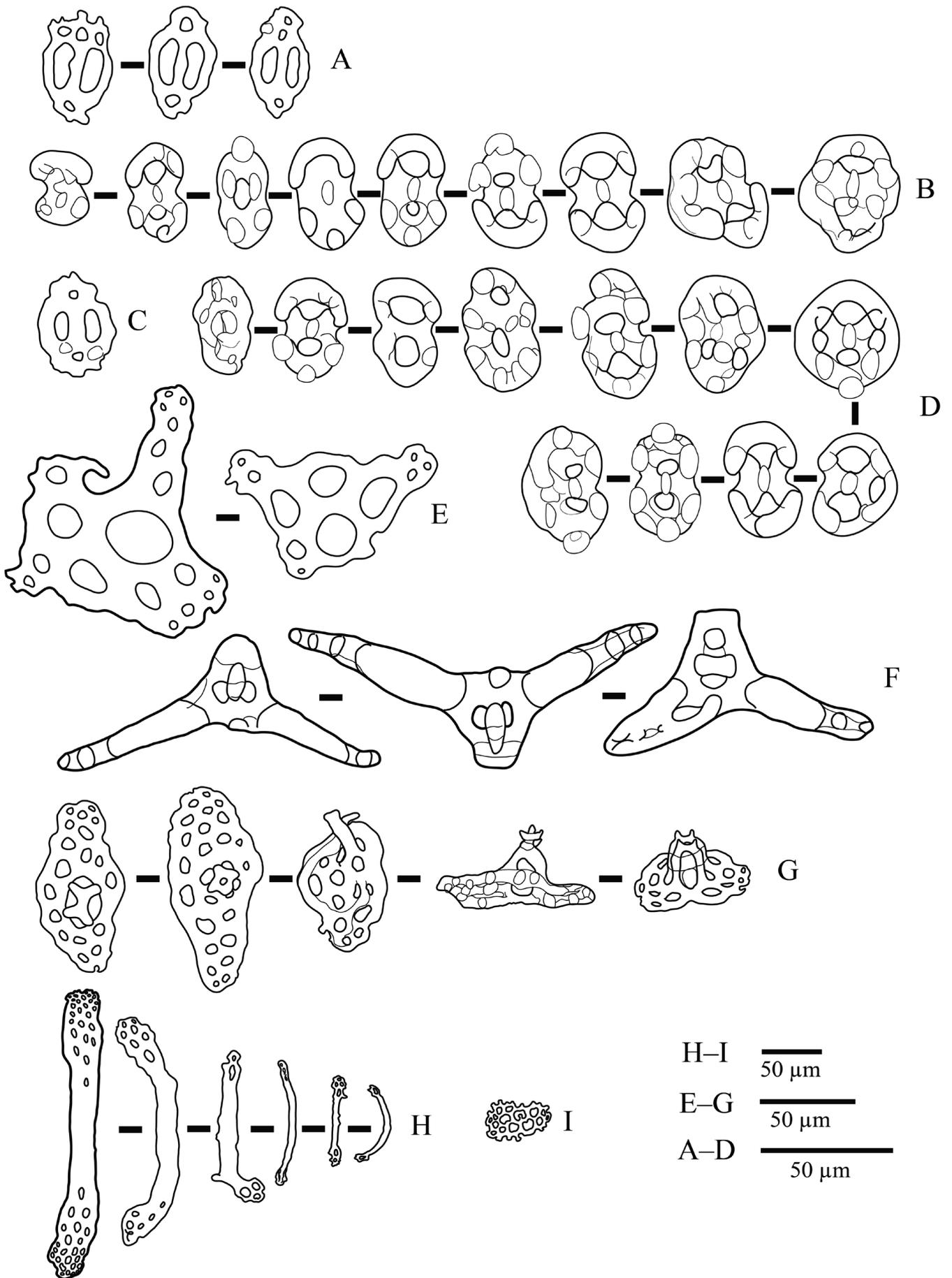


Fig. 15. *Actinocucumis* sp. ZRC.ECH.0554. A, plates from ventral body wall; B, fenestrated ellipsoids from ventral body wall; C, plate from dorsal body wall; D, fenestrated ellipsoids from dorsal body wall; E, plates from tube feet; F, modified tables from tube feet; G, tables from introvert; H, rods from tentacles; I, rosette from tentacles.

anal ends. Tube feet restricted to ambulacra, two rows per series. Tentacles 20, dendritic.

Ossicles. Body wall ossicles comprise large numbers of fenestrated ellipsoids (length 13–48 μm , width 20–40 μm) and few simple plates (length 40–43 μm , width 21–28 μm) with two large holes and one to three small distal holes at each end. Fenestrated ellipsoids from body wall highly knobbed, predominantly 8-shaped with two perforations or oval shaped with two to four perforations (two larger ones in the middle and one to two smaller ones at the sides). Tube feet with irregular perforated large plates (up to 125 μm across) and modified tables (width 135–178 μm , height 48–53 μm) with two rod-like discs and conical shaped spire. Introvert tables with elongate disc (disc sizes range from $29 \times 55 \mu\text{m}$ to $43 \times 103 \mu\text{m}$) and four-pillar short spire (33–39 μm in height) ended in four blunt teeth. Tentacles with plates ($20 \times 50 \mu\text{m}$) and rods (60–231 μm) with both ends perforated.

Remarks. Specimens collected in Singapore possess similar body wall ossicle types and shapes (8-shaped fenestrated ellipsoids) as *Actinocucumis typica* Ludwig, 1875. However, the shape of the calcareous ring, body wall colour and the more complex fenestrated ellipsoids with more perforations do not agree with the original description of *A. typica* Ludwig, 1875 and those provided by Heding & Panning (1954).

Genus *Colochirus* Troschel, 1846

Colochirus sp.

Material examined. ZRC.ECH.0578 (2 exx.), CMBS spec. no. SS-2380, stn. SW77, St John's Island, lagoon, N01°12.913', E103°51.080', 0–5 m depth, hand collection (snorkeling), coll. Nathaniel Evan, 25 May 2013; ZRC.ECH.0579 (1 ex.), CMBS spec. no. SS-2838b, stn. DR111, outside Eastern Boarding Ground A, (Start) N01°12.989', E103°53.062', (End) N01°12.862', E103°52.852', 125–146 m depth, rocky, rectangular dredge, coll. Bertrand Richer de Forges et al., 29 May 2013; ZRC.ECH.0580 (1 ex.), CMBS spec. no. SS-2839, stn. SB67, Pulau Hantu, western patch reef, N01°13.6', E103°44.8', 15.7 m depth, coral brushing (scuba diving), coll. Tan Heok Hui et al., 25 May 2013; ZRC.ECH.0603 (1 ex.), CMBS spec. no. SS-4693, stn. DR174, next to Eastern Boarding Ground A, near Kusu Island, (Start) N01°12.202', E103°52.178', (End) N01°12.141', E103°52.078', 135–79.6 m depth, reddish marine clay with gravels and dead shells, rectangular dredge, coll. Bertrand Richer de Forges et al., 4 June 2013.

Description. Sizes of preserved specimens range from $12 \times 3 \text{ mm}$ to $95 \times 25 \text{ mm}$. In life, body colour orange-pink mixed with green, with a thick body wall; body irregularly quadrangular in transverse section, slightly tapers orally to blunt end, distinctly tapers anally to upturned rounded end. Dorso-lateral and ventro-lateral radii each with a single row of prominent papillae. Tube feet in ventral trivium restricted to ambulacral areas. Ten dendritic tentacles; eight large, two ventral tentacles distinctly smaller.

Remarks. This is an undetermined and potential new species. Apart from these five specimens collected from the Singapore Strait, two specimens were also collected in the Johor Straits (Ong & Wong, 2015).

Genus *Mensamaria* H. L. Clark, 1946

Mensamaria intercedens (Lampert, 1885)

(Figs. 3C, 16)

Pseudocucumis intercedens Lampert, 1885: 254, fig. 54.
Pseudocucumis intercedens—Theél, 1886a: 267.—Ludwig, 1887: 25, pl. 1 fig. 2.—Koehler, 1895b: 379, pl. 9, figs. 10–11.—Chang, 1934: 20, fig. 9.—H. L. Clark, 1938: 482, pl. 16 fig. 6.
Cucumaria bicolor—Bell, 1887c: 532, pl. 45 fig. 2.
Pseudocucumis niger—Sluiter, 1914: 13, fig. 4.
Cucumaria striata—Joshua & Creed, 1915: 18.
Pseudocucumis eurystichus—H. L. Clark, 1921: 169, pl. 37 figs. 9–19.
Amphicyclus intercedens—Yang, 1937: 19, fig. 1, pl. 1 fig. 2.
Mensamaria intercedens—H. L. Clark, 1946: 406.—Heding & Panning, 1954: 92, fig. 31.—Chang et al., 1964: 28.—A. M. Clark & Rowe, 1971: 182, fig. 95a, pl. 29 fig. 20.—Liao & A. M. Clark, 1995: 483, fig. 291.—Liao, 1997: 173–175, fig. 101.—Rowe & Gates, 1995: 275.—Lane et al., 2000: 490.—Ong & Wong, 2015: 275, 279–280, figs. 2E, 4E.

Material examined. ZRC.ECH.0576 (1 ex.), CMBS spec. no. SS-4567, stn. TB58, around Tanah Merah, (Start) N01°16.808', E103°58.246', (End) N01°16.758', E103°57.981', 38.7–39.9 m depth, mud, beam trawl, coll. Bertrand Richer de Forges et al., 24 May 2013.

Description. Preserved specimen $9 \times 4 \text{ mm}$; spindle-shaped, body colour dark brown-black with distinct off-white ambulacral zones and tube feet. Tube feet restricted to ambulacra, two rows per series. Calcareous ring simple, lacking posterior processes. Tentacles approximately 18 in number; we could not determine the exact count due to small size of the specimen and also because the tentacles had contracted after preservation.

Ossicles. Ossicles of body wall tables, with disc diameter 45–133 μm ; margin of disc smooth; disc rounded, squarish or irregular, usually perforated by four large holes and three to four or more small holes; two-pillar high spire, with heights 65–88 μm , terminating in a tip with two to three teeth. In the tube feet, supporting plates with lengths and widths $113\text{--}143 \times 43\text{--}55 \mu\text{m}$. Tentacles with rods enlarged and perforated at both ends, up to 143 μm in length. Introvert with tables; disc with lengths and widths $45\text{--}103 \times 31\text{--}48 \mu\text{m}$; margin of disc undulating; disc elongate and irregular, perforated by 13–25 holes; two-pillar short spire, with heights 43–45 μm , terminating in a tip with four teeth.

Distribution. South China Sea, Indonesia, Australia and Singapore.

Remarks. Larger specimens of this species were collected from the Johor Straits, Singapore (see Ong & Wong, 2015).

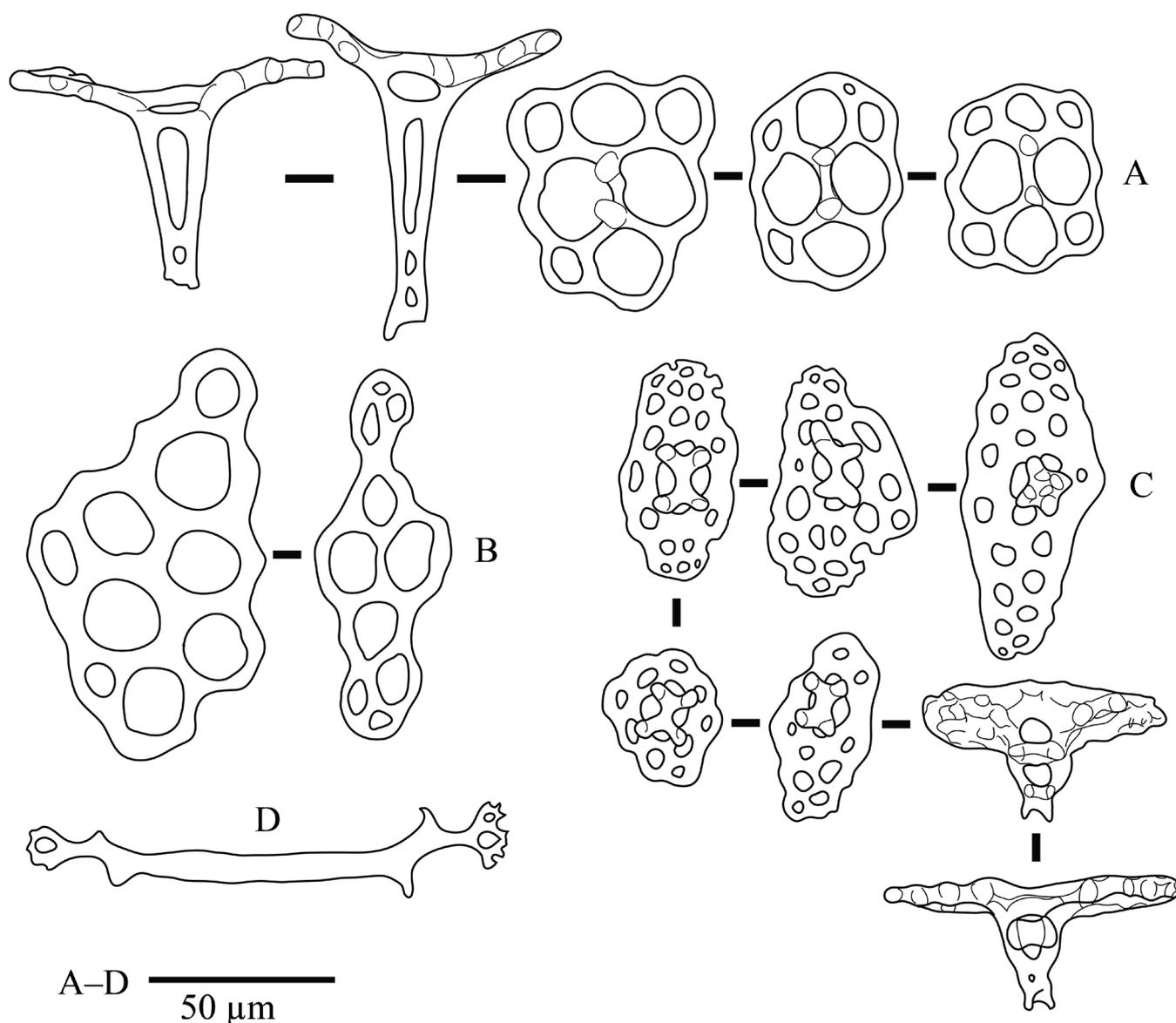


Fig. 16. *Mensamaria intercedens* (Lampert, 1885). ZRC.ECH.0576. A, tables from body wall; B, supporting plates from tube feet; C, tables from introvert; D, rod from tentacle.

Genus *Pseudocolochirus* Pearson, 1910

***Pseudocolochirus violaceus* (Théel, 1886)**

Colochirus violaceus Théel, 1886a: 78, pl. 5 fig. 4, pl. 13 figs. 1–2.
Colochirus violaceus—Koehler & Vaney, 1908: 24.
Cucumaria tricolor—Sluiter, 1901: 81, pl. 1 fig. 3, pl. 7 fig. 8.—
 Pearson, 1903: 188.—Heding, 1934: 15.—Mortensen, 1934: 6.
Colochirus axiologus—H. L. Clark, 1914: 171, pl. 25.
Pentacta arae—Boone, 1938: 186, pl. 69–70.—A. M. Clark &
 Rowe, 1971: 195.
Pseudocolochirus bicolor—Cherbonnier, 1970: 424, fig. 1.
Pseudocolochirus violaceus—A. M. Clark & Rowe, 1971: 180.—
 James, 1978: 59, figs. 1g–j, pl. 1B.—A. M. Clark, 1982:
 494.—Cherbonnier, 1988: 174, figs. 73, A–G, 74, A–J.—Liao
 & A. M. Clark, 1995: 479, fig. 289.—Rowe & Gates, 1995,
 Liao, 1997.—Thandar & Samyn, 2004: 3, 8.—Lane et al.,
 2000: 490. —Ong & Wong, 2015: 275.

Material examined. ZRC.ECH.0604 (1 ex.), CMBS spec. no. SS-2868, DR127, beside Eastern Boarding Ground A,

(Start) N01°12.974', E103°52.960', (End) N01°12.958', E103°52.832', 128–113 m depth, rocky, beam trawl, coll. Bertrand Richer de Forges et al., 30 May 2013.

Description. The specimen was not in good condition when retrieved from the trawl with a few small tears on the body wall. Preserved specimen ca. 30 mm in length; body oval, flattened laterally; mouth anterior and anus posterior, anus directed dorsally. In life, body reddish purple dorsally and bluish grey ventrally, tube feet yellowish white; in alcohol, body and tube feet uniformly white. Tube feet scarce dorsally, dense ventrally; minute tube feet scattered in the interambulacral region, larger ones arranged more or less in series along ambulacra. Anal teeth conspicuous; anus surrounded by a few large, conical shaped anal papillae. Tentacles contracted, not counted.

Distribution. Madagascar, Red Sea, South Africa, Bay of Bengal, East Indies, Australia, Philippines, China and southern Japan.

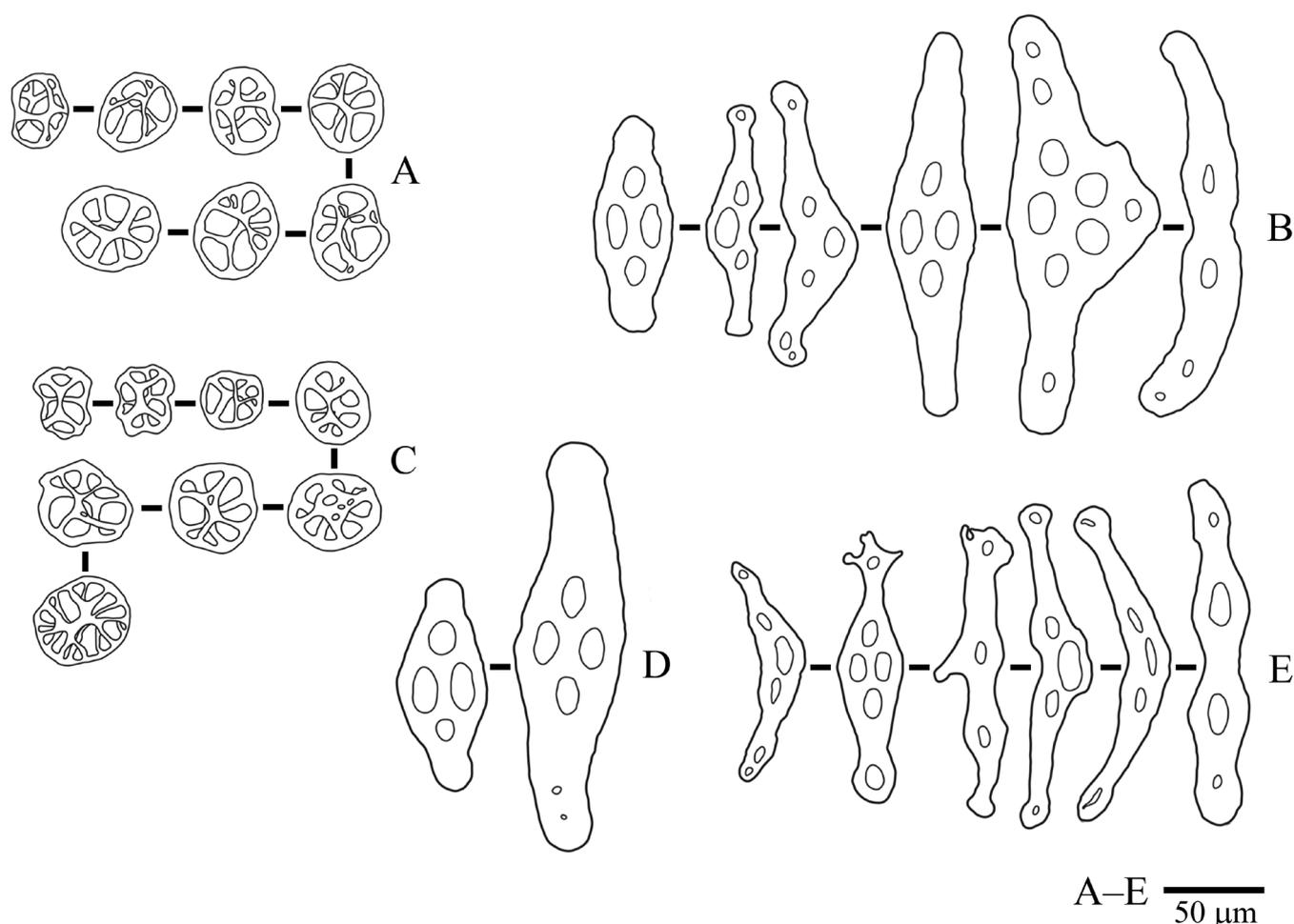


Fig. 17. *Hemithyone semperi* (Bell, 1884). ZRC.ECH.0564. A, ellipsoids from dorsal body wall; B, rods from dorsal body wall; C, ellipsoids from ventral body wall; D & E, rods from ventral body wall.

Remarks. The only specimen was unfortunately lost after preservation, which precluded further examination.

Family Phylloporidae Oesterger, 1907

Genus *Hemithyone* Pawson, 1967

***Hemithyone semperi* (Bell, 1884)**

(Figs. 3D, 17)

Cucumaria semperi Bell, 1884: 147, pl. 9 fig. A.
Cucumaria semperi—Pearson, 1910: 169.—Endean, 1957: 251.—
 Lampert, 1885: 138.—Théel, 1886a: 104.—H. L. Clark, 1938:
 445.—H. L. Clark, 1946: 388.
Cucumaria pigra—Koehler & Vaney, 1908: 38, pl. 3, fig. 13–16.
Hemithyone semperi—Pawson, 1967: 159, figs 1–10.—James,
 1969: 60.—A. M. Clark & Rowe, 1971: 180, fig. 92J, J', pl.
 29 fig. 15.—Rowe, 1983: 159.—James, 1984: 115, fig. 2b–c.—
 Cherbonnier, 1988: 208, figs. 90A–H.—Rowe & Gates, 1995:
 311.—Massin, 1999: 92, fig. 76a–h, 77.

Material examined. ZRC.ECH.0564 (1 ex.), CMBS spec. no. SS-0106, stn. TB16, outside Eastern Boarding Ground A, N01°13'537, E103°53'793, 98.0–89.5 m depth, laterite rock, rocky, gravel, beam trawl, coll. Lim Swee Cheng et al., 21 May 2013; ZRC.ECH.0565 (1 ex.), CMBS spec. no. SS-0109, stn. SW13, St John's Island, DRTech, north lagoon,

N01°13.116', E103°51.079', 0–1 m depth, sandy bottom with rocks, hand collection (snorkelling), coll. Nathaniel Evan, 21 May 2013; ZRC.ECH.0566 (1 ex.), CMBS spec. no. SS-2842, stn. DR70, near Sudong & Semakau, N01°13'134, E103°44'283, 20.6–22.6 m depth, sandy, rectangular dredge, coll. Lim Swee Cheng et al., 25 May 2013; ZRC.ECH.0567 (1 ex.), CMBS spec. no. SS-3912, stn. DR127, beside Eastern Boarding Ground A, N01°12'974, E103°52'960, 128–113 m depth, rocky, beam trawl, coll. Lim Swee Cheng et al., 30 May 2013.

Description. Preserved specimens 10 × 3 mm and 8 × 3 mm; colour in alcohol uniformly white-beige. Body elongate, tapering posteriorly and thin. Dorsal papillae and tube feet large, arrange along the ambulacra in two rows and a few present on the interambulacra. Mouth and anus terminal. Mouthparts were not dissected and the tentacles were not observed due to the very small sizes of the specimens.

Ossicles. Ossicles consist of ellipsoids and rods. Ellipsoids numerous, present in the dorsal and ventral; 30–50 μm in length, shape rounded and smooth with two bridges crossing in the central with bifurcated extremities on both sides, sometimes irregular in shape. Rods present in the dorsal and ventral wall; dorsal rods stout, 110–230 μm in length, with three to five holes centrally and one or two holes at

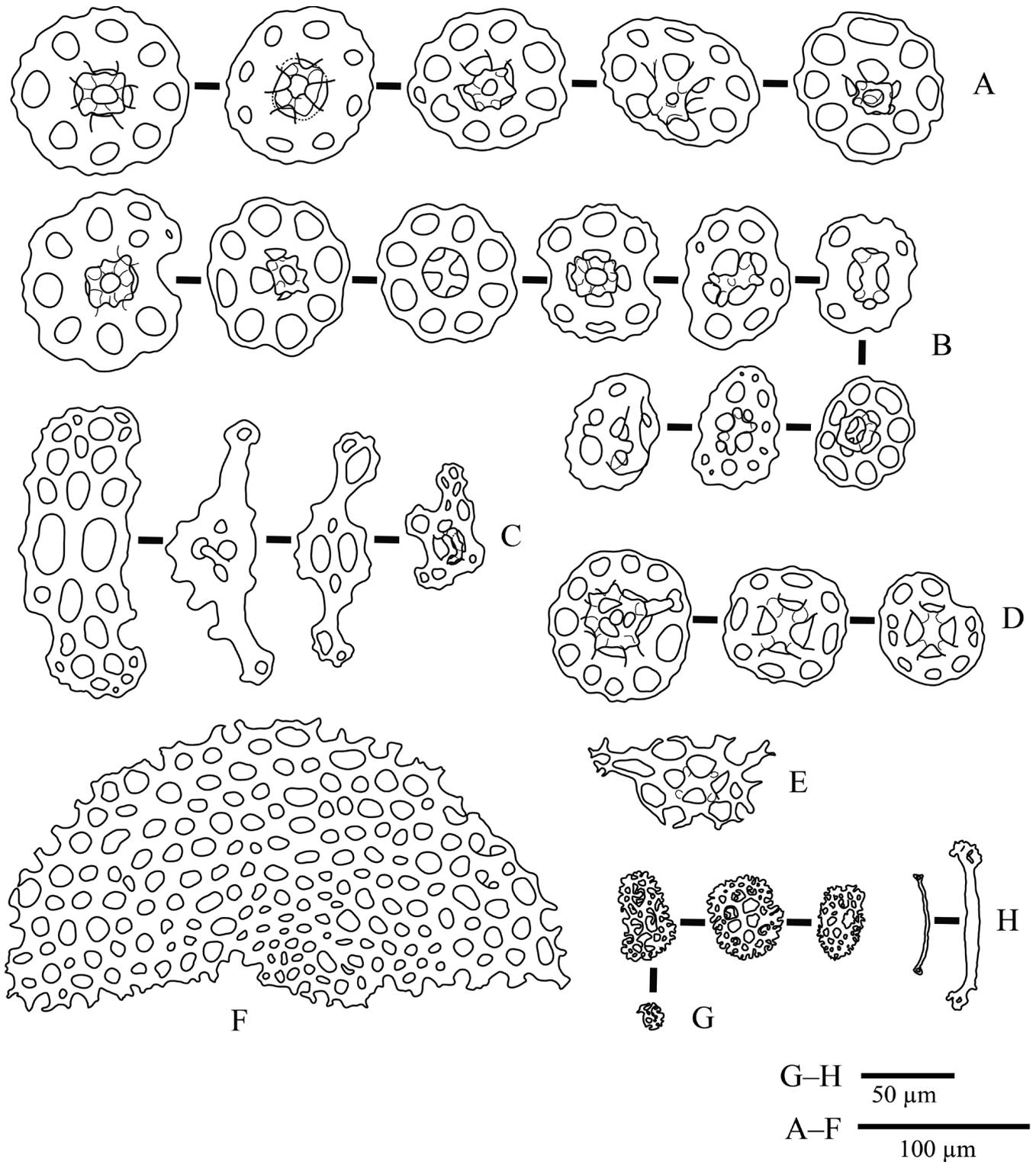


Fig. 18. *Phyllophorella kohkutiensis* (Heding & Panning, 1954). ZRC.ECH.0581. A, tables from dorsal body wall; B, tables from ventral body wall; C, supporting plates from tube feet; D, tables from anal papillae; E, irregular table from anal papillae; F, half of endplate from tube feet; G, rosettes from tentacles; H, rods from tentacles.

the extremities, although some are without holes; ventral rods slimmer, 110–210 µm in length, perforated by two to four holes centrally and one to two holes at the extremities.

Distribution. Mozambique, Madagascar, Pakistan, Sri Lanka, India, Myanmar, Indonesia, Vietnam, Australia and Singapore.

Remarks. The general morphology of these specimens is similar to the *H. semperi* specimens described in Massin (1999), but the anal triangular teeth referred to by Massin were not observed. The Singapore specimens possess ellipsoids and perforated rods that are similar to specimens observed by Pawson (1967) and Massin (1999), but the large end-plate ossicles are not illustrated in this study because we did not observe the tube feet. Ossicles described from the tentacles were rosettes and perforated rods (Pawson, 1967; Cherbonnier, 1988; Massin, 1999). In this study, we did not sample tentacle ossicles for observation.

Genus *Phyllophorella* Heding & Panning, 1954

Phyllophorella kohkutiensis (Heding & Panning, 1954)

(Figs. 3E, 18)

(?) *Thyonidium cebuense*—Théel, 1886a: 95, pl. 9 fig. 4 (Non *T. cebuense* Semper, 1868)

Phyllophorus (Phyllophorella) cebuense—Cherbonnier, 1960–1961: 431–433, figs. 4b–i, 5a–b (Non *T. cebuense* Semper, 1868)

Phyllophorus (Phyllophorella) kohkutiensis Heding & Panning, 1954: 156–157, fig. 69.

Phyllophorus (Phyllophorella) kohkutiensis—Thandar, 1994: 344.—Liao & A. M. Clark, 1995: 508, fig. 309.—Liao, 1997: 214–215, fig. 128.—Lane et al, 2000: 491.—Liao & Pawson, 2001: 63, figs. 4, 20B.—Liao et al., 2007: 32.

Phyllophorella kohkutiensis—O’Loughlin et al, 2012: 278.

Material examined. ZRC.ECH.0581 (1 ex.), CMBS spec. no. SS-1772, stn. TB58, around Tanah Merah, (Start) N01°16.808’, E103°58.246’, (End) N01°16.758’, E103°57.981’, 38.7–39.9 m depth, mud, beam trawl, coll. Bertrand Richer de Forges et al., 24 May 2013.

Description. Preserved specimen 17 × 10 mm; dark black-brown with some beige-white patches on dorsal side, crescent shaped with anus and mouth bent towards dorsal side in alcohol. Live specimen rounded at posterior and anterior ends, unevenly brown and light brown, lighter brown/beige at dorsal wall, some dark brown flecking at ventral wall. Tube feet distributed all over body, denser at ventral wall. Anus encircled by tiny papillae. Calcareous ring with paired posterior processes; posterior radial process with same height as the ring (broken into three pieces). Tentacles 20, dendritic.

Ossicles. Ossicles of body wall tables with disc diameter 50–105 µm; margin of discs undulating; disc perforated by a central large hole and usually eight peripheral holes; irregular discs of tables from ventral body wall have three to ten peripheral holes of variable sizes; four-pillar short spires with a cross beam, ending in a perforated crown surrounded by few blunt, rounded teeth. Anal papillae with two types

of tables, first type with discs similar to those from body wall (with disc diameter 70–90 µm; perforated by one large central hole and 8–11 peripheral holes; margin undulating; four-pillar shorted spire united by a crown of apical teeth); second type with irregular discs (58 × 110 µm). In the tube feet, endplates (330 × 365 µm) and supporting plates/rods, up to 175 µm in length were observed. In the tentacles, rods, up to 90 µm, and rosettes, 13–48 µm across, were found.

Distribution. Vietnam, Thailand, Gulf of Tonkin, South China Sea.

Remarks. This is the first record of this species in Singapore. The characteristic ossicles of this specimen agree with the original description and drawings by Heding & Panning (1954), as well as those shown in Cherbonnier (1961) and Liao & Pawson (2001), although some minor differences are apparent in the calcareous ring of the Singapore specimen compared to descriptions in previous publications. The posterior projections of the radial pieces in the specimen examined consist of only three pieces and the interradial pieces are composed of anterior and posterior pieces, which are different from the four to five pieces of radial projections and one whole piece of interradial as described by previous authors. The colour of *P. kohkutiensis* was described as “gray with a violet touch” by Heding & Panning (1954), whereas the Singapore specimen was brown in life and dark brown in alcohol.

Phyllophorella spiculata (Chang, 1935)

(Figs. 3F, 19)

Phyllophorus spiculatus. Chang, 1935: 8, figs. 6–8.

Phyllophorus spiculatus—Yang, 1937: 14, fig. 8, pl. 3 fig. 1.—Chang et al., 1964: 30.

Phyllophorus (Phyllophorella) parvipedes—Heding & Panning, 1954: 160, fig. 73.—A. M. Clark & Rowe, 1971: 184.

Phyllophorus parvipedes—H. L. Clark, 1938: 489, fig. 47.—H. L. Clark, 1946: 409

Phyllophorus (Phyllophorella) spiculata—Heding & Panning, 1954: 157, fig. 70.—Thandar, 1994: 344.—Liao & A. M. Clark, 1995: 510, fig. 311.—Rowe & Gates, 1995: 312–313.—Liao, 1997: 216–218, fig. 130.—Lane et al., 2000: 491.—Marsh & Morrison, 2004: 329.

Phyllophorella spiculata—O’Loughlin et al., 2012: 278.

Material examined. ZRC.ECH.0582 (1 ex.), CMBS spec. no. SS-3910, stn. DR57, (Start) N01°16.297’, E103°57.677’, (End) N01°16.212’, E103°57.458’, 46.2 m depth, rectangular dredge, coll. Bertrand Richer de Forges et al., 24 May 2013.

Description. Preserved specimen 19.5 × 12 mm, flattened, spindle-shaped, anal end slightly more tapered than mouth end; body wall thin. Body colour in alcohol deep brown with black patches densest at both ends. Tube feet distributed all over body wall. Calcareous ring with paired posterior processes; posterior radial processes same height as ring, broken into three pieces. Tentacles 20, dendritic.

Ossicles. Ossicles of body wall tables, with disc diameter 65–100 µm; margin of discs spinous, surface of discs knobbed; disc perforated by four central holes and usually

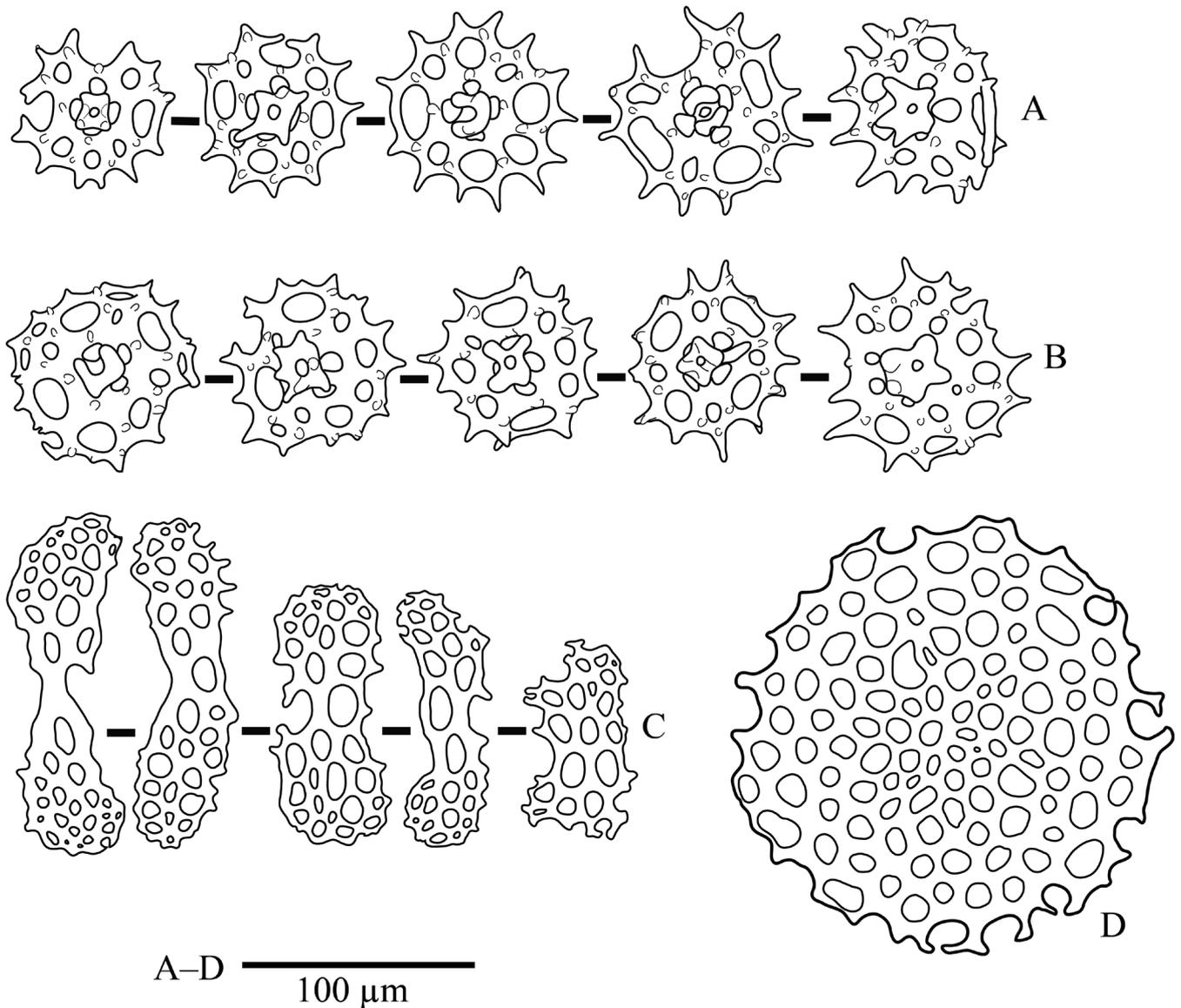


Fig. 19. *Phyllophorella spiculata* (Chang, 1935). ZRC.ECH.0582 . A, tables from dorsal body wall; B, tables from ventral body wall; C, supporting plates from tube feet; D, endplate from tube feet.

eight peripheral holes, with a range of 6–13 peripheral holes of variable sizes; four-pillar short spire terminating in a perforated crown with four to six teeth. In the tube feet, endplates with diameter 185–198 μm and supporting rods with lengths 88–153 μm and widths 40–53 μm are present. Rods in tentacles, up to 63 μm in length, and rosettes, 13–35 μm across. Introvert with rosettes 13–35 μm across.

Distribution. South China Sea, Western Australia and Singapore.

Remarks. The surfaces of table discs in the Singapore specimen are knobbed. The types and shapes of ossicles of this specimen agree with the original description by Chang (1935). There is no indication in the original description nor in subsequent publications whether the surfaces of the discs of tables in the body wall are knobbed.

Genus *Stolus* Selenka, 1867

***Stolus buccalis* (Stimpson, 1856)**

(Figs. 3G, 20)

- Thyone buccalis* Stimpson, 1856: 386
Thyone buccalis—Théel, 1886a: 136.—H. L. Clark, 1921: 167.—
 H.L. Clark, 1938: 461.
Thyone buccalis pallida—H.L. Clark, 1938: 462.
Stolus sacellus—Selenka, 1867: 355, pl. 20, fig. 115–116.—
 Heding, 1940a: 126.—Cherbonnier, 1955: 167, pl. 44, fig.
 u–z.—Panning, 1949: 462, fig. 57.
Thyone sacellus—Lampert, 1885: 154.—Bell, 1886: 27.—Sluiter,
 1901: 93.—Mitsukuri, 1912: 227, pl. 7, fig. 63, textfig. 43.—
 Erwe, 1913: 360, pl. 5, fig. 7.
Thyone sacella—Marenzeller, 1882: 134.
Thyone rigida—Semper, 1868: 66, pl. 13, fig. 23, pl. 15, fig. 7.
Stereoderma murrayi—Bell, 1883: 61, pl. 15, fig. 6, 6a–b.
Stolus buccalis—James, 1966: 285, fig. 1.—James, 1969: 60.—A.
 M. Clark & Rowe, 1971: 182, fig. 85g, pl. 29, fig. 14.—James,
 1984: 116, fig. 2d.—Cherbonnier, 1988: 202, fig. 88A–G. —

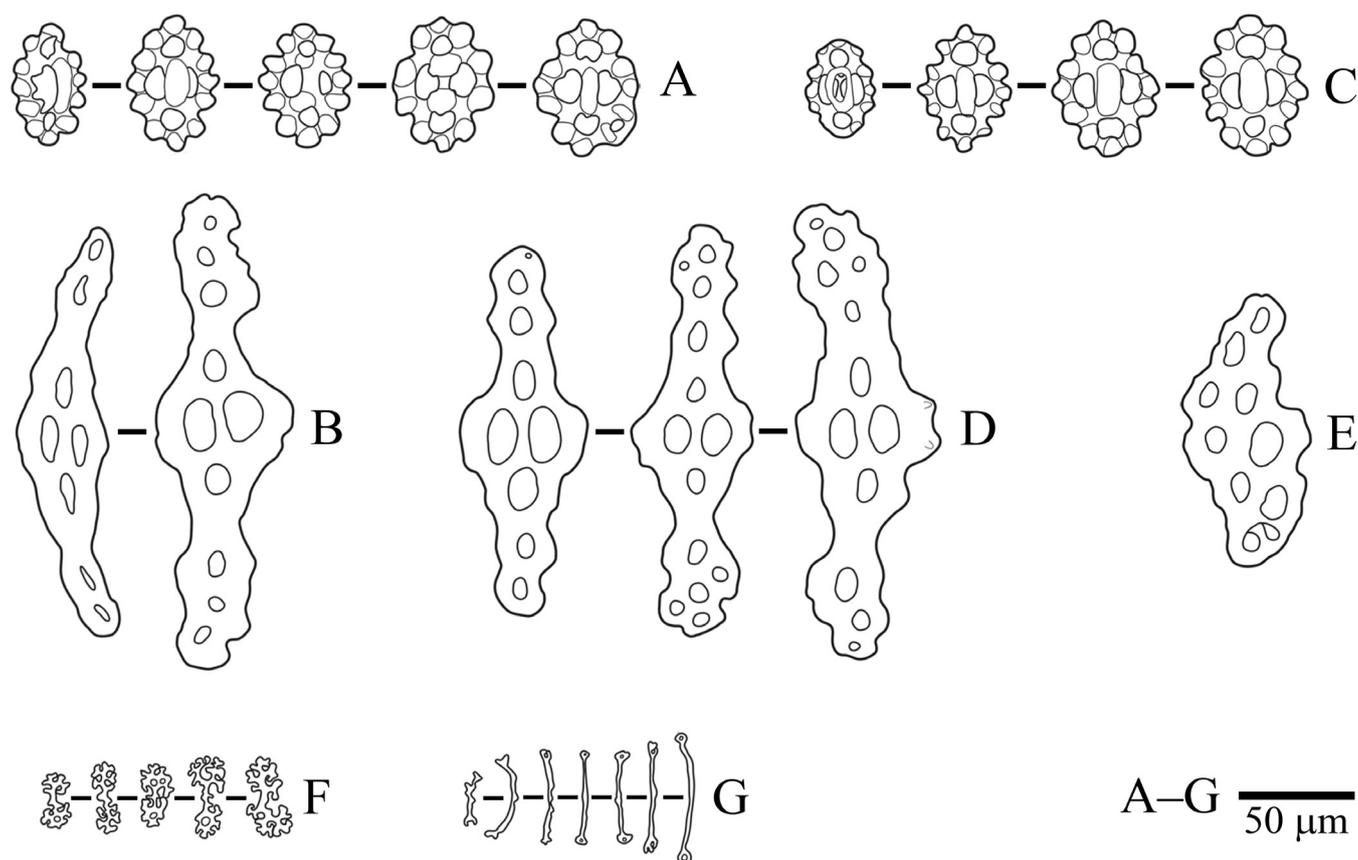


Fig. 20. *Stolus buccalis* (Stimpson, 1856). ZRC.ECH.0585. A, knobbed buttons from dorsal body wall; B, perforated rods from dorsal body wall; C, knobbed buttons from ventral body wall; D, perforated rods from ventral body wall; E, plate from ventral body wall; F, rosettes from tentacles; G, small rods from tentacles.

Thandar, 1990: 209–210, figs. 1a, 2, 10a.—Liao, 1997: 192–195, fig. 113.—Lane et al., 2000: 491.—Ong & Wong, 2015: 275.

Material examined. ZRC.ECH.0583 (1 ex.), CMBS spec. no. SS-1780, stn. SD34, Lazarus Island, North, 14 m depth, hand collection (scuba diving), coll. Tan Heok Hui, 22 May 2013; ZRC.ECH.0584 (1 ex.), CMBS spec. no. SS-2381, stn. SW77, St John’s Island, DRTech, south lagoon, N0 1°12.913’, E103°51.080’, 0–5 m depth, hand collection (snorkelling), coll. Nathaniel Evan, 25 May 2013; ZRC.ECH.0585 (1 ex.), CMBS spec. no. SS-2840, stn. SW77, St John’s Island, DRTech, south lagoon, N0 1°12.913’, E103°51.080’, 0–5 m depth, hand collection (snorkelling), coll. Nathaniel Evan, 25 May 2013; ZRC.ECH.0586 (1 ex.), CMBS spec. no. SS-3895, stn. IT140, Tekukor, N0 1°13.899’, E103°50.265’, intertidal, hand collection, coll. Lee Yen-Ling et al., 31 May 2013; ZRC.ECH.0587 (1 ex.), CMBS spec. no. SS-3896, stn. IT140, Tekukor, N0 1°13.899’, E103°50.265’, intertidal, hand collection, coll. Lee Yen-Ling et al., 31 May 2013.

Description. Preserved specimens cylindrical, 43 × 7 mm, 50 × 10 mm, 30 × 10 mm, 38 × 12 mm in size. In life, body colour uniformly dark purple, ventrally with light purple patches; in alcohol light purple. Body wall thick, smooth and hard when contracted. Dorsal papillae and tube feet purple, densely scattered on the surface. Mouth and anus terminal. Calcareous ring with paired posterior processes; posterior radial processes of calcareous ring complex, composed of a

mosaic of minute pieces. Tentacles 10, dendritic, purplish-black.

Ossicles. Ossicles consist of buttons, rods, plates and rosettes. Buttons 50–55 μm in length, present in the dorsal and ventral body wall, with four holes and knobs around the button margin and large knobs centrally. Perforated rods 180–230 μm in length, enlarged at the centre and extremities; these are present in the dorsal and ventral body walls. Small perforated plates ca. 160 μm in length present in the ventral body wall. Rosettes in tentacles 20–30 μm in length. Small rods in tentacles, 40–50 μm in length, with single perforation at the extremities, sometimes spiny and lacking in perforations; 20–30 μm in length.

Distribution. Red Sea, Africa, Saudi Arabia, Mozambique, Madagascar, Iran Bay, Bengal Bay, Indonesia, north of Australia, Philippines, Japan and Singapore.

Remarks. The colour of living specimens varies from yellowish-brown, reddish-brown, chocolate-brown to deep purplish-brown (H. L. Clark, 1938; Cherbonnier, 1988). In this study, specimens are uniformly dark purple, almost black with lighter colour on dorsal papillae and tube feet. Ossicles agree with the descriptions provided by Cherbonnier (1988); small perforated plates present in the ventral body wall are similar to those described by Mitsukuri (1912).

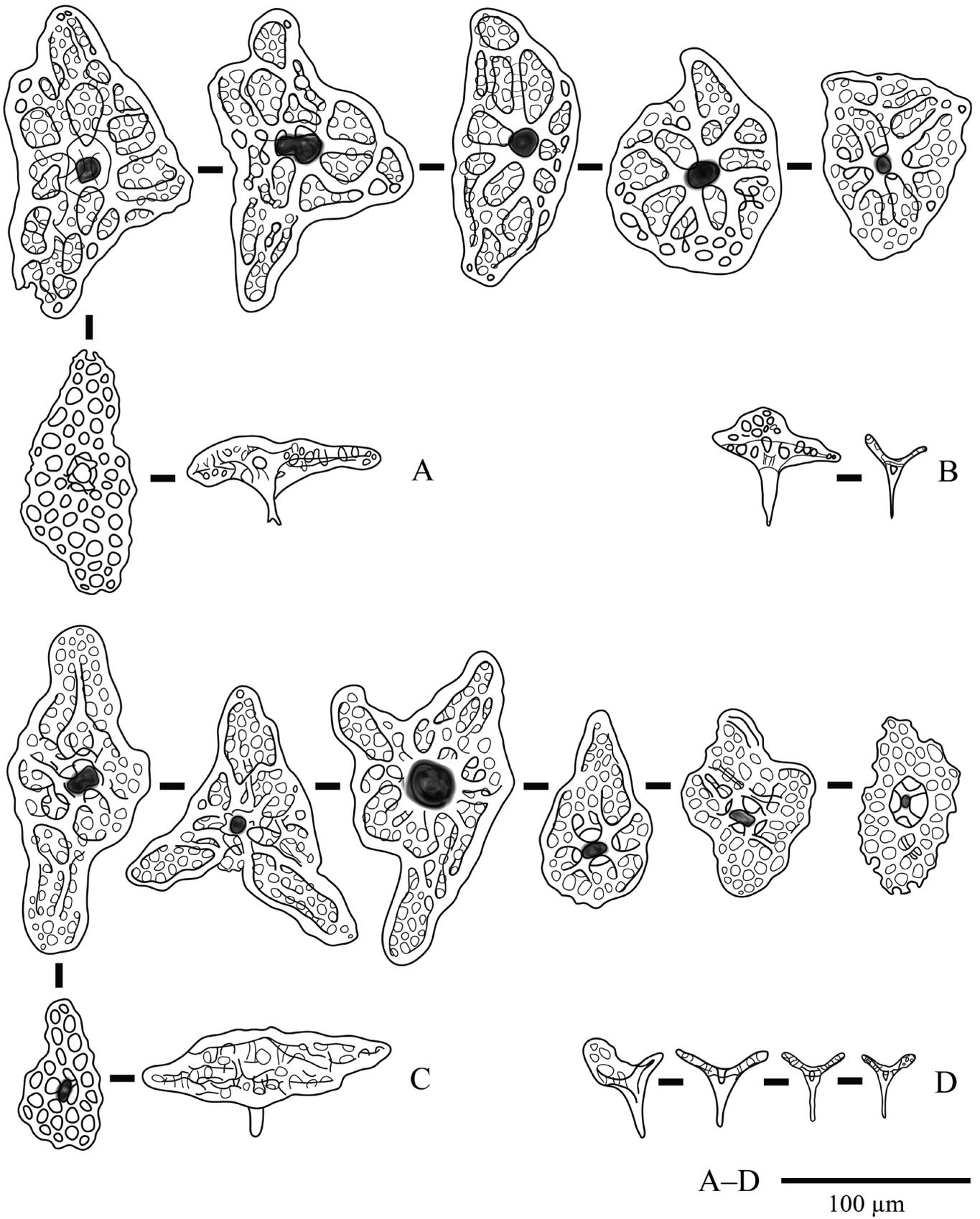


Fig. 21. *Thorsonia* sp., ZRC.ECH.0605. A, B, dorsal body wall ossicles; C, D, ventral body wall ossicles; A, C, plates with a solid central spine from body wall; B, D, tables with single needle-like spire from tube feet.

Genus *Thorsonia* Heding, 1940

***Thorsonia* sp.**
(Figs. 3H, 21)

Material examined. ZRC.ECH.0605 (1 ex.), CMBS spec. no. SS-0365, stn. TB15, Eastern Fairway, (Start) N01°16.300', E103°55.226', (End) N01°16.548', E103°55.381', 23.8–21.5 m depth, silty with gravels, beam trawl, coll. Bertrand Richer de Forges et al., 21 May 2013.

Description. Preserved specimen 23 × 6 mm. Spindle-shaped body with posterior and anterior ends tapered significantly, bent into U-shaped. Body colour similar in life and under preservation in alcohol, white body wall with yellowish-beige long, slender tube feet. Tube feet distributed in irregular rows along ambulacra, dense at ventral side. Five anal papillae. Radials of calcareous ring with bifurcate long posterior extensions made of tiny pieces. Tentacles 10, dendritic.

Ossicles. Body wall ossicles are tables with perforated triangular, oblong, or water-droplet shaped disc and single solid central spire, up to 168 µm in diameter. Tube feet ossicles are tiny tables with elongate perforated curved disc (up to 45 µm across) and single needle like spire (upt to 38 µm in height). These tiny tables encircle the tube feet, such that their solid, needle-like spines protrude from the epidermis.

Remarks. Currently there are three accepted species belonging to the genus *Thorsonia*, namely *T. adversaria* (Semper, 1867), *T. fusiformis* Heding, 1940 (refer to Heding, 1940a) and *T. investigatoris* (Koehler & Vaney, 1908). The specimen from Singapore has the distinctive plate ossicles of the genus *Thorsonia* but does not agree with the characteristics of the three species above.

Family Sclerodactylidae Panning, 1949

Genus *Afrocucumis* Deichmann, 1944

***Afrocucumis africana* (Semper, 1868)**
(Figs. 4A, 22)

Cucumaria africana Semper, 1868: 53, 270, pl. 15 fig. 16.
Pseudocucumis africana—Ludwig, 1888: 815.—Koehler, 1895a: 276.—Lampert, 1896: 61.—Bedford, 1899: 144.—Sluiter, 1901: 107.—Mitsukuri, 1912: 257, textfig. 52, pl. 8, fig. 66.—Erwe, 1913: 363, pl. 5, fig. 9.—H. L. Clark, 1920: 131.—H. L. Clark, 1923: 417.—H. L. Clark, 1932: 226.—H.L. Clark, 1938: 481.
Phyllophorus transvectus—Sluiter, 1914: 19, fig. 7 a, b.
Orcula cucumiformis—Semper, 1868: 244, 274, pl. 40, fig. 8, 9.—Bell, 1884: 150.—Lampert, 1896: 61.
Cucumaria assimilis—Bell, 1886, p.27.—Ludwig, 1899: 561.
Discumaria africana—H. L. Clark, 1946: 404.—Endean, 1957: 252.
Afrocucumis africana—Deichmann, 1948: 358.—Heding & Panning, 1954: 109, fig. 39.—James, 1969: 60.—A. M. Clark & Rowe, 1971: 182, pl. 30, fig. 2.—Liao, 1975: 202, Fig. 3, 1–3.—Rowe & Doty, 1977: 226, fig. 2a.—Rowe, 1983: 160.—James, 1984: 118, fig. 1e–g.—Cannon & Silver, 1986:

32, fig. 2K, 8D.—Cherbonnier, 1988: 218, fig. 95A–E.—James, 1989: 131.—Jangoux et al., 1989: 163.—Levin & Dao Tan Ho, 1989: 57.—Thandar, 1989: 298, fig. 5, 9d.—Kerr, 1994: 171.—Marsh, 1994: 11.—Rowe & Gates, 1995: 321.—Massin, 1996a: 39, fig. 27A–E.—Liao, 1997: 179, fig. 104a–b.—Massin, 1999: 96, fig. 79, 113c.—Samyn & Vanden Berghe: 2000, 5, 18, 32.—Samyn, 2003a: 180, 194, fig. 1A–C, 51A.—Purwati & Wirawati, 2012: 244, fig. 10, 11A–E.

Material examined. ZRC.ECH.0558 (1 ex.), CMBS spec. no. SS-0114, stn. SW32, St John's Island, rocky shore, 0–0.5 m depth, rocky shore, coll. Ria Tan & Daphne Gail Fautin, 22 May 2013; ZRC.ECH.0559 (1 ex.), CMBS spec. no. SS-0115, stn. SW32, St John's Island, rocky shore, 0–0.5 m depth, rocky shore, coll. Ria Tan & Daphne Gail Fautin, 22 May 2013; ZRC.ECH.0560 (1 ex.), CMBS spec. no. SS-0120, stn. SW44, St John's Island, rocky shore, hand collection, coll. Ria Tan et al., 23 May 2013; ZRC.ECH.0561 (1 ex.), CMBS spec. no. SS-1761, stn. SW48, St John's Island, DRTech, near north lagoon, N01°13'13.9", E103°51'4.8", intertidal, under boulders, hand collection, coll. Shane Timothy Lum Ahyong, 23 May 2013; ZRC.ECH.0562 (2 exx.), CMBS spec. no. SS-1783, stn. SW44, St John's Island, rocky shore, N01°13.399', E103°50.681', coll. Ria Tan et al., 23 May 2013; ZRC.ECH.0563 (1 ex.), CMBS spec. no. SS-3899, stn. IT140, Tekukor, N01°13.899', E103°50.265', intertidal, hand collection, coll. Lee Yen-Ling et al., 31 May 2013; ZRC.ECH.0606 (1 ex.), CMBS spec. no. SS-1762, stn. SW48, St John's Island, DRTech, near north lagoon, N01°13'13.9", E103°51'4.8", intertidal, under boulders, hand collection, coll. Shane Timothy Lum Ahyong, 23 May 2013; ZRC.ECH.0607 (1 ex.), CMBS spec. no. SS-1763, stn. SW48, St John's Island, DRTech, near north lagoon, N01°13'13.9", E103°51'4.8", intertidal, under boulders, hand collection, coll. Shane Timothy Lum Ahyong, 23 May 2013.

Description. Preserved specimens 17 × 4 mm, 28 × 7 mm, 17 × 3 mm, 40 × 12 mm, 28 × 7 mm, 20 × 7 mm, 12 × 5 mm; living animals have a uniformly black fusiform body, sometimes with brown patches. Body wall thin and rugose. Dorsal papillae large, cylindrical, brown and arranged in two rows on each ambulacral area. Tube feet similar in shape, size and arrangement with dorsal papillae. Mouth and anus terminal. Calcareous ring with paired posterior processes; posterior radial processes same height as ring, broken into three pieces. Tentacles 15, dendritic, black.

Ossicles. Ossicles consist of lenticular plates, perforated plates and rods. Lenticular and perforated plates present in dorsal and ventral body wall; the plates are covered with pyramidal spines; rim spinous, diameter 300 µm. Rods slender with one to three holes at the extremities, 150–200 µm in length, present in dorsal and ventral body wall; branched rod rarely present in ventral body wall. Small perforated plates present in dorsal and ventral body wall; 100 µm in length; rim spinous. Tentacle rods similar with those from the body wall, some branched at the extremities, 120–200 µm in length.

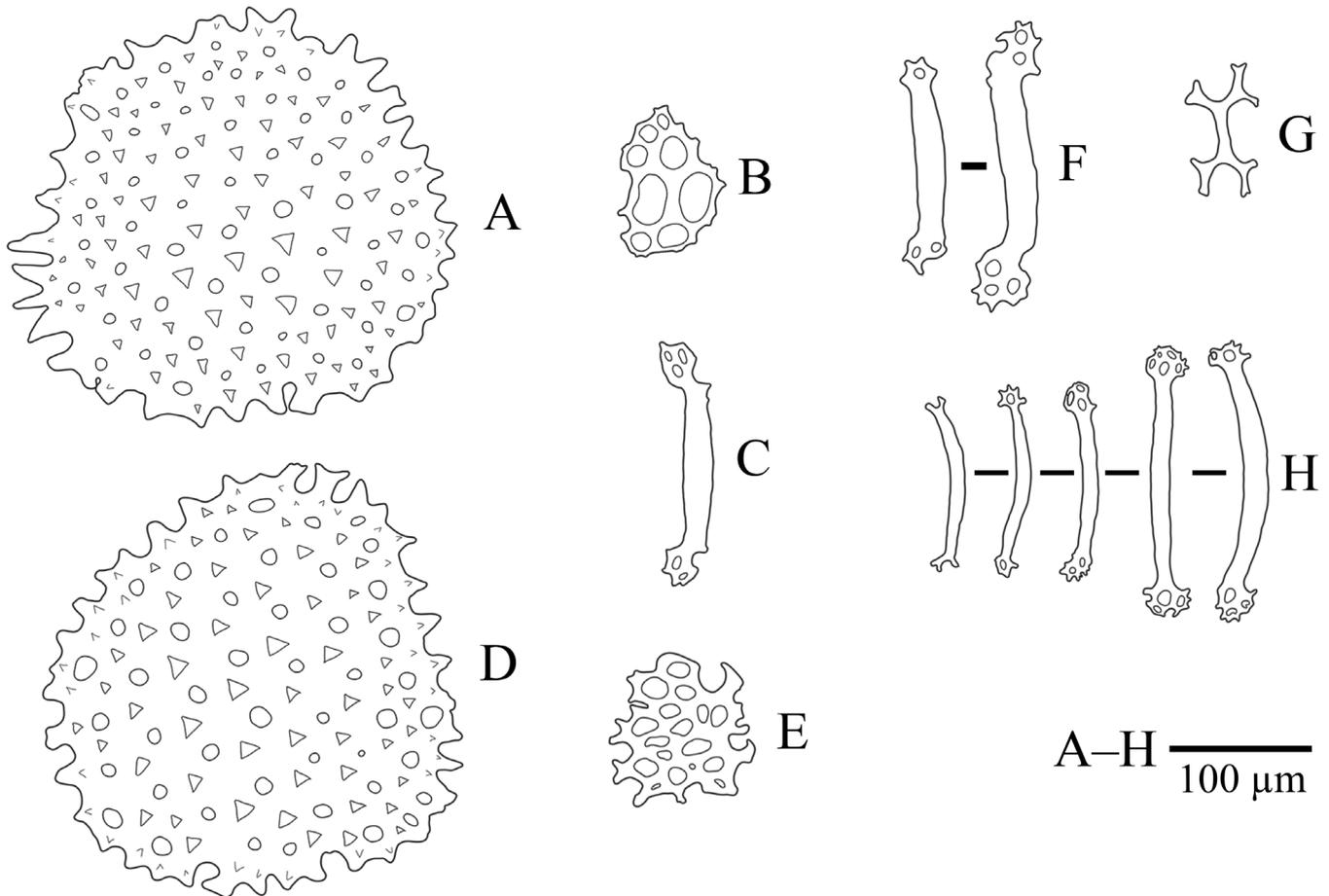


Fig. 22. *Afrocucumis africana* (Semper, 1868). ZRC.ECH.0562. A, lenticular plate from dorsal body wall; B, plate from dorsal body wall; C, rod from dorsal body wall; D, lenticular plate from ventral body wall; E, plate from ventral body wall; F, rods from ventral body wall; G, branched rod from ventral body wall; H, rods from tentacles.

Distribution. Somalia, Kenya, Zanzibar, Mozambique, South Africa, Madagascar, Seychelles, Mauritius, India, Myanmar, Cocos Keeling Islands, Indonesia, Australia, Vietnam, Taiwan, China, Korea, Japan, Mariana Islands, Caroline Islands, New Caledonia, Marshall Islands, Ellice Islands, Fiji and Singapore.

Remarks. These specimens are uniformly black, similar to those from other parts of their distributional range. Specimens from Kenya described by Samyn (2003a) varied from dark green to brown. Based on Massin (1996), this species has 15 outer tentacles and four inner tentacles whereas only 15 tentacles are visible in our specimens from Singapore.

Genus *Cladolabes* Brandt, 1835

***Cladolabes hamatus* (Sluiter, 1914)**
(Figs. 4B, 23)

Phylloporus hamatus Sluiter, 1914: 17–19, figs. 6a–d.
? *Urodemas hamatum*—H. L. Clark, 1938: 502.—H. L. Clark, 1946: 411.
Urodemas hamatum—Deichmann, 1944:734, figs. 3a–b.
Cladolabes hamatus—Heding & Panning, 1954: 129–130, fig. 55.—A. M. Clark & Rowe, 1971: 182–183.—Rowe & Gates, 1995: 322.—Mucharin, 2008: 20–23, figs. 3–4.—Ong & Wong, 2015: 275, 280–281, figs. 3B, 5A.

Material examined. ZRC.ECH.0608 (1 ex.), CMBS spec. no. SS-1782, stn. DR31, Marina Barrage, outside Marina Bay, (Start) N01°16.415', E103°52.838', (End) N01°16.175', E103°52.713', 19.6–19.4 m depth, muddy with gravels, rectangular dredge, coll. Bertrand Richer de Forges et al., 22 May 2013.

Description. Preserved specimen 16 × 8 mm. Preserved body stout and spindle shaped with a thick body wall; body wall dirty white in colour, contracted tube feet appeared as faint yellow dots in living animals. Tube feet distributed all over body wall, appearing to be denser ventrally. Calcareous ring soft, simple, of distinct pieces, with posterior bifurcate prolongations on the radial plates. Tentacles 19(?), difficult to count due to their small size and highly contracted state after preservation.

Ossicles. Body wall ossicles consist of rod-like tables with reduced discs (83–145 μm in height, 25–45 μm in disc diameter) and oval perforated plates (18–53 μm in diameter). Tube feet with hook-like tables (75–100 μm in height, 133–180 μm in width), irregular plates (75–128 μm in length, 53–58 μm in width). Tentacles with rosette rods (45–63 μm in length, 3–18 μm in width) and rosette plates (18–38 μm in diameter).

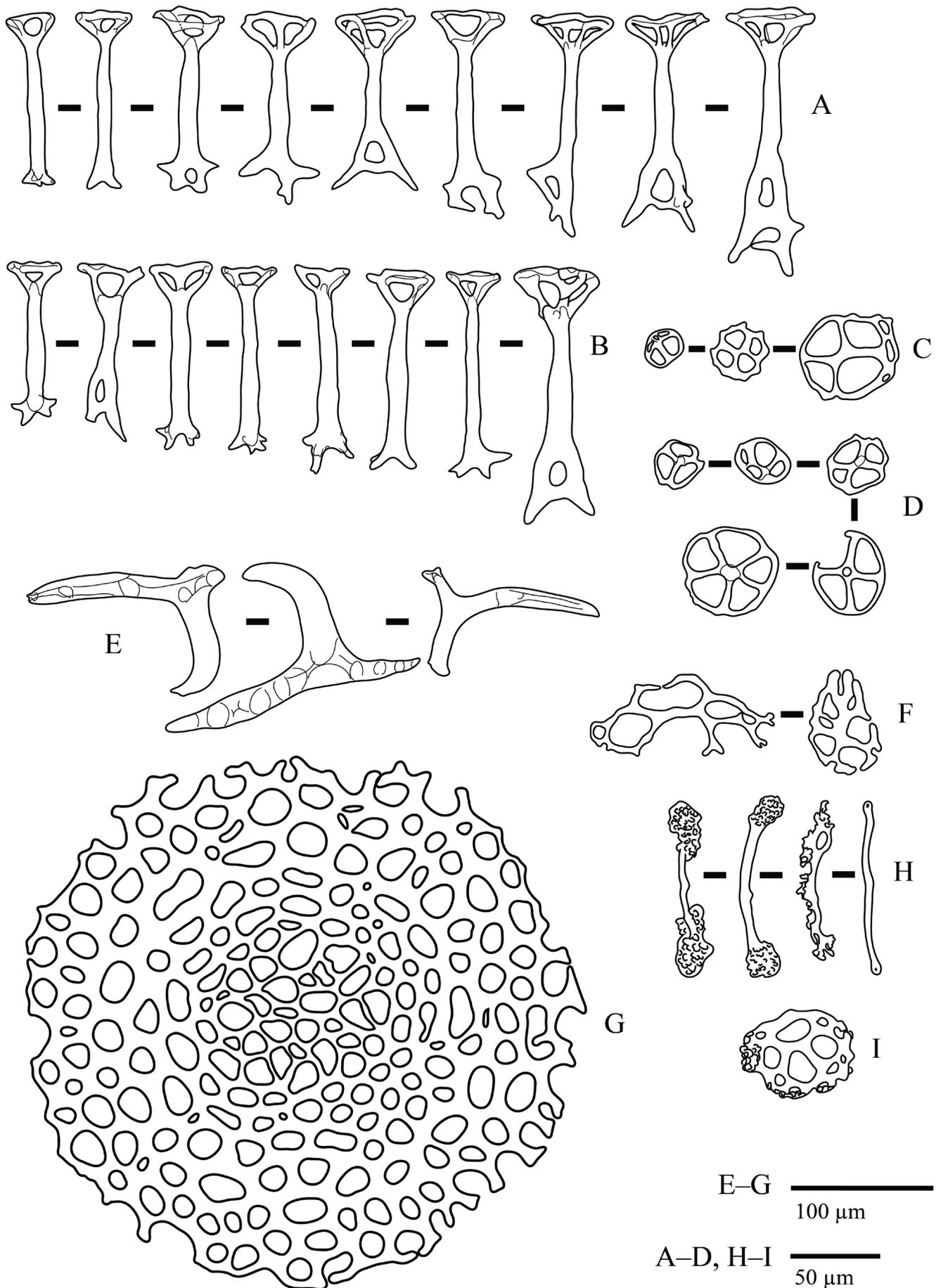


Fig. 23. *Cladolabes hamatus* (Sluiter, 1914). ZRC.ECH.0608. A, tables from ventral body wall; B, tables from dorsal body wall; C, plates from dorsal body wall; D, plates from ventral body wall; E, hook-shaped modified tables from tube feet; F, irregular plates from tube feet; G, endplate from tube feet; H, rosette rods and rod from tentacles; I, rosette plate from tentacle.

Distribution. Indonesia, north Australia, Gulf of Thailand and Singapore.

Remarks. The characteristic ossicles of this species are the rod-like tables with reduced discs present in the body wall and the hook-like tables found in the tube feet. These were well depicted in Heding & Panning (1954) and Mucharin (2008), apart from the original description by Sluiter (1914). Mucharin (2008) reported one specimen from the Gulf of Thailand and commented that the *Cladolabes* species “are however nearly invariably reported in relatively low numbers. This is probably due to their grazing behavior, making them hard to spot when sampling”. A total of five specimens were collected in Singapore waters. Apart from this small specimen reported herein, one larger specimen (preserved size 75 × 45 mm) was collected from the Johor Straits, Singapore (Ong & Wong, 2015) and three other specimens collected from the Singapore Strait during the Comprehensive Marine Biodiversity Survey (CMBS).

Genus *Havelockia* Pearson, 1903

Havelockia sp.

(Fig. 4C)

Material examined. ZRC.ECH.0568 (1 ex.), CMBS spec. no. SS-0112, stn. TB17, Eastern Holding, (Start) N01°13.816', E103°54.060', (End) N01°13.733', E103°53.917', 86.7–90.9 m depth, rocky, beam trawl, coll. Bertrand Richer de Forges et al., 21 May 2013; ZRC.ECH.0569 (3 ex.), CMBS spec. no. SS-0700 to SS-0702, stn. TB16, outside Eastern Boarding Ground A, (Start) N01°13.537', E103°53.793', (End) N01°13.437', E103°53.556', 98.0–89.5 m depth, laterite rocks and gravels, beam trawl, coll. Bertrand Richer de Forges et al., 21 May 2013; ZRC.ECH.0572 (1 ex.), CMBS spec. no. SS-1773, stn. TB58, around Tanah Merah, (Start) N01°16.808', E103°58.246', (End) N01°16.758', E103°57.981', 38.7–39.9 m depth, mud, beam trawl, coll. Bertrand Richer de Forges et al., 24 May 2013; ZRC.ECH.0573 (2 ex.), CMBS spec. no. SS-1781, stn. TB29, Singapore Port Limit, near Eastern Boarding Ground A, (Start) N01°13.036', E103°52.820', (End) N01°12.968', E103°52.636', 103–98.0 m depth, gravels and rocks, beam trawl, coll. Bertrand Richer de Forges et al., 22 May 2013; ZRC.ECH.0609 (1 ex.), CMBS spec. no. SS-1784, stn. SD34, north of Lazarus Island, 14 m depth, hand collection (scuba diving), coll. Tan Heok Hui et al., 22 May 2013; ZRC.ECH.0610 (1 ex.), CMBS spec. no. SS-2838a, stn. DR111, outside Eastern Boarding Ground A, (Start) N01°12.989', E103°53.062', (End) N01°12.862', E103°52.852', 125–146 m depth, rocky, rectangular dredge, coll. Bertrand Richer de Forges et al., 29 May 2013; ZRC.ECH.0574 (1 ex.), CMBS spec. no. SS-2869, stn. DR127, beside Eastern Boarding Ground A, (Start) N01°12.974', E103°52.960', (End) N01°12.958', E103°52.832', 128–113 m depth, rocky, rectangular dredge, coll. Bertrand Richer de Forges et al., 30 May 2013; ZRC.ECH.0575 (1 ex.), CMBS spec. no. SS-4565, stn. SD25, southwest of St John's Island, 7.6 m depth, hand collection (scuba diving), coll. Tan Heok Hui et al., 22 May 2013; ZRC.ECH.0611 (1 ex.), CMBS spec. no. SS-4740, stn. SD166, southwest of Kusu Island,

19.1 m depth, hand collection (scuba diving), Tan Heok Hui et al., 3 June 2013; ZRC.ECH.0612 (1 ex.), CMBS spec. no. SS-5027, stn. DR184, beside Raffles Lighthouse, (Start) N01°09.280', E103°44.049', (End) N01°09.278', E103°43.980', 31.6–35.4 m depth, rocky and sandy with shell fragments and gravel, rectangular dredge, coll. Bertrand Richer de Forges et al., 5 June 2013.

Description. Twelve specimens were collected and preserved. Preserved specimens with lengths 11–56 mm and mid-body widths 3–23 mm, with an average size of 34 × 12 mm; body cylindrical to spindle shaped, tapering at posterior and anterior ends. Colour in life reddish orange with black interambulacral zones, fading to beige or beige-brown in alcohol whilst retaining the black pigmentation in the interambulacral zones. Long slender tube feet densely covered the ventral side, modified into conical-shaped papillae and arranged as two series per row at the dorsal ambulacral zones. Tentacles 10 (eight plus two smaller ventral tentacles).

Ossicles. Scarce in some of the specimens collected. Body wall ossicles include tables, tables with quadrilobular discs and reduced pillars, tables with elongate perforated discs, and short two-pillar spires.

Remarks. This species was quite abundant and common at some places in Singapore; many specimens were collected from intertidal shores along the western end of the Johor Straits, Singapore. This is a potential new species to be described in a future publication.

Order Synaptida Cuénot, 1891 (sensu Smirnov 2012)

Family Synaptidae Burmeister, 1837

Genus *Protankyra* Östergren, 1898

Protankyra pseudodigitata (Semper, 1867)

(Figs. 4D, 24)

Synapta pseudo-digitata Semper, 1867–1868: 2, pl. IV fig. 12, pl. VII fig. 3.

Synapta innominata—Ludwig, 1875: 79, pl. VI fig. 4.

Protankyra innominata—Östergren, 1898: 217.—H. L. Clark, 1907: 108.

Protankyra pseudodigitata—Östergren, 1898:217.—Yang, 1937:32, pl. IV fig. 4, textfig. 19.—Heding, 1940a: 118.—A. M. Clark & Rowe, 1971: 186.—Liao, 1997: 274, fig. 163.—Lane et al., 2000: 492.—Ong & Wong, 2015: 277, 279, figs. 2B, 4B.

Material examined. ZRC.ECH.0597 (1 ex.), CMBS spec. no. SS-1776, stn. DR57, cryo number 110447, (Start) N01°16.297', E103°57.677', (End) N01°16.212', E103°57.458', 46.2 m depth, rectangular dredge, coll. Bertrand Richer de Forges et al., 24 May 2013.

Description. Preserved specimen 26 × 5 mm. Tubular in shape, with both ends wider than the middle portion. Body wall generally thin. Living animal translucent white, turning beige with a faint tint of brown in alcohol. This specimen was damaged during collection, and all tentacles and calcareous

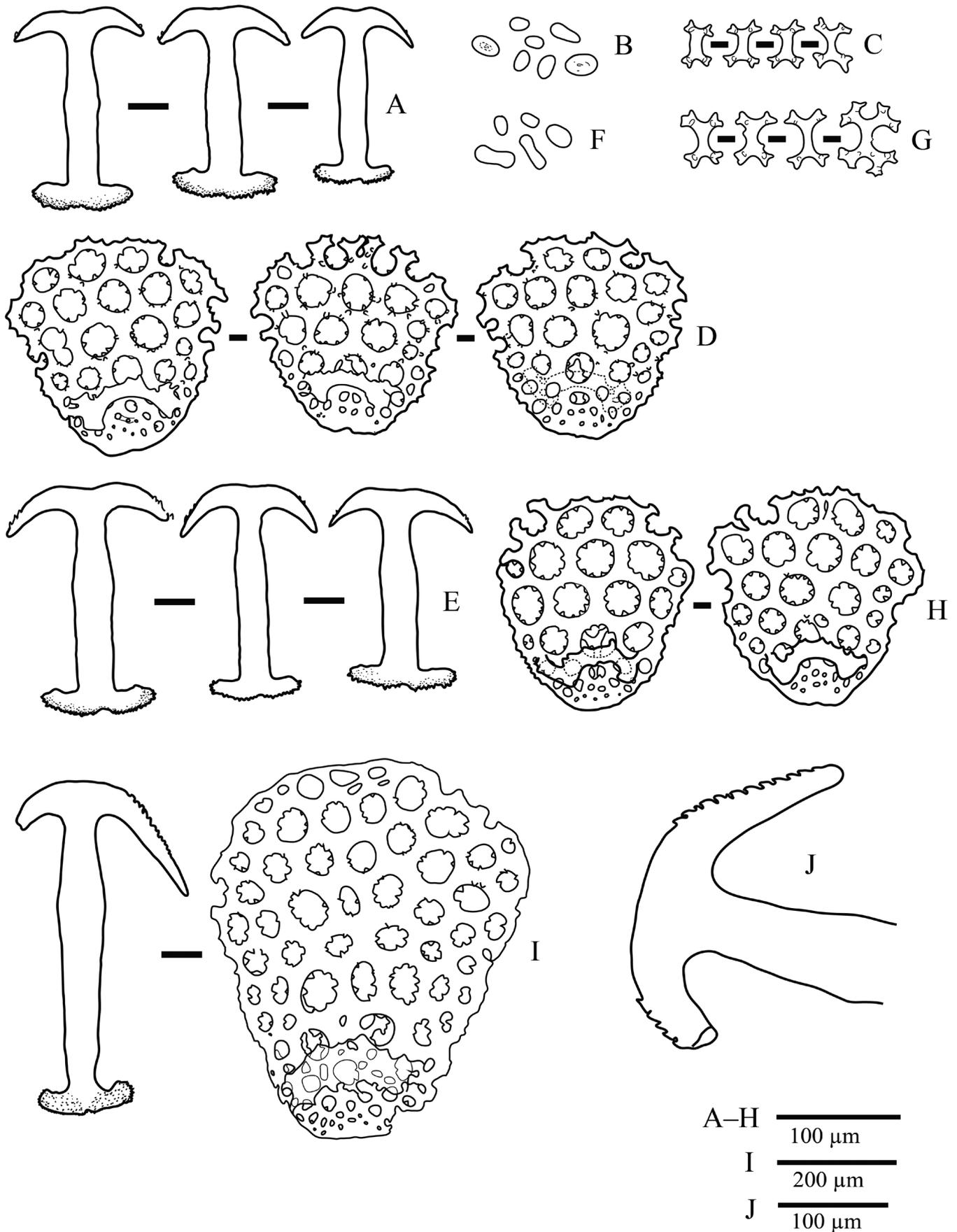


Fig. 24. *Protankyra pseudodigitata* (Semper, 1867). ZRC.ECH.0597. A, anchors from anterior body wall; B, miliary granules from anterior body wall; C, cruciform particles from anterior body wall; D, anchor-plates from anterior body wall; E, anchors from posterior ambulacra; F, miliary granules from posterior body wall; G, cruciform particles from posterior body wall; H, anchor-plates from posterior ambulacra; I, large anchor and plate from posterior interambulacra; J, close-up of the arms of large anchor depicted in I.

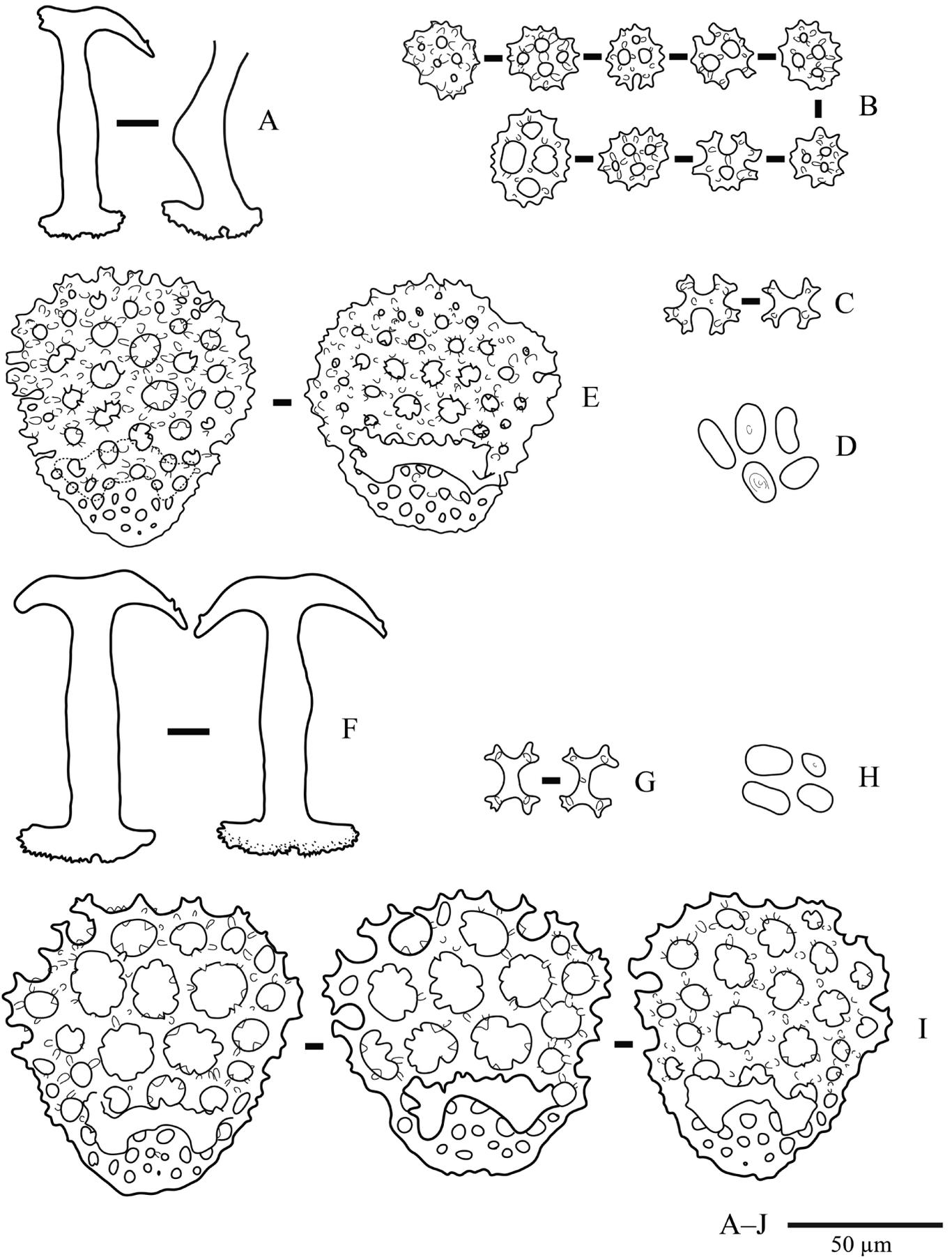


Fig. 25. *Protankyra bidentata* (Woodward & Barrett, 1858). ZRC.ECH.0596. A, anchors from anterior body wall; B, knobbed plates from anterior body wall; C, cruciforms from anterior body wall; D, miliary granules from anterior body wall; E, anchor-plates from anterior body wall; F, anchors from posterior body wall; G, cruciforms from posterior body wall; H, miliary granules from posterior body wall; I, anchor-plates from posterior body wall.

ring were lost. There are abundant anchors that protrude outwards from the epidermis.

Ossicles. Body wall anchors, anchor-plates, miliary granules and cruciform particles. Ossicles from anterior end of the fragment are on average slightly smaller than those at the posterior end. Anchors and anchor-plates at posterior end of animal of two distinct sizes. Anchor-plates ovate, serrated margin, surface smooth or with a few spinlets, numerous smooth or toothed holes, not narrowed into handle posteriorly. Anterior anchor-plates 160–178 µm in length and 130–178 µm in width; posterior ambulacral anchor-plates 175–178 µm in length and 155–173 µm in width. Anchors symmetrical, each arm with one to three teeth, vertex smooth and slightly concave, stock finely dented. Anterior anchors 140–171 µm in length and 88–118 µm in width, posterior ambulacral anchors 163–185 µm in length and 110–130 µm in width. Posterior interambulacral wall with very large anchors (500–590 µm in length, 280–390 µm in width) and anchor-plates (630–885 µm in length, 525–600 µm in width). Miliary granules are mainly small ovals (15–28 µm in length, 10–20 µm in width) in the anterior wall; more oblong and hourglass particles (15–31 µm in length, 11–15 µm in width) present in the posterior wall. Anterior cruciforms 39–40 µm in length and 24–23 µm in width, posterior cruciforms 44–60 µm in length and 19–35 µm in width.

Distribution. From Philippines to the Red Sea, Iranian Gulf (soft bottoms), Persian Gulf, Bay of Bengal, East Indies, South China Sea and Singapore.

Remarks. Semper (1867–1868) noted two kinds of anchors and anchor-plates without providing exact sizes of the ossicles. Yang (1937) reported four specimens whereas Liao (1997) reported 35 specimens from the South China Sea with drawings and size measurements of anchors and anchor-plates. Anchors and anchor-plates of this incomplete specimen found in Singapore Straits are congruent with those described in Yang (1937) and Liao (1997) as well as the drawings in Semper (1867–1868).

***Protankyra bidentata* (Woodward & Barrett, 1858)**
(Figs. 4E, 25)

Synapta bidentata Woodward & Barrett, 1858: 365, pl. 14 figs. 23–25.

Synapta distincta—Marenzeller von, 1881: 123, pl. 4 fig. 2.—Ludwig, 1882: 172.—Théel, 1886a: 11, 12, 32, pl. 1 fig. 8.

Synapta molesta—Semper, 1867: 2, pl. IV fig. 13, pl. V fig. 22, pl. VI fig. 8, pl. VIII fig. 3.

Protankyra bidentata—Östergren, 1898: 117; H. L. Clark, 1908: 102, pl. 5 fig. 30.—Ohshima, 1913: 256, pl. 6 figs. 7–8.—Ohshima, 1914: 471.—Heding, 1928: 252, figs. 46 (1), fig. 47 (1–4).—Chang, 1934: 33, fig. 17.—Yang, 1937: 28, pl. 4 fig. 1, textfig. 16.—Chang, 1948: 83, fig. 22.—Chang et al., 1964: 48.—A. M. Clark & Rowe, 1971: 186, pl. 31 fig. 5.—Yi, 1985: 1, pl. 1 figs. 1–4.—Liao & A. M. Clark, 1995: 534, fig. 329.—Liao, 1997: 271, fig. 161.

Protankyra bidentata (misspelling).—Lane et al., 2000: 492.

Material examined. ZRC.ECH.0596 (1 ex.), CMBS spec. no. SS-1774, stn. DR57, cryo number 110448, (Start) N01°16.297', E103°57.677', (End) N01°16.212', E103°57.458', 46.2 m depth, rectangular dredge, coll. Bertrand Richer de Forges et al., 24 May 2013.

Description. Preserved specimen 14 × 5 mm, vermiform. Preserved body wall thick and soft with coarse surface due to densely distributed ossicles, constricted in the middle part of body. Body wall translucent faint pink in life, opaque beige-white in alcohol. Tentacles 12, pinnate, each with two pairs of lateral digits.

Ossicles. Body wall anchors, anchor-plates, miliary granules, cruciform particles and small plates. Anchors and plates in anterior body wall are slightly smaller than those in the posterior body wall. Anchor-plates ovate, serrated margin, surface knobbed, with numerous toothed holes, narrowed posteriorly. Anterior anchor-plates 140–158 µm in length and 135–153 µm in width; posterior anchor-plates 150–165 µm in length and 133–160 µm in width. Anchors usually symmetrical, each arm with one to two teeth, vertex smooth and slightly concave, stock finely dented. Anterior anchors 123–145 µm in length and ca. 80 µm in width, posterior anchors 135–158 µm in length and 88–105 µm in width. Miliary granules are small elongate ovals (15–31 µm in length, 10–16 µm in width). Cruciforms 33–43 µm in length and 29–33 µm in width. Small knobbed plates with normally two to five holes and serrated margin occur only at anterior body wall, 33–53 µm in length and 30–43 µm in width.

Distribution. South China Sea, Korea, Japan, Philippines and Singapore.

Remarks. To date, three species of *Protankyra* have been recorded in Singapore, i.e., *P. pseudodigitata*, *P. bidentata* and *P. scaphia*. These three species are similar in outer appearance but clearly distinguishable by their ossicle morphology. Specimens collected in Singapore are small in number for each species and diminutive in size (not longer than 20 mm). Large specimens of *P. pseudodigitata* and *P. bidentata* were recorded from the South China Sea by Liao (1997), with lengths up to 100 mm and 280 mm, respectively. Body-size dependent ossicle variation was not mentioned in Liao (1997). Although the specimens of the three species collected in Singapore are small, the ossicles agree well with the original description by Woodward & Barrett (1858) and the descriptions in Liao (1997).

Genus *Synaptula* Oersted, 1849

***Synaptula minima* Heding, 1928**
(Figs. 4F, 26)

Synaptula minima Heding, 1928: 200, fig. 27 (11–13).

Material examined. ZRC.ECH.0594 (1 ex.), CMBS spec. no. SS-3898, stn. SD133, Kusu Island, south, 8 m depth, coral, coral brushing (scuba diving), coll. Tan Heok Hui et al., 31 May 2013.

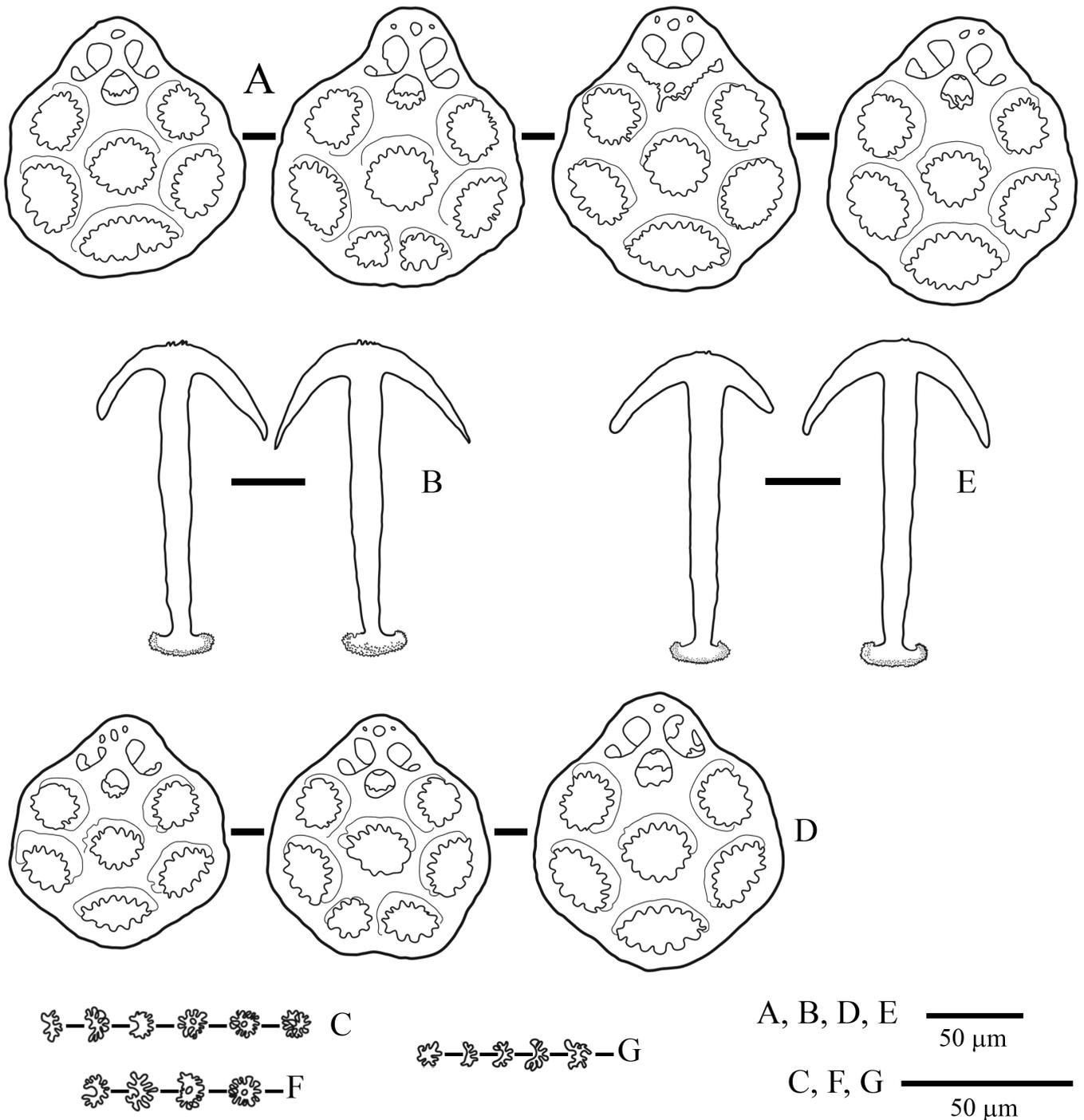


Fig. 26. *Synaptula minima* Heding, 1928. ZRC.ECH.0594. A, anchor-plates from anterior body wall; B, anchors from anterior body wall; C, miliary granules from anterior body wall; D, anchor-plates from posterior body wall; E, anchors from posterior body wall; F, miliary granules from posterior body wall; G, miliary granules from tentacles.

Description. Preserved specimen 57 × 5 mm. Vemiform body, body wall very thin and sticky to the touch. In alcohol body colour white with faint light brown stripes, translucent at the posterior end. Mouth and anus terminal. Tentacles 10, pinnate and white.

Ossicles. Ossicles consist of anchors, anchor-plates and miliary granules. Anchors 150–170 μm in length and 75–100 μm in width, arms smooth, vertex with 2–4 minute knobs; stock finely dented, present in the anterior and posterior

body walls. Anchor plates rounded with prominent posterior part, 100–120 μm in length and 105–125 μm in width with six (sometimes seven) serrated holes; three articular holes with the central one serrated on the anterior margin and the lateral one smooth; bridge with few sharp teeth, prominent central tooth present from the anterior body wall; one to three posterior small holes; present in the anterior and posterior body wall. Miliary granules 10–13 μm in length, numerous in the anterior and posterior body walls as well as in the tentacles.

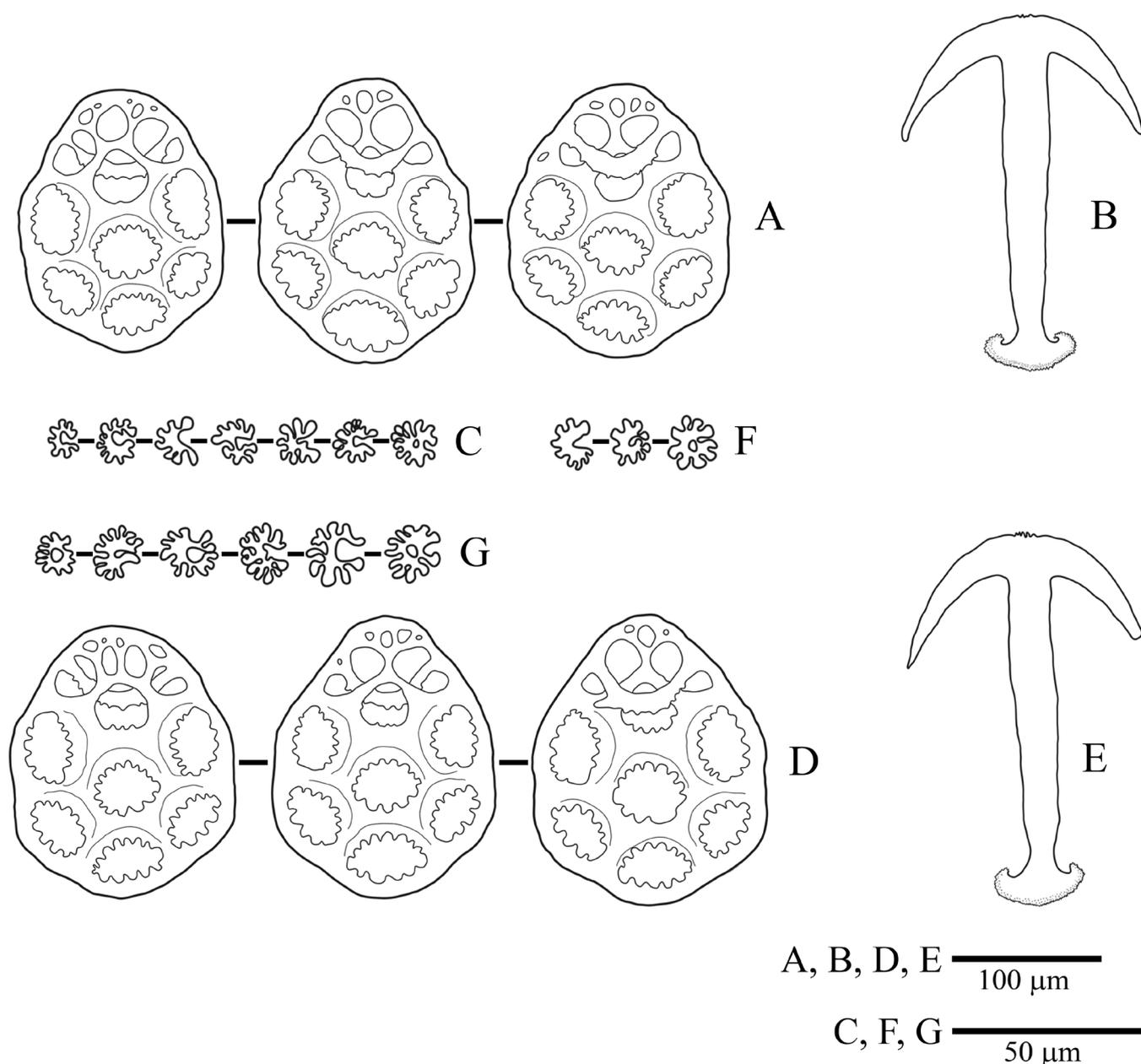


Fig. 27. *Synaptula cf. recta* (Semper, 1868). ZRC.ECH.0592. A, anchor-plates from anterior body wall; B, anchors from anterior body wall; C, miliary granules from anterior body wall; D, anchor-plates from posterior body wall; E, anchors from posterior body wall; F, miliary granules from posterior body wall; G, miliary granules from tentacles.

Distribution. Kei Islands and Singapore.

Remarks. Heding (1928) described the (living?) colour of this species as grey with four to five faint purple stripes. In our specimen from Singapore, it is white with faint light brown stripes in ethanol. The anchor size of this specimen is larger than those described from Heding's specimen.

***Synaptula cf. recta* (Semper, 1868)**
(Figs. 4G, 4H, 27, 28)

Synapta recta Semper, 1867–1868: 14, pl. 4 figs. 2–3, pl. 5 fig. 18, pl. 8 fig. 2.

Synaptula recta.—H. L. Clark, 1908: 84.—H. L. Clark, 1924: 475, pl. 1 fig. 13, pl. 3 fig. 9, pl. 4 fig. 3.—Heding, 1928: 167, figs 16 (4–6), 17 (3–8).—Rowe & Gate, 1995: 338.—Tahera,

1997: .—Massin, 1999: 116, fig. 101a–k, 102, 114b, c.—Lane et al., 2000: xxx.—Samyn, 2003a: 262, fig. 48A–F, 56F, pl. 4H.

Material examined. ZRC.ECH.0592 (1 ex.), CMBS spec. no. SS-2833, stn. IT94, Cyrene Reef, N01°15.374', E103°44.816', intertidal, hand collection, coll. Koh Kwan Siong, 28 May 2013; ZRC.ECH.0598 (1 ex.), CMBS spec. no. SS-2416, stn. IT86, Cyrene Reef, N01°15.374', E103°44.816', intertidal, hand collection, coll. Lee Yen-Ling et al., 27 May 2013; ZRC.ECH.0601 (1 ex.), CMBS spec. no. SS-2413, stn. IT86, Cyrene Reef, N01°15.374', E103°44.816', hand collection, intertidal, coll. Lee Yen-ling et al., 27 May 2013.

Description. Preserved specimens ranged from 240 × 10 mm to 359 × 90 mm; vermiform, body wall very thin. Body

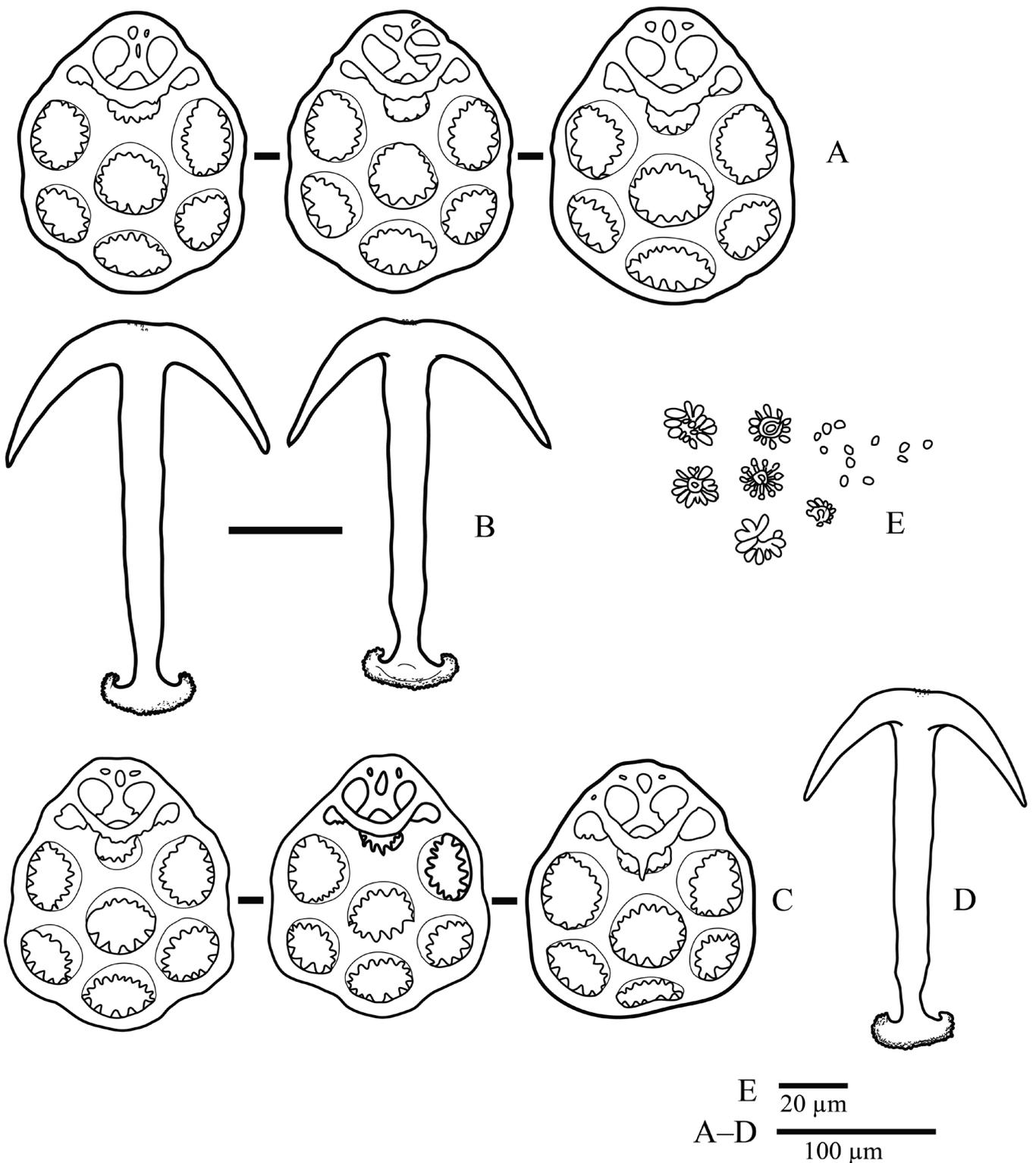


Fig. 28. *Synaptula* cf. *recta*. ZRC.ECH.0601. A, anchor-plates from anterior body wall; B, anchors from anterior body wall; C, anchor-plates from posterior body wall; D, anchor from posterior body wall; E, rosettes from body wall.

colour in life varied from brown with evenly distributed black patches (ZRC.ECH.0601) to uniformly brown with short light brown stripes in each interambulacrum (ZRC.ECH.0592 and 0598), with white spots scattered all over body including tentacles. In alcohol, colours turned darker and duller. Tentacles 10–13, pinnate, approximately 30 pairs of digits united by either a distinct or a very shallow web.

Ossicles. Body wall ossicles consist of anchors, anchor-plates and miliary granules; no distinctive size difference is discernible between ossicles from the anterior and posterior body wall. Anchors 240–270 µm in length, 130–175 µm in width; vertex with four to five minute knobs, arms smooth, shaft constricted at base, stock finely dented. Anchor-plates 158–219 µm in height, 117–173 µm in width, ovate, anterior part wider than posterior, surface and margin smooth; six

serrated holes at the anterior part; central articular hole serrated, sometimes smooth; lateral articular holes smooth or partially serrated; bridge spinous, sometimes a prominent spine is present; posterior holes up to six, usually three; three to five in anterior body wall, three to six holes in posterior body wall. Miliary granules numerous in the body wall and tentacles, comprising flower-shaped rosettes (10–17 µm in diameter) and tiny ovals (probably dissociated from rosettes; 3–4 µm in diameter); miliary granules in the tentacles slightly larger in size than those from the body wall, 14–20 µm in length. Figs. 27 and 28 show the ossicles of ZRC.ECH.0592 and ZRC.ECH.0601 respectively that have different body colour patterns.

Distribution. Red Sea, French Somalia, Pakistan, Maldives Islands, Sri Lanka, India, Myanmar, Cocos Keeling Islands, Malaysia, Indonesia, Philippines, Vietnam, Australia, Papua New Guinea, Caroline Islands and Singapore.

Remarks. The body colour of *Synaptula recta* is known to be highly variable (H. L. Clark, 1907, 1946; Massin, 1999; Samyn, 2003a). However, the colour patterns of specimens from Singapore do not match those described in the available literature. The anchor and anchor-plates of the present specimens are smaller than those described by Heding (1928), Massin (1999) and Samyn (2003a). The original description by Semper (1867–1868) does not provide size measurements. Based on Heding (1928) and Massin (1999), the digits of the tentacles in *S. recta* are not united by a web, but in Singapore specimens, the digits are united by a web.

***Synaptula reticulata* (Semper, 1868)**
(Figs. 4H, 29)

Synapta reticulata Semper, 1868: 13, pl.4 figs 4–5, pl. 5 figs. 12, 23, pl. 6 fig. 9.
Synapta reticulata—Lampert, 1885: 226.—Théel, 1886a: 27.—Sluiter, 1887: 214.—Lampert, 1889: 845.—Koehler, 1895b: 385.
Chondrochloea reticulata—Sluiter, 1901: 127.
Synaptula reticulata—H.L. Clark, 1908: 86.—H.L. Clark, 1924: 477.—Heding, 1928: 191, fig 25 (1–4).—A.M. Clark & Rowe, 1971: 188.—Rowe & Doty, 1977: 338.—Liao, 1997: 279, fig 167a–c.—Massin, 1999: 119, fig. 10a–e, 104.
Synaptula oestergreni—Heding, 1928: 199, fig. 27 (7–10).

Material examined. ZRC.ECH.0588 (4 exx.), CMBS spec. no. SS-1766, stn. SD54, Kusu Island, southwest, N01°13.9', E103°52', 4 m depth, coral, coral brushing (scuba diving), coll. Tan Heok Hui et al., 24 May 2013; ZRC.ECH.0589 (6 exx.), CMBS spec. no. SS-1767, stn. SD54, Kusu Island, southwest, N01°13.9', E103°52', 4 m depth, coral, coral brushing (scuba diving), coll. Tan Heok Hui et al., 24 May 2013; ZRC.ECH.0600 (1 ex.), CMBS spec. no. SS-3897, stn. SD133, Kusu Island, south, 8 m depth, coral, coral brushing (scuba diving), coll. Tan Heok Hui et al., 31 May 2013.

Description. Preserved specimens 180 × 7 mm, 130 × 5 mm, 56 × 5 mm; uniformly white in alcohol. Vermiform body, body wall very thin and sticky to the touch when alive. Tentacles 10, pinnate.

Ossicles. Ossicles consist of anchors, anchor-plates and miliary granules. Anchors few, present in anterior and posterior body wall; ca. 210 µm in length and ca. 130 µm in width; arms smooth, 2–4 knobs on the vertex, stock finely dented. Anchor-plates present in anterior and posterior body wall; ca. 200 µm in length and ca. 130 µm in width; nearly rounded with 6 serrated holes; central articular hole serrated, sometimes smooth; lateral articular holes smooth; bridge spinous; posterior holes 3, sometimes 2 or 4. Miliary granules slightly larger in the body wall (10 µm) than in the tentacles (8 µm).

Distribution. China, Philippines, Indonesia, Australia, New Caledonia and Singapore.

Remarks. The uniform white colouration of Singapore specimens in alcohol is similar to that described by Massin (1999). Living animals were described to be either brown or purple (H. L. Clark, 1908; Heding, 1928). The anchors and anchor-plates in the Singapore specimens are similar in shape but larger than those described by Heding (1928) and Massin (1999).

***Synaptula* sp. 1**
(Fig. 5A)

Material examined. ZRC.ECH.0593 (1 ex.), CMBS spec. no. SS-2978, stn. SD145, Pulau Hantu, west, 11.7 m depth, hand collection (scuba diving), coll. Tan Heok Hui et al., 1 June 2013.

Description. Preserved specimen size 440 × 10 mm. Colour in life light brown with dark brown irregular stripes. Body wall very sticky. Tentacle 10, pinnate, digits not united by web.

Ossicles. Ossicles consist of ovate nearly rounded anchor-plate; six serrated holes; central articular hole serrated and smooth; three to five posterior holes. Anchors with three to four small knobs at the apex, stock finely dented. Miliary granules present in the body wall and tentacles.

Remarks. Anchor-plates in the Singapore specimen are similar to those of *Synaptula lamperti* Heding, 1928 in having a posterior part that almost as wide as the anterior part; the number of posterior holes is fewer in the Singapore specimen, i.e., three to five instead of nine holes (Heding, 1928).

***Synaptula* sp. 2**
(Fig. 5B)

Material examined. ZRC.ECH.0590 (1 ex.), CMBS spec. no. SS-3906, stn. SD133, Kusu Island, south, 8 m depth, coral, coral brushing (scuba diving), coll. Tan Heok Hui et al., 31 May 2013; ZRC.ECH.0591 (2 exx.), CMBS spec. no. SS-3907, stn. SD133, Kusu Island, south, 8 m depth, coral, coral brushing (scuba diving), coll. Tan Heok Hui et al., 31 May 2013.

Description. Preserved specimens 90 × 15 mm, 140 × 10 mm. Body colour in life uniformly white with an orange

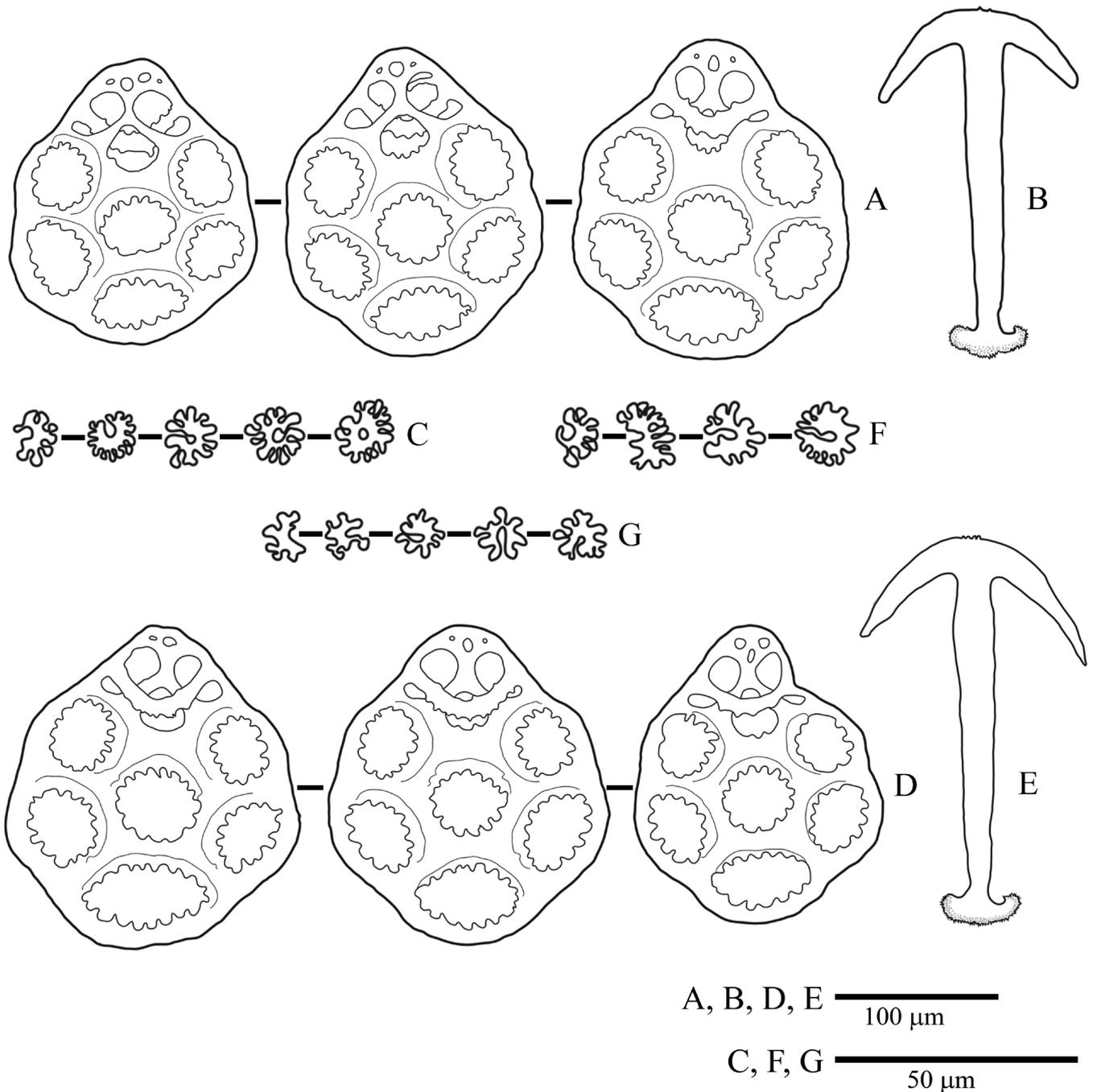


Fig. 29. *Synaptula reticulata* (Semper, 1868). ZRC.ECH.0589. A, anchor-plates from anterior body wall; B, anchors from anterior body wall; C, miliary granules from anterior body wall; D, anchor-plates from posterior body wall; E, anchors from posterior body wall; F, miliary granules from posterior body wall; G, miliary granules from tentacles.

line vertically on the interambulacral. Tentacles 10, pinnate, digits united by web.

Ossicles. Ossicles consist of anchors, anchor-plates and miliary granules. Anchors with smooth arms, sometimes bent; vertex with two to four knobs; stock finely dented. Anchor-plates rounded, posterior part prominent; six serrated holes on the anterior part, sometimes with irregular shape; central articular hole smooth and sometimes serrated; lateral articular holes smooth; bridge with small spines, sometimes with prominent spine especially from posterior body wall; with one to four small posterior holes. Miliary granules numerous, present in the body wall and tentacles.

Remarks. The anchors and anchor-plates of *Synaptula* sp. 2 are similar in shape with those of *S. minima*, but the anchor-plate size of *Synaptula* sp. 2 (200 µm in length) is much larger than those of *S. minima* (135 µm in length) reported by Heding (1928).

***Synaptula* sp. 3**
(Fig. 5C)

Material examined. ZRC.ECH.0595 (1 ex.), CMBS spec. no. SS-4898, stn. SD178, Terumbu Pempang Tengah, N01°13'39", E103°43'40", 9.6 m depth, hand collection (scuba diving), coll. Tan Heok Hui, 5 June 2013.

Description. Preserved specimen 630 × 35 mm. Body colour in life dark brown with light brown spots, posterior part lighter in colour than the anterior and middle part. Tentacles 10, light brown with dark brown spots, digits not united by web.

Ossicles. Ossicles consist of anchors, anchor-plates and miliary granules. Ovate anchor-plates, anterior part wider than posterior; six serrated holes at the anterior part; central articular hole smooth, sometimes serrated; lateral articular holes smooth; posterior holes three to four. Anchors with smooth arms, stock finely dented. Miliary granules present in the body wall and tentacles.

Remarks. The articular holes of the anchor-plates in this specimen are elongate, similar to *Synaptula madreporica* (Heding, 1928), except that the anterior margins of the articular holes are serrated. Living colour of *Synaptula* sp. 3 is different from *S. madreporica*, i.e., dark brown for *Synaptula* sp. 3, dark grey for *S. madreporica*. Hence we do not regard the Singapore specimen as conspecific to *S. madreporica*.

Order Molpadida Haeckel, 1896

Family Caudinidae Heding, 1931

Genus *Acaudina* H. L. Clark, 1908

Acaudina sp.
(Fig. 5E)

Material examined. ZRC.ECH.0613 (1 ex.), CMBS spec. no. SS-3301, stn. TB96, near Eastern Bunkering A, (Start) N01°18.140', E104°04.221', (End) N01°18.329', E104°04.396', 25.1–22.4 m depth, clay, beam trawl, coll. Bertrand Richer de Forges et al., 28 May 2013.

Description. Preserved specimen 18 × 11 mm, body stout and spindle shaped, flattened, body wall thin. Preserved body colour translucent white with tiny yellowish orange flecking. Tentacles 15, pinnate, each with a pair of lateral digits. Anal papillae arranged in five groups, each group with two to four soft finger-like papillae.

Ossicles. Ossicles absent; only phosphatic bodies present.

Remarks. This specimen has no identifiable ossicles from its tissues; however its outer morphology is similar to that of *Acaudina rosettii* O'Loughlin & Ong, 2015.

Genus *Paracaudina* Heding, 1932

Paracaudina chilensis (Müller, 1850)
(Figs. 5F, 30)

Molpadia chilensis Müller, 1850: 139
Molpadia chilensis—Müller, 1854: pl. 6 fig. 14, pl. 9 fig. 1.—Semper, 1868: 233.—Théel, 1886a: 55.
Synonymys (refer to O'Loughlin et al., 2011 and Liao, 1997):
Microdactyla caudata—Sluiter, 1880: 348–351, pl. 6 fig. 1, pl. 7 figs. 1–6.

Caudina ransonnetii—Marenzeller, 1881: 126–127, pl. 4 figs. 5.—Ludwig, 1883: 158–159.—Lampert, 1885: 210.—Théel, 1886: 54.—Ludwig, 1891: 354.—Mitsukurii, 1912: 261–262, pl. 8 fig. 76.
Caudina meridionalis—Bell, 1883: 58, pl. 15, fig. 1.
Caudina coriacea—Théel, 1886a: 47, pl. 3 fig. 4. (non *Caudina coriacea* Hutton, 1872).
Caudina rugosa—Perrier, 1904: 16.—Perrier, 1905: 66–69, pl. 4 figs. 10–12. (synonymy with *Caudina chilensis* (Müller) by H. L. Clark 1908).
Caudina pigmentosa—Perrier, 1904: 16–17.—Perrier, 1905: 69–75, pl. 4 figs. 1–9. (synonymy by H. L. Clark 1935).
Caudina pulchella—Perrier, 1905: 121, fig. N.
Caudina contractacauda—H. L. Clark, 1908: 38–39, 173, 177–178, pl. 9 figs. 9–13. (synonymy by H. L. Clark 1935).
Caudina chilensis—H. L. Clark, 1908: 173, 175–176.—Hozawa, 1928: 361–378, pls. 14–17.—Ohshima, 1929: 39–45.—Chang, 1934: 29, fig. 15, pl. 13 fig. 3.—Yang, 1937: 22, fig. 3, pl. 4 fig. 3.
Pseudocaudina chilensis—Heding, 1931: 283.
Pseudocaudina ransonnetii—Heding, 1931: 283.
Paracaudina ransonnetii—Heding, 1933: 455, pl. V figs. 1–18, pl. VII figs. 1–3, figs 8 pl. 1–2).—Djakonov et al., 1958: 377.
Paracaudina chilensis var. *ransonnetii*—H. L. Clark, 1935: 281.—H. L. Clark, 1938: 540–541.—Chang et al., 1946: 45.—H. L. Clark, 1946: 444.—A. M. Clark & Rowe, 1971: 194–195, fig. 96a. (synonymy by Pawson & Liao, 1992)
Paracaudina chilensis.—Heding, 1933: 127–142, pls. 5–8.—H. L. Clark, 1935: 267–284.—Deichmann, 1938: 383–384, fig. 15.—Pawson, 1963: 18, pl. 4.—Pawson, 1969: 139–140.—Pawson, 1970: 49, pl. 2 fig. 2.—A. M. Clark & Rowe, 1971: 184–185.—Cannon & Silver, 1986: 40.—Rowe & Gates, 1995: 264.—Pawson & Liao, 1992: 385, fig. 8.—Liao & A. M. Clark, 1995: 518–519, fig. 316.—Liao, 1997: 249–250, fig. 148.—Lane et al., 2000: 491.—O'Loughlin et al., 2011: 52–53, figs. 1c, 7, 8, 12b.—Davey & O'Loughlin, 2013: 362–364, figs. 1c, 4.

Material examined. ZRC.ECH.0614 (1 ex.), CMBS spec. no. SS-1771, stn. DR57, (Start) N01°16.297', E103°57.677', (End) N01°16.212', E103°57.458', 46.2 m depth, rectangular dredge, coll. Bertrand Richer de Forges et al., 24 May 2013.

Description. Preserved specimen 39 × 9 mm. Body wall thin and parchment-like in alcohol; mouth and anal ends dorsally oriented; posterior with discrete long thin tail, 2 mm wide, wrinkled, around one third of total body length. Body colour beige-white with faint pink coloration in life, opaque greyish white in alcohol. Calcareous ring with paired posterior processes; posterior processes of calcareous ring simple, entire. Tentacles were not examined for ossicles.

Ossicles. Octagonal plates/ shallow cups in body wall; surface of plate/ cup knobbed, with a central perforation bridged by basal box with four supporting arms on one side and a cross-bridge on the other side; margins with knobs or finger-like projections; octagonal plates from posterior body wall are more heavily knobbed and less regular in shape. 40–73 µm in length, average 57 × 52 µm.

Distribution. Circum-Pacific; South China Sea, Japan, Florida, California, Chile, New Zealand, Antarctica and Singapore.

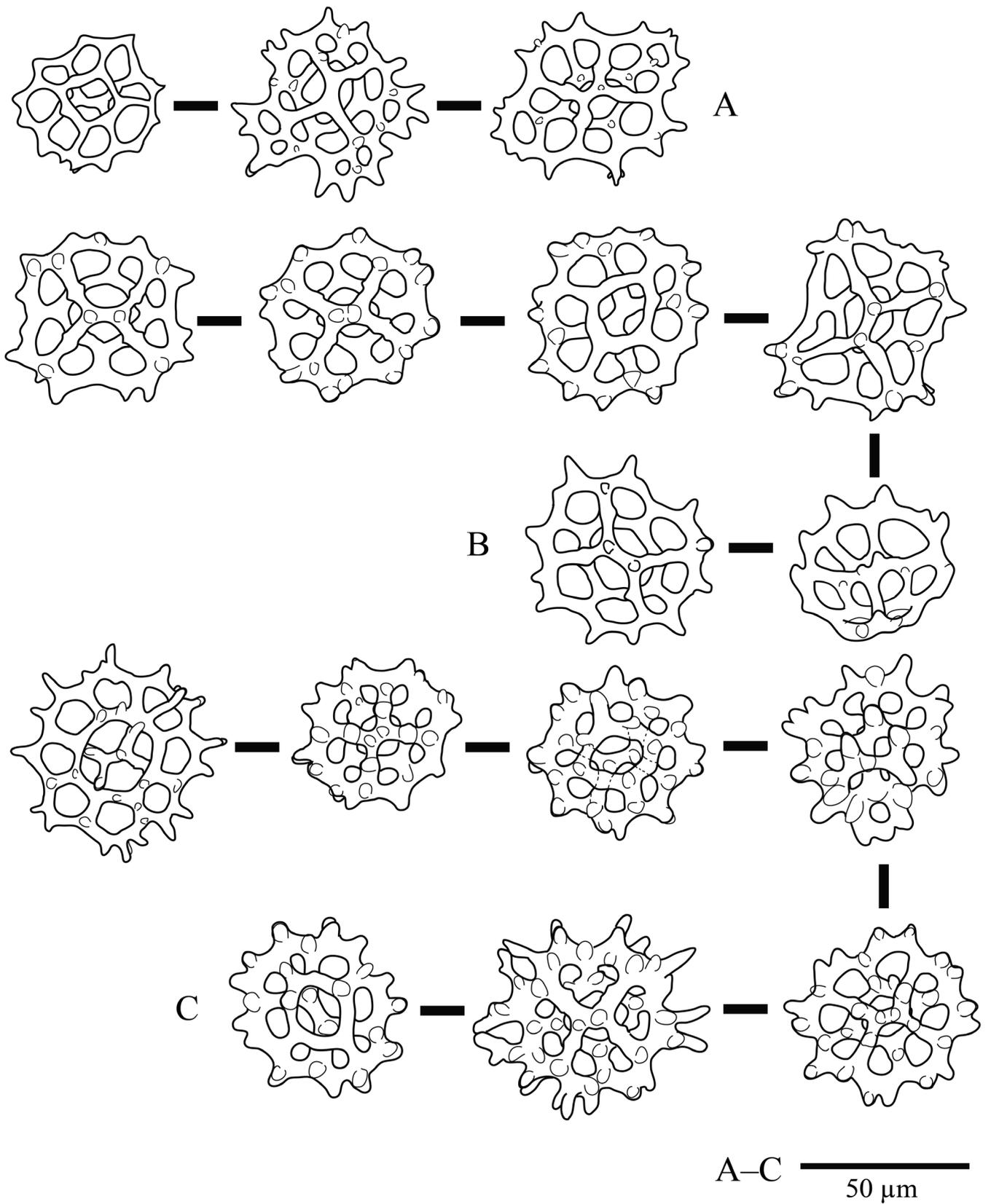


Fig. 30. *Paracaudina chilensis* (Müller, 1850). ZRC.ECH.0614. Octagonal plates/ shallow cups from, A, mid body wall, B, posterior body wall, C, anal wall.

Remarks. This is the first record of this species in Singapore. It is widespread in the Pacific Ocean and can be found to depths of 1009 m (Davey & O’Loughlin, 2013).

DISCUSSION

Adding to the previous checklist (29 species; Ong & Wong, 2015) that documented the holothuroid fauna in the Johor Straits, a total of 50 species of holothuroids are now documented for Singapore based on surveys carried out by the Comprehensive Marine Biodiversity Survey. Of the 50 species, two species were proved to be new to science (O’Loughlin & Ong, 2015) and eight are potential new species. Although the Johor and Singapore Straits are environmentally different, some 11 species were recorded from both ecosystems including two potential new species.

The documented richness of holothuroid fauna in Singapore (50 species, 718 km²) as shown in the previous works (Ong & Wong, 2015) is comparable with other studies in similar-sized areas, including Guam (65 species; Michonneau et al., 2013), Yap (37 species; Kim et al., 2014), Spermonde Archipelago (56 species; Massin, 1999) and part of eastern coast of Thailand (31 species; Mucharin et al., 2005). The environmental heterogeneity, with habitats ranging from mudflats, sandy beaches, rocky shores, submerged reefs, to artificial coastline structures, and the location of Singapore in the centre of the Indo-West Pacific biogeographical region, may have contributed to the comparable species richness in Singapore waters. As the abundances of holothuroids are usually low at each location, increased sampling effort, such as the CMBS, may have resulted in new records and possible new species as documented in this study.

While the holothuroid species diversity in Singapore is comparable with other areas in the Indo-West Pacific, a major difference can be seen in the composition of species at higher taxonomic level. The dominant order in Singapore waters was the Dendrochirotida, with 12 species out of a total of 32 species (38%), followed by the Aspidochirotida and the Synaptida with nine species each (28%), and lastly the Molpadida with two species (6%). The dominance of the order Dendrochirotida was even more apparent in the Johor Straits (Ong & Wong, 2015), comprising 23 out of 50 species (46%), followed by the Aspidochirotida (11 species; 22%) and the Synaptida (11 species; 22%), and lastly the Molpadida (4 species; 8%). The dominance of aspidochirotids and under-representation of dendrochirotids is said to be typical of tropical oceanic islands (Michonneau et al., 2013). In Singapore, the environment may have become more favourable for suspension-feeding dendrochirotids, as the level of coastal eutrophication in the Singapore waters has increased 30-fold in the Singapore Strait and about 60-fold in the Johor Straits over the last 50 years (Gin et al., 2000).

Sampling location, method, and effort all affect our perception of faunal patterns and taxonomic structure. Previous studies done in Singapore to document holothuroid diversity were done mainly by SCUBA diving in the Southern Islands (e.g., Lane et al., 2000; Lane & Vandenspiegel, 2003), where

reef-associated aspidochirotids are dominant. In contrast, the dendrochirotids have a wider distribution from the intertidal mudflats in the Johor Straits to the subtidal seabed in the Singapore Strait. In contrast, the CMBS surveys have sampled intertidal mudflats and the soft subtidal seabed extensively, although specimens were also collected by hand on the intertidal and subtidal reefs. This could be another reason for the appearance of new records of dendrochirotids, molpadids and synaptids which are not generally observed in reef-associated habitats.

While some of the past records cannot be verified, online nature blogs and field guides with photographs (Lane & Vandenspiegel, 2003; Tan & Yeo, 2003; Tan, 2014; Project Semakau, 2014; Yeo, 2012) have provided useful additional records for some conspicuous species. The rare *Holothuria (Metriatyla) lessoni* Massin, Uthicke, Purcell, Rowe & Samyn, 2009, which was first photographed by nature enthusiasts in Singapore was earlier mistaken for a black variant of *H. (Metriatyla) scabra* Jaeger, 1833 (Yeo, 2012). Similarly, the recently described *Acaudina rosetti* O’Loughlin & Ong, 2015 was observed and photographed but was initially identified as *Paracaudina* sp. (Lane & Vandenspiegel, 2003; Tan, 2014).

On the other hand, a number of previous holothuroid records are doubtful and probably in error. For example, a deep-sea species, *Pelagothuria* species was listed in a compilation of animal species found in Singapore (Chou et al., 1994). Its occurrence in Singapore is highly unlikely. In another example, Chou (1988), it was stated that “...the edible sea cucumber, *Halodeima edulis*, (is) black on top and pink below...” whereas subsequently in Chou (1993) a photograph of a sea cucumber with brown-black on top and pink below was identified (erroneously) as *Stichopus chloronotus* Brandt, 1835. To date there are no specimen or photographic records of the distinctive dark blue-green *S. chloronotus* with orange-tipped papillae, although it remains possible that this species occurs in Singapore.

Prior to the studies conducted by the CMBS team, 33 species of holothuroids were recorded from Singapore based on previous literature (see Table 4 in Ong & Wong, 2015). Taking into account of these records prior to CMBS, we estimate that some 70 species of holothuroids can be found in Singapore waters. The uncertainties are due to unconfirmed/unaccountable species in the literature where only photos and/ or brief mention of species names are available. Hence further discovery of holothuroid fauna in Singapore is possible with additional targeted sampling efforts and taxonomy work.

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Table 2. Sea cucumber collection sites during the Singapore Strait Biodiversity Workshop held from 15 May to 2 June 2013. Start and end latitude and longitude coordinates refer to approximate start and end points using a rectangular dredge (DR) or beam trawl (TB); Other abbreviations used for station numbers: SB– scuba diving (coral brushing), SD– scuba diving (hand collection), SW– shallow water (non- reef, various collection methods), IT– intertidal reef (hand collection).

Collection Site	Station Number	Collection Date	Tidal Height / Depth (m)	Habitat / Substratum	Latitude (Start)	Longitude (Start)	Latitude (End)	Longitude (End)
1	TB96	28 May 2013	25.1–22.4	Clay	01°18.140'	104°04.221'	01°18.329'	104°04.396'
	TB97	28 May 2013	22.7–22.4	Sticky, lumpy clay	01°18.425'	104°04.607'	01°18.502'	104°04.844'
2	TB58	24 May 2013	38.7–39.9	Mud	01°16.808'	103°58.246'	01°16.758'	103°57.981'
3	DR57	24 May 2013	46.2–46.2	?	01°16.297'	103°57.677'	01°16.212'	103°57.458'
4	TB15	21 May 2013	23.8–21.5	Silty, gravel	01°16.300'	103°55.226'	01°16.548'	103°55.381'
5	TB17	21 May 2013	86.7–90.9	Rocky	01°13.816'	103°54.060'	01°13.733'	103°53.917'
6	DR111	29 May 2013	125.0–136.0	Rocky	01°12.989'	103°53.062'	01°12.862'	103°52.852'
7	TB16	21 May 2013	98.0–89.5	Laterite rocks, rocky, gravel	01°13.537'	103°53.793'	01°13.437'	103°53.556'
8	DR127	30 May 2013	128.0–113.0	Rocky	01°12.974'	103°52.960'	01°12.958'	103°52.832'
	DR174	04 June 2013	135.0–79.6	Reddish marine clay, gravel, dead shells	01°12.202'	103°52.178'	01°12.141'	103°52.078'
9	TB28	22 May 2013	97.6–94.3	Gravel, rocky	01°13.181'	103°52.900'	01°13.058'	103°52.746'
	TB29	22 May 2013	103.0–98.0	Gravel, rocky	01°13.036'	103°52.820'	01°12.968'	103°52.636'
10	DR31	22 May 2013	19.6–19.4	Very muddy, gravel	01°16.415'	103°52.838'	01°16.175'	103°52.713'
11	TB185	05 June 2013	24.5–24.3	Anoxic mud, laterite rocks, gravel	01°09.942'	103°43.458'	01°09.949'	103°43.471'
12	DR184	05 June 2013	31.6–35.4	Rocky, sand, shell fragments, gravel	01°09.280'	103°44.049'	01°09.278'	103°43.980'
13	DR70	25 May 2013	20.6–22.6	Sandy	01°13.134'	103°44.283'	01°13.176'	103°44.531'
14	SB152	03 June 2013	11.0	Coral Reef	01°13.274'	103°51.659'		
	SD133	31 May 2013	11.0	Coral Reef	01°13.260'	103°51.683'		
	SD166	03 June 2013	19.1	Coral Reef	01°13.274'	103°51.659'		
	SD54	24 May 2013	7.8	Coral Reef	01°13.900'	103°52.000'		
15	SD34	22 May 2013	14.0	Coral Reef	01°13.835'	103°51.058'		
	SW23	21 May 2013	0	Sandy rocky high shore	01°13.417'	103°51.371'		
16	SD25	22 May 2013	7.6	Coral reef	01°12.882'	103°50.952'		
	SW13	21 May 2013	1	Sandy bottom with rocks	01°13.116'	103°51.079'		
	SW32	22 May 2013	0–0.5	Rocky Shore				
	SW44	23 May 2013	0	Rocky Shore				
	SW48	23 May 2013	0	Rocky Shore	01°13.231'	103°51.080'		
	SW77	25 May 2013	0–5	?	01°12.913'	103°51.080'		

Collection Site	Station Number	Collection Date	Tidal Height / Depth (m)	Habitat / Substratum	Latitude (Start)	Longitude (Start)	Latitude (End)	Longitude (End)
17	IT140	31 May 2013		Intertidal reef	01°13.899'	103°50.265'		
18	IT87	27 May 2013		Intertidal reef				
20	SB67 SD145	25 May 2013 01 June 2013	15.7 11.7	Patch reef Patch reef	01°13.600' 01°13.514'	103°44.800' 103°44.784'		
19	IT80	26 May 2013		Intertidal reef	01°12.575'	103°44.493'		
21	SD178	05 June 2013	9.6	Coral reef	01°13.650'	103°43.667'		
23	IT86 IT94	27 May 2013 28 May 2013		Intertidal reef Intertidal reef	01°15.374' 01°15.374'	103°44.816' 103°44.816'		
22	IT124	30 May 2013		Intertidal reef	01° 13.912'	103° 43.402'		
24	IT108 IT95	29 May 2013 28 May 2013		Intertidal reef Intertidal reef	01°09.600' 01°09.600'	103°44.456' 103°44.456'		

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