

Sea cucumbers (Echinodermata: Holothuroidea) from the Johor Straits, Singapore

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Abstract. Thirty species of sea cucumbers (holothuroids) are recorded from the Johor Straits based on the Comprehensive Marine Biodiversity Survey between December 2010 and April 2014. Specimens were collected by hand at intertidal sites and by trawling and dredging at subtidal sites. A total of 193 lots of specimens were examined, which comprised 30 species from four orders and seven families. Of these, five species have previously been documented from Singapore, 11 are new records for Singapore, ten are potential new species, and four are unconfirmed at species level. The new records and possibly new species represent six families: five species of Synaptidae, i.e., *Anapta gracilis* (Semper), *Protankyra pseudodigitata* (Semper), *Protankyra* species, *Synaptula recta* (Semper) and *Synaptula reticulata* (Semper); one species of Holothuriidae, i.e., *Holothuria (Metriatyla) albiventer* (Semper); three species of Cucumariidae, i.e., *Colochirus* species, *Leptopentacta imbricata* (Semper) and *Mensamaria intercedens* (Lampert); five species of Phyllophoridae, i.e., *Stolus* species, *Thorsonia adversaria* (Semper), *Thyone* species a, *Thyone* species b, and *Thyone* species c; two species of Psolididae, i.e., *Psolidium* species a and *Psolidium* species b; two species of Sclerodactylidae, i.e., *Cladolabes hamatus* (Sluiter) and *Globosita* species; three species of Caudinidae, i.e., *Acaudina leucoprocta* (H. L. Clark), *Acaudina molpadioides* (Semper) and *Acaudina* species. 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 muddy estuarine habitat in the Johor Straits is surprisingly diverse.

Key words. Intertidal, subtidal, mudflat, Johor Straits, holothuroid, Comprehensive Marine Biodiversity Survey

INTRODUCTION

Southeast Asian and Australasian sea cucumbers are generally well documented, as evidenced by publications on holothuroids from the South China Sea (Lane et al., 2000; Liao, 1997; Liao & Pawson, 2001; Massin et al., 2002) and Indo-Pacific waters (Clark & Rowe, 1971; Lampert, 1885; Panning, 1941; Semper, 1867). Clark (1938) and Rowe & Gates (1995) have listed holothuroids from Australia, Marsh & Morrison (2004) briefly noted holothuroids from Western Australia, and there are also recently described new species from Australia (Mackenzie & Whitfield, 2011; O’Loughlin & O’Hara, 1992; O’Loughlin, 2007; O’Loughlin et al., 2007; O’Loughlin & Maric 2008; O’Loughlin et al. 2011). A number of recent publications documented holothuroids from Malaysia (Forbes et al., 2009; Kamarudin et al., 2010; Kamarudin 2011), Thailand (Mucharin et al., 2005; Putchakarn & Sonchaeng 2004), Indonesia (Massin, 1999), and western coast of Philippines (Cherbonnier & Féral, 1981).

In contrast, the holothuroid (sea cucumber) fauna of Singapore is poorly represented in museum collections, especially species that inhabit non-reef habitats. Reef dwelling holothuroids, particularly species that are of commercial value, are well known in Singapore. Even so, most records of holothuroids in Singapore to date are in the form of field guides (Lane & VandenSpiegel, 2003; Tan & Yeo, 2003) and online guides (Tan, 2014). There have been few taxonomic accounts of sea cucumbers from Singapore waters except for a number of new records observed recently (Teo & Ng, 2009; Teo et al., 2010a, Teo et al., 2010b). Some of the species recorded in popular guides and online sites are difficult to verify, as there are no corresponding museum specimens. Identifications are often based solely on external features such as the colouration and appearance of the body wall and the shape of tentacles. These outer features may indeed be valuable in determining the identity of species, but the examination of ossicles and other internal features such as the calcareous ring can be crucial in distinguishing closely related species. Common species may be easily overlooked. Indeed, one of the two new species recognised here and described elsewhere in this volume by O’Loughlin & Ong (2015) is a frequently misidentified member of the molpadid family that is widely distributed in the Johor Straits.

The main objective of this study is to provide a baseline taxonomic record of sea cucumbers found in the Johor Straits. It is hoped that the results from this study can help to provide a more complete picture of the non-reefal holothuroid

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biodiversity in Singapore. Specimens reported here are deposited in the Lee Kong Chian Natural History Museum (formerly Raffles Museum of Biodiversity Research).

MATERIAL AND METHODS

The surveys were carried out over four years between 2011 and 2014 along the Johor Straits of Singapore with the involvement of volunteers (Fig. 1), and included material from the international biodiversity workshop held at the Outward Bound School on Pulau Ubin in October 2012.

Intertidal holothuroid specimens were collected during 44 intertidal surveys at 13 different sites (Fig. 1; Tables 1, 2). At each site, a 50 m transect line was set up parallel to the water line, during low tide. The sampling area was 5 m on both sides of the transect line. Random sampling was carried within the sampling area by up to 20 volunteers. Sieves of either 1 mm or 2 mm mesh size were used to sample the substratum 30 cm below the surface, digging with the help of hand trowels and spades. Random sampling without transect line was also carried out during reconnaissance trips. Holothuroids retained in the sieves and/or dug up by trowels/spades were collected.

Subtidal surveys were conducted from a research vessel using naturalist dredges, bottom trawling and epibenthic sled along the seabed at a speed of 1.5 knots for 10 minutes. The Johor

Straits waters of Singapore were divided into approximately 61 quadrats, each one square nautical mile in area. Survey areas were limited to areas with at least five meters of water depth during high tide. Holothuroid specimens were collected from 26 subtidal sites (Fig. 1; Tables 1, 3).

Specimens collected were anaesthetised with 7.5% magnesium chloride solution whenever possible prior to preserving in 70% denatured ethanol. Selected specimens were tissue sampled and/or photographed live and examined under an Olympus stereomicroscope SZX10. Ossicle examination was carried out using Olympus compound microscope BX43. All specimens and tissue samples are deposited in the Zoological Reference Collection (ZRC) and Cryogenic Collection (MRH) in the Lee Kong Chian Natural History Museum (LKCNC; formerly Raffles Museum of Biodiversity Research), National University of Singapore (NUS).

RESULTS

A total of 280 specimens (193 lots) representing 30 species of holothuroids were collected from the Johor Straits (Table 1). The holothuroids represented four orders (Synaptida, Aspidochirotida, Molpadida and Dendrochirotida), seven families (Synaptidae, Holothuriidae, Cucumariidae, Phylloporiidae, Psolidae, Sclerodactylidae, and Caudinidae) and 18 genera (*Anapta*, *Protankyra*, *Synaptula*, *Holothuria*,

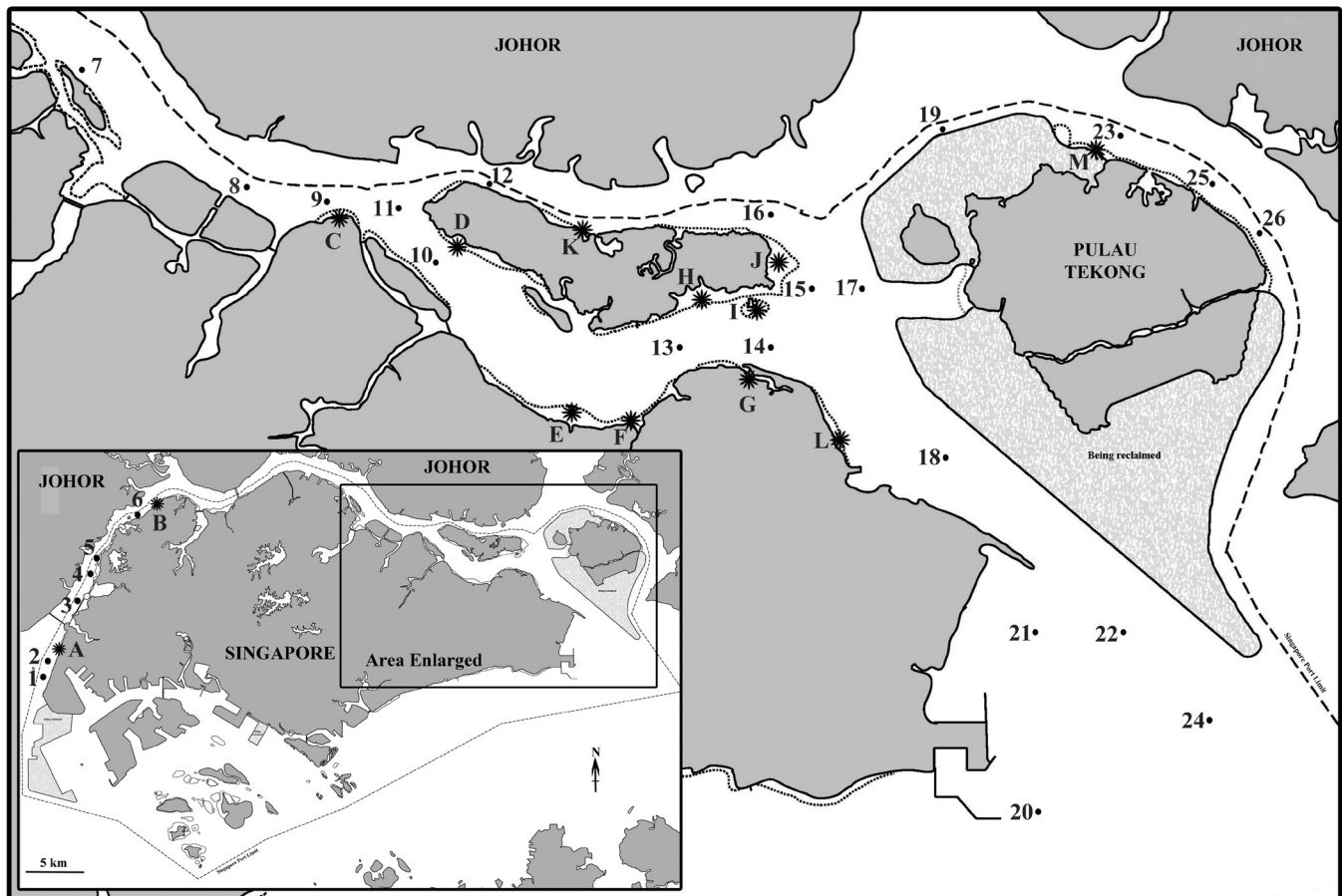


Fig. 1. Holothuroid collecting sites in the Johor Straits, 2011–2014. See Tables 2 and 3 for details of intertidal (stars) and subtidal (circles) sites respectively.

Table 1. Sea cucumbers from the Johor Straits, Singapore, collected by the Comprehensive Marine Biodiversity Survey.

Family	Species	Remarks	Intertidal Collection Site (See Fig. 1)	Subtidal Collection Site (See Fig. 1)	Material examined (ZRC.ECH.)
Order Synaptida Cuénot, 1891 (sensu Smirnov, 2012)					
Synaptidae	<i>Anapta gracilis</i> Semper, 1867	New record	B, E, F, G, J, K, M		0179–0191
	<i>Protankyra pseudodigitata</i> (Semper, 1867)	New record		22	0291
	<i>Protankyra</i> species	Potential new species		15	0292
	<i>Synaptula recta</i> (Semper, 1867)	New record	D, I, J		0327–0330
	<i>Synaptula reticulata</i> (Semper, 1867)	New record		11	0331
Order Aspidochirotida Grube, 1840					
Holothuriidae	<i>Holothuria (Meiriartyla) albiventer</i> Semper, 1867	New record		13	0265
	<i>Holothuria (Meiriartyla) scabra</i> Jaeger, 1833	Previously recorded	A		0270
	<i>Holothuria (Meiriartyla)</i> species	Not determined	A, E	14, 25	0263–0264, 0266–0270
Order Dendrochirotida Grube, 1840					
Cucumariidae	<i>Actinocucumis</i> cf. <i>typica</i> Ludwig, 1875	Not determined	A, J	4, 5, 13, 14, 15, 16, 17, 25, 26	0169–0178, 0534–0535
	<i>Cercodemas anceps</i> Selenka, 1867	Previously recorded	I, J, L	16, 19	0192–0201
	<i>Colochirus quadrangularis</i> Troschel, 1846	Previously recorded	A, I, J, L	13, 15, 16, 26	0206–0223
	<i>Colochirus</i> species	Potential new species		25	0224–0225
	<i>Leptopentacta imbricata</i> (Semper, 1867)	New record		1, 2, 3, 15	0271–0282
	<i>Mensamaria intercedens</i> (Lampert, 1885)	New record	I		0283–0289
	<i>Plesiocolochirus</i> species specimen	Not determined		10	0290
	<i>Pseudocolochirus violaceus</i> (Théel, 1886)	Previously recorded		18, 25	0293–0298
	<i>Plesiocolochirus</i> cf. <i>australis</i> (Ludwig, 1875)	Not determined		15	0202
Phyllophoridae	<i>Stolus buccalis</i> (Stimpson, 1855)	Previously recorded	A, I	10, 15, 25	0301–0309
	<i>Stolus</i> species	Potential new species	A, I	5, 15, 16, 19, 25, 26	0310–0326
	<i>Thorsonia adversaria</i> (Semper, 1867)	New record		15	0332–0333
	<i>Thyone</i> species a	Potential new species		24	0334
	<i>Thyone</i> species b	Potential new species		25	0335
Psolidae	<i>Thyone</i> species c	Potential new species	I, J	5, 13, 14	0336–0347
	<i>Psolidium</i> species a	Potential new species		26	0299
	<i>Psolidium</i> species b	Potential new species	J		0300
Sclerodactylidae	<i>Cladolabes hamatus</i> (Sluiter, 1914)	New record		15	0203
	<i>Globosita</i> species	Potential new species	C, E, H, I, J, L	6, 7, 8, 9, 10, 11, 12, 14, 15, 16, 17, 19, 23, 25	0226–0262

Table 1...continued

Family	Species	Remarks	Intertidal Collection Site (See Fig. 1)	Subtidal Collection Site (See Fig. 1)	Material examined (ZRC.ECH.)
Order Molpadida Haeckel, 1896					
Caudiniidae	<i>Acaudina leucoprocta</i> (H. L. Clark, 1938)	New record	A, J	14, 20	0150–0153
	<i>Acaudina molpadioides</i> (Semper, 1867)	New record		14	0154
	<i>Acaudina</i> species	Potential new species	A, L	10, 14, 21	0156–0157, 0162–0164, 0348–0349
	<i>Acaudina</i> species	Not determined	I	11, 13, 14	0155, 0158– 0161

Actinocucumis, *Cercodemus*, *Colochirus*, *Leptopentacta*, *Mensamaria*, *Plesiocolochirus*, *Pseudocolochirus*, *Stolus*, *Thorsonia*, *Thyone*, *Psolidium*, *Cladolabes*, *Globosita*, and *Acaudina*). There were five synaptid species, three holothuriid species, nine cucumariid species, six phyllophorid species, two psolid species, two sclerodactylid species and three caudinid species. Ten are potential new species and 11 are new records for Singapore. Two of the new species are described by O'Loughlin & Ong (2015) in this volume.

There were four undetermined species (Table 1): *Actinocucumis* cf. *typica* (Ludwig, 1875), *Plesiocolochirus* species, *Plesiocolochirus* cf. *australis* (Ludwig, 1875) and *Holothuria* (*Metriatyla*) species. We noted differences in external morphology (presence of longitudinal dark coloured lines along the interambulacra in *Actinocucumis* cf. *typica*) as well as in ossicle shape and combination (rare flat plates and an abundance of dumbbell-shaped ossicles without distal knobs were present in the body wall of specimens) between the *Actinocucumis* cf. *typica* collected in this survey and the *A. typica* of the original descriptions (Ludwig, 1875). We thus refer to it as *Actinocucumis* cf. *typica* in this study.

Specimens of the undetermined *Acaudina* species (Table 1) have a white body wall with orange freckles due to phosphatized ossicles. Only phosphatic bodies were found, but there were no recognisable ossicles. Morphologically they showed affinity to the three listed species of *Acaudina* found in this study, i.e., *A. molpadioides*, *A. leucoprocta* and *Acaudina*, new species. Hence the undetermined *Acaudina* species is not considered a separate species here.

The 11 new records in this report are briefly described below together with Zoological Reference Collection catalogue numbers (ZRC), Cryogenic Collection catalogue numbers (MRH), appearance of the living and/or preserved animals, distribution in the Johor Straits and general remarks. Photographs of living specimens are included as far as possible.

Order Synaptida Cuénot, 1891 (sensu Smirnov, 2012)

Family Synaptidae Burmeister, 1837

Genus *Anapta* Semper, 1867

Anapta gracilis Semper, 1867 (Figs. 2A, 4A)

Material examined. ZRC.ECH.0179 (1 ex.), ZRC.ECH.0180 (1 ex.), ZRC.ECH.0181 (1 ex.), ZRC.ECH.0182 (1 ex.), ZRC.ECH.0183 (4 ex.), ZRC.ECH.0184 (15 ex.), ZRC.ECH.0185 (2 ex.), ZRC.ECH.0186 (2 ex.) (MRH109022), ZRC.ECH.0187 (1 ex.), ZRC.ECH.0188 (1 ex.), ZRC.ECH.0189 (1 ex.), ZRC.ECH.0190 (1 ex.), ZRC.ECH.0191 (1 ex.).

Field description. Cylindrical elongate body. Translucent beige to reddish brown body wall with dense white spots/bumps distributed all over body and trunks of tentacles. Tentacles 12, with one terminal digit and six to seven pairs

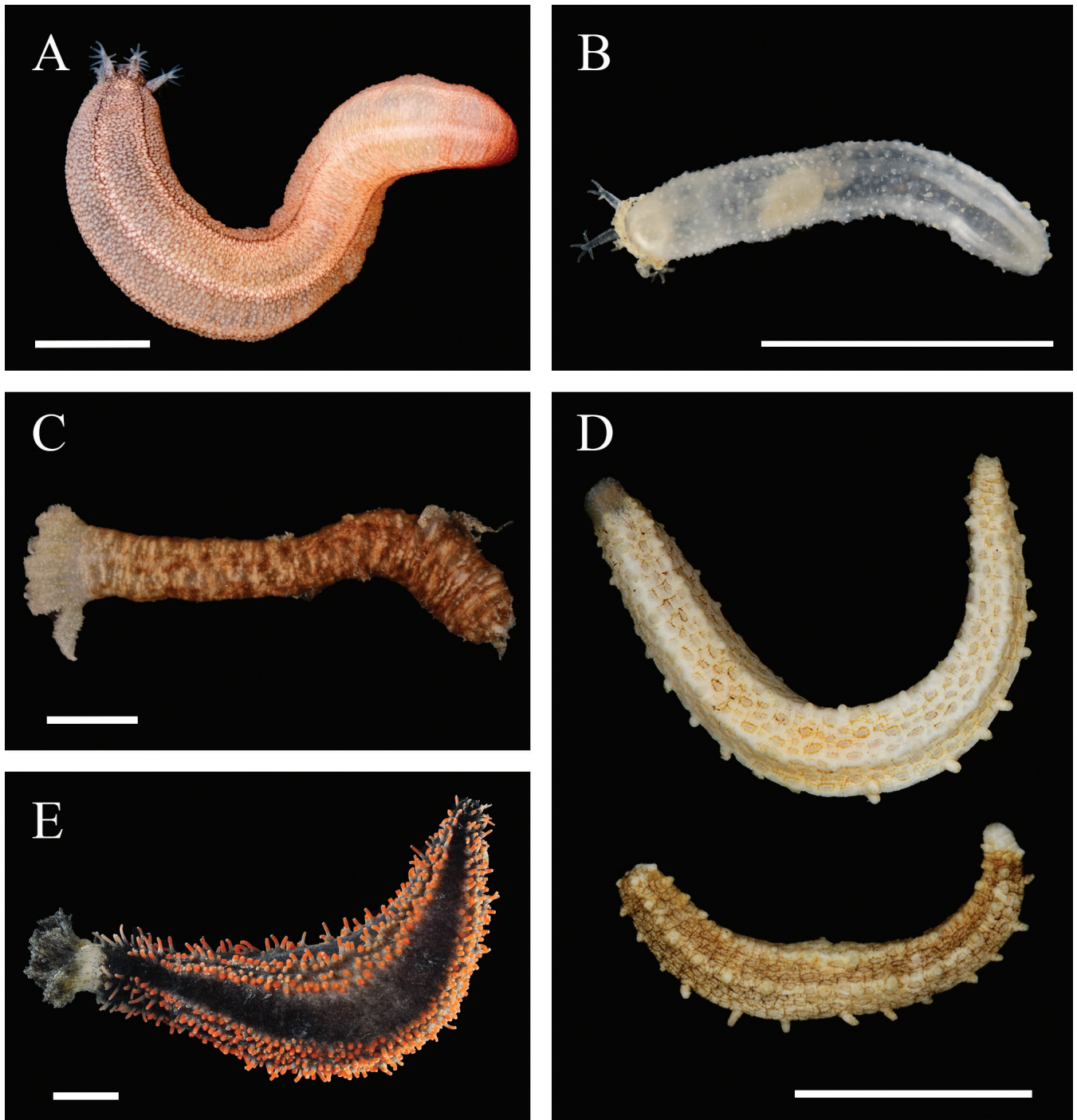


Fig. 2. Sea cucumbers from the Johor Straits, Singapore. A, *Anapta gracilis* Semper, 1867, ZRC.ECH.0186; B, *Protankyra pseudodigitata* (Semper, 1867), one out of four specimens in the lot ZRC.ECH.0291; C, *Synaptula recta* (Semper, 1867), ZRC.ECH.0328; D, *Leptopentacta imbricata* (Semper, 1867), ZRC.ECH.0274; E, *Mensamaria intercedens* (Lampert, 1885), ZRC.ECH.0286. Scale bars = 1 cm.

of lateral digits. Usually found burrowing in soft mud. Preserved specimens 2.0–20.5 cm in length.

Ossicles of body wall. Granules, 15–28 μm in length.

Distribution in Johor Straits. Found in both the eastern and western Johor Straits. Mudflat and sandy/seagrass habitats. Intertidal.

Remarks. Some specimens were broken into segments during collection.

Genus *Protankyra* Östergren, 1898

Protankyra pseudodigitata (Semper, 1867)
(Figs. 2B, 4B)

Material examined. ZRC.ECH.0291 (4 ex.).

Field description. Cylindrical, elongate body. Small, living specimens less than 2 cm in length. Translucent white with opaque white spots due to anchor and plate ossicles embedded in body wall. Tentacles 12, each with two pairs of lateral digits.

Table 2. Intertidal sea cucumber collecting sites (as indicated by stars in Fig. 1).

	Intertidal Collection Site	Station Number	Latitude	Longitude	Tidal Height	Collection Date	Habitat
A	Tuas	MF24	1°20.212' (Start); 1°19.841' (End)	103°37.989' (Start); 103°37.849' (End)	0.6–1.2 m	06 July 2011	Sandy shore + Mud
		SW16	1°19.771'	103°37.842'	0.5–0.6 m	16 October 2012	Sandy shore + Mud
		SW26	1°19.765'	103°37.85'	0.4–0.9 m	17 October 2012	Sandy shore + Mud
B	Lim Chu Kang	MF7	1°26.766' (Start); 1°26.788' (End)	103°42.494' (Start); 103°42.481' (End)	0.7–1.3 m	16 April 2011	Mudflat
		MF30	1°26.843' (Start); 1°26.834' (End)	103°42.551' (Start); 103°42.581' (End)	0.4–0.9 m	04 Aug 2011	Mudflat
C	Punggol	RF375	1°25.268'	103°54.760'	0.3–0.5 m	20 April 2014	Sandy shore + Rock
D	Pulau Ubin, Shore of Outward Bound School	SW1	1°25.260'	103°55.950'	1.8–2.8 m	15 October 2012	Mudflat
E	Pasir Ris	MF22	1°22.965' (Start); 1°22.950' (End)	103°57.034' (Start); 103°57.103' (End)	0.3–1.0 m	04 July 2011	Mudflat
		MF58	1°22.955' (Start); 1°22.949' (End)	103°57.130' (Start); 103°57.154' (End)	0.2–0.3 m	11 May 2012	Mudflat
F	Sungei Loyang	MF67	1°22.926' (Start); 1°22.901' (End)	103°57.999' (Start); 103°58.021' (End)	1.0 m	11 July 2012	Mudflat
G	Changi Creek	MF52	1°23.396' (Start); 1°23.397' (End)	103°59.468' (Start); 103°59.496' (End)	0.4–0.5 m	12 April 2012	Mudflat
H	Pulau Ubin, shore of Kampong Melayu	MF41	1°24.454' (Start); 1°24.462' (End)	103°58.748' (Start); 103°58.721' (End)	0.6–1.3 m	11 November 2011	Mudflat
I	Pulau Sekudu	SW24	1°24.263'	103°59.241'	0.3–0.4 m	17 October 2012	Sandy shore + Rock
		SW31	1°24.280'	103°59.300'	0.1–0.7 m	18 October 2012	Sandy shore + Seagrass bed + Algae
J	Pulau Ubin, Chek Jawa	SW23	1°24.748'	103°59.711'	0.3–0.4 m	17 October 2012	Seagrass bed + Algae
K	Pulau Ubin, Sungei Besar	SW95	1°25.025'	103°57.607'	1.2–1.3 m	26 October 2012	Sandy shore + Mud
L	Changi	SW33	1°22.432'	104°00.350'	0.7–0.1 m	18 October 2012	Sandy shore
		MF54	1°23.500'	103°59.500'	0.5–0.8 m	12 April 2012	Mudflat
M	Pulau Tekong	MF47	1° 25.864'	104° 03.269'	0.4–0.6 m	20 October 2012	Mudflat

Ossicles of body wall. Anchors, anchor-plates, oval-shaped granules, and cupped crosses. Anchors, 110–180 µm in length, with smooth vertex, serrated arms and finely dented stock. Anchor-plates 80–170 µm in length, with serrated margin and dented holes. Granules 12–45 µm in length. Cupped crosses of two sizes, ca. 70 µm in length and ca. 35 µm in length.

Distribution in Johor Straits. Changi (eastern side of Johor Straits). Collected by epibenthic sled from a depth of 18.5–18.7 m on sandy substratum.

Remarks. The specimens were collected in a single lot comprising small individuals that were generally similar in size. This species was described as having body length of less than 8 cm in the original description and other previous work (Heding, 1928; Ludwig, 1875; Semper, 1867).

Genus *Synaptula* Örstedt, 1849

***Synaptula recta* (Semper, 1867)
(Figs. 2C, 4C)**

Material examined. ZRC.ECH.0327 (1 ex.), ZRC.ECH.0328 (MRH108908) (1 ex.), ZRC.ECH.0329 (1 ex.), ZRC.ECH.0330 (1 ex.).

Field description. Cylindrical, elongate body. The colours of the specimens collected in the Johor Straits are of two different colour patterns, i.e., 1) brown or beige-brown with white patches/ spots scattered on tentacles and body wall (Fig. 2C); 2) white with a network of deep-brown discontinuous longitudinal lines from tentacles to anus end. Tentacles 12–14, with 23–25 pairs of lateral digits for the brown or beige-brown colour specimens; tentacles seven, six pairs of lateral digits for the only white specimen ZRC.ECH.0329. Often found adhering to algae fronds. Preserved specimens 3.7–15.0 cm in length.

Ossicles of body wall. Anchors, anchor-plates and rosettes. Anchors 210–280 µm in length, vertex with a few knobs, with finely dented stocks. Anchor-plates 160–180 µm in length, with 6 serrated holes, articular hole serrated, number of posterior holes varies from 3–7. Miliary granules are rosettes 10–15 µm, many dissociated.

Distribution in Johor Straits. Pulau [=Island] Ubin and Pulau Sekudu. Mudflat or sandy shore with seagrass and algae. Intertidal.

Remarks. This species is highly variable in colour (Clark, 1907; Massin, 1999). It is a medium-large species with length up to 24.0 cm (Clark, 1907). The specimens collected in the Johor Straits are generally smaller.

***Synaptula reticulata* (Semper, 1867)**

Material examined. ZRC.ECH.0331 (9 ex.)

Field description. Colour of living specimens unknown. Preserved specimens with translucent faint yellowish white body with dense white spots and patches; some with tint of dark purplish brown. Tentacles 10, only one specimen with 12 tentacles. Digits of tentacles are difficult to determine due to the contraction of the tentacles in preserved specimens. Preserved specimens 1.5–7.0 cm in length.

Distribution in Johor Straits. Pulau Ubin (eastern side of Johor Straits).

Remarks. Specimens were obtained from a gill net/ tangle net set overnight in the vicinity of Pulau Ubin.

Order Dendrochirotida Grube, 1840

Family Cucumariidae Ludwig, 1894

Genus *Leptopentacta* Clark, 1938

***Leptopentacta imbricata* (Semper, 1867)
(Figs. 2D, 4D)**

Material examined. ZRC.ECH.0271 (1 ex.), ZRC.ECH.0272 (2 ex.), ZRC.ECH.0273 (1 ex.), ZRC.ECH.0274 (2 ex.), ZRC.ECH.0275 (3 ex.), ZRC.ECH.0276 (1 ex.), ZRC.ECH.0277 (1 ex.), ZRC.ECH.0278 (3 ex.), ZRC.ECH.0279 (1 ex.), ZRC.ECH.0280 (1 ex.), ZRC.ECH.0281 (1 ex.), ZRC.ECH.0282 (1 ex.).

Field description. Rigid pentagonal shaped body, tapered towards posterior end. With regularly arranged, single row tube feet along ambulacra. Each row has 11 to 24 tube feet depending on the length of the animal. Living specimens faint yellowish white to brown in colour. Preserved specimens 1.8–3.1 cm in length.

Ossicles of body wall. Mostly thick knobbed buttons of variable sizes, up to 67 µm. Rosettes and cupped rosettes, up to 32 µm. Multi-layered scales up to 1 mm in length.

Distribution in Johor Straits. Found at both the western and eastern sides of Johor Straits in muddy or sandy substratum mixed with marine shells. Subtidal.

Genus *Mensamaria* Clark, 1946

***Mensamaria intercedens* (Lampert, 1885)
(Figs. 2E, 4E)**

Material examined. ZRC.ECH.0283 (2 ex.), ZRC.ECH.0284 (MRH108742) (1 ex.), ZRC.ECH.0285 (MRH108768) (1 ex.), ZRC.ECH.0286 (1 ex.), ZRC.ECH.0287 (8 ex.), ZRC.ECH.0288 (1 ex.), ZRC.ECH.0289 (1 ex.).

Field description. Spindle-shaped body. Distinctive black body with bright orange tube feet restricted to ambulacra. Tentacles 30. Preserved specimens 3.7–8 cm in length.

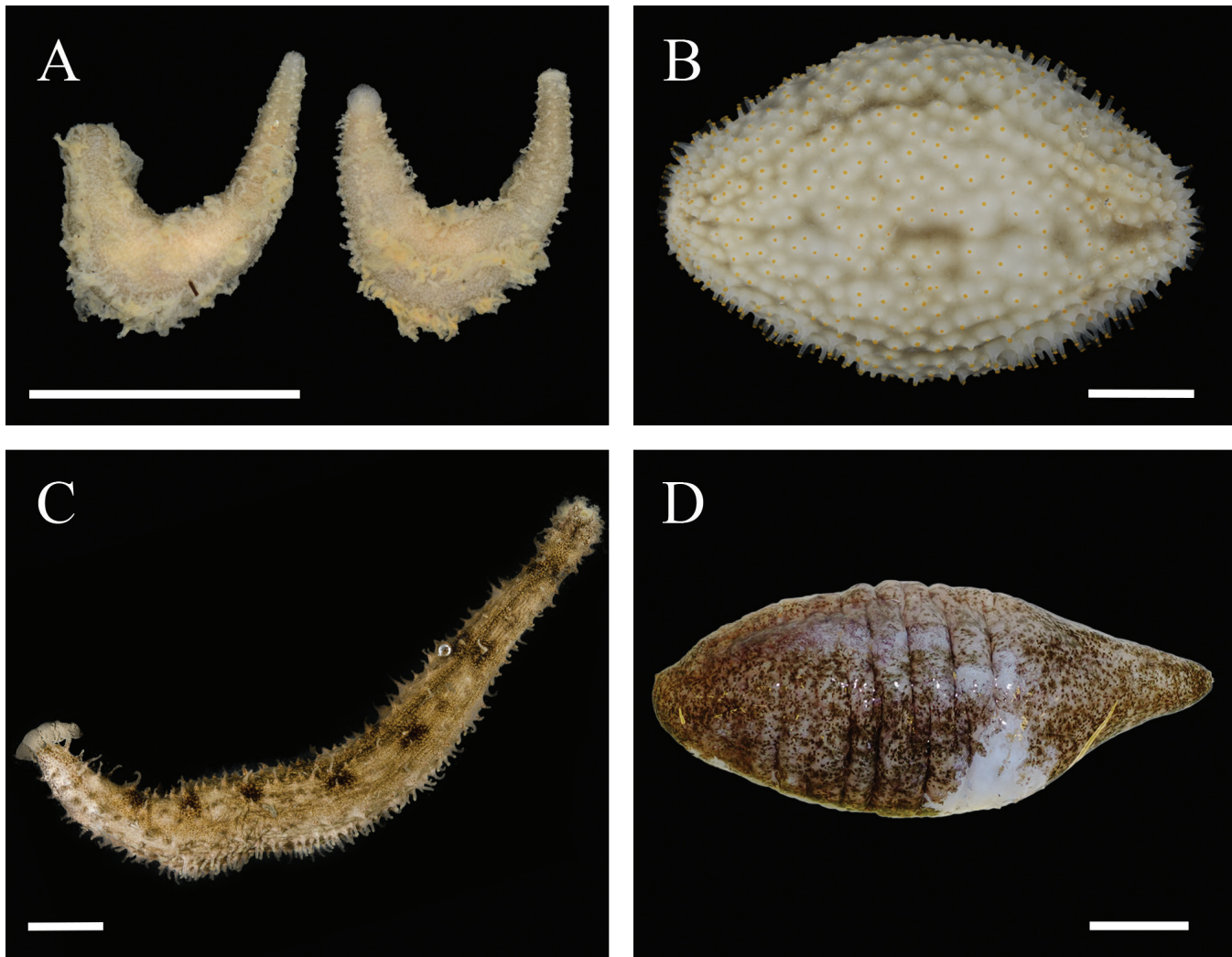


Fig. 3. Sea cucumbers from the Johor Straits, Singapore. A, *Thorsonia adversaria* (Semper, 1867), ZRC.ECH.0332; B, *Cladolabes hamatus* Sluiter, 1914, ZRC.ECH.0203; C, *Holothuria (Metriatyla) albiventer* Semper, 1867, ZRC.ECH.0266, upper: ventral side, lower: dorsal-ventral side; D, *Acaudina leucoprocta* (H. L. Clark, 1938), ZRC.ECH.0150. Scale bars = 1 cm [A]; 2 cm [B–D].

Ossicles of body wall. Two-pillared tables with an asymmetrical disc. Discs usually 56–97 μm in diameter, with four large holes and four or more marginal holes. Spires usually 59–76 μm in height.

Distribution in Johor Straits. Pulau Sekudu (eastern side of Johor Straits) in sandy/ rocky substratum. Intertidal.

Family Phyllophoridae Östergren, 1907

Genus *Thorsonia* Heding, 1940

Thorsonia adversaria (Semper, 1867) (Figs. 3A, 4F)

Material examined. ZRC.ECH.0332 (1 ex.), ZRC.ECH.0333 (1 ex.).

Field description. Small species. Faint beige-yellow or greyish body wall. Spindle-shaped body with both ends tapered significantly, usually bent into C-shaped. Tube feet restricted to ambulacra, denser at ventral side. The roughness of the skin is due to the densely distributed tiny ossicle spikes

(visible to the naked eye) piercing through the body wall. Tentacles eight to 10 (?), of which two ventral tentacles are smaller. Number of tentacles is difficult to be identified due to the small slender sizes and the state of contraction state of the tentacles. Preserved specimens less than 6 cm in length.

Ossicles of body wall. Tables of variable sizes, with a four-arm (occasionally five-arm) disc and a high single pillar. Diameter of disc up to 500 μm .

Distribution in Johor Straits. Off southeast of Pulau Sekudu (eastern side of Johor Straits). Collected by dredge. Sandy substratum mixed with dead shells. Subtidal.

Family Sclerodactylidae Panning, 1949

Genus *Cladolabes* Brandt, 1835

Cladolabes hamatus Sluiter, 1914 (Figs. 3B, 5B)

Material examined. ZRC.ECH.0203 (MRH108836) (1 ex.).

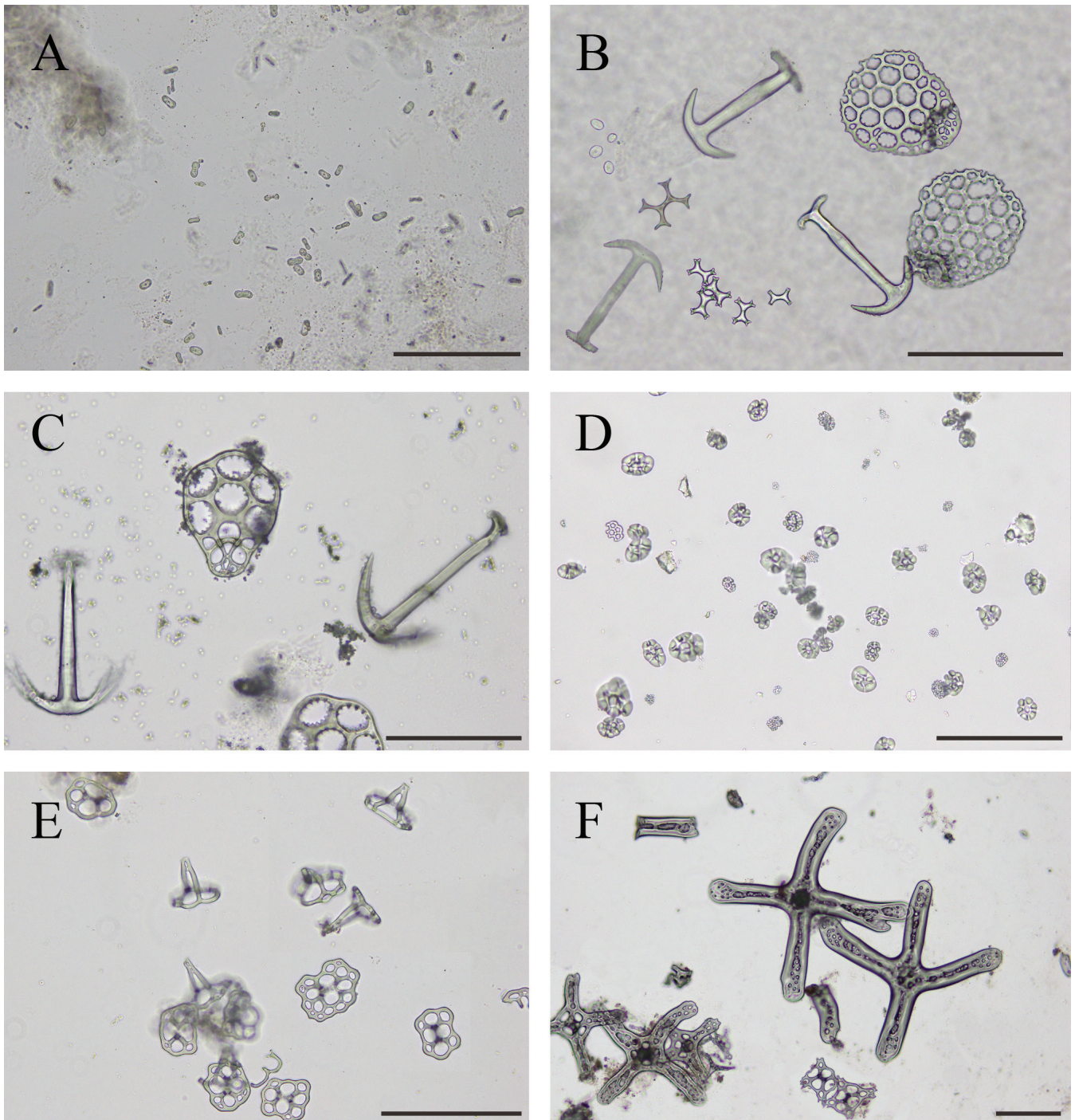


Fig. 4. Body wall ossicles of sea cucumbers from the Johor Straits, Singapore. A, *Anapta gracilis* (Semper, 1867), ZRC.ECH.0186; B, *Protankyra pseudodigitata* (Semper, 1867), ZRC.ECH.0291; C, *Synaptula recta* (Semper, 1867), ZRC.ECH.0328; D, *Leptopentacta imbricata* (Semper, 1867), ZRC.ECH.0274; E, *Mensamaria intercedens* (Lampert, 1885), ZRC.ECH.0286; F, *Thorsonia adversaria* (Semper, 1867), ZRC.ECH.0332. Scale bars = 200 μ m.

Field description. Oval to stout spindle shaped. White with some shades of greenish grey, covered with numerous evenly distributed orange tipped tube feet. Tentacles 20 (15 large and 5 small). Preserved specimen 7.5 cm in length.

Ossicles of body wall. Rod-like tables (spire 76–93 μ m in height, disc 25–40 μ m) with reduced discs, hook-like tables (spire 167–195 μ m in height, disc 80–90 μ m in diameter) from papillae and small oval cups (30–41 μ m in diameter) with smooth or spinous margin.

Distribution in Johor Straits. Off southeast of Pulau Sekudu (eastern side of Johor Straits). Collected by dredge. Sandy substratum mixed with dead shells. Subtidal.

Remarks. A specimen of *Cladolabes hamatus* was recently recorded by Mucharin (2008) in the Gulf of Thailand. Prior to that it was recorded from Indonesia (Heding & Panning, 1954; Sluiter, 1914) and Northern Australia (Deichmann, 1944). Specimens collected in the Johor Straits were lighter in body wall colour compared with the “dark grey” of the single specimen described by Mucharin (2008).

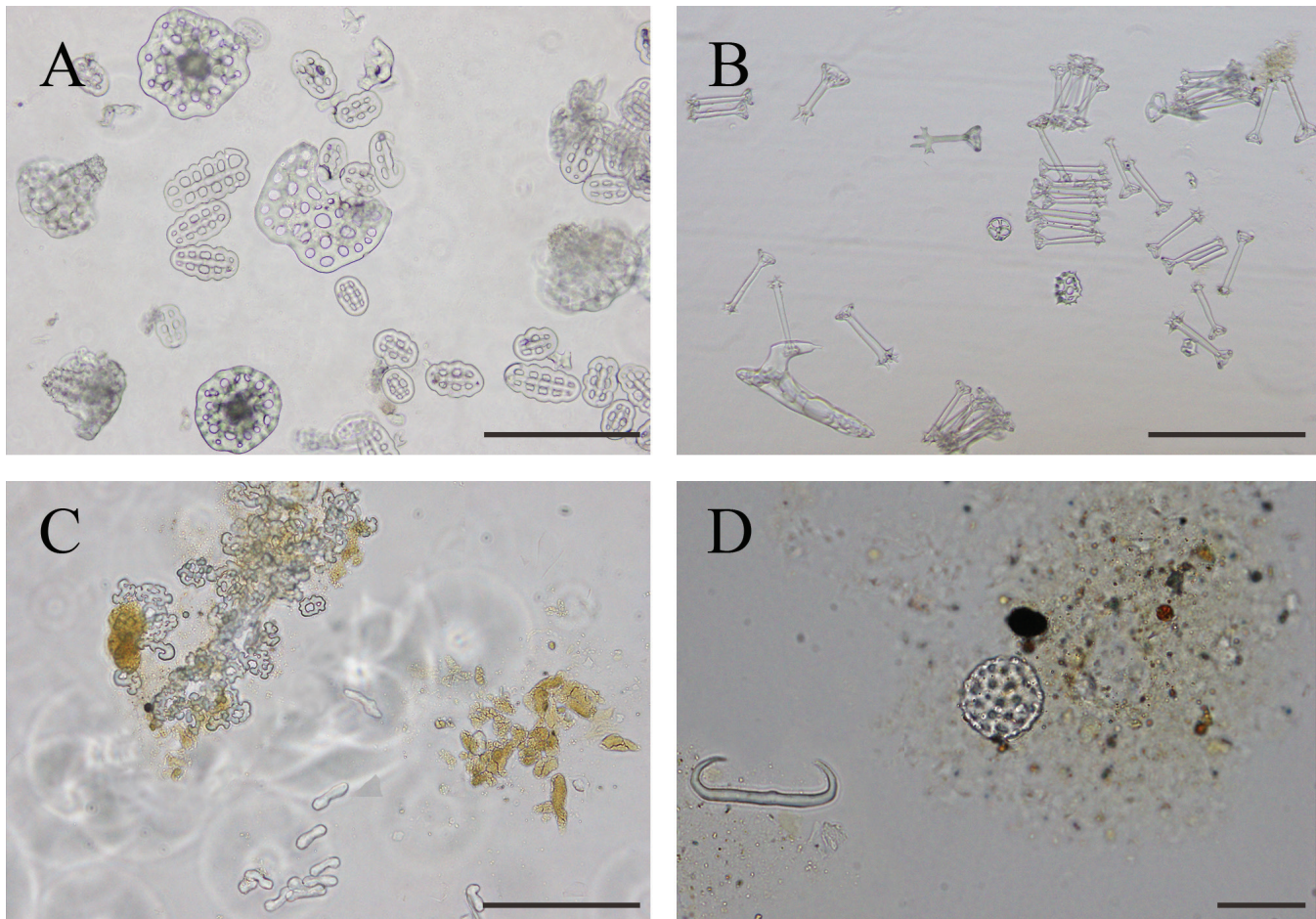


Fig. 5. Body wall ossicles of sea cucumbers from the Johor Straits, Singapore. A, *Holothuria (Metriatyla) albiventer* Semper, 1867, ZRC.ECH.0265; B, *Cladolabes hamatus* (Sluiter, 1914), ZRC.ECH.0203; C, *Acaudina leucoprocta* (H. L. Clark, 1938), ZRC.ECH.0150; D, *Acaudina molpadioides* (Semper, 1867), ZRC.ECH.0154. Scale bars = 200 μ m [A–B]; 100 μ m [C]; 20 μ m [D].

Order Aspidochirotida Grube, 1840

Family Holothuriidae Burmeister, 1837

Genus *Holothuria* (*Metriatyla*) Rowe, 1969

Holothuria (Metriatyla) albiventer Semper, 1867 (Figs. 3C, 5A)

Material examined. ZRC.ECH.0265 (1 ex.).

Field description. Slender long body with slightly tapered ends. Living specimen about 20 cm in length. With two parallel series of large dark ‘spots’ arranged longitudinally along dorsal wall. Lighter brown on ventral side. Papillae denser on ventral and ventral-lateral body walls. Tentacles 20. Found covered with mud and sand. Colour patterns revealed after removal of sediment from body surface.

Ossicles of body wall. Knobbed or smooth buttons, 51–126 μ m in length, with 3–7 pairs of holes. Tables with discs of 76–120 μ m in diameter, with smooth and undulating margin; 4–10 pillars; crown of spires with cluster of spines.

Distribution in Johor Straits. Changi (eastern side of Johor Straits). Muddy sandy substratum. Subtidal.

Order Molpadida Haeckel, 1896

Family Caudinidae Heding, 1931

Genus *Acaudina* Clark, 1908

Acaudina leucoprocta H. L. Clark, 1938 (Figs. 3D, 5C)

Material examined. ZRC.ECH.0150 (1 ex.), ZRC.ECH.0151 (1 ex.), ZRC.ECH.0152 (1 ex.), ZRC.ECH.0153 (1 ex.).

Field description. Stout spindle-shaped when contracted, tapering towards the posterior end. Smooth and slimy body wall. Brownish orange or brown-black freckles densely distributed all over body wall. The dark coloration seems to retain only at surface layer. White opaque body wall is revealed when the dark surface layer disintegrated or rubbed off during collection (Fig. 3D). Colour and thickness of body wall variable, depending on the state of contraction of the body wall. Tentacles 15, each with a pair of lateral digits. Preserved specimens 4–13.3 cm in length.

Ossicles of body wall. Irregular perforated plates and irregular rosette-like branched rods, 15–25 μ m in length. Rods, straight or with rounded ends, some are dumbbell-shaped, thick or thin, 15–29 μ m in length.

Table 3. Subtidal sea cucumber collecting sites (as indicated by circles on Fig. 1).

Subtidal Collection Site	Station Number	Latitude	Longitude	Depth	Collection Date	Substratum
1	DR285	1°18.426' (Start); 1°18.263' (End)	103°37.073' (Start); 103°37.012' (End)	7.2–7.5 m	11 February 2014	Sand + Mud + Dead shell
2	DR286	1°19.911' (Start); 1°19.705' (End)	103°37.657' (Start); 103°37.544' (End)	7.5–7.7 m	11 February 2014	Sand + Mud + Dead shell
3	DR371	1°22.530' (Start); 1°22.308' (End)	103°38.921' (Start); 103°38.850' (End)	10.6–12.4 m	09 April 2014	Laterite gravel + Mud
4	3923 TO1	1°23.824' (Start); 1°23.734' (End)	103°39.401' (Start); 103°39.382' (End)	8.1–11.4 m	27 June 2012	Mud
5	3924 DR1	1°24.046' (Start); 1°24.000' (End)	103°39.574' (Start); 103°39.519' (End)	7.2–13.2 m	27 June 2012	Mud
6	DR367	1°26.214' (Start); 1°26.360' (End)	103°41.459' (Start); 103°41.603' (End)	7.3–10.0 m	09 April 2014	Mud + Sand
	DR368	1°26.454' (Start); 1°26.619' (End)	103°41.648' (Start); 103°41.778' (End)	8.8–9.2 m	09 April 2014	Mud + Sand
7	DR219	1°26.271' (Start); 1°26.329' (End)	103°51.748' (Start); 103°51.719' (End)	5.2–5.6 m	07 October 2013	Mud
8	DW66	1°25.729' (Start); 1°25.623' (End)	103°53.367' (Start); 103°53.687' (End)	13.9 m	23 October 2013	Mud
9	DR264	1°25.360' (Start); 1°25.385' (End)	103°54.201' (Start); 103°54.497' (End)	11.2–11.3 m	16 January 2014	Mud + Sand
10	DW36	1°24.545' (Start); 1°24.780' (End)	103°55.992' (Start); 103°55.764' (End)	16.8–18.6 m	19 October 2012	Mud + Shell
	DW37	1°24.822'	103°55.613'	15.0 m	19 October 2012	Mud + Shell
	DW61	1°24.962' (Start); 1°25.207' (End)	103°55.341' (Start); 103°55.154' (End)	7.4–11.0 m	23 October 2012	Mud
11	DW17	1°25.110'	103°55.722'	N.A.	16 October 2012	N.A.
	DW18	1°25.794' (Start); 1°25.647' (End)	103°55.897' (Start); 103°55.592' (End)	6.2–12.9 m	17 October 2012	Mud
	DW38	1°25.021' (Start); 1°25.225' (End)	103°55.377' (Start); 103°55.126' (End)	13.5–14.7 m	19 October 2012	Mud
12	DR218	1°25.669' (Start); 1°25.635' (End)	103°56.373' (Start); 103°56.497' (End)	11.8–14.6 m	07 October 2013	Mud
	DW20	1°25.570' (Start); 1°25.492' (End)	103°56.524' (Start); 103°56.765' (End)	10.3–10.6 m	17 October 2012	Mud
13	DW119	1°23.912' (Start); 1°23.875' (End)	103°58.577' (Start); 103°58.512' (End)	17.3–18.2 m	29 October 2012	Sand
	DW120	1°23.934' (Start); 1°23.742' (End)	103°58.629' (Start); 103°58.372' (End)	20.6–21.4 m	29 October 2012	Sand + Mud
	DW40	1°23.797' (Start); 1°23.768' (End)	103°58.751' (Start); 103°58.908' (End)	15.6–21.0 m	19 October 2012	Mud + Shell
14	DW117	1°23.619' (Start); 1°23.564' (End)	103°59.441' (Start); 103°59.855' (End)	5.3–9.9 m	29 October 2012	Mud
	DW86	1°23.581' (Start); 1°23.529' (End)	103°59.593' (Start); 103°59.990' (End)	5.6–14.7 m	25 October 2012	Mud
15	DW27	1°24.927' (Start); 1°25.273' (End)	103°59.980' (Start); 103°59.692' (End)	19.1–9.9 m	18 October 2012	Mud
	DW29	1°24.954' (Start); 1°24.956' (End)	103°59.906' (Start); 103°59.995' (End)	13.4–24.7 m	18 October 2012	Sand + Mud
	DW4	1°24.176' (Start); 1°24.132' (End)	103°59.489' (Start); 103°59.686' (End)	6.9–7.3 m	16 October 2012	Sand + Shell
16	MF20	1°25.356' (Start); 1°24.092' (End)	103°59.882' (Start); 103°59.901' (End)	10.0 m	29 June 2011	Mud + Shell
17	DW89	1°24.242' (Start); 1°24.542' (End)	104°00.444' (Start); 104°00.208' (End)	20.5–22.1 m	25 October 2012	Mud

Table 3...continued

Subtidal Collection Site	Station Number	Latitude		Longitude	Depth	Collection Date	Substratum
18	DW78	1°22.720' (Start); 1°22.997' (End)	104°01.221' (Start); 104°00.692' (End)	20.5–23.6 m	24 October 2012	Sand + Broken shell + Mud	
19	DR342	1°26.284' (Start); 1°26.091' (End)	104°01.416' (Start); 104°02.163' (End)	4.7–4.9 m	25 Mar 2014	Sand + Broken shell + Mud	
20	DR362	1°18.522' (Start); 1°18.874' (End)	104°02.751' (Start); 104°02.672' (End)	17.5–10.9 m	08 April 2014	Mud + Sand + Big rock	
21	DW87	1°20.178' (Start); 1°19.732' (End)	104°02.322' (Start); 104°02.507' (End)	7.3–8.1 m	25 October 2012	Mud	
22	DW130	1°20.546' (Start); 1°20.591' (End)	104°03.913' (Start); 104°03.900' (End)	18.5–18.7 m	30 October 2012	Sand	
23	DR337	1°26.254' (Start); 1°26.356' (End)	104°03.183' (Start); 104°02.929' (End)	7.9–8.6 m	25 Mar 2014	Sand + Broken shell + Ash	
24	DW129	1°19.075' (Start); 1°19.318' (End)	104°04.249' (Start); 104°03.868' (End)	21.7–22.5 m	30 October 2012	Mud + Clay	
25	DW57	1°25.342' (Start); 1°24.949' (End)	104°04.775' (Start); 104°05.080' (End)	10.3–10.6 m	22 October 2012	Sand + Shell	
	DW82	1°25.241' (Start); 1°25.119' (End)	104°04.827' (Start); 104°04.964' (End)	8.1–11.6 m	24 October 2012	Laterite gravel	
26	DW55	1°25.003' (Start); 1°25.097' (End)	104°05.049' (Start); 104°04.997' (End)	11.6–13.0 m	22 October 2012	Laterite gravel + Shell	
	DW80	1°25.073' (Start); 1°25.241' (End)	104°05.028' (Start); 103°04.891' (End)	10.3–11.7 m	24 October 2012	Sand + Shell	

Distribution in Johor Straits. East and west Johor Straits. Muddy or muddy sandy substratum. Intertidal and subtidal.

Acaudina molpadioides (Semper, 1867)
(Fig. 5D)

Material examined. ZRC.ECH.0154 (1 ex.).

Field description. Living animals were not examined. Preserved individuals flattened, stout, somewhat elliptical in outline with very short tapered caudal end. Preserved colour grey with dark brown-black patches. Tentacles 15, each with a pair of lateral digits. Preserved specimen 2.5 cm in length.

Ossicles of body wall. A few dumbbell-shaped rods (15–25 µm in length), one perforated plate (20 µm in diameter) and two C-shaped ossicles (25 µm and 35 µm respectively).

Distribution in Johor Straits. Changi (eastern side of Johor Straits). Muddy substratum. Subtidal.

DISCUSSION

The 30 species of holothuroids reported in this study herewith represent a first comprehensive taxonomic record of holothuroids found in the Johor Straits, Singapore, with a focus on muddy and sandy-muddy habitats in both intertidal and subtidal areas. With the exception of the potential 10 new species whose status remain undetermined, the other species are typical Indo-Pacific species and all of them have been reported elsewhere in South China Sea (Liao, 1997; Lane et al., 2000). Nonetheless, 11 of them are new records for Singapore.

Prior to the Comprehensive Marine Biodiversity Survey (CMBS), 33 species of holothuroids have been recorded for Singapore in the form of scientific publications and field guide entries (Table 4). Many of the reported species are holothuroids often found on reef flats, among seagrass or algae. Of these 33 species, 11 species were previously sighted or collected from the Johor Straits, Singapore. Five (i.e., *Cercodemus anceps*, *Colochirus quadrangularis*, a *Leptopentacta* species, a *Protankyra* species and *Pseudocolochirus violaceus*) were found in this study (Table 1). There appears to be little overlap in the species composition between this study and those previously recorded, and this is probably due to the focus on soft sediment habitats of the Johor Straits during the CMBS survey. Consequently, more non-reefal species were discovered herein. Adding to the previous records, there is now a total of some 58 species of holothuroids recorded for Singapore waters. This is a small number compared to the more than 200 species documented in the South China Sea (Lane et al., 2000) but the results of this study are based on a much smaller surveyed area (the around 50 km long Johor Straits) and attest to the diversity of sea cucumbers in this unlikely estuarine habitat.

Table 4. List of 33 species of holothuroids documented from Singapore.

Family	Species	Locality and Habitat Description in Singapore	Literature Source	Remarks
Order Synaptida Cuénot, 1891 (sensu Smirnov 2012)				
Synaptidae	<i>Ophedoesoma grisea</i> (Semper, 1867)	No mention of exact locality (reef)	Chou, 1988	Brief mention of its occurrence without illustration or description.
	<i>Polyplectana kefersteinii</i> (Selenka, 1867)	Singapore (reef slopes and reef flats)	Lane & VandenSpiegel, 2003	Morphological description with photograph in Lane & VandenSpiegel (2003).
	<i>Protankyra</i> species	Singapore Straits (dredged off East Coast Park)	Lane & VandenSpiegel, 2003	Morphological description with photograph in Lane & VandenSpiegel (2003).
Order Aspidochirotida Grube, 1840				
Holothuriidae	<i>Actinopyga lecanora</i> (Jaeger, 1833)	Singapore Straits (reef)	Chou, 1988; Lim & Chou, 1988; Lane & VandenSpiegel, 2003; Ng et al., 2011	Morphological description with photograph in Lane & VandenSpiegel (2003).
	<i>Actinopyga</i> species	Singapore Straits (reef slope at Sultan Shoal)	Lane & VandenSpiegel, 2003	Morphological descriptions with photograph.
	<i>Bohadschia ocellata</i> Jaeger, 1833	Johor Straits and Singapore Straits (Changi Beach, beside Changi Ferry Terminal, Pulau Seringat)	Teo & Ng, 2009 [<i>Holothuria ocellata</i>]	Taxonomic description.
	<i>Bohadschia vitiensis</i> (Semper, 1868)	Singapore Straits (Seagrass on reef flat of Cyrene Reef)	Lane & VandenSpiegel, 2003	Morphological description with photograph.
	<i>Holothuria (Platyperona) difficilis</i> Semper, 1868	No mention of exact locality (reef)	Chou et al., 1994 [<i>Microthele difficilis</i>]	Brief mention of its occurrence without illustration or description.
	<i>Holothuria (Halodeima) edulis</i> Lesson, 1830	Singapore Straits (reef)	Chou, 1988 [<i>Halodeima edulis</i>]	Brief mention of its occurrence without illustration or description.
	<i>Holothuria (Stauropora) fuscocinerea</i> Jaeger, 1833	Singapore Straits (seawall at Tanah Merah Ferry Terminal, intertidal zone of Beting Bemban Besar, Pulau Jong, Pulau Semakau and Pulau Subar Laut)	Teo et al., 2010a; Ng et al., 2011 [<i>Holothuria fuscocinerea</i>]	Taxonomic description in Teo et al. (2010a).
	<i>Holothuria (Thymiosycia) impatiens</i> (Forskål, 1775)	No mention of exact locality (reef)	Lim & Chou, 1988	Brief mention of its occurrence without illustration or description.

Table 4...continued

Family	Species	Locality and Habitat Description in Singapore	Literature Source	Remarks
Stichopodidae	<i>Holothuria (Mertensiothuria) leucospilota</i> (Brandt, 1835)	Singapore Straits (reef flat at Sentosa)	Chou, 1988 [<i>Holothuria vagabunda</i>]; Chou et al., 1994 [<i>Holothuria leucospilota</i>]; Lane & VandenSpiegel, 2003 [<i>Holothuria leucospilota</i>]; Ng et al., 2011 [<i>Holothuria leucospilota</i>]	Morphological description with photographs in Lane & VandenSpiegel (2003).
	<i>Holothuria (Metriatyla) scabra</i> Jaeger, 1833	Singapore Straits (Changi beach, reef flats of southern islands, Chek Jawa and Pulau Ubin)	Tan & Ng, 1988; Chou et al., 1994 [<i>Holothuria scabra</i>]; Lane & VandenSpiegel, 2003 [<i>Holothuria scabra</i>]; Ng et al., 2011 [<i>Holothuria scabra</i>]	Morphological description with photograph in Lane & VandenSpiegel (2003).
	<i>Holothuria (Lessonothuria)</i> species	No mention of exact locality (reef)	Lim & Chou, 1988	Brief mention of its occurrence without illustration or description.
	<i>Stichopus chloronotus</i> Brandt, 1835	No mention of exact locality	Chou, 1993	Brief mention of its occurrence without illustration or description.
	<i>Stichopus hermanni</i> Semper, 1868	Singapore Straits (reef slope of Pulau Hantu)	Lane & VandenSpiegel, 2003	Morphological descriptions with photographs in Lane & VandenSpiegel (2003).
	<i>Stichopus horrens</i> Selenka, 1867	No mention of exact locality (reef)	Lim & Chou, 1988 [<i>Stichopus variegatus</i>]; Ng et al., 2011	Brief mention of its occurrence without illustration or description.
	<i>Stichopus ocellatus</i> Massin, Zulficar, Hwai & Boss, 2002	Singapore Straits (reef slope at Pulau Semakau)	Lane & VandenSpiegel, 2003; Ng et al., 2011	Morphological descriptions with photographs in Lane & VandenSpiegel (2003).
	<i>Stichopus vastus</i> Sluiter, 1887	No mention of exact locality (reef)	Lane & VandenSpiegel, 2003	Morphological descriptions with photograph in Lane & VandenSpiegel (2003).
	Order Dendrochirotida Grube, 1840			
	<i>Cercodemas anceps</i> Selenka, 1867	Johor Straits (beach of Changi and Pulau Ubin)	Lane & VandenSpiegel, 2003	Morphological description with photograph.
Cucumariidae	<i>Colochirus quadrangularis</i> Troschel, 1846	Johor Straits and Singapore Straits (seagrass and seaweed on Changi Beach and Chek Jawa, southern islands)	Goh et al., 1999; Lane & VandenSpiegel, 2003; Ng et al., 2011	Morphological descriptions with photograph in Lane & VandenSpiegel (2003).
	Cucumariid species 1	Johor Straits (beach at Changi, Pulau Ubin, trawled at Pulau Tekong)	Lane & VandenSpiegel, 2003	Morphological description with photograph.

Table 4...continued

Family	Species	Locality and Habitat Description in Singapore	Literature Source	Remarks
	Cucumarid species 2	Johor Straits (intertidally and subtidally in Changi-Ubin-Tekong area)	Lane & VandenSpiegel, 2003	Morphological description with photograph.
	Cucumarid species 3	Johor Straits (algae and sea grass near the low tide mark at Chek Jawa)	Lane & VandenSpiegel, 2003	Morphological description with photograph.
	<i>Leptopentacta imbricata</i> (Semper, 1867)	Singapore Straits (East Coast Park)	Lane & VandenSpiegel, 2003	The species was identified by Lane & VandenSpiegel (2003) as ' <i>Leptopentacta imbricata</i> ' in a caption accompanying the illustration. However, the text referred to it as <i>Leptopentacta</i> species and mentioned it as the first record of this genus in Singapore waters. We have confirmed its presence in Singapore and Johor Straits.
	<i>Pentacta</i> species	No mention of exact locality. Sandy/muddy area.	Tan & Ng, 1988	Brief mention of its occurrence with photograph.
	<i>Pseudocolochirus violaceus</i> (Th��el, 1886)	Johor Straits and Singapore Straits (Changi Beach, Chek Jawa, reef slope of Pulau Semakau)	Chou et al., 1994 [<i>Pseudocolochirus axiologus</i>]; Lane & VandenSpiegel, 2003; Ng et al., 2011	Morphological descriptions with photograph in Lane & VandenSpiegel (2003).
Phyllophoridae	<i>Hemithyone</i> species	Singapore Straits (reef)	Lim & Chou, 1988	Not found in this survey.
	<i>Phyllophorus</i> (<i>Phyllophorella</i>) <i>spiculata</i> (Chang, 1935)	Johor Straits (in sediment at or below the low water mark at Changi beach and Pulau Ubin)	Chou et al., 1994 [<i>Phyllophorus parvipedes</i>]; Lane & VandenSpiegel, 2003 [<i>Phyllophorus spiculata</i>]	Morphological descriptions. It is possible that all the <i>Phyllophorus</i> (<i>Phyllophorella</i>) <i>spiculata</i> photographed and described in Lane & VandenSpiegel (2003) were the <i>Globosita</i> potential species found in this study. Brief mention of name in Chou et al., 1994.
	<i>Stolus buccalis</i> (Stimpson, 1855)	No mention of exact locality (reef)	Lim & Chou, 1988	Brief mention of its occurrence.
<i>Sclerodactylidae</i>	<i>Afrocucomis africana</i> (Semper, 1867)	Johor Straits and Singapore Straits (Pulau Sakijang Pelepah, Changi Beach, Chek Jawa, Pulau Sakijang Bendera, Pulau Satumu, Pulau Semakau, Sentosa and Sultan Shoal)	Chou et al., 1994 [<i>Pseudocucomis africanus</i>]; Teo et al., 2010b; Ng et al., 2011	Taxonomic description in Teo et al. (2010b)

Table 4...continued

Family	Species	Locality and Habitat Description in Singapore	Literature Source	Remarks
Order Molpadida Haeckel, 1896				
Caudinidae	<i>Paracaudina australis</i> (Semper, 1868)	Johor Straits (subtidally in dredge samples in Changi-Ubin-Tekong area, intertidally at Changi Beach and Chek Jawa)	Lane & VandenSpiegel, 2003	The photographed specimen of ' <i>Paracaudina australis</i> (Semper, 1868)' is likely to be a new species of <i>Acaudina</i> found in this study.
Order Elasipodida Théel, 1882				
Pelagothuriidae	<i>Pelagothuria</i> species	No mention of exact locality	Chou et al., 1994	This is a doubtful record as the only valid species in this genus is <i>Pelagothuria natatrix</i> (Ludwig, 1893), a deep sea pelagic species found at depths of 542 – 6776 m from eastern Pacific Ocean and Indian Ocean (Chun 1900; Clark, 1938; Ludwig, 1893; Miller & Pawson, 1990).

The Johor Straits is a narrow water body between the Johor and Singapore Island. It is typically 1.8 km wide over a length of about 50 km, and is separated into east and west sections by the Johor Bahru–Singapore Causeway (Fig. 1) since 1923. Ecologically, both East and West Johor Straits experience estuarine conditions and the resulting habitats observed differ considerably from those seen elsewhere in the Singapore Strait and the open sea. While both sections are affected by the tides, there is little exchange of water between them, which receive freshwater input from rivers in Johor and Singapore. Hence the Johor Straits is estuarine in nature, with typical salinities ranging between 19 and 33 ppt (Gin et al., 2000; Hajisamae & Chou, 2003). Such salinity fluctuations are generally not experienced in the Singapore Strait where the salinity ranges from 28.7 to 32.2 ppt (Gin et al., 2000) with fluctuations caused by rainfall episodes (Hajisamae & Chou, 2003; Wood et al., 1997). Although several species of hexacoralline corals can be found at Tuas and Pulau Ubin at the mouths of the East and West Johor Straits respectively, the seabed substratum within a few kilometres east and west of the Causeway consists of anoxic mud where benthic fauna is depauperate (Wood et al., 1997; unpublished CMBS seabed survey observations). Sea cucumbers were most diverse and abundant at both the easternmost (Pulau Ubin and east coast of Singapore mainland) and westernmost (Tuas) sections of the Johor Straits.

The most commonly encountered species in the Johor Straits has not been determined to date, but it is a possible new species in the sclerodactylid genus *Globosita*. It was often abundant in intertidal and subtidal sandy or muddy substrata in the East Johor Strait. Other common holothuroids were *Anapta gracilis* and *Actinocucumis* cf. *typica*. The former species were collected from intertidal mudflats, whilst the latter species occurred subtidally on sandy-mud or lateritic gravel substrata.

Based on the photographs of *Paracaudina australis* and *Phyllophorus* (*Phyllophorella*) *spiculata* in Lane & VandenSpiegel (2003) and specimens collected more recently in the Johor Straits, the two species were probably misidentified and are likely to represent possible new species in the genera *Acaudina* and *Globosita* respectively. A living specimen of *Protankyra* sp. also illustrated in Lane & VandenSpiegel (2003) showing red flecks on its body wall may be a third species in this genus occurring in the Johor Straits, since this characteristic does not occur in either of the two *Protankyra* species reported in this study. However, we could not determine the identity of the specimen illustrated by Lane & VandenSpiegel (2003) as we were unable to locate voucher specimens of the illustrated species. Several of the possible new species, including *Globosita* and *Acaudina* species, as well as *Thyone* species c, were not uncommon in the Johor Straits.

In contrast to some common species of holothuroids, some half of the total number of species identified in this study were collected only from a single site, and they were generally in small numbers. The scarcity of specimens

presented difficulties in taxonomic work. The small number of specimens obtained may be a result of their low density and/or the difficulty in collecting because of their small size and burrowing habit. While the survey was unprecedented in its frequency and coverage, there is still a distinct possibility that more species can be found in the Johor Straits. Further investigation of the ecology of sea cucumbers is also essential to facilitate the understanding of the ecological roles of this understudied yet prominent group of fauna in Singapore.

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