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## Extant Crinoidea (Echinodermata) of Singapore

Charles G. Messing<sup>1</sup> & Teresa S. Tay<sup>2</sup>

**Abstract.** The crinoid fauna of Singaporean waters now includes approximately 39 nominal species belonging to six families, all in Order Comatulida. Seventeen of the 22 species collected during the Singapore Strait Biodiversity Workshop (May–June 2013) were previously known from the area. Of the remaining five, *Cenometra bella* (Colobometridae) is definitely a new record for Singapore, while the taxonomic status of the other four is uncertain. Seventeen additional species, collected almost entirely in the nineteenth and early twentieth centuries, were not represented in the 2013 survey.

**Key words.** Crinoidea, feather star, Singapore, comatulid, echinoderm

### INTRODUCTION

Collections of living crinoids from Singaporean waters have previously included 34 nominal species in six families of Order Comatulida, many of which are widespread in the tropical Indo-Western Pacific region. All are feather stars, an informal term for those members of the order that shed the postlarval stalk and take up a free existence. Comatulida also includes taxa that retain the stalk as adults (Rouse et al., 2013; Hemery et al., 2013). Early material was obtained via shore collecting by German malacologist Carl Eduard von Martens in 1862–1864 and Svend Gamel Gad, Consul for Denmark, in 1904–1910 (Günther, 1904; Lucas, 1906), and described by A. H. Clark (e.g., 1909a, 1931, 1941). This paper summarises information about the Singaporean crinoid fauna and includes material collected during the Singapore Strait Biodiversity Workshop (SSBW) from 17 May to 5 June 2013, as well as information about species reported only previously.

This survey collected 366 specimens belonging to approximately 22 crinoid species at depths ranging from just below the low tide line to 150 m. Of these, 17 were previously collected in Singaporean waters as well. The remaining five include one definite new record [*Cenometra bella* (Hartlaub, 1890)], and four belonging to genera that require taxonomic revision [*Comatula* sp., *Capillaster* cf. *tenuicirrus* A. H. Clark, 1912a, *Decametra* sp., and *Heterometra schlegelii* (A. H. Clark, 1908a)]. Seventeen other species, collected chiefly by von Martens and Gad but

not during the SSBW, bring the total number of nominal species known from Singaporean waters to approximately 39. A number of specimens collected during the SSBW could not be assigned with certainty to named genera or species, either because they may be juveniles or they belong to taxa in need of taxonomic revision. They have not been included in this paper.

Singapore lies at the western end of the Indo-Malayan Archipelago, which also includes Indonesia, the Philippines, Brunei, Papua New Guinea, Timor-Leste, and the islands of Malaysia. The shallow-water (roughly  $\leq 50$  m depth) crinoid fauna of this region consists of  $\sim 100$  nominal species and is the richest in the world. However, both older dredging and trawling efforts and more recent scuba-based surveys have recorded only  $\sim 40$ – $55\%$  of the fauna from any local area within the region (Messing, 1998a). Such small numbers relative to the entire fauna are likely due as much or more to insufficient collecting and inadequate taxonomy as to limited distributional ranges. Given the location of Singapore at the margin of this rich region, the estimated 39 recorded species is not an unexpectedly low number. Putschakarn & Sonchaeng's (2004) literature review recorded 39 species as well from Thai waters but used outdated taxonomy; currently accepted nomenclature (e.g., Messing 1998b; Rowe et al., 1986; Rankin & Messing, 2008) reduces this number to  $\sim 31$ . Similarly, Mekhova & Britayev (2012) listed 31 species (one may be a synonym) from the Bay of Nhatrang, Vietnam.

### MATERIAL AND METHODS

Specimens were obtained during SSBW via hand collecting in shallow water or via scuba, rock dredge and beam trawl. Specimens collected by hand were placed underwater in Ziploc plastic bags. The majority of specimens were preserved shortly after collection in 75% ethanol; a few were preserved in 95% ethanol. Colour descriptions are based on living animals unless otherwise stated. Small portions of selected specimens were also preserved in DMSO or

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frozen. Commensals and parasites were variously preserved in ethanol, formalin or DMSO. Morphological terminology follows Messing (1997, 2001), Messing et al. (2000), and Hess & Messing (2011). Figs. 1 and 2 illustrate major components and abbreviations associated with feather star morphology.

Repository abbreviations: BSNH—Boston Society of Natural History, Boston, MA; MCZ—Museum of Comparative Zoology, Harvard University, Cambridge, MA; MNB—Museum für Naturkunde, Berlin, Germany; MNHN—Muséum national d'Histoire naturelle, Paris; NHM—Natural History Museum, London; USNM—National Museum of Natural History, Smithsonian Institution, Washington DC (=United States National Museum); NRS—Naturhistorisch Rijksmuseum, Stockholm, Sweden; SIO-BIC—Benthic Invertebrate Collection, Scripps Institution of Oceanography University of California San Diego; YPM—Yale University Peabody Museum; ZMC—Zoologisk Museum, Copenhagen; ZMUH—Zoologisches Museum Universität Hamburg, Germany; ZRC.ECH—Zoological Reference Collection, Echinoderms (Lee Kong Chian Natural History Museum, National University of Singapore). Station alphanumeric include abbreviations for gear used: DR—rectangular dredge; IT—intertidal hand collection; SB, SD—scuba; SW—snorkeling/hand collection, and TB—beam trawl.

Collection data and numbers of specimens in the USNM were verified by online catalog searches at <http://collections.nmnh.si.edu/search/iz/>.

## TAXONOMIC SECTION

Table 1 lists all nominal species known from Singaporean waters. Asterisks indicate species collected during the SSBW.

### Family COMATULIDAE Fleming, 1828

**Remarks.** This family was previously called Comasteridae A. H. Clark, 1908c. However, the senior name Comatulidae Fleming, 1828, is correct (see Summers et al., 2014). Although article 23.2 of the International Code of Zoological Nomenclature (ICZN, 1999, p. 25) states that “the Principle of Priority is...not intended to be used to upset a long-accepted name”, article 23.9.1 requires that two conditions both be met in order to maintain prevailing usage. Comasteridae has indeed been widely and continuously used for over 50 years (article 23.9.1.2). However, the senior synonym Comatulidae and its coordinate subfamily name Comatulinae have been used after 1899 (articles 23.9.1.1, 36.1). A. H. Clark (1908b) fixed *Comatula solaris* Lamarck, 1816, as the type of *Comatula* in Comatulidae but subsequently (and incorrectly) changed the family name to Comasteridae (A. H. Clark, 1908c). See Summers et al. (2014) for a discussion of suprageneric taxa of Comatulidae.

Members of order Comatulida have traditionally been referred to informally as comatulids, a term used synonymously with feather star—those extant crinoids that shed the postlarval

Table 1. List of crinoid species known from Singaporean waters. Asterisks indicate species collected during the 2013 Biodiversity Survey.

Family	Species	
Comatulidae	* <i>Comatula</i> cf. <i>solaris</i>	
	* <i>Comatula</i> cf. <i>pectinata</i>	
	* <i>Comatula</i> sp.	
	* <i>Capillaster multiradiatus</i>	
	<i>Capillaster sentosus</i>	
	* <i>Capillaster</i> cf. <i>tenuicirrus</i>	
	* <i>Phanogenia typica</i>	
	<i>Phanogenia schoenovi</i>	
	<i>Comaster schlegelii</i>	
	<i>Comanthus parvicirrus</i>	
	<i>Anneissia bennetti</i>	
	Colobometridae	* <i>Colobometra perspinosa</i>
		* <i>Cenometra bella</i>
* <i>Decametra</i> sp.		
<i>Decametra informis</i>		
<i>Decametra mylitta</i>		
* <i>Oligometra serripinna</i>		
* <i>Pontiometa andersoni</i>		
Himerometridae	* <i>Himerometra robustipinna</i>	
	<i>Himerometra bartschi</i>	
	<i>Craspedometra acuticirra</i>	
	<i>Heterometra affinis</i>	
	<i>Heterometra amboinae</i>	
	<i>Heterometra bengalensis</i>	
	* <i>Heterometra</i> cf. <i>crenulata</i>	
	<i>Heterometra producta</i>	
	<i>Heterometra quinduplicava</i>	
	* <i>Heterometra schlegelii</i>	
	<i>Heterometra singularis</i>	
	* <i>Amphimetra</i> cf. <i>discoidea</i>	
	* <i>Amphimetra ensifer</i>	
<i>Amphimetra mollerii</i>		
Mariametridae	* <i>Dichrometra flagellata</i>	
	* <i>Lamprometra palmata</i>	
	* <i>Stephanometra tenuipinna</i>	
	* <i>Stephanometra indica</i>	
Zygommetridae	* <i>Zygommetra comata</i>	
“Antedonidae”	* <i>Dorometra nana</i>	
	<i>Dorometra parvicirra</i>	

stalk and take up a free existence. However, with Comatulidae replacing Comasteridae, comatulid could refer either to a member of the family or the order. In addition, because recent molecular-based phylogenies (Rouse et al., 2013; Hemery et al., 2013) incorporate stalked bourgueticrinine crinoids into Comatulida, comatulid and feather star are no longer equivalent. To avoid confusion, Summers et al. (2014) recommend using comatulid for members of Comatulidae. Feather star should be used as a non-taxonomic term for taxa that shed the postlarval stalk.

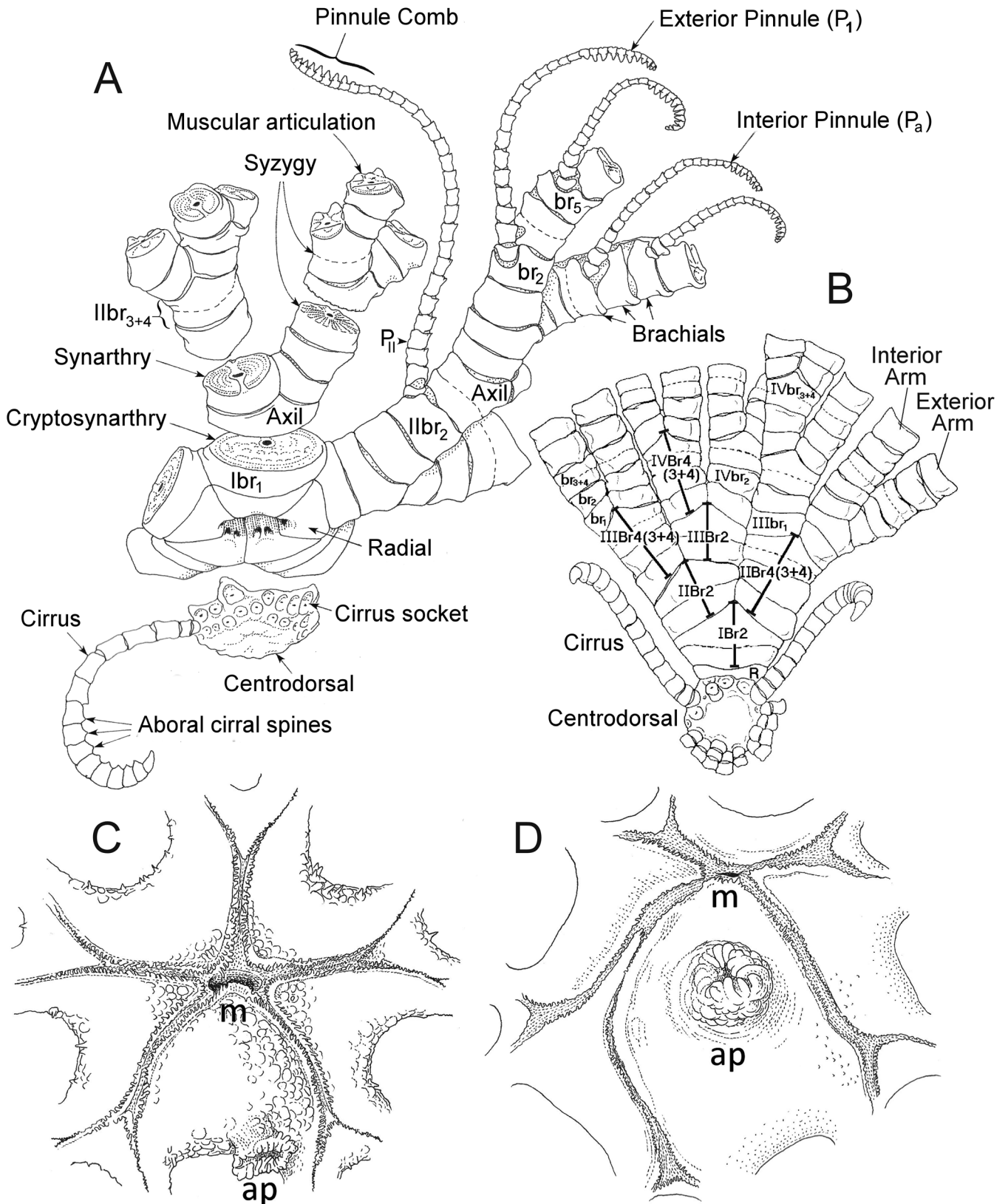


Fig. 1. Feather star morphology. A, exploded view of a feather star showing bases of two rays, types of articulations and ossicle nomenclature. Ibr<sub>1</sub> – first primibrachial ossicle; IIbr<sub>2</sub> – second secundibrachial ossicle; IIbr<sub>3+4</sub> – third and fourth ossicles of secundibrachial series united by syzygy; br<sub>2</sub> and br<sub>5</sub> – second and fifth brachials, respectively, of undivided arm; P<sub>II</sub> – pinnule arising from secundibrachial series; P<sub>1</sub> – first exterior pinnule; P<sub>a</sub> – first interior pinnule; B, aboral view of centrodorsal and base of one ray of Comatulidae illustrating abbreviations of brachitaxes (division series); Roman numerals followed by Br and an Arabic numeral identify specific brachitaxes (e.g., IIBr2 = secundibrachial series composed of two ossicles); Roman numeral followed by br and subscript Arabic numerals indicate specific ossicles (e.g., IIIbr<sub>1</sub> = first ossicle of third brachitaxis); C, oral surface of the disk of a feather star with a central mouth (m) and marginal anal papilla (ap); D, same of a feather star with a marginal (excentric) mouth (m) and central anal papilla (ap).



Subfamily COMATULINAE Fleming, 1828

COMATULINI Fleming, 1828

*Comatula* Lamarck, 1816

**Diagnosis.** Mouth excentric in fully developed individuals; arms usually 10 (rarely to 17 in *C. pectinata*, and to 20 and rarely 27 in *C. rotalaria*); centrodorsal pentagonal to circular, thin, sometimes reduced and lying within radial cirlet; cirri absent or, when present, usually only interradian; all brachitaxes of two ossicles united by syzygy; first syzygy at 1+2 on undivided arms; also at 3+4 on arms arising from II and III Br series; distal intersyzygial interval 2–11; combs composed of teeth confluent with outside of pinnule and tapering distally or not (modified from A. H. Clark, 1931; Summers et al., 2014).

**Remarks.** The genus currently includes seven morphologically-based species: *C. cratera* H. L. Clark, 1916, from eastern Australia; *C. micraster* A. H. Clark, 1909, from the eastern Indian Ocean to Indonesia; *C. solaris* Lamarck, 1816, from tropical Australia north to Hong Kong; *C. pectinata* from Sri Lanka to tropical Australia and north to Okinawa, Japan; *C. purpurea* (Müller, 1843) from tropical Australia north to the Philippines; *C. tenuicirra* A. H. Clark, 1912, from Indonesia, and *C. rotalaria* Lamarck, 1816, from tropical Australia and eastern Indonesia (A. H. Clark, 1931; Rowe & Gates, 1995; Kogo, 1998). The great majority of records are from depths shallower than 50 m, although half of the six depth records published for *C. micraster* range from 73 to 110 m, and the two published records for *C. tenuicirra* are 82 and 88 m (A. H. Clark, 1931).

*Comatula micraster* and fully developed *C. rotalaria* differ from the remaining species in lacking cirri. *C. rotalaria* is unique among feather stars in having exterior arms that develop from the first pinnule and remain shorter than interior arms. It also usually develops 20 arms, whereas other *Comatula* species rarely develop more than 10. At Lizard Island, Australia, *C. rotalaria* lives on sediment, with its shorter arms arrayed vertically; it uses several bent longer arms to prop its central calyx above the substrate (Messing et al., 2006). A. H. Clark (1909f) first placed *C. rotalaria* in a separate genus, *Validia*, which he later reduced to a subgenus of *Comatula* (A. H. Clark, 1918, 1931).

Morphological features of the other five species overlap substantially and descriptions are often confused. A. H. Clark (1931) diagnosed both *C. cratera* and *C. micraster* as lacking cirri. However, he then noted that five of the original 14 specimens on which *C. cratera* was based have 1–3 small cirri (A. H. Clark, 1931), and “3 or 4” of the 45 specimens from the type locality of *C. micraster* have 1–4 (rarely >1) delicate cirri (A. H. Clark, 1912, p. 82). He referred to *C. cratera* as “merely a form of *C. solaris*” but maintained use of the separate name. A small paratype (Australian Museum cat. no. E1361) bears 10 sockets in interradian pairs with one cirrus retained and a comb of 11 triangular teeth that taper distally.

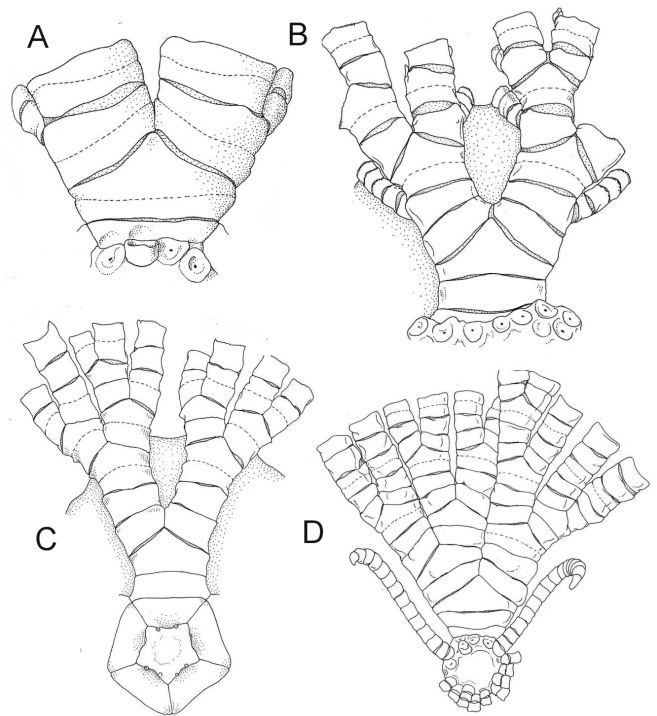


Fig. 2. Ray branching patterns of Comatulidae. A, *Comatula* with syzygies (dotted lines) at IBr<sub>2</sub>, br<sub>1+2</sub> and br<sub>3+4</sub>. B, *Capillaster* with syzygies at IIbr<sub>3+4</sub>, IIIbr<sub>2+3</sub> and br<sub>2+3</sub>. C, *Phanogenia* with a cryptosynarthry at IBr<sub>2</sub>, and syzygies at IIbr<sub>3+4</sub>, some IIIbr<sub>1+2</sub> and some br<sub>1+2</sub>. D, *Comanthus* with syzygies at II, III and IVbr<sub>3+4</sub> and br<sub>3+4</sub>.

A. H. Clark (1931) distinguished *C. purpurea* and *C. tenuicirra* from the others on the basis of their having cirri restricted to the interradian angles of the centrodorsal, either singly or in pairs. However, he identified several specimens as *C. purpurea* with cirri distributed more continuously around the centrodorsal margin, as in *C. pectinata*. H. L. Clark (1946) and Rowe & Gates (1995) treated *C. purpurea* as a junior synonym of *C. pectinata*. *Comatula tenuicirra* supposedly differs from *C. purpurea* in having more elongated cirrals length-to-width (LW) ratio to 2.0. However, LW in the types of *C. purpurea* and *C. pectinata* reach 1.3 and 1.5, respectively. The few known specimens of *C. tenuicirra* were collected on fine mud in 82–88 m, which might favor more elongated cirri. Cirral proportions for the very few specimens attributed to *C. purpurea* from sand and fine mud at similar depths (88–93 m) have not been reported (A. H. Clark, 1931).

A. H. Clark (1931) distinguished *Comatula solaris* from *C. pectinata* chiefly by its greater number of cirrals (17–24 vs. 10–15) but mentioned specimens of the former with as few as 15–19 and the latter with up to 17. Both are described as having both slender and robust overall forms with cirri in a complete or incomplete marginal row. *Comatula solaris* appears to differ from *C. pectinata* and the other conspecifics in having much longer combs with up to 30 teeth and a discrete terminal tooth versus a comb that tapers distally. Hoggett & Rowe (1986) used this feature to separate *C. solaris* and *C. micraster* from the other species as two unnamed generic groups.

The following describes three recognisable taxa collected during the SSBW.

***Comatula cf. solaris* Lamarck, 1816**

(Fig. 3A–C)

**Diagnosis.** *Comatula* with 10 arms; cirri up to XXV, 25, forming complete or partial marginal row; combs occupying approximately distal third or more of proximal pinnules, composed of up to 24 tall, crowded, triangular teeth; comb usually tapering distally but terminal tooth remaining distinct; teeth sometimes remaining tall to tip (modified from A. H. Clark, 1931).

**Remarks.** Specimens are attributed to *C. cf. solaris* only tentatively. The largest has R = ~100 mm, considerably smaller than fully developed specimens of this species collected elsewhere. Cirri are chiefly XIV–XVI, 12–14 with LW of longest cirrals <1.5. A small specimen has cirri XI, 12 with LW to 1.5. The type specimens of *C. solaris* (MNHN EcCs1009, 1010) were collected along the western or northwestern coast of Australia (Freycinet, 1815; A. H. Clark, 1931).

**Colour.** (Includes only those specimens attributed to this taxon following fieldwork) Yellow with pinnules white with purple or maroon lateral blotches or stripe; uniformly dark purple with yellow pinnule tips, or banded pale and darker lavender or purple with pinnules yellow or pale orange, yellow cirri, and rusty orange disk and ambulacra.

**Local depth range.** 11.7–125 (possibly 136) m.

**Ecology.** Substrates recorded during the SSBW include rocks >20 cm, laterite rock and gravel, rocky, gravel, sandy, and muddy with gravel and dead shells. A. H. Clark (1931) listed only two substrate records for this species: coral mud and mud. Messing et al. (2006) attributed one specimen to this species, found under a small piece of rubble between 12 and 18 m depth on a sediment bottom between reefs at Lizard Island, Australia. The specimen had nine of its arms coiled over its oral surface and one arm extended along the sediment surface.

**Material examined.** (Includes only those specimens attributed to this taxon following fieldwork) sta. 5313TB2, E of Pulau Seringat, start 01°14.009'N, 103°54.095'E, end 01°13.881'N, 103°53.837'E, 70.0–85.3 m, 17 May 2013 (1; SIO-BIC E6567); no data (3 specs.); sta. TB16, outside Eastern Boarding Ground A, 01°13.537'N, 103°53'793'E, 89.5–98.0 m, 21 May 2013 (1; ZRC.ECH.0386); sta. TB17, Eastern Holding, 01°13.816'N, 103°54.060'E, 86.7–90.9 m, 21 May 2013 (1; ZRC.ECH.0358); sta. TB28, Singapore Port Limit near Eastern Boarding Ground A, 01°13.181'N, 103°52.900'E, 94.3–97.6 m, 22 May 2013 (5; ZRC.ECH.0524, ZRC.ECH.0525, ZRC.ECH.0522, ZRC.ECH.0527, ZRC.ECH.0528); sta. TB29, Singapore Port Limit near Eastern Boarding Ground A, 01°13.036'N, 103°52.820'E, 98–103 m, 22 May 2013 (2; ZRC.ECH.0363, ZRC.ECH.0523); sta. TB30, Marina Barrage, outside Marina

Bay, 01°16.186'N, 103°52.375'E, 17.1–19.1 m, 22 May 2013, (1; ZRC.ECH.0615); sta. TB69, near Pulau Sudong and Pulau Semakau, 01°13.155'N, 103°43.880'E, 17.9–18.9 m, 25 May 2013 (1; ZRC.ECH.0517); sta. TB96, near Eastern Bunkering A, 01°18.140'N, 104°04.221'E, 22.4–25.1 m, 28 May 2013 (2; ZRC.ECH.0455); sta. DR111, outside Eastern Boarding Ground A, 01°12.989'N, 103°53.062'E, 125–136 m, 29 May 2013 (2; ZRC.ECH.0529, 3; ZRC.ECH.0368); sta. TB142, E Johor Strait, 01°17.838'N, 104°04.157'E, 28.7–28.8 m, 31 May 2013 (ZRC.ECH.0372); sta. SD145, W of Pulau Hantu, no lat., long, 11.7 m, 1 June 2013 (1; ZRC.ECH.0518); sta. DR160, Eastern Boarding Ground A, 01°13.584'N, 103°53.798'E, 92.5–97.5 m, 3 June 2013 (2; ZRC.ECH.0486, ZRC.ECH.0530); sta. DR161, beside St John's Island, 01°12.843'N, 103°51.449'E, 41.2–44.4 m, 3 June 2013 (1; ZRC.ECH.0373).

**Material previously collected at Singapore.** ZMUH (1), NHB (2), no data (see A. H. Clark, 1931).

***Comatula cf. pectinata* (Linnaeus, 1758)**

(Fig. 3D–F)

**Diagnosis.** *Comatula* with 10 arms (rarely to 12; a few specimens attributed to this species have 16–17 arms); IIBr series 2(1+2), when present; cirri up to XX, 17 (usually no more than XVI, 15), forming complete or partial marginal row but not restricted to interradial angles; arms broad basally and tapering rapidly distally, or long, slender and evenly tapered; comb occupying less than distal third of most proximal pinnules, composed of 12–16 rounded triangular teeth, with bases of successive teeth separated; distalmost teeth reduced so that comb tapers to a blunt tip (modified from A. H. Clark, 1931).

**Remarks.** Specimens are attributed to *C. cf. pectinata* only tentatively. The largest has R = ~80 mm, much smaller than fully developed specimens of this species collected elsewhere. Cirri are XIV–XVIII, 10–16, with LW of longest cirrals 1.2–1.4. Combs are distinctly different than those of Singapore specimens attributed to *C. cf. solaris*. One specimen has 12 arms with two IIBr2(1+2). The type specimen of *C. purpurea* (ZMB) was collected along the western or northwestern coast of Australia (Freycinet, 1815, A. H. Clark, 1931), whereas Linnaeus (1758) gave the type locality for his *Asterias pectinata* as “Indian seas” (“in mare Indico”), which could be anywhere in the Indian Ocean or East Indies.

**Colour.** White or pale yellow with a pair of dark brown or red-brown aboral arm stripes, centrodorsal yellow or yellow orange, disk dark maroon, pinnules white with lateral brown stripe or maroon articulations, often with bright red-brown ambulacra and yellow tips; yellow or pale yellow-brown with paler midaboral arm stripe.

**Local depth range.** 11.7–125 (possibly 141) m.

**Ecology.** Substrates recorded during the SSBW include silt and gravel, laterite rock and gravel, sandy, and rocky. One



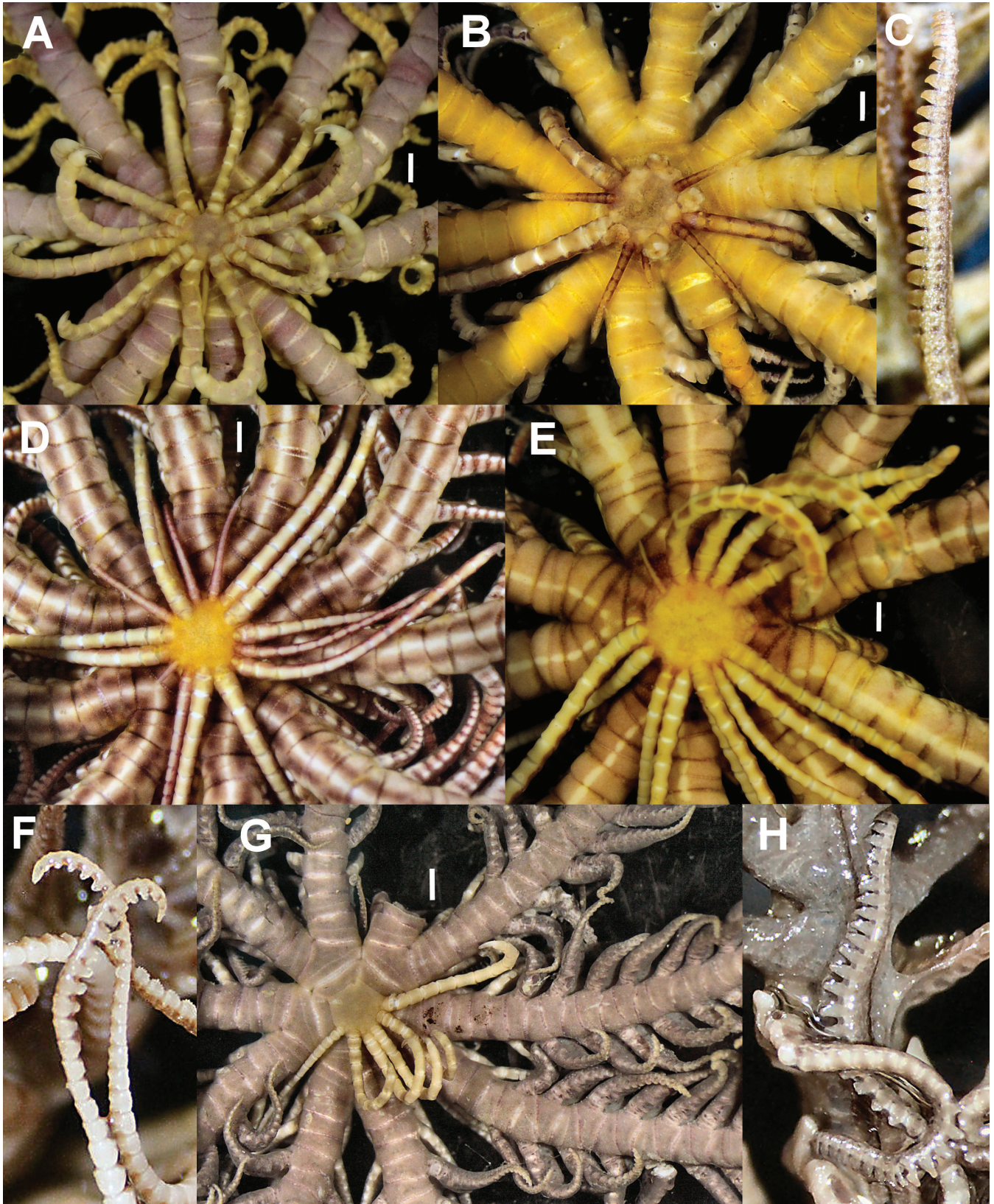


Fig. 3. *Comatula* species. A–C, *Comatula* cf. *solaris*. A, aboral view; (SIO-BIC E6567); B, aboral view; (ZRC.ECH.0386); C, detached oral pinnule comb. D–F, *Comatula* cf. *pectinata*. D, aboral view; (ZRC.ECH.0387). E, aboral view; (SIO-BIC E6532); F, Oral pinnules. G–H, *Comatula* sp.; G, Aboral view; (5314-TB2-089); H, Oral pinnules. Scale bars = 1 mm.



specimen had a black and pale yellow-white *Ophiomaza* ophiuroid. Substrates mentioned in A. H. Clark (1931) include shells, sand, lithothamnion, coral sand, pebbles and rock. Specimens attributed to *C. pectinata* are widely recorded from the Indo-western Pacific (A. H. Clark, 1931; Rowe & Gates, 1995), and as cryptic during the day with arms extending from reef interstices at night (Meyer, 1986; Messing, 1998).

**Material examined.** Sta. 5314TB1, E of Pulau Sentosa, start 01°14.730'N, 103°53.870'E, end 01°14.944'N, 103°53.890'E, 27.8–33.8 m, 17 May 2013 (1; ZRC.ECH.0532); sta. 5314TB2, start 01°14.924'N, 103°53.730'E, end 01°14.808'N, 103°53.528'E, 24.4–25.4 m, 17 May 2013 (2; ZRC.ECH.0509, ZRC.ECH.0510); sta. TB15, Eastern Fairway, 01°16.300'N, 103°55.226'E, 21.5–23.8 m, 21 May 2013 (1; SIO-BIC E6540); sta. TB16, outside Eastern Boarding Ground A, 01°13.537'N, 103°53.793'E, 89.5–98.0 m, 21 May 2013, (3; SIO-BIC E6533, SIO-BIC E6532, ZRC.ECH.0387); sta. TB28, Singapore Port Limit near Eastern Boarding Ground A, 01°13.181'N, 103°52.900'E, 94.3–97.6 m, 22 May 2013 (1; ZRC.ECH.0526); sta. TB29, Singapore Port Limit near Eastern Boarding Ground A, 01°13.036'N, 103°52.820'E, 98–103 m, 22 May 2013 (1; ZRC.ECH.616); sta. TB30, Marina Barrage, outside Marina Bay, 01°16.186'N, 103°52.375'E, 17.1–19.1 m, 22 May 2013, (1; ZRC.ECH.0521); sta. TB69, near Pulau Sudong and Pulau Semakau, 01°13.155'N, 103°43.880'E, 17.9–18.9 m, 25 May 2013 (1; ZRC.ECH.0367); sta. DR111, outside Eastern Boarding Ground A, 01°12.989'N, 103°53.062'E, 125–136 m, 29 May 2013 (1; ZRC.ECH.0519); sta. SD145, W of Pulau Hantu, no lat., long., 11.7 m, 1 June 2013 (1; ZRC.ECH.0520); sta. TB158, Singapore Port Limit, Near Southern Fairway off Kusu Island, 01°12.236'N, 103°52.116'E, 110–141 m, 3 June 2013 (1; ZRC.ECH.0485); sta. DR161, beside St John's Island, 01°12.843'N, 103°51.449'E, 41.2–44.4 m, 3 June 2013 (3; ZRC.ECH.0511).

**Material previously collected at Singapore.** NHM (1) (Carpenter, 1888; A. H. Clark, 1931); USNM 36259 (1), E1084 (2), Svend Gad; E3129, on sand bank, Johore Strait (1) (A. H. Clark, 1931); ZMC, Svend Gad (+76) (A. H. Clark, 1931). As *C. purpurea* USNM E1085, Svend Gad (1) (A. H. Clark, 1931).

*Comatula* sp.  
(Fig. 3G, H)

**Diagnosis.** *Comatula* with 10 arms; centrodorsal very thin with cirrus sockets usually confined to one side (sometimes in most or all interradial angles); cirri III–VIII (rarely XI), to 14 (chiefly 12–13), more slender than in previous two species; LW of longest cirrals 1.5–2.5; combs occupying up to approximately distal third of proximal pinnules, of up to 25 tall, crowded, triangular teeth; comb tapering distally but terminal tooth distinct.

**Remarks.** This species is similar to *C. cf. solaris* but with fewer, more slender cirri, chiefly confined to one side of a thinner centrodorsal, even in specimens of similar ray length

and centrodorsal diameter. Based on published diagnostic characters, it is not clear to which if any named *Comatula* species it should be assigned. As noted above, cirri in named species may occur in a complete or incomplete ring or be restricted to the interradial angles. However, none have been described as having cirri chiefly restricted to one side of the centrodorsal. One specimen was collected together with *C. cf. pectinata*, reducing the likelihood of environmental conditions contributing to the arrangement of the cirri.

**Colour.** Orange-brown with a paler orange mid-aboral arm stripe and pinnules white with purplish-brown mottling; pale gray-brown with hint of green and some distal arms yellow.

**Local depth range.** 23.8–67.9 m (possibly 21.5–79.3 m).

**Ecology.** Substrates recorded during the SSBW are mud, silt, and gravel.

**Material examined.** Sta. 5314TB1, E of Pulau Sentosa, start 01°14.730'N, 103°53.870'E, end 01°14.944'N, 103°53.890'E, 27.8–33.8 m, 17 May 2013 (3; ZRC.ECH.0507, ZRC.ECH.0531, ZRC.ECH.0508); sta. 5314TB2, start 01°14.924'N, 103°53.730'E, end 01°14.808'N, 103°53.528'E, 24.4–25.4 m, 17 May 2013 (1; ZRC.ECH.0533); sta. 5313TB3, Eastern Boarding Ground A, beside Eastern Holding B, start 01°14.079'N, 103°54.165'E, end 01°13.932'N, 103°53.811'E, 67.9–79.3 m, 17 May 2013 (7; ZRC.ECH.0500 to 0505, ZRC.ECH.0506); sta. TB5, Beside Sebarok, 01°10.533'N, 103°46.512'E, 63.8–64.1 m, 20 May 2013 (1; ZRC.ECH.0351); sta. TB15, Eastern Fairway, 01°16.300'N, 103°55.226'E, 21.5–23.8 m, 21 May 2013 (1; ZRC.ECH.0360); sta. DR57, around Tanah Merah, 01°16.297'N, 103°57.677'E, 46.2 m, 24 May 2013 (1; ZRC.ECH.0388); sta. TB58, around Tanah Merah, 01°16.808'N, 103°58.246'E, 38.7–39.9 m, 24 May 2013 (1; ZRC.ECH.0361); no data (1 spec.)

**CAPILLASTERINI A. H. Clark, 1909b**

*Capillaster* A. H. Clark, 1909b

**Diagnosis.** Mouth excentric in fully developed individuals; up to 110 arms; cirri in 1–2 marginal rows (absent in *C. macrobrachius*); IBr series united by synarthry; IIBr 2 or 4(3+4); IIIBr and beyond 3(2+3); first syzygy at 3+4 on arms arising from IBr, at 2+3 on arms arising from IIBr and beyond; distal intersyzygial interval 4–27; distalmost pinnule comb on P<sub>3</sub>–P<sub>21</sub> (in *C. tenuicirrus* at intervals as far as mid-arm); comb teeth single, triangular, confluent with outer edge of pinnule; comb not tapering significantly distally (Summers et al. 2014).

*Capillaster multiradiatus* (Linnaeus, 1758)  
(Fig. 4A, B, D)

**Diagnosis.** *Capillaster* with usually 15–25 arms and 15–28 (usually 20–24) cirrals; middle and distal cirrals short, broader than long (modified from A. H. Clark, 1931).



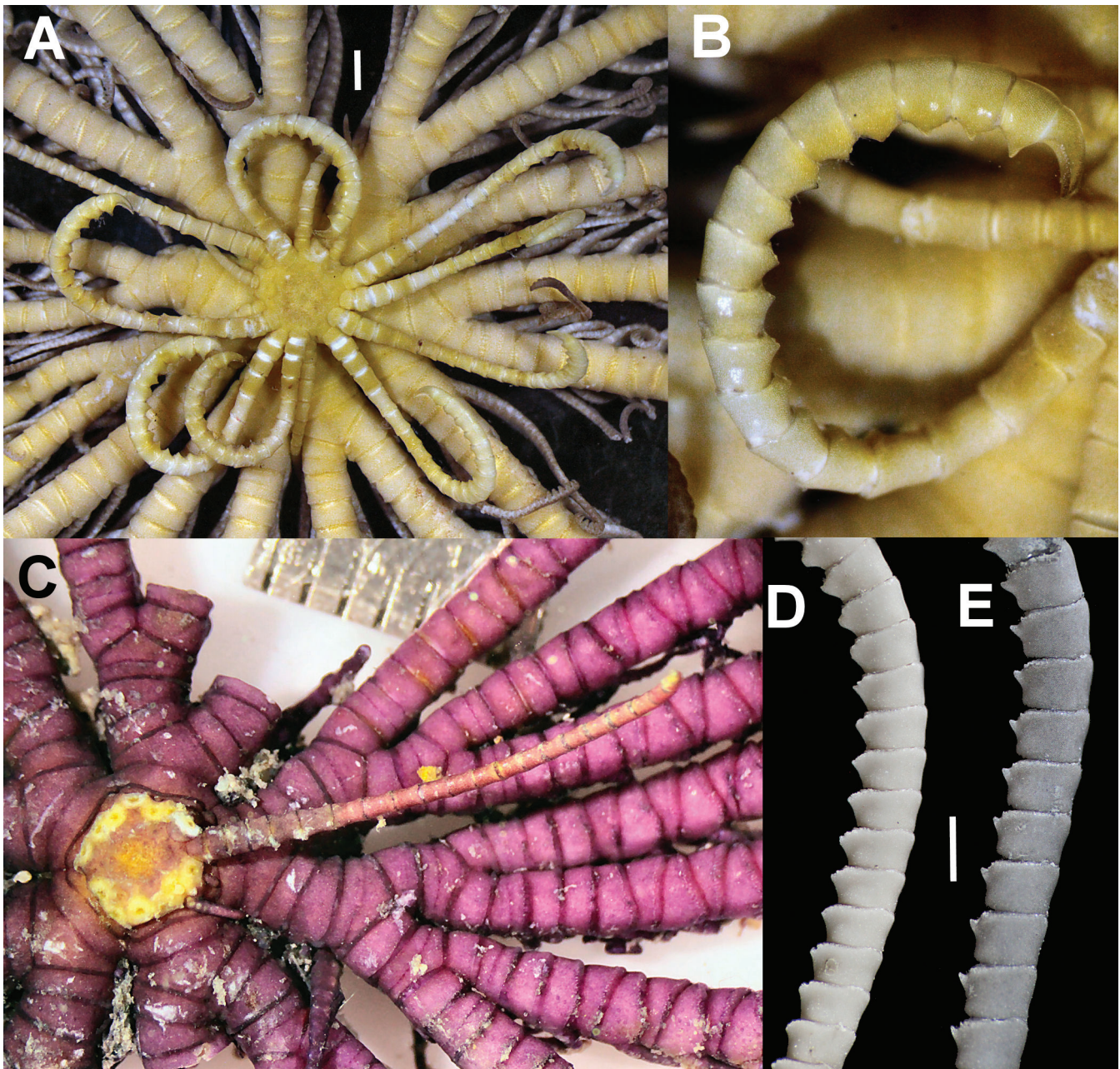


Fig. 4. *Capillaster* species. A, B, D, *Capillaster multiradiatus*. A, aboral view. B, cirrus (both SIO-BIC E6563). D, middle cirrals; (ZRC.ECH.0474); C, E, *Capillaster* cf. *tenuicirrus*. C, aboral view; (ZRC.ECH.0350); E, middle cirrals; (SIO-BIC E6556). Scale bars = 1 mm.

**Remarks.** *Capillaster multiradiatus* differs from *C. sentosus* (below) in being smaller with fewer arms, and having shorter, less robust cirri of fewer cirrals. The two are easily distinguished wherever they have been observed in situ together (Messing, 1998b), but it is not clear how smaller, incompletely developed specimens of *C. sentosus* can be distinguished from *C. multiradiatus*. A. H. Clark (1931) noted several “typical” *C. sentosus* specimens from Singapore with 57 to 100 arms, but also described a smaller specimen with 35 arms as “practically intermediate” between the two species. Specimens collected in Singapore were chiefly small, with at most 27 arms (chiefly 19–23) and ray lengths 55 mm at most. Several small specimens have 10 arms with ray length as little as 15 mm.

**Colour.** Entirely white or with proximal rays pale yellow, or entirely pale yellow with white pinnules and dark brown or black ambulacra. Elsewhere, colors are widely variable (Messing, 1994, 2007, unpublished data).

**Local depth range.** 22.7–125 (possibly 22.4–136) m.

**Ecology.** All specimens were collected during the SSBW via beam trawl or rectangular dredge. Habitats recorded included laterite rock, rocky, gravel, mud, or sandy, with two stations recording mud, two recording clay and one with wood, charcoal, rock and mud. *Capillaster multiradiatus* is a common reef-dweller elsewhere in the tropical Indo-Western Pacific. At Madang, Papua New Guinea, it is cryptic or semicryptic during the day with arms extended from sponges or foliaceous or branching corals and occurs



no shallower than 8 m. In >25 m, it may be completely exposed on octocoral fans or whips and usually forms an irregular radial fan with several arms curled. At Palawan Island, Philippines, it was found during the day in 17–20 m exposed on corals with arms coiled, and semicryptic in a sponge with arms in a multidirectional posture. Pinnules along each arm orient in a single plane rather than in a multidirectional posture (Messing, 1994, 2007). At Palau, however, it is cryptic during the day and semicryptic at night among coral branches or in crevices with arms forming monoplanar arm fans in as little as 1 m (Meyer & Macurda, 1980; Messing, 2007). This distinctive habit suggests that specimens identified as *C. multiradiatus* should be treated as tentative pending revision.

**Material examined.** Sta. 5314-TB1, start 01°14.730'N, 103°53.870'E, end 01°14.944'N, 103°53.890'E, 27.8–33.8 m, 17 May 2013 (SIO-BIC E6563); sta. TB16, outside Eastern Boarding Ground A, 01°13.537'N, 103°53.793'E, 89.5–98.0 m, 21 May 2013 (1; ZRC.ECH.0357); sta. TB28, Singapore Port Limit, Eastern Boarding Ground A, 01°13.181'N, 103°52.900'E, 94.3–97.6 m, 22 May 2013 (2; SIO-BIC E6534, ZRC.ECH.0370); sta. TB58, around Tanah Merah, 01°16.808'N, 103°58.246'E, 38.7–39.9 m, 24 May 2013 (1; ZRC.ECH.0374); sta. TB73, South of Pulau Semakau, 01°11.282'N, 103°46.632'E, 24.6–29.8 m, 25 May 2013 (specimen discarded); sta. TB97, near Eastern Bunkering A, 01°18.425'N, 104°04.607'E, 22.4–22.7 m, 28 May 2013 (4; SIO-BIC E6545); sta. TB98, Eastern Bunkering A, 01°18.938'N, 104°05.312'E, 30.2–33.6 m, 28 May 2013 (4; SIO-BIC E6543); sta. TB109, Eastern Boarding Ground A, 01°13.045'N, 103°52.943'E, 111–114 m, 29 May 2013 (1; ZRC.ECH.0446); sta. DR111, outside Eastern Boarding Ground A, 01°12.989'N, 103°53.062'E, 125–136 m, 29 May 2013 (1; ZRC.ECH.0447, 4; ZRC.ECH.0456); sta. TB141, East Johor Strait, 01°17.725'N, 104°04.363'E, 28.3–28.4 m, 31 May 2013 (3; ZRC.ECH.0471); sta. TB142, East Johor Strait, 01°17.838'N, 104°04.157'E, 28.7–28.8 m, 31 May 2013 (10; ZRC.ECH.0474).

**Material previously collected at Singapore.** USNM 35026 (1), E.1086 (1), ZMC (26), Svend Gad (in A. H. Clark, 1931); MNB 2455 (1), Prof. Eduard von Martens (in A. H. Clark, 1931); NHM[?] (1), Prof. Charles Stewart (in Carpenter, 1888, A. H. Clark, 1931).

#### *Capillaster sentosus* (Carpenter, 1888)

**Diagnosis.** Large, robust *Capillaster* with up to 110 arms (usually > 60); cirri to 40 mm long, of up to 40 cirrals; longest cirrals with LW no greater than ~1.3; distal cirrals short. (A. H. Clark, 1931).

**Remarks.** *Capillaster gracilicirrus* A. H. Clark, 1912, which is known from only five specimens collected off East Java, Indonesia, differs only in having longest cirrals with LW 2.0 and distal cirrals with LW ~1.0 (A. H. Clark, 1912). A. H. Clark (1931) attributed a small 17-armed specimen

from Banda, Indonesia, to *C. sentosus*, apparently because it has three IVBr series, which are rare in *C. multiradiatus*.

**Material previously collected at Singapore.** ZMC (12 specimens), Svend Gad (A. H. Clark, 1909a, 1931).

#### *Capillaster cf. tenuicirrus* A. H. Clark, 1912a

(Figs. 4C, E; 5)

**Diagnosis.** Similar to *C. multiradiatus*, but with proportionately longer cirrals (fewer cirrals for a given cirrus length); distal cirrals often as long as or slightly longer than wide; small erect or hooked aboral spine on distal cirrals, and smaller cirrus-free aboral pole for a given centrodorsal diameter (Fig. 5).

**Remarks.** A. H. Clark (1931) distinguished *C. tenuicirrus* from *C. multiradiatus* solely on the “elongated and slender cirri in which the distal segments from the tenth or eleventh onward are very slightly longer than broad” (p. 209). Although this is thin evidence on which to distinguish a species, several specimens collected during the SSBW appear to fit the published description of *C. tenuicirrus*. The distinguishing characters are chiefly relative, e.g., for a cirrus length of 17 mm, *C. cf. tenuicirrus* has 23–25 cirrals and *C. multiradiatus* from Singapore 27–28; the centrodorsal diameter to aboral pole diameter ratio is 1.3–1.4 in *C. multiradiatus* and chiefly 1.5–1.9 (1.4 in one smaller specimen) in *C. cf. tenuicirrus*. Color is also distinctive (see below). Specimens of both were collected at the same station, and although some specimens of *C. cf. tenuicirrus* are larger than any attributed to *C. multiradiatus*, some size overlap exists, suggesting that the distinctions are neither ecological nor ontogenetic, and *C. multiradiatus* gets larger elsewhere (A. H. Clark, 1931; Messing, unpublished observations). However, it is unclear if specimens distinguished here as *C. cf. tenuicirrus* represent a separate taxon. Also, the Singapore specimens were collected in substantially shallower water than the type series of *C. tenuicirrus* (82–118 m) (A. H. Clark, 1931).

**Colour.** Uniformly rich red-purple or dark purple; one specimen with a yellow centrodorsal.

**Local depth range.** ~22–28 m.

**Ecology.** All specimens were collected via beam trawl. Habitats recorded included clay, one with wood, charcoal, rock, and mud, and one very muddy with gravel, and dead shells.

**Material examined.** Sta. TB97, near Eastern Bunkering A, 01°18.425'N, 104°04.607'E, 22 m, 28 May 2013 (1; SIO-BIC E6544); sta. TB141, East Johor Strait, 01°17.725'N, 104°04.363'E, 28 m, 31 May 2013 (1; SIO-BIC E6556); sta. TB142, East Johor Strait, 01°17.838'N, 104°04.157'E, 28.7–28.8 m, 31 May 2013 (2; SIO-BIC E6551, 1; SIO-BIC E6550).

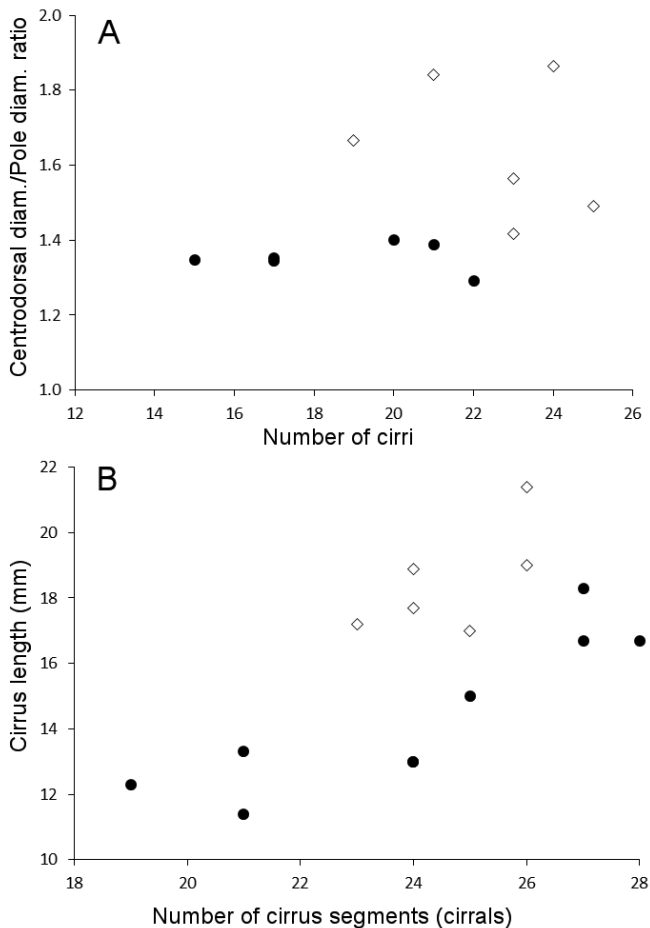


Fig. 5. Comparison of *Capillaster multiradiatus* (solid circles) and *Capillaster cf. tenuicirrus* (open diamonds) specimens. A, number of cirri versus ratio of centrodorsal base diameter to centrodorsal aboral pole diameter; B, number of cirrus segments (cirrals) versus cirrus length (mm).

**PHANOGENINI White & Messing  
(in White et al. 2001)**

***Phanogenia* Lovén, 1866**

**Diagnosis.** Mouth central in fully developed individuals; up to 170 arms; cirri absent or in 1–2 marginal rows; IBr series united by cryptosynarthry or synarthry; IIBr chiefly 4(3 + 4); subsequent brachitaxes chiefly 2(1+2); IIIBr and following axils often bearing one brachitaxis and one undivided arm, alternating on successive axils; first syzygy at 3+4 on arms arising from IBr, at 1+2 on arms arising from subsequent brachitaxes; distal intersyzygial interval 3–4; pinnule combs at intervals to near arm tip; comb teeth tall, triangular to spade-shaped, confluent with outer edge of pinnule; proximal tooth saucer-like and transverse; terminal tooth discrete (Messing, 1998b, 2001; Summers et al., 2014).

***Phanogenia typica* Lovén, 1866  
(Fig. 6)**

**Diagnosis.** *Phanogenia* with the centrodorsal reduced, pentagonal or stellate, and lacking cirri in all but the smallest specimens; combs typically coiled; number of teeth on P<sub>1</sub> widely variable, 10–29; arms detach easily; texture

extremely sticky/adhesive due to numerous fine spines on pinnules; color pattern usually including at least a broken dark aboral arm stripe.

**Remarks.** The type species, *P. typica*, first collected at New Harbour, Singapore, by Capt. Albert Vestö and described by Lovén (1866), was long treated as a junior synonym of the Australian endemic *Comaster multifidus* (Müller, 1841) (A. H. Clark, 1931). The latter shares with *P. typica* a reduced centrodorsal and few or no cirri, but otherwise differs in having massive ray bases, a pavement of small plates aborally between adjacent ray bases; no syzygy at br1+2, and a completely different comb form. Messing (1998b) resurrected *Phanogenia* for most species placed in *Comaster* by A. H. Clark (1931), recognised *P. typica* as distinct, and distinguished the type specimen from *P. gracilis*, the other *Phanogenia* with a reduced centrodorsal bearing few rudimentary or no cirri, on the basis of its significantly longer pinnule combs: 24–29 teeth on P<sub>1</sub>, and rarely fewer than 10 teeth on brachial pinnules. Similarly large or larger specimens attributed to *P. gracilis* had P<sub>1</sub> with 10–16 teeth and almost always <10 teeth on subsequent pinnules. The two species had been distinguished (as *Comaster multifidus* and *C. gracilis*) on various grounds in several studies (e.g., Meyer & Macurda, 1980; Zmarzly, 1985; Messing, 1998a). Owen et al. (2009) examined a large number of specimens from across the Indo-western Pacific and found two morphotypes—“stunted” with up to ~120 arms usually <12 cm long usually at depths of 2–5 m, and “large” with usually <60 arms to 25 cm long in >6 m. Their molecular phylogeny returned three clades with no areal congruity and with the two morphotypes scattered among all three clades. They treated all specimens as *P. gracilis* (none came from Singapore).

The SSBW retrieved the first long-combed specimens recognised since the species was described. However, specimens with short combs, collected on the same reefs, are otherwise morphologically identical, and may even exhibit the same color pattern. As a result, all are treated here as *P. typica*.

*Phanogenia typica* appears to drop its few juvenile cirri and increase arm number rapidly. One small specimen from Singapore (ZRC.ECH.0380) with only 21 arms, ray length ~65 mm, and the elongated ray ossicles characteristic of most juvenile feather stars, has a pentagonal centrodorsal 1.2 mm across that is raised above the surrounding radials and rises to low central apex (a vestige of the attachment site for the postlarval stalk); it has 9 functional cirrus sockets (3 cirri remain), and traces of obsolete sockets on the aboral pole. Another small specimen (sta. TB69; discarded) has a centrodorsal of the same diameter, already flattened and sunken, with cirri reduced to 10 buds, and 57 arms (ray length ~50 mm), including eight regenerating from a single brachitaxis. The largest specimens examined have 70–80 arms with ray length ranging from 55 to 155 mm.

**Colour.** *In situ*: gray, orange, pale green, or black, usually with beaded pinnules. *Detail*: rays mottled, blotched or



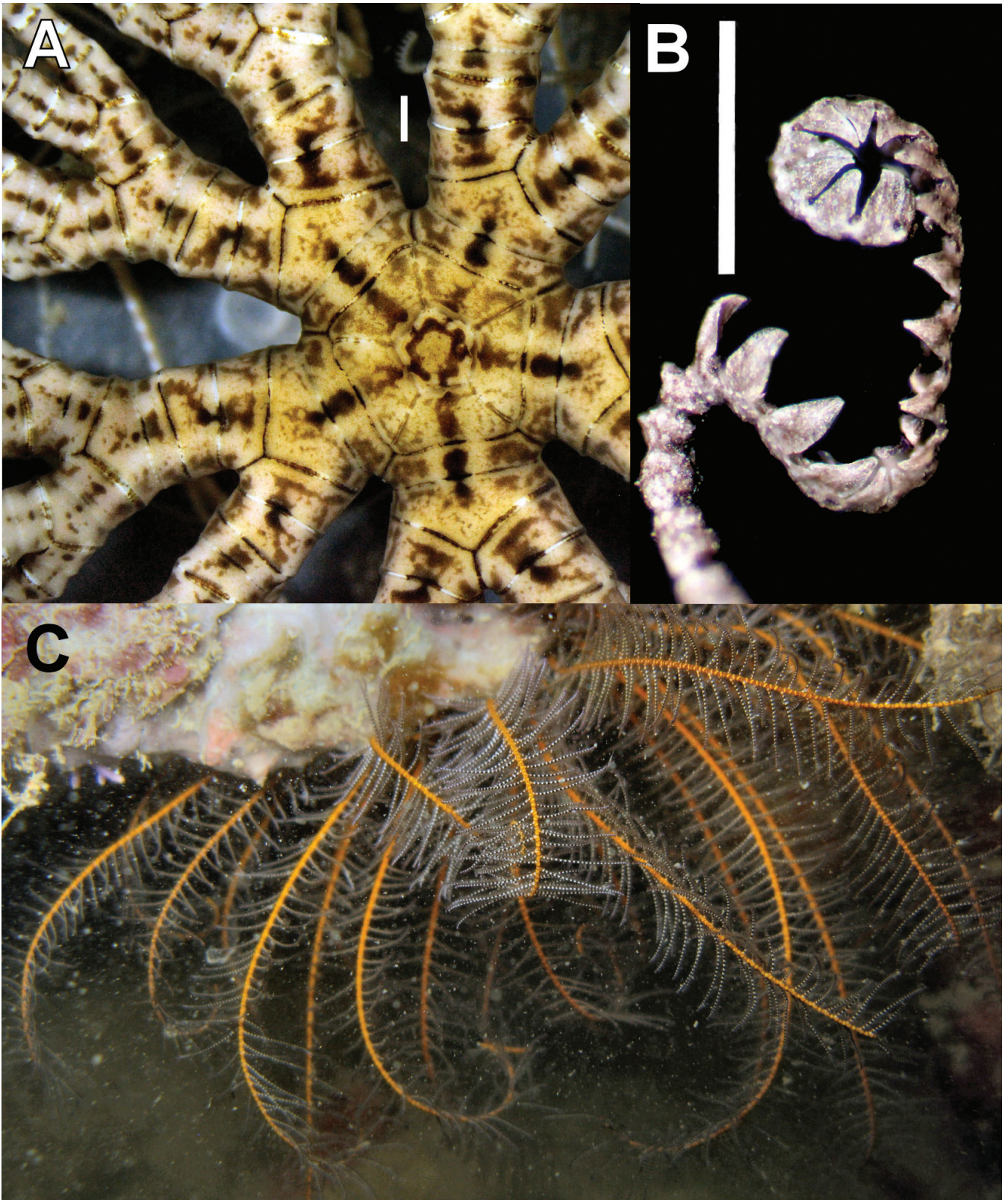


Fig. 6. *Phanogenia typica*. A, aboral view; (ZRC.ECH.0378); B, long oral pinnule comb (ZRC.ECH.0401); C, in situ (not collected). Scale bars = 1 mm.



spotted throughout or just proximally, with distal arms more or less a solid color; white and either charcoal gray, orange, dark brown or maroon; orange or yellow and black or maroon; usually with darker pigment producing at least a broken midaboral stripe. Darker pigment sometimes dominant, reducing paler color to mottling or spots. Dark sides of brachials may produce a pair of pale stripes flanking the dark midaboral stripe. Pinnules usually beaded the same color as the rays: charcoal gray and white, yellow and orange, orange and black or maroon; some or all pinnules may be all white or pale yellow; tips rarely darker. Gonads pink, tan or white. Disk white or dark gray.

**Local depth range.** 3.3–18.0 m.

**Ecology.** Semicryptic, with centrodorsal hidden in a crevice or under a ledge and arms extended in a multidirectional posture (Meyer & Macurda, 1980). Specimens are particularly sticky due to numerous fine spines on pinnules. Arms detach easily.

**Material examined.** Sta. SD25, Southwest St John's Island, 01°12'51"N, 103°50'57"E, 6.8–16 m, 22 May 2013 (4; ZRC.ECH.0378, ZRC.ECH.0380, ZRC.ECH.0395, ZRC.ECH.0397); sta. SD40, West Pulau Semakau, 01°12.389'N, 103°45.24'E, 3.3–7.3 m, 23 May 2013 (5; ZRC.ECH.0399, ZRC.ECH.0401, SIO-BIC E6542, ZRC.ECH.0402, ZRC.ECH.0403); sta. SD45, channel between Lazarus and St John's Islands, 01°13'12"N, 103°51'11"E; 16.2 m, 23 May 2013 (1; SIO-BIC E6541); sta. TB69, near Pulau Sudang and Pulau Semakau, 01°13.155'N, 103°43.880'E, 17.9–18.9 m, 25 May 2013 (2; discarded).

**Material previously collected at Singapore.** NRS (3 specimens), New Harbour, shallows and muddy places, Capt. Albert Vestöo (as *Phanogenia typica*, Lovén 1866); ZMC (2 spec.), Svend Gad (as *Comaster gracilis* in A. H. Clark, 1909a, 1931).

*Phanogenia schoenovi* (A. H. Clark, 1918)

**Remarks.** A. H. Clark (1918) described this species as *Comaster schoenovi* from a single specimen collected off the east coast of China (ZMC). Only two specimens are known. This species differs from *P. typica* and *P. gracilis* in having a complete ring of well-developed cirri around the centrodorsal margin. It is likely a junior synonym of *P. fruticosus* (A. H. Clark, 1911a), as it differs only in minor variations in the number and proportions of cirrus segments.

**Material previously collected at Singapore.** ZMC (1 specimen), no collector named (as *Comaster schoenovi* in A. H. Clark, 1931).

**COMASTERINI A. H. Clark, 1908c**

*Comaster Agassiz, 1836*

**Diagnosis.** Mouth excentric in fully developed individuals; up to 180 arms; centrodorsal small, discoidal or pentagonal;

cirri absent or present; aboral surface with irregular plates between bases of adjacent rays; IBr united by synarthry; IIBr series usually 4(3+4); IIIBr usually of 2 ossicles exteriorly and 4(3+4) interiorly; first syzygy on undivided arms always 3+4; distalmost pinnule comb on at least P<sub>3</sub>, sometimes at intervals to P<sub>14</sub>; combs arising gradually and tapering to a sharp point distally or with a discrete terminal tooth; comb teeth paired, erect, well separated; pairs of teeth of more or less equal size, each confluent with its edge of the pinnular, and sometimes joined to form a transverse bar (Messing, 1998b, 2001).

**Remarks.** Previous to the revision by Messing (1998b), species in this genus were chiefly referred to *Comanthina* A. H. Clark, 1909 (A. H. Clark, 1931; Hoggett & Rowe, 1986).

*Comaster schlegelii* (Carpenter, 1881)

**Remarks.** Hoggett & Rowe (1986) distinguished *C. nobilis* (Carpenter, 1888) as a separate species, but the two overlap enough to restore it to synonymy under *C. schlegelii*, following A. H. Clark (1931).

**Material previously collected at Singapore.** ZMC (2 specimens), Svend Gad [as *Comanthus (Comanthina) nobilis* in A. H. Clark, 1909a].

*Comanthus* A. H. Clark, 1908a

**Diagnosis.** Mouth excentric in fully developed individuals; up to 75 arms; centrodorsal circular to pentagonal; cirri present in one row or absent; IBr<sub>2</sub> united by synarthry; IIBr and subsequent brachitaxes 2 or 4(3+4); first syzygy at 3+4 on all undivided arms; distal intersyzygial interval 4; distalmost pinnule comb at intervals sometimes reaching near arm tip; comb terminating in large discrete tooth; proximal tooth transverse, saucer-like; primary comb teeth confluent with exterior edge of pinnulars; smaller secondary tooth present or not (Summers et al., 2014).

**Remarks.** Several *Comanthus* species are widespread in the eastern tropical Indo-western Pacific region, but only *C. parvicirrus* has been reported from Singaporean waters. *Comanthus wahlbergii* (Müller, 1843) has been recorded as far west as South Africa, but not from Singapore.

*Comanthus parvicirrus* (Müller, 1841)

**Material previously collected at Singapore.** USNM E1087 (syntype, 1 specimen); ZMC (6); Svend Gad, 16 April 1907 (as *Comaster tenella* A. H. Clark, 1931).—ZMC (1), Svend Gad [as *Comanthus (Comanthus) rotalaria* (Lamarck, 1816) in A. H. Clark, 1909a, and *Comanthus timorensis* (Müller, 1841) in A. H. Clark, 1931].—USNM 34996 (4); ZMC (41), Svend Gad, 17 June 1904 to 23 October 1910 [as *C. (C.) rotalaria* and *C. rotalaria* in A. H. Clark, 1909a), and *Comanthus parvicirrus* (Müller, 1841) (in A. H. Clark, 1931)].

**Anneissia Summers, Messing & Rouse, 2014**

**Diagnosis.** Mouth excentric in fully developed individuals; up to 120 arms; centrodorsal circular, large and thick; cirri always present; IBr<sub>2</sub> united by synarthry; IIBr and beyond all 4(3+4); first syzygy at 3+4 on all undivided arms; distal intersyzygial interval 4, occasionally 5; distalmost pinnule comb on P<sub>2</sub> to P<sub>5</sub>, tapering distally to a sharp point; teeth erect, non-confluent (Summers et al., 2014).

**Remarks.** Phylogenetic trees derived from molecular data and supported by morphological distinctions (Summers et al. 2014) split the former genus *Oxycomanthus* into two separate groups of species. One group, characterised by a reduced centrodorsal with relatively few or no cirri, falls out within a clade of *Clarkcomanthus* species. Because this group includes the type species of *Oxycomanthus*—*Comanthus* (*Vania*) *parvicirra* β *comanthipinna* Gislén, 1922—the remaining species formerly included in *Oxycomanthus* required a new generic epithet; hence, *Anneissia*, named for crinoid researcher Anne Hoggett.

***Anneissia bennetti* (Müller, 1841)**

**Remarks.** This species was previously treated as *Comanthus bennetti* (e.g., A. H. Clark, 1931, Meyer & Macurda, 1980) and *Oxycomanthus bennetti* (e.g., Hoggett & Rowe, 1986; Rowe et al. 1986; Kogo, 1998).

**Material previously collected at Singapore.** ZMUH (1 specimen), no collector (as *Actinometra bennetti* in Carpenter, 1882, 1888, and *Comanthus bennetti* in A. H. Clark, 1909, 1931).

**Family COLOBOMETRIDAE A. H. Clark, 1909c**

**Diagnosis.** Some or all cirrals with aboral transverse ridge, commonly serrate or tuberculate, or with transverse row of 2 or 3 tubercles or spines; distal (rarely all) spines often single; radial articular facet steep, separated along interradiar margin; interarticular ligament fossae moderate and triangular to large and high, separated by wide and shallow midradial furrow (except in *Cyllometra*); adoral muscle fossae small and vestigial to low, slightly curved along adoral margin; arms 10 to >80; brachitaxes 2 or 4(3+4); first syzygy on undivided arms at 3+4; proximal brachials sometimes with lateral processes; one or more proximal pinnules (usually P<sub>a</sub>) may be absent; some genera with pinnulars broadened over gonads (modified from Hess & Messing, 2011).

**Remarks.** The family as currently construed includes genera with individual characters that diverge from other confamilials, suggesting that the family may not represent a monophyletic clade, e.g., *Pontiometra* has a greatly elongated first exterior pinnule and apparently distinctive radial articular facets (A. H. Clark, 1921), whereas *Cyllometra* has interradiar ridges and a small radial pit on the adoral centrodorsal surface, the radial interarticular ligament fossa with a narrow median ridge, and muscle fossae uniquely tall (Hess & Messing, 2011).

Recent molecular phylogenies have placed Colobometridae somewhat differently relative to closely related families. Hemery (2011) returned eight terminals representing six taxa in four genera (*Oligometra*, *Decametra*, *Cyllometra*, *Colobometra*) as a clade sister to *Stephanometra* (Mariametridae), and this clade sister to a clade composed of Himerometridae, Zygometridae, and other Mariametridae. The colobometrid *Iconometra anisa* returned separately, nested within a clade of Indo-Pacific “antedonids” and sister to Apometridae. Subsequently, Hemery et al. (2013) returned three of the colobometrid terminals as a clade sister to a similar Mariametridae/Himerometridae/Zygometridae clade, but omitted *Stephanometra* and *Iconometra* from the analyses. Rouse et al. (2013) returned two colobometrid terminals (*Colobometra*, *Cenometra*) as a clade sister to a *Stephanometra*/*Lamprometra* clade, and this combined clade as sister to a clade including Himerometridae, Zygometridae and the mariametrid *Liparometra*.

***Colobometra* A. H. Clark, 1909d**

**Diagnosis.** Proximal cirrals with distal aboral fringe of spines; middle and distal cirrals with paired spines; arms 10; P<sub>a</sub> present or absent (Hess & Messing, 2011).

**Remarks.** As with *Zygotetra* (see below), most if not all of the six nominal species currently recognised in *Colobometra* by A. H. Clark (1947) are distinguished largely by size-related features and may be synonyms. Only *C. arabica* A. H. Clark, 1936a, described from the Red Sea, occurs outside the range recorded for the other five: Fiji through tropical Australia to Sri Lanka and north to Okinawa, Japan (A. H. Clark, 1947; Fishelson, 1974; Kogo, 1998).

***Colobometra perspinosa* Carpenter, 1881**

**Diagnosis.** The largest species of *Colobometra*. Cirri of 53–65 cirrals; P<sub>3</sub> slightly longer and larger than P<sub>2</sub>; following pinnules to P<sub>8</sub> or P<sub>9</sub> similar to P<sub>3</sub>, slightly decreasing in length; arms 120–150 mm long (A. H. Clark, 1947).

**Remarks.** *Colobometra* previously collected at Singapore was recorded as *C. vepretum* A. H. Clark, 1909a. Subsequently, A. H. Clark (1936) recorded intermediate specimens between *C. perspinosa* and *C. vepretum*, referring to them as probably representing “the same specific type,” but then (A. H. Clark, 1947) treated the latter as *C. perspinosa* var. *vepretum*. The differences between the two—relative stiffness of P<sub>1</sub> and proportions of some cirrals—are minor, and all *Colobometra* collected from Singapore so far are treated here as *C. perspinosa*. Two specimens were collected during the SSBW.

**Colour.** White with a few dark pinnules, or white with a broad dark chocolate aboral stripe, broadened as dark bands on middle and distal arms; cirri chiefly dark chocolate; pinnules white or chocolate. At Madang, Papua New Guinea, *C. perspinosa* is typically dark maroon or red-brown (black in situ) with a paler aboral stripe and cirri; its pinnules may have orange tips (Messing, unpublished).



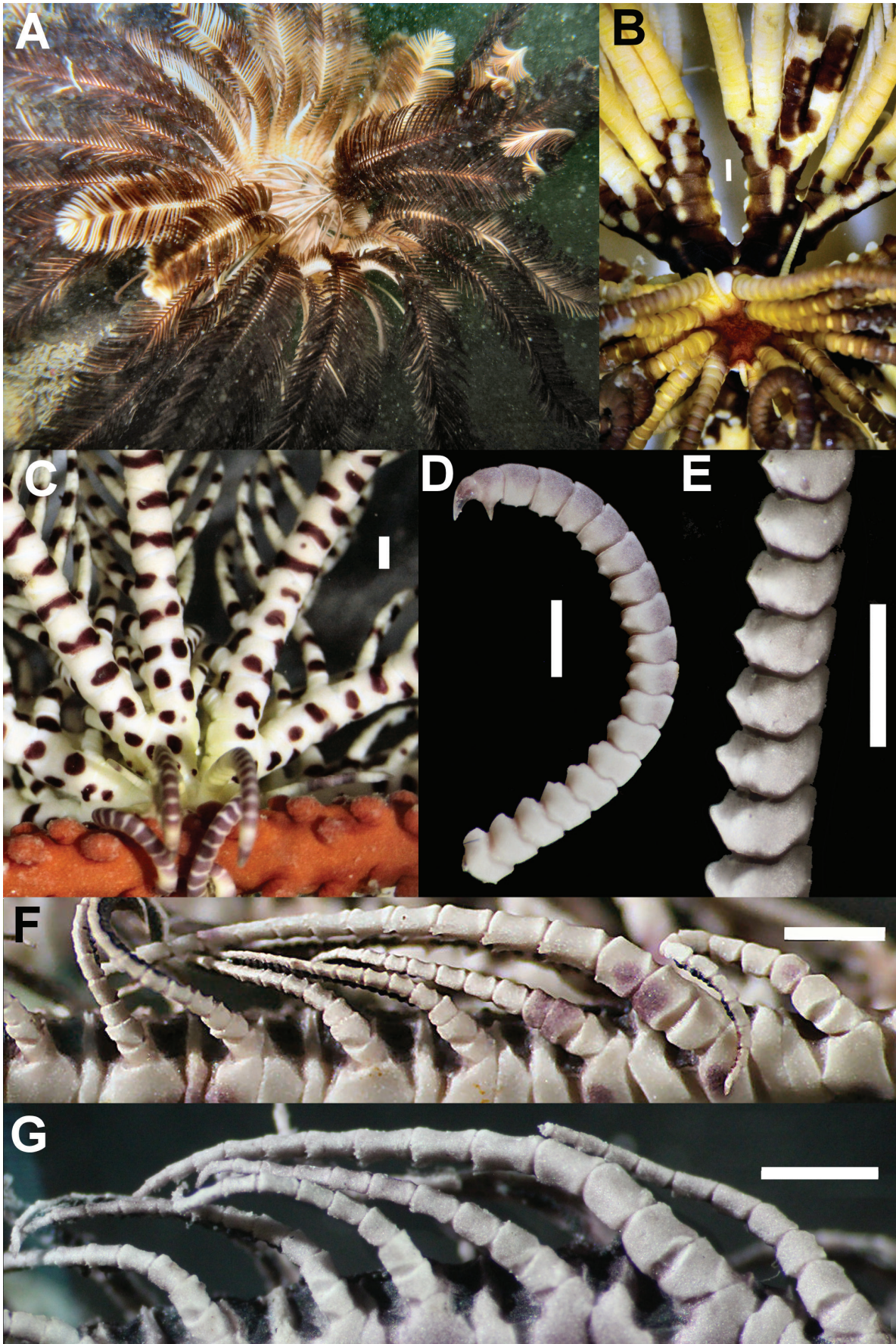


Fig. 7. A, *Pontometra andersoni* in situ; B, *Cenometra bella*, centrodorsal, bases of cirri and bases of two rays; (ZRC.ECH.0467). C, D, F, *Oligometra serripinna*; C, specimen on ellisellid octocoral; (ZRC.ECH.0405); D, cirrus, with middle cirrals bearing transverse ridge; (ZRC.ECH.0381). F, proximal pinnules with P<sub>1</sub> at right, showing carination on large P<sub>2</sub>; (ZRC.ECH.0381). E, G, *Decametra* sp. (ZRC.ECH.0476); E, middle cirrals showing paired low tubercles; G, proximal pinnules with P<sub>1</sub> at right, with P<sub>2</sub> bearing rim of spines on middle pinnulars and weak carination on distal pinnulars. Scale = 1 mm.



**Ecology.** Clings to usually fan-shaped octocorals with its ten arms arrayed in a planar or shallow-bowl-like radial fan (Meyer & Macurda, 1980).

**Material examined.** Sta. SD54, SW Kusu Island, 01°13.9'N, 103°52'E, depth not recorded, max. depth 7.8 m, 24 May 2013 (1; ZRC.ECH.0407); sta. SD151, SW Kusu Island, 01°13.9'N, 103°52'E, depth not recorded, max. depth 19.6 m, 3 June 2013 (1; ZRC.ECH.0484).

**Material previously collected at Singapore.** USNM 35313 (1 specimen), ZMC (1), Svend Gad, 17 June 1904 (as *Colobometra vepretum* in A. H. Clark, 1909a); MNB 6379 (1), Eduard von Martens (as *C. vepretum* in A. H. Clark, 1912c, with incorrect catalogue no. 5351).

#### *Cenometra* A. H. Clark, 1909d

**Diagnosis.** As many as 40 arms; brachitaxes of 2 ossicles, with adambulacral flanges; second pinnule large, stout, and curved (Hess & Messing, 2011).

**Remarks.** A. H. Clark (1947) distinguished four species of *Cenometra* on the basis of variations in the development of carination on the basal pinnulars of the proximal pinnules, although Gislén (1940) suggested that the differences were age-related. A. M. Clark & Rowe (1971, p. 19) stated that *C. cornuta* and *C. herdmani* “should be considered as synonyms” of *C. bella* and maintained only *C. emendatrix* from the western Indian Ocean as distinct. However, they distinguished all four in their key.

#### *Cenometra bella* (Hartlaub, 1890)

(Fig. 7B)

**Colour.** Zebra-banded yellow and dark chocolate.

**Ecology.** The single collected specimen was found clinging to an antipatharian whip.

**Material examined.** Sta. SD133, south of Kusu Island, no lat., long., 11 m, 31 May 2013 (1; ZRC.ECH.0467).

#### *Decametra* A. H. Clark, 1911c

**Diagnosis.** Proximal cirrals with transverse aboral ridge, becoming paired spines or tubercles, or rarely a single spine distally; arms 10; first interior pinnule ( $P_a$ ) absent; second pinnule ( $P_2$ ) rounded or rounded triangular in cross section (prismatic); distal ends of pinnulars uniformly spinose or smooth (Hess & Messing, 2011).

**Remarks.** The published distinction between *Decametra* and *Oligometra* (A. H. Clark (1947) is minor, and it is not clear that the two should remain separate (compare diagnosis above with that of *Oligometra* below). In addition, A. H. Clark (1947) diagnosed *Decametra* as having distal ends of  $P_2$  pinnulars uniformly spinous but described *D. parva* (A. H. Clark, 1912e) as having spines at the prismatic corners of the

pinnulars, *D. mollis* (A. H. Clark, 1909f) as having projecting outer corners, and *D. arabica* A. H. Clark, 1912d, as having the distal angles produced as in *Oligometra serripinna*. Similarly, his generic diagnosis refers to distal cirrals with paired spines or tubercles or rarely a single spine, but he described three species [*D. studeri* (A. H. Clark, 1909d), *D. brevicirra* (A. H. Clark, 1912d), *D. modica* A. H. Clark, 1911c] as having 4–6 cirrals preceding the penultimate with a single spine. He recognised 16 species but noted that: “... specific lines within the genus *Decametra* are difficult to draw, and the present interpretation of specific limits must be regarded as largely tentative” (p. 172). He suggested that a number of species, e.g., *D. informis* (Carpenter, 1888), *D. modica* and *D. taprobanes* (A. H. Clark, 1909g), *D. arabica* and *D. alaudae* A. H. Clark, 1911c, might prove conspecific. Hemery (2011) returned this genus as a paraphyletic clade including representatives of three other colobometrid genera.

#### ?*Decametra* sp.

(Fig. 7E, G)

**Remarks.** Specimens collected during the SSBW are very tentatively attributed to *Decametra* and may prove instead to be *Oligometra*. All are small; the largest has ray length 35 mm. Most conform to *Decametra* in having paired tubercles or spines on one or a few distal cirrals and  $P_a$  uniformly absent. However, the paired tubercles chiefly appear as stronger ends of a weak transverse ridge, and the latter feature may be a function of small size (ray length <20 mm). As in *Oligometra*, one or few distalmost cirrals preceding the opposing spine bear a single aboral spine, and pinnulars of  $P_2$  often bear a spine at the distal corner or corners.

**Colour.** Dark or pale purple, maroon, or reddish-purple, sometimes with white arm tips, or yellow with maroon articulations; cirri white, bluish-gray, or both; pinnules sometimes blue.

**Local depth range.** 18–125 m (possibly 15–136 m).

**Ecology.** One specimen was recovered clinging to a hydroid. Bottom data recorded for dredge and trawl stations include clay, silt, mud, gravel and rocks.

**Material examined.** Sta. DR14, Eastern Fairway, 01°16.835'N, 103°55.284'E, 15.8–18.0 m, 21 May 2013 (1; ZRC.ECH.0359); sta. TB17, Eastern Holding, 01°13.816'N, 103°54.060'E, 86.7–90.9 m, 21 May 2013 (1; ZRC.ECH.0365); sta. TB28, Singapore Port Limit, Eastern Boarding Ground A, 01°13.181'N, 103°52.900'E, 94.3–97.6 m, 22 May 2013 (1; ZRC.ECH.0369); sta. TB96, near Eastern Bunkering A, 01°18.140'N, 104°04.221'E, 22.4–25.1 m, 28 May 2013 (1; ZRC.ECH.0444); sta. TB97, near Eastern Bunkering A, 01°18.425'N, 104°04.607'E, 22.4–22.7 m, 28 May 2013 (3; ZRC.ECH.0439); sta. DR111, outside Eastern Boarding Ground A, 01°12.989'N, 103°53.062'E, 125–136 m, 29 May 2013 (1; ZRC.ECH.0457); sta. TB142, East Johor Strait, 01°17.838'N, 104°04.157'E, 28.7–28.8 m, 31 May 2013 (2; ZRC.ECH.0476).



***Decametra informis* (Carpenter, 1888)**

**Diagnosis.** *Decametra* with cirri 7 mm long with 14–18 segments;  $P_1$  and  $P_2$  of 10–12 segments, with distal edge of distalmost pinnulars with small tufts of spines;  $P_2$  longer and stouter than  $P_1$ ; arms 30–40 mm long (A. H. Clark, 1947).

**Remarks.** A. H. Clark (1947) noted that this species, previously also known from the Philippines, and *D. modica*, known from east Africa to the Maldives and possibly Sri Lanka, may be synonyms.

**Material previously recorded from Singapore.** MNB 5353 (1) Prof. Edouard von Martens (A. H. Clark, 1912c, 1947).

***Decametra mylitta* A. H. Clark, 1912c**

**Diagnosis.** *Decametra* with cirri 10–11 mm long with 21–23 cirrals; all cirrals markedly broader than long;  $P_2$  9 mm long with 17 segments, much longer and stronger than small weak  $P_1$ ;  $P_3$  of 14 segments, resembling  $P_2$  but about two-thirds as long; arms 55–75 mm long (A. H. Clark, 1947).

**Remarks.** A. H. Clark (1947) noted that this species, previously also known from the Philippines, Hong Kong and possibly Borneo, and *D. mollis*, known from the Persian Gulf and Pakistan to the Maldives, are likely synonymous.

**Material previously recorded from Singapore.** No repository given (1), Svend Gad (A. H. Clark, 1947).

***Oligometra* A. H. Clark, 1908b**

**Diagnosis.** Cirrals with transverse aboral ridge; arms 10; first interior pinnule present or absent; second pinnule enlarged, stiff, prismatic, with distal ends of pinnulars produced as broad spine, flange, or tuft of spines (Hess & Messing, 2011).

**Remarks.** Hemery (2011) returned *Oligometra serripinna*, *macrobrachius* A. H. Clark, 1936b and *Oligometra carpenteri* (Bell, 1884) separately in a clade including representatives of four colobometrid genera, with *O. carpenteri* as basal.  $P_2$  in *O. carpenteri*, with its uniquely broadened and keeled segments, differs substantially from that of both *O. serripinna* and all other colobometrids (A. H. Clark, 1947).

***Oligometra serripinna* (Carpenter, 1881)**  
(Fig. 7C, D, F)

**Diagnosis.** *Oligometra* with segments of  $P_2$  mostly longer than, or at least as long as, broad, with distal ends of prismatic ridges produced or with one or more spines (A. H. Clark, 1947).

**Remarks.** A. H. Clark (1947) recorded *O. serripinna* as occurring from the Red Sea and eastern Africa to the Philippines, Indonesia, and as far north as Hong Kong. He recognised three “true geographical races or subspecies” (p. 216) from outside this range: *O. s. chinensis* (A. H. Clark,

1918) (Fujian, China) with  $P_2$  not greatly enlarged, delicate distally, with distal pinnulars twice as long as broad or longer, pinnule profile serrate in distal half, proximal pinnules with second–fourth segments narrowly carinate, and cirri relatively long and slender with up to 24 segments; *O. s. electrae* A. H. Clark, 1913 (Eritrea), as ornate, with extravagantly developed processes on proximal pinnules, and *O. s. caledoniae* A. H. Clark, 1911b (New Caledonia and Tonga), with distal ends of pinnulars of  $P_2$  weakly produced and spinous, and distal ends of following pinnules not produced. It is unclear whether any of these or his other named local varieties have any validity, e.g., the single specimen of *O. s. electrae* was collected only about 250 km north of fragmentary material attributed to one of his local varieties, *O. s. occidentalis* A. H. Clark, 1911c (southern Red Sea to Mauritius). Kogo (1998) treated specimens that represented the first records from Japan as *Oligometra chinensis*, although he described the cirri as rather stout, “proximal pinnul[ar]s mostly about as long as broad” (p. 82) and did not mention the pinnule carination described by A. H. Clark (1947) for *O. s. chinensis*. The species has since been recorded, as *Oligometra serripinna*, from tropical Australia (Houtman Abrolhos WA to Tweed River NSW) (Rowe & Gates (1995), Palau (Meyer & Macurda, 1980; Messing, 2007) and Rarotonga, Cook Islands (USNM E 38906, <http://collections.USNM.si.edu/search/iz/> downloaded 11 September 2014).

Specimens from Singapore vary considerably and exhibit features of both *O. s. serripinna* and *O. s. chinensis*. Proximal pinnulars of  $P_1$  may be distinctly carinate or not. The second pinnule may have proximal pinnulars weakly carinate or not, and middle pinnulars with no distal projection or with a well-developed sometimes finely spinose triangular projection, sometimes on both interior and exterior distal corners of pinnulars. Distal pinnulars of  $P_2$  may be distinctly longer than wide or about as long as wide in the same specimen.  $P_a$  may be absent on some rays or uniformly present. Cirri are stout, of up to 20 cirrals, with the transverse aboral ridge reduced to a single small spine only on the distal 1–2 cirrals preceding the opposing spine. The brachials are smooth or somewhat everted. The specimens collected at Singapore during the SSBW are thus treated simply as *Oligometra serripinna*.

**Colour.** Arms usually variously banded or blotched: 1) white with large dark maroon blotch on each brachial bordered with orange and chiefly orange distally, 2) with numerous red-purple blotches; 3) three to four large chocolate blotches bordered by yellow blend into broad chocolate arm stripe that gradually covers arm; 4) banded golden brown and white with some maroon aborally; 5) white with dark chocolate spots proximally, becoming short dark bands on middle and distal arms; 6) white with purple bands, or 7) all purple. Pinnules white, chocolate, banded white and maroon or dark chocolate, or white with red-purple blotches arranged in curved lines spanning several adjacent pinnules. Centrodorsal white; cirri white proximally, light maroon distally or with pale maroon adoral spot; disk mottled white and maroon, with maroon areas bordered by olive.

**Local depth range.** Subtidal to 24.6 (possibly 29.8) m.

**Ecology.** On octocorals, including red ellisellid whip.

**Material examined.** Sta. SD25, SW of St John's Island, no lat., long., 7.6 m, 22 May 2013 (6; ZRC.ECH.0379, ZRC.ECH.0381, ZRC.ECH.0382, ZRC.ECH.0384, ZRC.ECH.0385, ZRC.ECH.0396); sta. SD54, SW of Kusu Island, 01°13.9'N, 103°52'E, 7.8 m, 24 May 2013 (3; ZRC.ECH.0409, ZRC.ECH.0405, ZRC.ECH.0408); sta. TB73, S of Pulau Semakau, 01°11.282'N, 103°46.632'E, 24.6–29.8 m, 25 May 2013 (discarded); sta. SD84, SW of Pulau Tekukor, 01°13.8'N, 103°50.25'E, 8 m, 27 May 2013 (1; ZRC.ECH.0429); sta. IT93, Pulau Jong, 01°12.901'N, 103°47.194'E, <1 m, 28 May 2013, hand collection (discarded); sta. TB113, Southern Fairway, S of Sisters' Islands, 01°12.001'N, 103°50.261'E, 29.3–30.5 m, 29 May 2013 (1; ZRC.ECH.0453); sta. SB132, S of Kusu Island, no lat., long., 8 m, 31 May 2013 (discarded).

**Material previously collected at Singapore.** ZMC (75?), shallow water, Svend Gad; USNM (2) 36265, E1072) (A. H. Clark, 1947).

***Pontiometra* A. H. Clark, 1907b**

**Diagnosis.** Adoral side of centrodorsal with irregular, radiating, coelomic furrows; cirri with up to 80 cirrals; proximal cirrals with distal aboral spinose edge; middle cirrals with paired spines; distal cirrals with single spine; to 120 arms; all brachitaxes of 2 ossicles. P<sub>1</sub> on exterior undivided arms much longer than those following (Hess & Messing, 2011).

***Pontiometra andersoni* (Carpenter, 1889)  
(Fig. 7A)**

**Remarks.** *Pontiometra andersoni* is the only species in the genus. It is easily recognised by its large size, many arms arrayed in a parabolic fan, very long cirri that elevate it above the substrate, and first pinnule on each arm much longer than those following. It is soft relative to most other local crinoids and sheds its arms easily.

**Colour.** Pale, creamy tan or white with short brown arm bands; one specimen with pair of faint tan aboral stripes flanking midaboral white stripe; pinnules pale creamy tan either with few or many brown pinnules, few dark brown pinnules forming 1–2 short irregular concentric bands on rays, or with brown bands on successive pinnules form stripes parallel to arm; one specimen each with pinnules and ambulacra dark brown, rays pale orange and white, or entirely white. Cirri pale creamy tan; disk with brown spots.

**Local depth range.** 3–39.5 (possibly 40.2) m.

**Ecology.** Perches fully exposed on rock or coral pinnacles and sponges with arms arrayed in a parabolic fan (Meyer & Macurda, 1980).

**Material examined.** Sta. SD45, channel between Lazarus and St John's Is., 01°13'21"N, 103°51'02"E, max. depth 16.2 m, 23 May 2013 (1; ZRC.ECH.0404); sta. TB73, S of Pulau Semakau, 01°11.282'N, 103°46.632'E, 29.8–24.6 m, 25 May 2013 (2; ZRC.ECH.0415, ZRC.ECH.0416); sta. SD66, W patch reef, Pulau Hantu, 01°13.6'N, 103°44.8'E, 3 m, 25 May 2013 (1; ZRC.ECH.0419); sta. TB69, near Pulau Sudong and Pulau Semakau, 01°13.155'N, 103°43.880'E, 17.9–18.9 m, 25 May 2013 (1; discarded); sta. TB71, S of Pulau Hantu, 01°13.157'N, 103°44.642'E, 21.1–22.6 m, 25 May 2013 (1; discarded); sta. SD133, S of Kusu Island, 01°13'13"N, 103°51'38"E, max. depth 11 m, 31 May 2013 (1; ZRC.ECH.0468); sta. SD151, SW of Kusu Island, 01°13.9'N, 103°52'E, max. depth 19.6 m; 3 June 2013 (2; ZRC.ECH.0482, ZRC.ECH.0483); sta. SD167, SW of Pulau Jong, 01°12'51"N, 103°47'07"E, max. depth 15.4 m, 4 June 2013 (1; ZRC.ECH.0492); sta. TB187, near Raffles Lighthouse, 01°09.239'N, 103°44.674'E, 39.5–40.2 m, 5 June 2013, trawl (1; ZRC.ECH.0498).

**Material previously collected at Singapore.** USNM 36264 (1 specimen), ZMC (4), Svend Gad (in A. H. Clark, 1909a, 1947); MNB 5351, 5372 (2 cirri and a visceral mass), Eduard von Martens (in A. H. Clark, 1912c); Raffles Museum (1), 1899, no collector (in A. H. Clark, 1934).

**Family HIMEROMETRIDAE A. H. Clark, 1908a**

**Diagnosis.** Centrodorsal aboral apex broad and flat, depressed or deeply concave; extant genera with cirrus sockets without distinct sculpturing, basal rosette but no basal rods, and adoral surface of centrodorsal with interradiating ridges and paired, Y-shaped, or radiating coelomic furrows (also on aboral surface of radials); cirrals with or without aboral tubercle or spine; radial articular facet moderately sloping to very steep; interarticular ligament fossae large and high; adoral muscle fossae low, curved along adoral edge and more or less continued along part of midradial furrow; radial cavity large; IBr<sub>2</sub> united by synarthry; following brachitaxes of either 2 or 4 ossicles; first arm syzygy at 3+4; brachials of undivided arms often extremely short, often discoidal; one or more proximal pinnules enlarged (modified from Hess & Messing, 2011).

**Remarks.** Relationships within and among Himerometridae, Zygometridae, Colobometridae and Mariametridae remain to be clarified (see under Colobometridae above and Mariametridae and Zygometridae below).

***Himerometra* A. H. Clark, 1907b**

**Diagnosis.** Himerometridae with proximal pinnules decreasing in length and stoutness from the most proximal (on the brachitaxes) to P<sub>3</sub>; brachitaxes strongly rounded aborally and well separated; usually more than 25 arms; IIIBr series usually 4(3+4) on the outside and 2 on the inside of each IIBr series.

**Remarks.** A. H. Clark (1941) distinguished six species in two groups: *H. robustipinna* (Carpenter, 1881), *H. magnipinna* A.

H. Clark, 1908d, *H. sol* A. H. Clark, 1912d, and *H. martensi* (Hartlaub, 1890) with stout proximal pinnules composed chiefly of short pinnulars lacking any carination, and *H. bartschi* A. H. Clark, 1908d, and *H. persica* A. H. Clark, 1908e, with long, slender, distally flagellate and proximally carinate proximal pinnules.

***Himerometra robustipinna* (Carpenter, 1881)**

**Diagnosis.** *Himerometra* with enlarged proximal pinnules stout with all or most pinnulars broader than long, or as broad as long, no carination, and with distal margins of proximal pinnulars swollen and everted or not.

**Remarks.** *Himerometra magnipinna* is here considered a junior synonym of *H. robustipinna*; the only characters on which A. H. Clark (1941) distinguished them (length and number of component pinnulars of enlarged proximal pinnules) overlap substantially, as do their ranges. The two known specimens of *H. sol* appear to be slightly more robust variants of *H. robustipinna* but were collected in the Maldivian Islands, whereas the westernmost record of *H. robustipinna* [recorded as its putative synonym, *H. kraepelini* (Hartlaub, 1890)] is Sri Lanka. A. H. Clark (1941) distinguished *H. martensi* (Hartlaub, 1890) as having distal margins of enlarged proximal pinnules projecting abruptly beyond the bases of succeeding pinnulars (but not overlapping) and armed with numerous fine spines (restricted to distal pinnulars in large specimens), and distal ends of proximal brachials strongly produced and everted. However, examination of several specimens collected by Svend Gad at Singapore (the type locality) and identified as *H. martensi* by A. H. Clark (USNM 36136, E1080), while exhibiting pinnulars of large proximal pinnules with distal margins thickened and projecting on one side, and brachials with everted distal margins, revealed no fine spines (numerous or otherwise) on pinnulars of enlarged proximal pinnules. The variations in these specimens and those collected during the SSBW fall well within the range of variation of *H. robustipinna*. *Himerometra martensi* is thus considered a junior synonym of *H. robustipinna*.

**Colour.** Rays orange or pale red; pinnules and ambulacra red or dark red; or entirely red.

**Local depth range.** <1.0–20.6 (possibly 22.6) m.

**Ecology.** Perches fully exposed on corals, rocks, sponges or octocorals with arms arrayed in a parabolic or radial fan; often with arms curled meridionally inward. Symbionts recorded during the SSBW were *Periclimenes commensalis* (sta. SD89) and *Allogalatea elegans* (sta. 133).

**Material examined.** Sta. SD25, SW of St. John's Island, 01°13'02"N, 103°50'48"E, 6.8 m, 22 May 2013 (3; ZRC.ECH.0390, ZRC.ECH.0377, ZRC.ECH.0383); sta. DR70, near Pulau Sudong and Pulau Semakau, 01°13.134'N, 103°44.283'E, 20.6–22.6 m, 25 May 2013 (1; ZRC.ECH.0420); sta. TB69, near Pulau Sudong and Pulau Semakau, 01°13.155'N, 103°43.880'E, 17.9–18.9 m, 25

May 2013 (9; discarded); sta. IT81, Big Sister's Island, ~ 01°12'51"N, 103°49'56"E, <1 m, 26 May 2013, hand collection (1; discarded); SD89, S of Small Sister's Island, 01°12.9'N, 103°49.88'E, 9–10 m, 27 May 2013 (1; discarded); sta. SD133, S of Kusu Island, 01°13'13"N, 103°51'38"E, max. depth 11 m, 31 May 2013 (1; discarded); sta. IT140, Pulau Tekukor, 01°13.899'N, 103°50.265'E, <1 m, 31 May 2013, hand collection (1; discarded).

**Material previously collected at Singapore.** Raffles Museum (1), 1899, no collector (as *Himerometra magnipinna* in A. H. Clark, 1934); MNB 5373 (1 specimen), Straits Settlements, von Martens (as *Antedon martensi* in Hartlaub, 1890, 1891; and in A. H. Clark, 1941); USNM 35968 (2), 36136 (6), 36176 (1), E1080 (1); ZMC (21?), Svend Gad (as *H. crassipinna* in A. H. Clark, 1909a, as *H. martensi* in A. H. Clark, 1941); BSNH (18), no collector (in A. H. Clark, 1909a, 1941); MCZ 59 (1), 289 (1), no cat. no. (1), no collector (as *H. martensi* in A. H. Clark, 1909a, 1941); Raffles Museum (1), no collector (as *H. martensi* in A. H. Clark, 1934, 1941); YPB (1) no collector (as *H. martensi* in A. H. Clark, 1941); NHM (1), Pulau Obin (as *H. martensi* in A. H. Clark, 1913, 1941).

***Himerometra bartschi* A. H. Clark, 1908d**

**Diagnosis.** *Himerometra* with enlarged proximal pinnules long, slender, distally flagellate; proximal pinnulars carinate (A. H. Clark, 1941).

**Material previously collected at Singapore.** ZMC (1 specimen), Svend Gad (in A. H. Clark, 1909a, 1941).

***Craspedometra acuticirra* (Carpenter, 1882)**

**Diagnosis.** Himerometridae with cirri long, nearly straight or slightly curved, tapering gradually to sharp tip; of 40–60 cirrals; distal cirrals much longer than broad and without aboral processes; no opposing spine; terminal claw nearly straight; P<sub>2</sub> longer and stouter than more proximal pinnules (modified from A. H. Clark, 1941).

**Remarks.** *Craspedometra* is a nonspecific genus that includes only *C. acuticirra*.

**Material previously collected at Singapore.** MNHN no cat. no. (1 specimen), M. Maidron, 1884 (A. H. Clark, 1911b); ZMC no cat. no. (1), Svend Gad (in A. H. Clark, 1909a, 1941).

***Heterometra* A. H. Clark, 1909d**

**Diagnosis.** Centrodorsal hemispherical to discoidal with flat aboral apex; adoral side with radiating coelomic furrows in paired depressions; arms 10–48; brachitaxes of 2 or 4 ossicles; ray bases separated or laterally apposed; proximal pinnules increasing in length and stoutness to P<sub>3</sub>; pinnulars smooth, carinate or distally spinose, or flanged (Hess & Messing, 2011).



**Remarks.** *Heterometra* currently includes 27 named species, 16 of which were described by A. H. Clark. Of the latter, ten were described from fewer than five specimens each (i.e., *H. astyanax* A. H. Clark, 1941, *H. ater* (A. H. Clark, 1911c), *H. flora* (A. H. Clark, 1913), *H. gravieri* A. H. Clark, 1911c, *H. joubini* A. H. Clark, 1911c, *H. madagascarensis* (A. H. Clark, 1911c), *H. parilis* (A. H. Clark, 1909h), *H. producta* (A. H. Clark, 1908a), *H. sarae* A. H. Clark, 1941, and *H. schlegelii* (A. H. Clark, 1908a)) (A. H. Clark, 1941). A. H. Clark (1941) wrote that many of the characters (i.e., cirri, pinnules, and arms) are highly variable and overlap those of the other himerometrid genera to varying degrees, and that members of the genus are recognised chiefly because they do not fall within any of the other himerometrid genera. Hemery (2011) returned two terminals in two separate clades (*Heterometra crenulata* among several Himerometridae and *Heterometra* sp. within Mariametridae), so it is possible that the genus will be dismantled.

Many species are differentiated on the basis of minor morphological differences, and A. H. Clark (1941) admitted that some species may intergrade (e.g., *H. producta* and *H. propinqua* (A. H. Clark, 1912e)) and that “species of *Heterometra* are among the most difficult of all comatulids to identify” (p. 227). Clark & Rowe (1971) also pointed out inconsistencies between A. H. Clark’s keys and descriptions. As an example, one of the primary dichotomies in A. H. Clark’s (1941, pp. 230–231) key to the species of *Heterometra* is: basal segments of the enlarged proximal pinnules with versus without prominent thin carinate processes or keels on the side toward the arm tip. However, the character is almost identical in the holotypes of *H. schlegelii* (ZMC cat. no. CRI-41) in the group with keels and *H. producta* (ZMC cat. no. CRI-34) in the group without, although the distal ends of the distal pinnulars bear a few spines in *H. producta* (C.G. Messing, personal observations).

Multiple specimens collected during the SSBW cannot be satisfactorily identified to species, either because of their small size or lack of definitive characters, and some are only tentatively identified as *Heterometra*; they have not been included herein. Identifications to the species level are also tentative.

#### *Heterometra affinis* (Hartlaub, 1890)

**Diagnosis.** *Heterometra* with enlarged proximal pinnules smooth with proximal pinnulars carinate; P<sub>2</sub> the largest and longest pinnule; cirri of up to 30 cirrals; few cirrals slightly longer than broad; distal cirrals with small aboral spines; arms 15–18, 65–120 mm long, composed of wedge-shaped brachials (A. H. Clark, 1941).

**Material previously recorded from Singapore.** USNM E1082 (1), ZMC (2?), Svend Gad (A. H. Clark, 1941).

#### *Heterometra amboinae* (A. H. Clark, 1912d)

**Diagnosis.** *Heterometra* with brachials distinctly wedge-shaped with ends never quite parallel, and not exceedingly

short; enlarged proximal pinnules smooth, with proximal pinnulars keeled; cirri of 28–40 (usually 30–35) subequal cirrals; all cirrals about twice as broad as long; arms 13–23 (usual 17–19), 105–180 mm long; P<sub>2</sub> and P<sub>3</sub> of 26–31 segments; P<sub>3</sub> usually longer than P<sub>2</sub> (A. H. Clark, 1941).

**Material previously recorded from Singapore.** ZMC (1), Svend Gad, 12 December 1906 (A. H. Clark, 1941).

#### *Heterometra bengalensis* (Hartlaub, 1890)

**Diagnosis.** *Heterometra* with brachials beyond the proximal fourth of the arms exceedingly short, discoidal, with ends parallel; distal ends of proximal brachials produced and everted; IIIBr series absent; cirri of 22–31 (chiefly <30) cirrals, 13–22 mm long; longest cirrals somewhat longer than broad; arms 11–18, 50–100 mm long; P<sub>2</sub> and P<sub>3</sub> similar, 9 mm long, of 24 pinnulars, or P<sub>3</sub> is somewhat smaller than P<sub>2</sub>.

**Remarks.** A. M. Clark (in Clark & Rowe, 1971, p. 12) suggested that the specimens from Singapore in the NHM identified by A. H. Clark “may be referable rather to *H. singularis*.”

**Material previously recorded from Singapore.** USNM E1073 (1), E1079 (5), ZMC (15?), Svend Gad; NHM (2), 13 m, 12 December 1898; Raffles Museum (1), New Harbor, 15 m, 31 July 31 1899 (A. H. Clark, 1941).

#### *Heterometra* cf. *crenulata* (Carpenter, 1882)

(Fig. 8A, C)

**Diagnosis.** A highly variable *Heterometra* with enlarged, strongly prismatic proximal pinnules; distal portion of prismatic ridges on each pinnular raised into conspicuous broad rounded triangular processes; pinnule profiles strongly serrate with ends of teeth broadly rounded (A. H. Clark, 1941).

**Remarks.** Specimens identified as *H. crenulata* have the enlarged proximal pinnules moderately to strongly prismatic with the distal ends of the ridges, especially the abambulacral ridge facing the arm tip, bearing a finely spinose projection that gives the pinnule a serrate profile. In some middle pinnulars the spines form a short partial rim across the distal margin facing the arm tip. The distal cirrals bear an aboral carina or longitudinally flattened, distally-directed spine; the spine may be blunt or sharp and the carina may be divided into 2–3 teeth. Low synarthrial tubercles are present, and at least some of the short middle brachials have projecting distal margins. Small specimens with at least some projection of the distal corners of the pinnulars on the proximal pinnules have been placed here; their cirri are substantially more delicate with longer, more slender cirrals, but retain an aboral spine or carina.

**Colour.** Red-orange, yellow-orange, pinkish-red, reddish-purple, pink, often with paler or white pinnules; rays often banded, e.g., rays yellow-orange with pale tan-yellow bands and white pinnules; pale purple or white with darker arm bands; dull reddish-purple with white bands; creamy yellow



with white bands; pink and white banded; white with broad light purple bands or with pale orange bands, or pale orange with white and pale red bands. Bands may be restricted to proximal or distal arms. Ambulacral tissue often darker (red, maroon or purple) with dark color sometimes restricted to more darkly-colored arm bands.

**Local depth range.** 22.7–125 (possibly 22.4–136) m.

**Ecology.** All specimens identified as *H. crenulata* were trawled or dredged on a variety of bottoms, including rocks, gravel, dead shells, shell fragments, coral rubble, laterite rock, sand, smelly sand, silt, mud, clay, sticky clay, big lumps of clay, reddish marine clay, and sponge, in various combinations.

**Material examined.** Sta. DR1, Raffles reserve near Raffles Lighthouse, 01°10.125'N, 103°45.419'E, 38.3–38.5 m, 20 May 2013 (2; ZRC.ECH.0352, 1; ZRC.ECH.0353, 1; ZRC.ECH.0355); sta. 5313TB3, Eastern Boarding Ground A, beside Eastern Holding B, start 01°14.079'N, 103°54.165'E, end 01°13.932'N, 103°53.811'E, 67.9–79.3 m, 17 May 2013 (1; ZRC.ECH.0617); sta. TB15, Eastern Fairway, 01°16.300'N, 103°55.226'E, 21.5–23.8 m, 21 May 2013, Beam trawl, (1; ZRC.ECH.0364); sta. TB16, outside Eastern Boarding Ground A, 01°13.537'N, 103°53.793'E, 89.5–98.0 m, 21 May 2013 (2; ZRC.ECH.0362, ZRC.ECH.0366); sta. TB28, Singapore Port Limit, Eastern Boarding Ground A, 01°13.181'N, 103°52.900'E, 94.3–97.6 m, 22 May 2013 (2; ZRC.ECH.0371, ZRC.ECH.0389); sta. TB73, S of Pulau Semakau, 01°11.282'N, 103°46.632'E, 24.6–29.8 m, 25 May 2013 (1; ZRC.ECH.0424); sta. TB96, near Eastern Bunkering A, 01°18.140'N, 104°04.221'E, 22.4–25.1 m, 28 May 2013 (3; ZRC.ECH.0442); sta. TB97, near Eastern Bunkering A, 01°18.425'N, 104°04.607'E, 22.4–22.7 m, 28 May 2013 (1; ZRC.ECH.0441); sta. DR111, outside Eastern Boarding Ground A, 01°12.989'N, 103°53.062'E, 125–136 m, 29 May 2013 (1; ZRC.ECH.0448); sta. TB127, beside Eastern Boarding Ground A, 01°12.974'N, 103°52.960'E, 113–128 m, 30 May 2013 (1; ZRC.ECH.0466); sta. TB129, beside Eastern Boarding Ground A, 01°12.783'N, 103°52.200'E, 66.5–74.7 m, 30 May 2013 (1; ZRC.ECH.0460); sta. TB142, East Johor Strait, 01°17.838'N, 104°04.157'E, 28.7–28.8 m, 31 May 2013 (1; ZRC.ECH.0472); sta. DR161, beside St John's Island, 01°12.843'N, 103°51.449'E, 41.2–44.4 m, 3 June 2013 (3; ZRC.ECH.0488, ZRC.ECH.0489, ZRC.ECH.0490); sta. DR174, next to Eastern Boarding Ground A near Kusu Island, 01°12.202'N, 103°52.178'E, 79.6–135 m, 4 June 2013 (1; ZRC.ECH.0494); sta. DR183, beside Raffles Lighthouse, 01°09.652'N, 103°44.908'E, 39.7–42.1 m, 5 June 2013 (1; ZRC.ECH.0495, 3; ZRC.ECH.0496, 1; ZRC.ECH.0497); TB185, next to Pulau Senang, 01°09.942'N, 103°43.458'E, 24.5–24.3 m, 5 June 2013 (4; ZRC.ECH.0499).

**Material previously recorded from Singapore.** ZMC (6), Svend Gad (A. H. Clark, 1941).

### *Heterometra producta* (A. H. Clark, 1909a)

**Diagnosis.** *Heterometra* with enlarged proximal pinnules rather slender, becoming flagellate distally; basal segments sharply carinate; pinnulars from the third onward with entire distal end somewhat produced and overlapping; outer portion of prismatic ridges produced into a blunt spine directed obliquely forward; cirri of 23–26 cirrals; longest cirrals with LW 1.5; distal cirrals with LW ~1.0; arms 10–13, 50 mm long (A. H. Clark, 1941).

**Material previously recorded from Singapore.** ZMC (1), Svend Gad (A. H. Clark, 1941).

### *Heterometra quinduplicava* (Carpenter, 1888)

**Diagnosis.** *Heterometra* with cirri of 25–36 (usually ~30) subequal cirrals about as long as broad; distal cirrals at least weakly carinate but aboral spines or tubercles absent; enlarged proximal pinnules slender, smooth, with basal pinnulars more or less abruptly rounded, sharpened, or obscurely carinate on side toward arm tip; arms 10–26 (usually 15–20), 60–145 mm long; brachials very short (A. H. Clark, 1941).

**Material previously recorded from Singapore.** ZMC (2), Svend Gad (A. H. Clark, 1941).

### *Heterometra schlegelii* (A. H. Clark, 1908a)

(Fig. 8B, D)

**Diagnosis.** *Heterometra* without IIIBr series; distal brachials exceedingly short and discoidal; distal margins of middle brachials everted; radials with beads along distal margin; brachitaxes laterally flattened; cirri ~20 mm long with usually 30–35 cirrals; longest cirrals about as long as broad; distal cirrals with LW ~1.3; aboral cirral spines long, sharp, beginning abruptly; arms 12–13 (possibly to 20?), 70–85 mm long; proximal pinnules with prominent thin carinate extensions or keels on the side toward the arm tip (modified from A. H. Clark, 1941).

**Remarks.** Several specimens referred to *H. schlegelii* agree with the diagnosis, key, and description in A. H. Clark (1941). The holotype (ZMC cat. no. CRI-41) is similar but appears somewhat more slender. The Singapore specimens differ chiefly in having more arms—up to either 19 or 20.

**Colour.** Orange with dark brown articulations. Live colour was not recorded for specimen ZRC.ECH.0513; it is pinkish gray with dark purple articulations in alcohol. ZRC.ECH.0434 is similar to the other two but with slightly more slender rays and a different color pattern: ray bases and cirri white; rays orange-brown; pinnules white with purple bases, some pinnules banded purple and white.

**Ecology.** Specimens were trawled or dredged. Substrates recorded were sandy and laterite gravel.

**Material examined.** Sta. TB73, S of Pulau Semakau, 01°11.282'N, 103°46.632'E, 24.6–29.8 m, 25 May 2013 (1; ZRC.ECH.0417, 3; ZRC.ECH.0512, 1; ZRC.ECH.0513); sta. DR90, Southern Fairway near St John's Island, 01°12.942'N, 103°51.946'E, 48.3–49.7 m, 27 May 2013 (1; ZRC.ECH.0432); sta. TB92, Southern Fairway near St John's Island, 01°12.926'N, 103°51.647'E, 39.5–49.9 m, 27 May 2013 (2; ZRC.ECH.0434, ZRC.ECH.0435); sta. TB113, Southern Fairway, S of Sisters' Island, 01°12.001'N, 103°50.261'E, 29.3–30.5 m, 29 May 2013 (1; ZRC.ECH.0452); sta. DR125, beside Sisters' Island, 01°12.416'N, 103°49.858'E, 25.3–30.8 m, 30 May 2013 (1; ZRC.ECH.0465).

***Heterometra singularis* A. H. Clark, 1909g**

**Diagnosis.** *Heterometra* with brachials distinctly wedge-shaped with ends never quite parallel and not exceedingly short; enlarged proximal pinnules smooth, with proximal pinnulars keeled; cirri of 36–39 cirrals, about 35 mm long; longest cirrals about as long as broad and distal cirrals slightly broader than long with conspicuous aboral spines; arms 12–20, 90–150 mm long; P<sub>2</sub> largest pinnule; P<sub>1</sub> and P<sub>3</sub> equally long (A. H. Clark, 1941).

**Material previously recorded from Singapore.** ZMC (1), Svend Gad (A. H. Clark, 1941).

***Amphimetra* A. H. Clark, 1909d**

**Diagnosis.** Himerometridae with centrodorsal low hemispherical to discoidal; adoral side with radiating coelomic furrows; exposed surface of radials low, but higher in small species; arms 10; rare individuals with more than 10 arms have IIBr<sub>2</sub>; proximal pinnules only slightly enlarged (Hess & Messing, 2011).

**Remarks.** Hess & Messing (2011) maintained *Amphimetra* within Himerometridae in part because of the radiating coelomic furrows on the adoral surface of the centrodorsal rather than an undivided coelomic impression as in Mariametridae. However, molecular data (Hemery, 2011) place *Amphimetra* within a clade consisting of several mariametrids (*Lamprometra* and *Mariametra* species) and *Heterometra* sp., separate from other himerometrids. Rare specimens with greater than ten arms have IIBr of two ossicles as in Mariametridae, rather than both 2 and 4(3+4) as in Himerometridae.

A. H. Clark (1941) recognised six species-level taxa within the genus, but acknowledged that four intergrade (*A. pinniformis*, *A. molleri*, *A. tessellata*, *A. spectabilis*), and he distinguished the other two, *A. ensifer* and *A. laevipinna*, chiefly on size-related features and the extent of development of synarthrial tubercles (see Clark & Rowe, 1971). Thus, the number of valid taxa and the placement of the genus both remain to be determined.

***Amphimetra* cf. *discoidea* (A. H. Clark, 1908d)**

**Diagnosis.** Medium to large *Amphimetra* with cirri moderately stout and straight proximally, becoming more slender and curved distally, of 34–51 cirrals; longest cirrals about as long as broad; distal cirrals with short dorsal spines or pointed tubercles; arms 110–200 mm long; prominent sharp-pointed synarthrial tubercles present (A. H. Clark, 1941).

**Remarks.** A. H. Clark (1941) treated *A. discoidea* as a geographic race, as *A. tessellata discoidea*, but wrote (p. 381): “Whether *discoidea* should be recognised as a species distinct from *tessellata*, or as a geographical race, or perhaps merely as a form, is at the present time simply a matter of personal opinion. Although when they are typically developed *tessellata* and *discoidea* are very different in appearance, they certainly intergrade. The ranges of the two types overlap, though generally speaking *tessellata* is characteristic of the region from the Sunda Islands to the Moluccas and southward along the coast of Western Australia, while *discoidea* is equally characteristic of the region from the Philippines to Singapore and eastern and northern Australia as far as the Aru Islands.” His photographic plate legends indicate both *A. discoidea* (pl. 39, figs. 178, 182) and *A. tessellata discoidea* (pl. 40, fig. 188).

The single small specimen collected during the SSBW agrees with the published description of *A. discoidea* and is similar to a specimen previously collected at Singapore. It has cirri straight proximally and low conical synarthrial tubercles. Cirri are XVII, 27–28; the proximal pinnules chiefly have 14 pinnulars but vary in relative lengths: P<sub>1</sub> is more slender than those following but may be about as long. Middle brachials are wedge-shaped but more distal brachials become more discoidal as in A. H. Clark's (1941) description. A. H. Clark included a specimen collected at Singapore by Svend Gad in his description of *A. formosa* (since synonymized under *A. discoidea*), which he described as having distal pinnulars of the proximal pinnules with “slightly thickened edges vaguely suggesting an approach to the conditions found in *Heterometra crenulata*” (A. H. Clark, 1941, p. 378)—a feature also present in the specimen collected during the SSBW.

**Colour.** Rich purple aborally with purple and white pinnules; ambulacral side of arms banded purple and white.

**Ecology.** Bottom recorded as gravel and dead shells.

**Material examined.** Sta. DR90, Southern Fairway near St John's Island, 01°12.942'N, 103°51.946'E, 48.3–49.7 m, 27 May 2013 (1; ZRC.ECH.0430).

**Material previously collected at Singapore.** ZMC (1), Svend Gad (originally as *A. formosa*); Raffles Museum (1), 1899 (A. H. Clark, 1941).



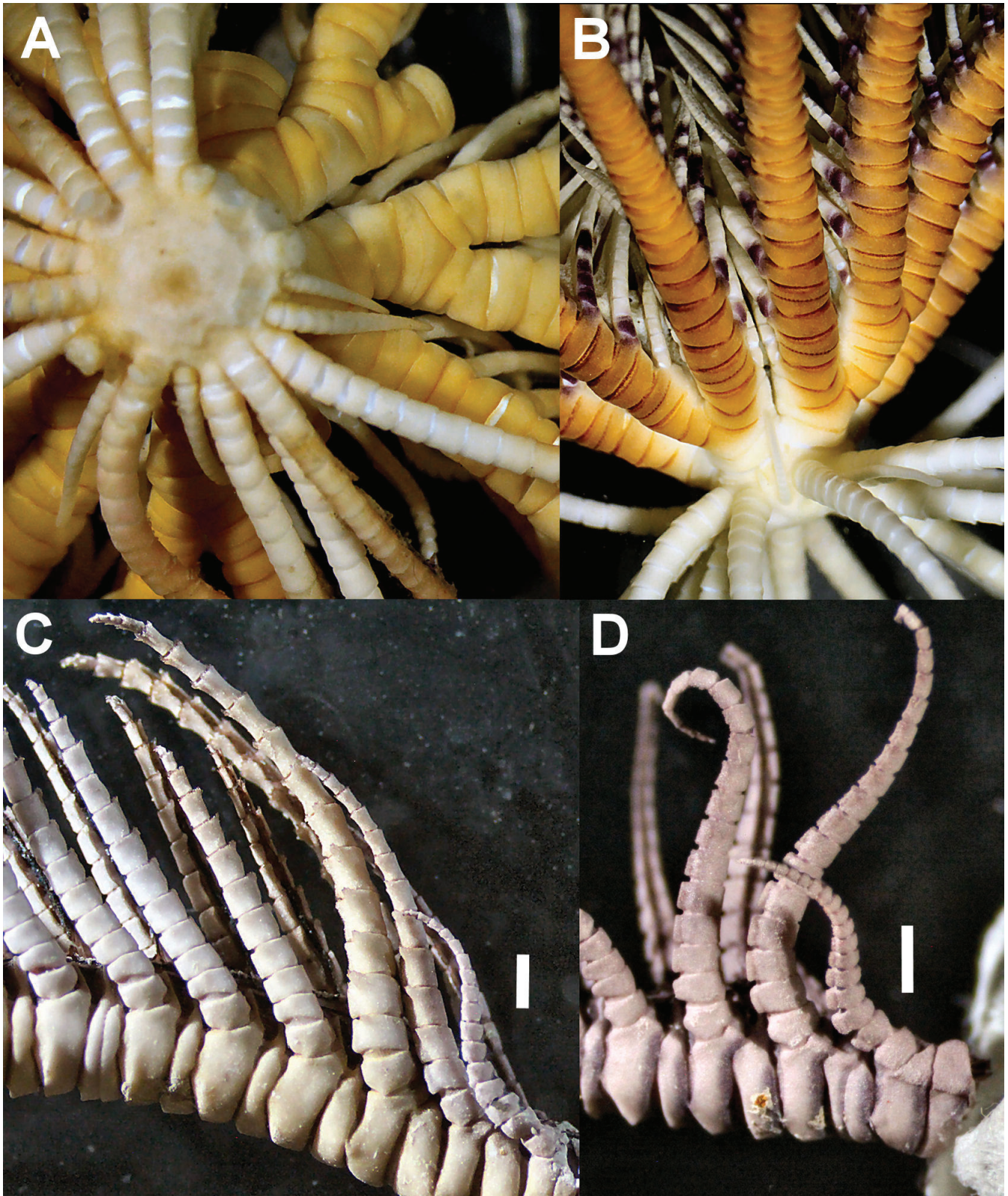


Fig. 8. *Heterometra* species. A, C, *Heterometra* cf. *crenulata*. A, aboral view, (ZRC.ECH.0466); C, Proximal pinnules, with P<sub>1</sub> at right, showing strong spines on distal corners of pinnulars of P<sub>3</sub>; (ZRC.ECH.0352); B, D, *Heterometra schlegelii*; B, lateral view showing bases of rays and cirri; (ZRC.ECH.0434); D, Proximal pinnules, with P<sub>1</sub> at right, showing strong carination on side of pinnulars facing arm tip; ZRC.ECH.0513. Scale bars = 1 mm (A, B).



***Amphimetra ensifer* (A. H. Clark, 1908a)**

(Fig. 9A, B)

**Diagnosis.** Medium to small *Amphimetra* with synarthrial tubercles extravagantly developed and produced; cirri 23–30 mm long, with usually 30–35 cirrals; longest cirrals usually slightly longer than broad; arms 80–120 mm long (A. H. Clark, 1941).

**Remarks.** All of the larger specimens collected during the SSBW have the very strongly developed synarthrial tubercles diagnostic of this species. Two smaller specimens collected with the larger specimens have less developed tubercles that are still larger than those of *A. cf. discoidea* above. The larger specimens have longest cirrals broader than long, similar to those described by A. H. Clark (1941) for *A. tessellata* as “from nearly twice as broad as long to nearly as long as broad.” Only the smaller specimens have cirrals slightly longer than broad, as described for *A. ensifer*. Until recently, *A. ensifer* was only known from Singapore. Messing (1998a) mentioned *A. ensifera/laevipinna* (following AM Clark & Rowe’s [1971] spelling of *A. ensifera*) from the Sulu Sea and noted that “large and small specimens of *Amphimetra* collected in the Sulu Sea survey key out as *A. ensifera* and *A. laevipinna*, respectively. Both occur in the same habitat (sometimes together)—clinging to isolated arborescent cnidarians or sponges on mud bottoms—and clearly represent a single species” (p. 190). Mekhova & Britayev (2012) recorded two specimens from Nhatrang Bay, Vietnam (South China Sea). They also attributed three specimens to *A. cf. tessellata*, distinguishing them on the basis of prominently developed (*A. ensifera*) vs. “purely developed” (*A. cf. tessellata*) synarthrial tubercles (p. 461), although they noted a personal communication from one of us (CGM) indicating that the two should be considered a single species. Although *A. tessellata* is the senior name, I retain *A. ensifer* herein because the specimens were collected from the Singapore type locality, and the status of the various *Amphimetra* species remains to be determined.

Fig. 9 illustrates variations in the development of synarthrial tubercles between a large and small specimen attributed to *A. ensifer* taken at the same station.

**Colour.** White with darker or dark brown ambulacra, the dark color sometimes restricted to short arm bands; centrodorsal and sometimes arm bases may be bright pale yellow; cirri pale purple, sometimes darker distally; some pinnules with pale yellow tips; one specimen with proximal arms pale lavender; a small specimen pale yellow with short purple arm bands.

**Local depth range.** 25.3–28.8 m (possibly 24.6–30.8 m).

**Ecology.** Substrates recorded for trawled and dredged specimens include very muddy, gravel, dead shells; laterite gravel and sand; sandy, and rocky.

**Material examined.** Sta. TB73, S of Pulau Semakau, 01°11.282’N, 103°46.632’E, 24.6–29.8 m, 25 May 2013

(8; ZRC.ECH.0422); sta. TB113, Southern Fairway, S of Sisters’ Island, 01°12.001’N, 103°50.261’E, 29.3–30.5 m, 29 May 2013 (1; ZRC.ECH.0451); sta. DR125, beside Sisters’ Island, 01°12.416’N, 103°49.858’E, 25.3–30.8 m, 30 May 2013 (5; ZRC.ECH.0459); sta. TB142, East Johor Strait, 01°17.838’N, 104°04.157’E, 28.7–28.8 m, 31 May 2013 (2; ZRC.ECH.0473).

**Material previously collected at Singapore.** USNM 36197 (1), 36260 (1), 36261 (1), E1083 (5), ZMC (?55), Svend Gad; NHM (7), 13 m, 12 December 1898 (A. H. Clark, 1941).

***Amphimetra molleri* (A. H. Clark, 1908a)**

**Diagnosis.** *Amphimetra* with cirri stout, curved throughout, of 24–50 short subequal cirrals with LW 0.3–0.5; aboral spines developed proximal to eighth cirral; arms to 150 mm long; P<sub>2</sub> with 18–21 pinnulars (A. H. Clark, 1941).

**Material previously recorded from Singapore.** NHM (1), 13 m, 12 December 1898; USNM E1081 (1), ZMC (8?), Svend Gad (A. H. Clark, 1941).

**MARIAMETRIDAE A. H. Clark, 1909e**

**Diagnosis.** Centrodorsal with interrarial ridges and undivided coelomic impression in each adoral radial area; cirrals fewer than 40 (up to 80 in *Oxymetra*); radial articular facet steep; interarticular fossae large and high; adoral muscle fossae low, curved along adoral edge and midradial furrow; brachitaxes always of 2 ossicles joined by synarthry; usually fewer than 40 arms (to 51 in *Oxymetra*) (Hess & Messing, 2011).

**Remarks.** In recent molecular phylogenetic reconstructions, Hemery et al. (2013) returned a monophyletic Mariametridae as sister to a clade composed of Himerometridae and Zygometridae. Hemery (2011) also found a chiefly monophyletic Mariametridae but also including the himerometrids *Amphimetra spectabilis* (see discussion under *Amphimetra* above) and a *Heterometra* sp. (*Heterometra crenulata* returned with other Himerometridae). However, Rouse et al. (2013) returned the family as paraphyletic, with two mariametrid sister terminals (*Stephanometra*, *Lamprometra*) as sister to a pair of colobometrid terminals, and this entire clade sister to another composed of the mariametrid *Liparometra* as sister to a Himerometridae/Zygometridae clade. Thus, the status and diagnosis of this family remain to be confirmed.

***Dichrometra* A. H. Clark, 1909**

**Diagnosis.** Mariametridae with cirri of fewer than 40 cirrals; brachitaxes separated laterally and smooth; P<sub>3</sub> the longest and largest proximal pinnule (Hess & Messing, 2011).

**Remarks.** See comments about the status of this genus under *Lamprometra* below. A. H. Clark (1941) recognised seven species distinguished on the basis of slight differences, chiefly variations in length-to-width proportions of cirrals and relative lengths of proximal pinnules, and wrote that *D.*



*flagellata*, *D. tenuicirra*, and *D. afra* were “probably merely local varieties of the same form” (p. 537). The status of all seven remains to be determined.

***Dichrometra flagellata* (Müller, 1841)**

(Fig. 9C)

**Diagnosis.** *Dichrometra* with longest proximal cirrals about as long as broad or slightly longer; distal cirrus segments as broad as long or broader, with usually short aboral spines; brachitaxes and arm bases more or less rugged or rugose due to more or less marked synarthrial tubercles; proximal pinnules markedly unequal in size, but none especially enlarged;  $P_3$  longest and stoutest, 9–18 mm long, with 21–38 (usually 25–30) stout cylindrical pinnulars;  $P_2$  7.5–12 mm long, with 18–27 (usually about 25) pinnulars;  $P_1$  small, weak, 4.5–11 (usually 8–9) mm long, with up to 28 pinnulars; arms 14–40 (averaging about 30), 65–150 (averaging about 110) mm long (A. H. Clark, 1941).

**Remarks.** Some specimens collected during SSBW approach *Liparometra* in having  $P_2$  and  $P_3$  the same or almost the same length on some arms. One specimen has pinnulars of enlarged oral pinnules longer than wide as described for *D. ciliata* A. H. Clark, 1912d, but has synarthrial tubercles as in *D. flagellata*.

**Colour.** Rays uniformly dark chocolate, maroon to almost black, sometimes with few short white, cream or gray bands on arms, or tan-beige with short white bands and with pinnules brown or banded brown and white, with orange tips, or rays banded gray and orange; cirri pale orange-brown.

**Ecology.** Clinging under ledges and in crevices with arms curled during the day. Commensals include *Ophiomaza* sp. (Ophiuroidea), *Periclimenes commensalis* (Crustacea, Decapoda) and unidentified myzostomes. The single trawled specimen (ZRC.ECH.0425), recorded as taken on a sandy bottom, was identified as *Dichrometra* sp.

**Local depth range.** ~3–24.6 (possibly 29.8) m.

**Material examined.** Sta. SD25, SW of St John’s Island, no lat., long., 7.6 m, 22 May 2013 (3; ZRC.ECH.0391, ZRC.ECH.0393, ZRC.ECH.0394); sta. SD56, S of Pulau Jong, 01°12.55’N, 103°47.2’E, 17 m, 24 May 2013 (1; ZRC.ECH.0411); sta. SD66, W patch reef of Pulau Hantu, 01°13.6’N, 103°44.8’E, 3 m, 25 May 2013 (1; ZRC.ECH.0418); sta. TB73, S of Pulau Semakau, 01°11.282’N, 103°46.632’E, 24.6–29.8 m, 25 May 2013 (1; ZRC.ECH.0425); sta. IT95, Raffles Lighthouse, no lat., long., no depth, 28 May 2013 (1; ZRC.ECH.0437). Two additional specimens identified in the field and discarded were collected at sta. SD89, S of Small Sister’s Island, 01°12.9’N, 103°49.88’E, 14.7 m, 27 May 2013.

**Material previously recorded from Singapore.** USNM 35238 (1), ZMC (?5), Svend Gad; NHM (5), Pulau Obin; [no collection identified] (1), Dr. Th. Mortensen, 1 June 1900 (A. H. Clark, 1941).

***Lamprometra* A. H. Clark, 1913**

**Diagnosis.** Mariametridae with centrodorsal thin, discoidal; radials partly or completely concealed by centrodorsal; cirrus sockets restricted to centrodorsal margin, not encroaching on broad aboral pole; brachitaxes separated or in close lateral apposition; brachitaxis ossicles usually thickened laterally, producing characteristically apposed flattened margins, sometimes weakly crenulate, or weakly thickened with margins not apposed; cirri of <35 cirrals; distal cirrals smooth or bearing aboral carination that may develop into a low triangular spine;  $P_1$ ,  $P_2$  and sometimes  $P_3$  with reduced ambulacral groove;  $P_2$  largest, tapering to finely flagellate tip; pinnulars barely longer than broad; articular facets normally developed (Rankin & Messing, 2008).

**Remarks.** Distinctions between *Lamprometra*, *Liparometra* and *Dichrometra* are based only on variations in relative length and strength of the proximal three oral pinnules. These are variable characters, and Gislén (1922) and H. L. Clark (1938) questioned whether the three should remain distinct. A. H. Clark (1941) acknowledged that some specimens could not be assigned to genus based on oral pinnule form, though he maintained them as separate genera, and Rankin & Messing (2008) described intermediate specimens. Among specimens collected during the SSBW, one had  $P_2$  only slightly longer than  $P_3$ , another had one arm at least with  $P_3$  as long as or longer than  $P_2$ , and a third had one  $P_1$  almost as long as  $P_2$ . The three genera are maintained as distinct here pending detailed taxonomic revision. *Lamprometra* is currently treated as monotypic (Rankin & Messing, 2008).

***Lamprometra palmata* (Müller, 1841)**

**Diagnosis.** Same as for genus.

**Remarks.** *Lamprometra palmata* as currently recognised is an extremely variable species with at least 17 synonyms. A. H. Clark (1941) reduced the number to two species—*L. klunzingeri* (Hartlaub, 1890) from the Red Sea and western Indian Ocean, and *L. palmata* with two subspecies, *L. p. palmata* and *L. p. gyges* (Bell, 1884), both with broad and broadly overlapping Indo-western Pacific ranges—but Rankin & Messing (2008) united them all as *L. palmata* based on overlapping characters. Several specimens collected during the SSBW were identified as *L. palmata* form *brachypecha*, which was originally described as a distinct species (*Lamprometra brachypecha* H. L. Clark, 1915) and is characterized by shorter arms, a color pattern including pale green blotches, spots or bands, and an enormously enlarged  $P_2$ . However, the form of  $P_2$  and the color pattern do not uniformly occur together, and Rankin & Messing (2008) treated it as an infrasubspecific variant of *L. palmata*.

**Colour.** Widely variable, ranging from one color (e.g., purplish- or dark brownish-black) to variously banded, often concentrically, e.g., white with black, purplish-black, red-purple, pale purple, yellow-orange, pale greenish-gray, gray, gray-brown, or chocolate bands; brown and tan; white with orange blotches and orange-brown bands, or pale purplish-



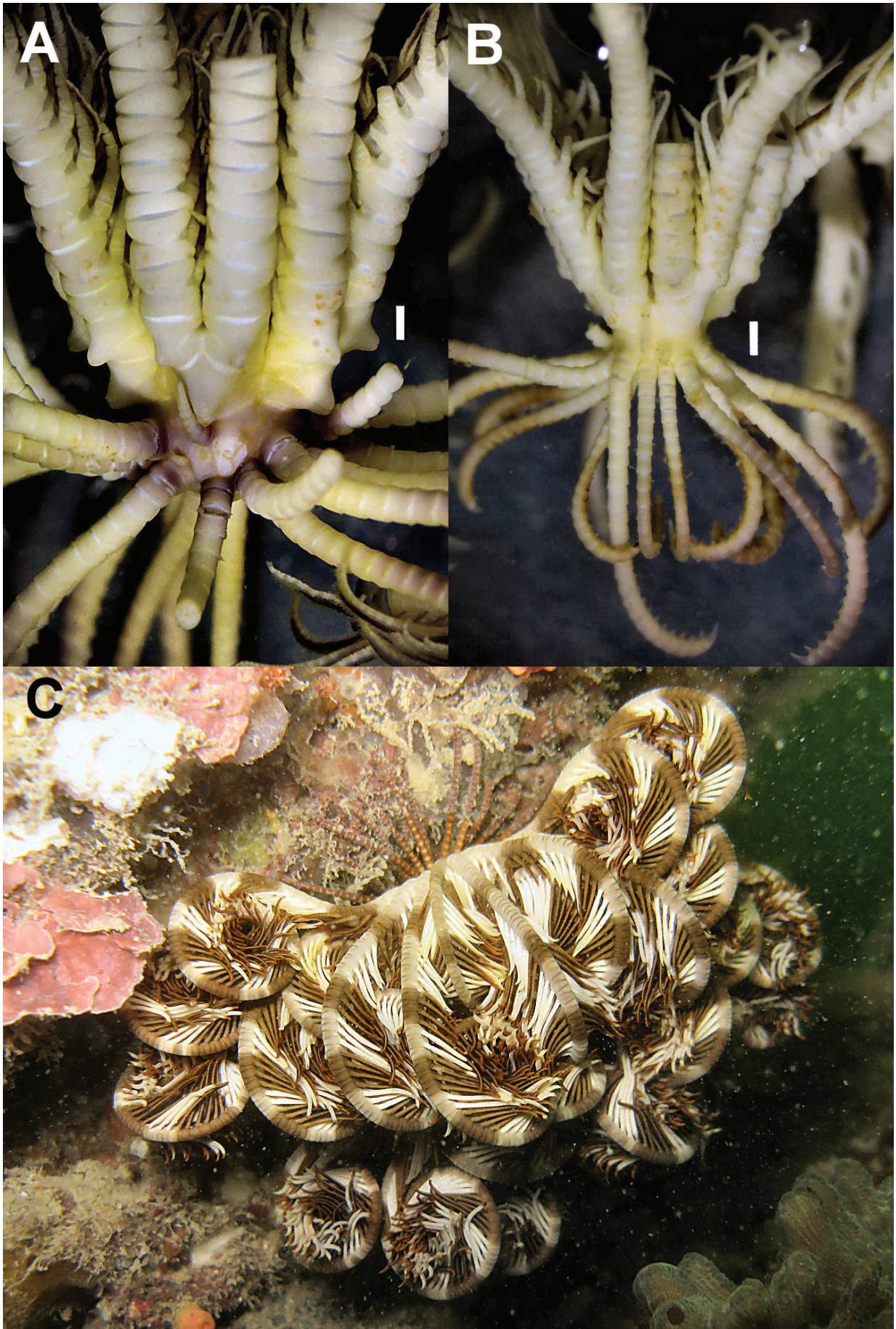


Fig. 9. A, B, *Amphimetra ensifer*; (ZRC.ECH.0459). A, large specimen in lateral view showing strongly developed conical synarthrial tubercles. B, smaller specimen with weak synarthrial tubercles. C, *Dichrometra flagellata*, in situ, Pulau Hantu, depth 3 m, night, not collected. Scale bars = 1 mm.



gray with darker bands. Bands may short or long, crowded or well-spaced, or restricted to middle and distal rays, sometimes with different colors distally and with proximal rays often paler and sometimes with darker blotches or spots, e.g., pale grayish-orange distally and spotted gray and white proximally; mottled light green and white with few narrow faint tan bands and distal arms off white; proximal rays white with light gray-brown blotches that form an irregular broken double stripe, and middle and distal rays with short tan and brown bands. Bands may be chiefly obvious on ambulacral surface. Articulations between brachials may be distinctly darker. Pinnules variously banded or spotted; oral pinnules may be colored differently than those following. Centrodorsal and cirri may be paler or white.

**Local depth range.** <1–29.3 (possibly 30.5) m.

**Ecology.** Cryptic on reefs during the day under coral rubble and slabs or within the reef infrastructure, in some areas in as little as 1 m depth among branching corals among macroalgae and seagrass. At night, perched on branching corals, large rubble, coral rock projections or prominent coral heads or sponges, with arms arranged in a biplanar arcuate fan, funnel or shallow bowl. Specimens may form feeding fans during the day under reduced light conditions, e.g., under ledges, caves, tunnels, turbid conditions or deeper water (Stevens, 1989; Messing, 2007; Rankin & Messing, 2008). Meyer & Macurda (1980) reported that, at Palau, they emerge within an hour before dusk and crawl to the tops of coral perches within ~15 min.

**Material examined.** Sta. SW6, St John's Island, DRTech pontoon at S lagoon, 01°12.928'N, 03°51.099'E, no depth, 20 May 2013 (1; ZRC.ECH.0354); sta. SD25, SW of St John's Island, no lat., long., 7.6 m, 22 May 2013 (1; ZRC.ECH.0398); sta. SB67, W patch reef of Pulau Hantu, 01°13.6'N, 03°44.8'E, 15.7 m, 25 May 2013 (1; ZRC.ECH.414); sta. IT81, Big Sister's Island (?S side), no lat., long., <1 m, 26 May 2013, hand collection (3; ZRC.ECH.0426, ZRC.ECH.0427, ZRC.ECH.0428); sta. IT102, Big Sister's Island, no lat., long., <1 m, 29 May 2013, hand collection (1; ZRC.ECH.0445); sta. SB132, S of Kusu Island, no lat., long., 8 m, 31 May 2013 (1; ZRC.ECH.0478); sta. TB113, Southern Fairway S of Sister's Island, 01°12.001'N, 103°50.261'E, 29.3–30.5 m, 29 May 2013 (2; ZRC.ECH.0449 as *L. p.* form *brachypecha*, ZRC.ECH.0450); sta. DR125, beside Sisters' Island, 01°12.416'N, 103°49.858'E, 25.3–30.8 m, 30 May 2013 (1; ZRC.ECH.0464 as *L. p.* form *brachypecha*, 10; ZRC.ECH.0461); (following specimens identified on location as *L. p.* form *brachypecha*) sta. SD56, S of Pulau Jong, 01°12.55'N, 103°47.2'E, 17 m, 24 May 2013 (1; ZRC.ECH.0412); sta. TB71, between Pulau Hantu and Pulau Sudong, 01°13.157'N, 103°44.642'E, 21.1–22.6 m, 25 May 2013 (1; ZRC.ECH.0421); sta. TB73, S of Pulau Semakau, 01°11.282'N, 103°46.632'E, 24.6–29.8 m, 25 May 2013 (1; ZRC.ECH.0423); sta. SD89, S of Small Sisters' Island, 01°12.9'N, 103°49.88'E, 14.7 m, 27 May 2013 (1; ZRC.ECH.0436); sta. IT95, Raffles Lighthouse, no lat., long., <1 m, 28 May 2013, hand collection (1; ZRC.

ECH.0438); sta. SB132, S of Kusu Island, no lat., long., 8 m, 31 May 2013 (1; ZRC.ECH.0477).

**Material previously recorded from Singapore.** Raffles Museum (1); MNB (1), Herr Jagor; ZMC (22), Svend Gad; ZMC (3) Pulau Ubin, Johore Strait, Marius Jensen (A. H. Clark, 1941).

#### *Stephanometra* A. H. Clark, 1909d

**Diagnosis.** Mariametridae with centrodorsal convex discoidal with gently sloping sides, and with cirrus sockets encroaching on aboral pole; brachitaxes well-separated; brachitaxis ossicles bearing rounded adambulacral processes oriented parallel or oblique to longitudinal axis of ossicle and producing characteristically scalloped or knobbed lateral margins; cirrals <40; distal cirrals with aboral ornamentation ranging from prominent spine to slight carination; one or more pairs of oral pinnules with reduced ambulacral groove, flattened articular facets, reduced tissue between pinnulars, conical tip and with LW of middle pinnulars 1.5–4.0; P<sub>2</sub> of 8 to 18 pinnulars (Rankin & Messing, 2008).

**Remarks.** Rankin & Messing (2008) revised and re-diagnosed the genus, reducing the number of included species from six to two.

#### *Stephanometra tenuipinna* (Hartlaub, 1890)

**Diagnosis.** *Stephanometra* with lateral margins of brachitaxis ossicles weakly swollen or with well-rounded lateral processes oriented parallel or obliquely to ray axis; at least distal cirrals with prominent aboral spine; pinnulars of P<sub>1</sub>–P<sub>4</sub> and sometimes P<sub>5</sub> elongated, LW 1.5–3.5, with reduced ambulacral groove and conical terminal segment; proximal and distal pinnular facets with elongated triangular fossae flanking ambulacral groove (Rankin & Messing, 2008).

**Remarks.** Rankin & Messing (2008) synonymized *Stephanometra echinus* (A. H. Clark, 1908d) under this species.

**Colour.** Very dark purplish black; cirri paler. Elsewhere, rays variously banded with red, red-purple, maroon, orange, brown or tan and usually some white; sometimes with orange blotches; sometimes all white with red tips, or red proximally and white distally with or without red tips. Rarely gray proximally and deep purple distally. Brachitaxes may be orange, dark rose, purple or maroon with white, pink, orange or brown speckles, or with orange blotches or with scattered pink and white areas. Mid-arm may be dark orange-brown with numerous white or tan bands (Rankin & Messing, 2008).

**Ecology.** Diurnally cryptic, curled within reef infrastructure or deep among *Acropora* colony branches; perches at night on prominent coral heads. Arms usually arrayed in a biplanar arcuate filtration fan, or spread radially over its perch, sometimes with upcurrent arms raised perpendicular to

substrate (Rankin & Messing, 2008). The specimen collected during the SSBW was exposed during the day, probably due to low visibility and low light penetration.

**Material examined.** Sta. SD25, SW of St John's Island, 01°12'51"N, 103°50'57"E, 6.8 m, 22 May 2013 (1; ZRC.ECH.0376).

**Material previously collected at Singapore.** ZMC (1 specimen), Svend Gad (in A. H. Clark, 1909a).

### *Stephanometra indica* (Smith, 1876)

**Diagnosis.** *Stephanometra* with brachitaxis ossicles weakly swollen laterally or with thick rounded ridge-like extensions oriented obliquely to longitudinal axis of ray; middle and distal cirrals bearing midaboral carination, sometimes with small spine distally; P<sub>1</sub> slender, tapering delicately to conical tip; P<sub>2</sub> alone or P<sub>2</sub> and following 1–3 pinnules composed of elongated pinnulars with reduced ambulacral groove, conical terminal segment, and flattened articulations lacking triangular fossae (Rankin & Messing, 2008).

**Remarks.** Based on numerous morphologically intermediate specimens, Rankin & Messing (2008) placed three species [*S. spicata* (Carpenter, 1881), *S. oxyacantha* (Hartlaub, 1890) and *S. spinipinna* (Hartlaub, 1890)] in synonymy under *S. indica*. They were formerly distinguished on the basis of variations in number of stiff, spinelike proximal pinnules.

**Colour.** Arms appear zebra-striped; articulations black or chocolate, sometimes bordered with brown; brachials white, with series of gray, light and/or dark brown brachials forming concentric bands; pinnules orange, yellow or both, or banded white or light brown and brown, sometimes with orange tips.

**Ecology.** Cryptic during the day under slabs or rubble, or within reef infrastructure. Exposed at night on coral rock projections, prominent coral heads, and sometimes on massive soft corals. Although the typical nocturnal posture is a biplanar arcuate fan, individuals may also form a flat or shallow bowl-like radial fan with arms spread across the surface of their perch (Rankin & Messing, 2008). Individuals may actively form fans during the day, but only under reduced light conditions, e.g., under ledges, in recesses or caves (Meyer & Macurda, 1980), or at greater depths (Stevens 1989).

**Local depth range.** 3–15.4 m.

**Ecology.** Symbionts collected on *S. indica* during the SSBW include *Harrovia* sp., *Allogalthea elegans*, *Periclimenes commensalis* and unidentified shrimp, myzostome and scaleworm.

**Material examined.** Sta. SD25, SW of St. John's Island, no lat., long., 6 m, 22 May 2013 (1; ZRC.ECH.0392 *S. indica* f. *spicata*); sta. SD40, W of Pulau Semakau, 01°12.389'N, 103°45.24'E, 7.5 m, 23 May 2013 (1; ZRC.ECH.0400); sta. SB54, SW of Kusu Island, 01°13.9'N, 103°52'E, 7.8

m, 24 May 2013 (1; ZRC.ECH.0406); sta. SB55, SW of Kusu Island, 01°13.9'N, 103°52'E, 4 m, 24 May 2013 (1; ZRC.ECH.0410); sta. SD56, S of Pulau Jong, 01°12.55'N, 103°47.2'E, 3–6 m, 24 May 2013 (2; ZRC.ECH.0413 *S. indica* f. *oxyacantha* with ophiuroid and scaleworm, ZRC.ECH.0375); sta. SD123, St John's Island, lagoon next to public jetty, no lat., long., 5–13 m, 30 May 2013 (1; ZRC.ECH.0454 *S. indica* f. *spicata*); sta. SD133, S of Kusu Island, no lat., long., 11 m, 31 May 2013 (2; ZRC.ECH.0470 *S. indica* f. *spicata*/*oxyacantha* with *Periclimenes commensalis*, myzostome, scaleworm, ZRC.ECH.0469); sta. SD150, SW of Kusu Island, no lat., long., 10.7 m, 1 June 2013 night, (1; ZRC.ECH.0481 with *Harrovia* sp.); sta. SD167, SW of Pulau Jong, no lat., long., 15.4 m, 4 June 2013 (1; ZRC.ECH.0493 with *Allogalthea elegans* (2) and shrimp).

**Material previously recorded from Singapore.** ZMC (4), Svend Gad; NHM (1) Pulau Ubin; Raffles Museum (1), Blakang Mati (all as *S. spicata*); ZMC (1), Svend Gad; Raffles Museum (1) (both as *S. indica protectus*) (A. H. Clark, 1941).

### Family ZYGOMETRIDAE A. H. Clark, 1908b

**Diagnosis.** Centrodorsal large; adoral side with large, paired or V-shaped radial impressions; 1–4 marginal circlets of sockets; radial articular facet rather flat, moderately sloping to almost vertical; adoral muscle fossae narrow, curved bands along adoral edge and midradial furrow; up to 100 arms; IBr2 united by syzygy; II and III Br series usually 4(3+4); first syzygy on undivided arms at 3+4 (modified from Hess & Messing, 2011, to exclude *Catoptometa* following Hemery, 2011).

**Remarks.** Zygometridae has traditionally included two genera: *Zygometa* A. H. Clark, 1907a, and *Catoptometa* A. H. Clark, 1908c (A. H. Clark, 1941). Hemery's (2011) molecular phylogeny returned *Catoptometa* (as *C. ophiura* A. H. Clark, 1911a) separate from *Zygometa* species as sister to a clade composed of *Tropiometra* species (Tropiometridae) and the "antedonid" *Annametra occidentalis* (A. H. Clark, 1915). Molecular phylogenies in Hemery (2011) and Hemery et al. (2013) returned *Zygometa* species as sister to a clade of three himerometrids (*Himerometra*, *Homalometra*, and *Heterometra crenulata*). Rouse et al. (2013) reported a sister relationship between one terminal each of *Zygometa* and *Himerometra*. This relationship is not surprising, as *Zygometa* species differ chiefly from *Himerometra* species only in having the IBr2 ossicles joined by syzygy, a character that, in the most recent molecular reconstruction of Comatulidae, distinguishes *Comatula* only at the generic level (Summers et al. 2014).

### *Zygometa* A. H. Clark, 1907a

**Diagnosis.** Same as family.

**Remarks.** Five of the six currently recognised species of *Zygometa* [*Z. microdiscus* (Bell, 1882), *Z. elegans* (Bell, 1882), *Z. comata* A. H. Clark, 1911a, *Z. punctata* A. H.



Clark, 1912a, and *Z. pristina* A. H. Clark, 1911a] are largely distinguished on the basis of size-related meristic characters (e.g., numbers of arms, cirri and cirrals) and appear to represent growth series of fewer valid species. A. H. Clark (1941), who treated all six as distinct, admitted that intermediate forms existed between at least *Z. microdiscus*, *Z. elegans* and *Z. comata*. Only *Z. andromeda* A. H. Clark, 1912b, known from a single specimen outside the distributional ranges of the others (probably from Sri Lanka), differs in having thickened and everted proximal ray ossicles (A. H. Clark, 1941). *Zygometra microdiscus*, *Z. elegans* and *Z. punctata* are restricted to tropical Australia and eastern Indonesia. *Zygometra comata* occurs from the Mergui Archipelago, Burma, east to the Philippines and Indonesia and north to Sagami Bay, Japan (A. H. Clark, 1941, Kogo & Fujita 2014). *Z. pristina* is known only from the Philippines.

Unlike the majority of shallow-water feather stars from the Indo-western Pacific region, *Zygometra* species are often found on sediment substrates rather than reefs (e.g., Stevens & Connolly 2003; Messing et al., 2006).

#### *Zygometra comata* A. H. Clark, 1911a

(Fig. 10)

**Diagnosis.** *Zygometra* with moderately long cirri of usually 25–30 cirrals; usually 25–35 arms; proximal and distal edges of brachitaxes ossicles and first two brachials of undivided arms plain, not thickened or everted and scalloped (A. H. Clark, 1941).

**Remarks.** As noted above, the distinction between *Z. comata* and at least some other *Zygometra* species may be ontogenetic. The largest specimen collected has 21 arms, ray length 70 mm; cirri XXIII with up to 33 cirrals. Small specimens with centrodorsal diameter of ~1 mm, ray length ~20–25 mm, and as few as 18 cirrals, still have 11–13 arms, which appears to distinguish them from *Z. pristina*, which is known from a single specimen with 10 arms 50 mm long.

**Colour.** (in alcohol) Purple with numerous short white arm bands; pinnules white with short distal purple band; pinkish gray with darker purple tissue; pinkish gray with few short darker reddish purple arm bands; cirri sometimes banded pale pinkish gray and purple.

**Local depth range.** 11–125 (possibly 136) m.

**Ecology.** Most material was trawled or dredged with substrates recorded as broken shell, silty; clay; rocky; clean, big sponges, and gravel. One specimen was collected via scuba, but no notes were taken.

**Material examined.** Sta. TB3, near Raffles Lighthouse, Gusong Boarding Ground, S of Pulau Semakau, 01°10.653'N, 103°46.772'E, 40.7–40.9 m, 20 May 2013 (1; ZRC.ECH.0356); sta. DR90, Southern Fairway near St John's Island, 01°12.942'N, 103°51.946'E, 48.3–49.7 m, 27 May

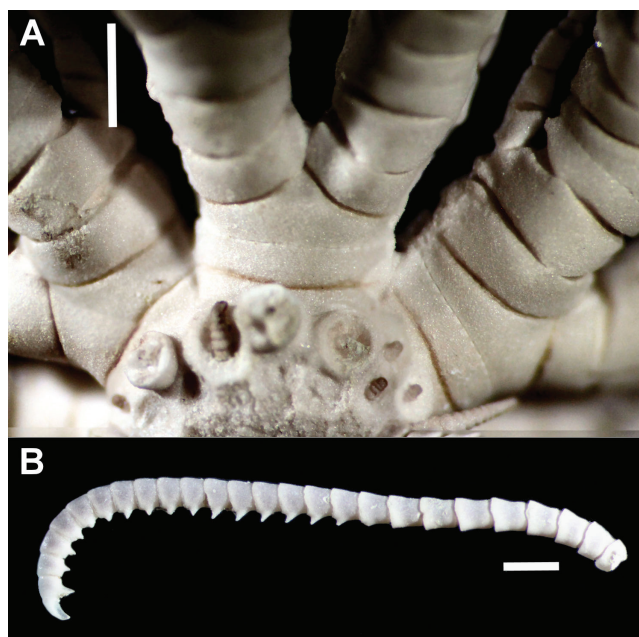


Fig. 10. *Zygometra comata*; ZRC.ERH.0514. A, Bases of three rays showing syzygy (dotted) at middle and right-hand IBr2. Syzygy not visible on left-hand IBr2. B, Cirrus. Scale bars = 1 mm.

2013 (1; ZRC.ECH.0431); sta. TB92, Southern Fairway near St John's Island, 01°12.926'N, 103°51.647'E, 39.5–49.9 m, 27 May 2013 (2; ZRC.ECH.0618); sta. TB96, near Eastern Bunkering A, 01°18.140'N, 104°04.221'E, 22.4–25.1 m, 28 May 2013 (3; ZRC.ECH.0514); sta. TB98, Eastern Bunkering A, 01°18.938'N, 104°05.312'E, 30.2–33.6 m, 28 May 2013 (1; ZRC.ECH.0515); sta. DR111, outside Eastern Boarding Ground A, 01°12.989'N, 103°53.062'E, 125–136 m, 29 May 2013 (5; ZRC.ECH.0516); sta. SD145, W of Pulau Hantu, no lat., long., 11.7 m, 1 June 2013 (2; ZRC.ECH.0479, ZRC.ECH.0480); sta. DR161, beside St John's Island, 01°12.843'N, 103°51.449'E, 41.2–44.4 m, 3 June 2013 (1; ZRC.ECH.0491).

**Material previously collected at Singapore.** USNM 36262 (1 specimen), 36263 (1); E1076 (1), Svend Gad, no dates (in A. H. Clark, 1941).—ZMC (22), Svend Gad, 20 April 1906 to 9 January 1908 (as *Zygometra fluctuans* in A. H. Clark, 1909a).—NHM (1), no collector, 13 m, 12 December 1898 (in A. H. Clark, 1929, 1941).

#### “ANTEDONIDAE” Norman, 1865

**Remarks.** This nominal family was previously characterised as having a centrodorsal cavity moderate to large; apical cirri usually retained in large specimens; basal rosette not sunken within radial circlet; radial cavity narrow, without calcareous plug; radial articular facets deeply excavated with large, thin-walled muscle fossae; very rarely more than 10 arms, and pinnules chiefly cylindrical with no carination or ambulacral plates (modified from Clark & Clark, 1967; Hess & Messing, 2011). However, recent molecular phylogenies clearly demonstrate that the family is polyphyletic (Hemery, 2011; Rouse et al., 2013; Hemery et al., 2013).

***Dorometra* A. H. Clark, 1917**

**Diagnosis.** “Antedonidae” with cirri rarely >40; up to 17 cirrals with distal ends produced and overlapping; distal cirrals much longer than proximal width.  $P_3$  longest and stoutest (Hess & Messing, 2011).

**Remarks.** Hemery et al. (2013) returned *Dorometra briseis* (A. H. Clark, 1907c), a member of the only “antedonid” genus recorded from Singapore, within a clade including several other “antedonid” taxa belonging to four nominal genera, as well as *Aporometra* sp. (Aporometridae) and *Eudiocrinus* spp. (Eudiocrinidae). (Both of these families are monogeneric.) Phylogenetic placement of Aporometridae varies among reconstructions (Hemery, 2011; Rouse et al., 2013; Hemery et al., 2013), and Eudiocrinidae was formerly placed in superfamily Mariametroidea (A. H. Clark, 1941; Hess & Messing, 2011). All genera formerly placed in Antedonidae require taxonomic revision.

***Dorometra* cf. *nana* (Hartlaub, 1890)**

**Diagnosis.** *Dorometra* with  $P_3$  of 13–16 pinnulars, twice as long as  $P_1$  and  $P_2$ , of 8–10 pinnulars; cirri of 10–14 (usually 10–12) cirrals, 4–9 mm long;  $c_4$ –7 longest, 2–3 times longer than broad with much expanded ends; antepenultimate 1.5 times longer than broad; arms 25–60 (usually 30–45) mm long (Clark & Clark, 1967).

**Remarks.** The largest specimen collected (ZRC.ECH.0455) conforms to the diagnosis of *D. nana*: R ~30 mm,  $P_1$  and  $P_2$  both ~4 mm long with 9–10 pinnulars,  $P_3$  ~8 mm long with 19–20 pinnulars, and cirri of 14–15 cirrals with LW of longest cirrals 2.6. However, several smaller specimens (R < 20 mm) have  $P_3$  only about 1.5 times longer than  $P_2$  (e.g., ZRC.ECH.0487), or  $P_2$  intermediate in length between  $P_1$  and  $P_3$  as in *Dorometra parvicirra* (Carpenter, 1888), which has also been collected at Singapore. As these may be ontogenetic variations, all specimens are treated here as *D. cf. nana*.

**Color.**—White or pale tan with brown bands; arms purplish black, sometimes with white distal arms, with white centrodorsal, cirri and pinnules; yellow with brownish pinnules; arm tips sometimes darker; disk black or mottled.

**Local depth range.** 22.7–125 (possibly 22.4–136) m.

**Ecology.** All specimens were dredged or trawled; bottoms recorded include clay; lumps of clay; gravel; rocky; broken shells and coral rubble; laterite gravel and sand, and mud, gravel and dead shells. One specimen was recovered clinging to a large verruciform barnacle.

**Material examined.** Sta. TB92, Southern Fairway near St John’s Island, 01°12.926’N, 103°51.647’E, 39.5–49.9 m, 27 May 2013 (1; ZRC.ECH.0433); sta. TB96, near Eastern Bunkering A, 01°18.140’N, 104°04.221’E, 22.4–25.1 m, 28 May 2013 (1; ZRC.ECH.0443); sta. TB97, near Eastern Bunkering A, 01°18.425’N, 104°04.607’E, 22.4–22.7 m, 28

May 2013 (1; ZRC.ECH.0440); sta. DR111, outside Eastern Boarding Ground A, 01°12.989’N, 103°53.062’E, 125–136 m, 29 May 2013 (1; ZRC.ECH.0458); sta. DR112, Southern Fairway, S of Sister’s Island, 01°12.024’N, 103°50.170’E, 33.6–34.4 m, 29 May 2013 (1; ZRC.ECH.0455); sta. DR125, beside Sister’s Islands, 01°12.416’N, 103°49.858’E, 25.3–30.8 m, 30 May 2013 (2; ZRC.ECH.0462, ZRC.ECH.0463); sta. TB142, East Johor Strait, 01°17.838’N, 104°04.157’E, 28.7–28.8 m, 31 May 2013 (1; ZRC.ECH.0475); sta. DR161, beside St John’s Island, 01°12.843’N, 103°51.449’E, 41.2–44.4 m, 3 June 2013 (1; ZRC.ECH.0487).

**Material previously collected at Singapore.** ZMC (7 specimens), Svend Gad, 1906, 1907 (in A. H. Clark, 1909a, Clark & Clark, 1967).

***Dorometra parvicirra* (Carpenter, 1888)**

**Diagnosis.** Robust *Dorometra* with  $P_2$  intermediate in size and number of pinnulars between  $P_1$  and  $P_3$ ; cirri with up to 17 cirrals; longest cirrals not more than twice as long as width of expanded ends;  $P_1$  with 10–15 pinnulars,  $P_2$  with 13–14 or more, and  $P_3$  with 17–19; arms 50–60 mm long (Clark & Clark, 1967).

**Remarks.** A few small specimens collected during SSBW have some characters of *D. parvicirra*, but appear to be incompletely developed specimens of *D. cf. nana*.

**Material previously collected at Singapore.** USNM E1074, Svend Gad, 27 November 1907 (2 specimens) (<http://collections.nmnh.si.edu/search/iz/>). Clark & Clark (1967, p. 65) list a single record from Singapore as USNM E3202 and ZMC (9 specimens) with no other data. However, the National Museum of Natural History online catalog gives the locality data for E3202 as Sta. 36, Mortensen Kai Expedition, Bay at N end Noehoe Roa Island, Kepulauan Kai, Indonesia, 23 April 1922 (3 specimens).

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