THE ASTEROID FAUNA (ECHINODERMATA) OF SINGAPORE, WITH A DISTRIBUTION TABLE AND AN ILLUSTRATED IDENTIFICATION TO THE SPECIES

Didier VandenSpiegel

Laboratoire de Biologie Marine, Faculté des Sciences, Université de Mons-Hainaut, 19 Avenue Maistriau, B-7000 Mons, Belgium. Correspondance Address: Museé Royale de l'Afrique Centrale, Invertébrés non insectes, B-3060 Tervuren, Belgium

David J.W. Lane

Department of Biological Sciences, National University of Singapore, Lower Kent Ridge Road, Singapore 119260, Republic of Singapore. E-mail: dbslaned@nus.edu.sg

Salvatore Stampanato

Laboratoire de Biologie Marine, Faculté des Sciences, Université de Mons-Hainaut, 19 Avenue Maistriau, B-7000 Mons, Belgium. E-mail: Salvatore.Stampanato@umh.ac.be

Michel Jangoux

Laboratoire de Biologie Marine, Faculté des Sciences, Université de Mons-Hainaut, 19 Avenue Maistriau, B-7000 Mons, Belgium & Laboratoire de Biologie Marine C.P. 160, Université libre de Bruxelles, 50 Avenue F.D. Roosevelt, 1050 Bruxelles, Belgium. E-mail: Michel.Jangoux@umh.ac.be & mjangoux@ulb.ac.be

ABSTRACT. - Twenty-seven species of asteroids have been collected over the period 1991-1995 by dredging, SCUBA-diving, and hand-collecting in the territorial waters of Singapore. They include fourteen species newly recorded for the area: *Luidia hardwicki* (Gray), *Astropecten novaeguineae* Döderlein, *Asterina coronata* von Martens, *Nepanthia belcheri* (Perrier), *Nepanthia maculata* Gray, *Patiriella pseudoexigua* Dartnall, *Tegulaster ceylanica* (Döderlein), *Anthenea aspera* Döderlein, *Gymnanthenea laevis* H.L. Clark, *Fromia monilis* Perrier, *Ophidiaster granifer* Lütken, *Tamaria fusca* Gray, *Echinaster callosus* von Marenzeller, *Echinaster stereosomus* Fisher. A total of thirty-one species, belonging to nine families, are known presently from off Singapore. A distribution table and an illustrated identification key to the species are provided. A new synonymy is proposed: *Asterina spinigera* Koehler becoming a junior synonym of *Asterina coronata* von Martens.

KEYWORDS. - Asteroid, Echinodermata, Singapore, Indo-Pacific, biogeography.

Received 3 Feb 1998 Accepted 30 Apr 1998

INTRODUCTION

Although echinoderms commonly occur in tropical littoral waters, our knowledge of the recent asteroid fauna inhabiting Singaporean waters is relatively limited. The few available data dealing with Singaporean asteroids consist of sparse information published mostly before the Second World War (*viz.*, von Martens, 1866; Grube, 1876; Sladen, 1889; de Loriol, 1891; Bedford, 1900; Goto, 1914; Döderlein, 1920; Tortonese, 1956; Aziz, 1986; Lim & Chou, 1988).

This paper is mainly based upon material collected during an EC sponsored research programme conducted by the University of Mons-Hainaut (UMH) and the National University of Singapore (NUS) in the years 1991 to 1995. During these years, an intensive benthic sampling programme performed on the shallow continental shelf of Singapore resulted in the collection of twenty-seven different species of asteroids among which fourteen are newly reported for the area. This brings to thirty-one the total number of asteroid species reported as occurring in the territorial waters of Singapore.

The present contribution reviews the asteroid fauna of Singapore, a fauna which is surprisingly diverse given Singapore's' limited sea domain and its intense shipping and land reclamation activities. This paper consists essentially of three sections, *viz.*: (1) the distribution table of species (both local and Indo-Pacific), (2) a comprehensive identification key to the asteroids of Singapore, and (3) the taxonomic descriptions of species new for the region.

MATERIAL AND METHODS

Location of material examined. - The benthic samplings were carried out in seven areas which are, from east to west, the Changi-Tekong area (Area 1), the Johor Shoal area (Area 2), the mainland Singapore coastline area (Area 3), the Sentosa area (Area 4), the Semakau area (Area 5), the Ayer Chawan Islands area (Area 6), and the Sultan Shoal area (Area 7) (Figure 1). From all these prospected areas specimens of asteroids were collected (see Table 1) by either dredging (d samplings), SCUBA-diving (s samplings) or hand-collecting (h samplings) at low tide. Except for shipping fairways, restricted areas and other obstructions in Singapore's congested waterways, the dredge sampling coverage is almost complete. The SCUBA component of the faunal survey has concentrated on the fringing reefs, patch reefs and near-slope sea bed around the southern islands. The lists of stations together with their detailed characteristics are provided by Jangoux et al. (1992).

Asteroid specimens collected during these surveys constitute the bulk of the material studied, and specimens are deposited in the Zoological Reference Collection (ZRC), Department of Biological Sciences, National University of Singapore under the catalog numbers given in this systematic account. Additional Singapore material and related species —which included single specimens, some of them being type specimens — were also examined on loan from the following institutions: Museum National d'Histoire Naturelle (MNHN, Paris, France), Museo Civico di Storia Naturale (MCVR, Verona, Italy), the Zoologiske Museum, København (ZMK, Copenhagen, Denmark), the Australian Museum (AM, Sydney, Australia), and the Western Australian Museum (WAM, Perth, Australia). Finally, the third author was able to examine material for comparison with some Singaporean species during his visit to the United States National Museum, Smithsonian Institution (USNM, formerly National Museum of Natural History [NMNH], Washington D.C., U.S.A.).

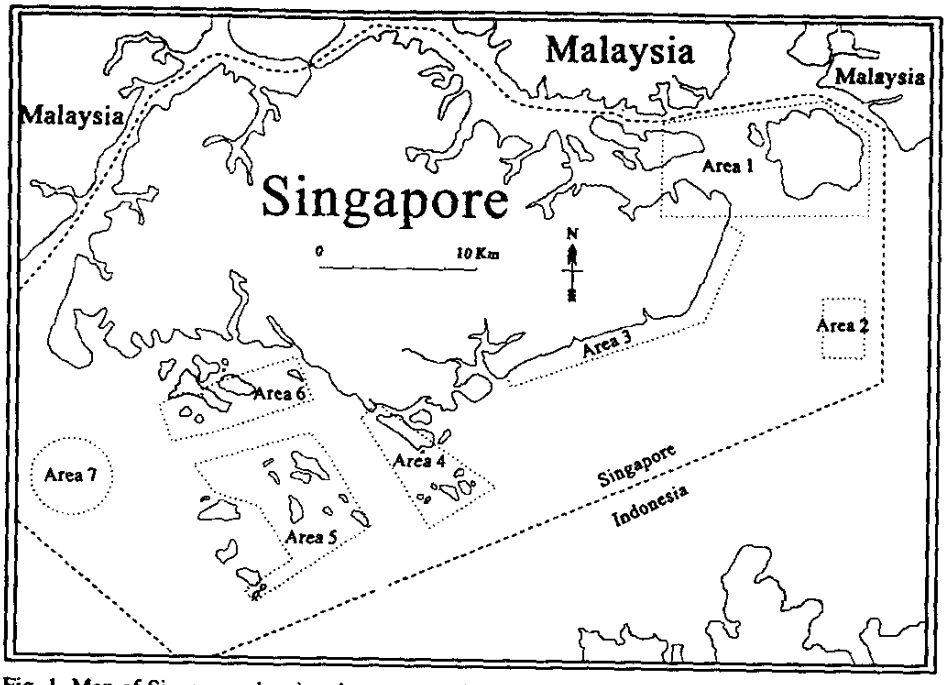


Fig. 1. Map of Singapore showing the prospected areas.

All line drawings were made using a camera lucida Leica MZ8.

Descriptive terminology. - The taxonomic study of asteroids is based chiefly upon the architecture of plates, which compose a large proportion of the whole body, as well as the various tegumentary appendages. Most of the terms used in this paper for describing the Singapore asteroids are of fairly obvious meaning and are illustrated in figures 2 to 7.

Discrimination of taxa also depends upon the location and abundance of non-calcified structures such as (1) papulae; (2) the general shape of the podia -viz. terminated apically with either a rounded or conical knob (Fig. 7A) or with a disc-like sucker (Fig. 7B)-; and (3) the presence/absence of a supradorsal membrane.

THE ASTEROIDS OF SINGAPORE

Distribution table of Singaporean asteroids. - All species recorded in Singapore waters are listed in Table 1. This table is composed of three columns, labelled as (1) List of Species, (2) Local Distribution, and (3) Indo-Pacific Distribution. Distribution of species has been subdivided into distinct zoogeographical areas. These areas correspond as follows: for the local distribution, to the various areas delimited by the UMH-NUS surveys (see Figure 1) plus another area (namely, unspecified locality) which was added in order to include the vague distributional data published; and for the Indo-Pacific distribution, to the geographical subdivision areas defined by A.M. Clark & Rowe (1971).

Table 1. Indo-West Pacific and local distribution for Asteroids recorded in Singaporean waters.

LIST OF SPECIES	LOCAL DISTRIBUTION									INDO-PACIFIC DISTRIBUTION															
	Unspecified locality	Changi-Tekong area	Johor Shoal area	Singapore coastline area	Sentosa area	Semakau area	Ayer Chawan Islands area	Sultan Shoal area		Is. of W. Indian Ocean	Mascarene Is.	E. Africa & Madagascar	Red Sea	S.E. Arabia	Persian Gulf	W. India & Pakistan	Maldive area	Sri Lanka	Bay of Bengal	Indonesia	North Australia	Philippine Is.	China & S. Japan	South Pacific Is.	Hawaiian Is.
LUIDIIDAE																									
Luidia chefooensis Grube	1																								
Luidia hardwicki (Gray)							d			X				X	X		X	X	X	X	X		X		
Luidia longispina Sladen	2															X	X			X		X	X		
Luidia maculata Müller & Troschel		d								X		X	X	X	X		X	X	X	X	X	X	X		
Luidia penangensis de Loriol	4	d																		X					
ASTROPECTINIDAE																									
Astropecten bengalensis Döderlein	5																	X	X						
Astropecten indicus Döderlein	2	d												X	X	X	X	X	X	X					
Astropecten novaeguineae Döderlein		h																		X					
Craspidaster hesperus (Müller & Troschel)	2						d	d											X	X		X	X		
ASTERINIDAE																									
Anseropoda rosacea (Lamarck)	2																		X	X	X		X		
Asterina anomala H.L. Clark	6						d			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Asterina coronata von Martens	5																	X		X	X	X	X	X	X
Nepanthia belcheri (Perrier)							d,s												X	X	X	X	X	X	
Nepanthia maculata Gray							s													X	X	X			
Patiriella pseudoexigua Dartnall							s				X						X		X	X	X	X	X		
Tegulaster ceylanica (Döderlein)							d										X	X							
ARCHASTERIDAE																									
Archaster typicus Müller & Troschel	2					h	h			X	X						X		X	X	X	X	X	X	X

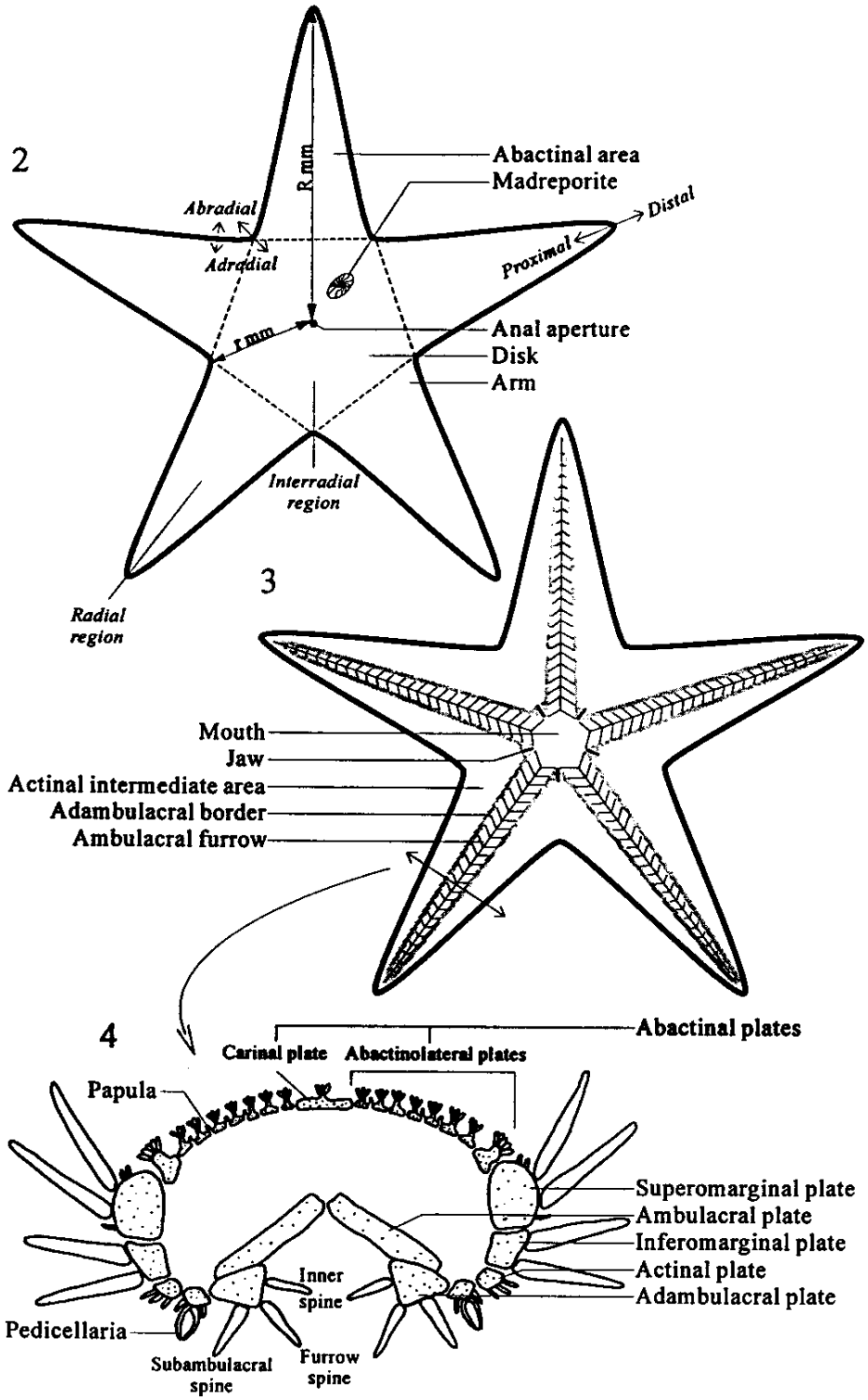
Table 1. continued

LIST OF SPECIES	LOCAL DISTRIBUTION								INDO-PACIFIC DISTRIBUTION															
	Unspecified locality	Changi-Tekong area	Johor Shoal area	Singapore coastline area	Sentosa area	Semakau area	Ayer Chawan Islands area	Sultan Shoal area	Is. of W. Indian Ocean	Mascarene Is.	E. Africa & Madagascar	Red Sea	S.E. Arabia	Persian Gulf	W. India & Pakistan	Maldive area	Sri Lanka	Bay of Bengal	Indonesia	North Australia	Philippine Is.	China & S. Japan	South Pacific Is.	Hawaiian Is.
GONIASTERIDAE																								
Iconaster longimanus (Möbius)	2,3				s	d,s	d	d,s					X						X	X	X			
Stellaster equestris (Retzius)	3			d*	d						X	X	X	X	X	X	X	X	X	X	X	X		
OREASTERIDAE																								
Anthenea aspera Döderlein		d																		X		X		
Culcita novaeguineae Müller & Troschel	2					d,s		s										X	X	X	X	X	X	X
Goniodiscaster scaber (Möbius)	2,3	d				d,s	d,s	d,s								X		X	X					
Gymnanthenea laevis H.L. Clark						d														X				
Protoreaster nodosus (Linneaus)	2					h			X		X						X		X	X	X	X	X	
OPHIDIASTERIDAE																								
Fromia monilis Perrier								s								X			X		X	X	X	
Ophidiaster granifer Lütken						d		d											X		X	X	X	
Tamaria fusca Gray						s														X	X			
PTERASTERIDAE																								
Euretaster insignis (Sladen)	8					d	d	s											X	X	X	X	X	
ECHINASTERIDAE																								
Echinaster callosus Marenzeller						s			X		X	X					X	X	X	X	X	X	X	
Echinaster stereosomus Fisher								d											X	X	X			
Metrodira subulata Gray	3		d			d		d									X	X	X	X	X			

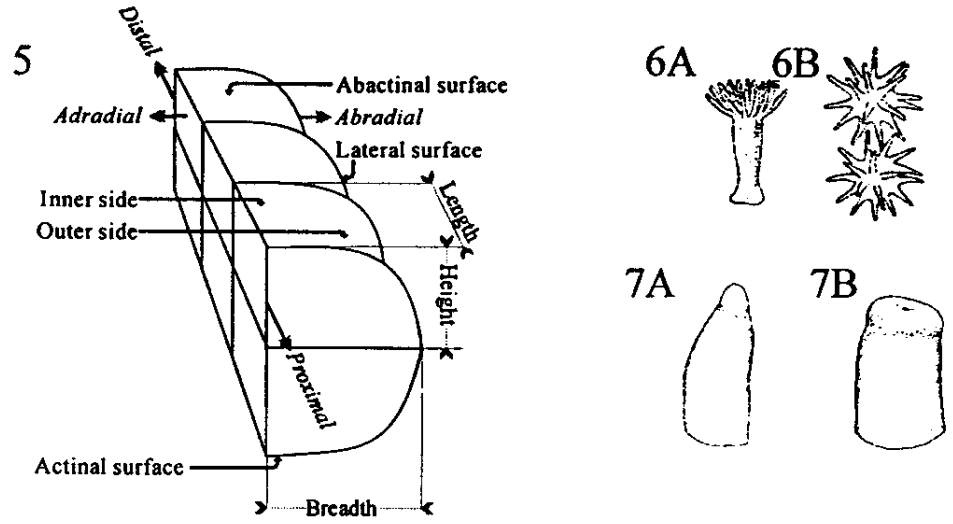
h: species presently reported by hand-collecting; s: species presently reported by SCUBA-diving; d: species presently reported by dredging; *: Tuas, West Johor strait.

1: Grube, 1876; 2: Bedford, 1900; 3: Aziz, 1986; 4: de Loriol, 1891; 5: Tortonese, 1956; 6: Lim & Chou, 1988; 7: Koehler, 1910; 8: A.M. Clark & Rowe 1971.

X: Aziz, 1986; Aziz & Jangoux, 1984; H.L. Clark, 1938; A.M. Clark & Rowe, 1971; Doderlein, 1888; Fisher, 1919; James, 1989; Jangoux, 1978; Koehler, 1910; Liao & A.M. Clark, 1995; Moosleitner, 1997; Rowe & Marsh, 1982; Rowe & Gates, 1995.



Figs. 2-4. The asteroid body form: explanation of terminology.



Figs. 5-7. Marginal plate terminology (5); abactinal paxillae (6); pointed (7A) and suckered (7B) tube-feet.

Illustrated Key to the Singaporean species of Asteroids

1 Podia with a terminal rounded or conical knob 2
- Podia with a terminal disk (« sucker ») 10

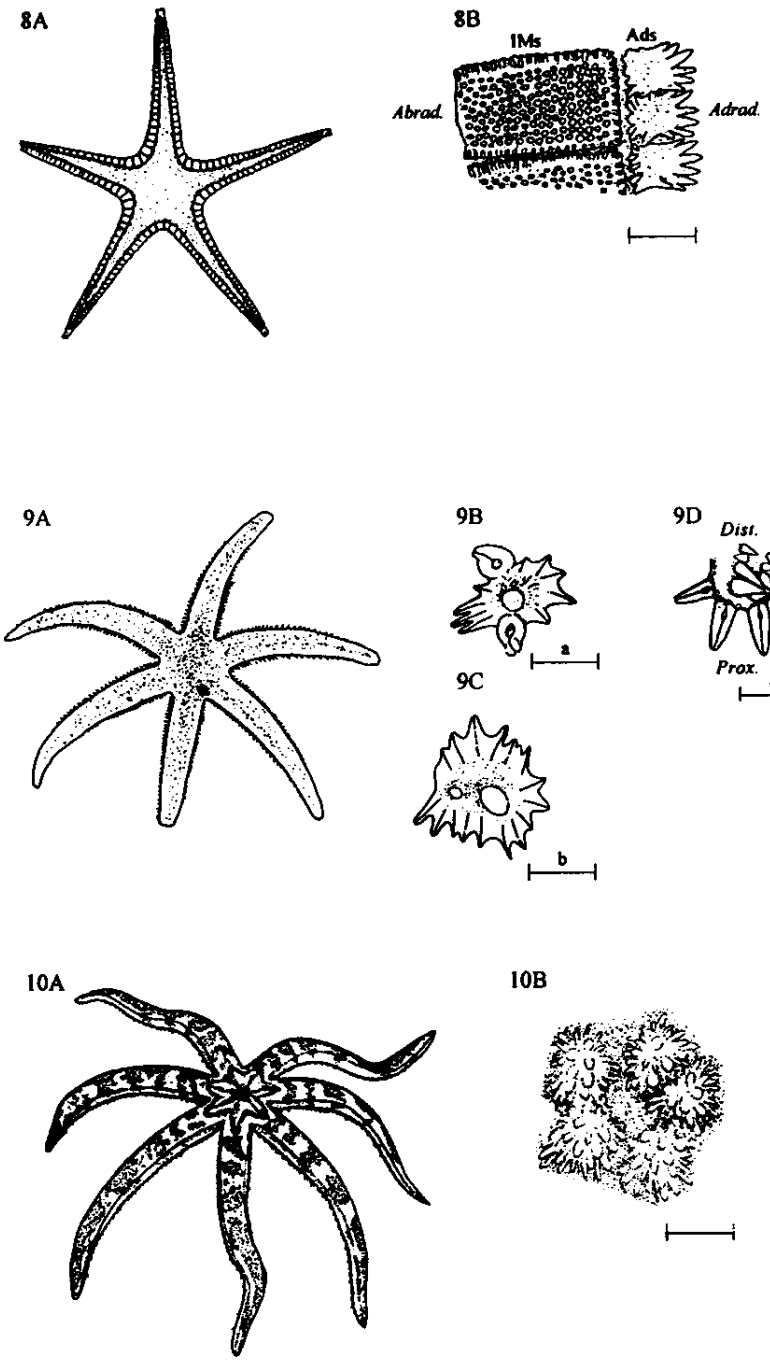
2 (1) Superomarginal plates massive, block-like (Figure 8A); inferomarginal plates bordered with series of webbed spinules (Figure 8B); disk large; Figure 8A-B ..... *Craspidaster hesperus* (Müller & Troschel, 1840)
- Superomarginal plates not massive; inferomarginals without webbed spinules; disk small 3

3 (2) Edge of the body defined by a single row of conspicuous marginal plates (*i.e.*, inferomarginal plates); superomarginal plates ornamented with paxillae 4
- Edge of the body defined by two rows of conspicuous marginal plates; superomarginal plates ornamented with spines or spinelets 8

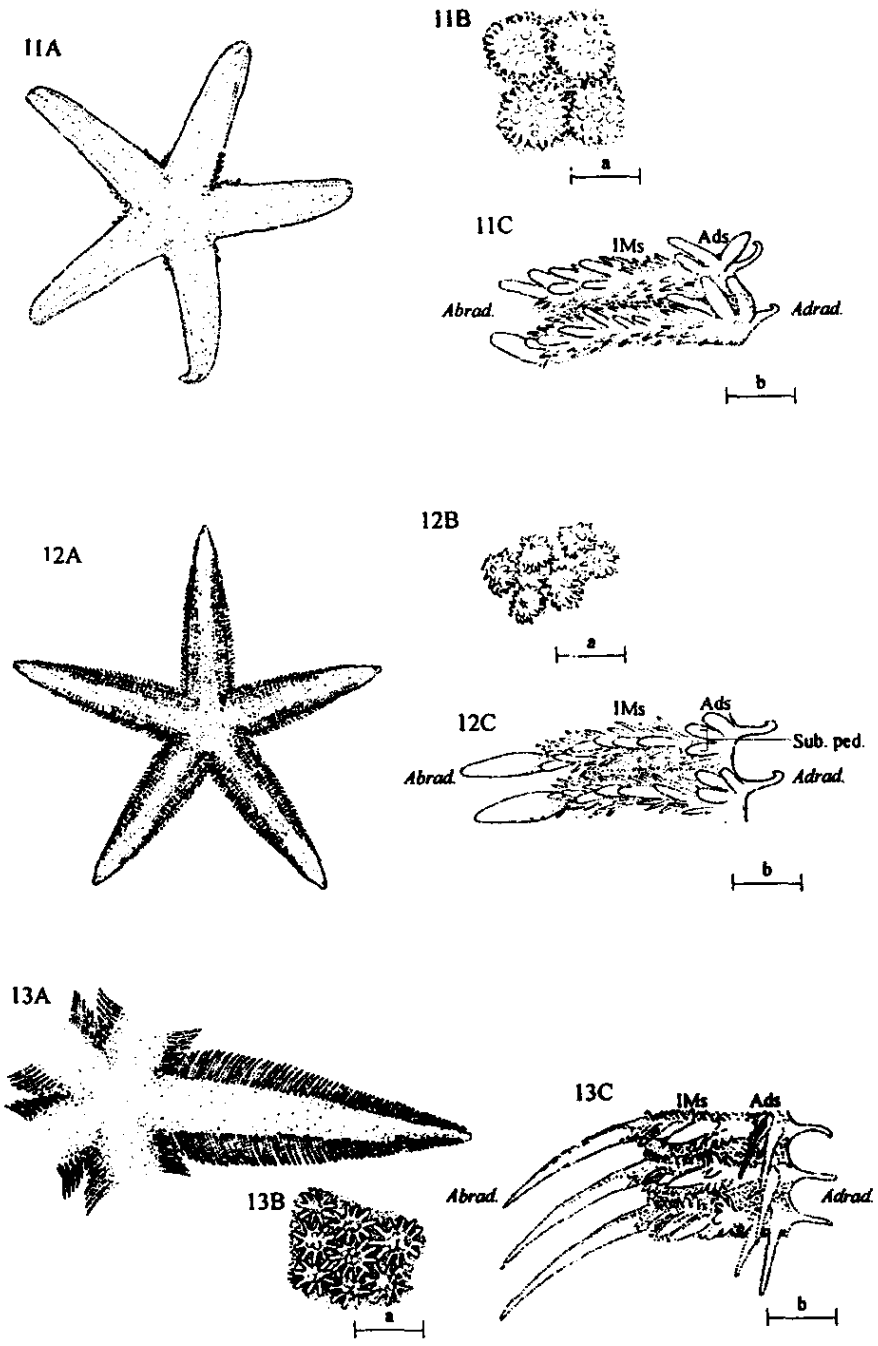
4 (3) Six to nine arms 5
- Five arms 6

5 (4) Six arms (Figure 9A); abactinal paxillae furnished with one stout central tubercle encircled by sixteen to twenty elongated peripheral, webbed spinelets (Figure 9C), and sometimes armed with pedicellariae (Figure 9B); adoral margin of oral plates armed with one or two large bivalve pedicellariae (Figure 9D); Figure 9A-D ..... *Luidia penangensis* de Loriol, 1891
- Seven to nine arms (Figure 10A); abactinal paxillae with twenty or more central spinelets and with about thirty to thirty-five peripheral ones (Figure 10B); adoral margin of oral plates without large bivalved pedicellariae; Figure 10A-B ..... *Luidia maculata* Müller & Troschel, 1842

6 (4) Abactinal paxillae with four to seven granuliform spinelets and with twelve to fifteen blunt peripheral ones (Figure 11B); adambulacral plates furnished with one curved furrow spine and two or three subambulacral spinules (Figure 11C); no adambulacral pedicellariae; Figure 11A-C ..... *Luidia chefooensis* Grube, 1876[1]
- Spinous armament of paxillae and of adambulacrals not as above; adambulacrals with pedicellaria 7



Figs. 8A-B. *Craspidaster hesperus*, ZRC.1995.912 (R/r mm = 45/11) : A. General abactinal view; B. oral view of inferomarginal and adambulacral plates. Figs. 9A-D. *Luidia penangensis*, ZRC.1996.1694 (R/r mm = 169/19): A. General abactinal view; B-C. Basobrachial abactinal paxillae, with (B) or without (C) pedicellariae; D. large bivalve pedicellariae on oral plates margin. Scale bars : a = 5 mm, b = 6 mm, c = 2.2 mm. Figs. 10A-B. *Luidia maculata*, ZRC.1995.921 (R/r mm = 117/15): A. General abactinal view; B. basobrachial abactinal paxillae. Scale bar : 1.8 mm - Abreviations : Ads, adambulacrals ; Dist., distal ; Ims, inferomarginals ; Prox., proximal.



Figs. 11A-C. *Luidia chefooensis*, paratype, ZMK.211 (R/r mm = 40/9): A. General abactinal view; B. basobrachial abactinal paxillae; C. proximal inferomarginal and adambulacral plates. - Scale bars: a = 1.3 mm, b = 0.8 mm. Figs. 12A-C. *Luidia hardwicki*, ZRC.1995.922 (R/r mm = 35/6): A. General abactinal view; B. basobrachial paxillae; C. proximal adambulacral and inferomarginal plates. - Scale bars: a = 0.7 mm, b = 1.3 mm. Figs. 13A-C. *Luidia longispina*, from Sladen, 1889, pl. 43 fig 3, pl. 45 figs 3-4 (R/r mm = 57/7): A. Partial abactinal view; B. basobrachial abactinal paxillae; C. proximal inferomarginal and adambulacral plates. - Scale bars: a = 1.2 mm, b = 1.4 mm. — Abbreviation: Sub. ped., subambulacral pedicellaria.

7 (4) Length of lateral inferomarginal spines inferior or equal to the length of two consecutive inferomarginal plates (Figure 12A, C); abactinal paxillae with subequal, blunt-tipped, central spinelets and with twelve to twenty equal peripheral spinelets (Figure 12B); adambulacral plates armed with a large bivalved, subambulacral pedicellaria (Figure 12C); Figure 12A-C ..... *Luidia hardwicki* (Gray, 1840)

\- Length of lateral inferomarginal spines superior to the length of three consecutive inferomarginal plates (Figure 13A, C); abactinal paxillae with slender and elongated spinelets (Figure 13B); one bivalve pedicellaria often associated with one subambulacral spine, or present on the furrow side of adambulacral plates (Figure 13C); Figure 13A-C ..... *Luidia longispina* Sladen, 1889

8 (3) Superomarginal plates clearly higher than broad: plates rather restricted to the lateral surface of arms, their abactinal side being always narrow (Figure 14A); largest abactinal paxillae with one central spinelet and six to eight peripheral spinelets (Figure 14B); Figure 14A-C ..... *Astropecten novaeguineae* Döderlein, 1917

\- Superomarginal plates as broad as or broader than high: plates always with a broad, well-developed abactinal surface throughout the arms; largest abactinal paxillae with central spinelet and peripheral spinelets numbering ten to about twenty 9

9 (8) Inner side of proximal superomarginal plates ornamented with a prominent spine; largest abactinal paxillae with about twenty peripheral spinelets (Figure 15B); Figure 15A-C ..... *Astropecten bengalensis* Döderlein, 19176[2]

\- Proximal superomarginal plates spineless or ornamented with an inconspicuous spine that is not prominent compared with the remaining superomarginal ones (Figure 16C); largest abactinal paxillae with ten to sixteen peripheral spinelets (Figure 16B); Figure 16A-D ..... *Astropecten indicus* Döderlein, 1888

10 (1) Marginal plates well-developed and conspicuous 11

\- Marginal plates reduced in development and inconspicuous 22

11 (10) Abactinal plates ornamented with paxillae, medioradial paxillae conspicuously larger than the others (Figure 17B); pedicellariae, if present, spiniform; a single short spine on each inferomarginal plate; Figure 17A-B ..... *Archaster typicus* Müller & Troschel, 1840

\- Abactinal plates bare or with various kinds of skeletal elements (i.e., granules, spinules, spines, tubercles); pedicellariae, if present, not spiniform 12

12 (11) Relatively slender asteroids with reduced intermediate areas 13

\- Massive asteroids ornamented with extensive intermediate areas 16

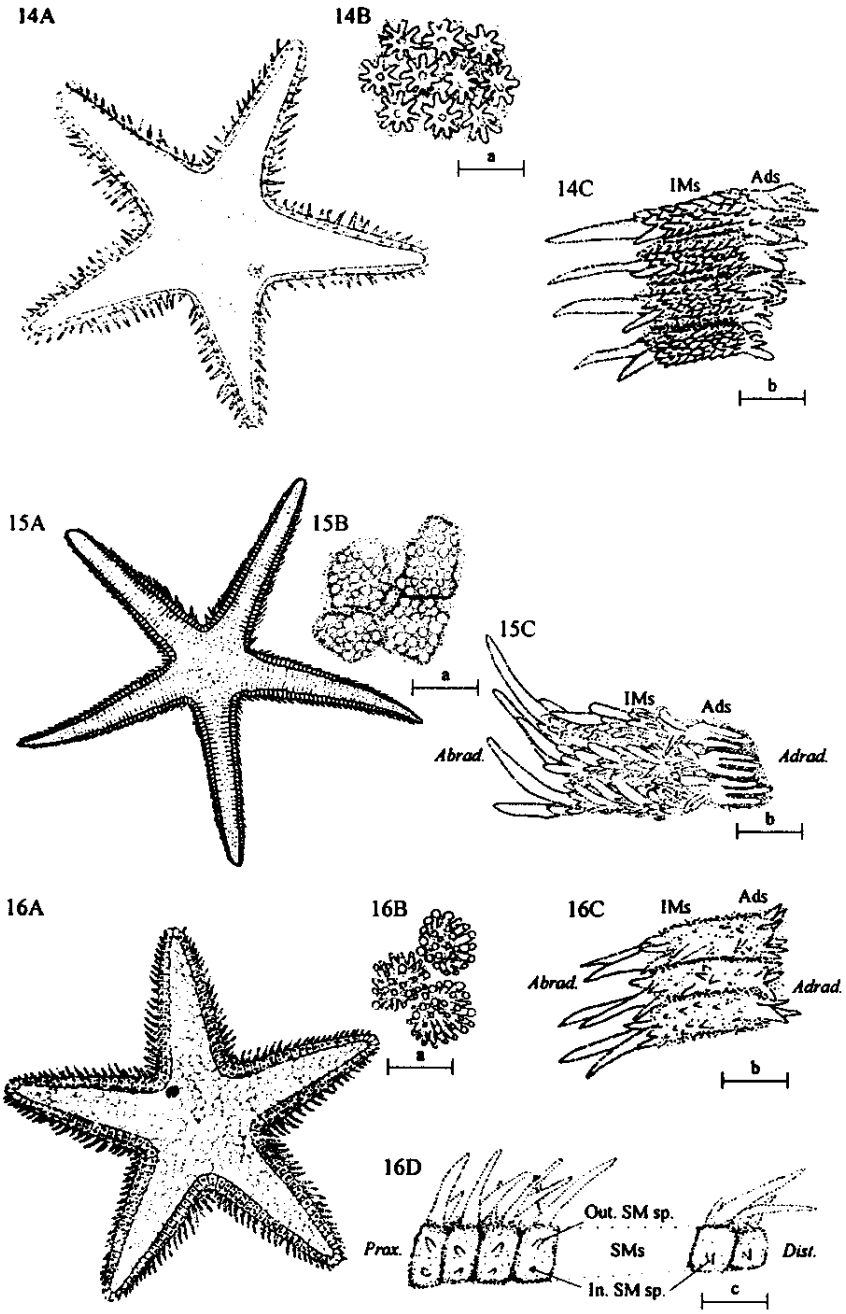
---

1 Examination of the paratype specimen identified by Grube as *Luidia chefooensis* revealed these features: abactinal paxillae without spines; superomarginal paxillae similar to those adjacent abactinal; inferomarginal plates with one or two irregular transverse series of five to seven compressed spines; lateral inferomarginal spine short and subconical, whose length is almost equal to that of one inferomarginal plate; pedicellariae occurring on the adoral surface of oral plates.

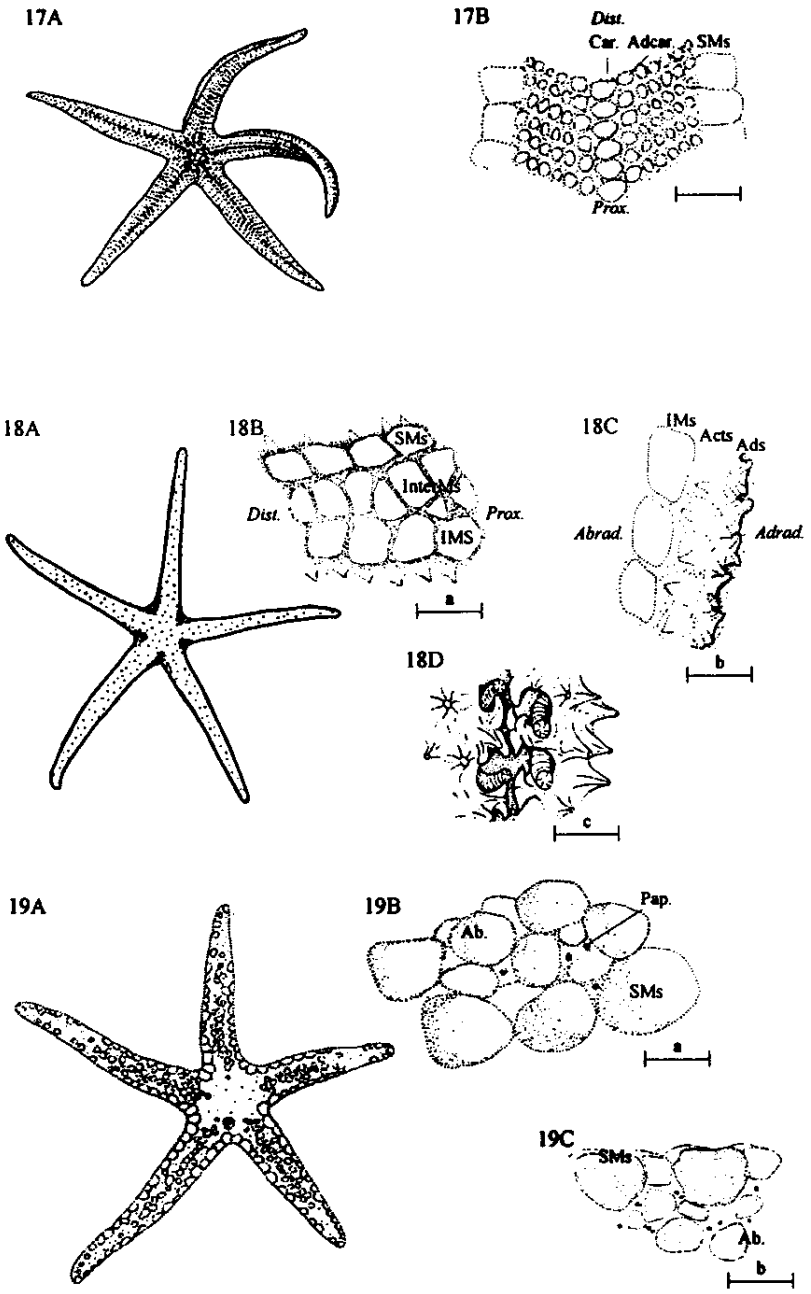
It should be noted that although Döderlein (1920) did not assign *L. chefooensis* to any particular group of *Luidia*, the presence of oral pedicellariae allows its inclusion in the *Quinaria* group. Moreover, Goto (1914) suggested that *L. chefooensis* is closer to *L. quinaria*; but it seems to us that both species are distinct enough to warrant their respective specific status because of the shape of lateral inferomarginal spines, and the armature of paxillae and adambulacral plates.

2 The single representative of the species collected and reported by Tortonese (1956) off Singapore, is registered in the E. Tortonese collection housed at the MCVR.

Tortonese's specimen has the following complementary features: arms elongated, with tips rather pointed; superomarginal plates broader than long, the three or four most proximal being either spineless, or armed with one spine situated on their inner side; the remaining superomarginals all with one short spine usually situated in abradial position; inferomarginal plates each with one lateral, tapering, pointed spine (its length equal two to three times that of the plate which bears it) followed by two or three shorter spines; and the adambulacral armature consisting of three blunt, tapering furrow spines, and two subambulacral spines arranged in one or two irregular series.



Figs. 14A-C. *Astropecten novaeguineae*, ZRC.1996.1710 (R/r mm = 27/8): A. General abactinal view; B. basobrachial abactinal paxillae; C. proximal inferomarginal and adambulacral plates. - Scale bars: a = 0.7 mm, b = 1.9 mm. Figs. 15A-C. *Astropecten bengalensis*, MCVR, E. Tortonese collection (R/r mm = 91/21): A. General abactinal view; B. basobrachial paxillae; C. proximal adambulacral and inferomarginal plates. - Scale bars: a = 1.2 mm, b = 3.1 mm. Figs. 16A-D. *Astropecten indicus*, ZRC.1995.920 (R/r mm = 55/12): A. General abactinal view; B. basobrachial paxillae; C. proximal adambulacral and inferomarginal plates; D. abactinal view of superomarginal plates. - Scale bars: a = 1.0 mm, b = 2.3 mm, c = 2.0 mm. — Abbreviations: In. SM sp., inner superomarginal spine; Out. SM sp., outer superomarginal spine; SMs, Superomarginal plates.



Figs. 17A-B. *Archaster typicus*, ZRC.1995.925 (R/r mm = 99/13): A. General abactinal view; B. partial abactinal view of the arm, showing arrangement of plates. - Scale bar: 5.0 mm. Figs. 18A-D. *Metrodira subulata*, ZRC.1996.1712 (R/r mm = 61/7): A. General abactinal view; B. lateral view of the arm base, showing intermarginal plates; C. partial latero-actinal view of the arm base, showing actinal plates and their armament; D. partial oral view of the arm base. - Scale bars: a = 1.7 mm, b = 2.0 mm, c = 2.0 mm. Figs. 19A-B. *Fromia monilis*, ZRC.1996.1715 (R/r mm = 52/10): A. General abactinal view; B. partial abactinal view of distal superomarginal plates; C. partial lateral view of distal superomarginals. - Scale bars: a = 2.3 mm, b = 2.6 mm. — Abbreviations: Ab, Abactinals; Acts, actinals; Adcar., adcarinals; Car., carinals; InterMs, intermarginals; Pap., papula.

13 (12) Skeletal plates ornamented with spines or bare (proximal marginal plates); intermarginal plates present proximally (Figure 18B); adambulacral plates with curved inner spines (Figure 18D); Figure 18A-D ..... *Metrodira subulata* Gray, 1840
- Skeletal plates ornamented with conspicuous granules; no intermarginal plates; adambulacral plates without inner spines 14

14 (13) Abactinal plates rather irregular in arrangement (Figure 19A); outline of plates circular to oval; abactinal granulation very fine; distal superomarginal plates conspicuously convex, alternating with smaller, flat ones (Figure 19C); papulae single; Figure 19A-C ..... *Fromia monilis* Perrier, 1869
- Abactinal plates in regular longitudinal series for the whole length of arms; outline of plates trapezoidal; actinal granulation dense and well-developed; distal superomarginal plates similar both in size and in shape; papulae grouped 15

15 (14) Papular areas in up to six longitudinal series (no papulae below the inferomarginal plates); adcarinal pedicellariae, if present, with very broad valves (Figure 20B-C); Figure 20A-D ..... *Tamaria fusca* Gray, 1840
- Papular areas in eight longitudinal series (a series of papular areas below the inferomarginal plates); adcarinal pedicellariae, if present, with valves not so broad; Figure 21A-C ... *Ophidiaster granifer* Lütken, 1872

16 (12) Abactinal skeleton reticular with broad papular areas; superomarginal plates well-developed but not very apparent abactinally 17
- Abactinal skeleton consisting of juxtaposed plates, papular areas small; superomarginal plates strongly apparent, always forming a wide border abactinally 18

17 (16) Outline of the body pentagonal to circular; body cushion-like; no prominent tubercles; Figure 22 ..... *Culcita novaeguineae* Müller & Troschel, 1842
- Outline of the body distinctly stellate; abactinal plates ornamented with prominent conical tubercles; Figure 23 ..... *Protoreaster nodosus* (Linneaus, 1758)

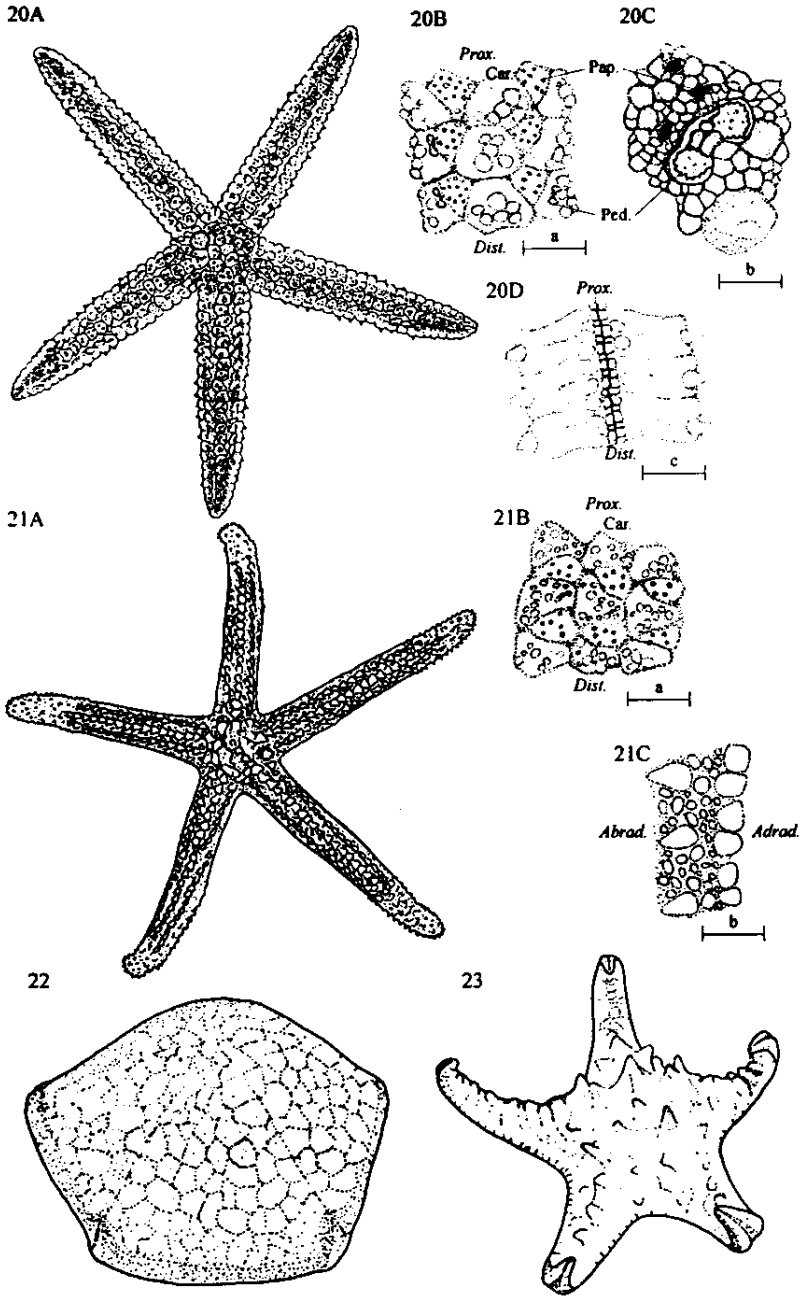
18 (16) Actinal plates each armed with one huge bivalved pedicellaria encircled with granules (Figure 24C); upper part of superomarginal plate quite bare, while the lateral part of plates covered with coarse granules (Figure 25C) 19
- No huge actinal pedicellariae; entire surface of superomarginal plates either bare or covered with granules 20

19 (18) Proximal carinal plates ornamented with a pointed tubercle conspicuously larger than those on the adcarinals; abactinal surface with few pedicellariae (Figure 24B); Figure 24A-C ..... *Gymnanthenea* laevis, H.L. Clark 1938
- Proximal carinal tubercles not conspicuously enlarged, often many adcarinal plates bearing similar tubercles; abactinal surface densely covered with small bivalved pedicellariae (Figure 25B); Figure 25A-C ..... ***Anthenea aspera* Döderlein, 1915**

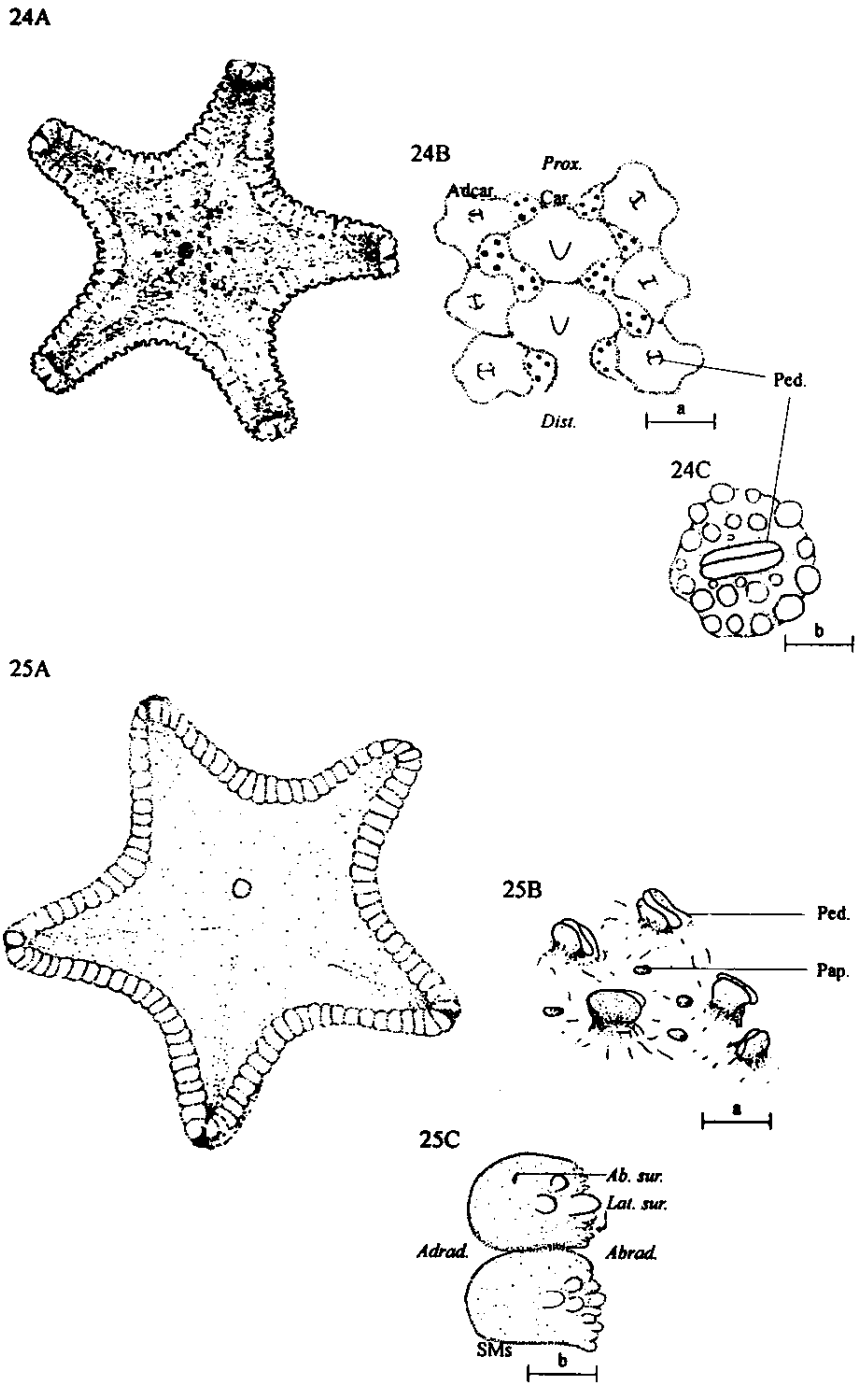
20 (18) Marginal plates covered with well-developed, subequal granules (Figure 26B-C); Figure 26A-C ..... *Goniodiscaster scaber* (Möbius, 1859)
- Marginal plates bare or very finely covered with a uniform granulation 21

21 (20) Superomarginal plate series contiguous aborally throughout the length of arms (Figure 27A, C); largest abactinal plates are interradial ones; no articulated, flattened, spatulate spine on inferomarginal plates; Figure 27A-C ..... *Iconaster longimanus* (Möbius, 1859)
- Superomarginal plate series not contiguous along entire arm length, separated proximally by carinal plates (Figure 28A); largest abactinal plates are carinal ones; inferomarginal plates each armed with an articulated flattened, spatulate spine (Figure 28C); Figure 28A-C ..... *Stellaster equestris* (Retzius, 1805)

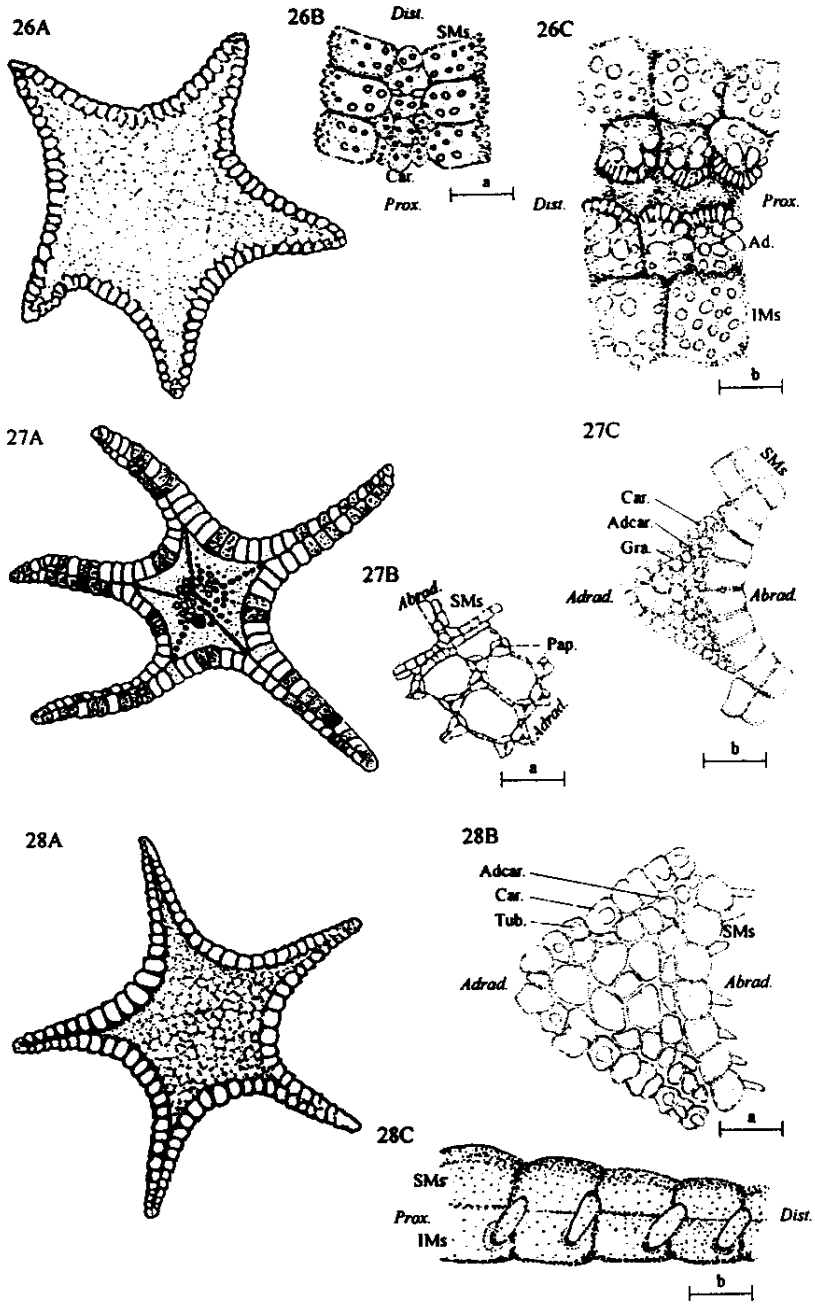
22 (10) Supradorsal membrane present, supported by the tip of long paxillar spinelets (Figure 29B); Figure 29A-B ..... *Euretaster insignis* (Sladen, 1882)
- No supradorsal membrane 23



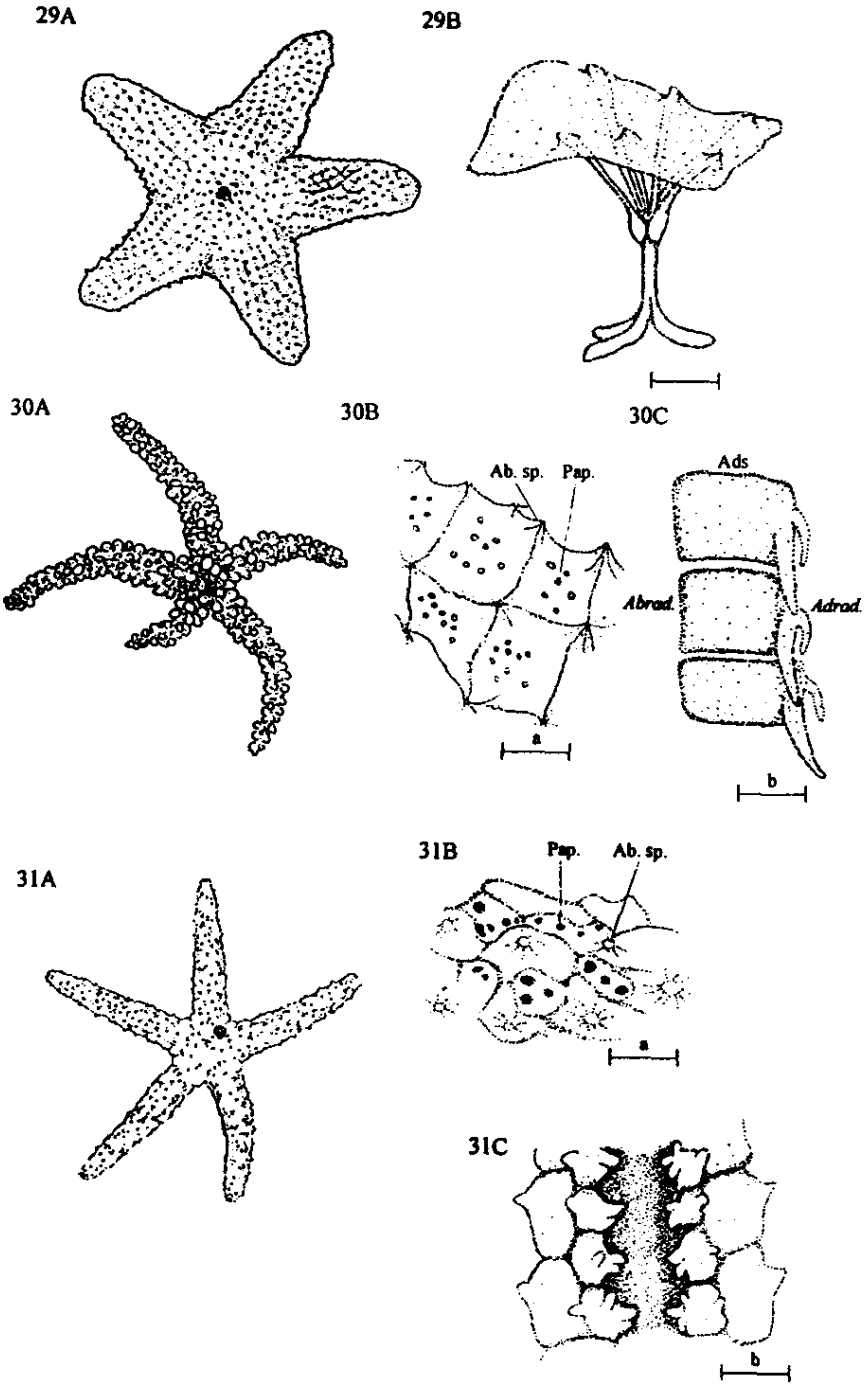
Figs. 20A-D. *Tamaria fusca*, ZRC.1995.893 (R/r mm = 61/8): A. General abactinal view; B. partial abactinal view of the arm base, showing arrangement and outline of plates. C. an abactinolateral pedicellaria; D. partial actinal view of the arm base. - Scale bars: a = 4.8 mm, b = 0.6 mm, c = 4.6 mm. Figs. 21A-C. *Ophidiaster granifer*, ZRC.1996.1714 (R/r mm = 29/4): A. General abactinal view; B. partial abactinal view of the arm, showing arrangement and outline of plates and the papular areas; C. proximal adambulacral plates with their armament. - Scale bars: a = 1.8 mm, b = 0.7 mm. Fig. 22. *Culcita novaeguineae*, ZRC.1995.932 (R/r mm = 118/100): General abactinal view. Fig. 23. *Protoreaster nodosus*. ZRC.1996.1818 (R/r mm = 165/60): General abactinal view. — Abbreviations: Abrad., abradial; adrad., adradial.



Figs. 24A-C. *Gymnanthenea laevis*, ZRC.1996.1708 (R/r mm = 57/27): A. General abactinal view; B. partial abactinal view of the arm base; C. a huge actinal pedicellaria. - Scale bars: a = 2.7 mm, b = 1.0 mm. Figs. 25A-C. *Anthenea aspera*, ZRC.1994.4290 (R/r mm = 121/62): A. General abactinal view; B. partial abactinal view of the arm base; C. abactinolateral view of two proximal superomarginals. - Scale bars: a = 1.3 mm, b = 8.8 mm. — Abbreviations: Ab. sur., abactinal surface; Lat. sur., lateral surface.



Figs. 26A-C. *Goniodiscaster scaber*, ZRC.1996.1699 (R/r mm = 88/84): A. General abactinal view; B. partial abactinal view of the arm base; C. partial actinal view of the arm base. - Scale bars: a = 7.5 mm, b = 3.4 mm. Figs. 27A-C. *Iconaster longimanus*, ZRC.1996.1711 (R/r mm = 59/17): A. General abactinal view; B. partial abactinal view of admarginal, intermarginal plates, showing triplet of granules around papular pores; C. partial abactinal view of the interradius. - Scale bars: a = 2.7 mm, b = 8 mm. Figs. 28A-C. *Stellaster equestris*, ZRC.1995.911 (R/r mm = 40/16): A. General abactinal view; B. partial abactinal view of the interradius; C. lateral view of an arm, showing articulated spines appressed to the inferomarginal plates. - Scale bars: a = 4.5 mm, b = 2.9 mm. — Abbreviations: Gra., granules; Tub., tubercles.



Figs. 29A-B. *Euretaster insignis*, ZRC.1995.946 (R/r mm = 52/23): A. General abactinal view; B. partial lateral view of a basobrachial paxilla. - Scale bar: 1 mm. Figs. 30A-C. *Echinaster callosus*, ZRC.1996.1707 (R/r mm = 176/17): A. General abactinal view; B. partial abactinal view of the arm base; C. adambulacral armature. - Scale bars: a = 7.0 mm, b = 1.4 mm. Figs. 31A-C. *Echinaster stereosomus*, ZRC.1995.899 (R/r mm = 16/3): A. General abactinal view; B. partial abactinal view of the arm base; C. partial actinal view of the arm base, showing the adambulacral armature. - Scale bars: a = 0.7 mm, b = 0.9 mm. — Abbreviation: Ab. sp., Abactinal spine.

23 (22) Abactinal skeleton reticular with meshes corresponding to the papular areas 24
- Abactinal skeleton made of imbricating plates notched for papulae and ornamented with clusters of short spinelets 25

24 (23) Abactinal spines large (four to five mm long), and well-spaced; abactinal meshes filled with ten to thirty papulae (Figure 30B); Figure 30A-C ..... *Echinaster callosus* von Marenzeller, 1895
- Abactinal spines small (up to two mm long) (Figure 31B); abactinal meshes filled with three to six papulae (Figure 31B); Figure 31A-C ..... *Echinaster stereosomus* Fisher, 1913

25 (23) Body extremely thin, leaf-like; at least eleven arms; Figure 32 ..... *Anseropoda rosacea* (Lamarck, 1816)
- Body flattened to very convex; not more than nine arms 26

26 (25) Outline of the body stellate; arms elongated and finger-like 27
- Outline of the body pentagonal to substellate; arms rather short and blunt 28

27 (26) Abactinal surface of arms very convex (Figure 33A); actinal surface flat, forming a conspicuous actinolateral edge; three to seven abradial spinelets on adambulacral plates (Figure 33C); abactinal surface without dark spots; Figure 33A-C ..... *Nepanthia belcheri* (Perrier, 1875)
- Arms quite cylindrical, no distinct actinolateral edge (Figure 34A); nine to twelve abradial spinelets on adambulacral plates (Figure 34C); abactinal surface with dark spots; Figure 34A-C ..... *Nepanthia maculata* Gray, 1840

28 (26) Abactinal armament very reduced, consisting of plates bare or monocanthid (Figure 35A-D); actinal plates mono- or diplacanthid (Figure 35D); pedicellariae, if present, forficiform (Figure 35C); arms well-keeled abactinally (Figure 35A); Figure 35A-D. ..... *Tegulaster ceylanica* Döderlein, 1888
- Abactinal armament well-developed, consisting of multicanthid plates; actinal plates ornamented with two to six spinelets; pedicellariae, if present, not forficiform; arms not keeled 29

29 (28) Actinolateral plates with none, one or (distally) two spinelets; Figure 36 ..... *Patiriella pseudoexigua* Dartnall, 1971
- Actinolateral plates each usually with three to six spinelets; 30

30 (29) Non fissiparous, invariably five arms; some abactinal plates conspicuously more convex, ornamented with markedly enlarged subequal spines (Figure 37B-C); Figure 37A-D. ..... *Asterina coronata* von Martens, 1866
- Fissiparous; arms usually irregular in size and number; abactinal plates similar both in size and in shape, uniformly covered with fairly equal spinelets; Figure 38 ..... *Asterina anomala* H.L. Clark, 1921[3]

TAXONOMIC ACCOUNT

The description and the taxonomic affinities of fourteen species newly recorded for Singapore, *viz. Luidia hardwicki* (Gray), *Astropecten novaeguineae* Döderlein, *Asterina coronata* von Martens, *Nepanthia belcheri* (Perrier), *Nepanthia maculata* Gray, *Patiriella pseudoexigua* Dartnall, *Tegulaster ceylanica* (Döderlein), *Anthenea aspera* Döderlein, *Gymnanthenea laevis* H.L. Clark, *Fromia monilis* Perrier, *Ophidiaster granifer* Lütken, *Tamaria fusca* Gray, *Echinaster callosus* Marenzeller, *Echinaster stereosomus* Fisher are discussed and the status

3 *Asterina anomala* was previously collected by Lim & Chou in 1988, but identified as *A.burtonii*. Taxonomic validity for *anomala* given in Rowe & Gates, 1995.

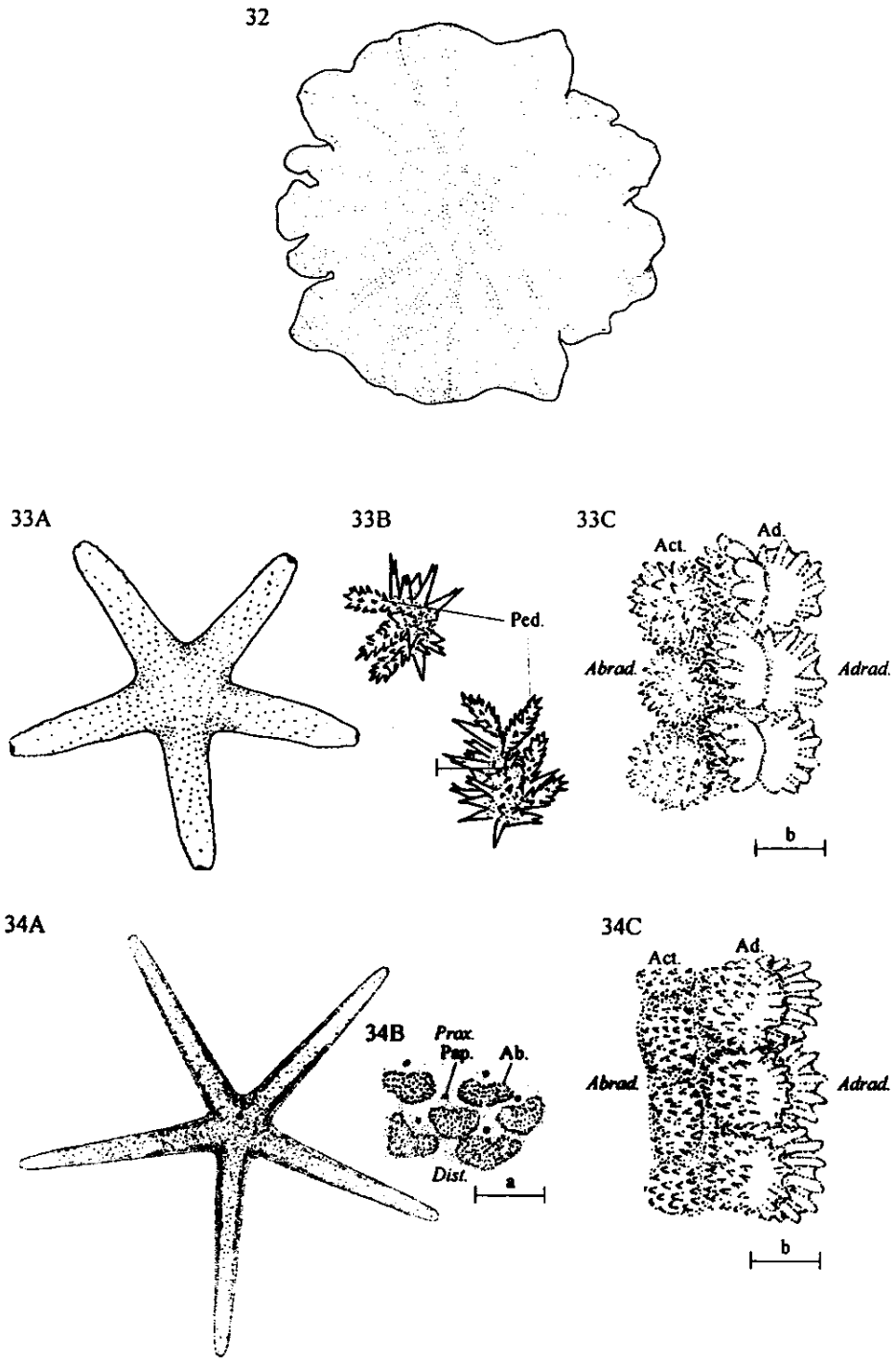
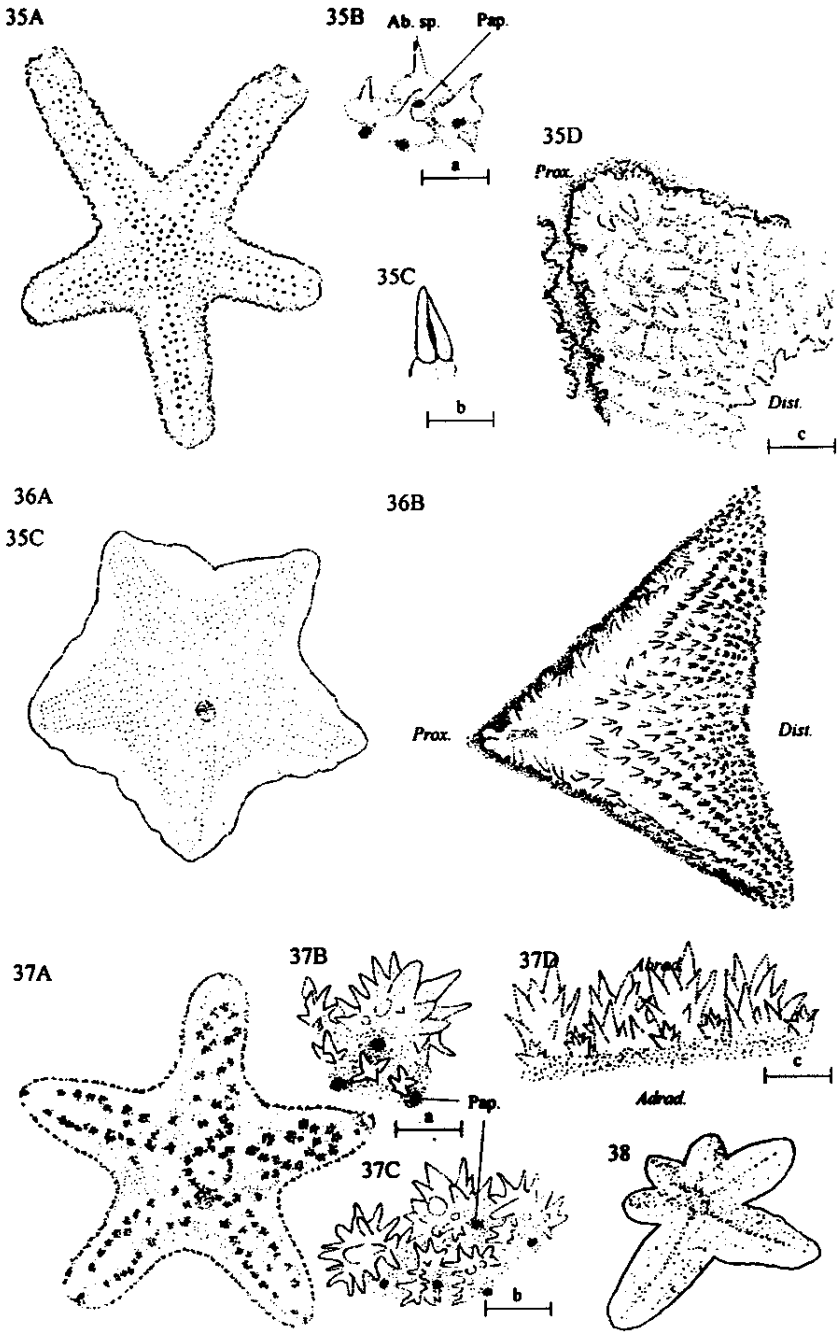


Fig. 32. *Anseropoda rosacea*, from Koehler, 1910, pl. 20 fig. 1 (R/r mm = 75/60): General abactinal view. Figs. 33A-C. *Nepanthia belcheri*, ZRC.1995.905 (R/r mm = 45/10): A. General abactinal view; B. abactinal fasciculated pedicellariae; C. adambulacral plates. - Scale bars: a = 1.3 mm, b = 0.7 mm. Figs. 34A-C. *Nepanthia maculata*, ZRC.1995.906 (R/r mm = 30/6): A. General abactinal view; B. partial abactinal view of the arm base; C. adambulacral plates. - Scale bars: a = 1.1 mm, b = 1.1 mm.



Figs. 35A-D. *Tegulaster ceylanica*, ZRC.1995.904 (R/r mm = 18/6): A. General abactinal view; B. some abactinal plates with their armament; C. a forficiform pedicellaria; D. an actinal intermediate area. - Scale bars: a = 0.7 mm, b = 0.3 mm, c = 1.3 mm. Figs. 36A-B. *Patiriella pseudoexigua*, ZRC.1994.3745 (R/r mm = 20/12): A. General abactinal view; B. An actinal intermediate area. Figs. 37A-D. *Asterina coronata*, ZRC.1995.903 (R/r mm = 20/9): A. General abactinal view; B. discal abactinal plates; C. basobrachial abactinal plates; D. abactinal view of inferomarginal plates. - Scale bars: a = 0.4 mm, b = 0.5 mm, c = 0.5 mm. Fig. 38. *Asterina anomala*, ZRC.1995.902 (R/r mm = 10/4): General abactinal view.

of *Asterina coronata* von Martens is considered. The systematic arrangement of these species is that proposed and currently adopted by A.M. Clark (1989, 1993, 1996).

ORDER PAXILLOSIDA PERRIER

FAMILY LUIDIIDAE SLADEN

***Luidia hardwicki* (Gray)**
(Fig. 12A-C, pl. III fig. 1)

Petalaster hardwicki - Gray J.E., 1840: 183; 1866: 4.
Luidia hardwicki - Perrier E., 1875: 331 [1876: 251].
Luidia forficifer - Sladen W.P., 1889 : 258, pls 44(5-6), 45(5-6).

Taxonomic decision for the synonymy : Clark, A.M & Rowe, F.W.E., 1971: 44.

Material examined. - ZRC.1995.922-924 : 3 specimens measuring R/r = 35/6 mm, 26/5 mm & ?/7 mm (arms broken), dredged near Pulau Ayer Chawan islands, Singapore, at 16 m depth, 18 Feb.1994.

Description of the ZRC specimens. - Arms five in number. Abactinal paxillae packed, of which those admarginal being distinctly enlarged and rectangular, arranged in three or four longitudinal regular series. Paxillar armament made of a central group of up to five robust, subequal, blunt-tipped spinelets, surrounded by a peripheral series of twelve to twenty shorter, rather equal, slender spinelets. Superomarginal paxillae being quite similar to the adjacent abactinal ones. Inferomarginal plates strongly keeled, confined entirely to the actinal surface, bearing one long, lateral, flattened, lancet-shaped spine, and an irregular transverse series of three or four shorter, similar spines appressed to the plates, the margins of which are lined with delicate, thin, papilliform spinelets. Actinal intermediate areas very reduced in development, formed by two plates, armed with three to six fine spinelets and one bivalve pedicellaria. Adambulacral armature consisting of one curved, sabre-shaped, long, obtuse-tipped spine, followed by one longer, stouter, flattened or triangular in cross section, slightly curved, subambulacral spine, below which occur a pair of similar spines forming a pedicellaria and three or four delicate spinelets in abradialmost position. Furrow margin of adambulacral plates armed with bivalve pedicellariae.

Remarks. - The combination of the following series of characters, *viz.* the number of arms, the paxillar ornamentation, and the occurrence of bivalve pedicellariae on the furrow margin of oral plates and on adambulacral plates, should serve to attribute the ZRC specimens to *L. hardwicki* and not to either of its Singaporean congeners (i.e., *Luidia penangensis* and *L. maculata*), or to any species of *Luidia* presently known within the wider geographical region of the Indo-West Pacific.

FAMILY ASTROPECTINIDAE GRAY

***Astropecten novaeguineae* Döderlein**
(Fig. 14A-C, Pl. III fig. 5)

Astropecten novaeguineae - Döderlein, L., 1917: 51, 136, pl. 4 figs 1-3, pl. 12 figs 6-6a.

Material examined. - ZRC.1995.915-918: 4 specimens, 2 of them measuring R/r = 24/8 mm, 17/

6mm, collected at Changi Beach, Singapore, low tide, 16 Apr.1995; ZRC.1995.919 : 1 specimen, measuring R/r = 17/7 mm, collected at Changi Beach, Singapore, low tide, 7 Oct.1994.

Description of the ZRC specimens. - Arms five in number, triangular in contour with a broad base and blunt at the tips. Abactinal paxillae small, similar, packed, with a regular arrangement in transverse oblique series on abactinolateral areas. Paxillar armament elaborated by a radiating peripheral series of about ten clavate spinelets, encircling one slightly larger, central, similar spinelet. Superomarginal plates very narrow, conspicuously high, except distally where they become broadened. Superomarginal armament consisting of spaced, similar, papilliform spinelets, and one stout, conical, small spine erected from the actinal surface of plates. Inferomarginal plates confined to the actinal surface, bearing one large, slightly flattened, lateral spine obliquely truncate at the apex, associated with a smaller, flattened spine, below which are present one or two irregular vertical series of lanceolate, flattened spinelets, flanked on both sides by a marginal series of papilliform spinelets. Actinolateral intermediate areas reduced in development, paved with two or four small, roundish, convex plates ornamented with five to twelve fine spinelets. Oral plates with five or six furrow spines, five to seven smaller, flattened, adsutural, suboral spines, and some small scattered spinelets in aboralmost position.

Remarks. - *Astropecten novaeguineae* is most closely allied to *Astropecten polyacanthus*. However in the latter, some proximalmost superomarginal plates are reduced in development and also devoid of spines. This is in contrast with *A. novaeguineae* in which all the superomarginals are well-developed and each armed with one spine on their upper side.

According to Mortensen (1940), *A. novaeguineae* should be a synonym of *A. phragmorus*. After an examination of three specimens dredged in Timor waters, Jangoux (1978) did not share this opinion, considering it as a valid, distinct species.

ORDER VALVATIDA PERRIER

FAMILY ASTERINIDAE GRAY

Asterina coronata von Martens
(Fig. 37A-D, Pl. III fig. 8)

Asterina coronata -von Martens, E., 1866: 73.
Asterina coronota fascicularis - Fisher, W.K., 1918: 10.
Asterina spinigera - Koehler, R., 1911: 20.

Taxonomic decision for the synonymy: present work

Material examined. - ZRC.1995.903: 1 specimen measuring R/r = 20/9 mm, collected at Sungei Buloh, Singapore, depth unknown, 1993.

Description of the ZRC specimen. - Five elongate arms, equal in length and round at the tips. Abactinal plates convex, forming a conspicuous pentagonal series on the disk. Abactinolateral areas paved with plates arranged in very regular and oblique series; those of radial areas rather irregular in arrangement. Abactinal armament consisting of spaced spinelets, apically furnished with few small points. Some medioradial plates conspicuously enlarged, and ornamented with prominent, subequal, blunt-tipped spines. Papulae single, widely

distributed in more or less regular longitudinal oblique series. Superomarginal plates slightly larger than the adjacent abactinals, broader than long, bearing six to nine spaced spinelets. Inferomarginal plates larger, protruding under the superomarginals, and furnished with a boss, the top of which bears about ten blunt spinelets, of which two to four are more prominent and conspicuously subequal. Actinal intermediate areas wide, paved with six or seven series of plates arranged in chevrons, and ornamented with a cluster of three to five spinelets. Adambulacral armature made up of two fans of webbed spines, furrow spines being slender, and subambulacral spines being stouter. Oral plates with six or seven furrow spines and with four or five adsutural, suboral spines.

Remarks. - On the basis of a single specimen collected off Singapore, Koehler (1911) described a new species of *Asterina*, *A. spinigera*. The only difference that this author gave to separate it from other species of *Asterina* — generally characterized by abactinal plates furnished with small spines — is the occurrence of some greater and more convex abactinals bearing a tuft of enlarged spines, particularly apparent abactinally. However, this skeletal feature proves to be insufficient for establishment of a new species since it was already reported in the original description of the species *A. coronata*. Koehler did not compare his specimen with the previously known species, and thus failed to provide an accurate identification.

Considering this fact, a critical re-examination of the Koehler's type specimen was made for confirmation. We were unable to find any substantial differences to separate it from the ZRC specimen at hand, a specimen that we herein undoubtedly assign to *A. coronata*. Consequently, *A. spinigera* is a junior synonym of *A. coronata*.

Nepanthia belcheri (Perrier)
(Fig. 33A-C, Pl. I fig. 1)

Asterina (Nepanthia) belcheri - Perrier, E., 1875: 320 [1876: 240].
Asterina (Nepanthia) brevis - Perrier, E., 1875: 321.
Nepanthia belcheri - Sladen, W.P., 1889: 387.
Nepanthia suffarcinata - Sladen, W.P., 1888: 328, pl 28 figs 9-12.
Nepanthia joubini - Koehler, R., 1908: 232, figs 1-4.
Henricia heteractis - Clark, H.L., 1909: 530, pl. 49(1-2).
Nepanthia polyplax - Doderlein, L., 1926: 20, pl.4 (2-2a).
Nepanthia magnispina - Clark, H.L., 1938: 174, pl. 20 (1-2).
Nepanthia variabilis - Clark, H.L., 1938: 176, pls 10(4-5), 20(4-5).

Taxonomic decision for the synonymy: Rowe, F.W.E. & L.M. Marsh, 1982 : 99, figs 1, 3c-3d, 5a-5b, 6a-6b.

Material examined. - ZRC.1995.901: 1 specimen measuring R/r = 18/4 mm, collected at Pulau Semakau, Singapore, 18m, Jul.1991; ZRC.1995.905: 1 specimen measuring R/r = 45/10 mm, dredged at Beting Bembang Besar, Singapore, depth unknown, 8 Feb.1994.

Description of the ZRC specimens. - Arms five in number, elongate, equal in length, subcylindrical and slightly tapering to a blunt tip. Abactinal surface of arms strongly convex while actinal one is quite planar, forming a conspicuous actinolateral edge. Abactinal plates of two types; primary plates being crescentic in contour, clearly broader than long, notched for single papulae, ornamented on the top with spaced spinelets disposed along irregular transverse series and on the lower parts with embedded crystal bodies; secondary plates being fewer in number, smaller, roundish in contour, bearing on their top radiating spinelets

disposed in a cluster; abactinal spinelets slender, vitreous, slightly enlarged apically, and tetra- or pentafid-tipped; brachial papulae tending to align along regular longitudinal series. Superomarginal plates inconspicuous from adjacent abactinal ones; inferomarginal plates rather conspicuous, and elongated. Actinal intermediate areas reduced in development, formed of three or four longitudinal series of plates, each plate bearing a cluster of about twenty robust multifid-tipped spinelets. Adambulacral plates with a series of seven or eight webbed furrow spines, the medial ones being the longest and more developed, another series of seven or eight larger, webbed subambulacral spines, and three to six small, actinal-like spinelets in abradialmost position.

Remarks. - The genus *Nepanthia* Gray, 1840 has been the subject of a revision by Rowe & Marsh (1982). This revisionary study recognized eight well-defined species, two of which — *Nepanthia belcheri* and *N. maculata* (see below)— are presently recorded for the first time in the waters of Singapore.

The convoluted nomenclatural history of *N. belcheri* arises from the morphological variability of this taxon. However, the general appearance of arms — having a markedly angular actino-lateral angle due to the marginal plates — and microscopic details of spinelets, are the most striking characters found in *N. belcheri*, allowing a clear separation from any other *Nepanthia* species. The present ZRC material has skeletal features which undoubtedly fall within the morphological variability commonly reported in the literature for the species.

Nepanthia maculata Gray
(Fig. 34A-C, Pl. I fig. 2)

Nepanthia maculata - Gray, J.E., 1840: 287.
Chaetaster cylindratus - Möbius, K., 1859: 3, pl. 1(3-4).
Nepanthia tenuis - Clark, H.L., 1938: 175, pl. 20(3).

Taxonomic decision for the synonymy: Rowe, F.W.E. & L.M. Marsh, 1982: 106 figs 1-6.

Material examined. - ZRC.1995.906: 1 specimen measuring R/r = 30/6 mm, collected by SCUBA-diving at North Pulau Semakau, Singapore, 19 m depth, 26 Apr.1995.

Description of the ZRC specimen. - Five elongated, slender arms, subcylindrical and blunt at the tips. Abactinal plates regularly arranged on arms only and disposed in longitudinal oblique series. Centrodiscal and abactinolateral plates roundish to oval in contour, medioradial plates being crescentic in contour. Papulae single, situated at the notch of crescentic plates. Abactinal plates much broader than long, bearing a dense cluster of radiating, vitreous, slender, mono- to tetrafid-tipped spinelets; marginal plates quite similar to the adjacent abactinals, and not making a conspicuous actinolateral edge. Actinal intermediate areas with two regular longitudinal series of roundish plates, similarly armed, extending whole arm length. Adambulacral armature made of a series of eight or nine elongated, slender, webbed, furrow spines, the median ones being the longest, behind which rise a series of eight thicker, sharply tapering subambulacral spines, and several small spinelets in abradialmost position.

Remarks. - *Nepanthia maculata* is distinguished from its Singaporean congener mainly in having arms slender, quite cylindrical (*i.e.*, without distinct actino-lateral edges as occurring in *N. belcheri*), and by the dense armature of abactinals ornamented with small, slender, spinelets tipped by 1-4 points (*versus* 4-5 points for *N. belcheri*).

***Patiriella pseudoexigua* Dartnall, 1971**
(Fig. 36A-B, Pl. IV fig. 1)

Patiriella pseudoexigua - Dartnall, A.J., 1971: 43, pl. 3(a).
Patiriella obscura - Dartnall, A.J., 1971: 45, pl.4(b).

Taxonomic decision for the synonymy: Rowe, F.W.E. & J. Gates, 1995: 41

***Material examined*.** - ZRC. 1994. 3145 : 1 specimen measuring R/r = 20/12mm, collected by SCUBA-diving at West Pulau Semakau, Singapore, depth unknown, 1994.

***Description of the ZRC specimen*.** - Five arms. Radial and mediodiscal areas covered with abactinal plates mostly crescentic in contour, notched for single papulae, and arranged rather irregularly, except along the arms where there is a tendency to form longitudinal series. Interradial areas of disk, admarginally, are devoid of papulae, covered with smaller abactinals, more or less oval in contour, and arranged in very regular transverse-oblique series. All plates armed with short, granuliform spinelets, of which there are up to ten on basobrachial plates. Madreporite relatively large, circular in contour, and adcentral in position. Superomarginal plates inconspicuous from adjacent abactinals. Inferomarginal plates significantly larger than superomarginals, rectangular in contour (i.e. higher than long), and forming with their projecting spinelets, a distinct fringe around the body. Actinolateral areas well developed with plates mostly monocanthid, sometimes diplacanthid (distally). Actinal spines are stout, coniform, and pointed. Adambulacral plate armature composed of two flattened furrow spines, and one, much stronger, subambulacral spine. Oral plates with a furrow margin bordered with four very compressed, spatuliform spines, and with an actinal surface armed with one subambulacral-like spine.

***Remarks*.** - The species *Patiriella pseudoexigua* Dartnall is distinguished from its most allied species *P. exigua* (Lamarck) by the position of gonopores, the larger body size of the former and by their respective zoogeographical distributions: representatives of Dartnall's species possess abactinally directed gonopores, and are known to occur in the tropical Western Indo-West Pacific waters north of 28° S; while representatives of Lamarck's species possess actinally directed gonopores, and are known to occur in the Southern temperate waters south of 28° S.

However, it is necessary to point out that, in many specimens of *Patiriella pseudoexigua*, the gonopore positions remain indiscernible (Aziz, 1986:436), as is notably the case for the ZRC representatives at hand. For this reason, it seems advisable to redefine the exact taxonomic affinities between *P. pseudoexigua* and *P. exigua*. But, until such study is done, we have established our identification on the basis of large size (R=20mm), and geographical place of collection which corresponds to the latitudinal zone north of 28°S.

***Tegulaster ceylanica* (Döderlein)**
(Fig. 35A-D, Pl. I fig. 3)

Disasterina ceylanica - Döderlein, L., 1888: 825.
Tegulaster ceylanica - Livingstone, A.A., 1933: 6.

***Material examined*.** - ZRC.1995.904 : 1 specimen measuring R/r = 18/6 mm, collected at Pulau Hantu Jetty, Singapore, depth unknown, 3 Jan.1995.

Description of the ZRC specimen. - Five long, subequal arms, markedly keeled abactinally throughout, and tapering very slightly to a well rounded tip. Abactinal plates having no particular arrangement on disk; while those on arms are disposed in rather regular longitudinal oblique series. Discal and abactinolateral plates irregularly circular in contour and lobated, those medioradial being crescentic. Papulae single, restricted to the centrodiscal and medioradial areas, within notches or between lobes of plates. Abactinal spinelets sacculated at their base, very fine, vitreous, delicate, covered by a thin skin, and rising from a plate eminence. A two-bladed, forficiform pedicellaria may be present in the interradius. Superomarginal plates slightly developed, small, circular in contour, monocanthid, hardly larger than the adjacent abactinals. Inferomarginal plates longer than broad, armed with a series of two (one to three) well-aciculated spinelets, and protruding beyond the superomarginals, defining the ambitus of the body. Actinal intermediate areas paved with series of five or six imbricating, lobated plates, arranged in chevrons, and ornamented with one spinelet and with embedded crystal bodies. Adambulacral armature consisting of four or five furrow spines and one larger subambulacral spine.

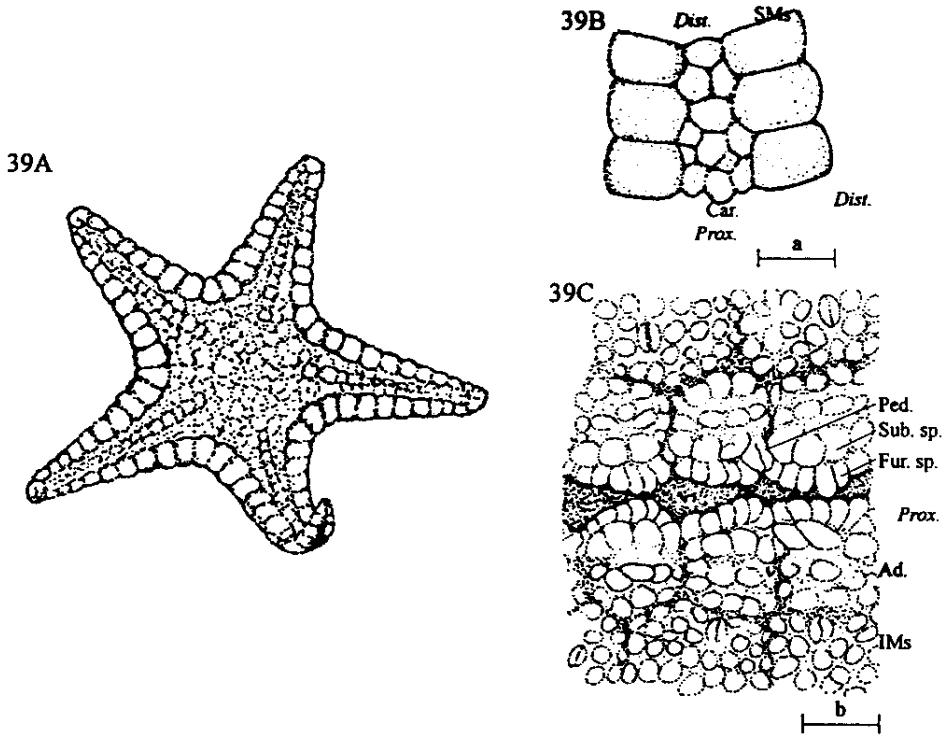
Remarks. - The genus *Tegulaster* includes only two described species and is relatively very little-known, *viz. T. ceylanica* (Döderlein, 1888) and *T. emburyi* Livingstone, 1933. The latter is hitherto represented only by the holotype specimen, collected near Norwest Island, Capricorn Group, Great Barrier Reef, Queensland (Australia). Table 2 gathers what little information exists dealing with the taxonomic differences of both species of *Tegulaster*.

The ZRC material contains one subadult specimen whose characteristics fit more closely with the original description of *Tegulaster ceylanica*, as well as with the supplementary details published for the species.

Table 2: Difference between the described species of *Tegulaster*

Tegulaster ceylanica Döderlein, 1888	*Tegulaster emburyi* Livingstone, 1933
(1) R/r mm: Död: 32/10.5, 25/10 & 14/7; ZRC: 18/6 Sas: 21/7	Liv: 19/7.5
(2) Arrangement of brachial abactinals: Död, Sas & ZRC: irregular	Liv: regular
(3) Number of abactinal spinelets: Död & Sas: ?; ZRC: 1	Liv: 1
(4) Number of inferomarginal spinelets: Död: 4-5; Sas: 6-8; ZRC: 2 (1-3)	Liv: 3-6
(5) Number of actinal spinelets: Död, Sas & ZRC: 1	Liv: 1-4
(6) Number of adambulacral furrow spines: Död, Sas & ZRC: 4-5	Liv: 6 (7)
(7) Number of subambulacral spines: Död: 2 (1); Sas: 2; ZRC: 1	Liv: 2-4

• Reference Codes: Död = Döderlein, 1888; Sas = Sastry, 1991; Liv = Livingstone, 1933; ZRC = present work; ? = data not given.



Figs. 39A-C. *Goniodiscaster forficulatus*: A-B. (from Fisher, 1919, pl. 80 fig. 3, specimen measuring R/r mm = 37/15) General abactinal view (A), partial abactinal view of the arm base (B); C. (from Jangoux, 1980, fig. 1) partial actinal view at the arm base. - Scale bars: a = 2.9 mm, b = 0.9 mm.

FAMILY OREASTERIDAE FISHER

Remarks. - The oreasterid species *Goniodiscaster forficulatus* (Perrier, 1875), the most closely allied species of *G. scaber* (Möbius, 1859), has been reported to occur in Singaporean waters by Aziz (1986) on the basis of a single specimen which is currently held by the ZMK. However, a critical inspection of this specimen reveals morphological characters proper to *G. scaber* such as central granules on abactinal and marginal plates that are more developed and conspicuously coarser (Figure 39A-C). A distinction between both species can be clearly established when Figure 26 and Figure 39 are compared. Therefore, the species, *G. forficulatus* will be not included below.

Anthenea aspera Döderlein
(Fig. 25A-C, Pl. I fig. 5)

Anthenea aspera - Döderlein, L., 1915: 28, 35, pl. 5 (2-3).

Material examined. - ZRC 1994.4290 : 1 specimen measuring R/r = 121/62 mm, dredged between Pulau Tekong and P. Ubin (off Changi, 1:24'N ; 104:00'E), Singapore, at 18 m, 26 Jan.1994. ZRC 1998.16: 1 specimen, R/r = 115/70 mm, same location and depth, 15 Mar.1992.

Description of the ZRC specimens. - Five relatively long, triangular arms tapering from a broad base to an upward-directed pointed tip. Disk very massive, abactinally convex and actinally quite planar. Body completely covered by a thick translucent skin concealing the limits of subjacent plates. Some centrodiscal and proximal carinal plates bearing one short round-tipped tubercle. Anal aperture surrounded by one to three irregular series of elongated small granules. Madreporite large, oval in contour, slightly convex, and situated near the centre of the disk. Almost the whole surface over the abactinal skeleton densely covered by small papulae and small bivalve pedicellariae having flattened broad-tipped valves as high as broad or higher. Only distal brachial plates without skeletal ornament. Marginal plates well-developed, and massive; plates being broader than long, hardly convex, and rather rectangular in contour. Superomarginal series has interradial plates obliquely disposed which become progressively block-like towards the radial areas and evenly developed on both abactinal and lateral surfaces; plates armed with a central vertical series of one to three short tubercles, and on outer side of plates with several subequal granules and up to two (or three) bivalve pedicellariae with valves clearly broader than high. Abactinal surface of superomarginals quite bare. Inferomarginal series slightly protruding interradially under the superomarginals; plates largely developed on their actinal surface, bearing a uniform, dense covering of globular granules which become coarser, spaced, and subequal on the outer side of plates. Up to three bivalve pedicellariae similar to superomarginal ones, but larger, occurring on each inferomarginal. Actinal intermediate areas very large, triangular in contour, and paved with six or seven longitudinal transverse series of oval plates; each plate carrying one large bivalve pedicellaria flanked by one (or two) series of subequal globular granules. Armature of adambulacral plates constituted by a furrow series of six or seven slender subequal spinelets, a first subambulacral longitudinal series of three or four larger, robust spinelets, and a second series of two or three robust subequal granules. Oral plates prominent, bordered by nine or ten slender prismatic furrow spinelets; a suboral series adjacent to the furrow one is formed by four or five enlarged massive granules, and the remaining actinal surface of plates filled with translucent membrane and some small, subequal granules.

Remarks. - The ZRC now contains two large adult specimens collected during this study and having very strong morphological affinities with the rare species *Anthenea aspera*. Their identification herein is mainly supported by the occurrence of few, small, and well-spaced abactinal tubercles, by a naked area on the abactinal surface of superomarginals, and by the presence of small bivalve pedicellariae typically abundant on the whole abactinal surface as mentioned by Döderlein (1915) and Mortensen (1934).

Gymnanthenea laevis H.L. Clark
(Fig. 24A-C, Pl. IV fig. 5)

Gymnanthenea laevis - Clark, H.L., 1938: 108; 1946: 100.

Material examined. - ZRC.1995.909 : 1 specimen measuring R/r = 10/5 mm, dredged at Beting Bembang Besar, Singapore, depth unknown, 8 Feb.1994; ZRC.1995.948 : 1 specimen measuring R/r = 14/7 mm, collected at Changi Beach, Singapore, low spring tide, 29 Sep.1988; ZRC.1996.1708: one specimen R/r=57/27mm, collected 1992 Singapore, depth and locality unknown.

Description of the ZRC specimens. - Arms five in number, broad, elongated and blunt at the tips. Disk large, slightly convex and pentagonal in contour. Interradial arcs wide and rounded. Abactinal plates arranged in regular series parallel to the carinal series. Centrodiscal plates and those of two interradial series being oval to irregularly circular in contour, the remaining

ones being substellate; each proximal carinal plate bearing a stout, conical tubercle raised on an eminence, some centrodiscal and proximalmost adcarinal plates armed with a similar tubercle but smaller and subequal; a small, bivalved, low pedicellaria present on most adcarinal plates, the remaining plates being bare. The whole abactinal surface covered by a skin embedded with a fine inconspicuous granulation. Papular areas very extensive, only narrow interradial areas without papulae; papular area grouping usually three to five papulae. Anal aperture central, encircled with irregular, coarser granules; madreporite adcentral, distinct and convex. Marginal plates well-developed, clearly visible abactinally, laterally and actinally, massive, block-like, convex, broader than long and as high as long; abactinal surface of superomarginals bare, abactinolateral edge ornamented with one or two small, robust, conical tubercles, and the lateral surface with a covering of subequal, enlarged, coarse granules, and up to three small, sugar-tong bivalve pedicellariae. Inferomarginal plates similar in shape to superomarginals; interradial plates slightly protruding under the upper marginal series; inferomarginal armament consisting laterally of enlarged, subequal, coarse granules and actinally of a uniform covering of small granules surrounding one (or two) large, sugar-tong pedicellaria. Actinal intermediate areas extensive, paved with five or six plate series disposed in chevrons; the adambulacral series only extend up to about two-thirds of the length of arms. Actinal plates bearing a huge, bivalve, sugar-tong pedicellaria, flanked on both sides by one or two irregular series of subequal, coarse granules. Adambulacral armature furnished with slightly curved series of seven or eight elongated, transversally compressed, webbed, round-tipped, furrow spines, the median ones being the longest ; the first subambulacral series of three larger, robust, subeqal, conspicuously compressed, round-tipped spines, the median is the more prominent and the proximalmost spine may be replaced by a forficiform, bivalve pedicellaria, and a second irregular series of three or four subequal, elongated granules rather like those of actinal plates. Oral plates large, each bearing a series of ten or eleven furrow spines, the proximalmost being strongly compressed and enlarged at the apex, and two suboral series of six or seven larger spines and five or six subequal adsutural granules.

Remarks. - The ZRC specimens undoubtedly belong to the monotypic genus *Gymnanthenea* because of several morphologic characters proper to this genus as follows: (1) a carinal armature more developed than that of abactinolaterals, (2) superomarginals with a large abactinal surface, which is quite bare — defining a broad naked, stellate contour to the body in abactinal view—, and (3) actinal intermediate areas wholly covered with a thick integument concealing the outline of subjacent plates, each armed with a huge bivalved pedicellaria flanked by granules (Clark, H.L. 1938, 1946, Aziz 1986).

According to Rowe & Gates (1995 - formalises listing by Marsh, 1976) *G. laevis* is a synonym of *G.globigera*. After the examination of 3 specimens of *G. globigera* on loan from the Western Australian Museum we do not share this opinion, considering *G. laevis* as a valid species.

FAMILY OPHIDIASTERIDAE VERRILL

Fromia monilis Perrier

(Fig. 19A-C, Pl. II fig. 2)

Fromia monilis - Perrier, E., 1869: 62.

Material examined. - ZRC.1996.1715: 1 specimen, measuring R/r = 52/10 mm; collected by SCUBA at Sultan Shoal, Singapore, depth 18 m, 23 Mar.1992.

Description of the ZRC specimen. - Five subequal arms, broad at the base and attenuating to a blunt tip. Disk flattened. Abactinal plates large, subcircular to irregularly polygonal in contour, generally arranged in irregular longitudinal series on arms, but with enlarged carinals often forming regular series proximally; plates wholly covered with packed, tabulate, small, polygonal granules. Papulae single, surrounded by enlarged granules, and confined to the angles of abactinals, except for the interradial ones. Two oval madreporites in ZRC.1996.1715. Marginal plates large, somewhat convex, irregular in contour, conspicuously subequal and uniformly covered with granules; moniliform plates alternating with smaller, rather planar plates on distal areas of arms. Actinal intermediate areas small, paved with two or three series of plates; the adambulacral series extending up to about two-thirds of the length of arms. Granulation of plates coarse. Actinal papulae single, rare, and confined to the admarginal areas. Adambulacral plates armed with two (or three) long, flattened, blunt to truncate-tipped spines, two subequal, thicker, subambulacral spines, the distal ones being more developed, and several, subequal, polyhedrical granules, sometimes slightly enlarged as thick, small spinelets in abradialmost position.

Remarks. - The alternation of large superomarginal plates with small ones, at least in the distal part of arms, may be found in the allied species *Fromia pacifica*. But the latter has planar superomarginals as well as carinals similar in size to the abactinolaterals. As could be observed on ZRC specimens, *F. monilis* has the larger superomarginals conspicuously convex and carinals also mostly enlarged. The above-mentioned characteristics of *F. monilis* with regard to the carinals and superomarginals may be used for its specific distinction between the diverse species of *Fromia*. The taxon designated as *Fromia nodosa maldiviensis* by Moosleitner (1997, 1998) is very similar to the ZRC *Fromia* material described herein. In consequence, Moosleitner's record for the Indian Ocean (Maldives) is tentatively assigned to *F. monilis* in Table 1.

Ophidiaster granifer Lütken
(Fig. 21A-C, Pl. IV fig. 7)

Ophidiaster granifer - Lütken, C.F., 1872: 276.
Ophidiaster trychnus - Fisher, W.K., 1913: 215.

Taxonomic decision for the synonymy: Clark, H.L., 1921: 81.

Material examined. - **ZRC.1996.1714: 1 specimen, measuring R/r = 29/4 mm, dredged at Sultan Shoal, Singapore, depth 20 m , Apr.1992.**

Description of the ZRC specimen. - Five arms, equal in length, cylindrical and blunt at the tip. Abactinal plates with marginal series on both sides of arms numbering seven longitudinal series in register transversely; each plate densely covered with granules, the central ones becoming clearly coarser and more developed and even subtuberculated on distal marginals. Papulae grouped in three to six per papular area, disposed in eight longitudinal series. Very small, bivalve, alveolar pedicellariae occurring on marginals, hardly larger than the adjacent granules. The adambulacral armature consisting of two thick, longitudinally compressed, round-tipped, subequal furrow spines, one to three irregular longitudinal series of subequal granules and one prominent, conical spine which enlarges distally; the remaining surface covered with small granules.

Remarks. - The characteristics of the ZRC specimen fit closely with the original description of *O. trychnus* Fisher, which is a synonym of *O. granifer* (see Clark, H.L, 1921).

Tamaria fusca Gray
(Fig. 20A-D, Pl. IV fig. 8)

Tamaria fusca - Gray, J.E., 1840: 283.

Material examined. - ZRC 1995.893-894 : 2 specimens, measuring R/r = 61/8 & 57/9 mm, collected by SCUBA off N. end of P. Semakau, Singapore, depth 17 m, 18 May.1993 & 28 Dec.1994.

Description of the ZRC specimens. - Five long arms, tapering very gently to a blunt tip. Abactinal plates are mostly convex. They are subequal in size, irregular in arrangement and coarsely roundish on the disk, while on the arms they are trapezoidal and arranged in three very regular transverso-longitudinal series (one carinal flanked on both sides by one abactinolateral series); carinals conspicuously enlarged and more convex. All plates are armed with packed granules that become larger and subequal on central area of plates. Madreporite very large. Marginal plates are arranged in perfect register with the adjacent abactinals. Superomarginal plates restricted to the lateral surface; inferomarginal plates developed on the actinal surface, forming a conspicuous actinolateral angle throughout the arm length. Granuliform armature of marginals similar to abactinals, except that a well developed, stout, coniform spine (becoming larger distally) occupies the central position of most superomarginals and the actinolateral angle of inferomarginals. About ten papulae per papular area which are disposed in six longitudinal series between the series of abactinals and marginals (no actinolateral papulae). Rare pedicellariae with two broad valves generally carried by abactinals and marginals. One rather inconspicuous, longitudinal series of actinolateral plates present. Adambulacral armature furnished with a pair of short furrow spines and, on some plates, a larger subambulacral spine.

Remarks. - The close resemblance of the genus *Tamaria* with that of *Ophidiaster* has resulted in some dispute among previous authors regarding the systematic affinities of these taxa. Some authors as e.g. Döderlein (1926) & Livingstone (1932) have discussed the status of *Tamaria*, tending to consider it more as a subgenus of *Ophidiaster*. In contrast, Clark, & Rowe (1971) have treated them as distinct genera.

The precise reason of this dispute may be explained by the fact that the above genera are distinguished only by the following character: presence/absence of papular areas below the inferomarginal plates, or, in other words, the total number of longitudinal series of papular areas being 6 for the genus *Tamaria* versus 8 for *Ophidiaster*. Actually, it was admitted by H.L. Clark (1921: 88) that a few papulae do sometimes occur between actinals in *Tamaria*. This is probably the reason for inconsistent identification. Aziz (1986: 370-371) reported: « All the specimens of the Amsterdam Museum (Siboga records) were identified to either *Ophidiaster pusillus*, or *Ophidiaster* (*Tamaria*) *pusilla*. These specimens differ by one character alone: they present either 6, or 8 longitudinal series of papulae (abactinal papular areas with 4-8 papulae, actinal areas with 1-3 papulae). I arbitrarly referred the species with 8 series of papulae to the genus *Ophidiaster* (species: *O. granifer*), that with 6 series to the genus *Tamaria* (species *T. pusilla*). This situation precisely manifests the difficulty about the distinctness of these two ophidiasterid genera and raises up the question on the validity of the genus *Tamaria* ». Clearly, a critical re-examination of both genera is necessary in order to clarify their precise relationship, a project which is outside the scope of this paper.

ORDER SPINULOSIDA PERRIER

FAMILY ECHINASTERIDAE VERRILL

Echinaster callosus Marenzeller
(Fig. 30A-C, Pl. II fig. 4)

Echinaster callosus - Marenzeller, E., 1895: 531, pl. 1.

Material examined. - ZRC.1996.1707: 1 specimen, measuring R/r = 176/17, off W. coast of P. Semakau, 12m of depth, 15 Feb.1993.

Description of the ZRC specimen. - Five cylindrical, elongate arms. Abactinal skeleton reticulate having large meshes; each mesh filled with ten to thirty papulae. Each node of the reticulum armed with a conspicuous spinelet, measuring up to four mm in length. Marginal plates may be armed with one abactinal-like spinelet. Adambulacral armature composed of two inner curved spines and one larger furrow spine. No intermarginal and actinal papulae present.

Remarks. - This species is generally considered to belong to the genus *Echinaster* (within the subgenus *Echinaster*). Nevertheless, it should be noted that A.M. Clark (1987) did question this systematic rank, urging rather a supraspecific distinction within *Echinaster* ; a decision on this is beyond the scope of the present work.

The specific name *callosus* refers to the dermal callosity occurring around the base of each abactinal spine, and whose the function is still unknown.

Echinaster stereosomus Fisher
(Fig. 31A-C, Pl. II fig. 5)

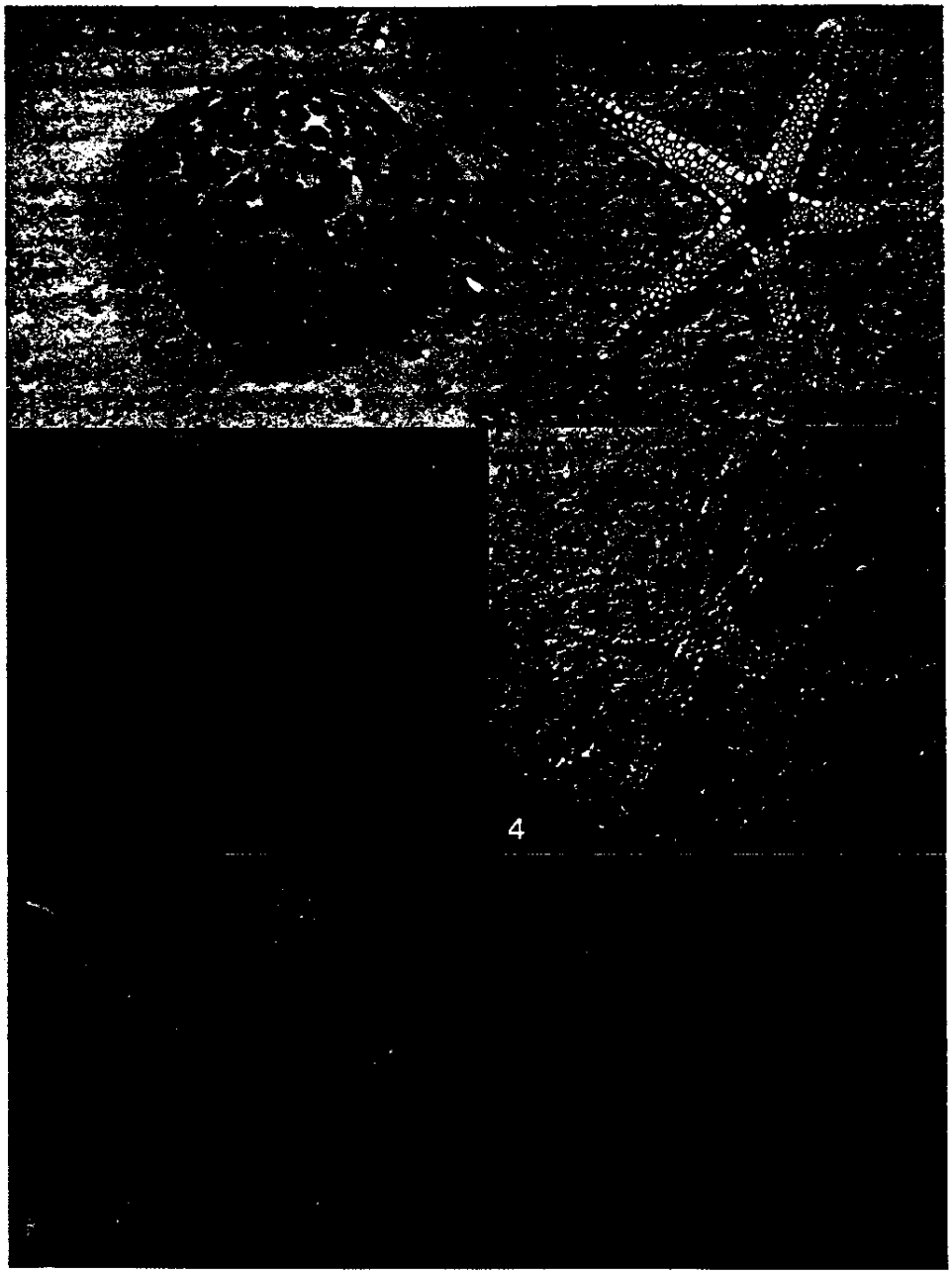
Echinaster stereosomus - Fisher, W.K., 1913: 195.
Echinaster acanthodes - Clark, H.L., 1916: 61, fig.7,pl. 19(1-2).

Taxonomic decision for the synonymy: Jangoux, M., 1978.

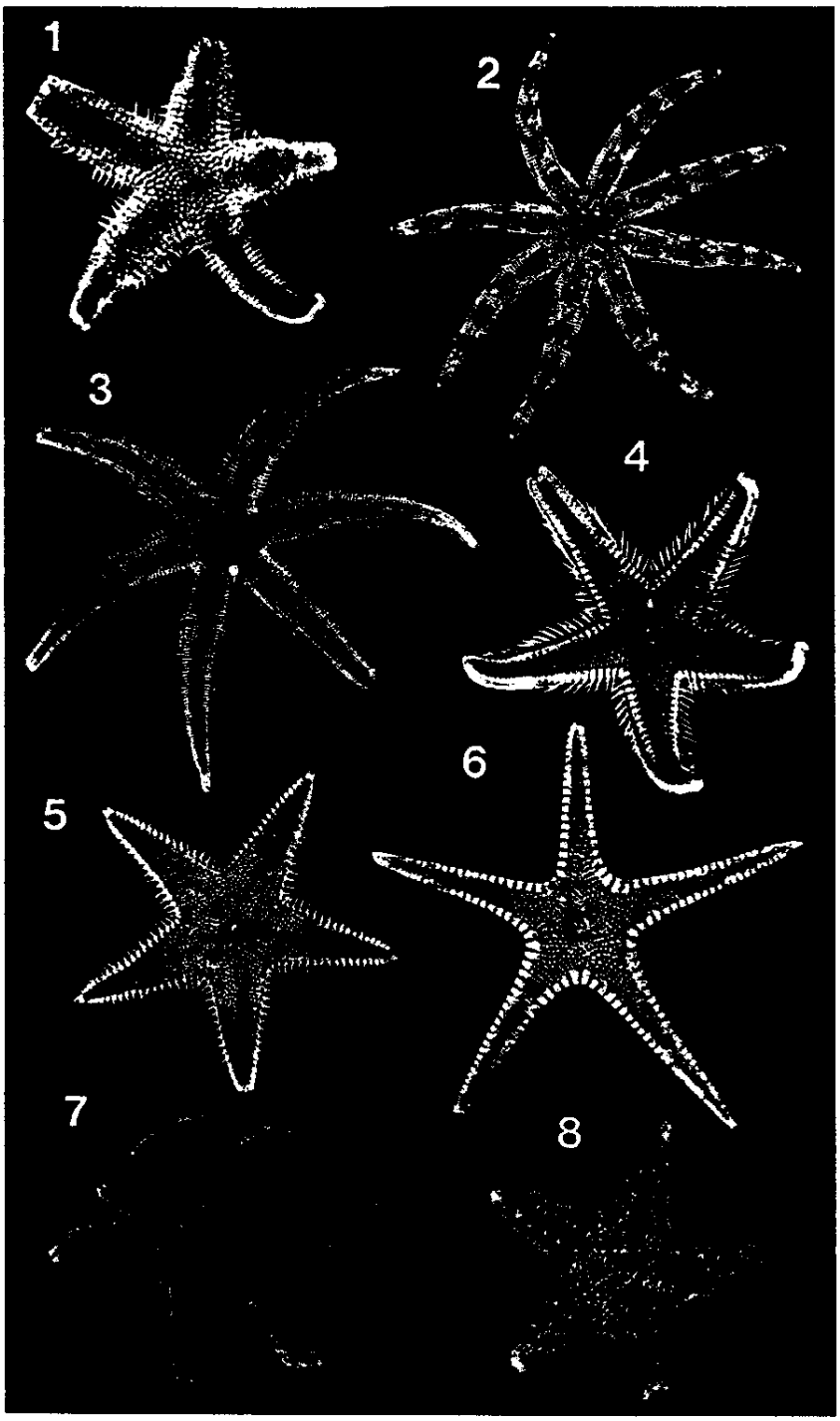
Material examined. - ZRC.1995.899: 1 specimen, measuring R/r = 16/3 mm, dredged near Sultan Shoal, Singapore, depth 19 m, 18 Feb.1994; ZRC.1995.900-902 : 3 specimens, measuring R/r = 18/3.2, 14/3.2 & 13/2.8 mm, dredged at Sultan Shoal, Singapore, depth 19 m, 23 Mar.1994.

Description of the ZRC specimens. - Five long, cylindrical, slender arms, equal in length. Abactinal plates convex, forming a reticulum with relatively large meshes; each plate bearing a stout, conical, blunt-tipped spine. Papulae single or in groups of four per papular area. Marginal plates large, rectangular with rounded corners, elongate, forming a prominent lateral side to the body; except interradially and sometimes on the proximalmost plates which are spineless, marginals are monocanthid. Adambulacral plates with a vertical irregular series of three spines, the two inner ones being one above the other on the furrow surface of plates, while the third is on the furrow margin.

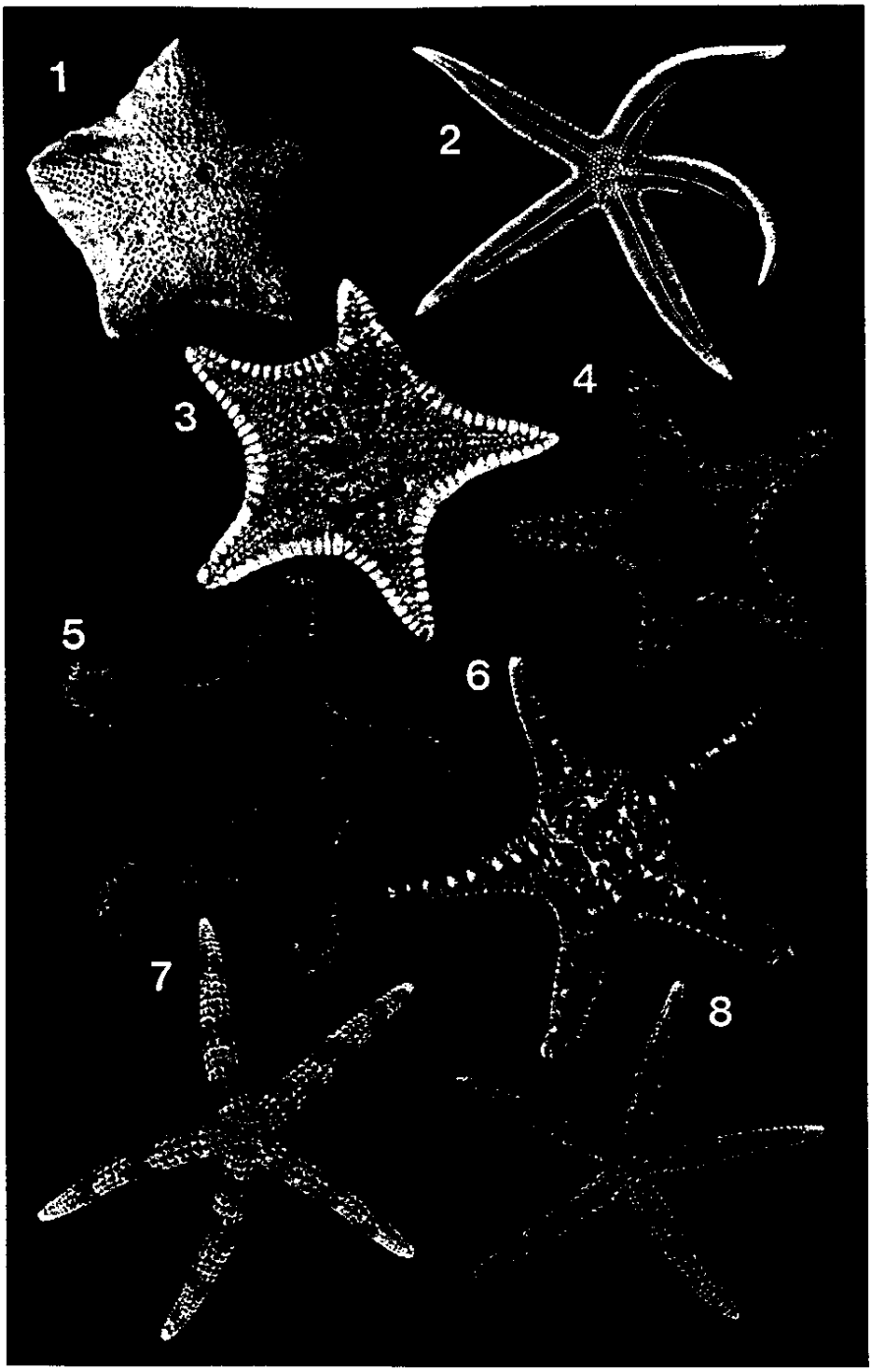
Pl. I. **1**: *Nepanthia belcheri* (Perrier), ZRC.1995.905, R = 45mm. **2**: *Nepanthia maculata* Gray, ZRC.1995.906, R = 30mm. **3**: *Tegulaster ceylanica* (Döderlein), ZRC.1995.904, R = 18mm. **4**: *Iconaster longimanus* (Möbius), R = 49mm. **5**: *Anthenea aspera* Döderlein, ZRC.1998.16, R = 115mm. **6**: *Stellaster equestris* (Retzius), ZRC.1995.911, R = 40mm., eulimid parasite near madreporite.



Pl. II. **1**: *Culcita novaeguineae* Müller & Troschel, ZRC.1998.36, R = 130mm. **2**: *Fromia monilis* Perrier, R = 58mm. **3**: *Euretaster insignis* (Sladen), ZRC.1995.927, R = 33mm. **4**: *Echinaster callosus* von Maranzeller. **5**: *Echinaster stereosomus* Fisher, ZRC.1995.899, R = 16mm. **6**: *Metrodira subulata* Gray, ZRC.1995.897, R = 45mm.



Pl. III. **1**: *Luidia hardwicki* (Gray). **2**: *Luidia maculata* Müller & Troschel. **3**: *Luidia penangensis* de Loriol, ZRC.1998.18, R = 102mm. (dried). **4**: *Astropecten indicus* Döderlein, ZRC.1995.920, R = 58mm. **5**: *Astropecten novaeguineae* Döderlein, ZRC.1996.1710, R = 27mm. **6**: *Craspidaster hesperus* (Müller & Troschel). **7**: *Asterina anomala* H.L. Clark, ZRC.1995.902, R = 10mm. **8**: *Asterina coronata* von Martens, ZRC.1995.903, R = 20mm. (dried).



Pl. IV. **1**: *Patiriella pseudoexigua* Dartnall, ZRC.1994.3745, R = 20 mm. **2**: *Archaster typicus* Müller & Troschel, ZRC.1995.925, R = 99 mm. (dried). **3**: *Goniodiscaster scaber* (Möbius), ZRC.1996.1699, R = 88 mm. **4**: *Goniodiscaster scaber* (Möbius), ZRC.1998.17, R = 43 mm. (dried). **5**: *Gymnanthenea laevis* H.L. Clark, ZRC.1996.1708, R = 57 mm. (dried). **6**: *Protoreaster nodosus* (Linnaeus). **7**: *Ophidiaster granifer* Lütken, ZRC.1996.1714, R = 29 mm. **8**: *Tamaria fusca* Gray, ZRC.1995.893, R = 61 mm.

CONCLUSION

The intensive benthic sampling done during the EC research programme allowed us to record twenty-seven species of asteroids, fourteen of them collected for the first time in Singaporean waters (Table 3). This, together with the literature data, brings to thirty-one the total number of asteroid species for Singapore, among which four were not found again during the NUS-UMH Survey.

Table 3. Number of asteroid species in Singapore waters.

	A	B	C	D	E
Number of species	17	27	31	4	14

A: number of species recorded in the literature; B: number of species recorded during the NUS-UMH survey; C: total number of species from Singapore waters; D: number recorded but not collected again during the survey; E: number of newly recorded species

The asteroid fauna, originally thought to be impoverished in Singapore waters, turns out to be quite diverse and comparable to other islands of similar size in the region (e.g., east coast islands of peninsular Malaysia). However, many species characteristic of fringing coral reefs in the Indo West Pacific are absent from local reefs and adjacent soft sediments (e.g., the species *Choriaster granulatus, Linckia laevigata, Linckia multifora, Echinaster luzonicus* and *Acanthaster planci*). This was also true at the beginning of this century as Bedford (1900) did not record the above cited species in the Singapore region. Judging from the number of species recorded, the decline noticed by Lim & Chou (1988) in the reef associated crinoids since the onset of reclamation works and gradual increase of shipping activities, is seemingly not evident for the asteroids.

Moreover, the present faunal survey, particularly the dredging component, has established the existence of many uncommon or rare species, including several taxa last collected in the earlier part of this century and lodged in the former Raffles Collection (now the NUS Zoological Reference Collection [ZCR]) but thought to have subsequently disappeared.

ACKNOWLEDGEMENTS

We thank Prof. T.J. Lam for providing facilities at the National University of Singapore. Thanks are due to L. M. Marsh and two anonymous reviewers for critical reading of the manuscript, Miss R. Teo (NUS) and Mr. JC Grignard (UMH) for help during various field trips in Singapore, Mr. P. Postiau (UMH) for black and white photography, and the following collection managers for loan of type specimens: Prof. Ruffo (MCNV, Verona, Italy), Dr. P.B. Berents (Australian Museum), Dr. J. Margit (ZMK), and Dr. N. Cominardi (Muséum National d'Histoire Naturelle, Paris, France). Dr. B.P. Halder (From the Zoological Survey of India, Calcutta, India) kindly provided some Indian publication particularly useful for this work. The third author is deeply indebted to Mrs. C. Ahearn and Dr. D. Pawson (both from USNM) for the hospitality and kindnesses manifested during his stay in the Smithsonian Institution, and also G. Controversio and L. Girotto for their assistance and companionship in Washington D.C. This work was supported by EEC contract no. CL1-CT91-0909, and (for S. Stampanato) by an IRSIA grant, Contribution of the « Centre Interuniversitaire de Biologie Marine » (CIBIM).

LITERATURE CITED

Aziz, A., 1986. *La faune d'astérides (Echinodermata) de la région indo-malaise: Taxonomie, zoogéographie et bathymétrie.* Thesis, Université Libre de Bruxelles. 663 pp.

Aziz, A. & M. Jangoux, 1984. Les Astéries (Echinodermes) du Plateau de la Sonde. *Indo-Malayan Zool.*, 1(1): 127-140.

Bedford, F.P., 1900. On the echinoderms from Singapore and Malacca. *Proc. zool. Soc. Lond.*, 14: 271-299, 1 fig., pls. 21-24.

Clark, A.M., 1987. Notes on Atlantic and other Asteroidea. Echinasteridae. *Bull. Br. Mus. Nat.Hist. (Zool.)*, 57: 65-78, 3 figs.

Clark, A.M., 1989. An index of names of recent Asteroidea - Part 1: Paxillosida and Notomyotida. In: M. Jangoux & J. M. Lawrence (eds.), *Echinoderm Studies*, Vol. 3. Pp. 225-347. Balkema, Rotterdam.

Clark, A.M., 1993. An index of names of recent Asteroidea - Part 2: Valvatida. In: M. Jangoux & J.M. Lawrence (eds.), *Echinoderm Studies*, Vol. 4. Pp. 187-366. Balkema, Rotterdam.

Clark, A.M., 1996. An index of names of recent Asteroidea - Part 3: Velatida. In: M. Jangoux & J.M. Lawrence (eds.), *Echinoderm Studies*, Vol. 5. Pp. 183-250. Balkema, Rotterdam.

Clark, A.M. & F.W.E. Rowe, 1971. *Monograph of Shallow-water Indo-west Pacific Echinoderms.* London, Trustees of the British Museum (Natural History). 238 pp., 31 pls.

Clark, H.L., 1909. Notes on some Australian and Indo-Pacific echinoderms. *Bull. Mus. comp. Zool. Harv.*, 52: 107-135, 1 pl.

Clark, H.L., 1916. Report on the sea lilies, starfishes, brittle-stars and sea-urchins obtained by the F.I.S. « Endeavour » on the coasts of Queensland, N.S.W., Tasmania, Victoria, S. Australia and W. Australia. *Endeavour Res.*, 4: 1-123, 44 pls.

Clark, H.L., 1921. The echinoderm fauna of Torres Strait. *Pap. Dep. mar. biol. Carnegie Instn Wash.*, 10: 1-224

Clark, H.L., 1938. Echinoderms from Australia. An account of collection made in 1929 and 1932. *Mem. Mus. comp. Zool. Harv.*, 55: 1-596, 28 pls.

Clark, H.L., 1946. The echinoderm fauna of Australia. Its composition and origin. *Publs. Carnegie Instn.* Washington, 566: 1-567.

Dartnall, A.J., 1971. Australian sea stars of the genus *Patiriella* (Asteroidea : Asterinidae). *Proc. Linn. Soc. NSW*, 96(1): 39-49, pls. 3-4.

Döderlein, L., 1888. Echinodermen von Ceylon. Bericht über die von Herren Drs. Sarasin gesammelten Asteroidea, Ophiuroidea und Echinoidea. *Zool. Jb.*, 3: 822-846, pls. 31-33.

Döderlein, L., 1915. Die Arten der Asteroidea: Gattung *Anthenea* Gray. *Jb. nassau. Ver. Naturk.*, 68: 21-55, 11 pls.

Döderlein, L., 1917. Die Asteriden der Siboga Expedition. I. Die Gattung *Astropecten* und ihre Stammesgeschichte. *Siboga Exped.*, 46a: 1-190, pls. 1-17.

Döderlein, L., 1920. Die Asteriden der Siboga Expedition. II. Die Gattung *Luidia* und ihre Stammesgeschichte. *Siboga Exped.*, 46b: 193-291, pls. 18-20.

Döderlein, L., 1926. Über Asteriden aus dem Museum von Stockholm. *K. svenska Vetensk. Akad. Handl.*, (3)2(6): 1-22, 4 pls.

Fisher, W.K., 1913. A new species of *Echinaster* with a note on the name *Othilia*. *Zool. Anz.*, 42(5): 193-196.

Fisher, W.K., 1918. Notes on Asteroidea. II. *Ann. Mag. Nat. Hist.*, 2(9): 103-111, 13 pls.

Fisher, W.K., 1919. Starfishes of the Philippines seas and adjacent waters. *Bull. U.S. natn. Mus.*, 100(3): 1-711, 156 pls.

Goto, S., 1914. A descriptive monograph of Japanese Asteroidea. I. Archasteridae, Benthopectinidae, Porcellanasteridae, Astropectinidae, Luidiidae, Pentagonasteridae, Oreasteridae, Gymnasteridae, Asterinidae. *J. Coll. Sci. imp. Univ. Tokyo*, **29**(1): 1-808, 19 pls.

Gray, J.E., 1840. A synopsis of the genera and species of the class Hypostoma (*Asterias* Linn.). *Ann. Mag. nat. Hist.*, 6(1): 175-184; 275-290.

Grube, A.E., 1876. Über eine Sammlung von wirdbellosen Seethieren, welche Herr Dr. Eugen Reimann dem hiesigen zoologischen Museum zum Geschenk gemacht. *Jber. schles. Ges. vaterl. Kult.* :48-59.

James, D.B., 1989. Echinoderms of Lakshadweep and their zoogeography. *Bull. cent. mar. Fish. Res. Inst.*, **43**: 97-114.

Jangoux, M., 1978. Biological results of the Snellius Expedition 29. Echinodermata, Asteroidea. *Zool. meded.*, **52**(25): 287-300, 3 pls.

Jangoux, M., 1980. Echinodermes: Astéroïdes. *Resultats des Campagnes Musorstom. I - Philippines (18-28 Mars 1976).* Pp. 457-476. ORSTOM, Paris.

Jangoux, M., I. Eeckhaut, J.C. Grignard, T.J. Lam, D.J.W. Lane, & D. VandenSpiegel, 1992. *The Echinodermata: A biological tool for the control and protection of marine benthic environments in Singapore waters.* Periodic report n° 1 (unpublished) of research project CL1-CT91-0909 financed by the commission of the European Communities within the frame of the EC research action in international scientific cooperation. 27 pp.

Koehler, R., 1908. Description d'une astérie nouvelle (*Nepanthia joubini*) provenant du Cap Saint Jacques (Cochinchina). *Bull. Mus. Hist. nat. Paris*, **14**: 232-649, 16 pls.

Koehler, R., 1910. Shallow-water Asteroidea. *Echinoderma of the Indian Museum*. Calcutta. 192 pp., 20 pls.

Koehler, R., 1911. Description de quelques astéries nouvelles. *Revue Suisse Zool.*, **19**: 1-21, 1pl.

Lamarck, J.B. de, 1816. *Histoire naturelle des animaux sans vertèbres*. (ed.1), **2**: 568 pp. Verdière, Paris.

Liao, Y. & A.M. Clark, 1995. *The Echinoderms of Southern China*. Science Press Beijing, New York. 614 pp., 23pls.

Lim, G.S.I. & L.M. Chou, 1988. The echinoderm fauna in sediment stressed reefs in Singapore. *Proc. 6th Int. Coral Reef Symp.* (Australia 1988), **2**: 245-250.

Linnaeus, C., 1758. *Systema Naturae*, Holmiae. Ed. 10, **1**: 1-824.

Livingstone, A.A., 1932. Asteroidea. *Scient. Rep. Gt. Barrier Reef Exped.*, **4**: 241-265, 12 pls.

Livingstone, A.A., 1933. Some genera and species of Asterinidae. *Rec. Aust. Mus.*, **19**:1-22, pls. 1-6.

Loriol, P. de, 1891. Notes pour servir à l'étude des échinodermes. III. *Mem. Soc. Hist. nat. Genève*, **29**(4): 1-84, pls. 7-22.

Lütken, C., 1872. Fortsatte kritiske og beskrivende Bidrag til Kundskab om Söstjernerne (Asterideme). *Vidensk. Meddr. dansk. naturh. Foren.*, **1871**: 227-304.

Marenzeller, E. von, 1895. Über eine neue *Echinaster*-Art von den Salomons-Inseln. *Denkschr. Akad. Wiss. Wien*, **62**: 1-2, 1 pl.

Marsh, L.M., 1976. Western Australian Asteroidea since H.L. Clark. *Thalassia Yugosl.*, **12**(1): 213-225.

Martens, E. von, 1866. Über ostasiatische Echinodermen. 3. Seesterne des indischen Archipels. *Arch. Naturgesch.*, **31**: 57-88.

Möbius, K., 1859. Neue Seesterne des Hamburgen und Keiler Museums. *Abh. Verh. naturw. Ver. Hamburg*, **4**(2): 1-14, 4 pls.

Moosleitner, H., 1997. Shallow water Asteroidea (Echinodermata) from the coral reefs of the Maldive islands. *Revue fr. Aquariol.*, **24**: 3-14.

Moosleitner, H., 1998. Is '*Fromia nodosa*' (Asteroidea: Ophidiasteridae) from the Maldives another species? In. R. Mooi & M. Telford (eds.), *Echinoderms: San Francisco. Proceedings of the Ninth International Echinoderm Conference San Francisco/California/U.S.A.* Pp. 287-289. Balkema, Rotterdam.

Mortensen, T., 1934. Echinoderms from Hong-Kong. *Hong-Kong Nat.*, suppl. 3: 3-14, 8 pls.

Mortensen, T., 1940. Echinoderms from the Iranian Gulf. Asteroidea, Ophiuroidea and Echinoidea. *Dan. Scient. Invest. Iran* Part 2: 55-110, 14 figs, 2pls.

Müller, J. & F.H. Troschel, 1840. Über die Gattungen der Asterien. *Arch. Naturgesch.*, 6(1): 318-326. (Also published in *Ber. K. preuss. Akad. Wiss.*, **1840**: 100-106.)

Müller, J. & F.H. Troschel, 1842. *System der Asteriden.* Braunschweig. 134 pp., 12 pls.

Perrier, E., 1869. *Recherches sur les pédicellaires et les ambulacres des astéries et des oursins.* Paris. 188pp., 2 pls. [Also published in *Annls. Sci. nat.*, 12(1869): 197-304; 14(1870): 1-81.]

Perrier, E., 1875. *Révision de la collection de stellérides du Museum d'Histoire Naturelle de Paris.* Paris. 384 pp. (Also published in *Arch. Zool. exp. gén.*, 4(1875): 263-449; 5(1876): 1-104 & 209-304.)

Retzius, A.J., 1805. *Dissertatio sistens species cognitas Asteriarum.* Lundae: 1-37.

Rowe, F.W.E. & J. Gates, 1995. Echinodermata. In: A. Wells (ed.), *Zoological Catalogue of Australia*, Vol 33. Melbourne, CSIRO, Australia. 510 pp.

Rowe, F.W.E & L.M. Marsh, 1982. A revision of the asterinid genus *Nepanthia* Gray, 1840 (Echinodermata: Asteroidea), with the description of three new species. *Austr. Mus. Mem.*, 16: 89-120.

Sastry, D.R.K., 1991. *Echinodermata : Asteroidea, Ophiuroidea and Echinoidea.* State fauna series 2: fauna of Lakshadweep, pp. 363-397.

Sladen, W.P. 1882. The asteroidea of H.M.S. Challenger expedition. (Preliminary notices). II Pterasteridae. *J. Linn. Soc. (Zool.)*, 17: 214-269.

Sladen, W.P., 1888. On the Asteroidea of the Mergui Archipelago. *J. Linn. Soc.* (Zool.), 21: 319-331, pl. 28.

Sladen, W.P., 1889. Asteroidea. *Rep. scient. Results Voy. « Challenger » Zoology*, 30: 1-893, 117 pls.

Tortonese, E., 1956. Su alcune species de Astropectinidae, con descrizione di un nuovo *Astropecten* (Asteroidea). *Ann. Mus. St. nat. Genova*, 68: 319-334.