

Euryalinid Ophiuroidea (Echinodermata) from Australia, New Zealand, and the south-west Pacific Ocean

ALAN N. BAKER

National Museum of New Zealand, Private Bag, Wellington, New Zealand

The euryalinid families Asteronychidae, Asteroschematidae, Gorgonocephalidae, and Euryalidae are represented in this region by 41 species in 21 genera. *Astromoana*, a new subgenus of *Asteropora* Oestedt & Lütken, is described and a new generic name, *Astrosierra*, is proposed for species of *Conocladus* H. L. Clark, which itself replaces *Astroconus* Döderlein. New species are assigned to *Astroschema* (1), *Astromoana* (2), *Astrosierra* (1), *Astroceras* (2), and *Asteromorpha* (1). Eighteen specific and three generic names are involved in synonymy, and four new combinations are proposed. Nineteen species are new to the region, and a further 18 have their recorded ranges extended. Only three genera are restricted to the region; the remainder are of wide Indo-Pacific or cosmopolitan distribution.

Keywords: Echinodermata; Ophiuroidea; Euryalinida; Pacific Ocean; Australasia; taxonomy; zoogeography; checklist.

INTRODUCTION

Euryalinid brittlestars are a primitive group of ophiuroids with a simple internal skeletal structure and a skin-covered external surface. Some members of the suborder are the largest known ophiuroids, with discs up to 140 mm in diameter and arms 700 mm long. All have arms which coil only in the vertical plane, and in many species the arms are branched.

All euryalinids are to some degree epizooic on other sedentary marine animals, e.g., gorgonians, antipatharians, and sponges. They are, as a group, cosmopolitan in depths ranging from a few metres to over 4000 m, but are not usually as locally abundant as most other kinds of ophiuroid. Their sporadic occurrence and hard-substrate epizooic habitat have resulted in a very slow accumulation of specimens in research collections. This, and the general paucity of useful taxonomic characters evinced by euryalinids, has meant that knowledge of the fauna has advanced at a somewhat slower rate than for other echinoderm groups.

Over the past two decades the techniques for sampling hard ocean substrates have improved considerably with the development of scuba collecting and the use of echo-sounders to place and monitor more conventional sampling apparatus such as dredges. In the south-west Pacific and eastern Indian Oceans much euryalinid material has been obtained from recent expeditions mounted by Australia's CSIRO, the Western Australian Museum, Australian Museum, N.S.W. State Fisheries Department, National Museum of New Zealand, and New Zealand Oceanographic Institute, as well as from various individual collectors. Those collections have facilitated the revisional work embodied in this paper.

SCOPE OF THE STUDY

The material reported on has come mostly from coastal waters of Australia and New Zealand, and deeper water in the northern Tasman Sea and north-east of New Zealand towards the Kermadec Islands. The main collections examined, however, range from Western Australia eastward to the Tongan Islands, and from Torres Strait south to Campbell Island. Thus, the area dealt with in this revision, and collectively termed here 'Australasia', extends between 112°E and 175°W, and 10°S and 52°S (Fig. 1). Additional comparative material from various Indo-Pacific localities was also studied.

The study is based on over 1800 specimens, most of which are in the collections of the major Australian and New Zealand museums and the N.Z. Oceanographic Institute. All species recorded from the region are described in detail from actual specimens, because many early descriptions are inadequate and widely scattered in journals now difficult to obtain. Also, members of suborder Euryalinida generally lack the wide range of useful specific characters common to other ophiuroid groups, making identifications based on isolated features unreliable. It is desirable, therefore, to have available as much descriptive information as possible when attempting identification.

EARLIER WORK

Representatives of the Euryalinida have been recorded from Australasia in piecemeal fashion since Verrill's (1876) description of *Astrophyton australe* (*Conocladus australis*). Isolated species were described by Studer (1884) and Farquhar (1900), and thereafter the main contributors to knowledge of this group

in the south-west Pacific region were H. L. Clark (1909–1938) and Mortensen (1924, 1933a).

On a wider Indo-Pacific scale, the revisional works of Döderlein (1911, 1927, 1930) covered a number of Australasian genera and contributed greatly to understanding of relationships within the suborder. Döderlein's papers constitute the nearest approach to a monographic treatment of the then known species of Euryalinida. He did, however, suffer from a lack of Southern Hemisphere material, and consequently there have remained, since Döderlein's time, a number of uncertainties over Australasian taxa in particular.

H. L. Clark's (1946) annotated list of Australian

echinoderms contains 25 nominal species of euryalinid ophiuroid (treated as Trichasteridae and Gorgonocephalidae). Of the 25, only 17 are here regarded as valid species, and one, *Astrogymnotes catasticta*, had earlier been rightly transferred to the Ophiomyxidae by Mortensen (1933a). Six of the validated species are here involved in generic reassignments, and an additional 11 species are recorded from Australian waters for the first time.

Fell (1958) listed seven euryalinids from New Zealand; that number is doubled by the present study. No euryalinids have previously been recorded from Norfolk Island or Lord Howe Island, but the collections have revealed 10 species at the former

Table 1. Summary of distribution and bathymetric ranges of Australasian Euryalinida (K – Kermadec Is; N.Z. – New Zealand; NI – Norfolk I.; LH – Lord Howe I.; EA – eastern Australia; SA – southern Australia; WA – western Australia; NA – northern Australia; PIM – Philippines, Indonesia, and Malaysia; C – cosmopolitan; J – Japan).

	Depth range (m)	K	NZ	NI	LH	EA	SA	WA	NA	PIM	Other localities
<i>Asteronyx loveni</i>	109–2963		+			+	+	+			C
<i>Astrodia tenuispina</i>	510–3720						+				C
<i>Asteroschema horridum</i>	1152–1185	+									
<i>Asteroschema salix</i>	341–1152	+									
<i>Asteroschema tubiferum</i>	325–965			+							J
<i>Asteroschema migrator</i>	670–1301	+		+						+	
<i>Asteroschema igloo</i>	450–501	+		+							
<i>Astrobrachion constrictum</i>	18–180		+		+	+					
<i>Astrobrachion adhaerens</i>	23–183	+				+		+	+		
<i>Ophiocreas oedipus</i>	760–2000	+	+							+	
<i>Ophiocreas sibogae</i>	201–1089						+	+	+	+	
<i>Astrothorax waitei</i>	73–998		+	+		+					S. Africa
<i>Astrothrombus rugosus</i>	37–512		+			+					
<i>Astrothrombus vecors</i>	204–751		+	+						+	
<i>Asteroporpa australiensis</i>	55–508	+	+	+		+	+				
<i>Asteroporpa reticulata</i>	71–301			+							
<i>Asteroporpa indicus</i>	141							+			
<i>Astroclon suensoni</i>	201–457							+		+	J
<i>Astrosierra amblyconus</i>	18–135					+					
<i>Astrosierra microconus</i>	36–219							+			
<i>Astrosierra densus</i>	77–95					+					
<i>Conocladus australis</i>	6–240					+	+	+			
<i>Gorgonocephalus chilensis</i>	22–658		+								Sthn Ocean
<i>Gorgonocephalus dolichodactylus</i>	150–1019		+			+				+	J
<i>Gorgonocephalus pustulatum</i>	421–751		+			+				+	S. Africa
<i>Gorgonocephalus sundanus</i>	521–834		+							+	
<i>Astrodendrum elingamita</i>	71–365		+	+						+	
<i>Astroboa ernae</i>	0–50						+	+	+		
<i>Astroboa nuda</i>	22–113							+		+	J
<i>Astroboa nigrofurcata</i>	71–128							+		+	
<i>Astroboa granulatus</i>	6–60			+	+			+	+		
<i>Astrocladus exiguus</i>	18–494							+		+	J
<i>Astrocladus ludwigi</i>	20–140							+	+	+	
<i>Astrocladus tonganus</i>	2–10										Tonga
<i>Astrochalcius tuberculatus</i>	16–105							+	+	+	
<i>Astroglymma sculptum</i>	73–300							+		+	
<i>Astroceras elegans</i>	92–508		+	+							
<i>Astroceras kermadecensis</i>	1165–1185	+									
<i>Astroceras pleiades</i>	60–365					+					
<i>Asteromorpha tenax</i>	? shelf					+					
<i>Euryale aspera</i>	0–20					+		+	+	+	J

Downloaded by [193.191.134.1] at 01:02 08 June 2012

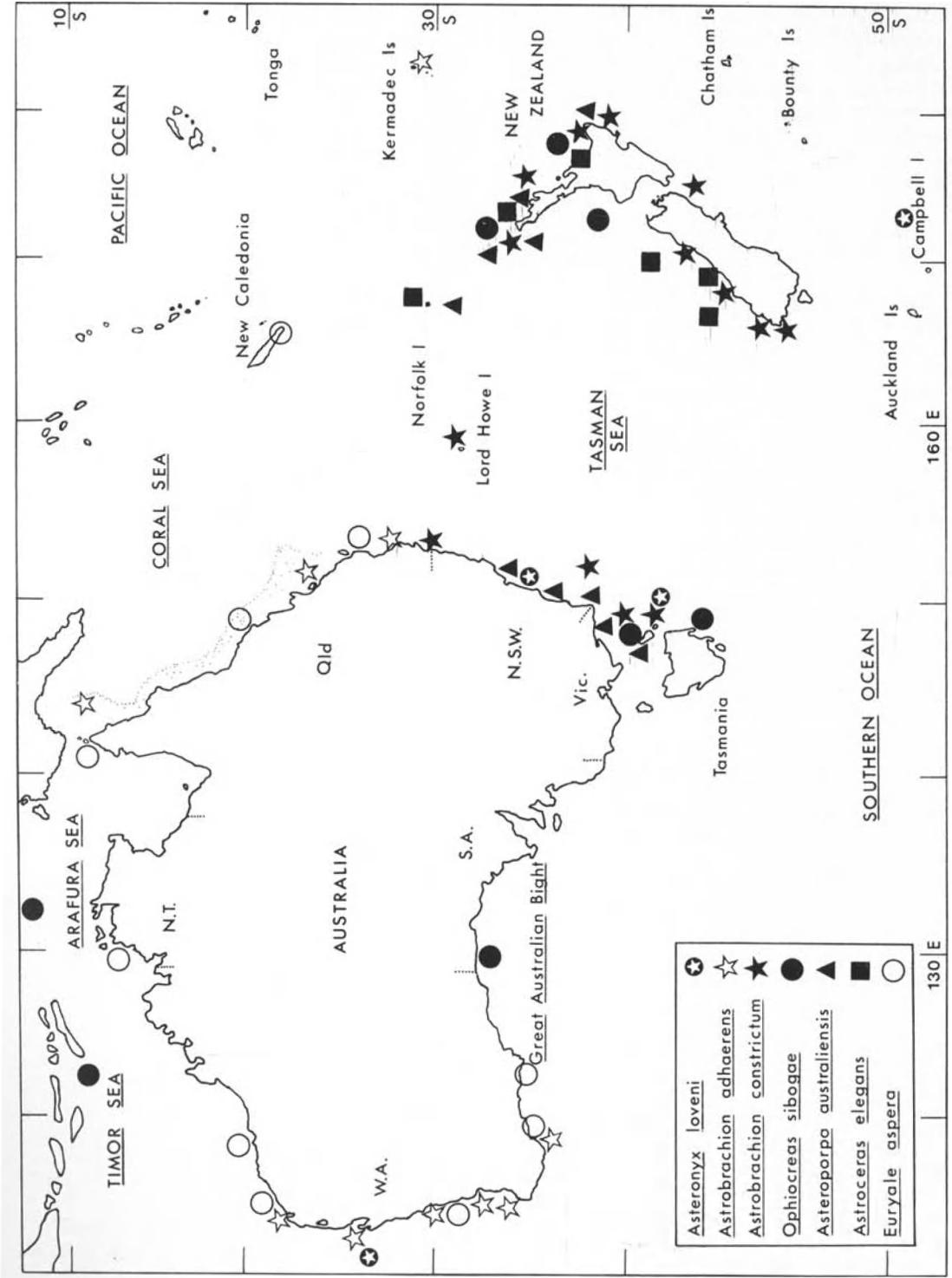


Fig. 1. Australia, New Zealand, and adjacent areas, showing the distribution of certain euryalinids; symbols represent collection sites.

and two at the latter. Similarly, a further six species can now be added to the two recorded from the Kermadec Islands by Lyman (1879):

Although Fiji, the New Hebrides, and New Caledonia fall within the geographical limits of this study, knowledge of the echinoderm faunas of those islands is poor, and I have been able to locate only one record of a euryalinid (*Euryale aspera*) from New Caledonia (Catala 1964).

Table 1 lists the currently known fauna of the Australasian region and summarises the distribution and bathymetric range of the 41 species involved.

CLASSIFICATION

Spencer & Wright's (1966) classification of suborder Euryalinida is followed in this paper. The four extant families in the suborder are all represented in Australasian waters; their characteristics may be summarised as follows.

Family ASTERONYCHIDAE Müller & Troschel, 1842.

Disc and arms covered with naked skin; arms not branched; gonads restricted to disc; hooklet-like distal arm spines with no perforated lamina; vertebrae with ventral groove open.

Family ASTEROSCHEMATIDAE Verrill, 1889. Similar to Asteronychidae, but may have tuberculated skin; gonads extending at least halfway along arms. (The genera *Astroscolex* and *Ophiuopsis*, allotted to this family by Spencer & Wright, are here deleted as being synonyms of *Astrobrachion* and *Asteronyx* respectively.)

Family GORGONOCEPHALIDAE Ljungman, 1867. Skin usually tuberculated; arms simple or branching; gonads restricted to disc; rows of hooks on dorsal surface of arms, hooks lacking lamina with serially arranged holes; vertebrae with open groove.

(The genera *Astroconus* and *Astrostephanus*, listed in this family by Spencer & Wright, are here deleted as being synonyms of *Conocladus* and *Astrothrombus* respectively. A new genus, *Astro-sierra*, is added.)

Family EURYALIDAE Gray, 1840. Skin naked or tuberculated; arms simple or branching; gonads extending into arms; no hooks on dorsal surface of arms, but distal arm spines may be hooklets with serially perforated lamina; vertebrae with ventral groove closed.

For a discussion of the history of the classification of this group of ophiuroids the papers of Döderlein (1911, 1927, 1930), Matsumoto (1915, 1917), and Mortensen (1933a) should be consulted. At the family level the present classification is acceptable; at lower levels, however, it has been necessary to make some changes, as outlined above. This study has also shown that stricter standards of generic diagnosis are neces-

sary for *Astrocladus* and *Astroboa*, for which a world revision will be necessary. Also, early in the study it became clear that the genera *Astroschema* and *Astroceras* require revisional treatment; I have begun work on the former in recent months.

SYSTEMATIC CHARACTERS

Many of the morphological characters successfully employed in systematic studies of the more advanced ophiuroid groups are of little use when dealing with euryalinids. For example, the plates of the oral frame are poorly developed and extremely variable, the teeth and oral papillae are usually undifferentiated in shape and variable in number, and the exposure, disposition, and proportions of the radial shields are not constant. In this study, use has therefore been made of a combination of characters to which rather less attention has been paid in those ophiuroid groups with a more obviously diagnostic hard morphology.

The general nature of the disc surface is usually characteristic of the genus, but its detail may be specifically diagnostic. The disc may be naked or covered to varying degrees with calcite grains (<0.1 mm diameter) and/or granules (0.1–0.5 mm) or tubercles (>0.5 mm). Grains and granules are usually smooth, but tubercles may be fluted, spiny, or smooth. Tubercles may be domed, conical, or spiniform and interspersed with flat plates or encircled by small platelets. In some genera the tubercles may be restricted to the radial shields or to a calcareous marginal ring.

The ventral inter-radial areas may differ greatly from the dorsal surface in their cover, and are generically diagnostic in some groups.

The dorsal surface of the arms may have a cover similar to that of the disc, or it may be very different. The patterns of granules, tubercles, or plates on each arm segment may be used as criteria for separation at the specific level. The occurrence, size, and shape of girdle bands is a useful generic character, as are the shape of the girdle hooklets and the number of teeth they bear.

The length of the arms is not usually measurable owing to the ubiquitous habit of coiling, but in some species the disc diameter/arm length proportions are important. Also, the basal width and height of the arms may be diagnostic. The number of branches on the main stem of the arms can have generic significance, but counting is difficult; the number of arm segments before the first branch is, however, a useful character and easily assessable. The system of arm branching has been described by Lyman (1877), Döderlein (1912), and Wolfe (1978).

The position of the first arm spines in relation to certain arm segments is unreliable as a taxonomic character, but the position of their first occurrence within the system of bifurcation is of generic rele-

vance at least in adult specimens. The number, size, and shape of arm spines are usually fairly constant for a genus, and the presence or absence of a serially perforated lamina on the hook-like distal spines is an important familial character.

Tentacle scales are absent in the suborder, but the tentacle pores may be surrounded by a tube of calcareous platelets; the number of such tubes is specifically important. The shape and pattern of granules and plates on the ventral arm surface and oral frame may be generically significant, as are the number and position of madreporites in the ventral interbrachia.

TEXT CONVENTIONS

The following abbreviations are used:

- Institutions*
- AM - Australian Museum, Sydney
 - BMNH - British Museum (Natural History), London
 - NMNZ - National Museum of New Zealand, Wellington
 - NMV - National Museum of Victoria, Melbourne
 - NZOI - New Zealand Oceanographic Institute, Wellington
 - MCZ - Museum of Comparative Zoology, Harvard
 - OM - Otago Museum, Dunedin
 - QM - Queensland Museum, Brisbane
 - QVM - Queen Victoria Museum, Launceston
 - RSAM - South African Museum, Cape Town
 - SAM - South Australian Museum, Adelaide
 - TM - Tasmanian Museum, Hobart
 - USNM - National Museum of Natural History, Washington, D.C.
 - WAM - Western Australian Museum, Perth
 - ZMA - Zoologisch Museum, Amsterdam
 - ZMC - Zoologiske Museum, Copenhagen
 - ZMB - Zoologische Museum der Humboldt-Universität zu Berlin

Geographic Names

- N.S.W. - New South Wales, Australia
- N.T. - Northern Territory, Australia
- N.Z. - New Zealand
- Qld - Queensland, Australia
- S.A. - South Australia
- Tas. - Tasmania, Australia
- Vic. - Victoria, Australia
- W.A. - Western Australia

Expeditions

- AAE - Australian Antarctic Expedition
- BANZARE - British, Australian, & New Zealand Antarctic Research Expedition

Morphology

d.d. - disc diameter.

CHECKLIST OF AUSTRALASIAN EURYALINIDA

	Page
Fam. ASTERONYCHIDAE	
<i>Asteronyx loveni</i> Müller & Troschel	16
<i>Astrodia tenuispina</i> (Verrill)	18
Fam. ASTEROSCHEMATIDAE	
<i>Asteroschema horridum</i> Lyman	20
<i>Asteroschema migrator</i> Koehler	22
<i>Asteroschema tubiferum</i> Matsumoto	22

<i>Asteroschema salix</i> Lyman	22
<i>Asteroschema igloo</i> n.sp.	24
<i>Astrobrachion constrictum</i> (Farquhar)	24
<i>Astrobrachion adhaerens</i> (Studer)	27
<i>Ophiocreas oedipus</i> Lyman	28
<i>Ophiocreas sibogae</i> Koehler	28

Fam. GORGONOCEPHALIDAE

<i>Astrothorax waitei</i> (Benham)	30
<i>Astrothrombus rugosus</i> H. L. Clark	32
<i>Astrothrombus vecors</i> (Koehler) n.comb.	34
<i>Asteroporpa australiensis</i> H. L. Clark	35
<i>Asteroporpa (Astromoana) reticulata</i> n.subgen. & sp.	38
<i>Asteroporpa (Astromoana) indicus</i> n.subgen. & sp.	38
<i>Astroclon suenisoni</i> Mortensen	40
<i>Astrosierra amblyconus</i> (H. L. Clark) n.gen.	42
<i>Astrosierra microconus</i> (H. L. Clark) n.comb.	42
<i>Astrosierra densus</i> n.sp.	44
<i>Conocladus australis</i> (Verrill) n.comb.	46
<i>Gorgonocephalus chilensis</i> (Philippi)	51
<i>Gorgonocephalus dolichodactylus</i> Döderlein	52
<i>Gorgonocephalus pustulatum</i> H. L. Clark	54
<i>Gorgonocephalus sundanus</i> Döderlein	56
<i>Astrodendrum elingamita</i> Baker	56
<i>Astroboa ernae</i> Döderlein	58
<i>Astroboa nuda</i> (Lyman)	60
<i>Astroboa nigrofurcata</i> Döderlein	60
<i>Astroboa granulatus</i> (H. L. Clark) n.comb.	62
<i>Astrocladus exiguus</i> (Lamarck)	63
<i>Astrocladus ludwigi</i> (Döderlein)	63
<i>Astrocladus tonganus</i> Döderlein	64
<i>Astrochalcis tuberculatus</i> Koehler	64
<i>Astroglymma sculptum</i> (Döderlein)	66

Fam. EURYALIDAE

<i>Astroceras elegans</i> (Bell)	66
<i>Astroceras kermadecensis</i> n.sp.	68
<i>Astroceras pleiades</i> n.sp.	68
<i>Asteromorpha tenax</i> n.sp.	70
<i>Euryale aspera</i> Lamarck	72

KEY TO AUSTRALASIAN GENERA OF ASTERONYCHIDAE

- More than 3 arm spines, most of which are modified into simple or compound hooklets *Asteronyx*
- Two or 3 (rarely 4) slender arm spines, never hooked *Astrodia*

KEY TO AUSTRALASIAN GENERA OF ASTEROSCHEMATIDAE

- 1 Lateral arm plates separated by ventral plate; coloration conspicuous *Astrobrachion*
- Lateral arm plates join in ventral midline; coloration inconspicuous 2
- 2 Disc and arms covered with smooth, naked skin, sometimes beset with scattered, minute grains *Ophiocreas*
- Disc and arms always covered with conspicuous granulation *Asteroschema*

KEY TO AUSTRALASIAN GENERA OF GORGONOCEPHALIDAE

- 1 Arms forked 2
- Arms simple 10

- 2 One madreporite (exceptionally 2 or 3 of different sizes) 3
 —Five madreporites of equal size *Astroglymma*
- 3 Arm spines present before 1st arm fork in adults 4
 —Arm spines absent before 1st arm fork in adults 8
- 4 Disc and arms uniformly covered with large, conical tubercles and small plates 5
 —Disc and arms covered with small stumps or tubercles; disc often naked inter-radially 7
- 5 Arm segments number 40–48 before 1st arm fork *Astroclon*
 —Arm segments number <30 before 1st arm fork 6
- 6 Arm segments number 13–26 (usually 15 or 16) before 1st arm fork; large tubercles present in ventral inter-radial *Astrosierra*
 —Arm segments number 6–16 (usually 8) before 1st arm fork; large tubercles absent or rare in ventral inter-radial *Conocladus*
- 7 Disc edge with girdle of plates *Gorgonocephalus*
 —Disc edge without girdle of plates *Astroedndrum*
- 8 Arm spines present after 1st or 2nd arm forks in adults (rudimentary spines occasionally occur just before 1st arm fork); disc granules usually thorny *Astrocladus*
 —Arm spines present after 4th to 14th arm forks in adults (rudimentary spines occasionally occur before 4th fork); disc granules usually smooth 9
- 9 Free arm near disc nearly as wide as high, with a narrow underside; disc granules more or less uniform in size *Astroboa*
 —Free arm near disc strikingly wide, with flat, wide underside; disc granules markedly dimorphic *Astrochalcis*
- 10 Girdle hooklets on both disc and arms *Asteroporpa*
 —Girdle hooklets on arms only 11
- 11 Girdle hooklets with 1 secondary tooth; up to 10 arm spines *Astrothorax*
 —Girdle hooklets with 2–6 secondary teeth; up to 5 arm spines *Astrothrombus*

KEY TO AUSTRALASIAN GENERA OF
 EURYALIDAE

- 1 Arms simple 2
 —Arms forked *Euryale*
- 2 Dorsal surface of arms bearing prominent tubercles; no distinct lamina on distal arm-spine hooklets *Asteroceras*
 —Dorsal and lateral arm surfaces bearing dense coat of granules; distinct lamina on distal arm-spine hooklets *Asteromorpha*

SYSTEMATIC ACCOUNT

Family ASTERONYCHIDAE Müller & Troschel, 1842

Genus *Asteronyx* Müller & Troschel, 1842

Asteronyx Müller & Troschel, 1842: 85.

Astronyx. Lyman, 1882: 285.

Ophiuropsis Studer, 1884: 55. **New synonymy.**

TYPE-SPECIES: *Asteronyx loveni* Müller & Troschel, 1842.

Asteronyx loveni Müller & Troschel (Fig. 2, 3, 29)

Asteronyx loveni Müller & Troschel, 1842: 119, pl. 10 fig. 3–5. —Döderlein, 1927: 59, 97, pl. 7 fig. 7, 7a, 8 [complete synonymy].

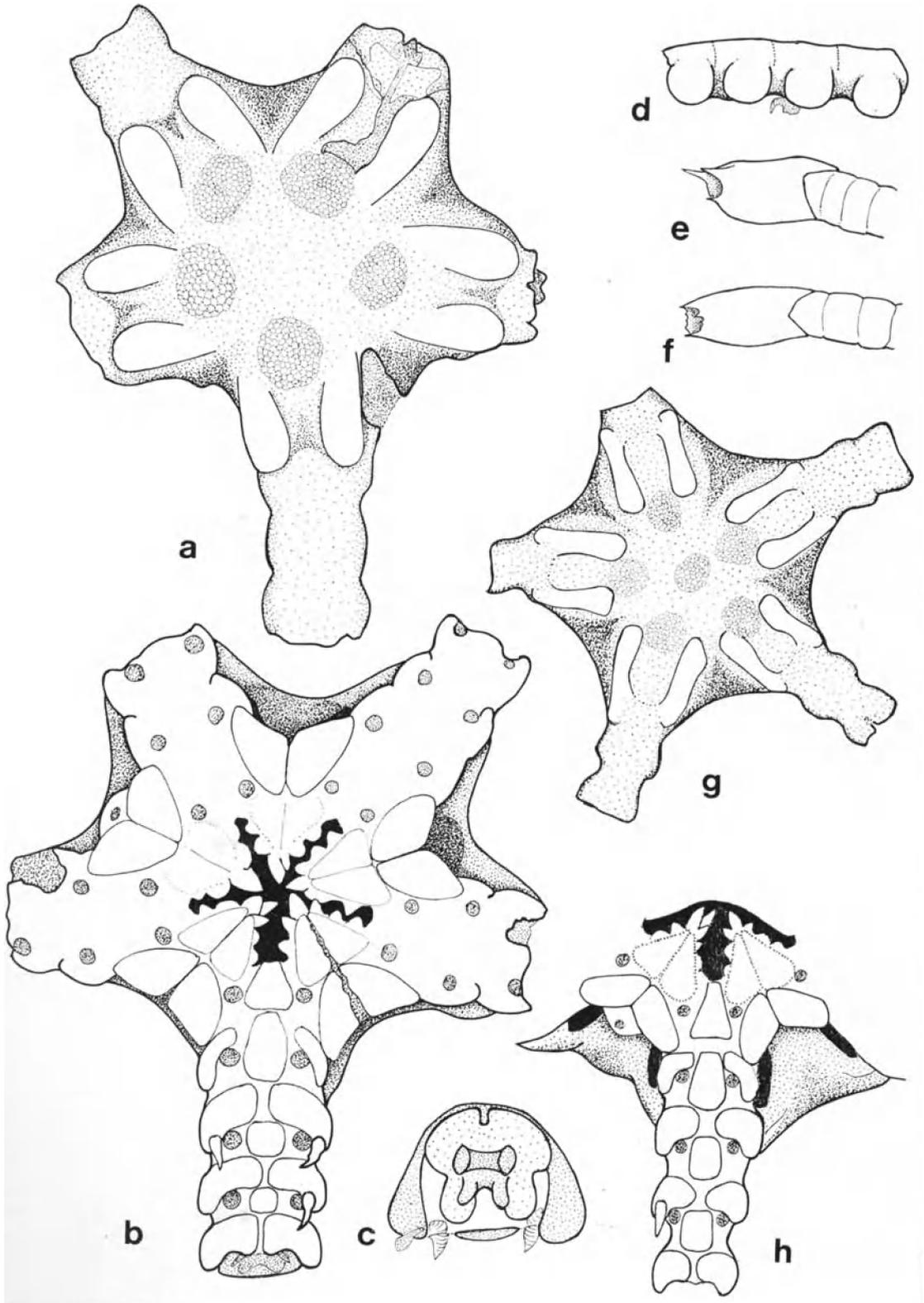
Ophiuropsis lymani Studer, 1884: 85, pl. 5 fig. 12a–d. —Döderlein, 1930: 389, pl. 2 fig. 11, 11a. —Mortensen, 1933a: 70. **New synonymy.**

MATERIAL EXAMINED. 4 specs, 50°31'S, 174°17'E, Campbell Plateau, N.Z., NZOI Sta. 149, 1026 m; 4 specs, 35°28'S, 150°48'E, E of Brush I., N.S.W., 448–566 m (AM); 1 spec., 35°31–37'S, 150°45–42'E, off southern N.S.W., 450 m (AM); 1 spec., 25°50'8"S, 112°36'8"E, off Dirk Hartog I., W.A., 109 m (**holotype** of *Ophiuropsis lymani* Studer; ZMB 2774).
 COMPARATIVE MATERIAL (14 specs): Okhotsk Sea (USNM 26173, 26174); Mizimoko Shima, Japan (USNM 25806); southern California (USNM 39745); Mazatlan, Mexico (USNM 25813); Gulf of Panama (USNM 26798); SE of George's Bank, NW Atlantic (USNM 12101); Monterey, California (USNM E 8743).

DESCRIPTION. Disc diameter 4–17 mm. Disc tumid; arms 7–10× d.d. in adults, 3× d.d. in juveniles. Radial shields narrow, usually contiguous proximally in adults. Central and inter-radial areas of disc usually covered with soft, naked skin, but occasionally with scattered small, delicate scales which extend on to ventral inter-radial. Large primary scales with a distinctly honeycombed surface may occur at disc centre and between proximal ends of radial shield pairs in juveniles.

Dorsal arm plates absent; lateral arm plates large, with a flap-like lateroventral protrusion bearing up to 9 hooked arm spines. Uppermost arm spine with 1 long terminal hook, lowermost with 3 or 4 hooks in vertical series (Fig. 29). Juveniles with initially 1, then 2 arm spines with a single, terminal hook. Rarely, lowermost arm spine becomes extra long and cylindrical in middle part of arm. Lateral arm plates contiguous in ventral midline. Ventral arm plates small, situated between each set of lateral plates.

Fig. 2. *Asteronyx loveni*. a–e, holotype of *Ophiuropsis lymani* Studer (ZMB 2774): (a, b) dorsal and ventral views of disc; (c) end view of broken arm base; (d, e) lateral view of arm base and arm tip (not to scale). f–h, 3.5 mm specimen (USNM 26173): (f) arm tip; (g, h) dorsal and ventral views of disc.



Teeth and 3 or 4 oral papillae short, spiniform. Oral shields minute or absent, apart from madreporic plate. Adorals large, contiguous, protuberant. Genital slits small, often situated in a depression in soft interbrachium.

REMARKS. The Campbell Plateau specimens are the first of this species to be recorded from the New Zealand region. The material compares well with that from other parts of the Pacific, including Australia, where the species was first recorded by H. L. Clark (1918).

A. loveni is the only representative of the genus so far known from the South Pacific and eastern Indian Oceans, although I have recently recorded *A. luzonicus* Döderlein from from off Mozambique*, so that species may be expected in the Australian region at least. *A. longifissus* Döderlein and *A. niger* D'yanakov are the only other recognised species, and like the first are known from the North Pacific. *Asteronyx banzareii* Madsen is here referred to *Astrobrachion adhaerens* (Studer) (see p. 27).

Studer's monotypic genus *Ophiuropsis* is a synonym of *Asteronyx*; the single specimen of *O. lymani* taken off Western Australia in 1874 by S.M.S. *Gazelle* is in fact a young *A. loveni*. *Ophiuropsis* has been the subject of considerable conjecture by earlier workers, who concentrated their efforts on trying to place this vaguely defined genus in a suitable family, rather than attempting to establish the relationship of the species *lymani*.

Matsumoto (1917), H. L. Clark (1923), and Döderlein (1927, 1930) referred *Ophiuropsis* to Döderlein's Trichasteridae (Euryalidae Gray). Matsumoto in fact followed Studer, who considered the genus to be close to *Astroceras* Lyman, but Döderlein could see no close relationship with any known trichasterid, although he thought that *Ophiuropsis* was satisfactorily placed in that family. Mortensen (1933a), noting the open ventral furrow in the vertebrae, decided that *Ophiuropsis* must be a member of the Astroschematidae Verrill. Mortensen believed *Ophiuropsis* to be closely related to *Astrobrachion*, but based this belief not on an examination of the holotype of *O. lymani*, but on a specimen from south-eastern Australia referred to *Ophiuropsis* by Koehler (1930) which Mortensen later (1933a) described as *O. lymani* var. *simplex*. This specimen is in fact an *Astrobrachion*, and is dealt with in the synonymy of *A. constrictum* Farquhar.

The holotype of *Ophiuropsis lymani* is now in rather poor condition (it consists of a 4-mm-diameter disc and 5 arm fragments totalling about 36 segments), but it compares very well with juvenile

A. loveni between 3.5 mm and 6.0 mm d.d. in the USNM series. The specimens have the following features in common.

1. The radial shields are short, and there are honey-combed primary scales on the disc between the ends of the radial shields.
2. There are no dorsal arm plates, but the laterals protrude lateroventrally and meet in the ventral midline.
3. The first two or three tentacle pores are naked; the following two to four segments have one arm spine, and thereafter there are two spines with simple terminal hooks.
4. The oral shields are absent or extremely minute, but the madreporic plate is present and of reasonable size.
5. The adoral shields are large and protuberant, and there are three oral papillae on each side of the jaws.
6. There is no evidence that the arms contain gonads.

The holotype of *Ophiuropsis lymani* and a small specimen of *A. loveni* from the Okhotsk Sea are illustrated (Fig. 2) to show these similarities more graphically. Mortensen (1912) made a detailed study of the young growth stages of *A. loveni*, and his illustrations may also be compared with those of *O. lymani*.

Ophiuropsis lymani Studer is, therefore, here regarded as a junior synonym of *Asteronyx loveni*. The basic mistake made by earlier workers in not recognising *Ophiuropsis* as an asteronychid was in regarding the only known specimen as fully adult. This misconception was based on the genital slits being open at a disc diameter of 4–5 mm. I can find no reason why open genital slits should prove that the animal is reproductively mature, let alone morphologically adult. Even if the specimen was sexually mature at such a small size, it does not necessarily follow that the hard morphology of the disc and arms had reached the final adult condition.

DISTRIBUTION. Known from many North Pacific and Atlantic localities, and from the south-west Pacific and eastern Indian Ocean.

BATHYMETRIC RANGE 109–2963 m.

Genus *Astrodia* Verrill, 1899

TYPE-SPECIES: *Asteronyx tenuispina* Verrill, 1884.

Astrodia tenuispina (Verrill) (Fig. 3, 29)

Asteronyx tenuispina Verrill, 1884: 219.

Astrodia tenuispina Verrill, 1899: 371. –Döderlein, 1911: 116; 1927: 97; 1930: 388. –Madsen, 1951: 112.

Astrodia bispinosa Koehler, 1922: 11, pl. LXXVI fig. 12–15. –Döderlein, 1927: 59; 1930: 387, fig.

*Report on Euryalinida of the International Indian Ocean Expedition (in prep.)

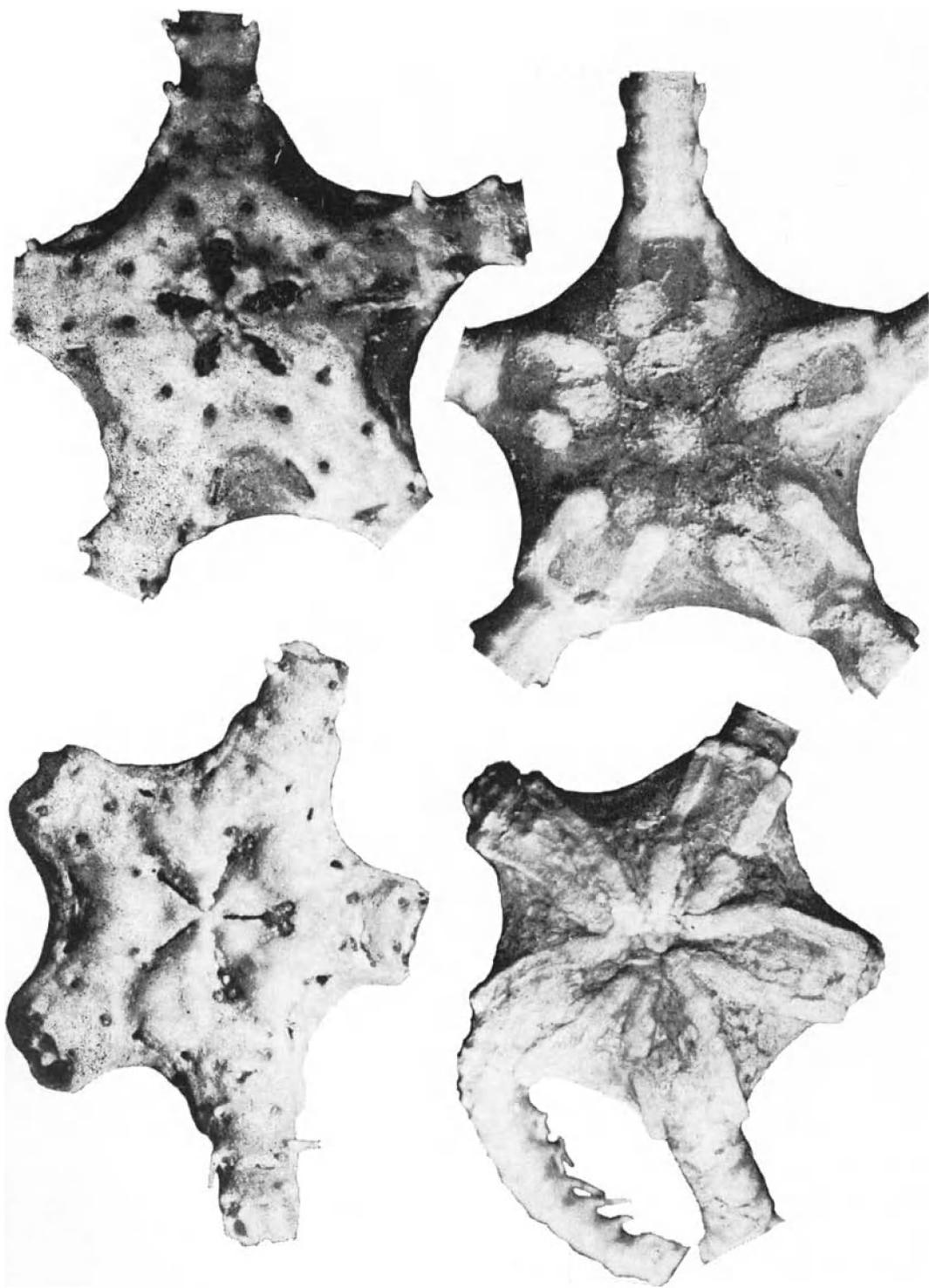


Fig. 3. Upper, *Asteronyx loveni*, juvenile (USNM 26173), 3.8 mm d.d. Lower, *Astrodia tenuispina*, syn-type of *A. bispinosa* Koe. (AM J3855), 7.5 mm d.d.

19, pl. III fig. 1-1c. —Madsen, 1967: 141. **New synonymy.**

MATERIAL EXAMINED. 3 specs, 35°55'S, 134°18'E, 200 km W of Kangaroo I., S.A., AAE Sta. 34, 3240 m (syntypes of *Astrodia bispinosa* Koehler; AM J3855). **COMPARATIVE MATERIAL** (7 specs): off Nantucket Shoals, U.S.A., U.S.F.A. *Albatross* Sta. 2042, 2843 m (syntypes of *Asteronyx tenuispina* Verrill; USNM 9033).

DESCRIPTION. Disc smooth, hardly at all excavate inter-radially, covered with thin, closely imbricating, punctate scales. Radial shields narrow, tapering slightly, bow-shaped, convergent proximally. Arms very long and thin, almost circular in cross-section, covered with delicate scales. Lateral arm plates protuberant lateroventrally, bearing 2 or 3 (occasionally 4) thin spines; innermost spine longest—just longer than an arm width—with a slightly swollen, thorny tip, remainder progressively shorter and tapering evenly to a slightly thorny tip. First 2 arm segments without spines. Dorsal and ventral arm plates small, indistinct.

Teeth triangular, heavy; a few low granules on jaw edges. Oral and adoral shields well developed. Genital slits small, well separated.

REMARKS. According to Koehler (1922) the main diagnostic character of *A. bispinosa* is the presence of two arm spines on each arm segment. A re-examination of the syntypes of both nominal species has shown that the arm spines number two or three in the Australian form and two, three, or four in the Atlantic form. Similar variation was noted also by Döderlein (1930), who remarked that his Maldivian specimen could be either species. Although the southern *Astrodia* may well have a lower average spine count, it would hardly warrant a specific distinction, particularly since *A. tenuispina* is a widely distributed bathyal species (Madsen 1951, 1967). The small differences in the shape and size of the radial shields mentioned by Koehler are certainly not diagnostic, and the type specimens are otherwise identical. *Astrodia bispinosa* is therefore here regarded as a junior synonym of *A. tenuispina*.

The station data for the type specimens of *A. bispinosa* given by Koehler (1922, pp. 22 and 86) are incorrect. The material was taken by the *Aurora* at AAE Station 34 (off South Australia), and not at Station 13 (Auckland Islands).

DISTRIBUTION: Atlantic, Pacific, and Indian Oceans.

BATHYMETRIC RANGE 510–3720 m

Family ASTEROSCHEMATIDAE Verrill, 1899

Genus *Asteroschema* Lütken, 1856

TYPE-SPECIES: *Asterias oligactes* Pallas, 1788.

Asteroschema horridum Lyman (Fig. 4, 5, 29)

Asteroschema horridum Lyman, 1879: 66, pl. XVII fig. 458–61; 1882: 275, pl. 30 fig. 1–4.

MATERIAL EXAMINED. 2 specs, 28°30.7'S, 177°49.3'W, NE of Raoul I., Kermadecs, NZOI Sta. K806, 1165–1185 m; 1 spec., 29°45'S, 178°11'W, W of Raoul I., Kermadecs, H.M.S. *Challenger* Sta. 170a, 1152 m (**holotype**; BMNH 82.12.23.25).

DESCRIPTION. Disc very small, flat, deeply excavate inter-radially, covered with small, tumid polygonal plates, most of which bear a tall, conical tubercle with a blunt, finely thorny tip; tubercles sparse near disc centre. Radial shields widely separated distally, convergent proximally, covered with tubercles except for an occasional distal bare patch.

Arms narrow, 16× d.d., circular in cross-section, slightly swollen over the first 5–7 free segments, covered on all sides with tumid, trapezoid plates bearing tubercles. Regular but slight differences in height and spacing of tubercles give arm a faintly banded appearance.

One, occasionally 2 arm spines present on arm segments 3–6, thereafter 2 per segment, the innermost longer than an arm width (3.5 mm) and twice as long as the outermost; spines cylindrical, the longer slightly swollen and thorny at the tip, the smaller less thorny, tapered.

Teeth blunt, triangular; sides of jaws paved with low, swollen granules. Oral tentacle pore surrounded by a tube of small plates. Entire oral surface outside jaws covered with polygonal plates, each bearing a conical tubercle which enlarges towards disc margin. Oral and adoral shields not visible. Genital slits straight, narrow, not within common depression.

Colour (in ethanol) pale reddish brown and pink.

REMARKS. The specimens agree almost entirely with Lyman's holotype, which was taken by H.M.S. *Challenger* at the Kermadec Islands. No other specimens have been reported.

In the number of arm spines on the first few segments the present material differs from the holotype, but this character shows much variation in other asteroschematids, and is thus probably of little importance in *A. horridum*. The two new specimens have the same dimensions as the holotype.

A. horridum, one of the few distinctive species in this genus, is characterised by its small, flat disc and entire cover of polygonal plates bearing tall, conical granules. Its closest relatives are *A. ferox* Koehler from the Arafura Sea and *A. edmondsi* A. H. Clark from Hawaii.

DISTRIBUTION. Vicinity of Kermadec Islands.

BATHYMETRIC RANGE 1152–1185 m.

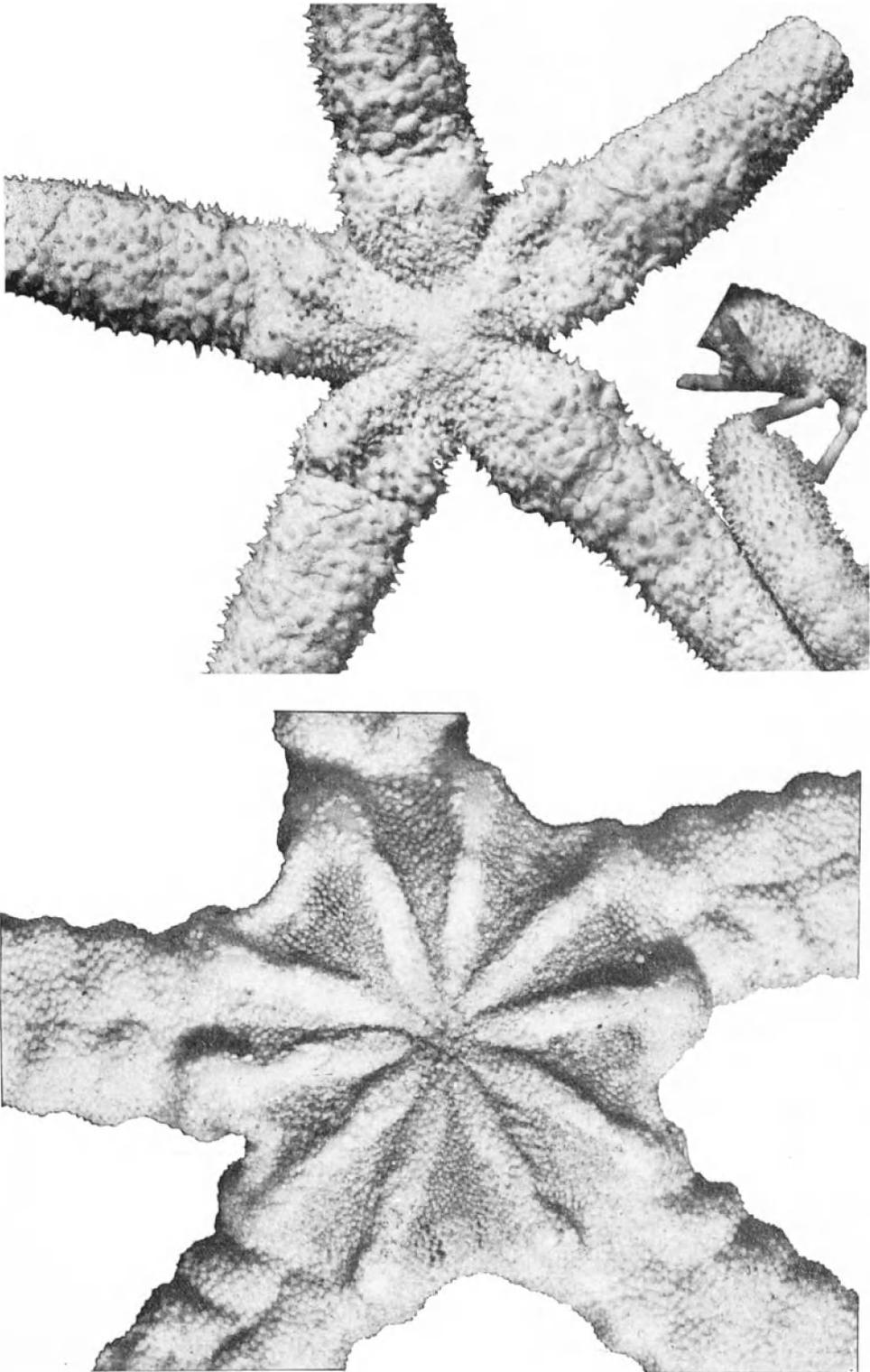


Fig. 4. Upper, *Asteroschema horridum*, Raoul I., 10.0 mm d.d.. Lower, *A. tubiferum*, Norfolk I., 14.0 mm d.d.

Asteroschema migrator Koehler (Fig. 5, 29)

Asteroschema migrator Koehler, 1904: 164, pl. XXIV fig. 8, pl. XXX fig. 5-7, pl. XXXV fig. 1.

Asteroschema migrator. Döderlein, 1911: 111.

MATERIAL EXAMINED. 1 spec., 29°12.6'S, 177°50.3'W, near Raoul I., Kermadecs, NZOI Sta. K800, 670-778 m.

DESCRIPTION. Disc small (11 mm d.d.), moderately excavate inter-radially, covered with a thin skin on which are scattered small, domed tubercles with finely thorny tips; tubercles dense on radial shields and near inter-radial margins, sparse elsewhere. Radial shields narrow, widest and divergent distally, convergent proximally.

Arms 25 × d.d., narrow, higher than wide, slightly swollen at base, closely paved dorsally and laterally with small, tumid granules which become smaller and spaced towards lateroventral margin, ventrally covered with clear skin on which are occasional small, scale-like pustules. Ventral arm plates small, rectangular, obscure or missing near disc. One arm spine present from 3rd segment; a second, outer spine appears at segment 6-8. Inner spine the longer (<2.5 mm), sinuous, with a thorny tip and inner top edge; outer spine half as long, tapered, with finely thorny tip.

Teeth triangular; lowermost tooth in several small pieces. Sides of jaws with low, round granules; remainder of oral surface outside jaws covered with transparent or finely pigmented skin bearing a few small pustules. No oral shields; adorals moderately large. Genital slits large, opening into a common depression.

Colour (in ethanol) pink and dark red on disc, dark pink on arms.

REMARKS. This specimen of *A. migrator* is only the second to be recorded since Koehler's holotype was taken by H.M. Siboga in the Strait of Macassar, Indonesia, from a depth of 1301 m. The Kermadec specimen agrees well with Koehler's description, and confirms that the species is distinct from, but closely allied to, the Atlantic form *A. intectum* Lyman. Both species have reduced granulation and sinuous, unevenly thorny arm spines. Their main differences are that *A. migrator* has a more sparsely tuberculated disc, both dorsally and ventrally, and arms that are completely covered with granules dorsally and laterally over most of their length, rather than just on the dorsal surface proximally. The large, common genital 'pouch' might also be diagnostic for *A. migrator*, but Koehler's figures are definite interpretation of that character in the holotype.

Lyman (1878) refers to the genital openings of *A.* rather too simple and diagrammatic to permit a

intectum as short and wide, yet his figure (pl. III fig. 59) shows them as narrow slits.

DISTRIBUTION. Indonesia, the Kermadec Islands.

Asteroschema tubiferum Matsumoto (Fig. 4, 29)

Asteroschema tubiferum Matsumoto, 1915: 52; 1917: 44, fig. 10. -A. H. Clark, 1949: 7.

MATERIAL EXAMINED. 1 spec., 168°13.2'E, 29°24.8'S, S of Norfolk I., NZOI Sta. I92, 570-578 m.

DESCRIPTION. Disc diameter 14.0 mm; arms 300 mm long. Disc excavate inter-radially, closely and evenly covered with small, round or polygonal granules (6 in 1 mm inter-radially). Radial shields narrow, constricted at one-third their length from arm bases, not meeting centrally, but convergent.

Arms narrow, wider basally than high (5.5 × 4.5 mm). First 7 segments slightly swollen, remainder of arm gently tapered. Entire arm surface covered with closely packed granules similar to those on disc (4-5 in 1 mm basally). Distally, granules become smaller and more widely spaced on ventral arm surface than elsewhere.

One arm spine present from 2nd segment, 2 present after 6 (occasionally fewer) segments. Spines cylindrical, initially tapering to a blunt, prickly tip, but after about 15 segments becoming distinctly club-shaped with small, sharp prickles evenly distributed around widened tip; innermost spine the longer (<3.2 mm) about twice as long as outermost spine. First 10-12 tentacle pores surrounded by a small sheath.

Oral frame entirely covered with closely packed granules; oral papillae reduced to low tubercles. Ten triangular teeth on each jaw, the lowermost often in several small pieces.

Genital slits large, vertical; 4 madreporites situated at base of narrow, densely granulated, vertical, ventral inter-radial surface.

Colour (in ethanol) pink; arm spines darker.

REMARKS. This specimen agrees well with Matsumoto's descriptions and figures. The distinctly club-shaped arm spines and the tubes surrounding the first 10 or so tentacle pores characterise this species, previously known only from the north Pacific.

DISTRIBUTION. Japan, Hawaii, Norfolk Island.

BATHYMETRIC RANGE 325-965 m.

Asteroschema salix Lyman (not figured)

Asteroschema salix Lyman, 1879: 66, pl. XVII fig. 466-9; 1882: 277, pl. 22 fig. 13-15.

MATERIAL EXAMINED. 1 spec., 37°22.5'S, 177°11.7'E, Te Arawa High, N of White I., N.Z., NZOI

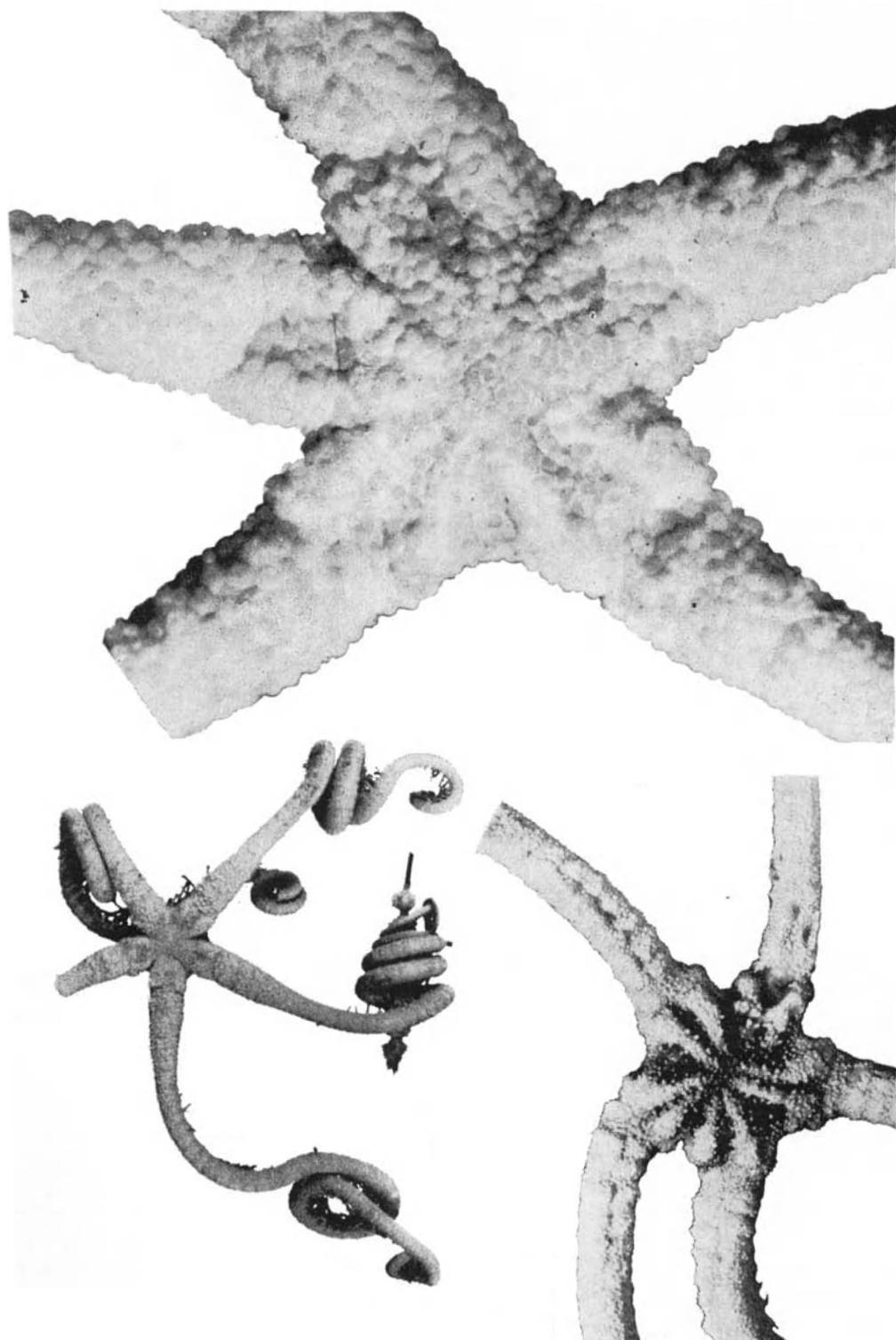


Fig. 5. Upper, *Asteroschema igloo*, holotype (NZOI H253), 5.7 mm d.d. Lower left, *A. horridum*, Raoul I., 10.0 mm d.d.; lower right, *A. migrator*, Raoul I., 11.0 mm d.d.

Sta. J676, 341–353 m; 1 spec, 29°45'S, 178°11'W, W of Raoul I., Kermadecs, H.M.S. *Challenger* Sta. 170a, 1152 m (holotype; BMNH 82.12.23.271).

DESCRIPTION. Disc small (5.5 mm d.d.), moderately excavate inter-radially, closely and evenly covered with very small, low, rounded granules with finely thorny surfaces. Radial shields parallel or slightly convergent proximally, mostly obscured by granulation.

Arms narrow (10× d.d.), higher than wide, completely clothed with granules similar to, but smaller than, those on disc. One arm spine present from 3rd segment; a second, outer spine appears at segments 11–13. Inner spine the longer—less than an arm width initially, with a finely thorny tip, but after about segment 20 becoming laterally compressed, with 4 or 5 curved teeth on its proximal edge; outer spine about half as long as inner, closely appressed to it. Granulation of ventral and lateral arm surfaces continues on to protuberant lateral arm plates and bases of arm spines.

Teeth triangular. Sides of jaws with domed granules; entire oral surface of jaws covered with minute, closely set granules. Oral shields absent; adorals large. Genital slits short, wide, in a common depression or pouch. Five small madreporites present.

Colour (in ethanol) pink.

REMARKS. This specimen is smaller than the hitherto unique holotype, but its proportions are the same and it matches Lyman's specimen well. The only major point of difference is the fewer arm segments with only one arm spine in the type specimen. The disc granulation is finer than Lyman states—12–14 granules in 1 mm, cf. 7–8 granules, but in this respect the type description matches neither the holotype nor Lyman's figure, both of which have 11–13 granules in 1 mm.

DISTRIBUTION. Kermadec Islands and Bay of Plenty, New Zealand.

BATHYMETRIC RANGE 341–1152 m.

Asteroschema igloo n.sp. (Fig. 5, 29)

TYPE DATA. **Holotype** (5.7 mm d.d.): W of Curtis I., Kermadecs, 30°34.2'S, 178°29.8'W, NZOI Sta. K856, 465–501 m, 30 Jul 1974 (NZOI H253). **Paratypes** (5.5 & 8.0 mm d.d.): NW of Norfolk I., 28°42.3'S, 167°56.7'E, NZOI Sta. P46, 475–450 m, 30 Jan 1977 (NZOI P510, NMNZ Ech. 2877).

DESCRIPTION OF HOLOTYPE. Ratio d.d to arm length 1:12. Disc slightly tumid, moderately excavate inter-

radially. Disc and arms entirely covered with rounded or polygonal domed granules (4–6 in 1 mm). Radial shields short, obscured, their general shape discernible only at distal ends. Arms slightly widened at base, elsewhere as wide as high, circular in cross-section; ventral side flat. One short arm spine present from 3rd segment; a second spine appears at segments 8–10. Innermost spine two-thirds an arm width long, cylindrical, with a very finely thorny blunt tip; outer spine half as long as inner, tapered. Distally, spines flattened into compound hooks with 3–6 long teeth (Fig. 29).

Teeth pointed, spearhead-shaped. Sides of jaws and entire oral area outside mouth covered with closely packed, round, domed granules. Genital slits short, wide, not enclosed in depression.

Colour (in ethanol) white.

ETYMOLOGY. The trivial name alludes to the covering of white, domed tubercles.

REMARKS. Although genus *Asteroschema* contains 21 nominal species, many of which are extraordinarily difficult to tell apart, the present species cannot be reconciled with any of them. Despite my desire not to complicate this genus any further, I have no option but to record these Kermadec and Norfolk Island specimens as a new species.

A. igloo is obviously related to that group of species within *Asteroschema* which possess an entire disc and an arm cover of polygonal plates bearing tubercles of various shapes, viz. *A. horridum*, *A. edmondsi* A. H. Clark, *A. ferox* Koehler, and *A. tumidum* Lyman. It differs from all these in that its tubercles are smooth and domed, not conical and terminally spiny.

DISTRIBUTION. Kermadec Islands, Norfolk Island.

BATHYMETRIC RANGE 450–501 m.

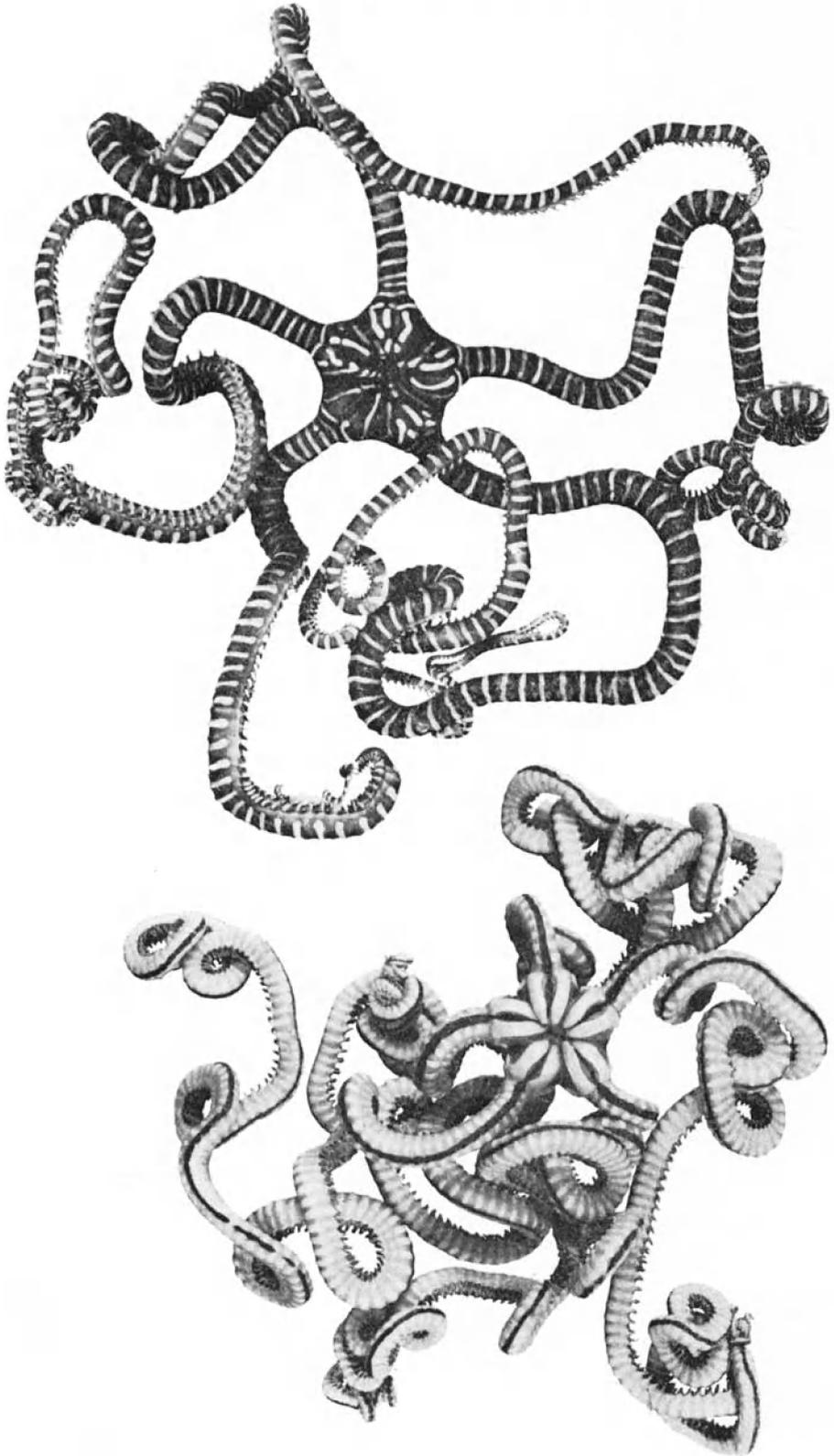
Genus *Astrobrachion* Döderlein, 1927

TYPE SPECIES: *Ophiocreas constrictus* Farquhar, 1900.

Astrobrachion constrictum (Farquhar) (Fig. 6, 30)

Ophiocreas constrictus Farquhar, 1900: 405.
Ophiocreas constrictum. H. L. Clark, 1915: 178.
 —Mortensen, 1924: 99, fig. 2.
Asteroschema (Ophiocreas) constrictum. Döderlein, 1911: 113.
Ophiocreas phanerum H. L. Clark, 1916: 79, pl. XXXIII fig. 1 & 2; 1946: 74. —Mortensen, 1924: 99. —Döderlein, 1927: 100.
Ophiomyxa brevissima H. L. Clark. Bell, 1917: 7.

Fig. 6. Upper, *Astrobrachion constrictum*, Bay of Islands, N.Z., 14.0 mm d.d. Lower, *A. adhaerens*, Denmark, W.A., 9.0 mm d.d.



Not *Ophiocreas constrictus*. Bell, 1917: 7 (= *Ophiocreas sibogae* Koehler).

Astrobrachion constrictus. Döderlein, 1927: 77, pl. IV fig. 4 & 5.

Astrobrachion constrictum. Mortensen, 1933a: 69, fig. 54. —Fell, 1952: 13; 1958: 22; 1962: 52.

Ophiuropsis lymani var. *simplex* Mortensen, 1933a: 71, pl. VI fig. 31 & 32. **New synonymy.**

Astroceras elegans (Bell). Fell, 1962: 51.

MATERIAL EXAMINED. 5 specs, 20 miles off Cape Barren I., Tasmania, 126 m (**holotype** (AM E 6297) and 4 **paratypes** (E 2267, J 2727) of *Ophiocreas phanerum*); 1 spec., eastern slope, Bass Strait, 126–180 m (**paratype** of *O. phanerum*; AM E 4726); 2 specs, 8 miles E of Sandon Bluffs, N.S.W., 63–72 m (**paratypes** of *O. phanerum*; AM J 2358); 1 spec., E of Flinders I., Bass Strait, 144–540 m (**paratype** of *O. phanerum*; AM E 4692); 1 spec., 30 miles S of Gabo I., Vic., 161 m (AM); 1 spec., S of Cape Everard, Vic. (AM); 1 spec., lower N.S.W. coast (AM J5981); 1 spec., Solitary I., off Coffs Hbr, N.S.W., 18 m (AM J8187); 1 spec., 36°40.9–40.1'S, 156°07.7'E, off Eden, N.S.W., 142–151 m (colour transparency in AM); 6 specs, 31°30.2'S, 158°57.9'E, Lord Howe I. Rise, NZOI Sta. P109, 69 m; 1 spec., 38°12'S, 149°40'E, off Cape Everard, Vic., 180–280 m (**holotype** of *Ophiuropsis lymani* var. *simplex*; ZMC); 1 spec., Dusky Sound, N.Z. (**holotype** of *Ophiocreas constrictus*; OM A75.29); 1 spec., Jackson's Bay, N.Z. (NMNZ; cited by Farquhar (1900)); 1 spec., Preservation Inlet, N.Z. (NMNZ); 1 spec., Bligh Sd, N.Z., 55 m (NMNZ); 1 spec., 12 miles E of Gisborne, N.Z., 91 m (NMNZ); 3 specs, Putney Rocks, Bay of Plenty, N.Z., 22 m (NMNZ); 24 specs, off White I., N.Z., 110 m (NMNZ); 8 specs, off Mayor I., N.Z., 110 m (NMNZ); 3 specs, Little Barrier I., N.Z. (NMNZ); 4 specs, Poor Knights Is, N.Z., 73 m (NMNZ); 1 spec., Whale Rock, N.Z. 110 m (NMNZ); 2 specs, Cavalli Is, N.Z., 36 m (NMNZ); 1 spec., off Doubtless Bay, N.Z., 73 m (NMNZ); 2 specs, off North Cape, N.Z., 128 m (NMNZ).

DESCRIPTION. Disc diameter to 22 mm. Disc low, slightly tumid, depressed centrally, moderately excavate inter-radially (depending on preservation), entirely covered with soft, smooth skin. Radial shields narrow, parallel or slightly divergent distally, sometimes contiguous, the 5 pairs not meeting at disc centre.

Arms long (22 × d.d.), narrow, higher than wide, horseshoe-shaped in cross-section; ventral surface flat; entire surface covered with soft skin. Two (occasionally 3) short arm spines, one-quarter to one-third an arm width long, usually beginning at 3rd segment. Outer spine the smaller, finely thorny, tapering to blunt tip; inner spine excavate on inner edge, bearing 4 or 5 long teeth more or less in a vertical series. Distally, arm spines become flattened, glassy, compound hooks bearing 2–4 lateral teeth. Very small specimens have such hooks along all but tip of arms, where they are simple, with a single, long terminal tooth or a short, bifid one (Fig. 30).

Arm plates visible only when skin dry. Dorsal plates initially in 4 pieces—2 small, median plates

which do not meet in midline, and 2 larger, rib-like plates which extend over curve of arm. Distally these plates are split transversely, giving a double row of plates across each arm segment. Lateral arm plates in a 6-piece double series, either adjacent or alternating. Ventral arm plates bluntly triangular, widest distally, separating lateral plates.

Teeth spearhead-shaped. Sides of jaws usually smooth, occasionally with a few domed granules. Area outside mouth covered with smooth, naked skin; underlying plates visible only when dry. Adoral plates large, longer than wide, contiguous within; oral shields variable in size, usually half as big as an adoral plate.

Colour: 3 colour varieties—reddish-brown, creamy yellow, and black-and-white banded (there are no longitudinal markings in this species). Red variety uniformly pigmented over dorsal and lateral surfaces of disc and arms; yellow variety similarly covered, except that sometimes lower edge of arms and arm spines darker brown. The black-and-white variety occurs in two forms. The commoner is predominantly black, with narrow, radiating white lines or spots on disc and transverse white bands on distal ends of radial shields and arms. Arm bands regularly placed one per segment, half as wide as adjacent black bands. A less common banded form has a paler overall appearance owing to the dark colour being less dense and the pale arm bands being wider than the dark bands, which are split into 'cells', making the arms appear transversely reticulated. All colour varieties have a similar pale, almost white, ventral surface to the disc and arms.

REMARKS. The striking variations in colour and colour pattern of *A. constrictum* are difficult to reconcile with a single species, but the fact that all varieties can be found living together on one black coral tree, and that they are identical morphologically, indicates that one colour-variable species is involved. An analogous situation pertains to the second species, *A. adhaerens* (Studer). The colour patterns of the two species differ, however, in that *constrictum* never has the longitudinal stripes on the arms which are characteristic of *adhaerens*, and *adhaerens* never has the transverse banding typical of *constrictum*. When both lack a striped pattern, their basic ground colours are much the same.

Morphologically the two species are very much alike. The largest specimens of *constrictum* are, however, about twice the size of the largest *adhaerens*, and there is a small difference in the arrangement of arm plates. In this genus, there is on each arm segment a series of six to eight plates extending from near the dorsal midline, down the sides of the arms, on to the ventral surface. The lowermost plate bears the arm spines, and is sep-

arated from its opposite number by an intervening ventral arm plate.

In *constrictum* there are four adjacent or alternate plates on the sides of the arms, whereas in *adhaerens* there are three arranged in a Y-shape.

Ophiuroopsis lymani var. *simplex* Mortensen is a synonym of *A. constrictum*; the 4 mm d.d. specimen dredged off Cape Everard, Victoria, is a juvenile. Strangely, two large examples of *A. constrictum* present in the same sample (Dr F. J. Madsen, pers. comm.) were recorded by neither Koehler (1930) nor Mortensen (1933a).

DISTRIBUTION. South-eastern Australia, from Tasmania to northern N.S.W.; Lord Howe Island; New Zealand from Fiordland to North Cape (Fig. 1).

BATHYMETRIC RANGE 18–180 m.

Astrobrachion adhaerens (Studer) (Fig. 6, 7, 30)

Ophiocreas adhaerens Studer, 1884: 54, pl. V fig. 11a-c.

Astroschema (*Ophiocreas*) *adhaerens*. Döderlein, 1911: 113.

Ophiocreas melambaphes H. L. Clark, 1914: 155; 1915: 177, pl. 1 fig. 9; 1946: 176. **New synonymy.**

Ophiocreas rhabdotum H. L. Clark, 1914: 156; 1946: 176. **New synonymy.**

Astrobrachion adhaerens. Döderlein, 1927: 100. —H. L. Clark, 1938: 202; 1946: 174.

Astroschema (*Ophiocreas*) *melambaphes*. Döderlein, 1927: 99.

Astroschema (*Ophiocreas*) *rhabdotum*. Döderlein, 1927: 99.

Astrobrachion (*Astroscolex*) *adhaerens*. Mortensen, 1933a: 68, fig. 53 & 57b,c, pl. V fig. 3.

Asteronyx banzareii Madsen, 1967: 140, fig. 6. **New synonymy.**

MATERIAL EXAMINED. 5 specs, E of Albany, W.A., BANZARE Sta. 76, 62 m (**holotype** (SAM K1318) and 4 named specimens of *Asteronyx banzareii* Madsen – 2 SAM (K1320), 2 ZMC); 5 specs, Torbay Hd, Denmark, W.A., 23 m (2 WAM, 3 NMNZ); 8 specs, 33°00'S, 114°52'E, W of Bunbury, W.A., 113–122 m (WAM); 1 spec., 32°17.5'S, 115°15'E, W of Garden I., W.A., 110 m (WAM); 7 specs, Jurien Bay, W.A., 183 m (WAM); 4 specs, off Jurien Bay, W.A., 146–183 m (**holotype** (WAM 4926) & **paratype** (MCZ 3668) of *Ophiocreas rhabdotum* H. L. Clark; **holotype** (WAM 4925) & **paratype** (MCZ 3669) of *O. melambaphes* H. L. Clark); 6 specs, 30°38'S, 114°46'E, NW of Green I., W.A., 146 m (WAM); 2 specs, Bald I., W.A., 51–58 m (WAM); 7 specs, 23°53'S, 113°43'E, off Pt Cloates, W.A., 44 m (WAM); 3 specs, 7 miles N of Northwest Cape, W.A., 137 m (WAM); 11 specs, 15–21 miles SW of Mer I., Murray Is, Great Barrier Reef, Qld (NMNZ); 1 spec, Heron I., Qld, 6 m (AM); 1 spec., Wistari Reef, Heron I., Qld, 50 m (NMNZ); 4 specs, Julian Rocks, Byron Bay, N.S.W., 18 m (NMNZ); 2 specs, SW Bay, Raoul I., Kermadec Is. 10 m, NZOI Sta. K812.

DESCRIPTION. Disc diameter to 18 mm. Disc slightly tumid, weakly excavate inter-radially, entirely covered with soft, smooth skin. Radial shields narrow, convex, parallel or divergent distally, the 5 pairs not quite meeting at disc centre.

Arms long (10–20 × d.d.), narrow, only just higher than wide, horseshoe-shaped in cross-section, covered with soft, naked skin; ventral surface flat. Two (occasionally 3) arm spines throughout, usually beginning at 2nd arm segment but sometimes as distant as 8th segment. Arm spines short, one-third an arm width long. Inner spine excavate on inner edge, bearing 1 large tooth and several small, irregularly placed teeth; outer spine simple, slightly shorter than inner, finely thorny, tapering evenly to a blunt tip. In small specimens, and at extremities of arms of large ones, both spines are flattened, compound hooks with 1 or 2 terminal teeth and 2 lateral teeth.

Arm plates visible only when dry. Dorsal plates initially in 4 pieces – 2 small, median plates which do not meet in the midline, and 2 larger, rib-like plates which extend over curve of arm to sides. Distally, these plates split transversely into a set of 8 narrow plates on each segment. Lateral arm plates Y-shaped, consisting of 3 pieces on side of arm and 1 piece ventrally bearing arm spines. Small ventral plates separating lateral plates throughout arm roughly triangular, with a slightly concave and wide distal margin.

Teeth spearhead-shaped. Sides of jaws usually smooth, occasionally with a few rounded grains. Area outside mouth covered with thin, smooth skin. Adoral plates large, wider than long; oral shields usually very small. Genital slits narrow, oblique.

Colour: 2 basic colour varieties—red, and whitish-yellow—with some dominant intermediates. Red variety usually uniformly pigmented, with a pale creamy-white ventral surface. Commonest variant of this has a thin, yellow line along dorsal midline of each arm, starting near disc centre and passing between and partly on radial shields of a pair. Within this yellow line, near its borders, are 2 thin, dark-red lines also running the length of the arms but joining at disc centre (Fig. 7). Whitish-yellow variety has a single, dark-red line along dorsal midline of arms, beginning either at disc centre or just outside proximal ends of radial shields, and a varying amount of dark red inter-radially.

REMARKS. *Astrobrachion adhaerens* is very closely related to *A. constrictum*; indeed, they are the only two known representatives of the genus, and inhabit the Australasian region together. The two species are most easily distinguished by differences in colour pattern, but there appears to be a slight morphological difference in the number and arrangement of small plates on the sides of the arms, as mentioned

above. Characters used by earlier workers—size of the oral and adoral shields, position of the first arm spines, and relative overall size—are far too variable for diagnostic purposes.

The good series of Australian *Astrobrachion* now available for study has brought to light some surprising synonyms. *Ophiocreas melambaphes* and *O. rhabdotum* are, as H. L. Clark suggested in 1946, colour forms of a single species, but of Studer's *adhaerens*, not a separate species. The holotypes of both *melambaphes* and *rhabdotum* have ventral arm plates separating the laterals, a feature of *Astrobrachion*, not *Ophiocreas* (see Mortensen 1924). Mortensen (1933a) erected subgenus *Astroscolex* for *A. adhaerens*, using the almost complete absence of an oral shield as a diagnostic feature. I have found much variation in the size of the oral shield: on one black coral, some individual *adhaerens* were found with only a trace of a shield, yet others had shields equivalent in size to the large adorals. Consequently there is no justification for retaining *Astroscolex* as a division in a genus with only two, very closely related species.

Having examined the types and other named specimens of *Asteronyx banzareii* Madsen, I can also add that species to the synonymy of *A. adhaerens*. The BANZARE specimens, taken off Albany, south-west Australia, are small examples of the pale-coloured variety lacking the red arm stripe.

DISTRIBUTION. Albany to Dirk Hartog's Island, Western Australia; North Queensland to Byron Bay, N.S.W.; Kermadec Islands. The obvious gaps in distribution—the northern Australian coast, and Lord Howe and Norfolk Islands—probably indicate a lack of collecting in those isolated regions.

BATHYMETRIC RANGE 23–183 m.

Genus *Ophiocreas* Lyman, 1879

TYPE-SPECIES: *Ophiocreas lumbricus* Lyman, 1879.

Ophiocreas oedipus Lyman (Fig. 7, 30)

Ophiocreas oedipus Lyman, 1879: 65, pl. XVI fig. 443–6; 1882: 282, pl. XXXI fig. 5–8, pl. XLVI fig. 1. —Koehler, 1904: 166; 1909: 206, pl. 7 fig. 2. —H. L. Clark, 1915: 178.

MATERIAL EXAMINED. 4 specs, 29°11.1'S, 177°49.3'W, NE of Raoul I., Kermadecs, 1225 m (NMNZ); 1 spec., 37°07.5'S, 177°14'E, off White I., N.Z., NZOI Sta. F881, 1260–1234 m.

DESCRIPTION. Disc small (5–10 mm d.d.), not deeply excavate inter-radially, depressed centrally, covered with thin skin bearing minute, closely set grains. Radial shields narrow, arched, convergent proximally, widely divergent distally. Arms 20× d.d., narrow, deeper than wide except for first 5–8 free

segments, which are swollen to twice normal width, covered with minute grains.

Dorsal arm plates in a single, overlapping series, narrow, rib-like, arching over arm bases. Lateral arm plates meet on ventral midline. Ventral arm plates in several small pieces. One arm spine present on segments 2–8, thereafter a second spine occurs. Inner spine the longer, as long as an arm width, with a thorny, cylindrical stem and blunt tip; outer spine half or less as long as inner, except distally, where they are about equal and are transformed into flattened, compound hooks with 6 lateral teeth.

Teeth blunt, chisel-shaped. Sides of jaws covered with small, closely set, rounded granules. Oral shield very small; adorals much longer than wide, meeting proximally. Oral plates set at an angle. Genital slits wide, vertical.

Colour (in ethanol): disc red or pink, arms paler.

REMARKS. These specimens are the first of this rare species to be recorded from the South Pacific; they agree closely with Lyman's description. The smallest has arms 70 mm long which are not swollen basally. The swellings must appear with the onset of reproductive maturity and the consequent enlargement of ovaries in the basal parts of the arms.

The ventrally protruding oral plates, a feature of the genus, are particularly prominent in the present material. *O. oedipus* can easily be distinguished from *O. sibogae*, the other Australasian *Ophiocreas*, by its much more delicate appearance and shorter, thinner arms with swollen basal joints.

DISTRIBUTION. Indonesia, Ascension Island, Kermadec Islands, New Zealand.

BATHYMETRIC RANGE 760–200 m.

Ophiocreas sibogae Koehler (Fig. 7, 30)

Ophiocreas sibogae Koehler, 1904: 165, pl. 32 fig. 9–11, pl. 36 fig. 1. —H. L. Clark, 1916: 80; 1946: 175. —Mortensen, 1924: 102, fig. 2a.

Ophiocreas constricta Farquhar, Bell, 1917: 7 (not *Astrobrachion constrictum* (Farquhar)).

Ophiocreas longipes Mortensen, 1924: 102, fig. 2b, pl. 3. **New synonymy.**

Asteroschema (Ophiocreas) longipes. Döderlein, 1927: 99.

Asteroschema (Ophiocreas) sibogae. Döderlein, 1927: 99; 1930: 391.

MATERIAL EXAMINED. 1 spec., 5°28.4'S, 132°0.2'E, E Banda Sea, Indonesia, H.M. *Siboga* Sta. 251, 204 m (**syntype**, here designated **lectotype**; ZMA); 4 specs, *Siboga* Sta. 251 (**syntypes**; ZMA); 3 specs, 10°39.5'S, 123°40'E, Timor Sea, H.M. *Siboga* Sta. 297, 520 m (**syntypes**; ZMA); 1 spec., 0°6'N, 129°7.2'E, Moluccan Is., H.M. *Siboga* Sta. 150, 1089 m (**syntype**; ZMA); 2 specs, 39°18'S, 172°01'E, Challenger Plateau, N.Z., NZOI Sta. C632, 201 m; 1 spec., 39°18'S, 172°10'E, NZOI Sta. C645, 440 m; 2 specs, 33°53'S, 172°17'E, NW of North Cape, N.Z., NZOI Sta. E841,

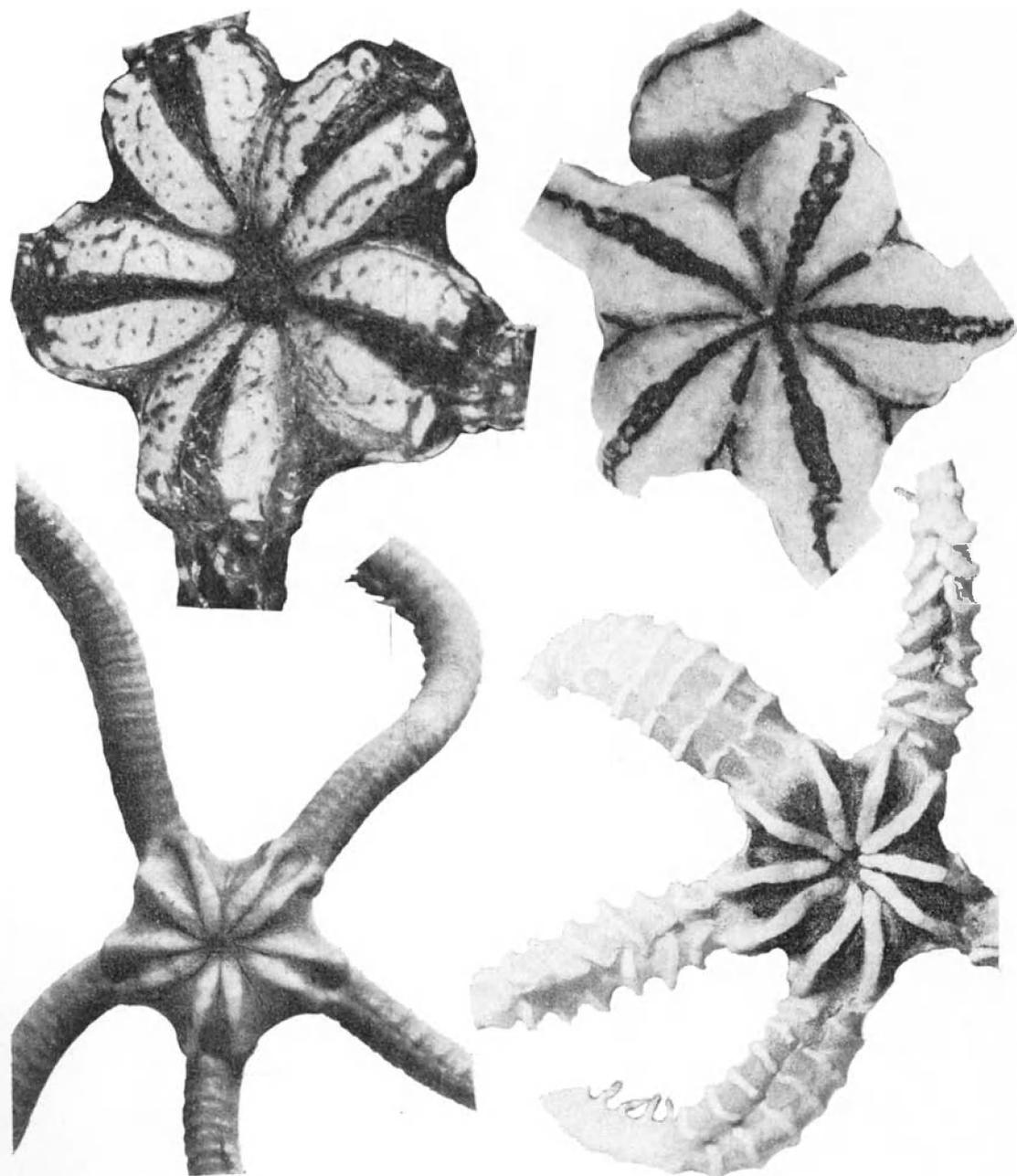


Fig. 7. Upper, *Astrobrachion adhaerens*, NW Cape, W.A., both 8.0 mm d.d. Lower left, *Ophiocreas sibogae*, Challenger Plateau, 17.0 mm d.d.; lower right, *O. oedipus*, White I., N.Z., 8.0 mm d.d.

428 m; 1 spec., 37°20.7'S, 177°06.8'E, N of White I., N.Z., NZOI Sta. J683, 388–400 m; 2 specs, 37°22.5'S, 177°11.7'E, N of White I., N.Z., NZOI Sta. J676, 341–353 m; 1 spec., 36°10.9'S, 176°23.6'E, E of Cape Brett, N.Z., NZOI Sta. I63, 585–400 m; 1 spec., 31°55'S, 153°08'E, E of Crowdy Heads, N.S.W., 402–548 m (AM); 4 specs, E of Flinders I., Bass Strait, 146–548 m (AM E4696–4699); 1 spec., Great Australian Bight (AM E3749); 1 spec., off Bicheno, Tas. (TM); 1 spec., 12 miles E of Cape Forestier, Tas., 621 m (TM); 1 spec., 17 miles off Bicheno, Tas., 475 m (QVM).

DESCRIPTION. Disc diameter <28 mm, Disc circular, weakly excavate inter-radially, tumid, sunken at centre, entirely covered with smooth, naked skin. Radial shields long, narrow, widest and separated distally, contiguous proximally. The 5 pairs of shields usually meet at disc centre.

Arms extremely long (<30 × d.d.), narrow, deeper than wide, covered with thick, smooth skin. One arm spine present from 2nd segment to segment 7–10; thereafter there are 2. Inner spine the longer, half as long as an arm width, with many closely set, strong, curved thorns on abradial side; a gland attached to these thorns gives the spine a claviform shape. Outer spine two-thirds as long as inner, finely rugose. Distally, spines transformed into hooks bearing 2–4 teeth (Fig. 30).

Dorsal arm plates transversely narrow, composed of 2 adjoining or closely parallel series of overlapping elements. Lateral arm plates join in ventral midline; small ventral plate lies distad of joint.

Teeth triangular, 14 or 15 in each column, the lowermost usually split into smaller pieces. Sides of jaws covered with low, domed granules. Adoral shields large, pear-shaped, meeting widely within; oral shield minute. Genital slits tall, narrow, oblique, set in a common inter-radial depression; genital plates protrude across inter-radius at dorsal edge of disc.

Colour: disc red, radial shields and arms pink, arm spines tipped with red.

REMARKS. The small differences used by Mortensen (1924) to distinguish *O. sibogae* from *O. longipes* have proved quite variable in the Indonesian and Australian material examined. Grains are present in varying numbers on all the jaw edges, the relative length of the arm spines is not constant, and the length of the arms varies with d.d. Although Koehler (1904) states that the arms of *O. sibogae* reach 30–35 cm (which influenced Mortensen to separate his New Zealand material as a distinct species), re-examination of the type series has shown that the arms are much longer: the specimen illustrated by Koehler (pl. 36), and selected here as lectotype, has a d.d. of

18.0 mm and arms 530 mm long. This compares well with similar measurements of Australian and New Zealand material: 28 mm d.d., arm length 640 mm; 24 mm d.d., arm length 700 mm; 18 mm d.d., arm length 400 mm.

There is no justification for retaining Mortensen's species, and it is therefore here regarded as a junior synonym of *O. sibogae*.

DISTRIBUTION. Indonesia, southern Australia, northern New Zealand (Fig. 1).

BATHYMETRIC RANGE 201–1089 m.

Family GORGONOCEPHALIDAE Ljungman, 1867

Genus *Astrothorax* Döderlein, 1911

TYPE-SPECIES: *Astrothorax misakiensis* Döderlein, 1911.

Astrothorax waitei (Benham) (Fig. 8, 31)

Astrotoma waitei Benham, 1909: 10. –Mortensen, 1924: 104, pl. 4 fig. 2. –Fell, 1952: 13.

Astrothamnus rugosus H. L. Clark, 1916: 85, pl. 35 fig. 1 & 2; 1946: 177. **New synonymy.**

Astrothamnus papillatus H. L. Clark, 1923: 316, pl. XX fig. 5 & 6. **New synonymy.**

Astrocrius waitei. Döderlein, 1927: 21.

Astrothamnus furtivus Koehler, 1930: 6, pl. 1 fig. 1 & 2. –Mortensen, 1933a: 22, pl. 5 fig. 33.

–H. L. Clark, 1946: 177. **New synonymy.**

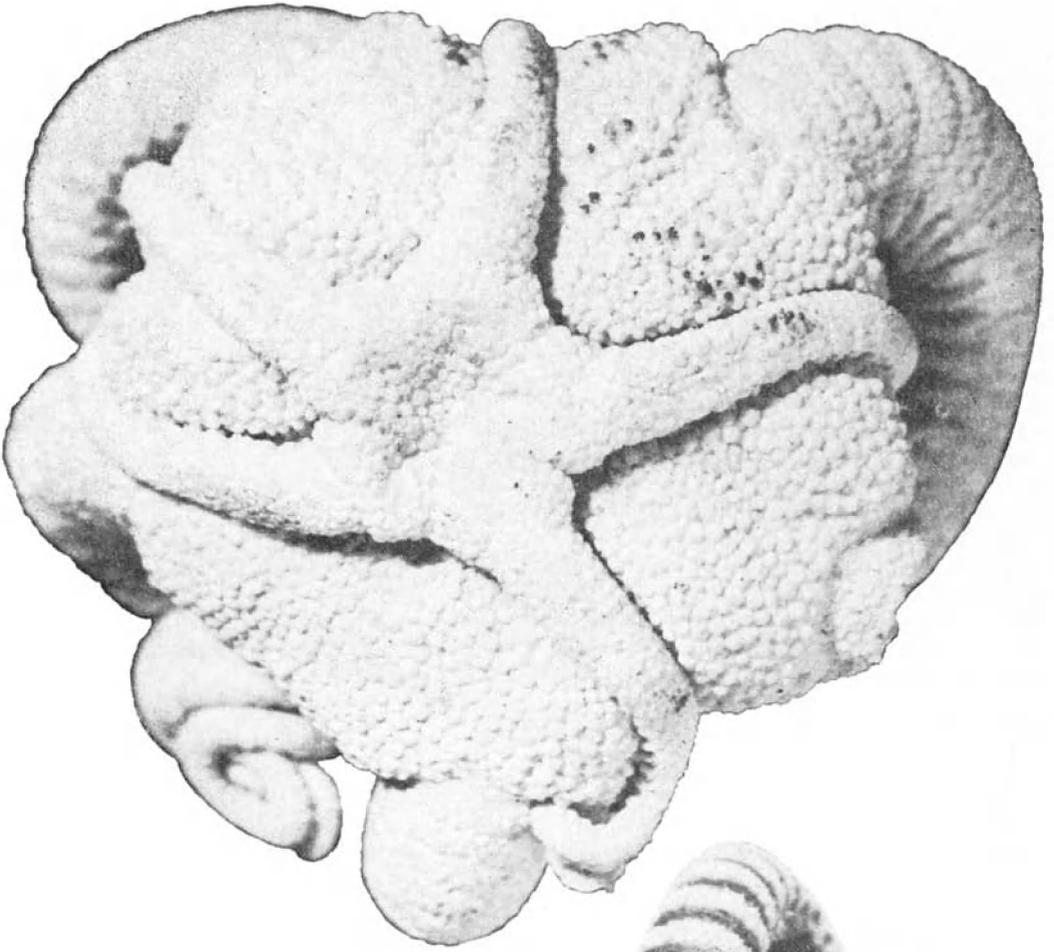
Astrothorax waitei. Döderlein, 1930: 380, pl. 2 fig. 2 & 2a. –Fell, 1958: 21; 1962: 54 (figured).

Astrothorax furtivus Koehler. McKnight, 1975: 61.

MATERIAL EXAMINED. 2 specs, 28°42.35'S, 167°56.7'E, off Norfolk I., NZOI Sta. P46, 425–450 m; 1 spec., 29°24.8'S, 168°13.2'E, off Norfolk I., NZOI Sta. I94, 308 m; 1 spec., 32°32'S, 167°26'E, Norfolk Ridge, Tasman Sea, NZOI Sta. E863, 900–998 m; 3 specs, 33°53'S, 172°17'E, off Three Kings Is, N.Z., NZOI Sta. E845, 277–179 m; 19 specs, off Castlepoint, N.Z., 73–109 m (NMNZ); 56 specs, Cook Strait, N.Z., 73–548 m (NMNZ); 6 specs, 44°23'S, 176°49'W, Chatham Rise, N.Z., 345 m (NMNZ); 1 spec., off Cape Foulwind, N.Z., 240–221 m (NMNZ); 3 specs, 15 miles off Mt Cook, N.Z., 329 m (NMNZ); 2 specs, SE of Cape Everard, Vic., 365 m (**holotype** (AM E4695) and paratype (AM E4733) of *Astrothamnus rugosus* H. L. Clark); 1 spec., E of Flinders I., Bass Strait, 109–545 m (**paratype** of *A. rugosus*; AM E4695); 1 spec., East London, South Africa, *Pieter Faure* 12884, 567 m (**paratype** of *Astrothamnus papillatus* H. L. Clark; MCZ 4310).

DESCRIPTION. Disc diameter 2.0–28.0 mm; arms up to 6 × d.d., mostly coiled, strongly arched in cross-section. Disc not deeply excavate inter-radially, usually tumid, covered with rounded or flat-topped tubercles which are wider than high (2–3 in 1 mm);

Fig. 8. Upper, *Astrothorax waitei*, Cook Strait, N.Z., adult of 18.0 mm d.d. with 6.0 mm juvenile attached to dorsal side of disc. Lower, *Asteropora australiensis*, North Cape, N.Z., 7.0 mm d.d.



tubercles smooth or tipped with a few or many short, glassy prickles, contiguous or separated by small grains or low, smooth platelets. Ventral inter-radial areas closely paved with small, low, smooth granules which extend on to a very flat oral area and ventral under-arm surface. Genital slits narrow, extending over 2 (sometimes 4) segments. One or several small madreporites present.

Arms simple. Girdle bands extend to edge of disc as groups of hooklets on separate plates; bands bordered on each side by a row of more or less contiguous tubercles which are sometimes rough-tipped like those on disc; bands become distinctly larger down sides of arms, and terminate as a tumid, round, smooth plate between each set of arm spines. Inter-girdle areas a narrow, sunken zone of low polygonal plates. Girdle hooklets with a secondary tooth. Arm spines lacking on 1st arm segment, 3 or 4 on 2nd, thereafter 5–10 short, cylindrical spines with 2–4 terminal glassy points; distally spines reduced to hooklets with a strong terminal tooth and a shorter secondary one.

Oral papillae spiniform, short; those near mouth taller and blunter; teeth similar but flattish.

Colour yellowish-cream, occasionally shiny white.

REMARKS. The large series of specimens has shown that *Astrothamnus rugosus* H. L. Clark and *A. furtivus* Koehler, both described from Bass Strait, Australia, and *Astrothorax papillatus* (H. L. Clark) from South Africa, are conspecific with *Astrothorax waitei*.

There is considerable variation in the nature of the disc cover in this species, some individuals having low, smooth tubercles and others having higher, domed or flat-topped tubercles tipped by either a few tall thorns or many short ones. The tubercles may be contiguous, or separated by smaller grains or plates, giving the disc quite different appearances. Also, the number of arm spines varies from 5 in a 6 mm d.d. specimen to 10 in the largest examples.

This variation negates the second bifurcation in Mortensen's (1933a, p. 18) key to the species of *Astrothorax*, and also raises the question of the relationship of the Indonesian *A. tessellata* Mortensen, which in the key is separated from *A. waitei* only on the basis of differences in disc cover.

Fell (1958) suggested that *A. waitei* is androphorous, but examination of specimens carrying smaller ones on the disc—both dorsal and ventral sides—has shown that these are juveniles, not dwarf males (Fig. 8). The species is in fact hermaphroditic, and broods its young. Each of the 10 ovaries contains about 30 eggs up to 0.5 mm in diameter, and the testes lie at the distal abradial edge of each

ovary. One to three young are carried in the bursae at any one time, and these depart for the outside at about 2 mm d.d.

The only other brooding euryalinid seems to be the Antarctic *Astrochlamys bruneus* Koehler. That species is androphorous, however, and the juveniles are released at a much earlier stage (Mortensen 1936).

DISTRIBUTION. New Zealand, Norfolk Island, south-eastern Australia, southern Africa.

BATHYMETRIC RANGE 73–998 m.

Genus *Astrothrombus* H. L. Clark, 1909

Astrothrombus H. L. Clark, 1909a: 548. –Döderlein, 1930: 371. –Pawson, 1969: 54.

Astrostephanus Döderlein, 1930: 369 (type-species, by monotypy, *Astrotoma vecors* Koehler, 1904: 155, pl. 21 fig. 9, pl. 27 fig. 9 & 10, pl. 32 fig. 2).
New synonymy.

TYPE-SPECIES: *Astrothrombus rugosus* H. L. Clark, 1909.

Astrothrombus rugosus H. L. Clark (Fig. 9, 31)

Astrothrombus rugosus H. L. Clark, 1909a: 548, pl. 54 fig. 3. –Mortensen, 1933a: 17, fig. 8f,g. –Pawson, 1969: 54, fig. 2a,b & 13. –Baker & Clark, 1970: 7.

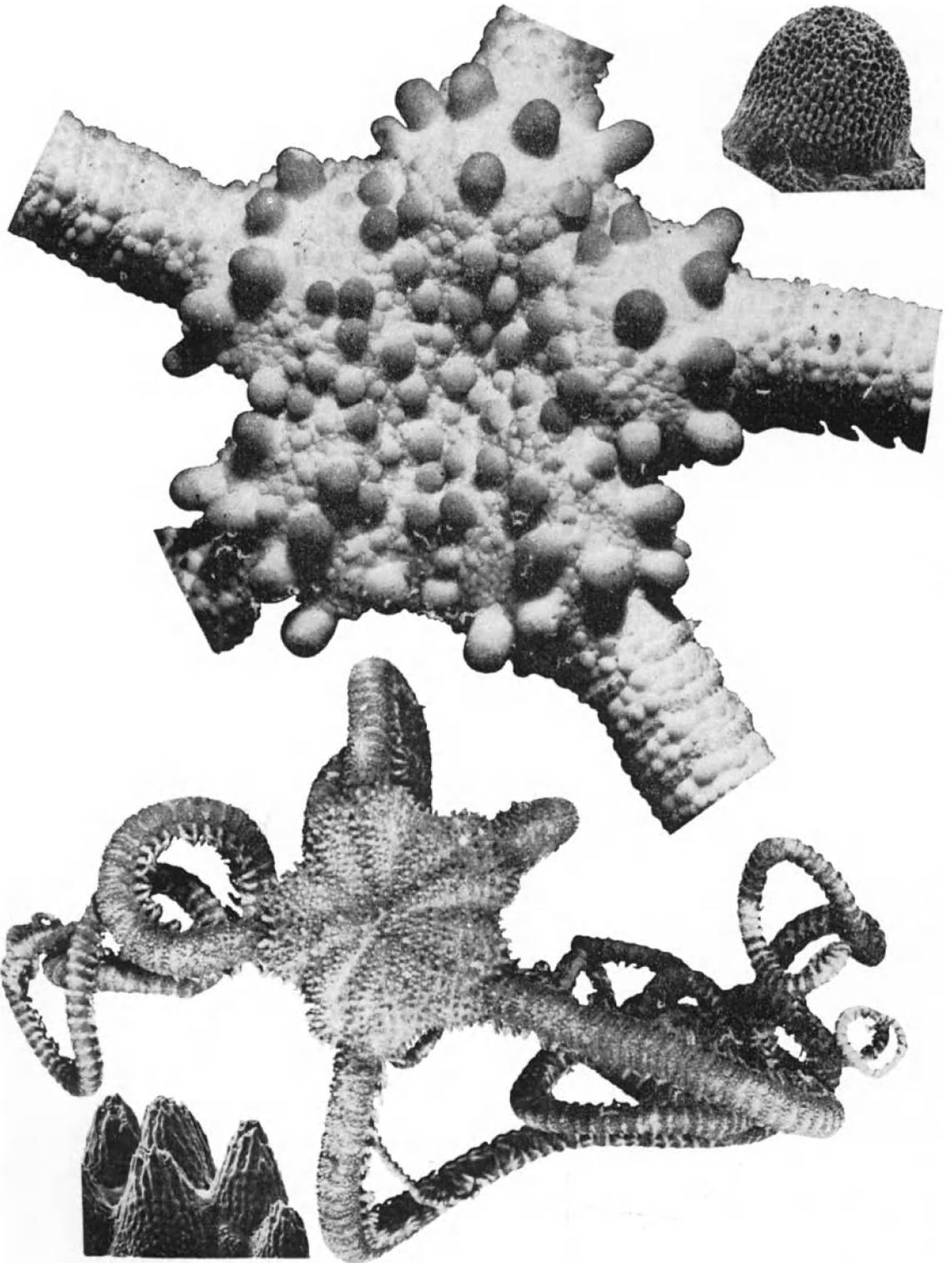
Astrotoma benhami Bell, 1917: 8. –Mortensen, 1924: 104, fig. 3, pl. 4 fig. 6 & 7. –Fedotov, 1927: 373, fig. 26–34. –Baker & Clark, 1970: 7.

Astrothamnus benhami. Mortensen, 1933a: 14, fig. 7.

MATERIAL EXAMINED. 1 spec., off Wollongong, N.S.W., 99–100 m (holotype; AM J871); 1 spec., between Merimbula and Tathra, N.S.W., 37–55 m (AM J871); 8 specs, 36°24'S, 176°14'E, off Cuvier I., N.Z., 550–560 m (NMNZ); 4 specs, Cook Strait, N.Z., 320 m (NMNZ); 1 spec., 41°30.7'S, 174°58.4'E, Cook Strait, N.Z., 448–512 m (NMNZ); 1 spec., off Kaitioura, N.Z., 306 m (NMNZ); 1 spec., off Three Kings Is, N.Z., 548 m (syntype of *Astrotoma benhami*; BMNH 1915-2-1-67-70).

DESCRIPTION. Disc diameter to 13 mm; arms up to 7× d.d. Disc slightly tumid, very weakly excavate inter-radially. Upper disc surface covered with irregularly placed, round tubercles up to 1 mm in diameter and 1.1 mm high, near disc centre 2 in 1 mm, towards margin spaced, larger; tubercles have evenly rounded, smooth or microscopically roughened tips, and are separated by a close mosaic of low polygonal plates and granules. Radial shields visible as very small, bare plates in specimens <6 mm d.d. Ventral inter-radial areas similarly covered, but with only a few of the larger tubercles. A large, circular madreporite present, at proximal corner of 1 ventral inter-radius.

Fig. 9. Upper, *Astrothrombus rugosus*, Cuvier I., N.Z., 10.0 mm d.d. Lower, *A. vecors*, Bay of Plenty, N.Z., 14.0 mm d.d. Upper right & lower left, enlarged tubercles from inter-radial edge of oral frame (×21).



Genital slits long (3–4 arm segments), narrow.

Girdle bands begin at 1st or 2nd free arm segment, continuous only after 2nd or 3rd segment respectively, consisting of slightly raised ridges bearing a double row of hooklets with up to 6 secondary teeth; basal bands angled proximad in dorsal midline, giving a chevron-like pattern. Intergirdle areas consist of 2 rows of polygonal or transversely oval, contiguous tubercles, the largest on dorsal midline.

Ventral surface covered by small, tumid granules mostly separated by narrow, skin-covered sutures. Arm spines 2, 3, or (rarely) 4 on 2nd segment, thereafter 2 or 3, though in some specimens the occasional segment has up to 5; spines cylindrical with a slight taper, blunt; innermost spines longest, at least as long as an arm segment.

Oral frame closely paved with round, tumid granules which become enlarged, tall, domed tubercles on areas covering oral shields, forming a fence-like margin to oral frame, particularly in specimens >6–7 mm d.d. Oral plates with a cluster of short, blunt spinules more or less in a double row. Oral papillae and teeth narrow, spiniform.

Colour (in ethanol) cream.

REMARKS. The type-species of *Astrothrombus* has hitherto been known from only three specimens of 6.4–8 mm d.d. The 8 mm specimen (AM J4761) was identified by H. L. Clark and recorded in the literature by Pawson (1969). On all three specimens the row of tubercles on the inter-radial edge of the oral frame is not very pronounced, and, understandably, the feature was not mentioned by Clark or Pawson as being of possible generic importance. Bell (1917) appears to have noticed the tubercles on his *Astrotopoma benhami*, but neither he nor Mortensen (1924) appreciated their possible taxonomic use. In the larger specimens examined this fence-like row of tubercles is much more noticeable, as is the cluster of spinules on the dental plates (although the latter are definitely present from an early stage). Fell (1960) recognised the importance of these features for *Astrostephanus* in his generic key to the Gorgonocephalidae, but was unaware of their occurrence in *Astrothrombus*, and consequently made them diagnostic for Döderlein's genus. Strangely, Döderlein did not mention the tuberculation of the oral area in his diagnosis of *Astrostephanus*, but instead stressed the stick-like arm spines and long genital slits. The type-species of *Astrostephanus*, *Astrotopoma vecors* Koehler, is represented in considerable numbers from eastern New Zealand waters in this study, and proves to be congeneric with *Astrothrombus rugosus*. *Astrostephanus* is therefore here synonymised with *Astrothrombus*.

Along with *rugosus* and *vecors* a third species, *Astrotopoma ringens* Koehler (1910), can be assigned to genus *Astrothrombus*. A Koehler-identified speci-

men from R.I.M.S.S. Investigator Station 355 (Arabian Sea, 900 m), sent to me by the Zoological Survey of India, has a rampart of tall tubercles at the edge of the oral frame; it has up to four cylindrical arm spines, each about one segment long, the girdle hooklets bear three to five secondary teeth (Fig. 31), and the girdle bands are constructed of continuous plates. The disc of this species is covered with scales and low, pointed tubercles.

Astrothrombus chrysanthi Matsumoto differs considerably from its congeners in having very short genital slits and arm spines only about half as long as an arm segment. Matsumoto's (1918) description indicates that the species is probably correctly placed in *Astrothrombus*, however, because the holotype had ventral inter-radial tubercles and "papilla-like" grains on the oral plates. Unfortunately Matsumoto did not describe in detail, or figure, the girdle hooklets of *chrysanthi*.

I regard the three species of *Astrothrombus* (*celingae*, *panningi*, and *ludingae*) described from the Philippines by Domantay (1957) and Domantay & Domantay (1967) as ophiothricids, probably *Ophiolithelia* spp.

Considering the uncertainty about the relationships of *Astrothrombus* expressed by Matsumoto and Döderlein, I give below an amended diagnosis for the genus.

A simple-armed gorgonocephalid with coarsely granulated disc, a row or zone of enlarged tubercles at edge of oral frame inter-radially, and a cluster of spinules on oral plates. Up to 5 arm spines, usually as long as an arm segment. Girdle bands not constructed of separated plates; hooklets with 3–6 secondary teeth.

DISTRIBUTION. South-eastern Australia, New Zealand.

BATHYMETRIC RANGE 37–512 m.

Astrothrombus vecors (Koehler) n.comb. (Fig. 9, 31)

Astrotopoma vecors Koehler, 1904: 155, pl. 21 fig. 9, pl. 27 fig. 9 & 10, pl. 32 fig. 2.

Astrothamnus vecors. Matsumoto, 1915: 59.

Astrostephanus vecors. Döderlein, 1930: 376, pl. 1 fig. 8.

MATERIAL EXAMINED. 17 specs, 28°42.3'S, 167°56.7'E, near Norfolk I., NZOI Sta. P46, 475–450 m; 14 specs, 33°53'S, 172°38'E, NE of North Cape, N.Z., NZOI Sta. E841, 691–751 m; 2 specs, 37°22.5'S, 177°11.7'E, Te Arawa High, Bay of Plenty, N.Z., NZOI Sta. J676, 341–353 m; 5 specs, 37°20.7'S, 177°06.8'E, Mahina Knoll, Bay of Plenty, N.Z., NZOI Sta. J683, 388–400 m.

DESCRIPTION. Disc diameter <14 mm; arms up to

10× d.d. Disc flat or slightly tumid, sunken at centre; inter-radial areas distinctly but not deeply excavate. Upper disc surface covered with spaced (3–4 in 1 mm), cylindrical or conical tubercles with flat tops bearing minute prickles; tubercles largest (0.5 × 0.75 mm) near disc margin, particularly over area covering radial shields, which are partly visible only in small specimens, becoming smaller and pointed at inter-radial edge of disc, and sparsely scattered over ventral area.

Genital slits long (4 segments), narrow. One large, circular madreporite present, in proximal angle of ventral inter-radial area.

Disc tubercles extend on to first few arm segments dorsally. Girdle bands begin at 1st or 2nd free segment, continuous only after 3rd free segment; bands consist of raised ridges bearing a double, alternating row of hooklets with up to 4 secondary teeth, and on first 5 segments are angled towards disc in dorsal midline, producing a chevron-like appearance. Inter-girdle areas slightly sunken, with a somewhat irregular arrangement of plates and small tubercles bordered on each side by a more regular row of taller tubercles which become lower but wider down sides of arms.

Ventral arm surface covered with low, round pustules embedded in thick skin; tentacle pores surrounded by a calcified tube, and sometimes carry a small, pointed scale or spinule on adradial edge basally. Arm spines 3 on 2nd free segment, then 4 or occasionally 5 (maximum of 3 in small specimens) per segment, eventually reducing to a single compound hooklet; spines cylindrical, with narrow bases and a rough tip; innermost ones longest, about as long as an arm segment.

Oral frame covered with low pustules like those on arms, except over areas covering oral shields and oral plates. Shield area with a cluster or fence-like row of closely packed, pointed tubercles (Fig. 13); oral plates with a double row of pointed spinules somewhat shorter and thicker than the spiniform oral papillae and teeth.

Colour (in ethanol) pinkish-brown.

REMARKS. This species was previously known from only three H.M. *Siboga* specimens collected in the Banda Sea and near Timor. The New Zealand and Tasman Sea material is smaller than the type specimens, but apart from such juvenile features as exposed radial shields and a reduced number of arm spines (in specimens 4–5 mm d.d.) it agrees closely with the descriptions of Koehler and Döderlein.

Neither of those workers had seen a specimen of *Astrothrombus rugosus*, their knowledge of which was based entirely on H. L. Clark's rather simplistic description of the 7 mm d.d. holotype. It is not surprising, therefore, that *vecors* was placed in a genus of its

own after being regarded as *incertae sedis* by Döderlein (1927). Only the large number of specimens of both *vecors* and *rugosus* now available has shown that both are representatives of a single genus, for which status *Astrothrombus* H. L. Clark has priority.

The 17 dried Norfolk Island specimens are clumped on one branch of a gorgonian. Large specimens (10–12 mm d.d.) carry smaller ones (7–8 mm d.d.) on their dorsal surfaces, but there is no evidence from dissection that these are brooded juveniles rather than males, as in *Astrothorax waitei*.

DISTRIBUTION. Indonesia, northern Tasman Sea, north-eastern New Zealand.

BATHYMETRIC RANGE 204–751 m.

Genus *Asteropora* Oestedt & Lütken, 1856

TYPE-SPECIES: *Asteropora annulata* Oestedt & Lütken, 1856.

Asteropora australiensis H. L. Clark (Fig. 8, 31)

Asteropora australiensis H. L. Clark, 1909a: 547.

Asteropora australiensis H. L. Clark, 1916: 80.

Asteropora wilsoni Bell, 1917: 7. –Mortensen, 1924: 106, pl. 6 fig. 8 & 9. –Fell, 1951: 4; 1962: 53 (figured). **New synonymy.**

Asteropora australiense. Koehler, 1930: 13, pl. 1 fig. 11–13, pl. 2 fig. 1 (in part).

Asteropora australiense. H. L. Clark, 1946: 178.

Asteropora wilsoni. A. M. Clark, 1966: 697, fig. 5. –McKnight, 1968: 519; 1975: 61.

MATERIAL EXAMINED. 2 specs, 32°30'S, 179°12'W, Kermadec Ridge, 508 m, NZOI Sta. C527; 6 specs, 32°41'S, 167°36'E, Wanganella Bank, 168 m, NZOI Sta. E865; 3 specs, 32°41'S, 167°28.6'E, Wanganella Bank, 150–136 m, NZOI Sta. P7; 1 spec., 34°00'S, 172°30'E, NE of Three Kings Is, N.Z., 119 m, NZOI Sta. E312; 7 specs, 34°13'S, 172°11.3'E, off North Cape, N.Z., 256 m (NMNZ); 1 spec., 34°26'S, 173°14'E, E of North Cape, N.Z., 146 m (NMNZ); 3 specs, 34°40'S, 172°14'E, W of Cape Maria Van Diemen, N.Z., 201 m, NZOI Sta. C758; 2 specs, 35°11'S, 174°20'E, Cape Brett, N.Z., 32 m (NMNZ); 1 spec., off Wollongong, N.S.W., 99–100 m (**holotype**; AM G11433); 4 specs, E of Babel I., Bass Strait, 109–146 m (AM E 5101, 5222, 5357); 4 specs, W of Babel I., Bass Strait, 128 m (AM J5868); 25 specs, off Cape Everard, Vic., ? depth (AM J5402); 1 spec., off Gabo I., Vic., 128–146 m (AM E5288); 3 specs, off Twofold Bay, N.S.W., 55–82 m (AM J5390).

DESCRIPTION. Disc diameter to 23 mm; arms 4–6 × d.d. In specimens under about 7 mm d.d., arm bases and disc merge evenly, giving appearance that disc composed of 5 wedge-shaped, widened arm bases; in larger specimens a distinct lateral and dorsal step occurs between arms and disc, and inter-radial area shallowly excavate. Disc centre covered with narrowly separated, raised, white plates bearing 4–12 small.

conical tubercles mostly tipped with a glassy thorn. Narrow, sunken areas between plates contain small, dark platelet or granules, some of which become larger and flatter towards disc margin. Raised plates arranged in a star shape with concave margins and with apices pointing inter-radially. Star surrounded by concentric ridges made up of roughly circular, white plates bearing marginally a row or rows of tubercles encircling a group of girdle hooklets. Ridges continue radially in a regular series across radial shields and along arms, separated throughout by slightly narrower, sunken areas of small, dark plates and granules, giving entire ophiuroid a strikingly annulated appearance.

Ventral inter-radial areas covered with small plates of irregular shape and size which, in larger specimens, bear scattered, conical tubercles similar to those on upper disc plates.

Ventral arm surface covered with low, oval or polygonal plates separated by areas of skin (small specimens) or distinct sutures (large ones). Lateral arm plates with a ventrally projecting flange bearing 4-7 very short, flat arm spines with 3-5 terminal points; innermost spine flattest. Girdle hooklets with 1 long secondary tooth.

Oral area closely paved with slightly raised, round or polygonal plates surrounded by distinct sutures. A small, flat madreporite present, on edge of oral frame. Oral papillae and teeth alike, spiniform. Genital slits short (spanning 2 segments), half-moon-shaped.

Colour: raised plates and tubercles white, sunken intervening areas mauve or dark grey; ventral arm surface and oral area mauve or grey; ventral inter-radial areas white.

REMARKS. A comparison between the holotype and other Australian specimens of *A. australiensis* and the eastern Tasman and New Zealand material shows that only one species is represented. The small differences in colour and in the shape of the oral papillae, tentatively suggested as being specific by Mortensen (1924), are encompassed by normal variation among the examples studied. Consequently, *A. wilsoni* Bell is here synonymised with *A. australiensis*.

The species is now known with certainty from the Australasian region between 32°S and 40°S. Koehler's (1930) specimen from Amboina, Indonesia, has been reidentified as *Asteromorpha rousseaui* (Michelin) by Mortensen (1933a). This specimen has been re-examined, and a distal arm spine is illustrated here (Fig. 33) to compare with a new species of *Asteromorpha*.

DISTRIBUTION. South-eastern Australia, northern Tasman Sea, northern New Zealand (Fig. 1).

BATHYMETRIC RANGE 55-508 m.

Astromoana new subgenus

DIAGNOSIS. An *Asteroporpa*-like gorgonocephalid without concentric ridges and hollows progressing continuously from arms across disc as in *Asteroporpa* sensu stricto. Instead, girdle bands occur only on distal part of radial shields, usually number only 2, and are slightly sunken rather than raised as in *Asteroporpa* s.s. Disc cover otherwise a mosaic of smooth, rounded or domed tubercles forming either a uniform pattern (*indicus*) or a reticulate pattern with a strong longitudinal component (*reticulata*).

TYPE-SPECIES: *Asteroporpa (Astromoana) reticulata* n.sp.

INCLUDED SPECIES: *Asteroporpa (Astromoana) indicus* n.sp.

ETYMOLOGY. The suffix *moana* is a Maori word meaning 'sea'.

REMARKS. That this taxon is closely related to *Asteroporpa* can be seen from the way the disc is divided into five radiating wedges, giving the appearance that it is formed from the widened arm bases alone. It also shares with *Asteroporpa* the unusual character of having girdle hooklets on the disc—a feature found in only one other gorgonocephalid, the branched-armed genus *Astrocnida* Lyman.

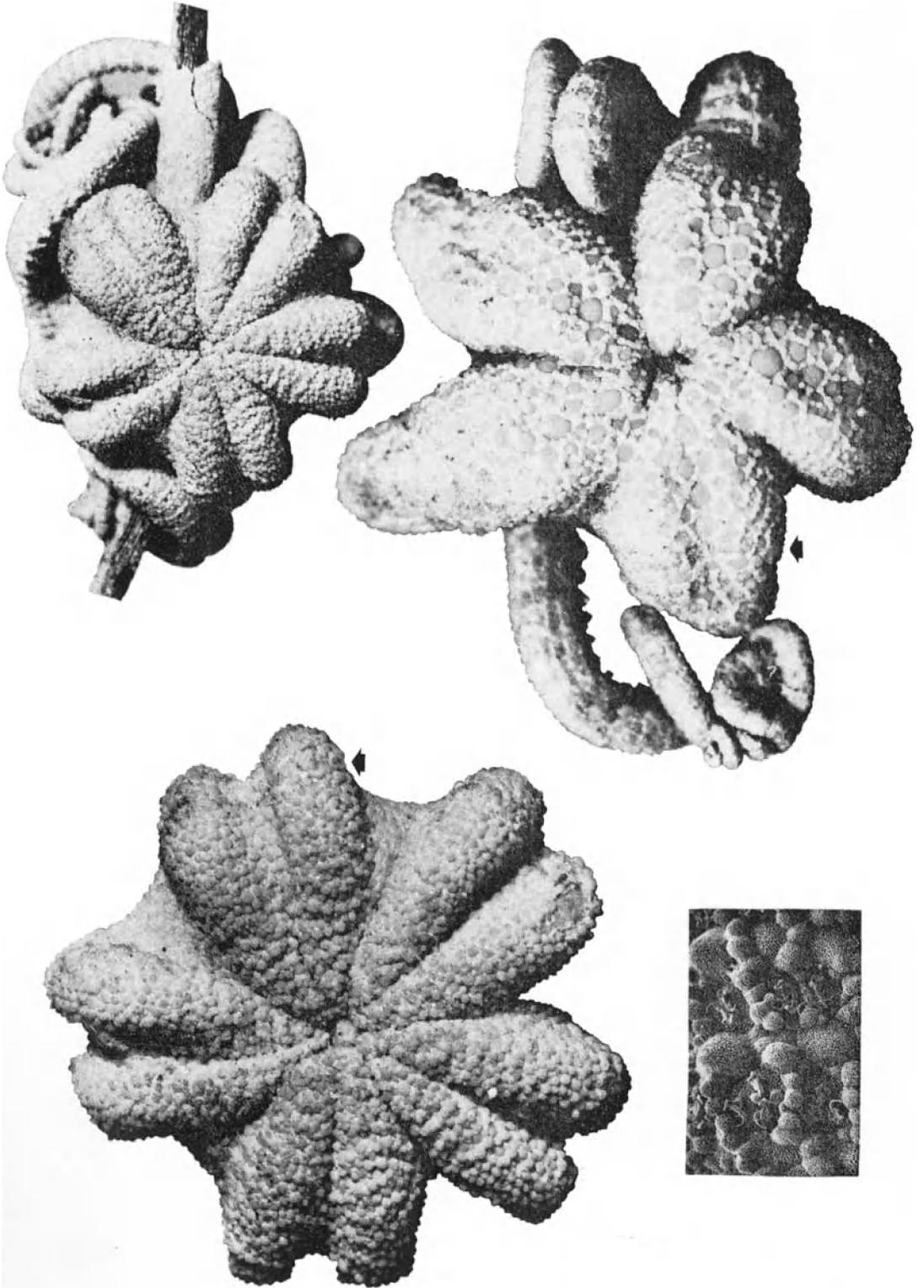
The new subgenus differs from *Asteroporpa* s.s. in the absence of conspicuous, alternating, concentric ridges and furrows on the dorsal side of the disc, which in the latter are simply continuations of the raised belts of hooklet-bearing plates and intervening furrows of flattened granules found on the arms. *Astromoana* has inconspicuous girdle bands on the distal ends of the radial shields as well as on the arms; these bands are slightly lower than the intervening areas of domed plates. There are thus no alternating concentric ridges and furrows, even on the arms.

Both species assigned to the new subgenus are new; one is from the northern Tasman Sea, near Norfolk Island, and the other from the eastern Indian Ocean, off Point Cloates, Western Australia.

Genus *Asteroporpa* is thus divided as follows.

Asteroporpa (Asteroporpa): concentric ridges and

Fig. 10. Left, *Asteroporpa (Astromoana) indicus*, holotype (WAM 737.753), 10.0 mm d.d. Upper right, *A. (Astromoana) reticulata*, holotype (NZOI H254), 9.0 mm d.d. Lower right, *A. reticulata*, paratype (NMNZ Ech. 2878), 1.6-mm-long section of dorsal surface of arm. Arrows mark position of girdle band.



furrows on arms and disc; girdle bands raised. Included species: *A. annulata* Oestedt & Lütken, Caribbean Sea; *A. affinis* Lutken, Caribbean Sea; *A. pulchra* H. L. Clark, Caribbean; *A. lidneri* A. H. Clark, Gulf of Mexico; *A. hadra-cantha* H. L. Clark, Japan; *A. australiensis* H. L. Clark, Australia and New Zealand.

Asteroporpa (Astromoana): no concentric ridges and furrows on arm and disc; girdle bands depressed. Included species: *A. (Astromoana) reticulata* n.sp., Norfolk Island; *A. (Astromoana) indicus* n.sp., Point Cloates, Western Australia.

Asteroporpa (Astromoana) reticulata n.sp.
(Fig. 10, 31)

TYPE DATA. **Holotype** (9.0 mm d.d.): near Norfolk I., 29°07.9'S, 168°15.0'E, NZOI Sta. 185, 280–90 m, 22 Jul 1975 (NZOI H254). **Paratypes** (2.5–8.0 mm d.d.): 2, same station as holotype (NZOI P511, NMNZ Ech. 2878); 3, 29°25.0'S, 168°0.56'E, NZOI Sta. 190, 71 m, 23 Jul 1975 (1 in each of AM, BMNH, USNM); 2, 29°10.4'S, 167°51.7'E, NZOI Sta. P39, 77–110 m, 29 Jan 1977 (1 in each of ZMC, MCZ); 1, 28°54.9'S, 167°44.8'E, NZOI Sta. P26, 130–301 m, 27 Jan 1977 (NZOI P512).

DESCRIPTION OF HOLOTYPE. Arms coiled, 3 mm wide, 2 mm high at base. Disc appears to consist of slightly widened arm bases; inter-radial areas excavate, very small, sunken, with a groove extending proximally towards disc centre.

Radial shields completely obscured, but wedge-like sections of disc obviously correspond to 5 pairs of shields. With exception of inter-radial areas, disc covered with a lace-like, fairly even network of small, finely rugose, distinctly flesh pink plates and tubercles, the largest round or pentagonal, wider than high (0.6 mm diameter), with a flat, domed or conical surface. Surrounding each one is a row of smaller (0.2 mm diameter), white granules of 2 sizes, the taller ones—usually 5 in number—situated at corners of pentagonal plate and joined by smaller tubercles.

On distal end of each wedge-shaped segment of disc are girdle bands which, like those on arms proper, consist of separate, flat plates bearing a group of girdle hooklets. Plates somewhat depressed, separated by rows of small, white granules which give arms a longitudinally striated appearance. Areas between girdle bands consist of 7–9 swollen, pink plates similar to those on disc, separated from one another and from adjacent girdle plates by small, white granules. Girdle bands as wide as or wider

than intervening areas; hooklets with 1 or 2 secondary teeth.

Inter-radial areas sunken, covered with close-set polygonal or round, tumid plates. Ventral arm surface flat, covered with transparent skin and low pustules not at all densely arranged. Arm spines begin with 3 on 2nd and 3rd segments, thereafter 4 (occasionally 5); spines short (<2.5 mm), cylindrical, with 1 or 2 terminal points, distally modified into hooklets. A group of girdle hooklets associated with outermost pair of spines.

Oral area covered with low, round tubercles separated by narrow areas of skin. Oral papillae short, spiniform; teeth spiniform, rather lens-shaped. Genital slits semicircular, very small, about as long as an arm segment.

Colour (in ethanol): disc and arms pink and white, inter-radial areas brown.

VARIATION. In the smallest paratype (2.5 mm d.d.) the primary rosette consists of six conical, flesh-pink tubercles.

ETYMOLOGY. The trivial name *reticulata* (Latin) alludes to the pattern of granules.

REMARKS. This species is characterised by its beautiful reticulated pattern of pink and white granules and its almost totally hidden radial shields. The reticulated pattern appears to be similar to that described for *Asteroporpa lidneri* A. H. Clark, from the Gulf of Mexico, and although the two species may be superficially similar they differ in such details as the number of girdle bands on the disc and the relative height of the bands. Unfortunately the unique and unfigured holotype of *A. lidneri* has not been located in the USNM collections (D. L. Pawson, pers. comm.).

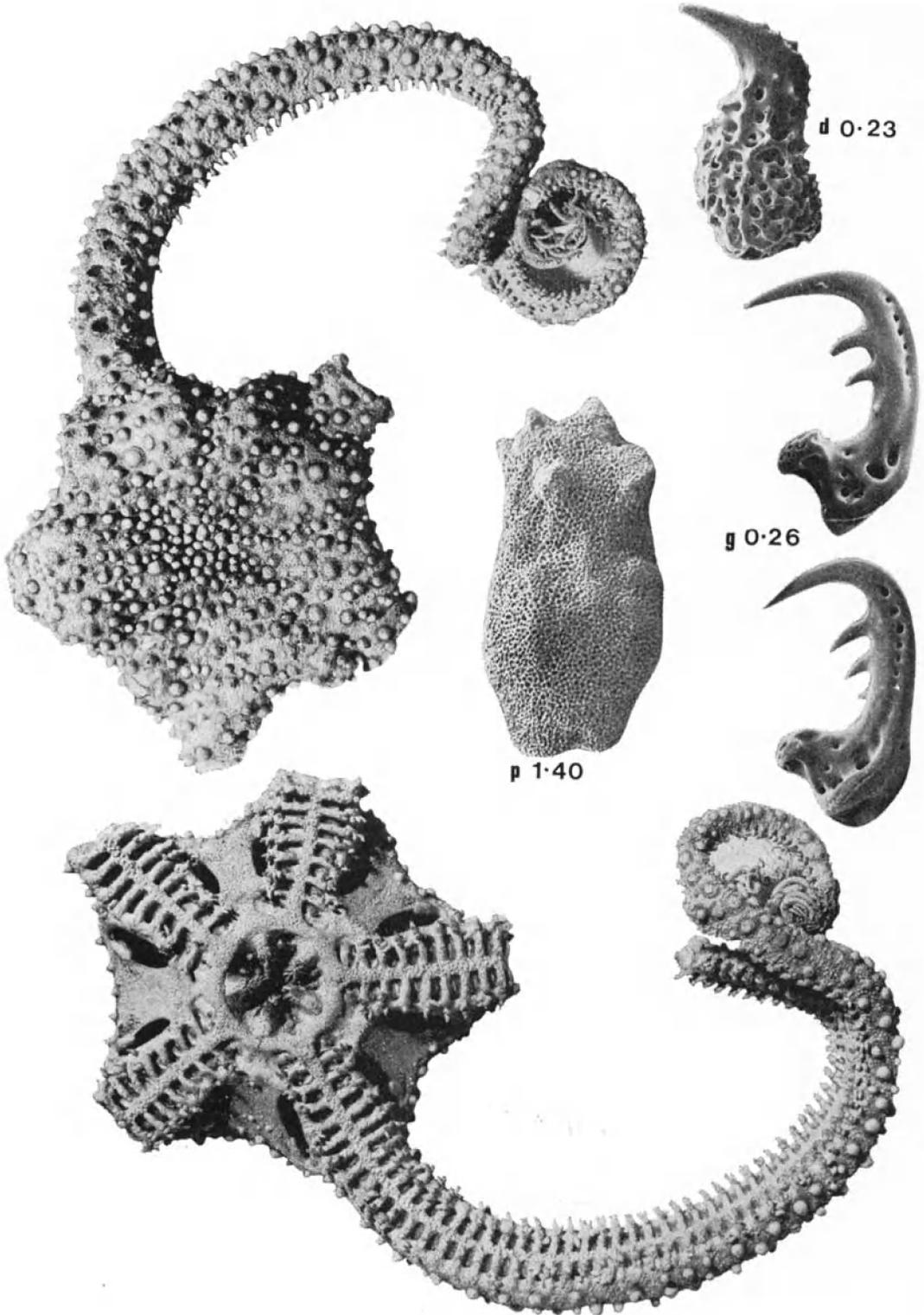
DISTRIBUTION. Northern Tasman Sea, near Norfolk Island.

BATHYMETRIC RANGE 71–301 m.

Asteroporpa (Astromoana) indicus n.sp. (Fig. 10, 31)

TYPE DATA. **Holotype** (10.0 mm d.d.): W of Pt Cloates, W.A., 23°05'S, 113°23'E, CSIRO Sta. 182, 141 m, 7 Oct 1963 (WAM 737.75).

DESCRIPTION OF HOLOTYPE. Arms coiled, but at least 50 mm long. Disc distinctly excavate and sunken inter-radially, also sunken radially between shields. Radial shields thus prominently outlined, wide distally, narrow at disc centre. Disc covered



with small, round, domed tubercles (5–6 in 1 mm) interspersed with smaller grains; tubercles and grains only microscopically roughened. Genital slits very small. A single madreporite present.

Dorsal side of arms covered with tubercles like those on disc, though most are transversely oval rather than round, the longest in centre of inter-girdle area, particularly at lowest edge of arm. Girdle bands consist of groups of hooklets on adjacent plates; 2 bands on radial shields; hooklets with a secondary tooth.

Ventral surface of arms with scattered, low granules not at all densely arranged. No arm spines on 1 free segment, 3 on 2nd, thereafter 4; spines short, flattened, with 2 or 3 terminal points, distally becoming hooklets with 2 or 3 teeth.

Oral area densely covered with low, round tubercles; oral papillae and teeth short, spiniform.

Colour (dry) pink.

ETYMOLOGY. The trivial name *indicus* (Latin) alludes to the Indian Ocean.

REMARKS. Like *A. (Astromoana) reticulata*, this eastern Indian Ocean species has only two girdle bands on the disc and no conspicuous concentric ridges and furrows. It differs from *reticulata* in having well defined radial shields, the shape of which is readily discernible beneath the dense cover of granules. Also, in *A. indicus* the small tubercles on the arms are arranged in a strongly transverse pattern, not a reticulated pattern with a strong longitudinal component as in *A. reticulata*.

DISTRIBUTION. Off north-western Australia.

BATHYMETRIC RANGE 141 m.

Genus *Astroclon* Lyman, 1879

TYPE-SPECIES: *Astroclon propugnatoris* Lyman, 1879.

Astroclon suenisoni Mortensen (Fig. 11)

Astroclon suenisoni Mortensen, 1911: 209; 1933a: 29, pl. I fig. 1 & 2, pl. II fig. 1, 2, & 4. –Döderlein, 1930: 383, pl. XV fig. 9.

MATERIAL EXAMINED. 1 spec., 17°35'S, 119°42'E to 17°32'S, 119°44'E, NE of Broome, W.A., 290–293 m (WAM 401–79).

DESCRIPTION. Disc diameter 65 mm, arms at least 340 mm long. Disc pentagonal, only weakly excavate inter-radially, depressed centrally. Dorsal surface of disc and arms closely paved with flat or slightly tumid, polygonal or round granules or plates 0.1–1.0 mm across. Scattered over disc and arms are smooth, conical or domed tubercles, the largest 3.0 mm in diameter and 2.0 mm high; 4–5 tubercles in

10 mm on discs, 3 in 10 mm on arms; tubercles surrounded by circlets of flat plates.

Ventral inter-radial areas mostly without large tubercles, paved (like oral frame and ventral arm surface) with small, tumid, cobble-like plates, 2–3 in 1 mm. Large tentacular pits in a distinct double ladder-like arrangement on ventral arm surface; ventral arm plates restricted to a continuous, narrow, median area. First arm fork occurs at about twice d.d. from disc; 43–48 arm segments before 1st fork, 7 or 8 bifurcations on each main stem. Arms strongly arched, 14 mm wide, 12 mm high at base, tapering very gradually. Arm spines present on all proximal segments, but disappearing distally; spines smooth, short, with blunt, lumpy tips over most of arm, but narrower distally, with a single, inclined terminal point. Girdle hooklets occur alongside outer arm spines near 1st arm fork, in continuous bands only after 2nd fork, mostly with 2–4 secondary teeth, occasionally fewer or more.

Tooth papillae and teeth narrow, spiniform; sides of jaws naked. Oral and proximal tentacle pores surrounded by sheath of calcite platelets. One circular madreporite present, with a raised central point.

REMARKS. *Astroclon suenisoni* is a new record for Australian waters and the Indian Ocean; it was previously known from only six specimens from southern Japan and one from northern Celebes, Indonesia. It is an easily recognised gorgonocephalid, with its stout arms branched only at a considerable distance from the disc, strongly tuberculated disc and arms, and double ladder-like arrangement of tentacular pits on the ventral surface of the arms.

The type-species, *A. propugnatoris* Lyman, is known from the Kei Islands, Indonesia, and Japan, and may also occur in northern Australian waters. It is distinguished from *A. suenisoni* by having a much less tuberculate dorsal cover, no sharp distinction between dorsal and ventral disc surfaces, and numerous dark patches on the disc and arms.

Astroclon resembles *Astrosierra* in the nature of its surface cover and distal, reduced arm branching; and *Astrothrombus* in the form of its multi-toothed girdle hooklets. It may thus be considered one of the most primitive branched-armed gorgonocephalids.

DISTRIBUTION. Southern Japan, Celebes, north-western Australia.

BATHYMETRIC RANGE 201–457 m.

Astrosierra new genus

DIAGNOSIS. A multi-armed gorgonocephalid with short arms (3× d.d.), 7–10 branches on main arm

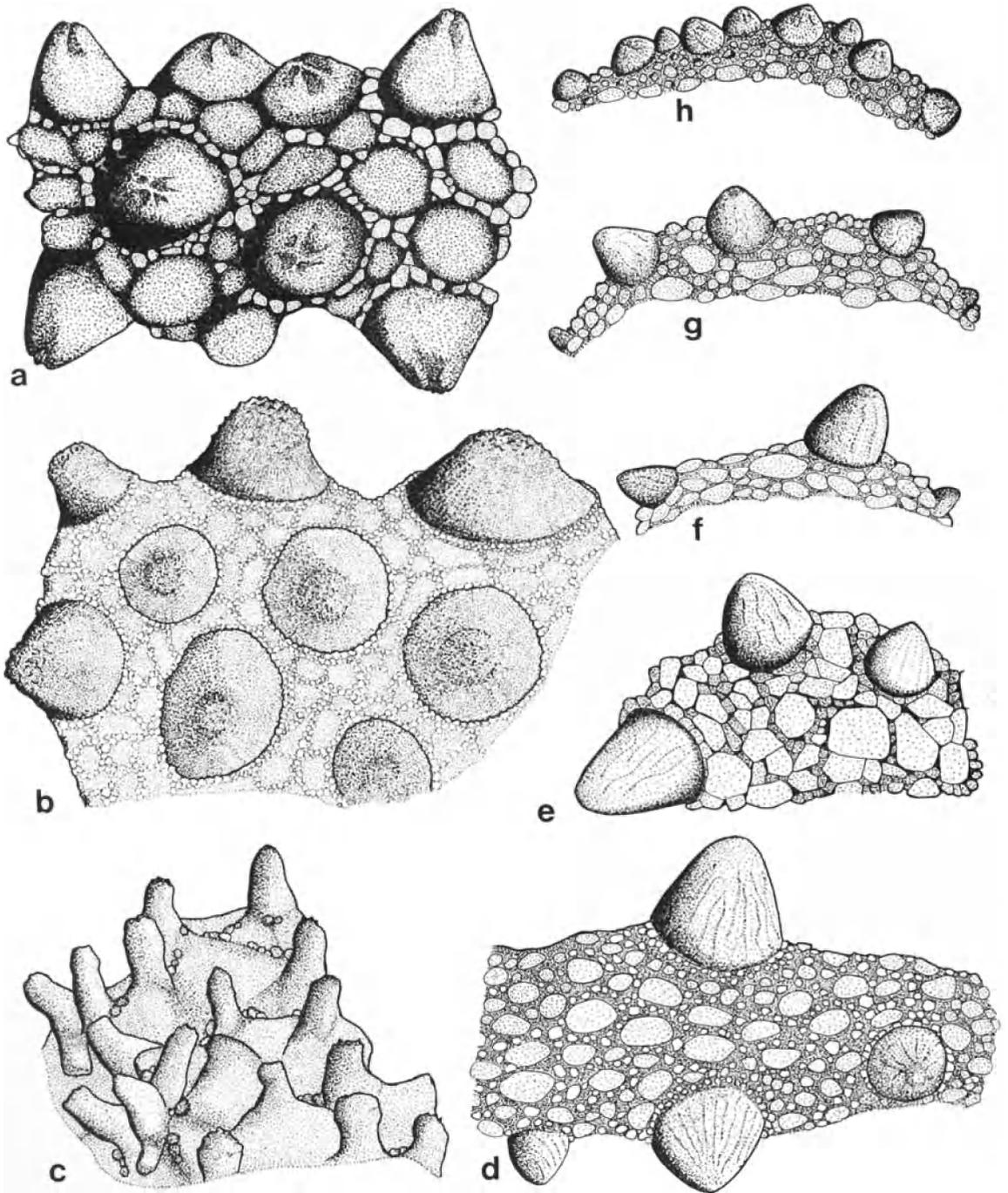


Fig. 12. a–e, surface of radial shield of: (a) *Astrosierra densus* (Fraser I; holotype, AM J12934); (b) *A. amblyconus* (Cronulla; NMNZ Ech. 1446); (c) *A. microconus* (Jurien Bay; NMNZ Ech. 2906); (d) *Conocladus australis* (S of Gabo I.; NMNZ Ech. 2907); (e) *C. australis* (Wata Mooli; AM G7924; identified as *C. oxyconus* by H. L. Clark). f–h, *C. australis*, dorsal surface of a proximal arm segment: (f) Wata Mooli, NSW (AM J7924); (g) upper Spencer Gulf, S.A. (NMNZ Ech. 2908); (h) Dunsborough, W.A. (NMNZ Ech. 1849).

stem, and 12–15 (usually 14 or 15) joints with spines before 1st branch. Disc covered above with many large domed or conical tubercles separated by flat plates with or without sutural granules. Ventral inter-radial areas with up to 30 large tubercles set in soft, pustule-covered skin. Inter-radial area of oral frame paved with enlarged plates distinct from those adjacent. Dorsal and lateral arm surfaces covered with numerous large tubercles arranged in no definite pattern, but separated by flat plates. Up to 5 short arm spines, Girdle bands continuous after 2nd main arm branch; girdle hooklets with a secondary tooth. One madreporite present.

TYPE-SPECIES: *Conocladus amblyconus* H. L. Clark, 1909b.

INCLUDED SPECIES: *Conocladus microconus* H. L. Clark; *Astrosierra densus* n.sp.

REMARKS. The abundant material of multi-armed Australian gorgonocephalids now available has shown that the type-species for *Conocladus* H. L. Clark, 1909a—*C. oxyconus* H. L. Clark—is conspecific with *Astroconus australis* (Verrill). Consequently, *Conocladus* must take precedence over *Astroconus* Döderlein as the valid generic name for *Astrophyton australe* Verrill, 1876. This, then, leaves *Conocladus amblyconus* and *C. microconus* H. L. Clark without an available generic name.

It is for these last two species, plus a new one, that the name *Astrosierra* is here proposed; the suffix *sierra* (Spanish, from Latin) alludes to the mountain range-like covering of tubercles on the arms and disc.

Astrosierra amblyconus (H. L. Clark) (Fig. 12b, 13, 32)

Conocladus amblyconus H. L. Clark, 1909a: 549, pl. 55; 1916: 81; 1946: 179. —Döderlein, 1911: 70, pl. 9 fig. 4 & 4a. —Koehler, 1930: 15.

MATERIAL EXAMINED. 1 spec., off Cape Three Points, N.S.W., 41–44 m (holotype; AM G11434); 1 spec., off Port Kembla, N.S.W., 113–135 m (paratype; AM J835); 2 specs, off Crookhaven River, N.S.W., 89–90 m (paratypes; AM J1045, 1046); 4 specs, within Jervis Bay, N.S.W., 18–19 m (paratypes; AM J1054, 1055, 1057, 1058); 6 specs, off Wollongong, N.S.W., 100–102 m (AM); 10 specs, Shoalhaven Bight, N.S.W., 27–82 m (AM); 2 specs, 11 miles NW of Crowdy Heads, N.S.W., 91 m (AM); 1 spec., 8 miles E of Sandon Bluffs, N.S.W., 64–82 m (AM); 2 specs, Gabo I., Vic., 21 m (AM); 2 specs, W of Babel I., Bass Strait, 128 m (AM); 1 spec., off Cronulla, N.S.W., 16 m (NMNZ Ech 1446); 2 specs, off Sydney, N.S.W., 109–137 m (NMNZ Ech. 1960).

DESCRIPTION. Disc diameter < 35 mm. Disc weakly excavate inter-radially; arms relatively short (3 × d.d.). Disc covered above with 50–130 large tubercles

wider basally than high (4.5 × 2.5 mm), with smooth sides and a weakly crenulate, domed or low rounded top. Large tubercles surrounded by a belt of small (0.1–0.2 mm) grains which also line sutures of flat or concave plates separating tubercles. At disc centre tubercles crowded, 2 or more sometimes fused together. Usually a large tubercle bridging depression between radial shields.

Ventral inter-radial areas with up to 12 much lower tubercles surrounded by small, crowded grains. Genital slits short, stretching between segments 4 and 5 or 5 and 6. One large madreporite present on edge of oral frame.

Arms branching 7–10 times, wider basally than high, with a low, curved transverse profile and a flat ventral side. Dorsal and lateral arm surfaces covered with tubercles, plates, and grains similar to, but smaller than, those on the disc, in no regular arrangement proximally, but distally 1 low tubercle per segment, and at fine extremities segments uniformly granulated.

Girdle bands present from after 1st arm branch (just before, in young specimens), beginning as lateral patches, continuous only after at least 3rd arm branch; hooklets with a small, down-turned secondary tooth.

Ventral surface of arms, and oral frame, closely paved with flat, polygonal plates, those in inter-radial areas distinctly larger than surrounding plates. Before the 1st arm branch, 12–25 (usually 14) segments bear spines. First tentacle pore naked, 2nd bordered by 2 or 3 spines, thereafter 4, increasing to 5, short, stubby spines with 2–10 terminal points; distally 1 arm spine per segment, modified into a flat hooklet with 2 strength teeth. Short, blunt, spine-like oral papillae and an oral tentacle scale present; teeth spearhead-shaped or spiniform.

Colour: alive, disc and arms creamy-white, tubercles rusty red; red disappears in preserved or dried specimens.

REMARKS. *A. amblyconus* is the most easily recognised species in the *Astrosierra*–*Conocladus* complex, with its disc cover of large, domed tubercles surrounded by a lace-like network of small platelets (Fig. 12b).

DISTRIBUTION. South-eastern Australia, from Babel Island, Bass Strait, to northern New South Wales (29°41'S).

BATHYMETRIC RANGE 18–135 m.

Astrosierra microconus (H. L. Clark) n. comb. (Fig. 12c, 14, 32)

Conocladus microconus H. L. Clark, 1914: 156, pl. 25; 1946: 179.

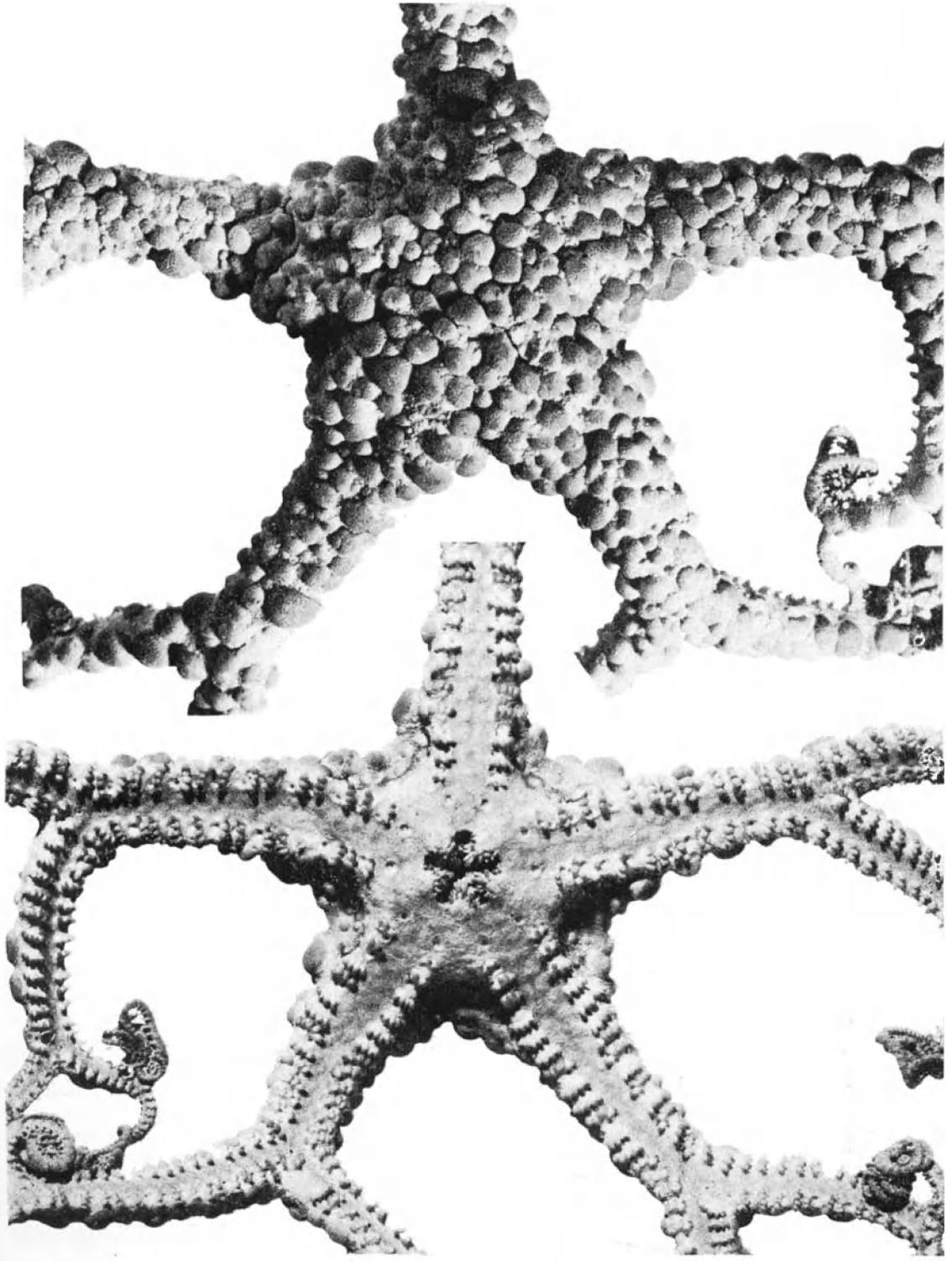


Fig. 13. *Astrosierra amblyconus*, Gabo I., Vic., 23.0 mm d.d.

MATERIAL EXAMINED. 1 spec., between Fremantle & Geraldton, W. A., 146–219 m (**holotype**; WAM 4921); 1 spec., 29°11–12'S, 113°52.2'–114°01'E, W of Dongara, W.A., 137 m (WAM 654–77); 1 spec., 29°15–16'S, 114°43–42'E, W of Dongara, W.A., 40 m; 1 spec., 29°59'S, 114°25'E, NW of Green Hd, W.A., 146 m (WAM); 2 specs, 30°37'S, 144°44'E, off Jurien Bay, W.A., 139–146 m (WAM & NMNZ); 1 spec., 31°04'S, 114°56'E, off Mandurah, W.A., 146–150 m (WAM); 1 spec., 33°06'S, 114°47'E, off Cape Naturaliste, W.A., 73 m (WAM); 1 spec., 34°18'S, 114°50'E, W of Cape Hamelin, W.A., 36 m (WAM).

DESCRIPTION. Disc diameter to 37 mm; arms short ($<3 \times$ d.d.). Disc weakly excavate inter-radially; each inter-radius deeply grooved on dorsal side of disc, outlining the 5 radial wedges. Upper disc surface closely covered with small, narrow, somewhat bottle-shaped tubercles up to 1.5 mm high, between which are smooth plates of irregular shape and size. Tubercles and plates arranged randomly on humps and in hollows and grooves, giving disc a very rough, jumbled appearance. Tubercles usually smooth-sided, with a fluted tip occasionally prolonged into several small points.

Inter-radial edge of disc with many small plates between bottle-shaped tubercles, below abruptly changing to skin encrusted with very small pustules and 20–30 large, round, conical or domed tubercles. Tubercles decrease in size towards oral frame, but continue across to jaws as a noticeable band of tumid plates different in size to those on radial areas. One small madreporite present, on edge of oral frame in 1 inter-radial area. Genital slits short, spanning arm segments 4 and 5 or 5 and 6.

Arms wider basally than high, covered dorsally with steep, uneven ridges bearing tubercles similar to those on disc, but with transversely widened bases; between ridges are smooth, polygonal plates. After 1st arm fork, ridges and tubercles weaken and intervening areas widen. Low tubercles persist on extremities of arms.

Girdle hooklets present as small patches low on arm, 1 per segment just before 1st arm fork, continuous bands after 3rd fork (in young specimens, after 1st fork), with a secondary tooth.

Ventral arm surface flat, covered with very fine, closely packed, low grains. Before 1st arm fork, 12–20 segments bear spines. First segment without spines, 2nd with 3, thereafter 4 or 5 per segment; spines short, flattened, with squared-off tips bearing 2–4 glassy points, distally reducing to a single hook with 2 large secondary teeth.

Oral papillae short, spiniform; teeth similar but longer. A papilla present on side of each jaw at a higher level.

Colour (dry) uniform grey-brown.

REMARKS. This Western Australian species is known from a relatively small area between Jurien Bay and Cape Hamelin. It is characterised by the disc cover of bottle-shaped tubercles, with few or no intervening platelets, arranged in a crowded, jumbled fashion (Fig. 12c). Specimens from the southern part of the range sometimes have wide-based, blunt tubercles with strong fluting, but are still recognisable as this species.

DISTRIBUTION. Western Australia.

BATHYMETRIC RANGE 36–219 m.

Astrosierra densus n.sp. (Fig. 12a, 15, 32)

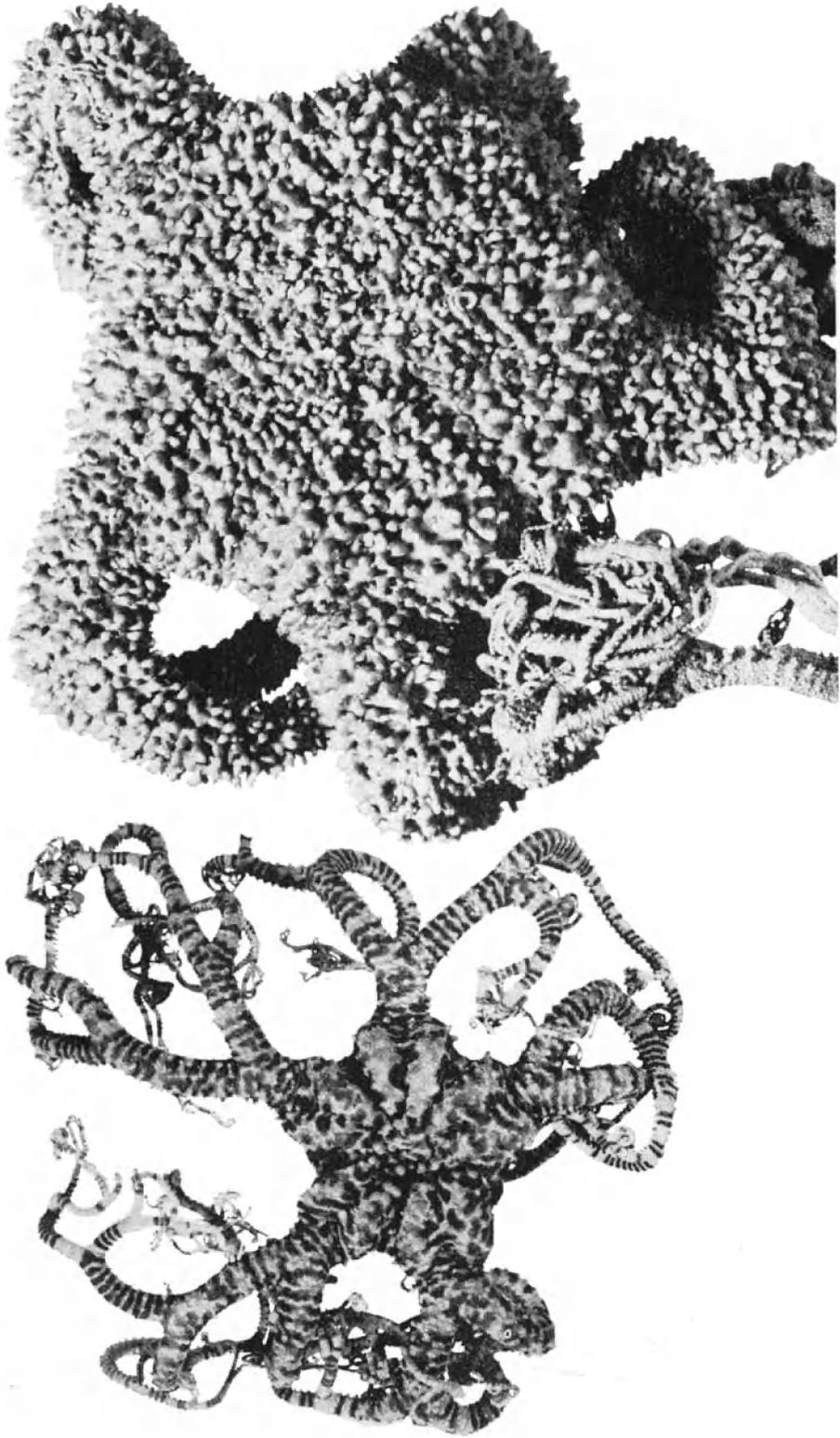
TYPE DATA. **Holotype** (29.0 mm d.d.): S of Fraser I., Qld, 25°48'S, 153°46'E, H.M.A.S. *Kimbla* Sta. QII, 73 m, 10 Nov 1976 (AM J12934). **Paratypes** (15.0–44.0 mm d.d.): 1, off Angourie, N.S.W., 27–25 m (AM J6658); 2, off Moreton Bay, Qld, 27°27.2'S, 153°39'E, 77 mm, 29 Mar 1969 (AM J8594); 2, off Stradbroke I., Qld, 27°00'S, 153°33'E, F.V. *Nimbus* Sta. 24, 95 m, 28 Jul 1968 (NMNZ Ech, 1860); 1, off Moreton I., Qld, ? depth (QM G2540); 1 [no locality data] (QM G8235).

DESCRIPTION OF HOLOTYPE. Arms partly coiled, but about 90 mm long and branching 9–10 times. Disc excavate inter-radially, sunken aborally in both radii and inter-radii. Radial shields long, narrow (18 × 4 mm), divergent distally, almost meeting proximally. Shields bear spaced, conical tubercles about as wide basally as high (up to 1.5 mm) and with a lightly fluted tip; between tubercles are low but slightly tumid polygonal plates 0.5–1.0 mm in diameter. On depressed sutures of these plates, and surrounding bases of most tubercles, are largely discontinuous rows of very small (0.1–0.2 mm) plates.

Dorsal inter-radial areas of disc covered with low, rounded tubercles up to 1.0 mm in diameter and many smaller intercalary plates; tubercles continue over on to ventral inter-radial areas, where they and the intervening plates become smaller and of more uniform size (0.5–0.1 mm). A series of similarly rounded plates extends across oral frame in each inter-radius. One square madreporite present, on edge of oral frame in 1 inter-radius. Genital slits span arm segments 3 and 4.

Arms wider basally than high, covered above with evenly spaced (1.0–1.5 mm apart) conical tubercles up to 1.2 mm wide and 1.0 mm high between which are flat, polygonal plates and smaller, raised plate-

Fig. 14. Upper, *Astrosierra microconus*, Dongara, W.A., 37.0 mm d.d. Lower, *Conocladus australis*, Gabo I., Vic., 30.0 mm d.d.



lets on sutures. Distally, tubercles become low and round, reduced to 2 or 3 per segment, and are surrounded by the now closely packed platelets.

Girdle hooklets present in small patches low on arms from 1st arm fork, becoming continuous bands after 2nd fork, with a secondary tooth.

Ventral arm surface flat, slightly depressed between segments, densely covered with small platelets, the sutures surrounding which are depressed. Arm spines 3-6 in number, short and fat (0.8 × 0.5 mm), surmounted by 2-5 glassy points, distally becoming compound hooklets with 2 or 3 teeth. Before 1st arm fork are 13 or 14 spined segments.

Oral papillae numerous, short, spiniform; teeth similar but longer. On sides of jaws, at a higher level, are 2 or 3 papillae.

ETYMOLOGY. The trivial name *densus* (Latin) alludes to the dense covering of tubercles on the disc and arms.

VARIATION. The Angourie specimen has a well eroded dorsal surface with many worn and pitted tubercles. The number of segments bearing spines before the first arm fork ranges from 12 to 21 in all the material examined, but 13 is the commonest number.

REMARKS. The new species is more closely related to *A. amblyconus* than to *A. microconus*, as might be expected from their respective distributions. It can be distinguished from *amblyconus* by the nature of the disc and arm cover (Fig. 12a-c). In *A. densus* the evenly spaced tubercles are conical rather than domed, and are smaller and more numerous; along with the low intervening plates they are surrounded by discontinuous single (rarely multiple) rows of platelets. In *amblyconus* these plates form continuous belts, giving a lace-like appearance to the disc surface.

DISTRIBUTION. Between Angourie, New South Wales, and Fraser Island, Queensland, eastern Australia.

BATHYMETRIC RANGE 77-95 m.

Genus *Conocladus* H. L. Clark

Conocladus H. L. Clark, 1909a: 132. -Döderlein, 1911: 37; 1927: 68 (in part).

Astroconus Döderlein, 1911: 36 (type-species *Astrophyton australe* Verrill, 1876). **New synonymy.**

TYPE-SPECIES: *Conocladus oxyconus* H. L. Clark, 1909b (= *Astrophyton australe* Verrill, 1876).

DIAGNOSIS. Multi-armed gorgonocephalid with short arms (3 × d.d.), up to 10 branches on main arm stems, and 6-16 (usually 8) arm segments with spines before 1st branch. Dorsal side of disc and arms covered with a mosaic of small, polygonal plates and platelets and well spaced, sculptured, conical tubercles. Ventral inter-radial areas of disc covered with platelets or small pustules of uniform size. Oral frame closely paved with uniform-sized polygonal plates. Girdle hooklets with a secondary tooth, present as patches between 1st and 2nd arm fork. One madreporite present.

REMARKS. As outlined under *Astrosierra*, the type-species of *Conocladus*, *C. oxyconus*, is conspecific with *Astroconus australis*, and thus *Conocladus* must take priority over *Astroconus* as the valid generic name for Verrill's *Astrophyton australe*.

In my opinion, *Conocladus* is a monotypic genus closely related to *Astrosierra*. I am convinced that the two should be separated at this level, not because of the shape and united or divided nature of the "radial wedges", as maintained by H. L. Clark (1916), but because of the very constant differences in the number of arm segments before the first arm fork and the tuberculation of the oral frame and ventral inter-radial areas of the disc. In these—and indeed most other—respects *Astrosierra* is the more stable genus, and thus may be considered the older, a view also held by Döderlein (1927) with regard to *C. amblyconus*.

Conocladus australis shows clinal variation from east to west, and has what may be regarded as incipient subspecies (*oxyconus* and *occidentalis*) at these extremes of its range. It would thus seem that *Astrosierra*, having had sufficient time to speciate and segregate, has given rise to *Conocladus*, which is still going through the process.

Conocladus australis (Verrill) n.comb. (Fig. 12d-h, 14, 16, 17, 32)

Astrophyton australe Verrill, 1876: 74.

Conocladus oxyconus H. L. Clark, 1909b: 32, pl. 1 fig. 1-3; 1909a: 550; 1916: 81; 1946: 179. **New synonymy.**

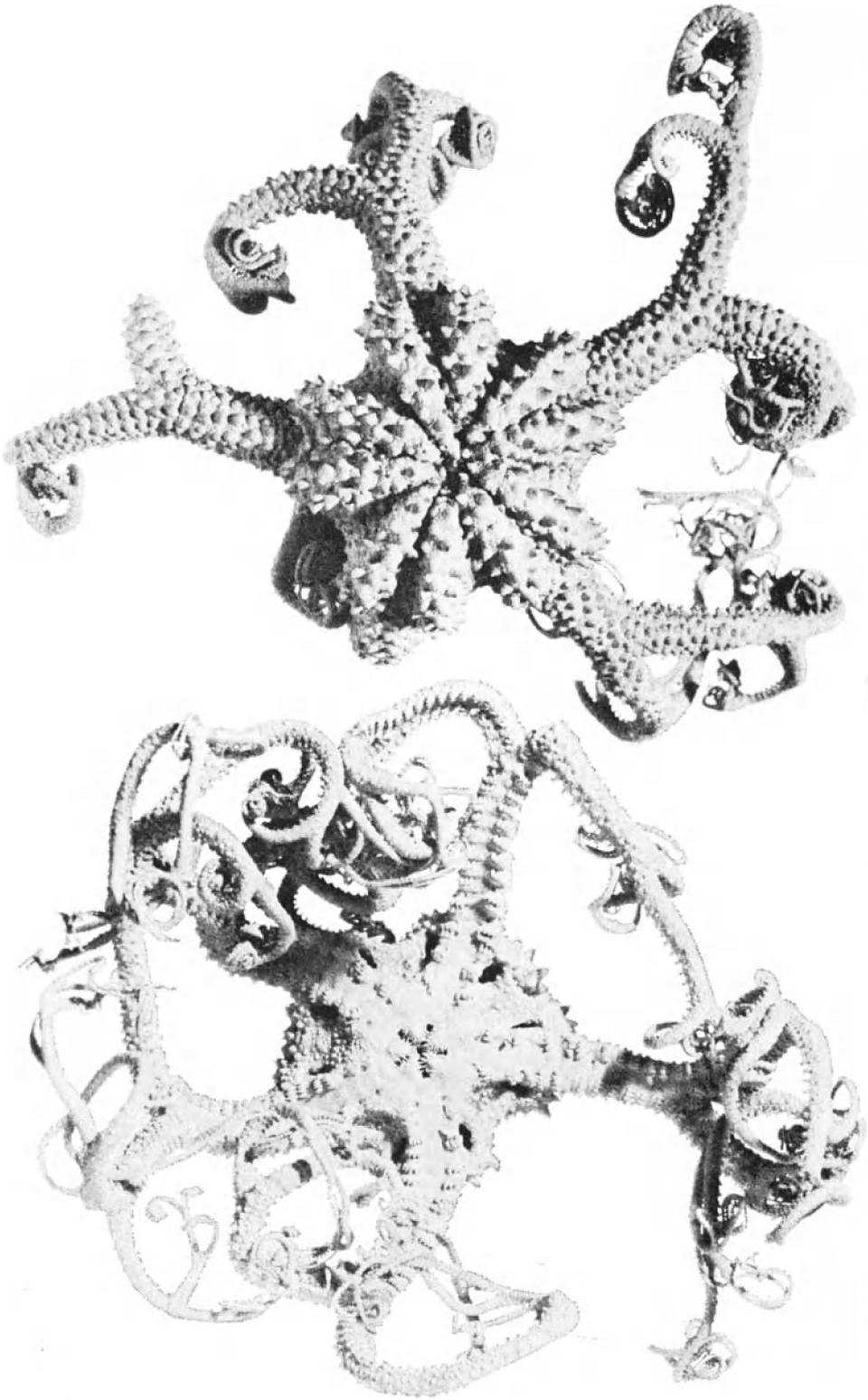
Astroconus australis: Döderlein, 1911: 37, fig. 7, pl. 5 fig. 2 & 2a. -H. L. Clark, 1916: 82; 1928: 419; 1938: 205; 1946: 180.

Astroconus annulatus Koehler, 1930: 16, pl. 1 fig. 8-10. -H. L. Clark, 1946: 179.

Astroconus occidentalis H. L. Clark, 1938: 205, pl. 23 fig. 2; 1946: 181. **New synonymy.**

Astroconus pulcher H. L. Clark, 1939: 207, pl. 18; 1946: 180. **New synonymy.**

MATERIAL EXAMINED. 1 spec., 8 miles E of Sandon Bluffs, N.S.W., 64-73 m; 1 spec., Port Stephens,



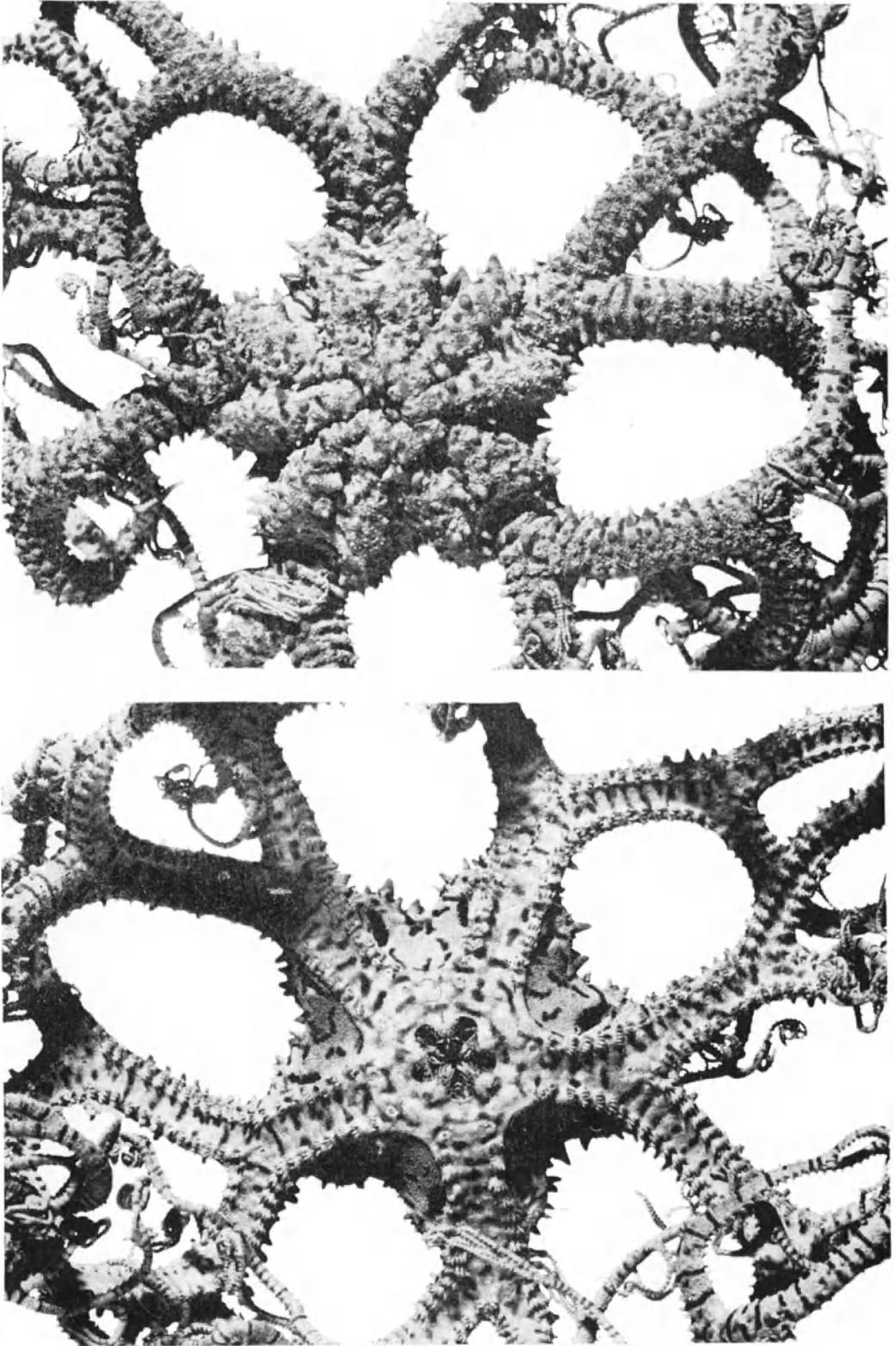


Fig. 16. *Conocladus australis*, Malacoota, Vic., 30.0 mm d.d.

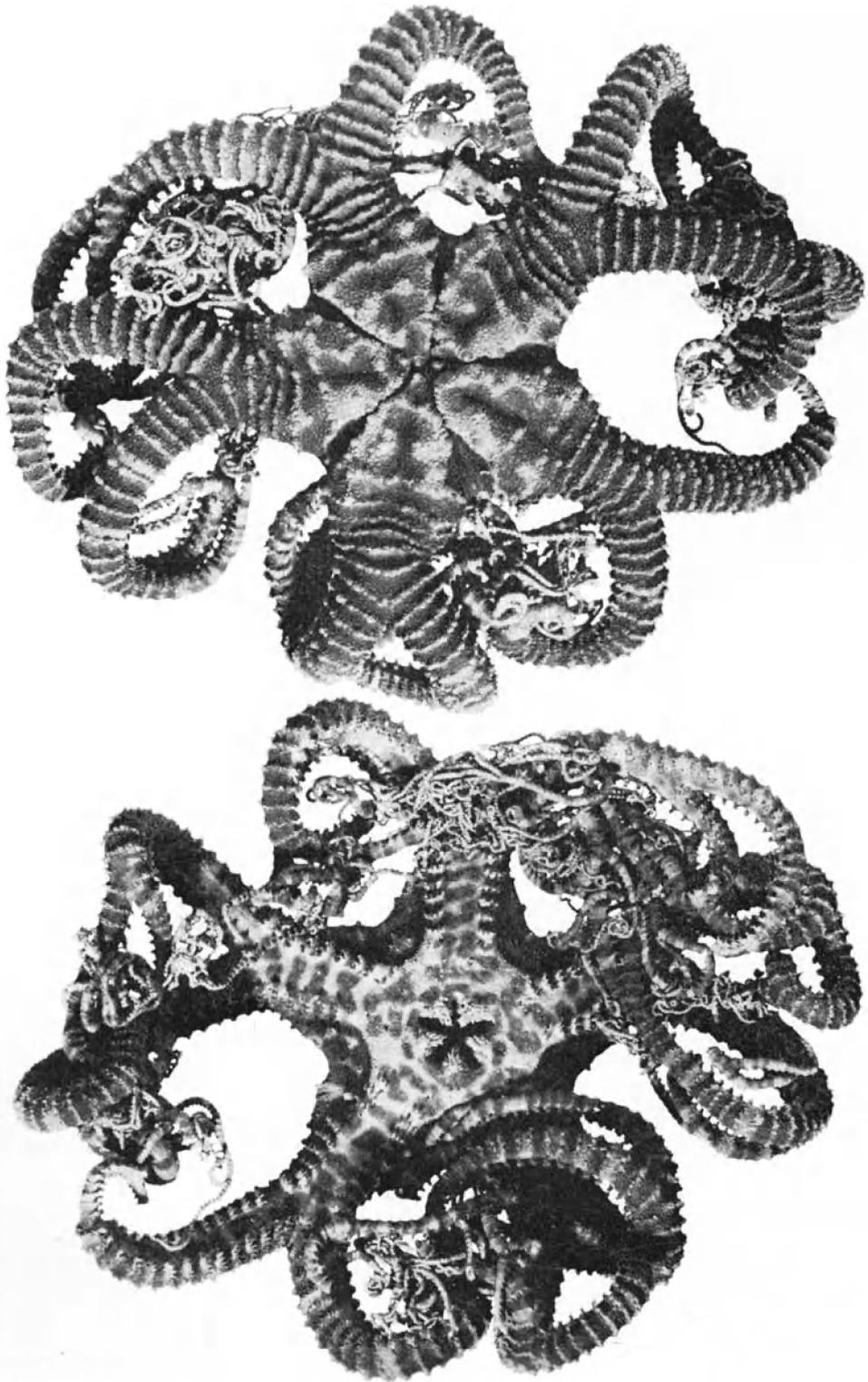


Fig. 17. *Conocladus australis*, Dunsborough, W.A., 26.0 mm d.d.

N.S.W., 15 m; 1 spec., off Port Jackson, N.S.W., "deep water"; 1 spec., off Coogee, N.S.W., 89–91 m (AM J2261; identified by H. L. Clark as *C. oxyconus*); 1 spec., off "Wata Mooli", N.S.W., 128–142 m; 2 specs, off Cronulla, N.S.W., 70–75 m; 2 specs, SW of Jervis Bay, N.S.W., 157 m; 2 specs, lower N.S.W. coast, ? depth; 2 specs, Shoalhaven Bight, N.S.W., 27–82 m (one, AM E175, identified by H. L. Clark as *C. oxyconus*); 6 specs, Gabo I., Vic., 20–24 m; 4 specs, S of Gabo I., Vic., 365 m; 1 spec., 20 miles SSW of Cape Everard, Vic., 106 m; 8 specs, E slope of Bass Strait, 128–182 m (AM E4727, identified by H. L. Clark as *A. australis*); 3 specs, Erith I., Bass Strait, 50 m; 4 specs, Deal I., Bass Strait, 50 m; 3 specs, E of Babel I., Bass Strait, 62–66 m; 1 spec., Banks Strait, Tas., 73 m; 1 spec., Banks Strait, Tas., 13 m (AM J6344; identified by H. L. Clark as *A. australis*); 1 spec., off Tamar Hds, Tas., 46 m; 1 spec., Bicheno, Tas., 22 m; 3 specs, Oyster Bay, Tas., 46 m; 1 spec., off Little Swanport, Tas., 13–15 m; 3 specs, NE Cape Pillar, Tas., 91–146 m; 2 specs, D'Entrecasteaux Channel, Tas., ? depth; 1 spec., 35 miles SE of Bruny I., Tas., 274–420 m; 1 spec., Pedra Blanca, Tas., 100 m; 1 spec., 1 mile SE of Mewstone Rock, Tas., 128 m; 1 spec., King I., Bass Strait, ? depth; 1 spec., 36 miles SW of Cape Wickham, King I., ? depth; 1 spec., between Devonport & Launceston, Tas., ? depth; 3 specs, 25 miles SE of Cape Everard, Vic., 128–164 m; 1 spec., off Lakes Entrance, Vic., 26 m; 8 specs, Bass Strait, ? depth; 1 spec., E of Seaspray, Vic., 55 m; 11 specs, East Gippsland, Vic., 31–54 m; 1 spec., 5 km off Waratah Bay, Vic., ? depth; 1 spec., Beaumaris, Vic., 18 m; 1 spec., Queenscliff, Vic., ? depth (NMV, identified by H. L. Clark as *A. australis*); 1 spec., 3 miles S of Port Phillip Hds, Vic., ? depth; 1 spec., 5 miles S of Port Phillip Hds, Vic., ? depth; 1 spec., SE of Portland, Vic., 219–292 m; 1 spec., Portland, Vic., ? depth; 6 specs, W of Cape Nelson, Vic., 164–201 m; 11 specs, 40 miles W of Kingston, S.A., 55 m; 1 spec., off Murray Mouth, S.A., 55 m; 2 specs, Encounter Bay, S.A., ? depth; 1 spec., Backstairs Passage, S.A., 50 m; 6 specs, off Pt Marsden, Investigator Strait, S.A., 20 m; 1 spec., Investigator Strait, S.A., 30 m; 1 spec., Sanders Bank, Kangaroo I., S.A., 51 m; 1 spec., off Cape Dutton, Investigator Strait, S.A., 37 m (**holotype** of *Astroconus pulcher* H. L. Clark; SAM K561); 1 spec., Christies Bch, St Vincent Gulf, S.A., 6 m; 1 spec., 15 miles S of Cape Wiles, S.A., ? depth; 1 spec., Baird Bay, S.A., ? depth; 1 spec., 15 miles S of St Francis I., S.A., 55 m; 3 specs, Nuyts Achipelago, S.A., 27–35 m; 27 specs, nr Flinders Reef, Denial Bay, S.A., 49 m; 10 specs, "South Australian Coast", ? depth (SAM); 2 specs, Emu Pt, Albany, W.A., ? depth; 8 specs, off Dunsborough, Geographe Bay, W.A., 16–36 m; 1 spec., Bussleton, W.A., ? depth; 1 spec., off Ludlow, W.A., 10 m; 6 specs, Bunbury, W.A., 16 m; 1 spec., W. Rottnest I., W.A., ? depth; 1 spec., North Beach, Fremantle, W.A. (**holotype** of *Astroconus occidentalis* H. L. Clark; WAM 116–37); 2 specs, W of Lancelin, W.A., 73 m.

DESCRIPTION. Disc diameter 3.5–55 mm; arms 3 × d.d., branching up to 10 times. Disc not usually deeply excavate inter-radially, covered above with flat or slightly concave or convex polygonal plates up to 2.5 mm in diameter, surrounded by smaller, flat or tumid platelets which are usually very dense

but sometimes form narrow, ladder-like belts between larger plates. Scattered over disc on radial shields and inter-radial areas are spaced, conical tubercles, usually higher than wide, up to 3.5 mm high, and often with some form of terminal fluting or other sculpturing. Tubercles arranged in no definite pattern, though often more common on—or even restricted to—radial shields, and sometimes form transverse ridges across distal ends of shields.

Ventral inter-radial areas covered with small, crowded platelets or pustules, rarely a few larger tubercles. Genital slits short, wide, spanning arm segments 4–6. One small madreporite present, at inner edge of ventral interbrachium.

Arms wider basally than high, flat ventrally, curved dorsally. Dorsal and lateral surfaces covered with tubercles and plates like those on disc; tubercles arranged in single or alternating double median row with interspaces equal to tubercle diameter, or in transverse bands with 3–12 tubercles situated on a slightly raised ridge.

Girdle hooklets present as patches low on arms after 1st fork, becoming continuous bands between 2nd and 3rd forks, with 1 secondary tooth.

Ventral arm surface and oral frame closely paved with small, slightly raised polygonal plates. Arm spines begin at 2nd segment; initially 3 or 4 per segment, increasing to 5 or 6; spines short, flat, with 4–6 glassy terminal points, distally becoming compound hooklets. Before 1st fork on most arms are 6–16 (usually 8) spined segments, occasionally more on one arm only.

Oral papillae short, blunt; teeth spiniform, twice as long as papillae. Oral tentacle pores encased in tubes of small platelets.

Colour pattern very diverse: in preserved specimens, from pale grey to dark brown with dark or pale lines and spots on disc and arms, the large tubercles mostly paler than surrounding areas, and the arms usually banded, with the strips between tubercles dark; in life, dark pigment red or black.

REMARKS. This diverse species has been described under five separate names. H. L. Clark on two occasions (1909a, 1916) discussed whether *C. oxyconus* and *Astroconus australis* are extremes of one species, but never had sufficient material from throughout the total range to settle the matter. He did, however, synonymise *Astroconus annulatus* Koehler with *C. oxyconus* (Clark 1946). The vast amount of material now available, particularly from southern Australia, has led me to believe that *oxyconus* and *occidentalis* are eastern and western extremes of the one clinal species, *australis*. *Astroconus pulcher* H. L. Clark is an intermediate.

The morphological features showing clinal variation are the disposition of the large tubercles on the

disc and arms and the number and height of the intervening plates (Fig. 12d-h). Some specimens—mainly from the south-eastern corner of Australia, but also westward to Spencer Gulf, South Australia—have few but large tubercles on the disc and arms and many large, flat, intervening plates sparsely surrounded by small, flat platelets. Included among these specimens are some identified by H. L. Clark as *C. oxyconus*. In the middle of the range (i.e., Tasmania-Victoria-South Australia) there occur specimens intermediate between the above condition and the more common one in which the tubercles are smaller and more numerous and the intervening large plates are fewer, smaller, slightly tumid, and surrounded by many tumid plates. The arm tubercles of these mid-range specimens are in various stages of band formation; this is not a size-related feature, for small specimens can have strong annulations on the arms. In the extreme west of the range the tubercles are arranged in distinct, raised, transverse bands along the entire length of the arms, one band of 8-12 tubercles on each segment. This is the form described by H. L. Clark as *Astroconus occidentalis*, and its very slight variations in the pattern of tuberculation probably indicate that the population is closer to becoming a separate species than any elsewhere in the range of *C. australis*. There are, however, specimens from the northern Great Australian Bight (Nuyts Archipelago) and Tasmania (Erith Island) that show identical arm banding to the western form.

Conocladus australis is thus an endemic Australian shallow-water gorgonocephlid showing east-west clinal variation.

DISTRIBUTION. Australia, from northern New South Wales (29°41'S) along the eastern and southern coasts, including Tasmania, to Western Australia as far north as Jurien Bay (30°37'S).

BATHYMETRIC RANGE 6-420 m.

Genus *Gorgonocephalus* Leach, 1815

TYPE-SPECIES: *Asterias caputmedusae* Linné, 1758.

Gorgonocephalus chilensis (Philippi) (Fig. 18d, 19, 30)

Astrophyton chilense Philippi, 1858: 268.

Gorgonocephalus chilensis. Lyman, 1882: 261. —Döderlein, 1927: 30 (synonymy to 1923). —Fell, 1958: 20.

Gorgonocephalus chilensis var. *novaezelandiae* Mortensen, 1924: 109, pl. IV fig. 1.

MATERIAL EXAMINED. 1 spec., Cook Strait, N.Z., 182 m (holotype of *G. chilensis* var. *novaezelandiae* Mortensen; NMNZ Ech. 1193); 1 spec., Cook Strait, N.Z., 256 m (NMNZ); 5 specs, 41°30.5'S, 174°54'E,

Cook Strait, N.Z., 640-658 m (NMNZ); 1 spec., 43°54'S, 179°44'W, W of Chatham Is, NZOI Sta. G200, 395 m; 1 spec., 44°00.5'S, 178°38'W, W of Chatham Is, NZOI Sta. G355, 432 m; 4 specs, 44°05'S, 176°12'E, western Chatham Rise, NZOI Sta. J55, 198 m.

DESCRIPTION. Disc diameter to 80 mm. Disc moderately deeply but narrowly excavate inter-radially, with a thick ring of peripheral plates. Radial shields very conspicuous, narrow, almost parallel-sided, tapering only near disc centre. Shields and peripheral ring moderately or densely covered with conical tubercles that are higher than wide. Disc centre and other soft areas skin-covered, with scattered tubercles. Ventral interbrachia with many low pustules and a few scattered conical tubercles which encroach on to oral area and form a row along edge of genital slits.

Arms branched at least 10 times. First segment with no arm spine, the next 2 with 2 spines, the next 8 or 9 with 3, and thereafter 4 or 5 spines per segment, reducing to 3 or 2 after the 5th fork. Spines short (one-quarter to one-fifth an arm width long), slightly flattened, unevenly pointed, distally transforming into multitoothed hooklets. Tentacles enclosed in a tube of small plates.

Dorsal arm surface covered with domed or conical tubercles that initially are rather sparse, particularly on sides. On proximal segments are occasional bare, flat plates; bare areas corresponding to girdle bands occur further along arm. After 2nd or 3rd arm fork, surface densely covered with closely packed tubercles. Underarm surfaces with small, evenly distributed granules.

Girdle bands begin at 2nd fork as 3 isolated clumps each side of arm, become continuous over arm after 4th fork, raised above surface of arms only after 6th or 7th fork. In mid arm, bands preceded by a transverse row of raised tubercles which give the arms an annulated appearance. Girdle hooklets with a small secondary tooth.

Teeth and papillae undifferentiated, spiniform. Oral shields obscure, triangular, with apex inward; adorals squarish. One, occasionally 2 madreporites present.

Colour: disc pale brown, radial shields, tubercles, and arms cream.

REMARKS. The 14 examples of this long-known species show little variation. The number of tubercles on the disc and radial shields varies slightly, but the pattern of distribution of tubercles is very constant. A feature of the tuberculation which distinguishes *G. chilensis* from other species in the region is the continuation of tubercles from the distal ends of the radial shields obliquely down on to the thickened peripheral disc plates. In the other species there is a distinct gap in tuberculation at the ends of the shields,

after which tubercles reappear on the peripheral band. Also, in *G. chilensis* the interbrachial area of the disc is narrower (18–27% d.d.) than in other species.

A specimen from off the Argentinian coast (38°15'S, 54°20'W) differs little from the New Zealand examples. There is certainly no justification for maintaining Mortensen's variety *novaezealandiae*.

DISTRIBUTION. New Zealand, Chile, Argentina, Falkland Islands, South Africa, Kerguelen Island.

BATHYMETRIC RANGE 22–658 m.

Gorgonocephalus dolichodactylus Döderlein (Fig. 18a, 20, 30)

Gorgonocephalus dolichodactylus Döderlein, 1911: 34, fig. 6a–d, pl. 1 fig. 4 & 5, pl. 4 fig. 6, pl. 7 fig. 3 & 4b; 1927: 27, 92 (synonymy to 1927).
–A. H. Clark, 1949: 13.

MATERIAL EXAMINED. Fragments, 33°32'S, 152°00'E, off Broken Bay, N.S.W., 823 m (AM); 2 specs., 33°43–40'S, 152°55–57'E, E of Broken Bay, N.S.W., 823 m (AM); 1 spec., 34°47.5'S, 151°14'E, off Gerringong, N.S.W., 503 m (AM); 1 spec., 35°01'S, 174°58'E, NE of Bay of Islands, N.Z., NZOI Sta. 145, 585 m; 3 specs., 36°32'S, 176°14'E, E of Cuvier I.,

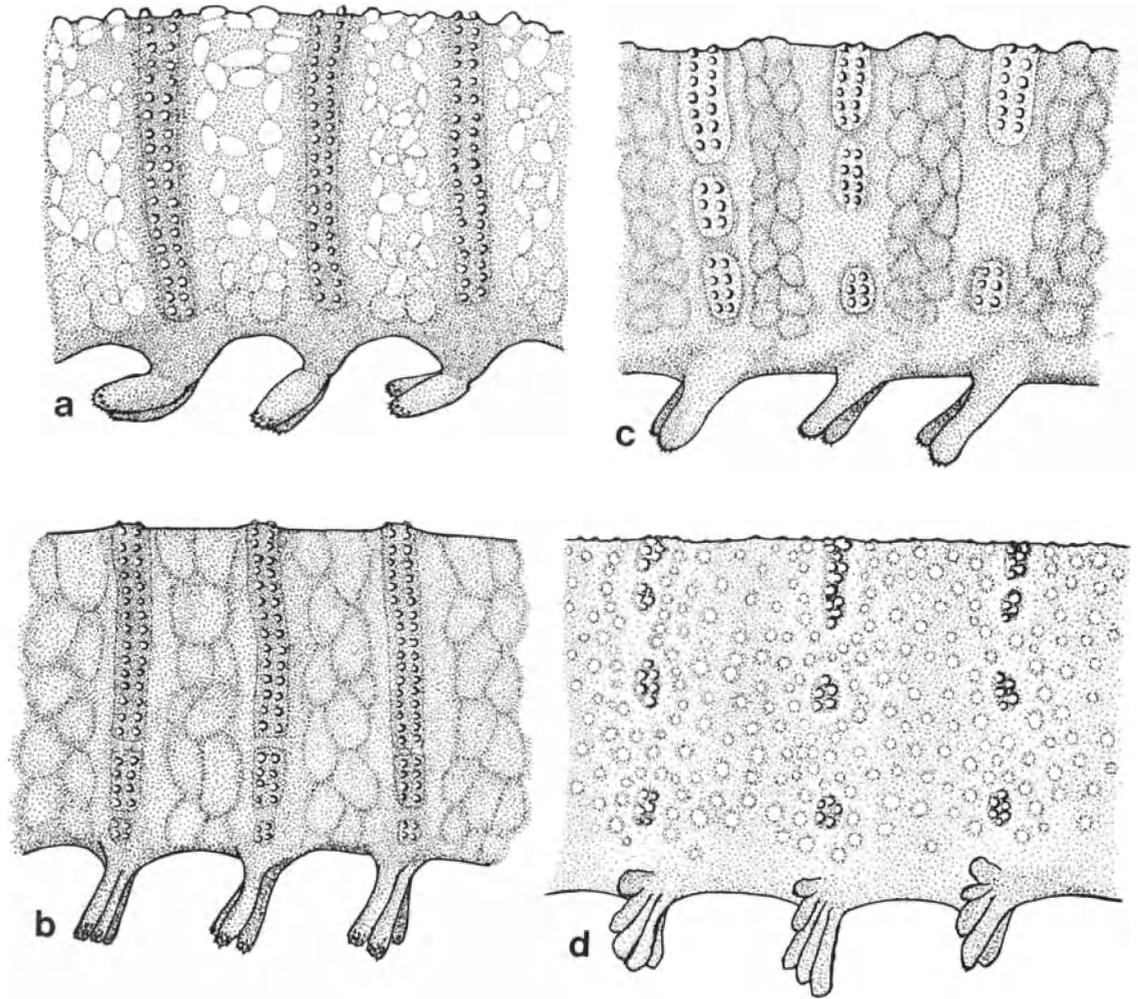
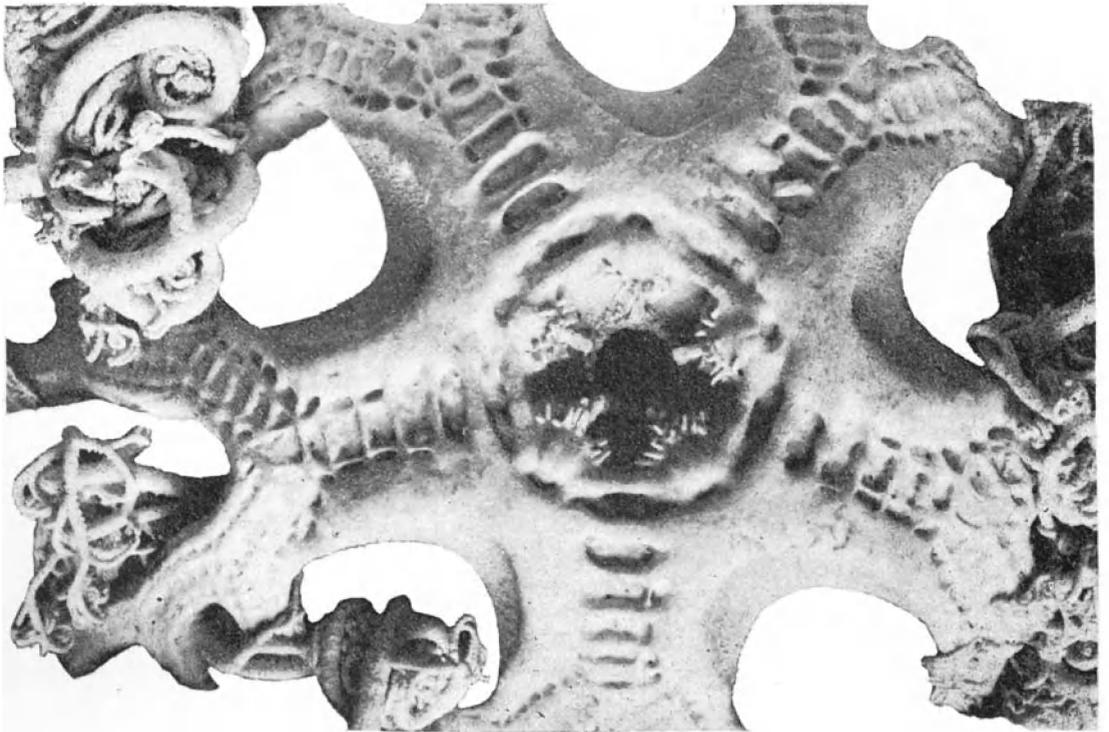
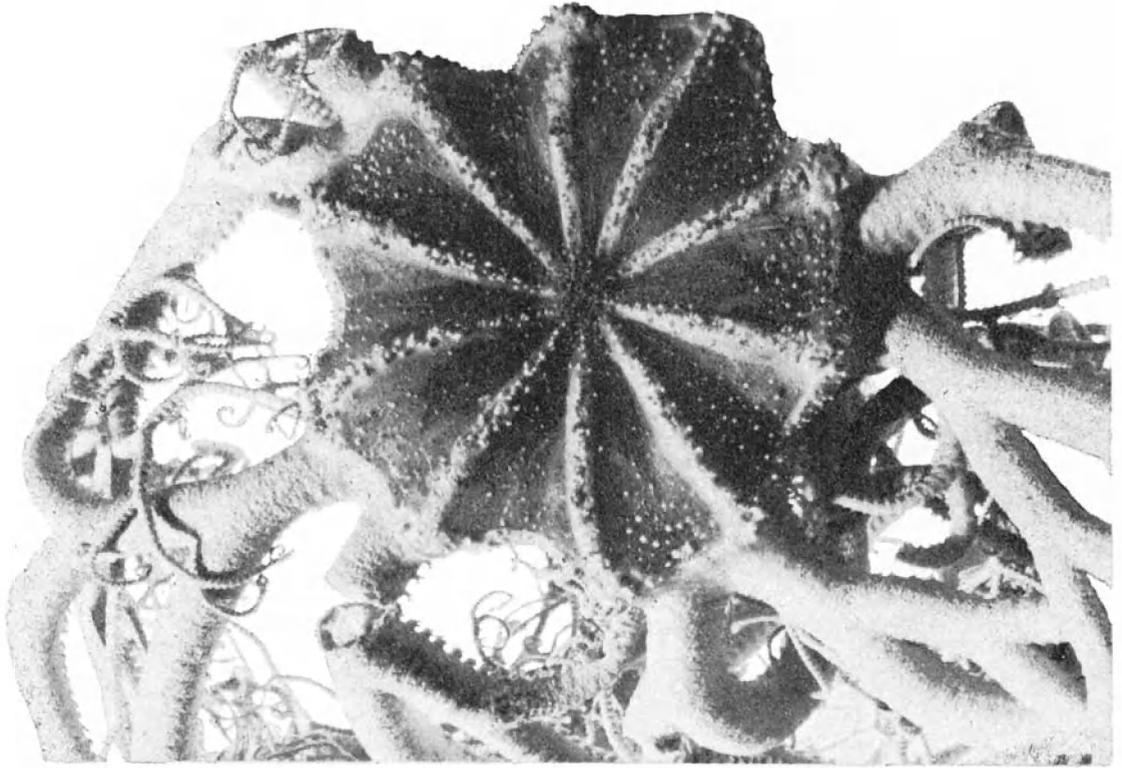


Fig. 18. *Gorgonocephalus* spp., lateral views of arm bases: a, *G. dolichodactylus* (E of Broken Bay; AM J9080); b, *G. pustulatum* (NW of Cape Egmont; NZOI); c, *G. sundanus* (Celebes; holotype, USNM E1473); d, *G. chilensis* (Chatham Rise; NZOI).

Fig. 19. Upper, *Gorgonocephalus chilensis*, Chatham Rise, 38.0 mm d.d. Lower, *Astroglymma sculptum*, NW Cape, W.A., 50.0 mm d.d.



N.Z., 480–455 m (NMNZ); 6 specs, 37°20.6'S, 176°28.0'E, E of Mayor I., N.Z., 482–550 m (NMNZ); 1 spec., 37°31'S, 176°18.5'E, off Mayor I., N.Z., 475–420 m (NMNZ); 1 spec., 37°23.5'S, 178°11'E, off Lottin Pt. N.Z., NZOI Sta. F871, 547–470 m; 1 spec., 38°40.1'S, 178°32'E, E of Poverty Bay, N.Z., NZOI Sta. E716, 551 m; 1 spec., 42°00.8'S, 174°41'E, SE of Cape Campbell, N.Z., 939–1019 m (NMNZ).

DESCRIPTION. Disc diameter to 83 mm. Disc moderately deeply and widely excavate inter-radially, with a thin ring of peripheral plates. Radial shields narrow, widest distally, tapering evenly towards disc centre. Shields with a dense covering of domed or pointed tubercles that are higher than wide. Peripheral plates with less dense tuberculation not continuous with that on shields. Disc centre and other soft areas mostly naked, occasionally with a very few small grains. Ventral interbrachia covered with low grains that are denser adorally and usually present in varying quantities and sizes on oral shield area. Genital slits bordered by a double row of slightly large tubercles.

Arms branched at least 10 times. First arm segment usually without spines, the next 6 with 2 (sometimes 3) spines; between 1st and 2nd forks are 3 spines per segment, thereafter only 2, and finally 1. Inner spine longest. Spines short, cylindrical, with blunt, prickly tips, distally becoming two-toothed hooklets.

Dorsal arm surface initially paved with polygonal plates that are wider than long, and low, scattered, domed tubercles. Further along arm, tubercles become denser, close-packed, and form a transverse ridge immediately distad of girdle bands. In large specimens (70+ mm d.d.) a second, incomplete ridge develops on proximal side of girdle bands.

Ventral arm surface with scattered low grains adjacent to each tentacle pore before 1st fork, and 1 or 2 higher granules similar to those on soft interbrachia.

Girdle bands begin near disc, become continuous over arm before 1st fork; hooklets with a long, strongly curved end tooth but usually no secondary tooth, although occasionally a rudimentary one may occur.

Teeth and papillae undifferentiated, spiniform. Oral and adoral shields obscure, but adorals large. One madreporite present.

Colour: disc reddish or dark brown, radial shields paler, arms pinkish or grey.

REMARKS. This species is well characterised by the nature of its girdle hooklets and the relatively wide inter-radial areas (30–39% d.d.). The shape and arrangement of the radial shields and the pattern of

tuberculation on them and on the peripheral disc plates is very constant in the specimens examined, and may also serve to distinguish the species from the other three *Gorgonocephalus* in the region.

G. dolichodactylus is a new record for the South Pacific.

DISTRIBUTION. Japan, Philippine Islands, Australia, New Zealand.

BATHYMETRIC RANGE 150–897 m.

Gorgonocephalus pustulatum (H. L. Clark)
(Fig. 18b, 20, 30)

Astrodendrum pustulatum H. L. Clark, 1916: 84, pl. XXXIV fig. 1 & 2; 1946: 181. Not Döderlein, 1927: 32.

Gorgonocephalus moluccanus Döderlein, 1927: 26, pl. 2 fig. 2 & 2b. **New synonymy.**

Gorgonocephalus pectinatus Mortensen, 1933b: 281, fig. 16, pl. XVIII fig. 1 & 2. **New synonymy.**

Gorgonocephalus pustulatum. Baker, 1974: 252.

MATERIAL EXAMINED. 1 spec., E of Flinders I., Bass Strait, 182–548 m (**holotype**; AM E4700); 2 specs, 48°14'S, 179°41'E, SE of Bounty Is, N.Z., NZOI Sta. G886, 370 m; 1 spec., 38°39'S, 172°38'E, NW of Cape Egmont, N.Z., NZOI Sta. E906, 691–751 m; 1 spec., 1°53'30"S, 127°39'E, Pitt Passage, Gomomo I., Indonesia, 731 m (**holotype** of *G. moluccanus* Döderlein; USNM E1472); 2 specs, 28 miles NE by E of Cape Point, South Africa, 549 m (RSAM); 4 specs, Table Bay bearing Lion's Head SE by E 50 miles, South Africa, 421 m (RSAM); 2 specs, off Buffels River, NNE 17 miles, South Africa, 355 m (RSAM).

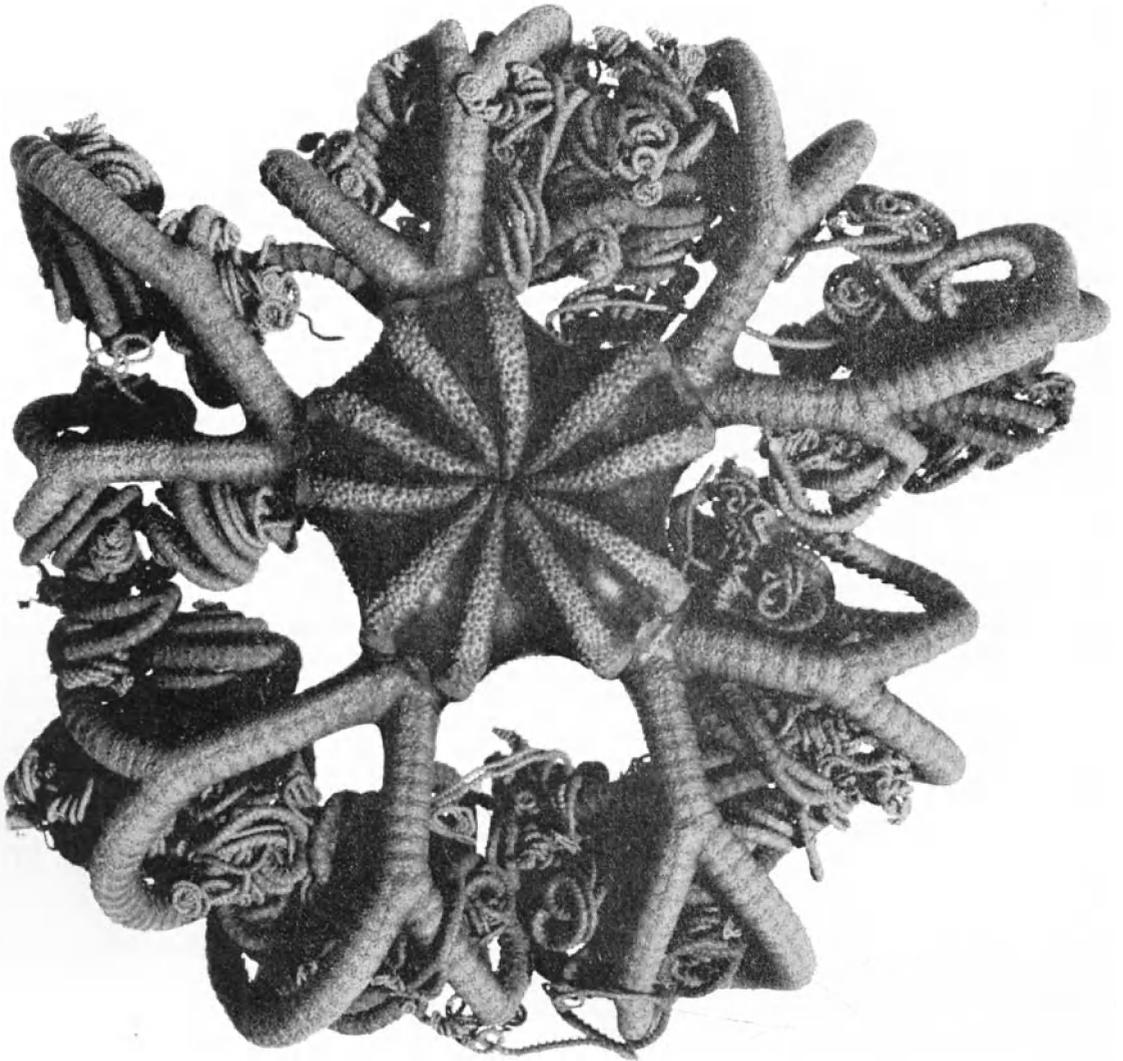
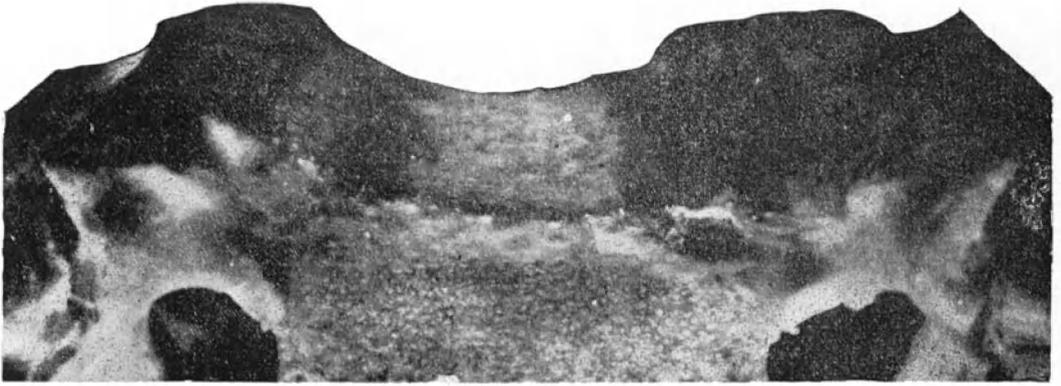
DESCRIPTION. Disc diameter to 60 mm. Disc moderately deeply and widely excavate inter-radially, with a thin ring of peripheral plates. Radial shields narrow, tapering towards disc centre. Shields, peripheral ring, and soft areas of disc with a sparse covering of low, smooth or thorny tubercles. Ventral inter-radii covered with numerous scale-like pustules. Genital slits edged with a few larger tubercles not arranged in a series.

Arms branched at least 8 times. First arm segment with no arm spine, the next 4–6 segments with 2 spines, thereafter 3 or 4 per segment gradually reducing to 1 distally. Spines short, cylindrical, with a blunt, prickly tip, distally becoming multi-toothed hooks.

Dorsal arm surface between girdles covered with low, smooth, transversely elongated plates and occasional pustules. Girdle bands sinuous, raised above arm surface, initially in isolated clusters but continuous from near arm base; hooklets with a very small secondary tooth.

Ventral arm surface smooth, with scattered, low

Fig. 20. Upper, *Gorgonocephalus pustulatum*, holotype (AM E4700). 40.0 mm d.d., view of inter-radial girdle. Lower, *G. dolichodactylus*, Mayor I., N.Z., 40.0 mm d.d.



pustules; oral and adoral shields similarly covered. Teeth and papillae spiniform; upper teeth stout, with flattened ends.

Colour: disc dark brown or red, radial shields and arms pale brown.

REMARKS. In general facies this species is nearer the *dolichodactylus-sundanus* group than the *chilensis-caryi* group in *Gorgonocephalus*. It is characterised by wide interbrachia, a thin peripheral ring, sparse, low tuberculation, and a maximum of four arm spines. Its position was not at all clear until I examined the holotype of Döderlein's *G. moluccanus* (an adult specimen of 60 mm d.d.) and the series of Mortensen's *G. pectinatus*. As is typical in the genus, there is considerable variation in the amount of disc tuberculation, and that feature cannot be used on its own to separate the species. The Indonesian, Australian, and Indian Ocean specimens show, however, a similar gradation of tuberculation in association with the other features, and I am unable to satisfactorily separate them. Consequently, *G. moluccanus* and *G. pectinatus* are here regarded as synonymous with *G. pustulatum*.

DISTRIBUTION. Western Indian Ocean, Indonesia, Australia, New Zealand.

BATHYMETRIC RANGE 421–751 m.

Gorgonocephalus sundanus Döderlein (Fig. 18c, 21, 30)

Gorgonocephalus sundanus Döderlein, 1927: 25, pl. 2 fig. 1 & 1b.

MATERIAL EXAMINED. 1 spec., 37°35'S, 177°16'E, near White I., N.Z., 521 m (NMNZ Ech. 1192); 1 spec., 5°31'30"S, 122°22'40"E, Buton Strait, Celebes, 834 m (holotype; USNM E1473).

DESCRIPTION. Disc diameter 30 mm and 60 mm. Disc distinctly excavate inter-radially, with an extremely thin peripheral ring of plates. Radial shields very conspicuous, with a distinctly 'soldered' appearance, wide in the middle, blunt proximally, tapering towards disc margin, where they suddenly widen. Shields, peripheral plates, and soft parts of disc entirely naked. An occasional low pustule present on ventral inter-radial areas. One flat madreporite present, occupying most of proximal inter-radial angle. Genital slits with an extremely thin border of minute plates.

Arms with at least 10 branches. First segment with no arm spine, then 1, 2, or (occasionally) 3 spines per segment to 1st arm fork, 3 or 2 thereafter. Spines peg-like, with prickly tips; distally they are laterally

flattened, with curved teeth, 1 terminal and 1 or 2 lateral. Girdles sinuous, present from 1st arm fork but continuous only after 2nd fork; girdle bands raised above surrounding arm surface, especially after 2nd fork. Intergirdle areas with irregular rows of small, flattened or slightly domed plates with intermediate naked areas, particularly on dorsal midline. After 3rd fork, small arm plates become more or less uniformly rounded and form a close cover raised into a slight ridge on either side of midline between each girdle. Distally, areas between girdles become bare. Girdle hooklets with a conspicuous secondary tooth.

Ventral arm plates closely set, covered with skin bearing a few low granules. Teeth spiniform, blunt and flattened at tips; oral papillae stump-like.

Colour (in ethanol): disc dark maroon, radial shields silvery cream, arms pink.

REMARKS. The New Zealand specimen compares well with the holotype, although much smaller. *G. sundanus* is characterised by its entirely naked disc, thin ring of peripheral plates, three arm spines, discontinuous girdle bands before the second arm fork, and strong secondary tooth on the girdle hooklets. Döderlein's suggestion that the shape of the radial shields might also be diagnostic holds good for the New Zealand specimen as well. His suspicion that *G. moluccanus* might not be distinct from this species is not confirmed by the present material.

G. sundanus is a new record for the south-west Pacific.

DISTRIBUTION. Indonesia, New Zealand.

BATHYMETRIC RANGE 521–834 m.

Genus *Astrodendrum* Döderlein, 1911

TYPE-SPECIES: *Gorgonocephalus sageminum* Döderlein, 1902.

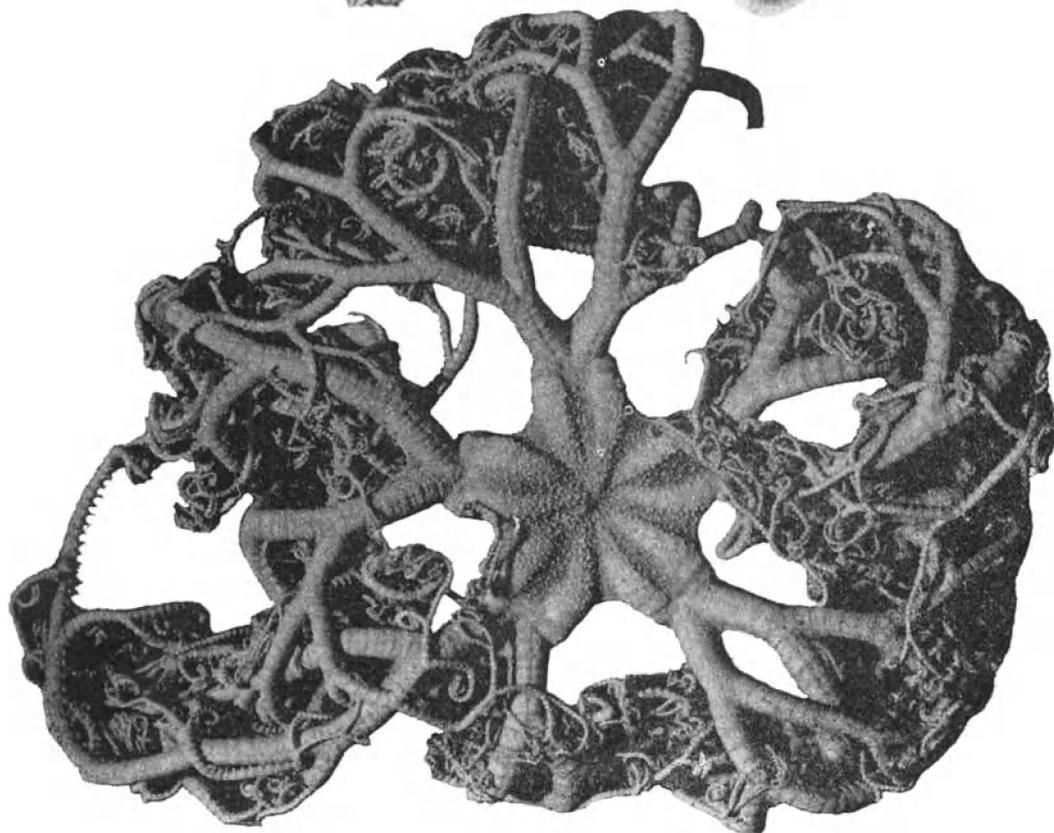
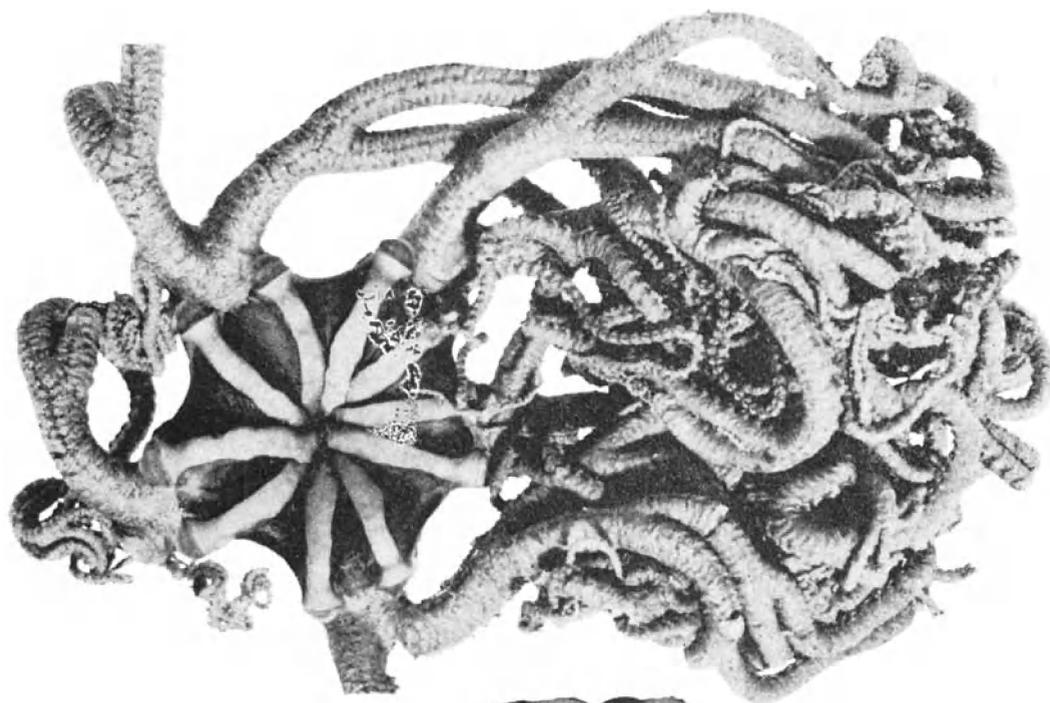
Astrodendrum elingamita Baker (Fig. 21, 33)

Astrodendrum elingamita Baker, 1974: 248, fig. 1–3.
Astrodendrum pustulatum H. L. Clark. Döderlein, 1927: 32, pl. 1 fig. 5–6a (not *Gorgonocephalus pustulatum* (H. L. Clark)).

MATERIAL EXAMINED. 1 spec., near West King I., Three Kings Is, N.Z., 110 m (holotype; NMNZ Ech. 1191); 1 spec., 29°25'S, 168°05.6'E, near Norfolk I., NZOI Sta. 190, 71 m; 1 spec., 12°55'26"N, 124°22'12"E, E of Luzon, U.S.F.S. Albatross Sta. 5504, 356 m (USNM E 4064); 1 spec., 8°35'30"N, 124°36'E, Mindona, Philippines, U.S.F.S. Albatross Sta. 5475, 365 m (USNM E 4063).

DESCRIPTION. Disc strongly excavate inter-radially, with no peripheral ring of plates. Radial shields dis-

Fig. 21. Upper, *Gorgonocephalus sundanus*, White I., N.Z., 28.0 mm d.d. Lower, *Astrodendrum elingamita*, holotype (NMNZ Ech. 1191), 25.0 mm d.d.



tinct, narrow proximally, wide distally. Disc and shields covered with small, domed tubercles of 2 distinct sizes, the smaller ones usually closely packed, the larger rather more scattered; tubercles smaller on underside of disc. One small madreporite present.

Arms branched at least 10 times, 1st branch at disc margin. Girdle bands prominent from arm bases, raised above arm surface. Between girdles, arm surfaces completely paved with close-packed, polygonal or rounded, flattened or slightly domed plates. First arm segment with no spines, 2nd and 3rd segments with 2, thereafter usually 3. Spines short, cylindrical, with 1 or 2 (exceptionally 3) terminal glassy points, distally becoming flattened, multi-toothed hooklets. Girdle hooklets with a strongly curved terminal tooth and a shortened, downward-directed secondary tooth.

Teeth and oral papillae spiniform, sharply pointed. Aboral mouth angle square. Oral area outside mouth (except adoral plates) closely paved with flattened or slightly domed granules.

Colour pale pink.

REMARKS. A re-examination of the U.S.F.S. *Albatross* material reported on by Döderlein (1927) has shown that it is this species, not *Gorgonocephalus pustulatum* (H. L. Clark). The Philippine and Norfolk Island specimens vary slightly in their disc cover: although domed tubercles of two distinct sizes are present, the larger ones are not always as uniformly distributed as in the type specimen. The small (7.5 mm d.d.) Norfolk Island specimen has very small arm spines and radial shields that are virtually contiguous. Otherwise the new material agrees with the holotype, and confirms as diagnostic the disc cover of domed tubercles of two distinct sizes.

Genus *Astrodermum* is strictly Indo-Pacific, with three Pacific species and one from the Indian Ocean. *A. sagraminum* and *A. galapagensis* A. H. Clark are known from Japan and the Galapagos Islands respectively; *A. capensis* (Mortensen) is known from one specimen taken off south-eastern Africa. The last-named species was originally assigned by Mortensen (1933b) to *Astroconus* Döderlein, but re-examination of the holotype (ZMC) has shown that it has girdle hooklets in patches on the dorsal side of the arms basally, a character unknown in *Astroconus* but present in all *Astrodermum* species. In most other respects the south-east African specimen is an *Astrodermum*. Its outstanding characteristic, however, which necessitates a modification to the generic diagnosis, is the presence of a row of conspicuously larger tubercles on the radial shields and inter-radial margins of the disc.

DISTRIBUTION. Philippines, Norfolk Island, northern New Zealand.

BATHYMETRIC RANGE 71–365 m.

Genus *Astroboa* Döderlein, 1911

TYPE-SPECIES: *Astrophyton clavatum* Lyman, 1861.

Astroboa ernae Döderlein (Fig. 28, 33)

Astroboa ernae Döderlein, 1911: 82, pl. 9 fig. 7 & 7a; 1912: 270, pl. 17 fig. 6. —H. L. Clark, 1914: 158; 1946: 182.

MATERIAL EXAMINED. SAM: 1 spec., Backstairs Passage, S.A., 50 m; 1 spec., West I., S.A., 20 m; 1 spec., Investigator Strait, S.A., ? depth; 1 spec., St Francis I., Nuyts Archipelago, S.A., 18 m; 5 specs, 32°34'S, 133°30'E, northern Great Australian Bight, ? depth. WAM: 1 spec., Busselton, W.A., on beach; 2 specs., NW Carnac I., W.A., ? depth; 2 specs., off Snag I., W.A., ? depth; 1 spec., Shark Bay, W.A., 22 m (type locality); 1 spec., Gulf of Carpentaria, N.T., ? depth. Of the many specimens in the collections of SAM and WAM, those listed here have been chosen to show the known range of the species.

DESCRIPTION. Disc markedly excavate inter-radially. Radial shields narrow (L:W = 4:1), widest distally, tapering evenly towards disc centre. Shield pairs widely separated distally, contiguous, or nearly so proximally. Disc centre not covered by shields. Radial shields uniformly covered with fine, rounded granules (3 or 4 in 1 mm); soft areas of both sides of disc covered with finer, lower granulation.

Arms branched up to 18 times. Arm spines rudimentary or absent before 4th branch, thereafter very small, with 1–3 erect glassy points, distally becoming flattened, multi-toothed hooklets. Initially 2 spines per segment, then 3, 4, and 5.

Girdle bands present as lateral patches after 2nd arm branch, continuous after 5th branch; hooklets with a strongly curved terminal tooth and a secondary tooth.

Dorsal arm surface with cover similar to that on radial shields; ventral arm surfaces and oral area paved with flat, polygonal plates. One madreporite present, at inner angle of inter-radius. Adradial edge of gill slits with a multiple row of prickly-tipped thorns; abradial edge smooth except for 1 or 2 stouter, blunter thorns.

Teeth pointed or chisel-shaped; oral papillae small, spiniform.

Colour leaden grey or buff when dry, orange-red when alive.

REMARKS. Young specimens of *Astroboa ernae* closely resemble the young of *Astrocladus* Verrill, particularly in the proximal position of the first arm spines. Of the six smallest specimens examined (6–20 mm d.d.), the very smallest have arm spines before the first arm branch, whereas on the larger ones spines appear between the second and third or third and fourth branches. Specimens over 25 mm d.d. invariably have no arm spines before the fourth branch.

Similar ontogenetic changes in *Astroboa globi-*

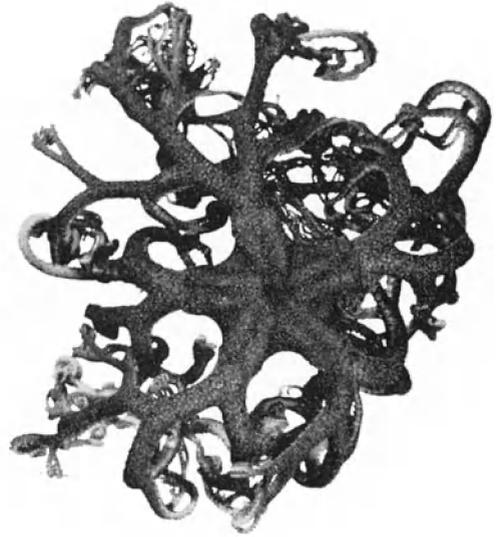
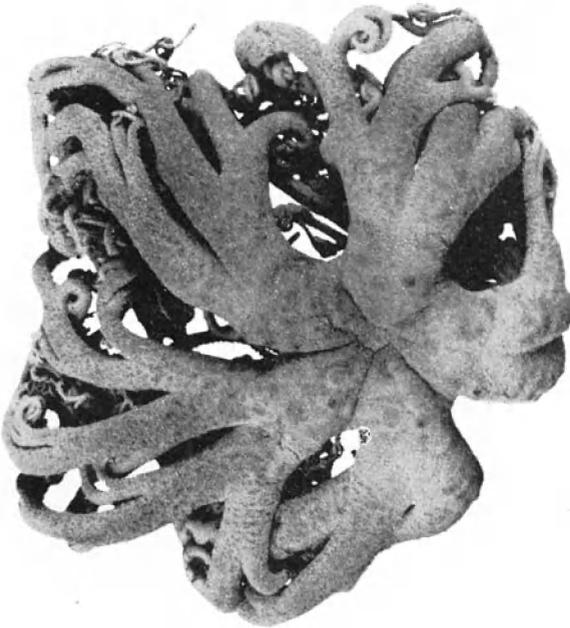
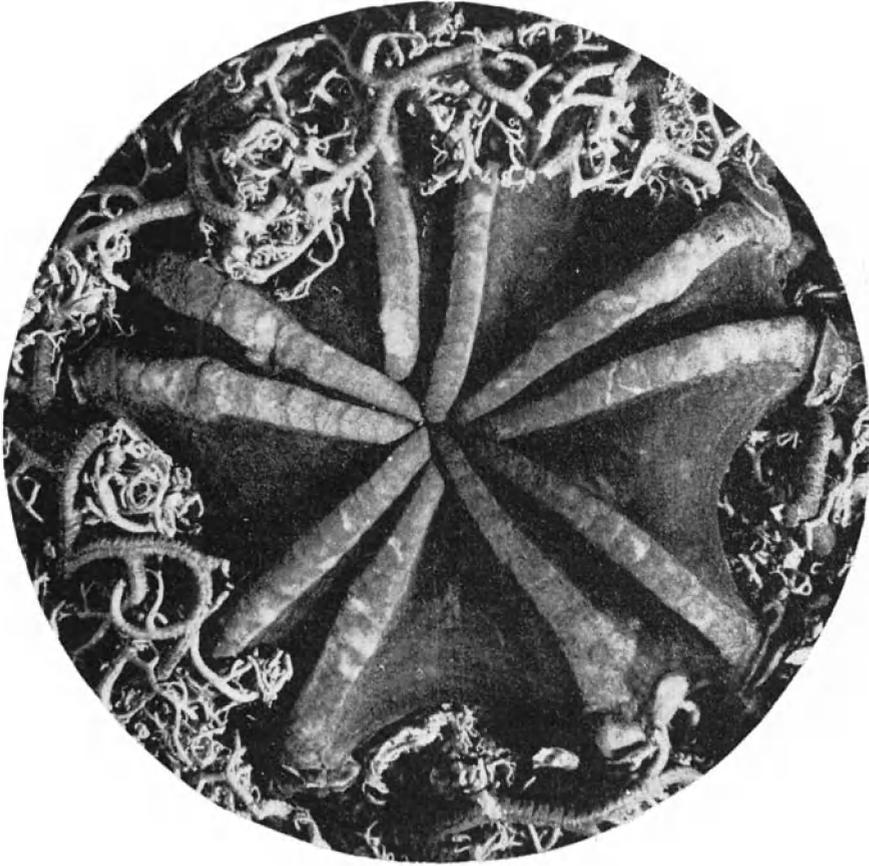


Fig. 22. Upper, *Astroboa nuda*, W of Carnarvon, W.A., 70.0 mm d.d. Lower left, *Astrochalcis tuberculosa*, Dampier, W.A., 17.0 mm d.d. Lower right, *Astroboa granulatus*, Lord Howe I., 11.0 mm d.d.

ferum were noted by Döderlein (1911, p. 51), although he did not take them into account in his generic diagnosis. H. L. Clark (1923), Mortensen (1933a), and A. M. Clark (1974) have also recorded such changes in *Astrocladus euryalae* (Retzius), type-species of its genus. If this phenomenon occurs in other *Astroboa* and *Astrocladus* species it leaves *Astroboa* on rather shaky ground, because the two taxa are basically separated on the relative position of the first arm spines (between the first and second arm branches in *Astrocladus*; after the fourth branch in *Astroboa*).

DISTRIBUTION. Southern, western, and northern Australia.

BATHYMETRIC RANGE 0–50 m.

Astroboa nuda (Lyman) (Fig. 22, 28, 33)

Astrophyton nudum Lyman, 1874: 251, pl. 4 fig. 4 & 5; 1882: 257.

Astrophyton elegans Koehler, 1905: 123, pl. 13 fig. 2, pl. 18 fig. 1.

Astroboa nuda. Döderlein, 1911: 86, 107; 1927: 43, pl. 5 fig. 1, 2, & 4.

Astroboa elegans. Döderlein, 1911: 50, 107.

Astroboa nigra Döderlein, 1911: 83, pl. 9 fig. 9 & 9a.

Astroboa nuda var. *nigra*. Koehler, 1930: 19.

Astroboa nuda var. *elegans*. Koehler, 1930: 20.

MATERIAL EXAMINED. 2 specs, W of Carnarvon (24°48'S), W.A., 73 m (WAM 589, 590–77); 1 spec., Denham Sound, Shark Bay, W.A., ? depth (WAM 34–76).

DESCRIPTION. Disc diameter 82–92 mm. Disc deeply excavate and sunken inter-radially, depressed in centre. Radial shields narrow (width : length = 1:10), convergent and low at disc centre, divergent and raised at disc margin, each terminating distally with a large, oval, slightly concave plate.

Radial shields densely paved with low granules (5–6 in 1 mm). Radial and inter-radial areas naked towards disc centre, but with increasing density of scattered pustules towards disc margin. Ventral inter-radial areas densely covered with small pustules. Genital slits with a 3-mm-wide strip of pointed stumps on adradial edge.

Arms branch at least 28 times, the first 2 branches within a line spanning ends of radial shields. Arms higher than wide basally, covered with a honeycomb pattern of irregular-sized, slightly roughened polygonal plates separated by marked sutures. A median dorsal strip of uniform-sized plates (7–8 in 1 mm basally) extends over half length of each arm. Narrow girdle bands present from after 2nd branch, continuous over arm before 3rd branch; hooklets with a strong secondary tooth. Main arm stems without spines before 15th branch, thereafter spines present as 2 glassy hooks beside each tentacle pore. On

secondary stems, however, 3 or 4 small, pointed spines occur within 3 branches of main stem. Distally, spines become hooklets with 2 strong teeth.

Ventral arm surface and oral frame covered with moderate-sized, flat polygonal plates. Jaw tips extremely obtuse, covered with small, round granules. Teeth and oral papillae short (1.5 mm), peg-like, quite undifferentiated in shape.

Colour (dry): upper surface of disc and arms dark reddish-grey; radial shields and arm tips paler, the latter off-white in these specimens; on arms, a darker, median dorsal stripe and a stripe just above the lateroventral edge, where there is an abrupt change to pale mottled grey; stripes persist until arm tips lighten.

REMARKS. The colour pattern of these large specimens is one of three exhibited by this species. An entirely dark mauve variety termed *nigra* has been described by Döderlein (1911, 1927), and a spotted variety, *elegans*, by Koehler (1905). Characteristic of the species, however, are the longitudinal dark lines on the arms—continuous in *nuda* sensu stricto and the *nigra* form, broken in the *elegans* form.

Other features which distinguish this species are the combination of fine, round granules on the disc, honeycombed, flat arm plates, and the absence of spines before the 13th–15th branches on the main arm stems.

Astroboa nuda is a new record for the eastern Indian Ocean and Australian waters.

DISTRIBUTION. Red Sea, western and eastern Indian Ocean, Persian Gulf, Indonesia, Philippines, Japan.

BATHYMETRIC RANGE 22–113 m.

Astroboa nigrofurcata Döderlein (Fig. 23, 28, 33)

Astroboa nigrofurcata Döderlein, 1927: 45, pl. 4 fig. 1–4. —Koehler, 1930: 19, pl. 3 fig. 12.

MATERIAL EXAMINED. 1 spec., 10°37'50"N, 120°12'E, Eastern Palawan, Corandago Is, Philippines, 93 m (**syntype**; USNM E1466); 1 spec., Rankin Bank, W of Carnarvon, W.A., 128 m (WAM 587.77); 1 spec., 56 miles NW of Dampier, W.A., ? depth (WAM 827–78).

DESCRIPTION. Disc diameter 50–53 mm; maximum recorded d.d. 85 mm. Disc deeply excavate and sunken inter-radially, depressed in centre. Radial shields narrow (width : length = 1:10), raised into high ridges, strongly curved in vertical plane. Shields separated distally, each terminating vertically with a large, subquadrate, slightly concave plate. Both disc surfaces covered closely with very fine, conical or pointed stumps (7–8 in 1 mm) and low pustules; stumps coincide with pale green areas of disc, pus-

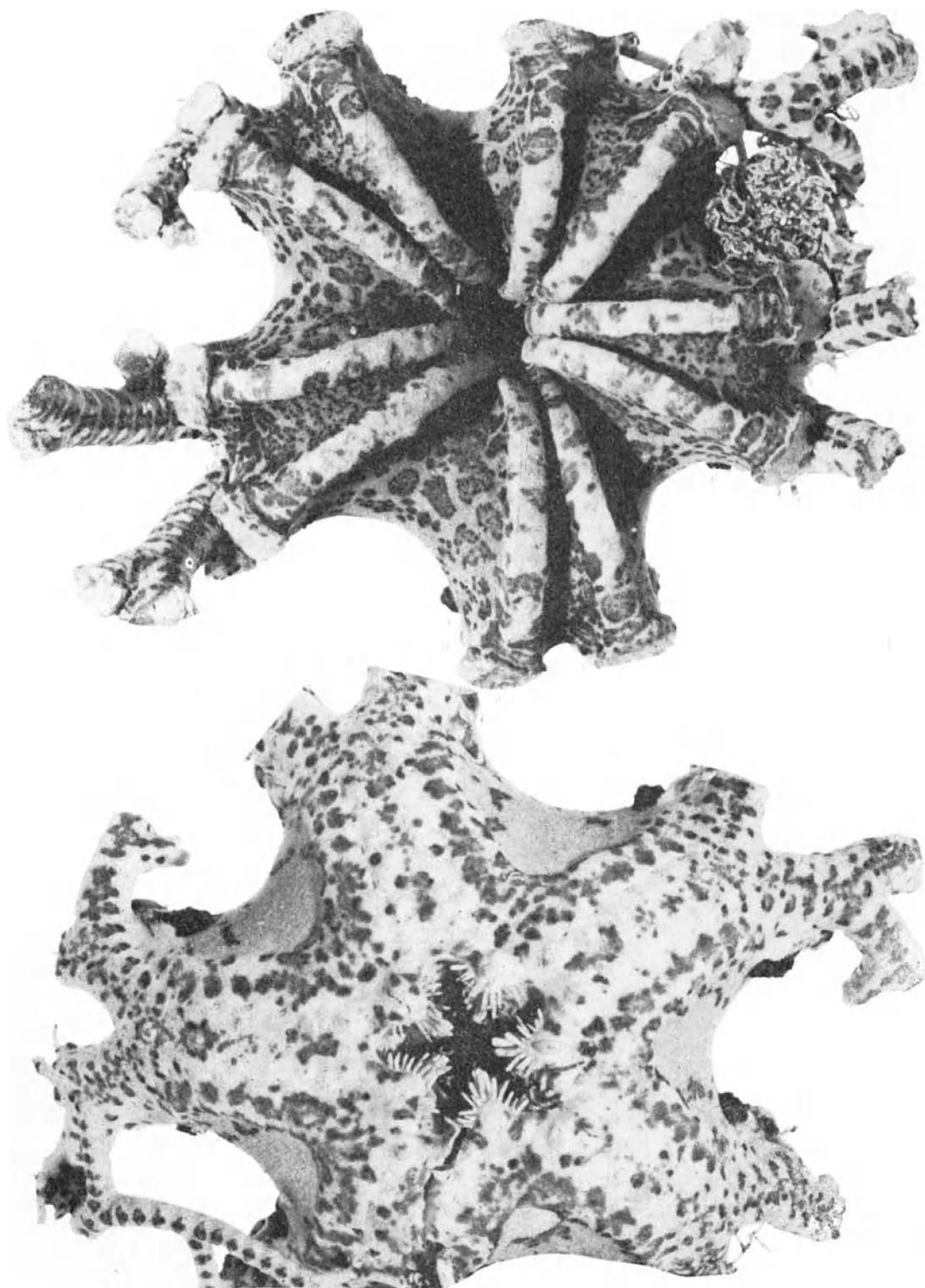


Fig. 23. *Astroboa nigrofurcata*, W of Carnarvon, W.A., 53.0 mm d.d.

tules with darker brown or pinkish areas. On ventral inter-radial areas, stumps rather more elongate; on adradial edges of genital slits they are virtually small spinelets.

Arms branch at least 30 times, just higher than wide basally, shallowly constricted between segments. First fork occurs at edge of disc, after 6 arm segments. All arm surfaces covered with smooth, flat, polygonal plates (3–5 in 1 mm). Continuous girdle bands begin at disc edge; hooklets with one secondary tooth. Arm spines rudimentary, extremely small, absent before 8th fork on main branch, numbering 2–4 per segment, tipped by 1–3 small, glassy points, distally becoming hooklets with an upwardly inclined secondary tooth. Tentacle pores initially surrounded by a low, calcareous tube.

Oral frame covered with flat, polygonal plates. Oral papillae spiniform, cylindrical; teeth longer, spatulate. Madreporite large, filling entire inter-brachial angle.

Colour (dry): disc very pale green, with irregular 'freckles' of brown or pink; darker freckles denser radially between ends of radial shields; outer edges of oral frame and arms within disc circumference covered with dark freckles, remaining areas mostly cream; arms with a continuous series of dark freckles on ventral, lateral, and dorsal surfaces, 1 freckle per segment, some coalescing on ventral surface only; entire animal very strikingly patterned with these contrasting colours.

VARIATION. The type specimen has faded to a uniform brown colour, and shrinkage of the disc has resulted in the radial shields flexing towards each other near their middle.

REMARKS. This species is characterised by having fine thorns on the disc, smooth, flat plates on the arms, and a strongly freckled colour pattern.

The specimens from Rankin Bank and off Dampier are the first of *A. nigrofurcata* to be recorded from the Indian Ocean.

DISTRIBUTION. Philippines, Indonesia, Western Australia.

BATHYMETRIC RANGE 71–128 m.

Astroboa granulatus (H. L. Clark) n. comb.
(Fig. 22, 28, 33)

Astrocladus granulatus H. L. Clark, 1938: 206, pl. 23 fig. 3; 1946: 181. Not Cherbonnier & Guille. 1978: 12, pl. II fig. 5 & 6.

MATERIAL EXAMINED. 1 spec., Lindeman I., Qld (holotype; MCZ 4899); 1 spec., Kennedy Sd, Trinity Passage, Great Barrier Reef (AM J7779; collected by Ward, but apparently not seen by H. L. Clark); 1 spec., off Lindeman I., Whitsunday Passage, Qld,

16.5 m (AM J6349); 1 spec., 5 miles NW of Basile I., Abrolhos Is, W.A., 33–37 m (WAM 290–71); 1 spec., Goss Pass, Abrolhos Is, W.A., 6 m (WAM 213–78); 4 specs, 15 miles WSW of Carnarvon, W.A., 22–25 m (WAM 1292, 1295, 1394, 1415.75); 1 spec., North Face, Lord Howe I., 15 m (AM J9958); 1 spec., Norfolk I., ? depth (NMNZ 1218); 1 spec., 31°45.8'S, 159°10.2'E, Lord Howe I., 60 m, NZOI Sta. P98; 1 spec., 31°37.6'S, 159°04.0'E, Lord Howe I., 31 m, NZOI Sta. P103; 1 spec., 31°32.1'S, 159°01.2'E, Lord Howe I., 30 m, NZOI Sta. P108.

DESCRIPTION. Disc strongly excavate inter-radially. Radial shields large, long, narrow, widest distally; pairs virtually contiguous at disc centre. Shields densely covered with fine granules (5–6 in 1 mm) with smaller grains between; inter-radial areas above and below more sparsely covered with fine grains and occasional larger granules. One madreporite present, on solid edge of oral frame.

Arms branched at least 20 times, weakly annulated. First arm spines rudimentary, present after 5th or 6th branch; initially 1 spine per segment, then 2 and 3, and after 10th branch up to 4; spines initially short, stubby, with 2 or 3 blunt terminal points becoming attenuated and upwardly inclined distally, and flattened two-toothed hooklets on arm tips.

Girdle hooklets present in isolated patches after 4th arm branch, continuous only after 14th branch, with a strongly curved terminal tooth and a downturned secondary tooth.

Dorsal arm surface with same covering of granules as disc; ventral surface and oral area closely paved with flattened granules. Oral papillae and teeth small, spiniform.

Colour (in ethanol): disc pale, mottled brown, arms lightly and widely banded.

REMARKS. This series of specimens, ranging from 6 mm to 60 mm d.d., shows that the 11 mm d.d. holotype has juvenile characters (e.g., arm spines on proximal arm segments) which are lost in the adult, and that the species is better placed in *Astroboa* than in *Astrocladus*. The 60 mm d.d. Norfolk Island and Lord Howe specimens agree well with the holotype except for their larger size, distal position of the first arm spines, and greater number of arm branches. These features show ontogenetic changes of a similar order to those occurring in *Astroboa ernae* and *A. globiferum*. Indeed, it seems that *A. granulatus* is most nearly related to the latter Japanese species, rather than to *A. ernae*. It has in common with *A. globiferum* the disc and arm cover of granules of two distinct sizes, and it is only this feature which separates them both from *A. ernae*. I have been unable to obtain comparative material of *A. globiferum*, so the possibility that the two species are synonymous cannot be discounted.

The range of *A. granulatus* is here extended from the type locality at Lindeman Island, Great Barrier

Reef, eastward to Lord Howe and Norfolk Islands and westward to the eastern Indian Ocean. Cherbonnier & Guille (1978) have hesitantly recorded this species from Madagascar; having recently examined their two juvenile specimens, I can state that the material is definitely not *A. granulatus*, but is certainly a species of *Astrocladus*, possibly related to *A. hirtus* Mortensen.

DISTRIBUTION. Western and north-eastern Australia, northern Tasman Sea.

BATHYMETRIC RANGE 6–60 m.

Genus *Astrocladus* Verrill, 1899

TYPE-SPECIES: *Asterias euryalae* Retzius, 1783.

Astrocladus exiguus (Lamarck) (Fig. 28, 33)

Euryalae exiguum Lamarck, 1816: 539.

Gorgonocephalus cornutus Kochler, 1897: 368, pl. 9 fig. 80 & 81.

Astrocladus exiguus. Döderlein, 1911: 41, 76, pl. 9 fig. 6; 1927: 34, pl. 5 fig. 9. —Koehler, 1930: 34, pl. 4 fig. 1 & 2. —Clark & Rowe, 1971: 92. —Cherbonnier & Guille, 1978: 11, pl. II fig. 1 & 2.

MATERIAL EXAMINED. 1 spec., 23°05'S, 113°23'E, W of Point Cloates, W.A., 140 m (WAM 740.75).

DESCRIPTION. Disc diameter 30 mm. Disc distinctly but narrowly excavate inter-radially. Radial shields narrow (L:W=4:1), slightly bowed, contiguous proximally. Shields and soft areas of disc with dense cover of very fine, conical granules tipped with 1 or 2 long, glassy points. A large, smooth tubercle with a lightly sculptured tip at distal end of each radial shield; a few smaller tubercles on soft areas. Ventral inter-radii densely covered with single-pointed granules. Genital slits edged with low, rounded granules.

Arms branched at least 10 times. Rudimentary arm spines present on 6th or 7th segments, just before 1st branch; thereafter 4 (occasionally 3 or 5) very small spines per segment, with several short, glassy terminal points, distally becoming flattened, curved hooks with 2 or 3 teeth.

Girdle bands present from edge of disc, continuous over arm only after 3rd branch; hooklets with a secondary tooth. Dorsal arm surface covered with conical granules similar to those on disc, but interspersed with flat plates which form a smooth pavement on sides of arms. Ventral arm surface flat, closely paved with flat plates bearing small grains along sutures. Teeth and oral papillae short, spiniform.

Colour (in ethanol) pink.

REMARKS. The occurrence of this easily recognised species of *Astrocladus* in the waters of north-

western Australia was not unexpected, for it was already known from the northern Indian Ocean and the Timor Sea.

DISTRIBUTION. Madagascar, Andaman Islands, Bay of Bengal, Timor, Philippines, southern Japan, western Australia.

BATHYMETRIC RANGE 18–494 m.

Astrocladus ludwigi (Döderlein) (Fig. 28, 33)

Euryale ludwigi Döderlein, 1896: 299, pl. XVII fig. 28a–c.

Astrocladus ludwigi. Döderlein, 1911: 40, fig. 8; 1927: 33, pl. 3 fig. 3a,b. —Koehler, 1930: 35, pl. IV fig. 3 & 4.

MATERIAL EXAMINED. 6 specs, 23°05'S, 113°23'E, W of Pt Cloates, W.A., 140 m, CSIRO Sta. 182 (WAM 746.75 (1), WAM 748.75 (5)); 1 spec., 212° from Zal I., Pearl Bank, Sulu Archipelago, Indonesia, 91 m (WAM 741.75); 1 spec., Holothuria Bank, NW Australia, 27 m (BMNH 92.1.14.129).

DESCRIPTION. Disc strongly excavate inter-radially. Radial shields narrow (L:W=5:1), parallel, reaching disc centre. Disc and radial shields covered with closely set, domed tubercles (5 in 1 mm); 6–15 large tubercles at disc centre and on or between radial shields; ventral inter-radial areas covered with the smaller tubercles. Genital slits very small, D-shaped, bordered on distal edges by a clump of pointed tubercles. One madreporite present.

Arms branched at least 10 times. All arm surfaces paved with angular, polygonal plates; those on dorsal surface slightly raised, those on ventral surface flat. Girdle bands prominent, not sinuous, continuous before 1st arm branch; hooklets with a secondary tooth. Arm spines begin after 1st arm branch, initially consist of 2 prickly-topped stumps but transformed into hooklets with 2 large teeth distally.

Oral area covered with flat plates similar to those on arms; near jaw-tips they are small and slightly domed. Oral papillae small, spiniform; teeth longer, flattish.

Colour: Point Cloates material basically pink, with some darker patches on arms and disc; Sulu specimen white with a discontinuous brown ring on disc and pale brown bands on arms, particularly at joints.

REMARKS. The specimens are all small, ranging from 1.2 mm to 11.2 mm d.d., and are not as densely covered with the larger tubercles as those illustrated by Döderlein and Koehler. According to Koehler, however, this feature changes with growth, larger specimens having more tubercles on the disc and radial shields. The Sulu Archipelago specimen has the same colour pattern as Koehler's Kei Islands

material. The Point Cloates specimens were associated with a gorgonian coral. The Holothuria Bank specimen was referred to *Astrophyton clavatum* Lyman by Bell (1894) and to *Astroboa tuberculosa* by Clark & Rowe (1971).

Astrocladus ludwigi is a new record for Australian waters.

DISTRIBUTION. Indonesia, north-western Australia.

BATHYMETRIC RANGE 20–140 m.

Astrocladus tonganus Döderlein (Fig. 24, 28, 33)

Astrocladus tonganus Döderlein, 1911: 77, 107, pl. 9 fig. 8; 1927: pl. 5 fig. 10. Not Cherbonnier & Guille, 1978: 14, pl. II fig. 3 & 4.

MATERIAL EXAMINED. 1 spec., Nuku'alofa Reef, Tonga, 2 m (NMNZ); 2 specs, Tonga, 21°07.8'S, 175°11.0'W, 0–10 m, NZOI Sta. 1173.

DESCRIPTION. Disc deeply excavate inter-radially. Radial shields narrow (L:W=4:1), widely separated distally, convergent proximally. Disc and shields covered with small, conical tubercles (6 in 1 mm) bearing 1 or 2 sharp, glassy terminal thorns; between tubercles are minute, round grains; ventral inter-radial areas with similar but less densely arranged tubercles. Genital slits short, very narrow. One large madreporite present, mostly on soft interbrachium.

Arms branched at least 26 times; 7 or 8 and 4 or 5 segments respectively within first 2 branches. Dorsal surface initially covered with flat plates and pointed tubercles similar to those on disc, but mostly with a single, terminal thorn; distally, tubercles become flattened. Girdle bands in isolated patches on lower parts of arms after 1st branch, continuous only after 7th branch, slightly sunken; raised areas between bands sinuous; hooklets with a strong secondary tooth.

Ventral arm surface and oral area covered with closely set, flat, polygonal granules of approximately equal size separated by marked sutures. Arm spines present between 2nd and 5th branches, initially 1 or 2 per segment but eventually 4, short, stubby, slightly flattened, with 2–4 short terminal points, distally becoming glassy hooklets with 2 large teeth. Oral papillae short, blunt; teeth longer.

Colour dark brown; sinuous whitish areas on arms.

REMARKS. These specimens are apparently the first to be recorded from the type locality since Döderlein's original two were described in 1911. Cherbonnier & Guille (1978) have referred five specimens of a Madagascan *Astrocladus* to this species, but examination of three of these shows that they are not *tonganus*, but a species allied to *A. hirtus*. The discs are much more densely covered with

small, conical tubercles, which themselves bear more terminal spines; the ventral inter-radial surfaces bear smooth tubercles; and the ventral surface of the disc and arms is covered with subequal flat plates surrounded by small granules.

DISTRIBUTION. Tongan Islands.

BATHYMETRIC RANGE 2–10 m.

Genus *Astrochalcis* Koehler, 1905

TYPE-SPECIES: *Astrochalcis tuberculosa* Koehler, 1905.

Astrochalcis tuberculosa Koehler (Fig. 22, 28, 31)

Astrochalcis tuberculosa Koehler, 1905: 130, pl. 16 fig. 1 & 2. –Döderlein, 1927: 50, pl. 5 fig. 7–7b. –H. L. Clark, 1938: 208.

MATERIAL EXAMINED. 1 spec., NNE of Port Hedland, W.A., 18°43'S, 119°27'E, 100–105 m (WAM); 1 spec., NE of Dampier, W.A., 77–86 m (WAM); 2 specs, 8 miles N of Delambre I., Dampier Archipelago, W.A., ? depth (WAM); 1 spec., 60 miles at 320° from Darwin, N.T., ? depth (WAM); 1 spec., Albany Passage, Qld, 16–22 m (AM J5294); 1 spec [no locality data; possibly N.T.] (SAM).

DESCRIPTION. Disc diameter 8–75 mm. Disc small in proportion to width of arm bases. Inter-radial areas very narrow and excavate; remainder of disc comprising the 5 wedge-shaped areas covering radial shields, which are more or less continuous with arm bases. Disc covered with closely set, small, rounded granules (6 in 1 mm) interspersed with much larger, low, rounded tubercles. One low-profile madreporite present, on edge of oral frame. Genital slits large, bordered by pointed tubercles.

Arms branched at least 12 times. Dorsal surface similar to that of disc, but large tubercles become smaller and flatter towards end of arms. Girdle bands continuous after 2nd arm branch (small specimens) or 7th branch (larger ones); hooklets with a strongly curved terminal tooth and a small secondary tooth. Ventral arm surface very wide and flat, paved with smooth, flat plates the largest of which lie on midline. Arm spines begin between 3rd and 4th branches, 1 on 1st segment and thereafter 2 or 3, increasing to 5 distally; spines very short, slightly flattened, with 2 or 3 (rarely 1 or 4) long, glassy points; at ends of arms, 2 spines modified into hooklets with 2 strongly curved teeth.

Oral area wide, paved with polygonal plates which become rounded granules towards jaw tips and eventually merge with the short oral papillae. Teeth spiniform; 3 papillae occur at a higher level in the mouth, associated with 1st oral tentacle pore.

Colour (in ethanol): small specimens cream, larger ones pale brown.

REMARKS. H. L. Clark (1938) recorded this species from Australian waters on the basis of the Albany Passage (northern Queensland) specimen in the Australian Museum collection. Because the specimen was very tightly coiled, however, he was not absolutely certain of his identification. Subsequent dissection of that individual, and collection of further

material from north-western and northern Australia, confirms the occurrence of *A. tuberculatus* in the region. It is otherwise known only from the H.M. *Siboga* stations in the Banda Sea and near the Aru Islands, Indonesia.

The one other species of *Astrochalcis*, *A. micropus* Mortensen, known only from the Philippines, may

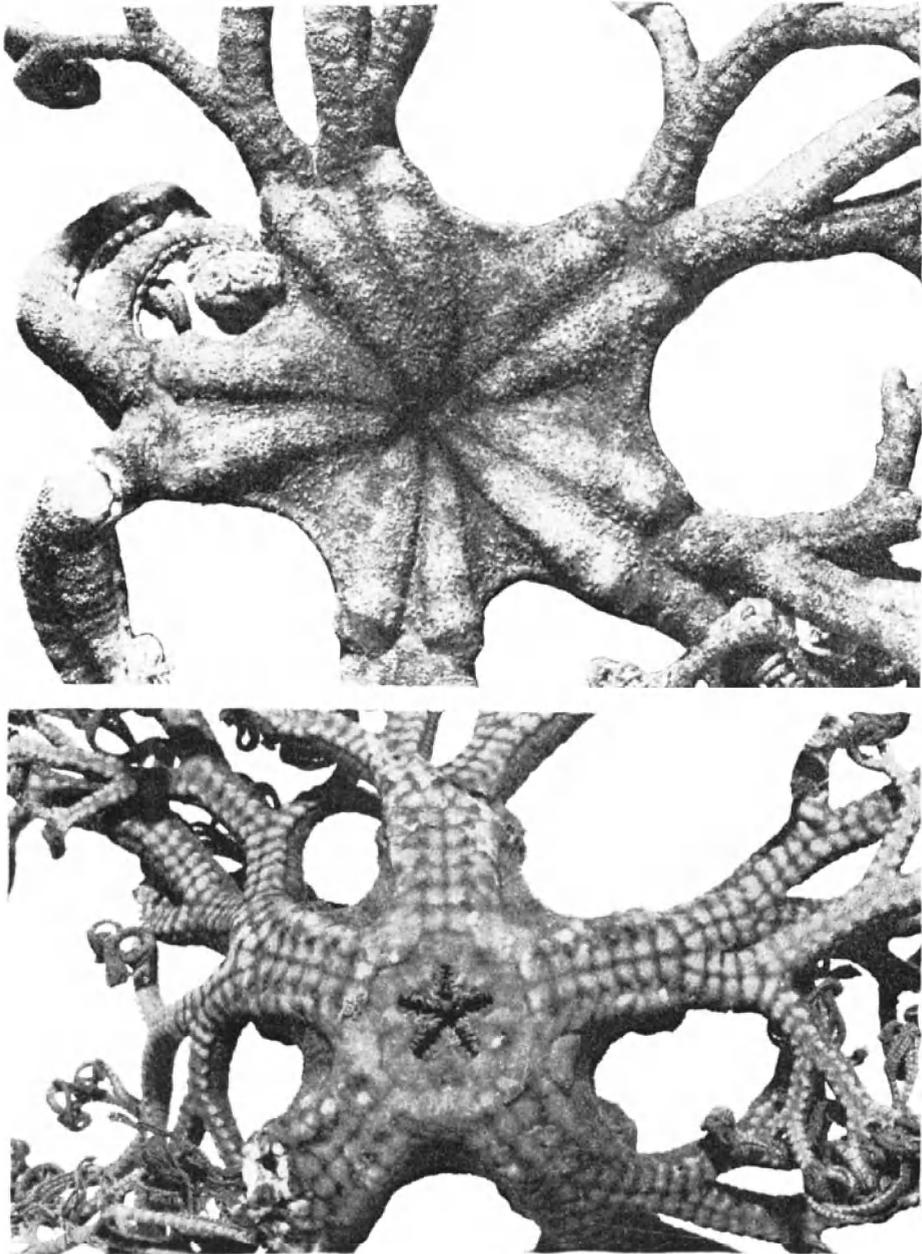


Fig. 24. *Astrocladus tonganus*, Tonga, 25.0 mm d.d.

also be expected to occur in northern Australian waters.

DISTRIBUTION. Indonesia, northern Australia.

BATHYMETRIC RANGE 16–105 m.

Genus *Astroglymma* Döderlein, 1927

TYPE-SPECIES: *Astrophyton sculptum* Döderlein, 1896.

Astroglymma sculptum (Döderlein) (Fig. 19, 28, 31)

Astrophyton sculptum Döderlein, 1896: 299, pl. 18 fig. 29.

Gorgonocephalus robillardi De Loriol, 1893: 31, pl. 3 fig. 3. **New synonymy.**

Astroglymma sculptum Döderlein, 1927: 47, pl. 1 fig. 3 & 4, pl. 5 fig. 13. —Koehler, 1930: 15, pl. 2 fig. 10–12.

Astroglymma robillardi. Mortensen, 1933a: 34, pl. 3 fig. 1 & 2, pl. 4 fig. 1.

MATERIAL EXAMINED. 1 spec., 7 miles N of North-west Cape, W.A., 137 m (WAM 747.75); 1 spec., Rankin Bank, W of Carnarvon, W. A., 128 m (WAM 588.77); 1 spec., W of Carnarvon, W.A., 73 m (WAM 265.78); 1 spec., NNE of Broome, W.A., 18°58'S, 119°02'E, 90–92 m (WAM); 1 spec., NNW of Bedout I., W.A., 18°32'S, 120°22'E, 85–88 m (WAM).

DESCRIPTION. Disc diameter <50 mm. Disc deeply excavate inter-radially. Radial shields narrow, parallel, almost reaching disc centre; distal ends slightly divergent. Shields and both disc surfaces covered with minute (10 in 1 mm) conical tubercles; ventral interbrachia sometimes bear long (0.6 mm) spinelets. Genital slits short, D-shaped, bordered by a multiple row of tall but blunt-tipped tubercles on distal edge. Five small madreporites present, each deeply embedded in a ventral inter-radial angle.

Arms branched at least 20 times. Dorsal surface paved with uniform-sized, domed polygonal plates. Girdle bands very narrow, continuous over arm from arm base; hooklets with a secondary tooth. Ventral arm surface covered with small, flat, polygonal plates; 1st 3 arm divisions with a ladder-like arrangement of large pits, the remainder smooth and flat. Arm spines present after 6th fork as 2 very small stumps, further along as 3 somewhat larger stumpy spines with 1 or 2 terminal points, distally becoming hooklets with a large terminal point and a smaller secondary tooth.

Oral area smooth, covered with barely visible flat plates like those on arms. Deep pits surround mouth, which gapes wide leaving a central basin-like depression bordered by jaws. Oral papillae small, spiniform; teeth small, spatulate.

REMARKS. The specimens agree closely with Döderlein's accounts of the species, and also with De

Loriol's and Mortensen's description of *A. robillardi*. I can confirm Mortensen's (1933a, p. 37) opinion that there is no reliable difference between these nominal species, and now that *A. sculptum* has been found in the Indian Ocean at 22°S there is no reason for maintaining *A. robillardi* as a distinct species. Consequently it is here synonymised with *A. sculptum*. Mortensen's *A. robillardi* var. *spinusum* (1933a, p. 38) probably warrants specific status, but for lack of additional material from the western Indian Ocean, to compare with *A. sculptum*, its varietal status must stand.

A. sculptum is a new record for Australian waters; its otherwise wide Indo-Malaysian distribution makes its occurrence there not unexpected.

DISTRIBUTION. Mauritius, north-western Australia, Malaysian Archipelago, China Sea.

BATHYMETRIC RANGE 73–300 m.

Family EURYALIDAE Gray, 1840

Genus *Astroceras* Lyman, 1869

TYPE-SPECIES: *Astroceras permagenum* Lyman, 1869.

Astroceras elegans (Bell) (Fig. 25, 32)

Astroschema elegans Bell, 1917: 7.

Astroceras elegans. Mortensen, 1924: 107, pl. IV fig. 3; 1933a: 53, fig. 37 & 38; 1936: 24. —Fedotov, 1927: 343. —Fell, 1958: 21. Not Fell, 1962: 51 (= *Astrobrachion constrictum* (Farquhar)).

Astroceras maui McKnight, 1968: 516, fig. 4 & 5. **New synonymy.**

MATERIAL EXAMINED. 2 specs, 29°20.2'S, 168°10.8'E, nr Norfolk I., 308 m, NZOI Sta. 194; 1 spec., 32°01'S, 168°03'E, Wanganella Bank, Tasman Sea, 500 m, NZOI Sta. E859; 8 specs, 32°30'S, 179°12'W, Star of Bengal Bank, N.Z., 508 m, NZOI Sta. C527 (includes **holotype** and 3 **paratypes** of *Astroceras maui* McKnight); 1 spec., 34°11'S, 172°10'E, N of Three Kings Is, N.Z., 92–98 m, *Discovery* Sta. 934 (BMNH); 31 specs, 34°13'S, 172°11.5'E, N of Three Kings Is, N.Z., 256 m (NMNZ); 4 specs, 34°00'S, 171°47.5'E, W of Three Kings Is, N.Z., 119 m, NZOI Sta. E312; 2 specs, 34°01.5'S, 172°43.5'E, Three Kings Is, N.Z., 155 m, NZOI Sta. E389; 2 specs, E of North Cape, N.Z., 128 m, *Terra Nova* Sta. 96 (**syntypes**, BMNH 1915.2.1.71.75, incl. 1 figured by Mortensen, 1924, fig. 3, upper); 71 specs, E of North Cape, N.Z., 146 m (NMNZ); 6 specs, off Cape Kari Kari, N.Z., 165 m (NMNZ); 1 spec., 38°27'S, 178°58'E, N of East Cape, N.Z., 161 m, NZOI Sta. F779; 3 specs, 41°23'S, 170°47'E, NW of Cape Foulwind, N.Z., 366 m, NZOI Sta. Z2371; 130 specs, 15 miles offshore near Mt Cook, N.Z., 220 m (NMNZ); 718 specs, 42°36.1'S, 170°40'E, Hokitika Trench, N.Z., 300 m (NMNZ).

DESCRIPTION. Disc diameter 2.0–14.0 mm; arm length to 12× d.d. Disc subpentagonal, usually skin, and visible when dried, are tubercles and/or slightly sunken at centre, covered with skin. Beneath

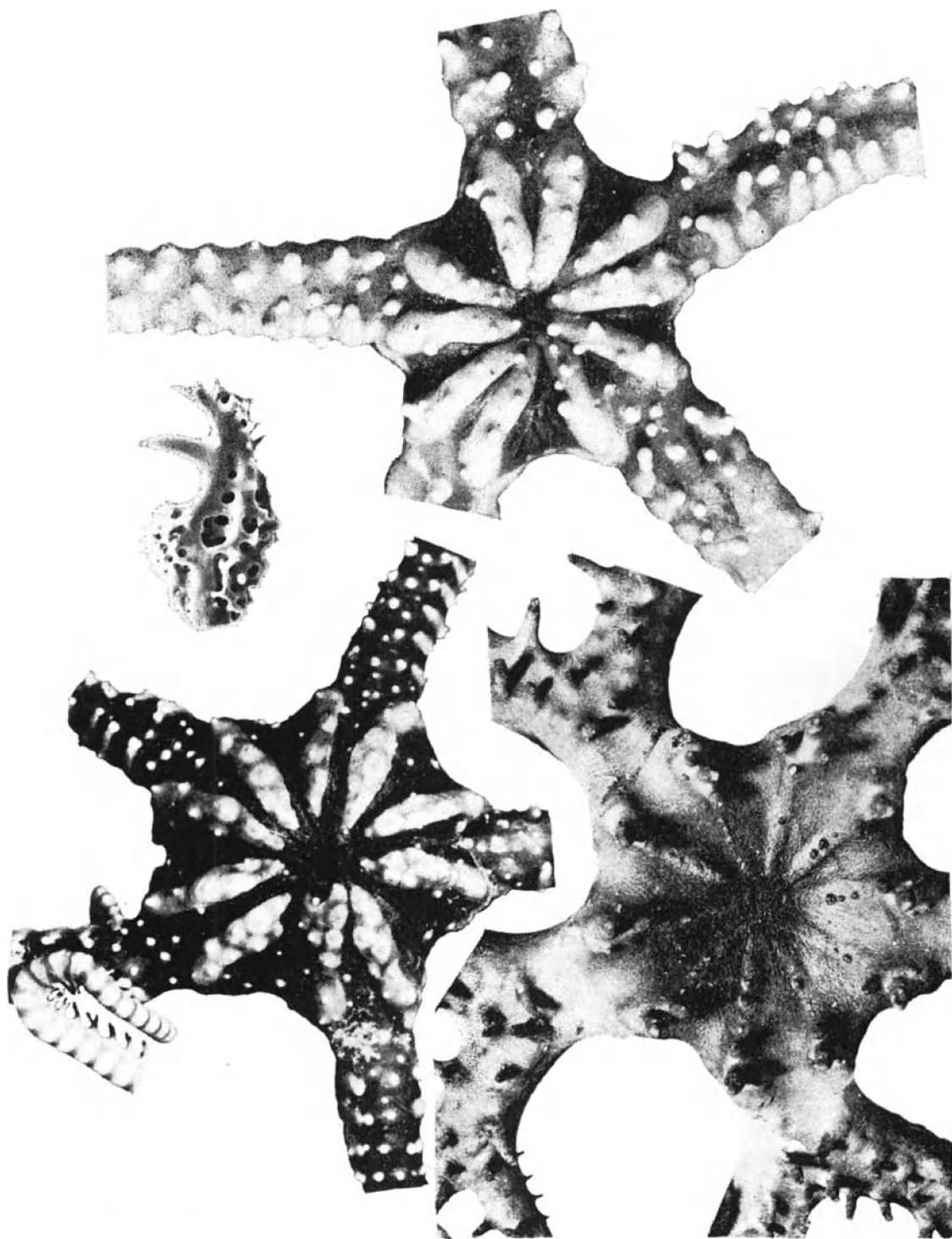


Fig. 25. Upper, *Astroceras elegans*, Three Kings Is, N.Z., 10.0 mm d.d. Middle left, distal arm-spine hooklet of *A. pleiades*, paratype (NMNZ Ech. 1947), 0.24 mm long. Lower left, *A. elegans*, North Cape, N.Z., 14.0 mm d.d. Lower right, *Euryale aspera*, Bunbury, W.A., 24.0 mm d.d.

granules 0.1–0.8 mm in diameter and height restricted mainly to radial shields, where they form a single or irregular double row; in some specimens, tubercles have a narrow base and swollen head. Radial shields 4–5× longer than wide, convergent or parallel, widely separated or almost contiguous.

The 5 arms swollen basally over first 6–8 segments, tapering evenly thereafter; tuberculation varying from a uniform cover of spaced granules to a roughly regular, transverse arrangement of knob-like tubercles restricted to widened proximal part or extending in ones and twos to arm tip. Granules and tubercles lie mostly on narrow dorsal arm plates, which, together with intervening areas of dark skin, give arms a marked annulated appearance.

Lateral and ventral arm surfaces covered with smooth, naked skin. Sometimes a few scattered pustules occur on oral frame in region of large adoral shields. Ventral arm plates in 2 (occasionally 3 or 4) pieces, widely separating lateral arm plates. Two arm spines present from 2nd arm segment; spines short (0.6 mm), with a rounded, prickly tip; innermost spine longest, after 18th–20th segment developing longer thorns on adradial side; distally, both spines become flattened hooklets with 2 or 3 strong teeth.

Oral papillae present as low, round granules at each jaw apex and along its sides; teeth wide-based, triangular. Genital slits long, narrow.

Colour (in ethanol) pale cream or fawn, with brown areas on disc between shields and forming bands on arms.

REMARKS. The vast collections of *A. elegans* now available show it to be a most variable species, particularly with regard to the presence and size of tubercles on the disc and the dorsal surface of the arms. *Astroceras maui* McKnight is one extreme, with very weak tuberculation. The variation is not size-related.

Mortensen's (1933a) illustration of the ventral surface shows the arm plates divided into four pieces. Such division is uncommon; more often there are only two pieces of ventral arm plate—a small proximal piece separated from a longer distal piece by the vertebral coverplate.

DISTRIBUTION. Northern Tasman Sea (Norfolk Island), New Zealand (Fig. 1).

BATHYMETRIC RANGE 92–508 m.

Astroceras kermadecensis n.sp. (Fig. 26b, 32)

TYPE DATA. **Holotype** (2.6 mm d.d.): Kermadec

Islands, 28°30.7'S, 177°49.3'W, NZOI Sta. K806, 1165–1185 m, 7 Jul 1974 (NZOI H252). **Paratypes** (1.0–2.5 mm d.d.): 10, same station as holotype (8, NZOI P510; 2, NMNZ Ech.2066).

DESCRIPTION OF HOLOTYPE. Arms coiled, approximately 10 mm long. Disc flat, slightly sunken centrally; radial shields small (0.2 × 0.7 mm), parallel. Disc covered above with very fine, closely packed rugose granules (12–14 in 1 mm); ventral inter-radial areas similarly covered. Genital slits extremely small.

The 8 arms covered above with granules similar to those on disc, but less densely packed and becoming quite sparse distally. Lateral arm plates large, meeting broadly on ventral midline, with a small ventral arm plate lying distad. Ventral arm surface and oral frame covered with smooth skin. Arm spines short (0.3 mm), cylindrical, blunt; 1 (occasionally 2) present from 2nd arm segment through to arm tip, where spines become flattened hooklets with 2–6 teeth.

Oral papillae low, rounded, on sides of jaws; teeth sharply triangular.

Colour (dry) golden brown.

VARIATION. The 10 paratypes have between three and nine arms. All are uniformly granulated on the dorsal side, like the holotype.

ETYMOLOGY. The trivial name *kermadecensis* alludes to the type locality.

REMARKS. This diminutive species of *Astroceras* is related to *A. compar* Koehler, from Indonesia and Japan, with which it shares the granulated disc and arms and contiguous lateral arm plates. It differs, however, in having no large tubercles on the dorsal side of the arms, ventral arm plates that join very broadly, and distal arm hooklets with unusually abbreviated upper teeth. Also, *A. kermadecensis* is self-dividing, with nine arms. This combination of features distinguishes it from all other known members of the genus.

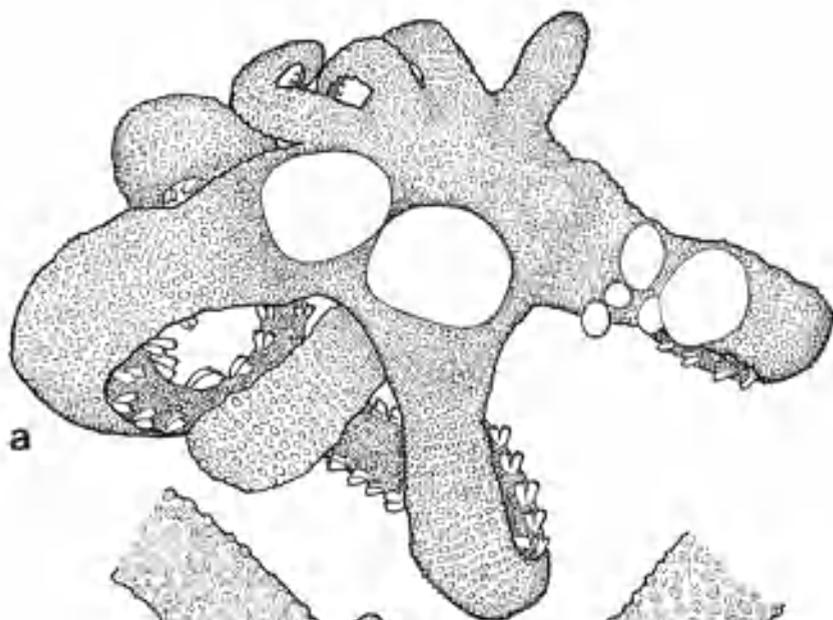
DISTRIBUTION. Kermadec Islands.

BATHYMETRIC RANGE 1165–1185 m.

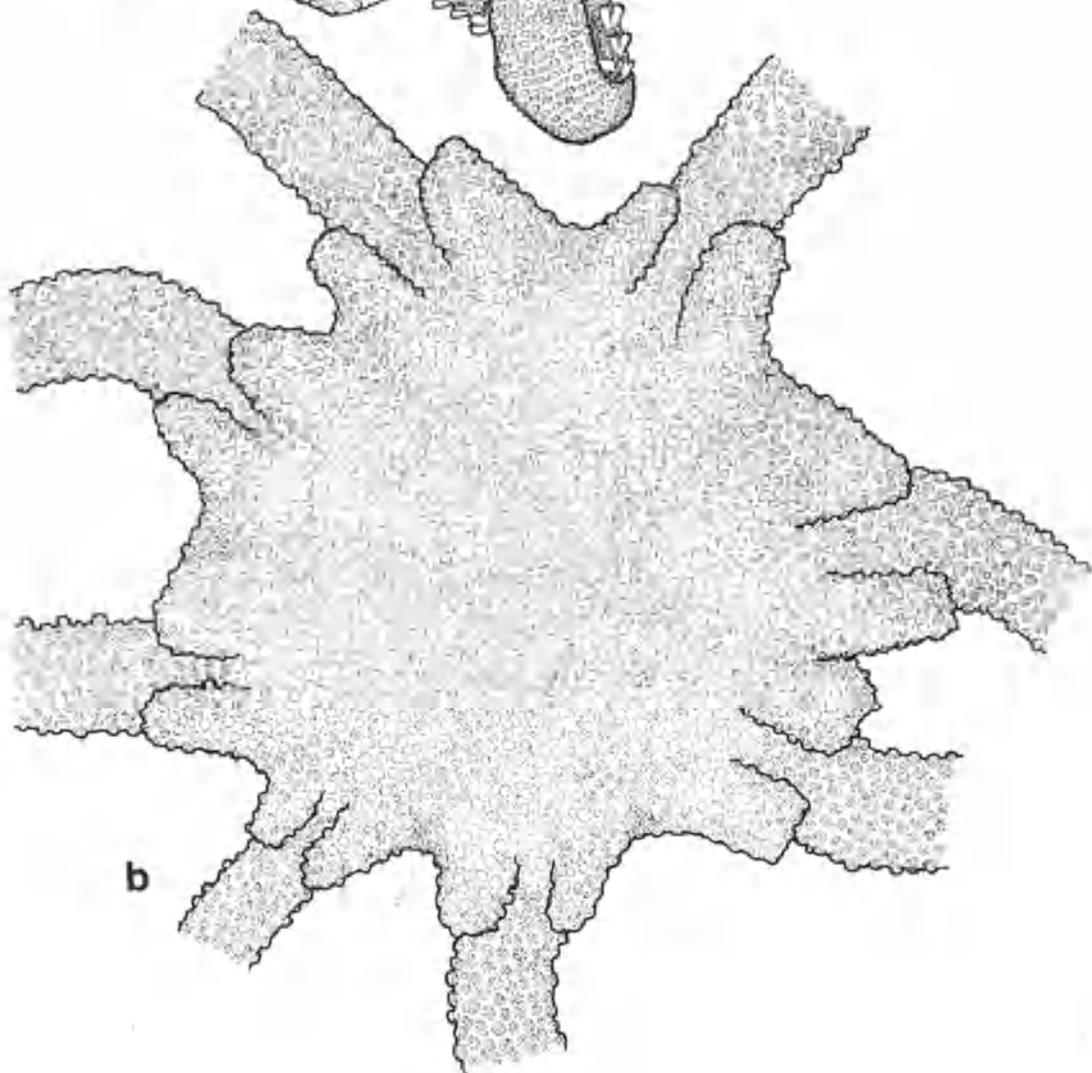
Astroceras pleiades n.sp. (Fig. 25, 27a,d–f)

TYPE DATA. **Holotype** (4.5 mm d.d.): 2.5–4 miles off Botany Bay, N.S.W., 60–102 m, 26 Sep 1921 (AM J8603). **Paratypes** (2.5–6.0 mm d.d.): 8, same sample as holotype (6, AM J3860; 2, NMNZ Ech. 1947); 9, E of Broken Bay, N.S.W., 33°18'S, 151°56'E, 365 m, 16 Apr 1975 (AM J10004); 18, off Sydney, N.S.W.,

Fig. 26. a, *Asteromorpha tenax* (holotype, QM G12051), dorsal surface of entire specimen. b, *Astroceras kermadecensis* (holotype, NZOI H252), dorsal surface of disc and adjoining arm bases.



a



b

? depth (AM J3279); 5, off Sydney, N.S.W., ? depth (AM G4196).

DESCRIPTION OF HOLOTYPE. Arms up to 25 mm long. Disc sunken centrally, covered with thick, smooth skin, naked except on radial shields, where there are domed, rugose tubercles up to 0.3 mm high. Radial shields short (1.5 × 0.6 mm), bearing 3–5 tubercles in series, the longest tubercles situated distally.

The 7 arms not swollen basally, tapering evenly, covered with skin. Dorsal arm plates bearing 3–7 transversely arranged tubercles, the median 2 or 3 largest. Lateral and ventral arm surfaces covered with smooth, naked skin. Lateral arm plates not contiguous in ventral midline; 1 isolated ventral arm plate per segment. From 2nd or 3rd segment, 2 short cylindrical arm spines present; distally, spines become hooklets with 2 or 3 teeth.

Oral frame naked; jaws with a few granule-like oral papillae; teeth sharply triangular. Genital slits oval, very small.

Colour (dry): radial shields and tuberculated plates white, intervening areas of skin brown—arms thus distinctly banded; disc with radiating dark and pale areas.

VARIATION. Most of the paratypes are coiled around branches of gorgonians. The number of arms varies from four to seven. The tuberculation of the radial shields and dorsal arm plates is very constant.

ETYMOLOGY. The Pleiades are a constellation of seven stars, and the trivial name thus alludes to the maximum of seven arms in this taxon.

REMARKS. This species is closely allied to *A. nodosum* Koehler, from Indonesia. A comparison between *A. pleiades* and a paratype of Koehler's species (USNM E86955, Amboina) shows that they differ mainly in the size and disposition of the tubercles on the arms. Both species have a very regular arrangement of tubercles—in *A. nodosum* each arm segment bears a single pair of large tubercles, surrounded by several much smaller ones (Fig. 27b,c), whereas in *A. pleiades* there are 3–7 tubercles of moderate and fairly uniform size arranged more or less transversely. Also, the radial shields are much more heavily tuberculated in *nodosum* than in *pleiades*.

DISTRIBUTION. Off New South Wales, Australia.

BATHYMETRIC RANGE 60–465 m.

Genus *Asteromorpha* Lütken, 1869

TYPE-SPECIES: *Asteromorpha steenstrupi* Lütken, 1869 (= *Astroschema rousseaui* Michelin, 1862).

Asteromorpha tenax n.sp. (Fig. 26a, 32)

TYPE DATA. **Holotype** (2.5 mm d.d.): off Moreton Bay, Qld, Queensland State Fisheries Sta. 1452, on gorgonian [no further data are available for this station, which cannot be traced by the Queensland State Fisheries; it may be assumed, however, that the sample was taken on the continental shelf because of the nature of past trawling and dredging investigations] (QM G12061).

DESCRIPTION OF HOLOTYPE. Arms coiled, but at least 10 mm long. Upper disc surface, including radial shields, covered with extremely fine, densely packed, rugose granules (12–15 in 1 mm). On 2 adjacent pairs of radial shields are 2 large, smooth-domed tubercles 1.0 mm in diameter. Ventral inter-radial areas also covered with granules. Genital slits small, oval.

Four of the 7 unbranched arms very small. One long arm has on its dorsal side, near base, 2 large and 3 smaller tubercles; otherwise, arms uniformly covered with round granules similar to those on disc. Arms weakly constricted between segments, giving a slightly annulated appearance.

From 2nd arm segment 2 short, blunt spines present; spines initially finely thorny, but along arm they develop longer thorns on adradial side near tip; at arm apex spines become flattened, glassy hooklets with 2 long teeth and a perforated lamina. Arm vertebrae with ventral furrow closed.

Ventral arm surface and oral frame covered with granules. Oral papillae granule-like, on side of jaws; teeth triangular.

Colour (dry): granules white, tubercles pearly.

ETYMOLOGY. The trivial name *tenax* (Latin, 'holding fast') alludes to the epizooic habitat of this ophiuroid.

REMARKS. The generic placement of this species is based on its disc and arms being entirely covered with granules and a few tubercles, the presence of a distinctly perforated lamina on the distal arm-spine hooklets, and the vertebrae having a closed-over furrow (Fig. 32). At first I considered *tenax* to be an *Astroceras*, but examination of the distal arm spines showed a smooth lamina more akin to *Euryale* and *Asteromorpha* than to *Astroceras* (Fig. 32). Even at 2.5 mm d.d. the simple arms of *tenax* precluded placing it in *Euryale*, which has arms with three branches at 2.0 mm d.d. I have therefore tentatively chosen *Asteromorpha* as the most likely genus for this species. The specimen is juvenile, and its adult characteristics may be quite different.

Genus *Asteromorpha* has hitherto been known from only two species, *A. rousseaui* (Michelin) and *A. kochleri* (Döderlein), the first from Mauritius

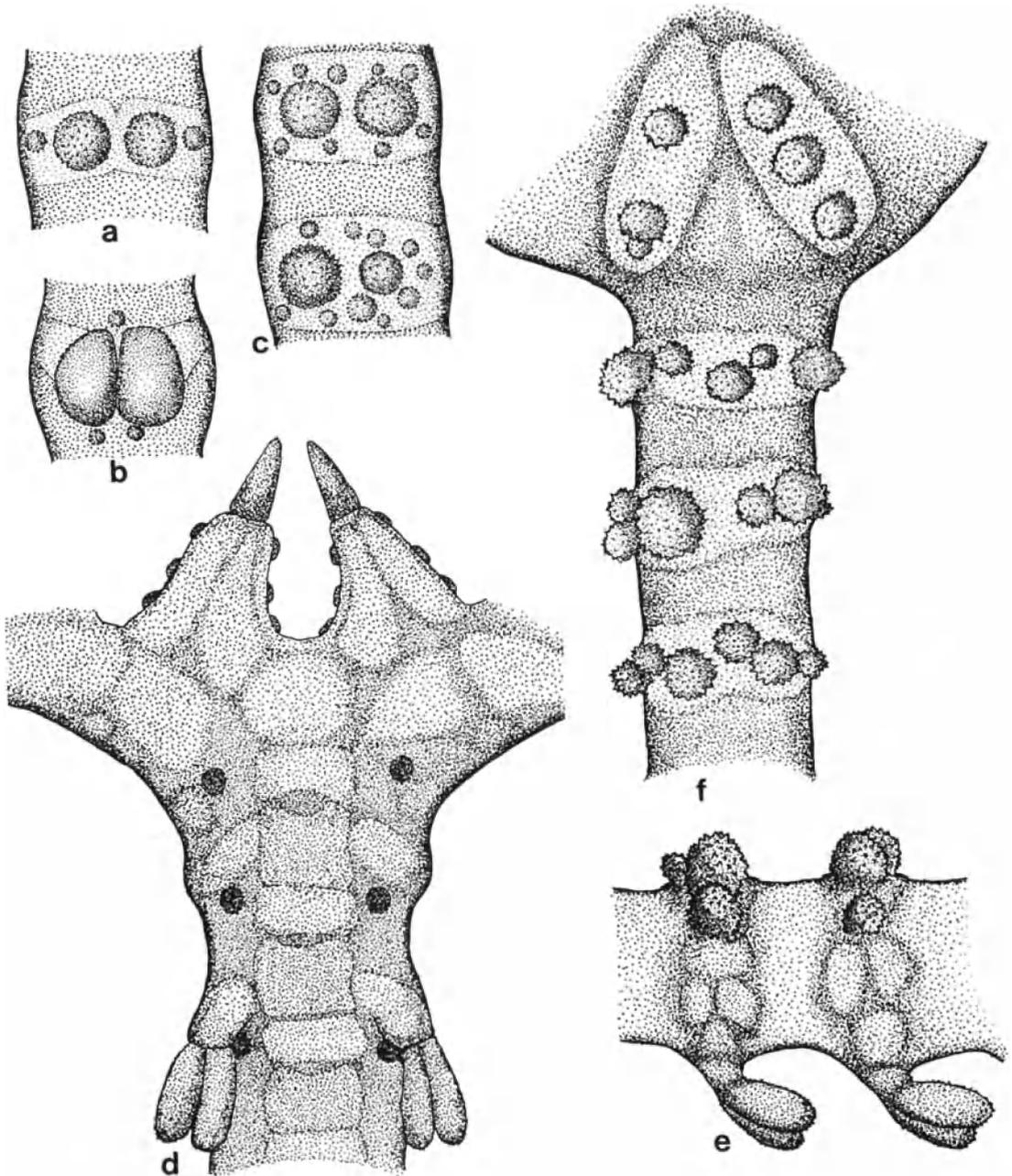


Fig. 27. a, d-f, *Astroceras pleiades* (holotype, AM J8603): (a) dorsal surface of distal arm segment; (d, f) ventral and dorsal views of arm base and adjoining disc; (e) lateral view of proximal arm segments. b, c, *Astroceras nodosum* (paratype, USNM E8695): (b) distal arm segment; (c) proximal arm segment.

and Réunion, Indian Ocean, and the second from Indonesia. *A. tenax* differs in lacking the regular transverse arm rings characteristic of those two; also, it has a few large tubercles on the disc and arms, a feature not previously known in *Asteromorpha*.

Like *A. koehleri*, the new species is self-dividing.

DISTRIBUTION. Off Moreton Bay, Queensland, Australia.

BATHYMETRIC RANGE: probably continental shelf.

Genus *Euryale* Oken, 1815

TYPE-SPECIES: *Euryale asperum* Lamarck, 1816.

Euryale aspera Lamarck, 1816 (Fig. 25, 32)

Euryale asperum Lamarck, 1816: 535.

Euryale aspera. Döderlein, 1911: 65, 115 (synonymy), pl. 5 fig. 7 & 7a; 1927: 57, 101 (synonymy).

—H. L. Clark, 1946: 172. —Eudean, 1957: 241.

—Clark & Rowe, 1971: 78.

Euryale euopla H. L. Clark, 1938: 203, pl. 23 fig. 1; 1946: 173. **New synonymy.**

MATERIAL EXAMINED. 2 specs, Thursday I., Torres Strait, ? depth (NMV); 1 spec., Lindeman I., Qld, ? depth (AM); 3 specs, Swain Reefs, Qld, 8 m (NMNZ); 10 specs, Port Curtis, Qld, 16–30 m (AM); 1 spec., Wide Bay, Qld, 33–40 m (AM); 5 specs, 25 miles SE of Double I. Pt, Qld, 60 m (AM); 1 spec., 26°03'S, 153°45'E, SE of Double I. Pt, Qld, 68 m (NMV); 1 spec., Rob I., Reserche Archipelago, W.A., 18–47 m (WAM); 1 spec., 5 miles NW of Christmas I., Reserche Archipelago, W.A., 40–50 m (WAM); 1 spec., Bald I., W.A. (**holotype** of *E. euopla*; WAM 9683); 3 specs, 11 miles E of Albany, W.A., 80 m (WAM); 1 spec., Bunbury, W.A., "deep water" (WAM); 1 spec., 33°06'S, 115°15'E, NW of Bunbury, W.A., 46 m (NMNZ); 2 specs, 33°00'S, 114°52'E, W of Bunbury, W.A., 115–122 m (WAM); 1 spec., City Beach, Perth, W.A., 18 m (WAM); 1 spec., 31°11'S, 115°01'E, W of Lancelin, W.A., 73 m (WAM); 1 spec., 31°08'S, 115°00'E, W of Lancelin, W.A., 109 m (WAM); 1 spec., 30°55'S, 114°48'E, W of Lancelin, W.A., 146 m (WAM); 2 specs, 30°15.9'S, 114°38.6'E, W of Jurien Bay, W.A., 137 m (WAM); 1 spec., 30°20'S, 114°35'E, W of Jurien Bay, W.A., 110 m (WAM); 1 spec., 30°00'S, 114°48'E, W of Green I., W.A., 46 m (WAM); 1 spec., 29°31.7'S, 114°15.5'E, W of Cliff Hd, W.A., 145 m (WAM); 1 spec., off Snag I., W.A., ? depth (WAM); 1 spec., 29°15'S, 114°38'E, W of Dongara, W.A., 46 m (WAM); 3 specs, 29°10'S, 114°20'E, W of Dongara, W.A., 47 m (WAM); 1 spec., 29°07.5'S, 114°10'E, W of Dongara, W.A., 64 m (WAM); 2 specs, off Geraldton, W.A., 53 m (WAM); 2 specs, 28°44'S, 113°34'E, Abrolhos Is, W.A., 38–44 m (WAM); 1 spec., Exmouth Gulf, W.A., ? depth (WAM); 1 spec., 2 miles W of Legendre I., Dampier Archipelago, W.A., 42 m (WAM); 1 spec., Delambre L., Dampier Archipelago, ? depth (WAM); 2 specs, Darwin, N.T., 15 m (WAM).

DESCRIPTION. Disc diameter to 49 mm; arms branched up to 22 times, arm length up to 5 × d.d. Disc sunken centrally, weakly excavate inter-radially. Radial shields straight, narrow (L:W=3–6:1), convergent, pairs almost meeting at disc centre. Disc and arms covered with smooth, naked skin (densely granular in juveniles <12 mm d.d.), bearing tall, cylindrical spines on raised bosses on each radial shield and arm joint. Spines to 6 mm high, bluntly rounded, swollen, constricted, pointed, bifurcate, excavate, or flared at tip. Each radial shield with up to 7 such spines, which increase in size distad; distal 2 or 3 spines often with a common base.

Ventral arm surface tumid, smooth, with small, rectangular plates beneath skin. Lateral arm plates widely separated, from 3rd segment bearing 2 (occasionally 3) stubby, cylindrical spines with rounded, rugose tips; innermost spine shortest; distally, spines become flattened hooklets with a long, curved, terminal tooth and a smaller secondary tooth.

Oral frame covered with smooth skin. Five small madreporites present, at distal median edge of huge adoral shields, which are joined widely along abradial margins. Tips of oral plates often pustulated; edges of jaws with 6–12 short, conical oral papillae; shorter papillae present at a higher level in mouth. Teeth rounded spearhead-shaped. Genital slits small, D-shaped, banded on adradial edge by a clump of low, rounded tubercles.

Colour: juveniles white; adults various shades of yellow, brown, orange, red, or deep purple.

VARIATION. There are five juveniles between 2.0 mm and 3.0 mm d.d. in the collections examined. Three are from Swains Reef, Queensland, and two are from off Bunbury, Western Australia. At 2.0 mm d.d. the arms have branched three times and are uniformly covered with granules. There are no larger tubercles on the arms. The disc centre is occupied by a primary rosette of six glassy scales, and there is one large domed tubercle and sometimes one or two smaller ones on or between the distal ends of the radial shields.

By 3 mm d.d. the arms have branched six times, the granulation on the arms has become sparser, and a few scattered tubercles have developed on the dorsal surface. The primary disc scales are still present, but much reduced in size. Each radial shield has at its distal end at least one tall, domed tubercle.

REMARKS. A comparison between the holotype of H. L. Clarke's *E. euopla* and 30 Western Australian specimens of *Euryale* ranging from the Reserche Archipelago to the Dampier Archipelago (1500 km of latitude) has shown that only one species, *E. aspera*,

is involved. Clark's holotype, from the furthest south of the range, is a morphological variant of *E. aspera* with thickened, clavate or bifurcate disc spines. Many other south-western Australian specimens have similar spines, but there are also individuals with slender spines, and intermediates occur, particularly in the mid-western region.

The length of the first arm fork, its number of arm segments, and the total number of arm branches, suggested as being diagnostic for *Euryale* by H. L. Clark (1938), provide no basis for separating these two nominal species. I am thus led to the conclusion that on the western coast of Australia *Euryale aspera* shows a north-south clinal variation in the thickness and shape of its disc spines.

DISTRIBUTION. Japan, Indonesia, western, northern and north-eastern Australia, New Caledonia.

BATHYMETRIC RANGE 0-290 m.

GENERAL DISCUSSION

COMPOSITION OF THE FAUNA

The euryalinid brittlestar fauna of the Australasian region comprises 41 species in 21 genera, distributed among the 4 extant families currently recognised in the suborder.

Family Asteronychidae is represented by the only two genera thus far assigned to it, and the Astero-schematidae by four of the five genera placed in that taxon. The largest family of euryalinid ophiuroids, the Gorgonocephalidae, for which 32 nominal genera are known, is represented in Australasian waters by only 12 genera. It is likely that the number of gorgonocephalid genera will increase when more deep-water sampling is carried out off the northern and western Australian coasts. Three of the six known genera of family Euryalidae are present in the region.

As might be expected, those widely distributed genera with many nominal species are best represented in the region: *Asteroschema* (five species); *Gorgonocephalus* (four species); *Astroboa* (four species). Most other genera are less polytypic, and are represented by one or two species. An exception is *Astroceras*, a genus with a dozen nominal species, including three from Australasia; I suspect that proportion will change as the number of species is eventually reduced by synonymy.

GEOGRAPHICAL DISTRIBUTION

Among the 21 euryalinid genera recorded here are 5 which are widely distributed in the major oceans—*Asteronyx*, *Astrodia*, *Asteroschema*, *Asteropora*, and *Gorgonocephalus*. All have species which live on the continental slope or in deeper water. *Asteroschema* has yet to be found in Australian coastal

waters, but its occurrence in the western Indian Ocean and off New Zealand make that only a matter of more extensive sampling.

Eight of the Australasian genera are restricted to the broad Indo-Pacific region—*Astrodrum*, *Astroboa*, *Astrocladus*, *Astrogylymma*, *Astrothorax*, *Astrothrombus*, *Astroceras*, and *Euryale*. All occur on the continental shelf, and their presence in the Australasian region has probably been effected by way of the shallows of the Indonesian archipelago and northern Australia.

The genera *Astrosierra*, *Conocladus*, and *Astrobrachion*, and subgenus *Asteropora* (*Astromoana*), are apparently restricted to Australasia. The first two are endemic to Australian coastal waters, and the remaining two are shared by Australia, Norfolk Island, and New Zealand. No euryalinid genera are known to be endemic to New Zealand alone.

Ten of the 21 genera have not yet been found in New Zealand waters; *Astrodia*, a deep-water genus, is to be expected, but *Astroclon*, *Astroboa*, *Astrocladus*, *Astrochalcis*, *Astrogylymma*, *Asteromorpha*, and *Euryale* are all tropical to warm-temperate genera which are unlikely to reach even the northern extremity of New Zealand. *Astrosierra* and *Conocladus*, although living in cooler Australian waters, have apparently evolved there in isolation, for no representatives occur on the eastern side of the Tasman Sea.

Twenty-one of the 41 species recorded here are known from other Indo-Pacific or Atlantic Ocean localities, although the bathyal *Asteronyx loveni* and *Astrodia tenuispina* are the only truly widespread species. Of the remainder, eight are endemic to Australia (*Astrosierra amblyconus*, *A. microconus*, *A. densus*, *Conocladus australis*, *Astroboa ernae*, *Asteropora* (*Astromoana*) *indicus*, *Astroceras pleiades*, and *Asteromorpha tenax*). One species, *A. (Astromoana) reticulata*, is known only from Norfolk Island, and two species, *Asteroschema salix* and *Astroceras kermadecensis*, are apparently restricted to the Kermadec Islands.

Tonga has one endemic euryalinid in *Astrocladus tonganus*—an unusual geographic restriction for a large, tropical shallow-water ophiuroid. The Kermadec Islands, Norfolk Island, and New Zealand share a single species, *Asteroschema igloo*, and Norfolk Island and New Zealand share *Astroceras elegans* and *Astrothorax waitei*. *Astroboa granuifatus* occurs in Australia and at Lord Howe and Norfolk Islands, and *Astrobrachion adhaerens* is present around western and northern Australia as well as at the Kermadecs; it may thus be expected at Norfolk and Lord Howe Islands.

Only seven species of euryalinid are shared by Australia and New Zealand—*Astrobrachion constrictum*, *Ophiocreas sibogae*, *Astrothrombus rugosus*,

Asteropora australiensis, *Astrothorax waitei*, *Gorgonocephalus dolichodactylus*, and *G. pustulatum*. *A. waitei* and *G. pustulatum* are also known from southern Africa.

The 41 species of Euryalinida recorded from the Australasian region are thus very unevenly distributed geographically. Australia has 27, New Zealand 14, Norfolk Island 10, the Kermadec Islands 8, Lord Howe Island 2, and Tonga 1.

The endemic species of *Astrosierra* and *Conocladus* are found in the cooler waters of the southern half of Australia. *Astroboa ernae* and *A. granulatus* are found mainly in the warmer northern areas, although the former has managed to establish itself in the warm waters of St Vincent and Spencer Gulfs, South Australia, probably by way of south-western Australia. *Astrobrachion adhaerens* is a western and northern species which has reached eastward to the Kermadec Islands.

Those euryalinids shared by Australia and New Zealand occur on the south-eastern and southern coasts of the former and mainly the north-eastern coast of the latter, although the pan-Tasman *Astrobrachion constrictum* does occur also in the south-west of New Zealand (Fig. 1).

Many of the shallow-water tropical species recorded from Australia (e.g., *Astroboa* spp., *Astrocladus* spp., *Astrochalcis*) have been collected only recently, and from a few localities in the north-west. It is probable that the distribution of these forms will eventually be shown to extend around the northern half of the continent, as indicated, for example, by *Astroboa granulatus*.

The deeper-water taxa also are known from very few stations, and because bathyal species often have a widespread distribution in that zone, any pattern of distribution is more likely to reflect the choice of sampling sites and bathymetry rather than zoogeographic relationships.

BATHYMETRIC DISTRIBUTION

The following 12 species have been collected only on the continental shelf (0–180 m):

Astrobrachion constrictum
A. adhaerens
Astroboa ernae
A. nuda
A. nigrofurcata
A. granulatus
Astrocladus ludwigi
A. tonganus
Astrochalcis tuberculosus
Asteropora (Astromoana) indicus
Astrosierra amblyconus
A. densus

Fourteen species are apparently eurybathic, having been collected on both shelf and slope:

Astrodendrum elingamita
Astrocladus exiguus
Astroglymma sculptum
Astrothrombus rugosus
Astrothorax waitei
Asteropora australiensis
A. (Astromoana) reticulata
Astroclon suensoni
Astrosierra microconus
Conocladus australis
Gorgonocephalus chilensis
Astroceras elegans
A. pleiades
Euryale aspera

Ten species are known only from the continental slope to just over 1000 m:

Asteroschema salix
A. igloo
A. horridum
A. tubiferum
A. migrator
Ophiocreas sibogae
Gorgonocephalus pustulatum
G. sundanus
G. dolichodactylus
Astrothrombus vecors

Of the remaining five species, *Asteronyx loveni* is eurybathic between 109 m and almost 3000 m (a remarkable bathymetric range for any marine animal), *Ophiocreas oedipus* ranges the slope between 760 m and 2000 m, and *Astrodia tenuispina* between 510 m and 3720 m. *Astroceras kermadecensis* is known from only one station, in 1165–1185 m. The depth range of *Asteromorpha tenax* is unknown, but it is most likely a shelf species.

ACKNOWLEDGMENTS

I am indebted to the Directors and Marine Invertebrate Curators of the institutions listed in the Introduction for access to their ophiuroid collections. Special thanks for the loan of comparative material and other collections of euryalinids are due to Miss A. M. Clark (BMNH), Mr A. Guille (Muséum Nationale d'Histoire Naturelle, Paris), Mr D. G. McKnight (NZOI), Dr F. J. Madsen (ZMC), Mrs L. M. Marsh (WAM), Dr P. Mather (QM), Dr N. Millard (RSAM), Dr D. L. Pawson (USNM), Dr F. W. E. Rowe (AM), Mr D. R. K. Sastry (Zoological Survey of India), Dr van der Spoel (ZMA), Dr R. M. Woollacott (MCZ), and Mr W. Zeidler (SAM). I am also grateful to the following persons who provided specimens for study or helped with field work: Mr A. J. Black, Mr Neville Coleman, Dr R. Endean, Mr W. B. Higgins, Mr S. A. Shepherd, and personnel of the Fisheries Research Division, N.Z. Ministry of Agriculture and Fisheries. The New Zealand Geological Survey (DSIR) and Victoria University of Wellington's Science Faculty kindly made available their scanning electron microscopes; most of the photomicrographs were taken by Mr B. A. Marshall. Mr W. N. Wilson was responsible for the

macrophotography, and Mr W. J. Anderson assisted with the line illustrations. Mr F. C. Kinsky helped with translations, and Drs R. K. Dell and J. C. Yaldwyn suggested improvements to the manuscript.

REFERENCES

- BAKER, A. N. 1974: New species of brittle-stars from New Zealand. *Records of the Dominion Museum, Wellington* 8(15): 247-66.
- BAKER, A. N.; CLARK, H. E. S. 1970: Some archibenthal echinoderms from northern New Zealand. *Records of the Dominion Museum, Wellington* 7(1): 1-11.
- BELL, F. J. 1894: On the echinoderms collected during the voyage of H.M.S. 'Penguin' and H.M.S. 'Egeria' when surveying the Macclesfield Bank. *Proceedings of the Zoological Society of London, 1894*: 392-413.
- 1917: Echinoderma. Part I. Actinogoniata. *Natural History Reports of the British Antarctic 'Terra Nova' Expedition, Zoology IV*: 1-10.
- BENHAM, W. B. 1909: Scientific results of the New Zealand Government trawling expedition 1907. Echinoderma. *Records of the Canterbury Museum* 1(2): 83-116.
- CATALA, R. L. A. 1964: *Carnival Under The Sea*. Sicard, Paris.
- CHERBONNIER, G.; GUILLE, 1978: *Faune de Madagascar. 48, Echinodermes: Ophiuroïdes*. Centre National de la Recherche Scientifique, Paris.
- CLARK, A. H. 1949: Ophiuroidea of the Hawaiian Islands. *Bulletin of the Bernice P. Bishop Museum* 195: 3-133.
- CLARK, A. M. 1966: Some crinoids from New Zealand waters. *N.Z. Journal of Science* 9(3): 684-705.
- 1974: Notes on some echinoderms from southern Africa. *Bulletin of the British Museum (Natural History), Zoology* 26(6).
- CLARK, A. M.; ROWE, F. W. E. 1971: *Monograph of shallow-water Indo-West Pacific Echinoderms*. British Museum (Natural History), London.
- CLARK, H. L. 1909a: Scientific results of the trawling expedition of H.M.C.S. 'Thetis' off the coast of New South Wales, in February and March 1898. Echinodermata. *Memoirs of the Australian Museum* 4(2): 519-64.
- 1909b: Notes on some Australian and Indo-Pacific echinoderms. *Bulletin of the Museum of Comparative Zoology, Harvard*, 52(7): 109-35.
- 1914: The echinoderms of the Western Australian Museum. *Records of the Western Australian Museum & Art Gallery* 1: 132-73.
- 1915: Catalogue of recent ophiurans: based on the collections of the Museum of Comparative Zoology. *Memoirs of the Museum of Comparative Zoology, Harvard*, 25(4): 165-367.
- 1916: Report on the sea lilies, starfishes, brittle-stars, and sea-urchins obtained by the F.I.S. 'Endeavour' on the coasts of Queensland, New South Wales, Tasmania, Victoria, South Australia, and Western Australia. *Biological Results of the F.I.S. 'Endeavour', 1909-14*, 4.
- 1918: Brittle-stars, new and old. *Bulletin of the Museum of Comparative Zoology, Harvard*, 62: 265-338.
- 1923: The echinoderm fauna of South Africa. *Annals of the South Africa Museum* 13: 221-435.
- 1928: The sea lilies, sea-stars, brittle-stars and sea-urchins of the South Australian Museum. *Records of the South Australian Museum* 3(4): 361-482.
- 1938: Echinoderms from Australia, an account of collections made in 1929 and 1932. *Memoirs of the Museum of Comparative Zoology, Harvard*, 55.
- CLARK, H.L. 1939: A new *Astroconus* from South Australia. *Records of the South Australian Museum* 6(3): 207-8.
- 1946: The echinoderm fauna of Australia, its composition and its origin. *Carnegie Institute, Washington, Publication* 566.
- DE LORIO, P. 1893: Catalogue raisonné des échinodermes recueillis par M.V. de Robillard à l'île Maurice. III. Ophiures et Astrophytides. *Memoirs de la Société de Physique et d'Histoire Naturelle de Geneve*, 32(1) (3): 3-63.
- DÖDERLEIN, L. 1896: Bericht über die von Herrn Prof. Semon bei Amboina und Thursday Island gesammelten Ophiuroidea. Pp. 279-300 in R. W. SEMON, "Zoologische Forschungsreisen in Australien und dem Malayischen Archipel". *Jenaische Denkschriften VIII*.
- 1911: Beiträge zur Naturgeschichte Ostasiens. Über japanische und andere Euryalae. *Abhandlungen der Bayerischen Akademie der Wissenschaften II, Suppl.-Bd. 5*.
- 1912: Die arme der Gorgonocephalinae. *Zoologische Jahrbücher, Suppl.* 15(2): 257-74.
- 1927: Indopacifische Euryale. *Abhandlungen der Bayerischen Akademie der Wissenschaften* 31(6).
- 1930: Die Ophiuroiden der Deutschen Tiefsee-Expedition. 2. Euryalae. *Deutsche Tiefsee-Expedition 1898-1899* 22(6).
- DOMANTAY, J. S. 1957: Preliminary reports on the marine fauna of One Hundred Island and vicinity, gulf of Lingayen, Pangasinan Province, Luzon, Philippines. *Araneta Journal of Agriculture* 4(4): 24-6.
- DOMANTAY, J. S.; DOMANTAY, C. R. 1967: Studies on the classification and distribution of Philippine littoral Ophiuroidea (Brittle Stars). *The Philippine Journal of Science* 95(1): 1-76.
- ENDEAN, R. 1957: The biogeography of Queensland's shallow-water echinoderm fauna (excluding Crinoidea), with a re-arrangement of the faunistic provinces of tropical Australia. *Australian Journal of Marine & Freshwater Research* 8: 233-73.
- FARQUHAR, H. 1900: On a new species of Ophiuroidea. *Transactions of the N.Z. Institute* 32: 405.
- FEDOTOV, D. M. 1927: Morphologische studien an Euryale. *Zeitschrift für Morphologie und Ökologie der Tiere* 9: 341-89.
- FELL, H. B. 1951: Some off-shore and deep-sea ophiuroids from New Zealand waters. *Zoology Publications from Victoria University College, Wellington*, 13: 1-4.

- FELL, H.B. 1952: Echinoderms from southern New Zealand. *Zoology Publications from Victoria University College, Wellington*, 18: 1-37.
- 1958: Deep-sea echinoderms of New Zealand. *Zoology Publications from Victoria University of Wellington* 24: 1-40.
- 1960: Archibenthal and littoral echinoderms of the Chatham Islands. "Biological Results of the Chatham Islands Expedition", Part 2. Pp. 55-75 in *N.Z. Department of Scientific & Industrial Research Bulletin* 139.
- 1962: Native Sea-Stars. *Nature in New Zealand*. Reed, Wellington.
- GRAY, J. E. 1840: A synopsis of the genera and species of the class Hypostoma (*Asterias* Linn.). *Annals & Magazine of Natural History* (16): 175-84; 275-90.
- KOEHLER, R. 1897: Echinoderms recueillis par l'Investigateur dans l'Océan Indien. I. Les Ophiures de mer profonde. *Annales des Sciences Naturelles* 8, Ser. Zool. 4: 277-372.
- 1904: Ophiures de l'Expedition du Siboga. Part 1. Ophiures de mer profonde. *Siboga Expedition Monograph XLV, Livr. XV*.
- 1905: Ophiures de l'Expedition du Siboga. Part 2. Ophiures littorales. *Siboga Expedition Monograph XLVb, Livr. XXI*.
- 1909: Echinodermes provenant des campagnes du yacht 'Princesse-Alice' (*Asteries*, *Ophiures*, *Echinides* et *Crinoides*). *Resultats des Campagnes Scientifiques accomplies sur son yacht par Albert Ier, Prince Souverain de Monaco, Fascicule 34*.
- 1910: Description d'ophiures nouvelles provenant des derniers campagnes de 'l'Investigateur' dans l'Océan Indien. *Records of the Indian Museum V(VII)*: 83-8.
- 1922: Ophiurians of the Philippine Seas and adjacent waters. *Bulletin of the United States National Museum* 100(5).
- 1930: Papers from Dr Th. Mortensen's Pacific Expedition 1914-16. LIV. Ophiures recueillis par le Docteur Th. Mortensen dans les mers d'Australie et dans l'Archipel Malais. *Videnskabelige Meddelelser Dansk naturhistorisk Forening i Kjobenhaven* 89.
- LAMARCK, J. B. P. 1816: *Histoire naturelle des animaux sans vertèbres*, 1st ed. Paris.
- LEACH, W. E. 1815: *Zological Miscellany*, London, 2.
- LJUNGMAN, A. 1867: Ophiuroidea viventina huc usque cognita. *Ofversigt af K. Vetenskapsakademiens forhandlingar, Stockholm*, 1866 (9): 303-36.
- LÜTKEN, C. F. 1856: Additamenta ad historiam Ophiuridarum. 2. Beskrivelser af nye eller hidtil kun ufuldstændigt kjendte Arter af Slangestjerner. *Kongelige Danske Videnskabernes Selskabs Skrifter* 5(5): 179-271.
- 1869: Additamenta ad historiam Ophiuridarum. 3. Beskrivende og kritiske Bidrag til kundskab om Slangestjerner. *Kongelige Danske Videnskabernes Selskabs Skrifter* 5(8): 24-109.
- LYMAN, T. 1874: Ophiuridae and Astrophytidae, old and new. *Bulletin of the Museum of Comparative Zoology, Harvard*, 3(10): 221-72.
- 1877: Mode of forking among astrophytons. *Proceedings of the Boston Natural History Society* 19: 1-8.
- 1878: Reports on the results of dredging, under the supervision of Alexander Agassiz, in the Gulf of Mexico, by the U.S.S. Coast Survey Steamer "Blake". Ophiurans and Astrophytons. *Bulletin of the Museum of Comparative Zoology, Harvard*, 5(9): 217-38.
- 1879: Ophiuridae and Astrophytidae of the exploring voyage of H.M.S. 'Challenger' under Prof. Sir Wyville Thomson, F.R.S. 2. *Bulletin of the Museum of Comparative Zoology, Harvard*, 6(2): 17-83.
- 1882: Ophiuroidea. *Report of the Scientific Results of the Exploring Voyage of H.M.S. Challenger*, N.Z. Ecological Society 20: 21-30.
- MCKNIGHT, D. G. 1968: Some echinoderms from the Kermadec Islands. *N.Z. Journal of Marine & Freshwater Research* 2(3): 505-26.
- 1975: Some echinoderms from the northern Tasman Sea. *N.Z. Oceanographic Institute Records* 2(5): 49-76.
- MADSEN, F. J. 1951: Ophiuroidea. *Reports of the Swedish Deep-Sea Expedition, II, Zoology* (9): 107-17.
- 1967: Ophiuroidea. *B.A.N.Z. Antarctic Research Expedition 1929-31, Reports Series B, IX*(3): 123-44.
- MATSUMOTO, H. 1915: A new classification of the Ophiuroidea. *Proceedings of the Academy of Natural Sciences of Philadelphia* 67: 43-92.
- 1917: A monograph of Japanese Ophiuroidea arranged according to a new classification. *Journal of the College of Science, Imperial University of Tokyo* 38.
- 1918: On a collection of Ophiurans from the vicinity of Kinkwasan, with description of a new species. *Annotationes zoologicae japonenses* ix: 475-80.
- MICHELIN, H. M. 1862: Echinides et Stellerides. Annex A, pp. 1-7, in L. MAILLARD, *Nôtes sur l'île de la Réunion II* (2nd ed.).
- MORTENSEN, T. 1911: *Astroclon suensoni* n.sp. a new East Asiatic Euryalid. *Videnskabelige Meddelelser Dansk naturhistorisk Forening i Kjobenhaven* 63: 209-12.
- 1912: Über *Asteronyx loveni* M. Tr. *Zeitschrift für Wissenschaftliche Zoologie* C1, 1/2: 264-89.
- 1924: Echinoderms of New Zealand and the Auckland-Campbell Islands. II. Ophiuroidea. Papers from Dr Th. Mortensen's Pacific Expedition 1914-16. *Videnskabelige Meddelelser Dansk naturhistorisk Forening i Kjobenhaven* 77: 91-177.
- 1933a: Studies of Indo-Pacific euryalids. *Videnskabelige Meddelelser Dansk naturhistorisk Forening i Kjobenhaven* 96: 1-75.
- 1933b: Echinoderms of South Africa (*Asteroidea* and *Ophiuroidea*). *Videnskabelige Meddelelser Dansk naturhistorisk Forening i Kjobenhaven* 93: 215-400.
- 1936: Echinoidea and Ophiuroidea. *Discovery Reports XII*: 199-348.

- MÜLLER, J.; TROSCHER, F. H. 1842: *System der Asteriden*. Braunschweig.
- OKEN, L. 1815: *Lehrbuch der Naturgeschichte*, Part 3, Zoologie. Leipzig & Jena.
- PALLAS, P. S. 1788: *Marina varia nova et rariora. Nova Acta Academiae Scientiarum Imperialis Petropolitanae II*: 229-40.
- PAWSON, D. L. 1969: *Astrothrombus rugosus* Clark, new to New Zealand, with notes on *Ophioceres huttoni* (Farquhar), *Hemilepis norae* (Benham), and *Ophiuroglyphya irrorata* (Lyman) (Echinodermata: Ophiuroidea). *N.Z. Journal of Marine & Freshwater Research* 3(1): 46-56.
- PHILIPPI, R. A. 1858: Beschreibung einiger neuer see-sterne aus dem meere von Chiloe. *Archiv für Naturgeschichte* 24(1): 268.
- SPENCER, W. K.; WRIGHT, C. W. 1966: Asterozoans. Pp. 4-107 in R. C. MOORE (Ed.), *Treatise on Invertebrate Paleontology, Part U, Echinodermata* 3(1).
- STUDER, T. 1884: Verzeichniss der während der Reise S.M.S. 'Gazelle' um die Erde 1874-76 gesammelten Asteriden und Euryaliden. *Abhandlungen der Preussischen Akademie der Wissenschaften* 2: 1-64.
- VERRILL, A. E. 1876: Annelids and Echinoderms from Kerguelen Island. *Bulletin of the United States National Museum* 3: 64-77.
- 1884: Notice of the remarkable marine fauna occupying the outer banks off the southern coast of New England, 9. *American Journal of Science (3rd Series)* 28: 219.
- 1889: North American Ophiuroidea. I. Revision of certain families and genera of West Indian ophiurans. *Transactions of the Connecticut Academy of Sciences* X(7): 301-71.
- WOLFE, T. J. 1978: "Aspects of the biology of *Astrophyton muricatum* (Lamarck, 1816) (Ophiuroidea: Gorgonocephalidae)." Unpubl. MSc. thesis, Department of Marine Science, University of Puerto Rico.

Overleaf. Fig. 28 (self-captioned) and Fig. 29-33 (captioned below).

Fig. 29-33. Scanning electron micrographs of arm spines and/or girdle hooklets of Australasian Euryalinida. Length measurements (mm) are below each specimen, and lower-case letters refer to position of spine or hooklet on arm: **p** - proximal arm spine, taken from within 20 arm segments of disc; **d** - distal arm-spine hooklet, taken from extremity of arm; **g** - girdle hooklet, taken from extremity of arm; **v** - vertebra. The following species are represented.

- Fig. 29.** *Asteronyx loveni*, *Astrodia tenuispina*, *Asteroschema tubiferum*, *A. igloo* (paratype, NMNZ Ech. 2877), *A. horridum*, and *A. migrator*.
- Fig. 30.** *Astrobrachion adhaerens*, *A. constrictum*, *Ophiocreas sibogae*, *O. oedipus*, *Gorgonocephalus pustulatum*, *G. sundanus*, *G. dolichodactylus*, and *G. chilensis*.
- Fig. 31.** *Astroglymma sculptum*, *Astrochalcis tuberculosus*, *Astrothorax waitei*, *Astrothrombus rugosus*, *A. vecors*, *A. ringens*, *Asteropora australiensis*, *A. (Astromoana) reticulata* (paratype, NMNZ Ech. 2878), and *A. (Astromoana) indicus* (holotype, WAM 737.75).
- Fig. 32.** *Astrosierra amblyconus*, *A. densus* (paratype, NMNZ Ech. 1860), *A. microconus*, *Conocladus australis* (AM E4727), *Astroceras elegans*, *A. kermadecensis* (paratype, NMNZ Ech. 2066), *Asteromorpha tenax* (holotype, QM G12061), *A. rousseaui* (Amboina; ZMC), and *Euryale aspera*.
- Fig. 33.** *Astrodendrum elingamita*, *Astroboa ernae*, *A. nuda*, *A. nigrofurcata*, *A. granulatus*, *Astrocladus exiguus*, *A. ludwigi*, and *A. tonganus*.

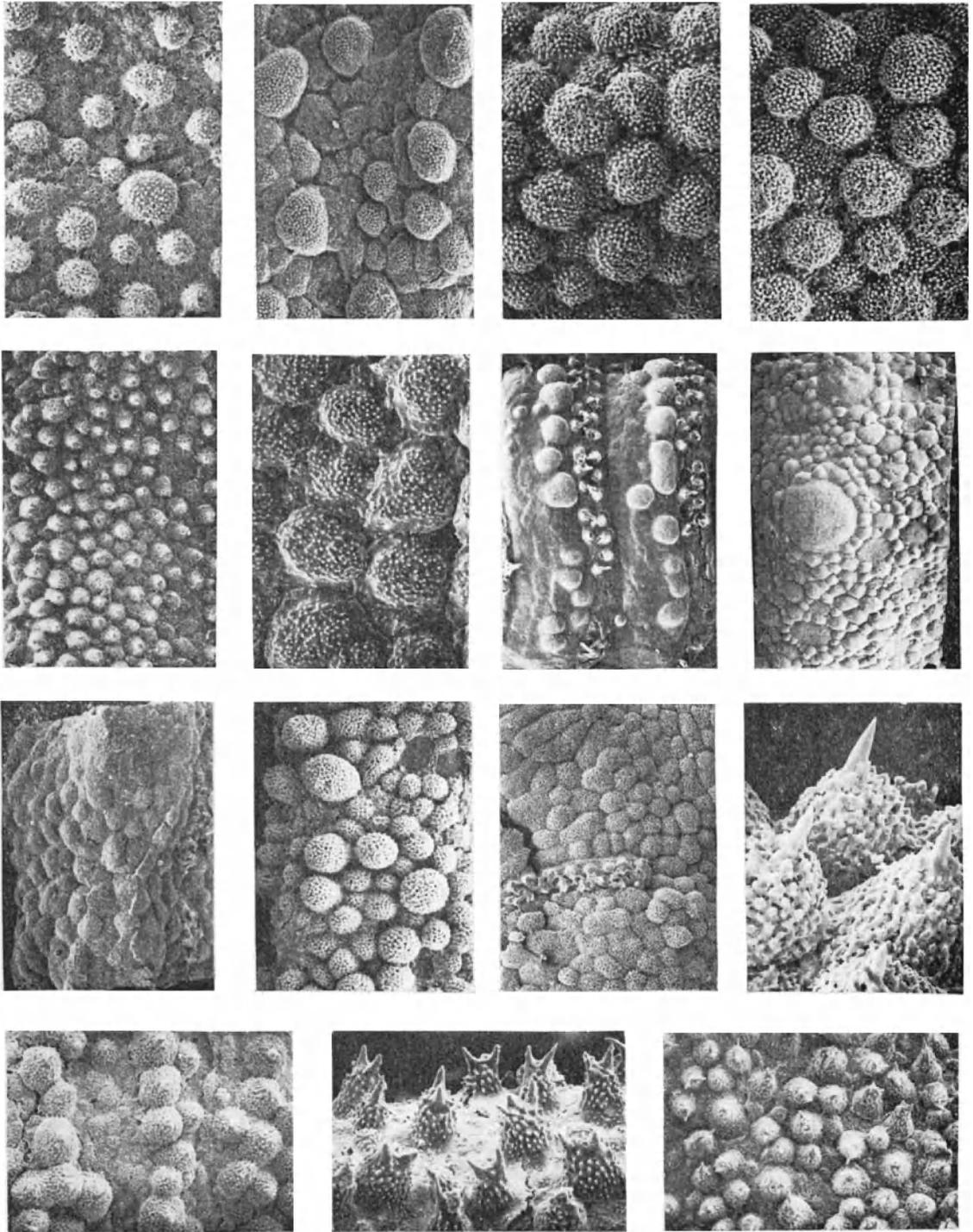
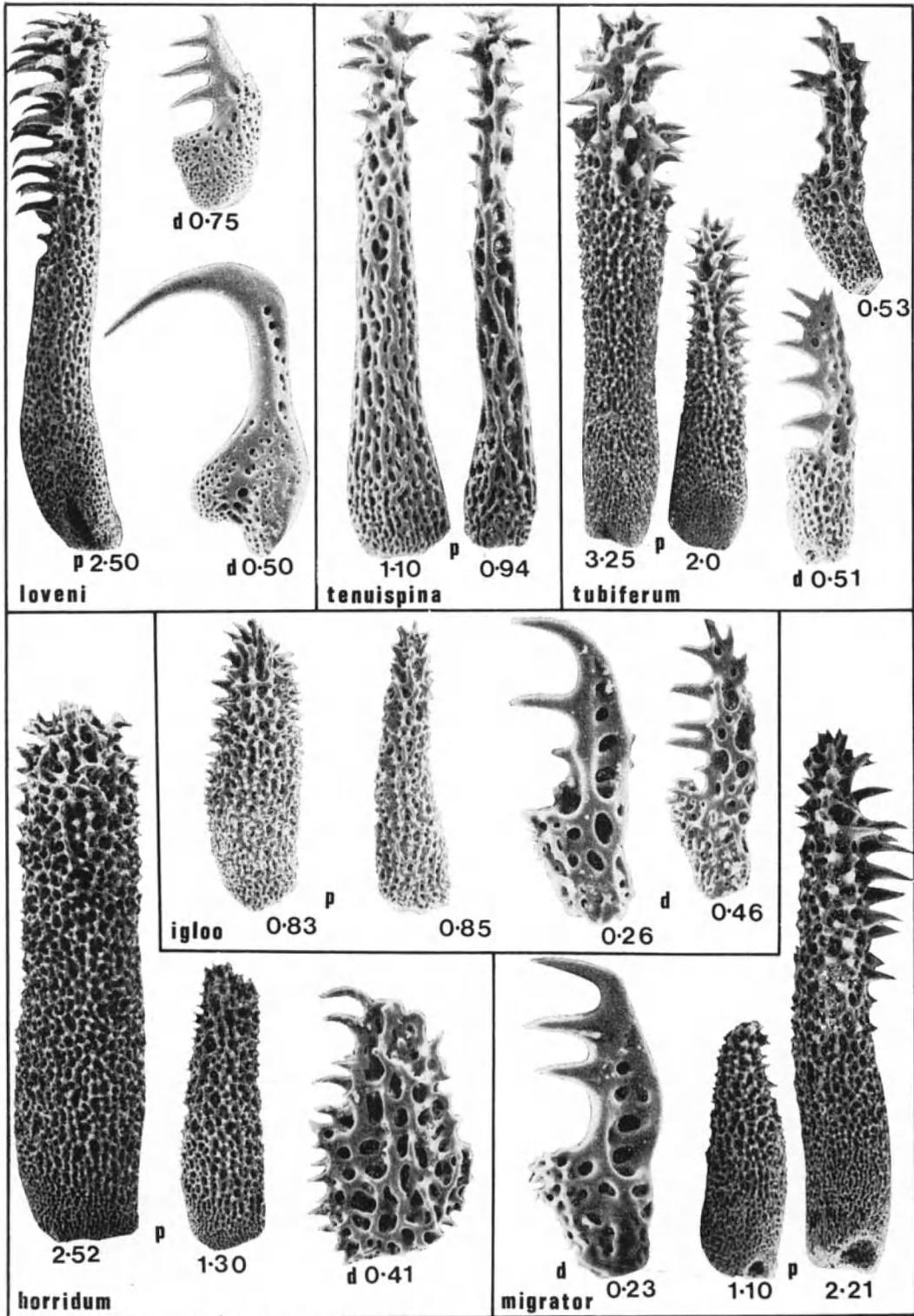


Fig. 28. Surface of disc (radial shield) and arms (basal dorsal, unless otherwise specified) of: **top row, left to right**, *Astroboea granulatus*, disc & arm; *A. ernae*, disc & arm; **2nd row**, *A. nigrofurcata*, disc; *A. nuda*, disc; *Gorgonocephalus dolichodactylus*, arm, latera!; *Astrochalcis tuberculosus*, disc; **3rd row**, *Astroglymma sculptum*, arm; *Astrocladus ludwigi*, disc & arm; *A. tonganus*, disc detail; **bottom row**, *A. tonganus*, arm; *Astrocladus exiguus*, disc detail & arm.



Downloaded by [193.191.134.1] at 01:02 08 June 2012

