

# A Review of the Genus *Ophiomastix* (Ophiuroidea: Ophiocomidae)<sup>1</sup>

DENNIS M. DEVANEY

Bernice P. Bishop Museum, P.O. Box 6037  
Honolulu, Hawaii 96818

**Abstract.**—A review of the ophiuroid genus *Ophiomastix* based upon comparisons of conventional and newly proposed morphological criteria is presented. The relationship of the genus within the subfamily Ophiocominae is discussed, providing evidence for the close connection of *Ophiomastix* to the Scolopendrina group of *Ophiocoma*. Material is drawn from previous descriptions as well as from specimens in various institutions around the world and including many previously undescribed or erroneously described specimens. One new species is included, increasing the number recognized in the genus to fifteen from various locations throughout the Indo-West Pacific region (East Africa to the Tuamotu Archipelago). A key to the identification of the species and illustrations of important taxonomic features are provided.

## Introduction

Brittlestars in the genus *Ophiomastix* generally, but not always, can be recognized by modification (enlargement) of upper arm spines combined with an alternating number of spines from segment to segment which results in alteration in shape of the upper arm plates, and by the type of disc covering. Representative species range in size from moderately large with a disc diameter (d.d) of 35 mm to moderately small (10 mm) in adult specimens.

The modified arm spines are described as: "Furcated," an arm spine with the tip produced into forked or cloven projections (Figs. 3a, b; 16a, 32); "Claviform," an arm spine inflated, swollen, or thickened—usually distal to the spine base—in evident contrast to adjacent arm spines at the same level or in the same vertical series (Figs. 5a, b; 16b; 22; 29a, b); "Elongated," an arm spine that may or may not be furcated, claviform or simply taper out to the tip but whose length is noticeably greater than spines adjacent to or on the opposite side from the modified spine at the same level or in the same vertical series.

A number of, if not all, species of *Ophiomastix* also are characterized by having a thickened epithelium covering most or at least the distal part of the enlarged arm spines (Fig. 3b; 7; 29b). The function of this epithelium is considered under *Ophiomastix annulosa*, a species in which the histology of this tissue has been studied (p. 283).

The disc cover of all species of *Ophiomastix* consists of a basal layer of scales and upon which granular and/or spiniform elements develop (although these are frequently absent in some specimens of *O. venosa*, and rarely absent in *O. flaccida*). The disc

<sup>1</sup> Part II of a series of Studies on Ophiocomid Brittlestars.

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elements are defined as follows: "Granules" are rounded, coneshaped or tapering elements whose height is two times or less than their diameter or greatest breadth; "Spinules" are disc elements usually strongly tapering toward the tip, smooth or minutely spinulose along their surface, whose height is more than two times their diameter or greatest breadth.

### Historical Resumé

The genus *Ophiomastix* was established by Müller and Troschel in 1842. The presence of both oral and dental papillae suggested a relationship with *Ophiocoma* in the family Ophiocomidae. The presence of spinules instead of low rounded granules on the disc and a very noticeable thickening of some of the upper arm spines (often elongated and with a widened or forked tip) were considered reasons enough to establish the new genus. *Ophiomastix annulosa* was the type and only species originally included. A few years later Peters (1851) added to the genus by describing *O. venosa*, a species with cloven-tipped claviform arm spines and only a few widely spaced disc spines.

As more species were included in this genus, the desirability of restricting species to those having *both* distinguishing characters (disc spines and clavifurcate arm spines) rather than *either* became difficult. Several change in Müller and Troschel's generic diagnosis was proposed by Lütken (1869) when he reported three new species, *O. mixta*, *O. asperula*, and *O. caryophyllata*, and after he observed that an adult specimen of *O. venosa* lacked disc spines entirely. Furthermore he found a 14 mm (d.d.) specimen of *O. annulosa* and an adult specimen of *O. venosa* without modification of the upper arm spines. He noted that *O. mixta* also lacked claviform arm spines and revealed further variation from the original generic diagnosis by having a disc cover of mixed spinules and granules.

With these variations evident, Lütken presented an amended diagnosis for *Ophiomastix*. Species were now not limited to only those with clavifurcate arm spines, but included those species allied to *Ophiocoma* with or without the modified arm spines and in which the disc was covered with spinules or spines, spinules and granules, or was entirely naked. Furthermore, he specified that certain species in this genus only, could have segments along part of the arm with the upper spine modified and enlarged into the form of a divided club (furcate) at its apex.

Lyman (1871) next described *Ophiomastix janualis* on the basis of a small (d.d. = 5 mm) specimen reportedly from Mexillones, Bolivia (in obvious error). Recent evidence suggests that this is an Indo-Pacific form confused with *O. luetkeni* Pfeffer (see p. 305).

Another new species, *Ophiomastix flaccida*, was reported by Lyman (1874) on the basis of a 15 mm specimen from the Philippines lacking tentacle scales and having a thick skin which obscured the lateral and upper arm plates. Smith (1878) described *Ophiomastix (Acantharachna) mirabilis* which he considered the type of a new subgenus. Except for size, there was little to distinguish *O. mirabilis* from *O. flaccida*

and the two taxa have been synonymized. The use of Smith's subgeneric name, based primarily on the peculiar absence of tentacle scales, has not been adopted by other echinoderm workers, although, as noted in the present report, the absence of the calcified ridge separating the radial water canal and radial nerve on the first true arm vertebra (Fig. 10c) also appears unique among members of the genus and rest of the subfamily.

In 1882, in his report on the Ophiuroidea collected by the Challenger Expedition, Lyman reviewed the five known species of *Ophiomastix*. In the form of a key (pp. 174–175) he separated them by the number of tentacle scales (two, one, or none), by the nature of the disc cover and by the shape of the lower arm plates. He gave a generic description, amending Müller and Troschel's original description and allowed more latitude with regard to the nature of the disc cover and shape of the arm spines (following Lütken's proposal in 1869).

Lyman, for the first time, commented on the internal skeleton of the group. He compared *Ophiomastix* to *Ophiocoma* and noted in the latter that a) the radial shields were proportionately larger, b) there was a difference in the position of the oral plates with respect to one another, and c) the genital plate was more rounded and longer. Also, the scaling (presumably on the inside of the disc) was found to be variable (i.e., in *O. venosa*, scales were minute and thin at the center of disc, whereas in *O. annulosa* the scales were larger and lumpy). My own comparisons of these internal characters, and the review by Murakami (1963) with regard to the oral plates, do not substantiate Lyman's generalizations and do not reveal these as generic differences between *Ophiocoma* and *Ophiomastix*. This becomes especially true when examining additional species in both genera, and variations caused by growth changes. For example, the radial shields of *Ophiocoma wendti*, *O. erinaceus*, and *O. dentata* are proportionately larger than those of *Ophiomastix variabilis*. Also, the genital plate of *Ophiomastix venosa* is no longer than that of *Ophiocoma dentata*. Murakami's (1963) examination of the dental as well as oral plates of species in both *Ophiomastix* and *Ophiocoma* indicated a similarity between the two genera in these characters.

A review of the genus *Ophiomastix* was made by Brock (1888) in which two new species were described (*O. pusilla* and *O. elegans*). He reached his own conclusions regarding the generic status of *Ophiomastix*, placing emphasis on the form of the upper arm spine. He tried to show that the modified swollen or clavifurcate upper arm spines develop with age in the known *Ophiomastix* species and that the spines were a very characteristic mark of distinction in comparison to *Ophiocoma*, indicating that each species of *Ophiomastix* has its own characteristic form and arrangement of claviform or furcated upper spines. Of the species in which enlarged upper arm spines were unknown or considered absent (i.e., *O. mixta* and *O. janualis*), Brock reported that one specimen of the former, found in the Göttingen Museum and identified by Lütken, had club-shaped arm spines. Brock believed that these spines might appear very late in the development of some species, especially after he noticed the absence of claviform spines in a small specimen of *O. caryophyllata* (d.d. = 12 mm). Therefore he was not surprised at the absence of enlarged forked spines in the case of Lyman's type of *O.*

*janualis* with a disc diameter of only 5 mm. Brock spent some time describing the nature of the modified upper spines for each of the species and the basis of his description was tabulated in the form of a key (as his Table I, p. 505). It is now known, however, that other species in the genus appear typically to lack the clavifurcated spines.

In addition to placing great emphasis on the shape and position of the modified arm spines, Brock arranged the species of *Ophiomastix* according to the nature of their disc cover. A key to the species based on the difference in disc cover was presented (as his Table II, p. 506).

Between 1888 and 1920, five additional species of *Ophiomastix* were described, increasing the number to twelve. These included Pfeffer's (1900) description of *O. luetkeni* which in many ways recalled the type specimen of *O. janualis* Lyman and in the present report *O. janualis* is indeed considered a senior synonym of *O. luetkeni* (see p. 302). Koehler (1905) added two new species, *Ophiomastix variabilis* and *O. ornata*, the latter based on a single specimen (d.d. = 9 mm) which showed cylindrical but pointed upper arm spines (not claviform), and unique small flattened spindle-shaped spinules on the disc. H. L. Clark (1915) described *O. corallicola* as having three and four alternating arm spines, two tentacle scales, and numerous disc spinules. *Ophiomastix bispinosa* was also described by H. L. Clark (1917), on the basis of a small (d.d. = 5 mm) specimen from the Tuamotu Islands, having two and three arm spines and the disc and upper arm plates covered by skin. This species is now considered a junior synonym of *O. variabilis* Koehler (Devaney, 1974).

Koehler (1907) mistakenly described *Ophiocoma wendti* from several Indo-West Pacific localities, apparently confusing several species. The name *O. wendti* has replaced *O. riisei* for a West Indian species of *Ophiocoma* (Devaney, 1970). However, at least one of Koehler's larger specimens showed definite clavifurcated upper arm spines recalling *Ophiomastix*, but the nature of the disc cover suggested *Ophiocoma* by its definite granulation. This specimen, together with additional material, are considered to be *Ophiomastix koehleri* a new, recently described species (Devaney, 1977). Koehler pointed out that, based on this form, the distinction between *Ophiomastix* and *Ophiocoma* broke down. Likewise, H. L. Clark (1921) indicated that *Ophiomastix asperula* also bridged the gap between the two genera.

H. L. Clark's (1921) review of the genus *Ophiomastix* attempted to distinguish the species primarily on the basis of pigmentation, and he gave a key to the species known at the time, emphasizing this character. He excluded Brock's (1888) use of the nature of the claviform arm spines for not making "sufficient allowance for individual diversity or for growth changes" (p. 134). Unfortunately, H. L. Clark did little more to verify his own use of characters. His emphasis of color as a specific character was amplified by several color drawings of species he encountered at Torres Strait (Mer Island) but included only seven of the thirteen previously recorded species. In all, fifteen species had now been described, but Clark rightly considered *O. (Acantharachna) mirabilis* Smith synonymous with *O. flaccida* Lyman, and also considered *Ophiomastix pusilla* Brock to be an *Ophiocoma*. Based on a few small specimens available to him, H. L. Clark indicated that specific characters developed rather slowly. For specimens less

than 10 mm (d.d.), he noted the upper and lower arm plates to be longer than wide and very different from adults of the same species (unfortunately not designated). He noted in passing that the oral shields and adoral plates differed from the adult condition but did not state in what way. Likewise he noted that very young specimens might lack the characteristic claviform arm spines and disc spinelets of the adult which supported the earlier findings of Lütken and Brock.

Since 1921, six new species of *Ophiomastix* have been described:

1. *Ophiomastix notabilis* from Western Australia by H. L. Clark (1938) now a synonym of *O. variabilis* (see p. 342).
2. *O. palaoensis* from the Caroline Islands by Murakami (1943a).
3. *O. sexradiata*, the only hexamerous species in the genus by A. H. Clark (1952) from the Marshall Islands. A. M. Clark (in A. M. Clark and Rowe, 1971:118) found *O. sexradiata* very similar to *Ophiocomella sexradia* Duncan, but differing from it in the absence of tentacle scales on segments one and two, shape of lower arm plates, and so forth. I found the lack of an alternating sequence of arm spines strongly precludes *O. sexradiata* from *Ophiomastix* and this species is better considered as a variant of *Ophiocomella*.
4. *O. stenozonula* from southeastern Polynesia by Devaney (1974).
5. *O. koehleri* from Zanzibar by Devaney (1977).
6. *O. marshallensis* from the Marshall Islands in the present report.

Including the new species described herein, a total of fifteen species of *Ophiomastix* are recognized.

### Diagnostic Characters of the Genus *Ophiomastix*

Members of the genus *Ophiomastix* are those of the subfamily Ophiocominae in which some of the upper arm spines are well developed, often modified in a clavifurcate, swollen and/or elongate condition, and with the disc covered by few to many spinules, spinules and cone-shaped granules or, in one species (*O. koehleri*), only granules. (*Ophiomastix venosa*, may lack disc spinules and have the disc bare, similar to the condition noted in *Ophiarthrum*; however, the presence of well defined clavifurcate upper arm spines in *Ophiomastix venosa* serves to distinguish it as a member of the genus *Ophiomastix*.) There are usually three oral papillae plus a well developed buccal tentacle scale; the dental papillae are well developed in two to four rows; the teeth have hyalinated tips; the dental plate is from 2.2 to 3.0 times as long as broad, and the vertical septa dividing the teeth foramina are narrow and thin; the oral plate has well defined muscle scars on the aboral surface and a rather elongate adoral muscle scar; all species are confined to the tropical Indo-West Pacific area with the greatest concentration of species in the Indo-Malayan and Indo-Australian regions; reef flats sublittoral to a depth of 80 meters. [A specimen of *O. flaccida* (as *Amphiura trepida*) was reported from depth of 289 m (see p. 298).]

Type species: *Ophiura annulosa* Lamarck, 1816.

Subclass Ophiuroidea  
 Order Ophiurida  
 Suborder Chilophiurina  
 Family Ophiocomidae  
 Subfamily Ophiocominae  
 Genus *Ophiomastix*

- Ophiomastix annulosa* (Lamarck)  
*Ophiomastix asperula* Lütken  
*Ophiomastix caryophyllata* Lütken  
*Ophiomastix corallicola* H. L. Clark  
*Ophiomastix elegans* Brock  
*Ophiomastix flaccida* Lyman  
*Ophiomastix janualis* Lyman  
*Ophiomastix koehleri* Devaney  
*Ophiomastix marshallensis* n. sp.  
*Ophiomastix mixta* Lütken  
*Ophiomastix ornata* Koehler  
*Ophiomastix palaoensis* Murakami  
*Ophiomastix stenozonula* Devaney  
*Ophiomastix variabilis* Koehler  
*Ophiomastix venosa* Peters

KEY TO SPECIES OF *OPHIOMASTIX*

1. Tentacle scales present, one or two over each podial pore . . . . . 2.  
 1'. Tentacle scales absent . . . . . *O. flaccida* Lyman  
   2. Disc with either only granules or granules and very few spinules . . . . . 3.  
     . . . . . 3.  
   2'. Disc with granules and many spinules, only spinules, or rarely bare (*O. venosa*) . . . . . 5.  
 3. Disc with only granules which are low and rounded, not tapering . . . . .  
     . . . . . *O. koehleri* Devaney  
 3'. Disc with predominance of granules but some spinules . . . . . 4.  
   4. Single tentacle scale except on a few basal pores; modified upper arm spines in limited number (8–12 between segments 20 and 42) with tip swollen and club-like [Fig. 5a, b] seldom forked . . . . .  
     . . . . . *O. asperula* Lütken<sup>1</sup>  
   4'. Two tentacle scales far out on arm; modified upper arm spines on about 3 to 4 segments, no swelling at their tip but taper and may fork . . . . .  
     . . . . . *O. elegans* Brock  
 5. Disc with numerous short (1 mm or less) spinules and granules mixed . . . . . 6.

<sup>1</sup> A. M. Clark (in Clark and Rowe, 1971:119) reported that the disc of specimens less than 7 mm d.d. has relatively more elongated and acute elements in the form of short spinules than do the discs of larger specimens.

- 5'. Disc otherwise ..... 8.
  - 6. A narrow dark longitudinal continuous line along center of upper arm plates [Fig. 18] ..... *O. marshallensis* n. sp.
  - 6'. No such line along center of upper arm plates ..... 7.
- 7. A narrow dark horizontal band across proximodistal borders of most arm plates continuing around entire arm [Fig. 32]; dark pigmentation brown to tan, colorfast (not lost upon preservation) ..... *O. stenozonula* Devaney
- 7'. No narrow dark band along proximodistal borders of upper arm plates; dark pigmentation reddish but not colorfast (lost upon preservation) ..... *O. mixta* Lütken
  - 8. Disc with spinules more than 1 mm long, sometimes with less frequent conical and/or rounded granules or, in *O. venosa*, only a few scattered thick blunt spinules which may be completely absent ..... 9.
  - 8'. Disc with spinules 1 mm or less in length (rarely *O. variabilis* with few elongate spinules alone or mixed with shorter ones) ..... 13.
- 9. One tentacle scale except sometimes on basal pores (up to first ten segments); disc spinules few or absent; disc marked with narrow dark lines often radiating irregularly from the area of radial shields and upper side of arms may have dark line centrally ..... *O. venosa* Peters
- 9'. Two tentacle scales; disc spinules numerous; otherwise pigmented ..... 10.
  - 10. Disc spinules blunt-tipped tapering only slightly from base; a light colored rim around each upper arm plate .. *O. annulosa* (Lamarck)
  - 10'. Disc spinules sharp-tipped, tapering evenly from base; no light colored rim around each upper arm plate ..... 11.
- 11. Two arm spines commonly on segment 2; disc dark except at base of spinules; oral shields with lateral edges light colored, center dark .. *O. janualis* Lyman
- 11'. Three arm spines commonly on segment 2; disc with both dark and light areas; oral shields with scattered spots or irregular dark marks, rarely with lateral edges light in contrast to dark center..... 12.
  - 12. Upper arm plates uniformly light colored (grey or fawn) in marked contrast to dark lateral arm plates [Fig. 8a] ..... *O. corallicola* H. L. Clark
  - 12'. Upper arm plates with distal portion either light color in contrast to a dark proximal portion or with some dark on both proximal and distal portions leaving the center light [Fig. 6a] ..... *O. caryophyllata* Lütken
- 13. Disc spinules compressed, spindle-shaped [Fig. 23a] upper arm spines regularly elongated and tapering ..... *O. ornata* Koehler
- 13'. Disc spinules regularly tapering or having distal end draw out to fine point; upper arm spines may be swollen and/or elongate but not regularly tapering ..... 14.
  - 14. Disc spinules regularly tapering; modified upper arm spines elongate thickened, not much tapering, sometimes even slightly inflated near

- tip which can be more or less compressed [Figs. 29a, b]; two tentacle scales on one or more basal segments of at least one arm, rarely only on segment one; narrow light bands on upper side of arms only towards distal part of arms . . . . . *O. palaoensis* Murakami
- 14'. Disc spinules tapering but tip drawn out to acute point; modified upper arm spines swollen, seldom greatly elongated but longer than unaltered spines; two tentacle scales, if present, confined to segment one; narrow light bands on arms at intervals along entire length . . . . . *O. variabilis* Koehler

#### ABBREVIATIONS OF INSTITUTIONAL COLLECTIONS

- AHF—Allan Hancock Foundation, University of Southern California, Los Angeles, California 90007.
- BMNH—British Museum (Natural History), Cromwell Road, London, S.W. 7, Great Britain.
- BPBM—Bernice P. Bishop Museum, P.O. Box 6037, Honolulu, Hawaii 96818.
- EMBL—Enewetak Marine Biological Laboratory (see MPML).
- IIOE—International Indian Ocean Expedition, Smithsonian Oceanographic Sorting Center, Smithsonian Institution, Washington, D. C. 20560.
- MCZ—Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts 02138.
- MNHP—Muséum National d'Histoire Naturelle, 61 rue de Buffon, Paris 5<sup>e</sup>, France.
- MPML—Mid-Pacific Marine Laboratory, c/o Hawaii Institute of Marine Biology, Kaneohe, Hawaii 96744.
- SMF—Natur-Museum Forschungsinstitut Senckenberg, Senckenberg-Anlage 25, 6000 Frankfurt/Main 1, Germany.
- USNM—National Museum of Natural History (formerly, United States National Museum), Smithsonian Institution, Washington, D. C. 20560.
- USP—University of the South Pacific, Suva, Fiji.
- WAM—Western Australian Museum, Francis Street, Perth, Western Australia 6000.
- ZMA—Zoologisch Museum Amsterdam, University of Amsterdam, Plantage Middenlaan 53, Amsterdam-C, Netherlands.

#### Systematic Account

##### *Ophiomastix annulosa* (Lamarck)

Figs. 1–3

*Ophiura annulosa* Lamarck, 1816: 543.

*Ophiomastix annulosa*: Müller and Troschel, 1842: 107, Pl. VII, fig. 4; Martens, 1870: 253–254 (describes 7 mm specimen); Brock, 1888: 497, 503–506 (nature of modified arm spines and disc cover); Hamann, 1889: 29, Pl. I, fig. 14 (histology of modified arm spine); Bell, 1902: 229 (Minikoi, So. Laccadive Ids., habitat);



Koehler, 1905: 65–66 (bibliography to 1905 includes several citations not listed in present paper); 1907: 329 (New Caledonia); 1922: 329, Pl. 72, figs. 4, 5 (Philippines); H. L. Clark, 1908: 297; 1921: 135, Pl. 14, fig. 6 (color figure, habitat); 1946: 248 (in key), 249; Matsumoto, 1917: 350–351; figs. 99a–c (Ryukyu, Formosa), Pl. VII, fig. 6 (internal skeleton); Domantay, 1936: 387, 389–391, 396, Pl. 6, fig. 48 (Puerto Galera Bay, Philippines, habitat); Domantay and Domantay, 1966: 55–56 (two varieties described, Philippines); Murakami, 1943a: 161–163, 165–167 (Palau habitat, and Tokobei Island, 197; 1943b: 206, 219 (Ryukyu); 1963: 27, 30, Pls. III, fig. 6 and Pl. VII, figs. 29–30 (dental and oral plates); Utinomi, 1961: 112, Pl. lvi, fig. 6 (size, color, habitat); Halstead, 1965: 544, Pl. VII, fig. 4 (color) (possible toxin of arm spines); Devaney, 1970: 37, fig. 50 (arm spines); A. M. Clark and Rowe, 1971: 86–87 (distribution), 120 (in key), Pl. 19, fig. 2.

*Ophiomastix venosa* Peters: Bell, 1902: 229 (according to A. M. Clark in, A. M. Clark and Spencer Davies, 1965: 599).

#### MATERIAL EXAMINED AND LOCALITIES

CAROLINE ISLANDS—**Palau**: without further data; 19 mm d.d. (1 BPBM W681). **Yap**: 15 July 1969, between Nimpol and Mil lagoon entrances off seaward reef, 4.5–12 m, D. M. Devaney; 5.5 mm d.d. (1 BPBM). 18 July 1969, lagoon north of Gatjug entrance, within coral head, 0.3–1.0 m, D. M. Devaney; 18 and 19 mm d.d. (2 BPBM).

RYUKYU ISLANDS—**Okinawa**:—rec'd. April 1946, J. T. Conover; 22 mm d.d. (1 BPBM W1096).

PHILIPPINE ISLANDS—**Luzon**: Batangas province, Nasugbu, leg. J. Domantay; 14 mm d.d. (1 BPBM W1744).

MALDIVE ISLANDS—**Male Atoll**: Dunidu Island, 18 March 1964, loose coral and rock in shallow water, F. Ziesenhenné; 7 mm d.d. (IIOE Collection Sta. F. Z. 64–9) (1 BPBM).

SRI LANKA—**Reef between Beruwala and Palli-Gala Pt., S. W. Coast**: 28 Feb. 1964, dead and live coral, 2 m, G. Beardsley; 27 mm d.d. (IIOE Collection Sta. F.Z. 64–7) (1 BPBM).

**Between Neptune and Triton Bastion Galle Fort**: 5 March 1964, loose boulders and coral on reef 0.6–0.9 m, F. C. Ziesenhenné; 21–23 mm d.d. (IIOE Collection Sta. F.Z. 64–8) (2 BPBM).

#### DISCUSSION

Not only is *Ophiomastix annulosa* the genotype, but it is one of the best known species in terms of its morphology, habitats, and illustrative coverage. H. L. Clark (1921) gave a fairly good review of *O. annulosa* including a color figure based on the

specimens collected at Mer Island, Torres Strait. Koehler (1922) mentioned that a colored figure of this species occurred in J. A. Herklots (1868) publication (*Echinodermes peints d'apres nature. Leiden*) which I have not seen. The localities listed above for the material examined cover nearly the entire range with the exception of the northeastern Australian coast. Below, I include a few remarks concerning the disc elements, tentacle scales and arm spines.

**DISC COVER.** A series of conical granules rather than typical spinules are found along the outer margin of the genital openings in specimens larger than 10 mm d.d. based on the material examined. Disc spinules are elongate and taper only gradually to a blunt tip.

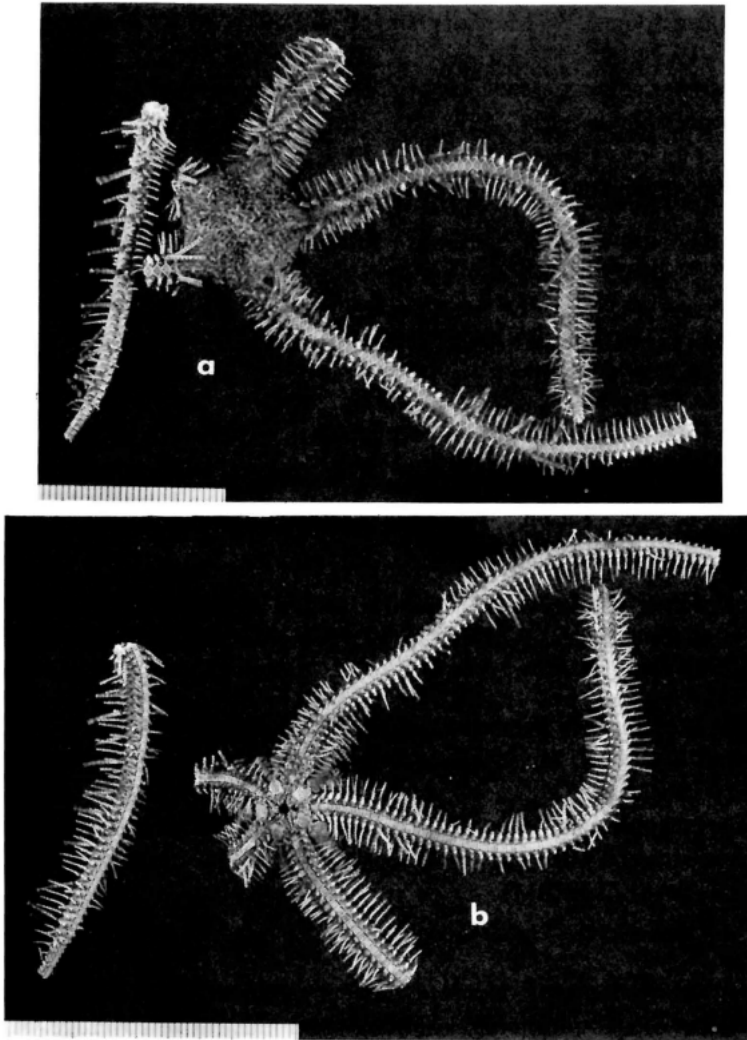


Fig. 1. *Ophiomastix annulosa*, BPBM W681, Palau, 19 mm d.d. (a) Upper side with lateral view of broken arm. (b) Lower side with lateral view of broken arm.

Domantay and Domantay (1966) described two variations of *O. annulosa*: one with short fine disc spines ("more conspicuous outward from center . . . appear somewhat knoblike toward center") and one with a different color pattern and having ". . . long prominent spines in interradial areas . . . spines spinous at distal tip and roughly compact granular in their entire length." Without the specimens for comparison it is difficult to comment further, but neither description suggests typical *O. annulosa*.

Lyman (1882: 174) remarks that *O. annulosa* has rather coarse disc scales ("larger and lumpy") compared with those of *Ophiomastix venosa*, and containing "two to three in 1 mm."

**TENTACLE SCALES.** The smallest specimen from Yap (5.5 mm d.d.) lacks two tentacle scales on the first three basal segments but shows this number irregularly over the pores of segments four to nine. The 7 mm specimen from Male Atoll has two scales out to segment 14 regularly and irregularly as far as segment 18. By a size of 10 mm d.d., two scales cover well over half the arm segments.

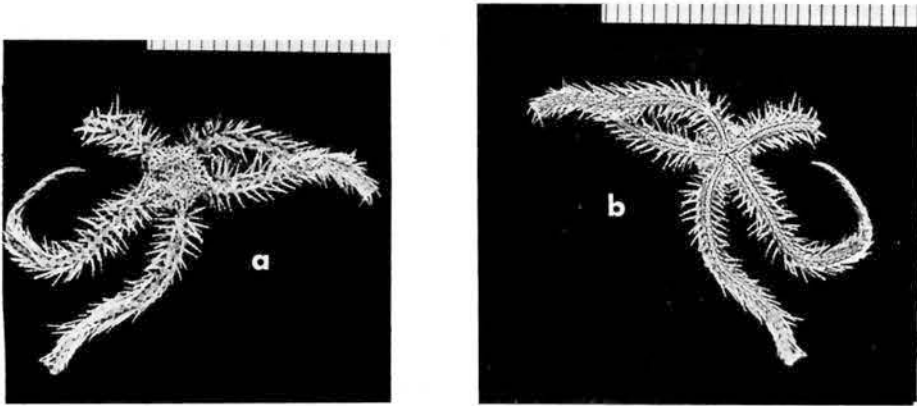


Fig. 2. *Ophiomastix annulosa*, BPBM, Yap, juvenile arm, 5.5 mm d.d. (a) Upper side. (b) Lower side.

**ARM SPINES.** I have found that typically all sides of segment one have two arm spines with segment two having two or two and three spines. Segment three carries two and/or three spines.

Clavifurcate upper arm spines are well developed in the larger specimens (Figs. 3a, b) but are lacking in the 5.5 and 7 mm specimens from Yap (Fig. 2a) and the Maldives. In these two, the upper spines are elongated and tapering to the tip.

Hamann (1889) investigated the nature of the striking epithelial covering of the enlarged clavifurcate "Keulenstachen" upper arm spines found on *Ophiomastix annulosa*. Histological examination of these revealed a glandular tissue with cellular components and so-called "Nervenstränge." It was subsequently suggested (Ludwig

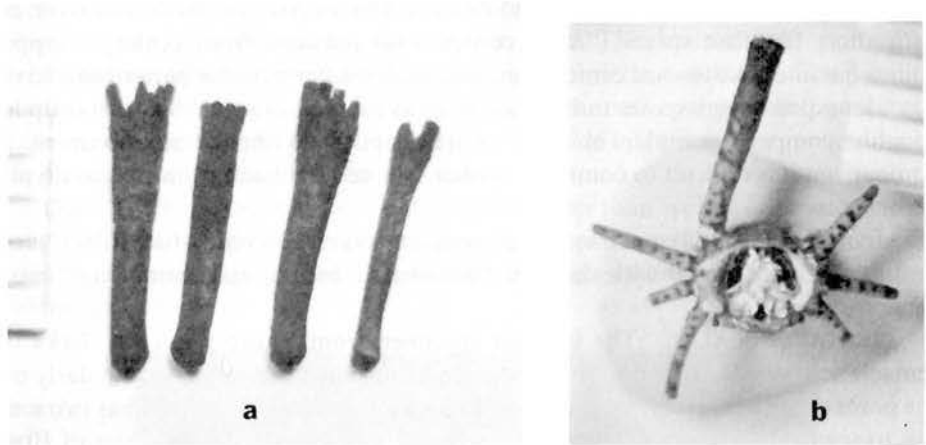


Fig. 3. *Ophiomastix annulosa*, BPBM W681, Palau, 19 mm d.d. (a) Four modified (clavifurcate) cleaned and stained arm spines. (b) Modified spine with dried distal epithelium.

and Hamann, 1901: 788) that this glandular epithelium might function in a similar manner as the pedicellaria of sea urchins, that is, act as organs secreting a poisonous substance having the ability to kill such small animals as worms. Hyman (1955:593) considered *O. annulosa* with "glandular spines, possibly poisonous, which occur in addition to ordinary spines. . . ." Halstead (1965) referred to the possible venomous nature of the spines but noted that toxicity was unconfirmed by either laboratory or clinical reports. Thus, there is apparently no evidence which clarifies the function of this peculiar thickened tissue nor its relationship to the modification (enlargement and often clavifurcation) of the upper spines so characteristic of most *Ophiomastix* species.

#### *Ophiomastix asperula* Lütken

Figs. 4, 5

*Ophiomastix asperula* Lütken, 1869:43; Brock, 1888:497, 503, 505-506 (nature of upper arm spine and disc cover, Amboina); Koehler, 1905:66, Pl. VI, figs. 11-12; 1927:5 (Fiji); 1930:203 (Philippines, reefs); H. L. Clark, 1915:295 (pt.); 1921:134, Pl. 14, fig. 1 (color, size, habitat Torres Strait); 1946:248; Murakami, 1943a:162, 164 (intertidal habitat), 197, fig. 15 (Palau); 1943b:206, 219 (littoral Ryukyu); 1963:27, Pl. III, fig. 6 (dental plate); Endean, 1956:126 (Low Is. Queensland, habitat); A. M. Clark and Rowe, 1971:86-87 (distribution), 119 (in key), Pl. 19, figs. 4, 5.

non *Ophiomastix asperula*: Döderlein, 1896 (= *Ophiomastix variabilis* Koehler, see p. 345); Burfield, 1924 (= *Ophiomastix? palaoensis*, see p. 345); H. L. Clark, 1915:294 (Zanzibar specimen = *Ophiomastix koehleri* n. sp.); A. H. Clark, 1949 (= *Ophiocoma macropilaca* (H. L. Clark) according to Devaney, 1970:34).

## MATERIAL EXAMINED AND LOCALITIES

FIJI ISLANDS—**Without definite locations:** “Viti—Museum Godeffroy,” “777,” “3825”; 15 and 17 mm d.d. (2 MCZ 1796).

NORTHERNAUSTRALIA—**Torres Strait:** Oct. 1913, Mer Island, Carnegie Expedition, H. L. Clark; 17 and 20 mm d.d. (2 MCZ 3769 and 3770; these are specimens reported by H. L. Clark in 1921).

## DISCUSSION

SIZE. H. L. Clark (1921) records a maximum size of 20 mm d.d., with the arms about nine times as long.

DISC COVER. The disc cover of *Ophiomastix asperula* can present variation between the typical *Ophiomastix* facies (spinules) and that of *Ophiocoma* (granules). Several examples are given below which discuss this variation.

I examined one nearly complete specimen with 17 mm d.d. and an incomplete one with 15 mm d.d. from MCZ collection (No. 1796) bearing the label “Viti-Museum Godeffroy 3825,” the same source as the type. A random assortment of twenty disc elements was examined from the 15 mm specimen. The disc elements averaged 170 microns in diameter (122 to 195) and 314 microns in height (146 to 464). Only three elements were more than twice as high as broad and thus could be considered spinules, while seventeen were two times or less higher than broad (i.e., granules); in nearly all cases these conical granules were more than 1.5 times higher than broad. Individual disc elements ranged between 2.4 and 1.0:1 (ratio, height: breadth) with a mean of 1.9:1. The elements are cone-shaped, neither rounded nor acutely pointed but bluntly tapered to the tip and they are quite close together.

Koehler (1905:PI VI, figs. 11, 12) showed disc elements that are definitely tapered spinules, from 2.2 to over 5 times higher than broad. His specimen is about 6.5 mm in disc diameter, judging from the scale for the figure. The possibility that there may be a change in the size and shape of the disc elements during the ontogeny of *O. asperula* is further indicated by A. M. Clark (in Clark and Rowe, 1971:119). In her key she describes the disc elements as consisting of “more or less elongated granules, many of them in the form of short blunt cylinders,” while for specimens less than 7 mm d.d. these are “relatively more elongated and acute, in the form of short spinelets.”

TENTACLE SCALES. Tentacle scales are single with the exception of the basal segments which carry two over each pore.

ARM SPINES. According to Brock (1888), and confirmed by my examination of *O. asperula* from Fiji and Torres Strait (MCZ specimens), the upper modified arm spines occur over only a limited part of the middle of the arm. These begin from about the twenty-second segment (Fiji specimen) or thirtieth segment (Brock, 1888) on eight to twelve alternating segments (Fig. 4a). They are claviform, noticeably elongated and swell gradually towards the free end. The tip is either evenly or unevenly rounded but not with any pronounced projections or furcations. A comparison between two modified spines from the same arm, one with dried epithelium and the other denuded by hypochlorite solution is shown in Fig. 5b.

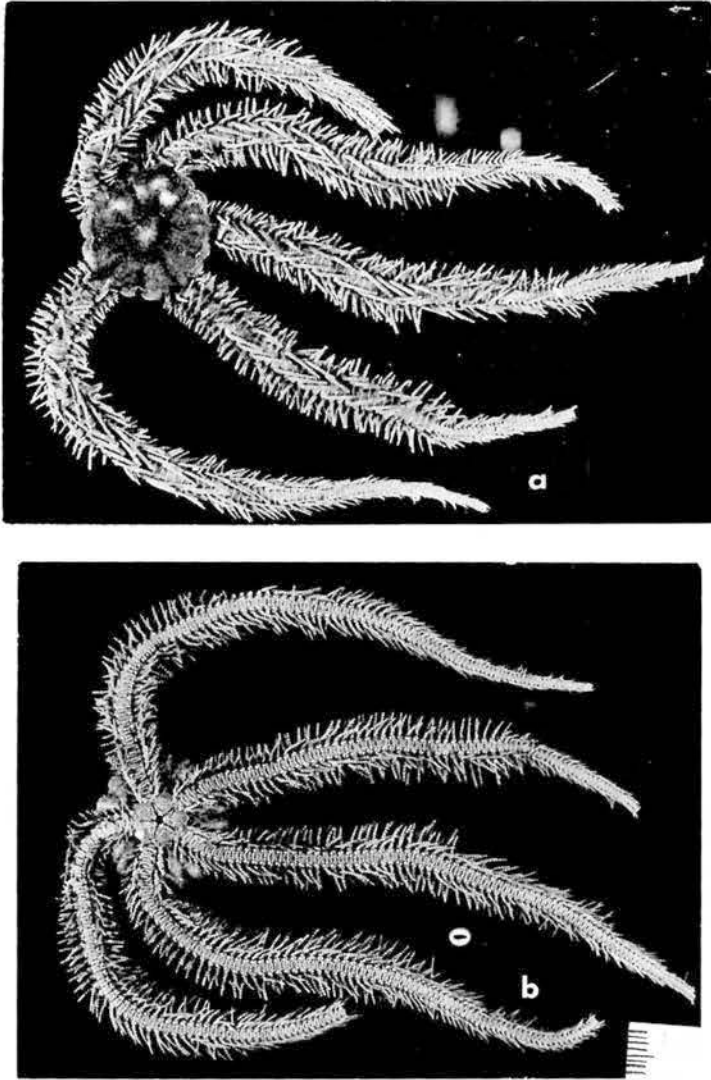


Fig. 4. *Ophiomastix asperula*, MCZ 3770, Mer, Torres Strait, 20 mm d.d. (a) Upper side. (b) Lower side.

**PIGMENTATION.** The color of typical specimens is quite distinctive, black or grey with fine white rings around or multiple stripes across each arm segment and the arm spines banded (A. M. Clark and Rowe, 1971). Koehler (1905) also shows the shorter disc spinules to be annulated.

**DISTRIBUTION.** *O. asperula* is known from Fiji (type locality), the East Indies, northern Australia, the Philippines and southern Japan. It has been collected beneath coral fragments (H. L. Clark, 1921) and was common among dead coral at Low Island

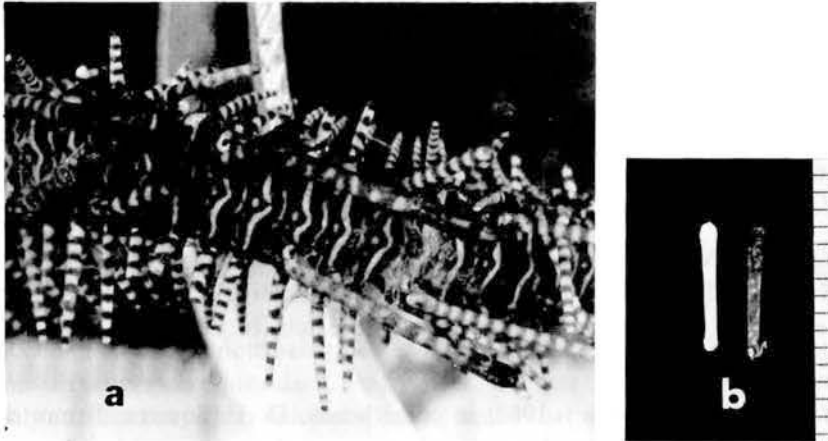


Fig. 5. *Ophiomastix asperula*, MCZ 1796, Fiji, 15 mm, d.d. (a) Portion of upper arm showing color pattern and modified clavi-elongate spines (segments 34 and beyond). (b) Cleaned modified spine (segment 23) and uncleaned modified spine (segment 25).

in the northern Australian Barrier Reef area (Endean, 1956). It appears to be confined to shallow reef areas, Koehler's (1905) Indonesian specimen being taken at the depth of 11 m.

### *Ophiomastix caryophyllata* Lütken

Figs. 6, 7

*Ophiomastix caryophyllata* Lütken, 1869:43, Brock, 1888:497–498, 503, 505 (nature of upper arm spines and disc cover); Loriol, 1893a:414 (Amboina, size, number of modified spines); Döderlein, 1896:290, Pl. XV, figs. 10–10a; Koehler, 1905:67 (pt.); H. L. Clark, 1921:134, 137, Pl. 14, fig. 4 (habitat and color), Pl. 36, fig. 10 (upper arm plate); Murakami, 1943a:198–199, Fig. 16 (Palao); 1963:27, Pl. III, fig. 8 (dental plate); Endean, 1961:292 (habitat); 1965:231 (habitat); A. M. Clark and Rowe, 1971:86–87 (distribution), 91, 120 (in key), Pl. 19, fig. 3 (as possible hybrid of *O. luetkeni* × *O. caryophyllata*).

*Ophiomastix luetkeni* Pfeffer: Boone, 1938:158–161, Pls. 57, 58 (Bali, Indonesia).

#### MATERIAL EXAMINED AND LOCALITIES

MARIANA ISLANDS—**Guam**: 7 July 1969, Apra Harbor, 2–9 m in limestone reef within crevices, D. M. Devaney; 23–26 mm d.d. (4 BPBM; 1 BMNH).

MARSHALL ISLANDS—**Enewetak Atoll**: 13 Dec. 1976, N. end of Enewetak Is., lagoon, Marine Pier Pinnacle (162°21'E, 11°21.9'N), in live branching coral (*Porites andrewsi*), 14–21 m, D. M. Devaney; 7–17 mm d.d. (3 BPBM; 1 MPML).

PALAU ISLANDS—**Koror**: 30 June 1974, reef off Ngerameayus Is., among dead staghorn *Acropora* on reef top; L. M. Marsh; 25 mm d.d. (1 WAM).

SOLOMON ISLANDS—3 July 1968, Gaskell Is., H. G. Veyers; 10–15 mm d.d. (1 BPBM; 2 BMNH Reg. No. 1968 7.3.43–48). 20 Oct. 1975, N. W. end Malaupaina Is. (161°57'E, 10°13'S), reef edge, under stone, 2 m, B. R. Wilson; 25 mm d.d. (1 WAM).

FIJI ISLANDS—"Viti," MCZ 1797, 18 mm d.d. and BMNH Reg. No. 1874. 10. 5. 15, 15 mm d.d. (both obtained from Godeffroy Museum). 21 June 1969, Great Sea Reef north of Kia Island, landward reef patch, in dead coral, 3.6 m, P. J. Beveridge; 5–13 mm d.d. (3, USP).

NEW CALEDONIA—**Noumea**: 1962, in coral heads, D. F. Squires; 10 mm d.d. (1 USNM E10, 011).

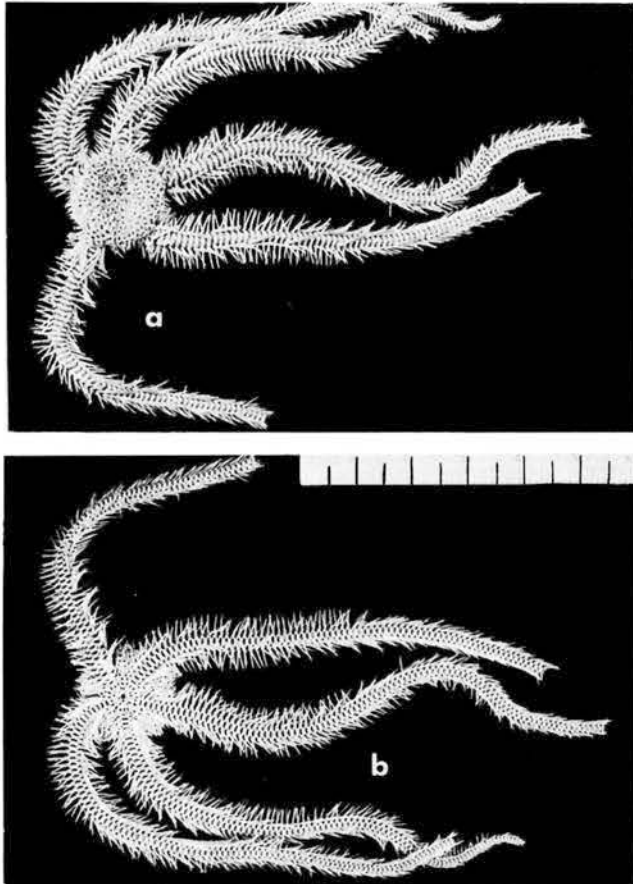


Fig. 6. *Ophiomastix caryophyllata*, MCZ 3771, Mer, Torres Strait, 17.5 mm d.d. (a) Upper side. (b) Lower side.



INDONESIA—Siboga Sta. 89, Pulu Kaniungan Ketjil, Coral, depth, 11 m; 10 mm d.d. (1 ZMA). Siboga Sta. 91, côté interne du récif de Muaras, côté E. de Borneo, coarse coral sand and coral, depth 54 m; 10.5 mm d.d. (1 ZMA). 8 July 1976, Pulau Kodingareng Lompo, So. Sulawesi (Celebes), coral reef, 1–2 m, L. M. Marsh; 18 mm d.d. (1 WAM).

NORTHERN AUSTRALIA—**Torres Strait:** Oct. 1915, Murray Islands, Mer, H. L. Clark, 2–18 mm d.d. (9 MCZ 3771). July 1975, King Sound, One Arm Point (16°26'N, 123°05'E) intertidal reef, P. Barrett-Lennard; 15 mm d.d. (1 WAN).

#### DISCUSSION

Koehler (1905:67) noted that two 15 mm specimens from the Siboga Stations in Indonesian waters were quite dark, nearly black, whereas the other two specimens were not only smaller but lighter colored. He also noted that the arm spines of the smaller specimens were comparatively more swollen than those of the larger specimens in which the arm spines were very long and little enlarged. H. L. Clark (1921:137) suggested that the two darker and larger ones might be *Ophiomastix luetkeni* or *O. janualis* rather than *O. caryophyllata* as Koehler reported. Reexamination of the Siboga material confirms Clark's suggestion in both pigmentation and arm spine sequence. The sequence of arm spines on proximal segments is given in Table 1.

Table 1. Arm spine sequence on the proximal five segments, *Ophiomastix caryophyllata*/  
*O. janualis* from the Siboga Expedition.

Specimen number and disc diameter		Segments					
		1	2	3	4	5	
Siboga Sta. 89 15 mm d.d.	No. of spines	2	2	2	3	3	(10 sides)
10 mm d.d.	No. of spines	2	3	1	2	2	(1 side) <sup>a</sup>
		2	3	0	1	2	(1 side) <sup>a</sup>
		2	3	3	3	3	(3 sides)
		3	3	3	3	3	(1 side)
		2	3	3	3	4	(2 sides)
2	3	x	x	x	(2 sides)		
Siboga Sta. 91 10.5 mm d.d.	No. of spines	2	3	3	3	4	(7 sides)
		2	3	3	3	3	(2 sides)
		2	2	3	3	4	(1 side)
Siboga Sta. 213 15 mm d.d.	No. of spines	2	2	2	2	3	(5 sides)
		2	2	2	3	3	(2 sides)
		2	2	2	2	2	(1 side)
		2	2	3	3	3	(2 sides)

<sup>a</sup> Altered sequence because of parasitic growth.



Table 2. (continued)

No. of Arm Spines							Location & Deposition	d.d. (mm)
3			2	7				23+
			1	8	1		1	24
				7				24
	1		1	6	1			25
			2	8				7
1	2		4	3				16
			10					16
			10					17
			9	1				25
								10
	4	5		1				12
6			1		1			15
	7	1		2				10
	8			2				24
				10 <sup>b</sup>				25
			7	3				25
				2	8			10
								15
					9			7
						6	4	1
								5
		10						12
			1	1	1			13
	3			2	5			7

<sup>a</sup> From ray infected by parasite.<sup>b</sup> "hybrid" form.

While all four specimens almost invariably have two arm spines on segment one, they differ in the number on segments two and three; both of the smaller, lighter colored individuals have a preponderance of three spines while the larger, darker colored specimens almost always have only two arm spines on these segments. A more complete analysis of the arm spine sequence of a number of additional individuals indicates that the presence of two arm spines on the first three or four segments is characteristic of *Ophiomastix janualis* [incl. *O. luetkeni* (Table 3)] while three arm spines on segments two, three and four typifies *O. caryophyllata* (Table 2). Therefore the arm spine sequence helps to establish that the two 15 mm Siboga specimens are *O. janualis* and the smaller are *O. caryophyllata*.

With the cooperation of Ailsa M. Clark at BMNH it was possible to determine the arm spine sequences for *O. caryophyllata* from a number of regions. These sequences and their frequencies are presented in Table 2. The data reveal two dominant sequences which appear to characterize the species and its populations generally: either 23334 or 33334 for the first five basal segments. Clark and Rowe (1971:120, Pl. 19, fig. 3) reported a possible "hybrid between *O. caryophyllata* and *O. luetkeni*" from the Solomon Islands. This specimen, measuring 24 mm d.d. was examined together with four others from the same locality by Miss Clark at my request. The "hybrid" revealed a uniform arm spine sequence of 33334 characteristic of *O. caryophyllata* but not of *O. luetkeni* (= *O. janualis*). However, the spine sequence of this individual is at a different end of the range from that of the other four BMNH Solomon Islands specimens which show a predominance of two arm spines on segment one rather than three spines (Table 2). However, the WAM Solomon Islands specimen is intermediate in arm spine sequence with the presence of 2 or 3 spines on segment one.

The presence of 5 arm spines on proximal arm segments, while not constant in *O. caryophyllata*, has been noted on several of the specimens with d.d. 18 to 25 mm on segments 8 to 12 regularly or irregularly alternating with 4 spines. While it was mentioned that the "hybrid" lacked clavate upper arm spines, this is in no way an anomaly in *O. caryophyllata*, since noticeably thickened spines are also absent in material from Guam, Palau, N. W. Australia, and Enewetak from 16 to 25 mm d.d. (Fig. 7). The intraspecific variability in modification of the upper arm spines is quite extensive in this species and several examples have been shown (Fig. 7). Much greater expansion and furcation of the tip of the spines also occurs. I am inclined to believe that the intermediate form is merely a color variant of *O. caryophyllata*.

It is mainly on the basis of the illustrations of Boone's (1938) specimens described as *O. leutkeni* that I tend to consider them as *O. caryophyllata* although the more densely covered disc also suggests this. Moreover, none of the specimens of *O. leutkeni* (= *O. janualis*) examined has more than half of the upper or lower arm plates light colored as illustrated by Boone.

There is some rather striking variation in the pigmentation pattern as well as extent of dark and light color present on *O. caryophyllata*. Many of the specimens show well defined annulated disc and arm spines with the dark bands narrower than the light ones. Sometimes the annulations of the arm spines are reduced to the more distal portion or, in the case of the Palau and N. W. Australian specimens, only a series of

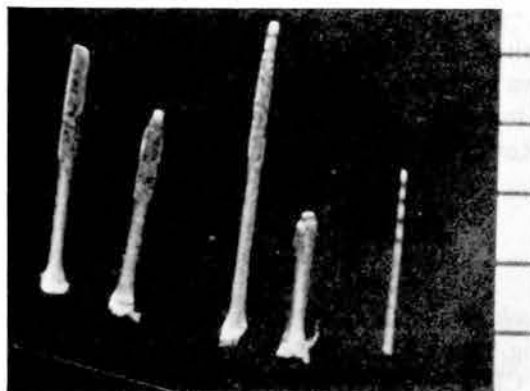


Fig. 7. *Ophiomastix caryophyllata*, BPBM, Enewetak, 16 mm d.d. Variations in modified upper arm spines, segments 13–22.

dark spots are evident or an interrupted series of dark and light color rather than annulations. Likewise the disc spines may show a reduction in dark color, from very faint annulations to irregular dark and light color present only at the distal end, or the absence of dark altogether.

The arm plates show color variation as well. H. L. Clark (1921) and A. M. Clark and Rowe (1971) distinguished *O. caryophyllata* as having the distal half of each arm segment light in contrast to a dark proximal half. The specimens before me have shown a uniformity only in the fairly regular alternation of light and dark on the arms above and below but the extent and location of the dark areas are variable. There are specimens in which the distal-proximal portions of successive arm plates are light and dark respectively but in other examples a portion of both the proximal and distal areas of each plate has some dark pigment. The extent appears as relatively narrow dark areas to areas where slightly more than half of the segment is dark.

The disc frequently shows a pattern of light and dark markings which may tend towards distinct dark spots or connected blotches or be of irregular shapes.

The arm length to disc diameter ratio seems to vary considerably in *O. caryophyllata* from 5:1 (H. L. Clark, 1921), 6:1 (Loriol, 1893a) to 9:1 for a 23 mm specimen from Guam or 10:1 for a 13 mm specimen from Fiji.

**DISC COVER.** While elongate (averaging more than 4 times longer than broad and exceeding 1 mm in length) pointed disc spinules are the most dominant disc elements, there are also a variable number of low granules present. An extreme case is the 18 mm d.d. WAM specimen from Indonesia which has a very heavy coating of granules intermixed throughout above and below with spinules. From this extreme are several specimens (Palau, Enewetak and N. W. Australia) which lack granules except at the base of the oral shields, lower edge of the disc and along the genital opening.

**HABITS AND HABITAT.** This species, while known from shallow water, seems more common in relatively quiet water several meters deep, within the branches of live coral. At Mer, H. L. Clark (1921) reported it as quite common from dead portions of coral on the reef flat.

DISTRIBUTION. *O. caryophyllata* is known from the East Indian region, (type locality), Torres Strait (H. L. Clark, 1921) Palao (Murakami, 1943a), as far north in the Pacific as the Ryukyu's (Murakami, 1943b) and from the locations shown above for material examined. Indian Ocean records include Aldabra and Zanzibar to the west (A. M. Clark and Rowe, 1971) and now Northwestern Australia.

*Ophiomastix corallicola* H. L. Clark

Fig. 8

*Ophiomastix corallicola* H. L. Clark, 1915:294, Pl. 16, figs. 1, 2; 1921:137, Pl. 14, fig. 3 (color), Pl. 36, fig. 11; 1946:250; Eudean, 1957:245 (in species list from Australian waters); A. M. Clark and Rowe, 1971:86-87 (distribution), 119 (in key).

MATERIAL EXAMINED AND LOCALITIES

NORTHERN AUSTRALIA—Torres Strait: Murray Islands, Mer (Holotype, MCZ 3775; Paratypes, MCZ 3773, 3774). 3 May 1977, S. W. Reef under rocks, intertidal, L. M. Marsh; 13 and 17 mm d.d. (2 WAM).

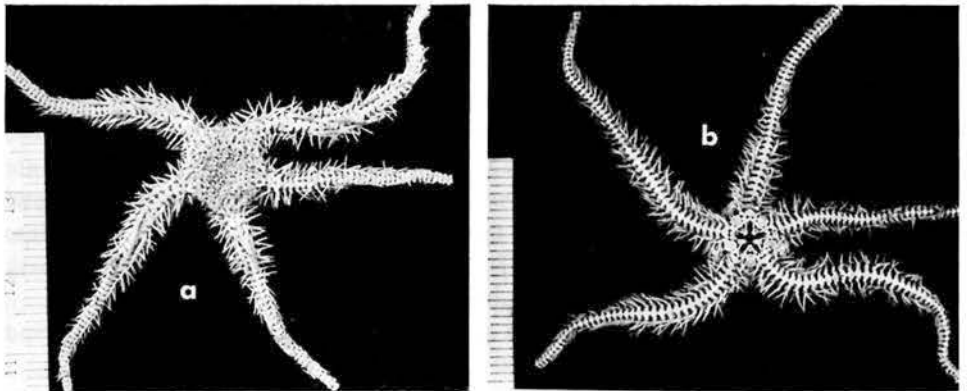


Fig. 8. *Ophiomastix corallicola*, MCZ 3773, Paratype, Mer, Torres Strait, 12.5 mm d.d. (a) Upper side. (b) Lower side.

DISCUSSION

Examination of the type material and two additional specimens from the type locality allows for further comment on taxonomic features of *O. corallicola*.

DISC COVER. Besides having characteristic elongate sharply pointed disc spinules, some conical granules are present, located at the base of the oral shields and partway along the entire edge of the genital slits. There is some variation in the degree of this granulation as shown below.

## LOCATION OF GRANULES ON DISC

Specimen (d.d.)	Base of Oral Shields	Along Genital Openings	Upper Side	Lower Side
MCZ 3773 13	+	-	-	-
WAM 13	+	+	+	-
WAM 17	+	+	-	+
MCZ 3774 18	-	-	+	+

(at disc margin)

A 10 mm d.d. MCZ paratype specimen lacked granules along the edges of the genital slits. It is important to note that granules are found among the disc granules in some specimens, but in far less abundance than the typical spinules. The spinules also were found frequently set in distinct pits on the underlying scales.

**TENTACLE SCALES.** H. L. Clark (1915) described these as "2, rather large, flat and rounded, but longer than wide." A 10 mm d.d. paratype specimen, one of the smallest reexamined, has 2 scales out to segment 39, more than two-thirds the length of the intact arm.

**ARM SPINES.** The sequence of arm spines on the basal five segments for several specimens follows:

Specimen	(d.d.)	Arm Spine Sequence
MCZ 3773	10	34444 (1 side) 33444 (3 sides)    Only two arms examined
MCZ 3773	13	33344
WAM	13	33344 (8 sides) 33334 (2 sides)
WAM	17	23344 (1 side) 33344 (1 side) 33334 (8 sides)

The longest attached arm of the 13 mm d.d. WAM specimen has only 12 arm segments with the following number of arm spines on segments six to twelve:

4 4 4 4 3-3-3  
4 4 4 4 3-3-4

The longest attached arm of the 17 mm d.d. WAM specimen has 18 segments with the following number of arm spines on segments six to eighteen:

4 4 4 4 4-3-3-3-4-3-3-3-3  
4 4 4 4 3-4-3-3-3-4-3-3-3

In the above two examples there is some indication of the irregular alternation of arm spines beyond the disc.

Claviform upper spines begin near the disc and the 10 mm d.d. MCZ paratype has these beginning three segments beyond the disc occurring three to five segments apart on the same side of the arm. Only rarely do claviform spines occur on opposite sides of the same segment. By the middle part of the arm some of the spines are clavifurcate.

**PIGMENTATION.** The upper arm plates are usually devoid of the dark color which characterizes the proximal part of the lateral arm plates. However, dark color sometimes occurs on the lateral distal portions of the upper arm plates and occasionally there is a dusky spot middistally or there may be a dark spot on the central proximal edge of the upper arm plates in larger specimens but which was not evident on regenerating arms nor on small specimens.

The distal lateral margins of the lower arm plates are regularly dark in contrast to light pigmentation elsewhere. The disc spinules are as described by H. L. Clark: grey with several narrow rings of dark more common on the distal half. The distinctive pigmentation pattern of *O. corallicola* is a major feature used to separate it from *O. caryophyllata* (Figs. 6, 8).

**UPPER ARM PLATES.** In addition to the differences in pigmentation of the upper arm plates, H. L. Clark distinguished *O. corallicola* from *O. caryophyllata* in the shape of these plates (Figs. 6a, 8a).

**HABITAT AND DISTRIBUTION.** At the type locality, H. L. Clark reported *O. corallicola* in the same habitat as *O. caryophyllata* in live coral colonies or among dead coral heads on the southeastern reef flat. The two WAM specimens were collected on the southeast reef under stones also at Mer Island. I have been informed that several specimens of *O. corallicola* were collected at Lizard Island, Great Barrier Reef (Alan Baker, pers. comm.). No other records are known.

### *Ophiomastix elegans* Brock

*Ophiomastix elegans* Brock, 1888: 500–501, 505 (modified arm spines, in key), 506 (disc cover, in key); H. L. Clark, 1921:135; A. M. Clark and Rowe, 1971:86–87 (distribution); 120 (in key, color pattern).

#### DISCUSSION

*Ophiomastix elegans* was described from a single (and since then the only recorded) specimen collected at Amboina Island, Indonesia. While I have included some of the characters of *O. elegans* in my evaluation of the apparently related species, *O. marshallensis*, *O. mixta*, and *O. stenozonula*, a review of Brock's original description is given below.

**SIZE.** The specimen was 16 mm in disc diameter, with arms about five times as long, 80 mm.

**DISC COVER.** The entire disc was covered by large projecting "glasperlenahnlichen" elements (seen under high magnification as short, thick button-like rounded off cylinders) as well as scarce and very irregular thorns or short spines. Brock used the disc elements to separate *O. elegans* from *O. mixta* in his tabular key (p. 506) by stating for *O. elegans* that disc spines were rare and irregularly mixed among the granulae and



that there was no difference between the upper and lower side of the disc. (In this latter respect he noted for *O. mixta* the lower side, at least near the genital slits, was bare.)

**TENTACLE SCALES.** There were two scales; the outer scale two or more times the size of the lance-shaped inner tentacle scale.

**ARM SPINES.** There were three to four, slender, conically tapering but blunt arm spines, with the upper five to six times longer than an arm segment, and with the lower shortest and two segments long. Modified spines only occurred on two arms and on a few segments (three or four which are on segments 19 to 22) about one-third to two-thirds the length of the arm. These modified spines showed a swelling at the end not very well developed and might have tapered to the tip, but the end could be divided into two obtuse knobs (i.e., bifurcated). The spines were finely granulated and roughened.

**ORAL SHIELDS.** The oral shields were approximately two times as long as broad.

**UPPER ARM PLATES.** Upper arm plates were fan-shaped with rounded-off aboral edge, two times broader than long.

**LOWER ARM PLATES.** They were broadly hexagonal.

**PIGMENTATION.** The basic color was dark chocolate brown; the granules were transparent, with a dark spot on each tip; the thorns were white; the mouth shields were delicately dark and light marbled; the borders of lower arm plates were marked by light lines, one dividing each plate into two equal parts diagonally; a similar color was found on upper plates, but these were more irregularly marbled with light lines and dots; arm spines and ambulacral feet (podia?) were very delicate and with regular alternation of light and dark rings.

**RELATIONSHIPS.** In having the disc with both granules and spinules, *O. elegans* can be considered allied with *O. marshallensis*, *O. mixta*, and *O. stenozonula*. Another feature allying these species is the inconsistent development of modified upper arm spines which are only slightly claviform and have the tip somewhat compressed and not always furcate. Other features will probably be evident once additional specimens of *O. elegans* are found and can be compared with the other three species.

**DISTRIBUTION.** Brock reported both *O. elegans* and *O. mixta* in his material from Amboina. The type specimen of *O. elegans* has not been located for examination and presumably was destroyed in W. W. II in the Göttingen Museum collection which housed most of Brock's (1888) specimens (P. Kuenzer, pers. comm.).

### *Ophiomastix flaccida* Lyman

Figs. 9, 10

*Ophiomastix flaccida* Lyman, 1874:226, Pl. VI, figs. 14–15. Studer, 1882:21 (New Guinea, color, habit); Brock, 1888:503, 505 (nature of modified upper arm spines), 506 (disc spines); Koehler, 1905:67; H. L. Clark, 1915:296; 1921:138 (habitat), Pl. 13, fig. 2 (color); Koehler, 1907:329; 1930:204; Domantay and Domantay, 1966:56; A. M. Clark and Rowe, 1971:86–87 (distribution), 119 (in key).

*Ophiomastix (Acantharachna) mirabilis* Smith, 1878:335-337, Pl. XVIII, figs. 1-6.  
*Amphiura trepida* Koehler, 1904a:93, Pl. XIV, figs. 1-2; A. M. Clark, 1970:37 (referred  
to *Ophiomastix*).

#### MATERIAL EXAMINED AND LOCALITIES

NORTHERN AUSTRALIA—**Torres Strait:** Murray Islands, 8 Oct. 1913, Mer Island,  
Southeast reef flat, H. L. Clark; 4 mm d.d. (1 MCZ 3776).

INDONESIA—**Bali sea, between Bali and Kangeang Islands** (7°15'S,  
115°15.6'E): (Holotype, *Amphiura trepida*), 14 Mar. 1899, mud and broken  
shell, depth, 289 m, trawl, Siboga Sta. 12; 4.5 mm d.d. (1 ZMA E70), near **Ternate:**  
20 May 1970, Teluk Dodinga (0°49'N, 127°32'E), depth 64-82 m (33-45 fms.),  
mud, Sta. HD I, Mariel King Memorial Expedition; 12 mm d.d. (1 WAM).

PHILIPPINES—**Basilan Island:** 11 Apr. 1948, Bojelebung, sand spit, shore, low tide, F.  
C. Ziesenhenne; 11.5 and 13.5 mm d.d. (2 AHF 106.0). **Cebu:** Silut Bay, Liloan,  
Florescia A. Jimenez; 4.5 and 8 mm d.d. (2 BPBM W1893). **without definite  
locality:** (Paratypes, *Ophiomastic flaccida*); 6-18.5 mm d.d. (8 MCZ 1799).

#### DISCUSSION

DISC COVER. The 4 mm specimen collected by H. L. Clark (1921) from Torres  
Strait (MCZ 3776) lacks disc spines. A 6 mm paratype specimen (MCZ 1977) has only a  
few spines. I am able to verify A. M. Clark's (1970:37) remarks concerning the type of  
*Amphiura trepida* as having "remnants of about eight irregularly placed spines on the  
disc, one as much as 0.35 mm long. . .". Philippine specimens in BPBM W1893 with  
disc diameters of 4.5 and 8 mm and the WAM Indonesian specimen (12 mm d.d.) reveal  
the following number of widely spaced disc spines and their size:

d.d. (mm)	No. spines	Size (microns)	
		Height	Diameter
4.5	14	600-680	100
8	17	880-920	80-100
12	30+	1100-1300	100-130

The disc coat is composed of fine scales above, with a distinctly larger series around the  
border of the disc ambitus; on the lower side of the disc, the scales are quite fine and  
there are no spines.

Lyman (1874) reported that a relatively heavy epidermis covered the disc as well as  
upper and side arm plates to some extent in the type of *O. flaccida*. Studer (1882) also  
described the soft skin concealing the radial shields and arm plates except when dry and  
referred such similarity of *O. flaccida* to *Ophiomyxa*. However, Smith's (1878) figures of  
*O. (Acantharachna) mirabilis* clearly showed the outline of the plates, and most of the  
dried specimens I examined reveal the plates.

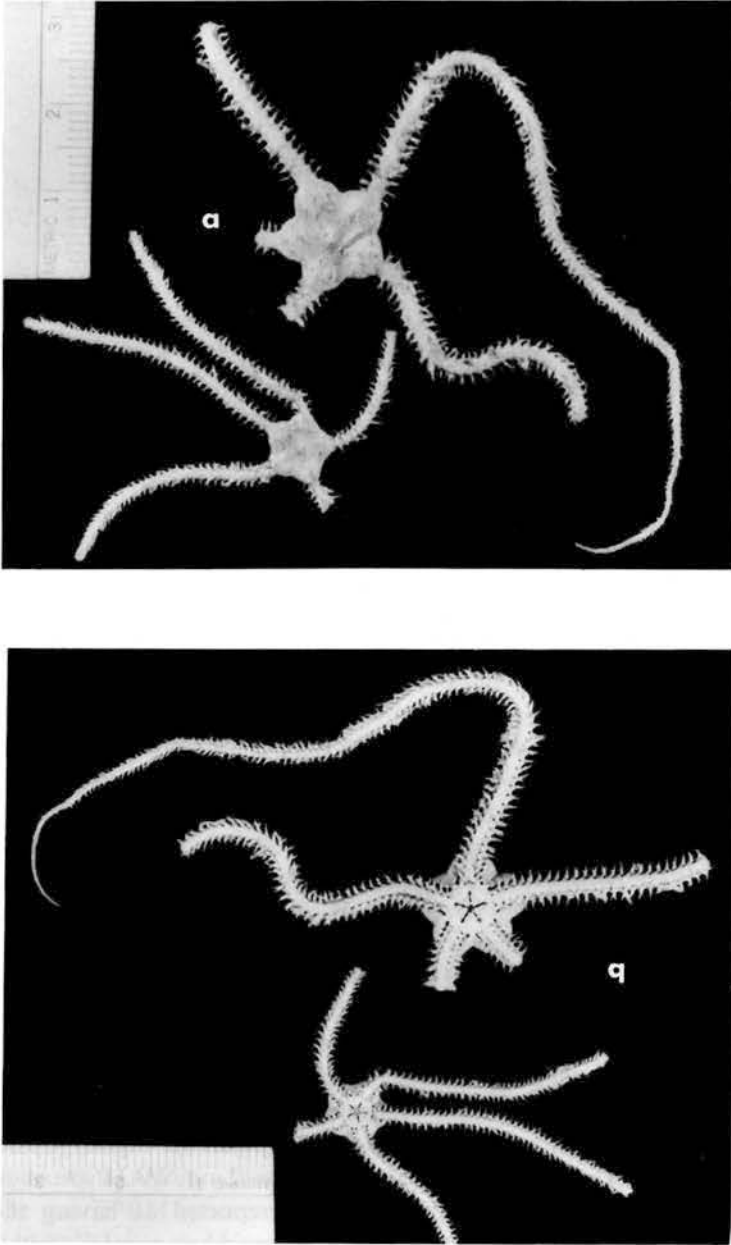


Fig. 9. *Ophiomastix flaccida*, MCZ 1799, Paratypes, Philippines, 8 and 13 mm d.d. (a) Upper side. (b) Lower side.

ARM SPINES. The presence of one and two, or only two arm spines on segment one, characterizes *O. flaccida*. Of the fifteen specimens examined, two showed only two spines on this segment, all the rest have one and two. All of the following sequences have been noted for the first five proximal segments:

12222	22222
12223	22223
12232	22232
12233	22233

As many as four arm spines were noted only on a few segments of the largest specimen (MCZ 1799, 18 mm d.d.), otherwise specimens invariably show an irregular 2/3 alternation of spines to the end of the arm.

Usually where three spines occur, the upper is enlarged (in no case where only two spines are present is the upper one enlarged). Far less frequently where three spines are present, the upper may be small and not unlike the lower spines in the row.

According to Brock (1888), one of the main features of *O. flaccida* was that although the modified upper spines were thicker, they were not any longer than the unmodified spines. However, there is apparently some variability in this diagnosis, or this feature may be characteristic of very large specimens, for Koehler (1905) remarks on the greater length of the modified spines and their variable shape. I have also noted in specimens 13.5 mm d.d. and smaller, the enlarged spines are considerably longer than the other spines.

In small specimens of *O. flaccida* (d.d. less than 9 mm) modification of the upper arm spines is quite different from that seen in larger specimens. While these spines are definitely longer and thicker than other spines in the smaller specimens, they only taper to a blunt point with no swelling or furcation at the tip. However, there is an indication of future modification as the distal part of the spine is noticeably spiculate in contrast to the less rugose (but not smooth) basal portion of the spine. In specimens larger than 9 mm, the upper spines that are modified become thicker all along the shaft and frequently are drawn out into spiculate tuber-shaped continuations at the tip, or they may be broadly rounded without obtuse furcations. The modified upper arm spines generally alternate from segment to segment, but there are times when both sides of the same segment have modified spines.

ADORAL SHIELDS. A peculiarity of *Ophiomastix flaccida* is the extent to which the paired adoral shields encroach proximally in front of the oral shields in some specimens. For example, in the 4.5 mm d.d. BPBM specimen these plates are in contact, while in the 8 mm specimen they do not quite meet. The specimen described by Koehler (1904a) as *Amphiura trepida* (4.5 mm d.d.) was shown with the adorals of one sector in contact. However, reexamination reveals that these plates are slightly separated in all sectors. Likewise the 11.5 mm AHF specimen and the 12 mm WAM specimen have the adorals distinctly separated. Lyman's type was reported as having the adorals separated, while Smith's specimen of *O. (Acantharachna) mirabilis* with a d.d. of 16 mm was reported having the adorals "just meeting at their base."

**DENTAL PLATE.** The length-breadth ratio and area occupied by the dental papillae will be given (p. 355) based on a 13.5 mm AHF specimen. Three thin and compressed vertical septa are present in the fossae (Fig. 10d) and there are four or five teeth on each plate.

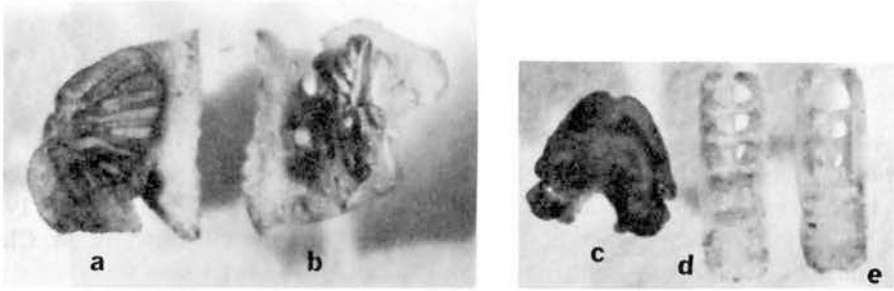


Fig. 10. *Ophiomastix flaccida*, AHF 106.0, Philippines, 13.5 mm d.d. (a) Oral plates, abradial side. (b) Oral plates, adradial side. (c) Proximal surface of first arm vertebra (stained). (d) Front surface of dental plates. (e) Back surface of dental plates.

**ORAL PLATE.** Oral plates were examined from the 13.5 mm AHF specimen and they demonstrated very well developed abradial muscle scars as well as a distinct elongate J-shaped adradial scar (Figs. 10a, b).

**FIRST ARM VERTEBRA.** The structure of this ossicle is unique among those noted in the Ophiocominae for there is an absence of the aperture for the radial water canal (Fig. 10c).

**PIGMENTATION.** Studer (1882) described a specimen as dark violet-red. A small specimen (4 mm d.d.) from Torres Strait was described (H. L. Clark, 1921) having a bluish disc with some orange-red lines, arms yellow with dark green marks along the sides and white arm spines. Preserved specimens, either wet or dry, lose their natural color and leave the disc a greyish hue with whitish arms.

**RELATIONSHIPS.** The absence of tentacle scales, lack of a calcareous ridge separating the radial nerve and radial water canal on the first arm vertebra, very widely spaced bare radial shields, and the fact that the adoral shields lie adjacent to or actually meet in front of the oral shield, easily separate *Ophiomastix flaccida* from other species in the genus. On the basis of the number of arm spines, nature of the disc cover (reduced spination and thick integument with very reduced scalation) *O. flaccida* resembles *O. venosa* most closely. The specimen described by Koehler (1904a) as *Amphiura trepida* and subsequently considered an *Ophiomastix* (A. M. Clark, 1970) species compared well morphologically with small *O. flaccida* and leave no doubt as to its identity.

**HABITS AND HABITAT.** Studer (1882) reported finding *O. flaccida* living on a sponge. The two BPBM specimens were received with a note stating that they were associated with a sponge being investigated. H. L. Clark (1921) found a small "colorfully pigmented" specimen at Torres Strait "on the underside of a rock fragment

on the southeastern reef-flat." Smith's (1878) specimen was from Manila Bay at a depth of 13 m on coarse sand and gravel.

DISTRIBUTION. *Ophiomastix flaccida* has been reported from the Philippine Islands, Indonesia, and Torres Strait. With the exception of one deep water record (*Amphiura trepida*, 289 m, Koehler, 1904a) other specimens are known from the reef flats to 82 m.

*Ophiomastix janualis* Lyman

Figs. 11, 12

*Ophiomastix janualis* Lyman, 1871:14, Pl. I, figs. 13, 14; Brock, 1888:505, 506 (keys based on nature of upper arm spines and disc cover); H. L. Clark, 1915:296; 1921, 134 (in key), 136 (habitat), Pl. 14, fig. 5 (color); Endean, 1957:245; A. M. Clark and Rowe, 1971:86-87 (distribution), 120 (in key, notes).

*Ophiomastix luetkeni* Pfeffer, 1900:83-85; H. L. Clark, 1915:296, Pl. 16, figs. 3-4; 1921:134 (in key), 136-137; Koehler, 1922:330 (Philippines, 22 fms.); Matsumoto, 1917:349 (Okinawa), fig. 98 (disc and claviform arm spines); Djakonov, 1930:246 (Ryukyu Islands); A. H. Clark and Bayer, 1948:144 (Biak, New Guinea); Murakami, 1963:27, Pl. III, fig. 9 (dental plate), 30, Pl. VII, figs. 27-28 (oral plate); Domantay and Domantay, 1966:57 (color, habitat, morphology); A. M. Clark and Rowe, 1971:86-87 (distribution), 120 (in key, notes), Pl. 19, fig. 1.

non *Ophiomastix luetkeni*: Boone, 1938:158-161, Pls. 57-58 (= *O. caryophyllata*).

*Ophiomastix caryophyllata* Lütken: Koehler, 1905:67 (pt.).

MATERIAL EXAMINED AND LOCALITIES

NORTHERN AUSTRALIA—**Torres Strait**: Murray Islands, October 1913, Mer Island, southeast reef flat, H. L. Clark; 10-22 mm d.d. (22 MCZ 3777, 3778, 3863).

INDONESIA—near **Ternate**: 20 May 1970, N. side of Teluk Dodinga (0°51'N, 127°35'E), depth 9-15 m, in amongst branches of *Acropora* coral, Sta. HD II, Mariel King Memorial Expedition Moluccas; 10-16 mm d.d. (3 WAM and BPBM). **Pulu Kaniungan Ketjil**: 21 June 1899, depth 11 m, coraux Siboga Sta. 89; 15 mm d.d. (ZMA). **Saleyser Island**: 26 Sept. 1899, depth 36 m, recifs de coraux, vase et sable, Siboga Sta. 213; 15 mm d.d. (1 ZMA). **Ternate**: depth 80 m, W. Kukenthal S. 1894, 15 mm d.d. "Typus" *Ophiomastix lütkeni* (1 SMF 675).

PHILIPPINES—**Basilan Island**: 11 April 1948, Bojelebung, sand spit, shore at low tide, F. C. Ziesenhenné; 6.5-16 mm d.d. (4 AHF 105.0). **Cebu**: Silut Bay, Liloan, F. A. Jimenez; 9.5 mm d.d. (1 BPBM W1900).

LOCALITY DOUBTFUL—[Mexillones, Bolivia]: 5.5 mm d.d. Holotype, *Ophiomastix janualis* (MCZ 1800).

SOLOMON ISLANDS—No data, H. G. Vevers; 15 mm d.d. (1 BPBM W2252).

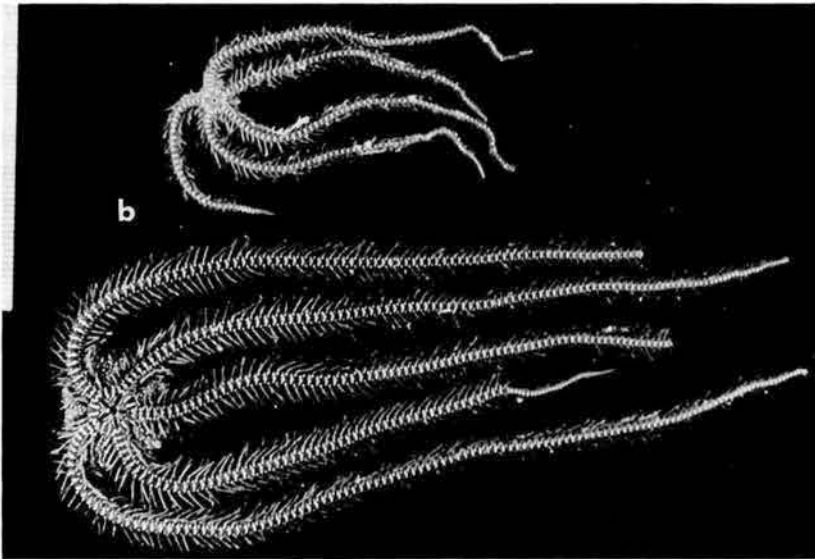
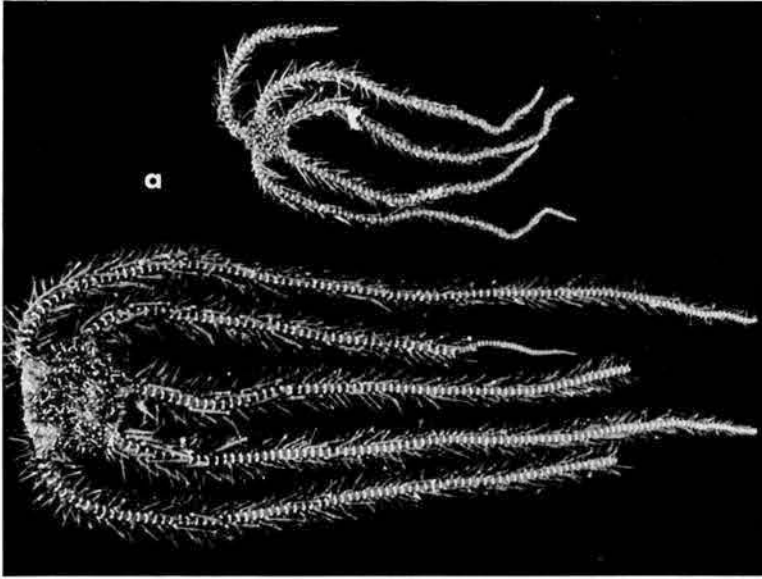


Fig. 11. *Ophiomastix janualis*, AHF 105.0, Philippines, 6.5 and 16 mm d.d. (a) Upper side. (b) Lower side.

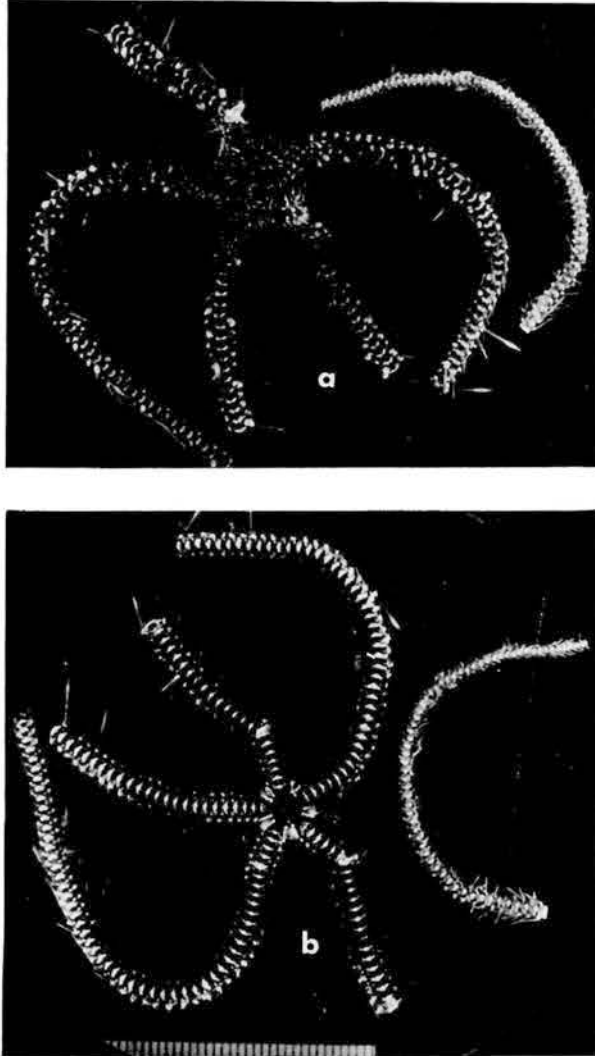


Fig. 12. *Ophiomastix janualis*, SMF 675, (Type, *O. luetkeni*), Ternate, 15 mm d.d. (a) Upper side. (b) Lower side.



## DISCUSSION

The status of *Ophiomastix janualis* Lyman, 1871, has been controversial mainly because the type specimen is small (5.5 mm d.d.) and the location (Mexillones, Bolivia) doubtful (vid. H. L. Clark, 1915, 1921; A. M. Clark and Rowe, 1971:120). Reexamination of the type strongly indicates that this specimen is conspecific with those reported subsequently as either *O. janualis* or *O. luetkeni* Pfeffer, 1900. The following discussion of pigmentation serves to establish this relationship. H. L. Clark (1921) distinguished specimens of *O. janualis* and *O. luetkeni* by color differences as follows:

	<i>O. janualis</i>	<i>O. luetkeni</i>
General color	Black and deep yellow	Dark brown and whitish
Arm spines	Black and not banded	At least proximally, more or less banded
Oral shields	Margins barely marked with yellow	Broad whitish margins

While A. M. Clark and Rowe (1971) retained the dichotomy between *O. janualis* and *O. luetkeni* on the basis of pigmentation, they realized the tenuous value of color alone to separate the taxa. My review of color characters of specimens from Torres Strait (Mer Island) reported as *O. janualis* by H. L. Clark (1921) showed some to have, while others lacked, the banding of the proximal arm spines. While this feature is not reported in the description of the type specimen of *O. janualis*, a reexamination clearly reveals some banding on a few proximal upper arm spines, especially on their upper half. H. L. Clark (1921:136) pointed out for *O. janualis* from Torres Strait, "the amount of yellow along the margins of the oral shields and arm plates is a trifle greater in some specimens than in others" clearly indicating the ambiguity in using this character to separate taxa.

In most specimens examined, the basal portion of the tentacle scales is light colored, especially on proximal segments; although this feature is not evident in the type of *O. janualis*, this is attributed to its dry and faded condition. Furthermore, in other small specimens (6–7 mm d.d.) the scales can be quite dark on distal segments. Generally the distal part of the upper and lower arm plates are light colored (Figs. 11, 12), with the light color extending through the center of the lateral arm plates on the lower side of the arms. This feature is evident on the type of *O. janualis*. (Lyman, 1871, merely stated "Color, in alcohol: chocolate brown, dappled with yellowish.") However, there are a few specimens which have many of the plates with very little light color, giving the arms a generally dark appearance. The type of *O. janualis* as well as the other specimens examined have a yellow or white area on the disc at the base of each light colored spinule. The spinules may be uniformly dark or light or show the upper half dark, lower half light.

The above color characteristics fit well with the original description given by Pfeffer for *O. luetkeni* and have been verified by my examination of one of his types

(SMF 675). Below, I discuss aspects of the morphology of *O. janualis*.

**SIZE.** The largest specimen known, 28 mm d.d., is recorded by H. L. Clark (1921). The arm length appears to be somewhat variable, between seven and ten times the disc diameter.

**TENTACLE SCALES.** Two scales usually cover each pore a considerable distance out on the arms even in small individuals. The type of *O. janualis*, with a disc diameter of 5.5 mm, shows two scales out to segment 29 (well out on the arm) on one arm before dropping to only one scale. A 9.5 mm specimen (BPBM W1900) has two scales to segment 71 at a distance more than four-fifths the arm length. A 20 mm specimen (BPBM W1885) from Torres Strait has a multiplicity of scales (three to six) occurring over pores on some sides in the proximal part of the arm but two scales predominate.

Frequently, the basal portion of the scales is light, the distal portion dark.

**ARM SPINE SEQUENCE.** It has already been discussed under *O. caryophyllata* the ability to distinguish between that species and *O. janualis* by differences in the arm spine sequence on proximal segments. Table 3 gives the sequence of arm spines for the first five segments of many specimens of *O. janualis* examined. On only two examples, and then on a minority of sides, are three spines found on segment two and the presence of two spines on the first two to three segments is characteristic of this species. The 9.5 mm Philippine specimen (BPBM W1900) has a 2/3 arm spine alternation common beyond segment five even well out toward the arm tip with some of the upper (third) arm spines elongated at intervals.

Four arm spines while infrequent on any one side of an arm can be found on some specimens beyond segment five (only once were four spines found on segment five). An 11 mm d.d. specimen from the Philippines showed the maximum number of segments with four spines (segments 6, 7, 16, 23, 27) of those examined. Thus while Domantay and Domantay (1966) reported four arm spines on a 24 mm specimen from the same region, it appears that for *O. janualis* this number occurs in low frequency.

**ARM SPINE MODIFICATION.** The upper modified spines of *O. janualis* exhibit a wide range of variation from elongated tapering to clavifurcate. The modification in these spines is not necessarily a function in size. For example the type specimen of *O. janualis* (5.5 mm d.d.) has some elongate upper spines, while the smallest Philippine specimen examined (6.5 mm d.d.) shows some of the upper spines with slight bifurcation and flattening of the distal end. A similar condition is noted on the larger Philippine specimens (6-7 mm d.d.) with even some swelling partway along the spine shaft. The specimen from the Solomon Islands (20 mm d.d.) and three from Ternate (11 to 16 mm d.d.) show only long tapering upper spines. The type of *O. luetkeni* examined (15 mm d.d.) has some very definite clavifurcate spines and Matsumoto (1917, fig 98c) clearly showed bifurcation at the tip in a specimen from Okinawa about 15 mm in disc diameter. Generally the modified spines occur as the upper one in a row of three spines, rarely where there are only two spines. The modified spines reach four to six segments in length.

**ORAL SHIELDS.** The oral shields in most cases are distinctly longer than wide with the following measurements and ratios noted:

Table 3. Proximal arm spine sequence (segments 1 to 5). *Ophiomastix janualis*.

No. of Arm Spines													Location & Deposition	d.d. (mm)			
03333	12223	12232	12233	12333	22222	22223	22232	22233	22322	22323	22332	22333	22334	23323	23333		
					1	5		10 2					2			Indonesia Siboga Sta. 89	15
																Indonesia Siboga Sta. 213	15
					1	2		7								Loc.? Type- <i>O. janualis</i> MCZ	5.5
							1		2	1			2(2)		(2)	Indonesia (Ternate) Type- <i>O. luetkeni</i> SMF	12.5
																Indonesia (Ternate)	
				1				1					6			BPBM	11 <sup>a</sup> 15 16
1	1				2	5	1	5					2				
						3		7								Philippines AHF	6.5 7 11 16
						1		9 5					4	1			
						2	1	4		1	1						
						3										BPBM	9.5
						2		3		2			3			MCZ <sup>b</sup>	—
					2	2	5		1							Torres Strait BPBM	22
					1	1	4		4							Solomon Ids. BPBM	20
						2							2	6		Okinawa MCZ	—

<sup>a</sup> Specimen with four arms regenerating at or near disc which may be cause for increased number of spines on segment 3; specimen also with only single tentacle scale many on sides of regenerating segments.

<sup>b</sup> Specimen reported as *O. lütkeni* by H. L. Clark (1921:136).

Specimen number	d.d. (mm)	Length (mm)	Breadth (mm)	Ratio 1:b
MCZ 1800 (Type <i>O. janualis</i> )	5.5	0.9	0.6	1.5:1
AHF 105.0	7	1.5	1.0	1.5:1
BPBM W1900	10	1.5	1.2	1.3:1
AHF 105.0	11	2.0	1.3	1.5:1
SMF 675 (Type <i>O. luetkeni</i> )	15	2.5	1.5	1.7:1
AHF 105.0	16	2.0	1.5	1.3:1
BPBM W1885	22	3.0	1.8	1.6:1

Nearly invariably, the lateral margins of the oral shields are light in color, in contrast to the darker central portion.

**LOWER ARM PLATES.** The distal border frequently has a well defined median prominence. This feature was described and illustrated by Lyman for the type specimen of *O. janualis*, and in larger specimens is most obvious on the more proximal arm plates (Fig. 11b). Pfeffer (1900:84) stated for *O. luetkeni*: "Die Bauchschilder sind trapezisch fächerförmig, die Distalkante flach gerundet . . ." and does not mention a median projection on the distal border. However, examination of one of his original specimens from Ternate (SMF 675) shows this clearly (Fig. 12b).

**HABITS AND HABITAT.** At Mer Island, Torres Strait, H. L. Clark (1921) reported finding this species quite common among several coral genera (*Porites*, *Pocillopora* and *Acropora*) far out on the southeastern reef flat. It was noted as one of the "most active" ophiuroids encountered. Domantay and Domantay (1966:57) reported this brittlestar from the Philippines being "Always found inside coral head together with *O. annulosa*, never in crevices of shore line and sea bottom."

One of the specimens (BPBM 1885) collected at Torres Strait by H. L. Clark (1921) with a disc diameter of 22 mm has a parasitic styliiferid gastropod attached over a tentacle pore of segment 10 on one arm.

**DISTRIBUTION.** *Ophiomastix janualis* is known from the northern Great Barrier Reef (Murray Islands), Indonesia, the Philippines, and north to the Ryukyu Islands.

### *Ophiomastix koehleri* Devaney

Figs. 13-16

*Ophiomastix koehleri* Devaney, 1977:274-283, figs. 1-4.

*Ophiocoma wendti*: Koehler, 1907 (in part): 327-328, Pl. XIII, fig. 38; H. L. Clark, 1921:129; 1938:336; Devaney, 1970:35, 37; A. M. Clark and Rowe, 1971:86-87, 91, 118-119 (note), Pl. 18, fig. 5 [non *O. wendti* Müller and Troschel, 1842].

*Ophiomastix asperula* (in part): H. L. Clark, 1915:294; 1921:134 (Zanzibar specimen referred to *Ophiocoma wendti*) [non *O. asperula* Lütken, 1869].

**MATERIAL EXAMINED AND LOCALITIES** (Also see Addendum, p. 313).

ZANZIBAR— No details, origin, M. Angel; 23–25 mm d.d. (2 BMNH 1965–6–1–451, Holotype and Paratype). No details, the specimen discussed by H. L. Clark (1921) as *Ophiocoma wendti*; 25 mm d.d. (1 MCZ 1795, Paratype).

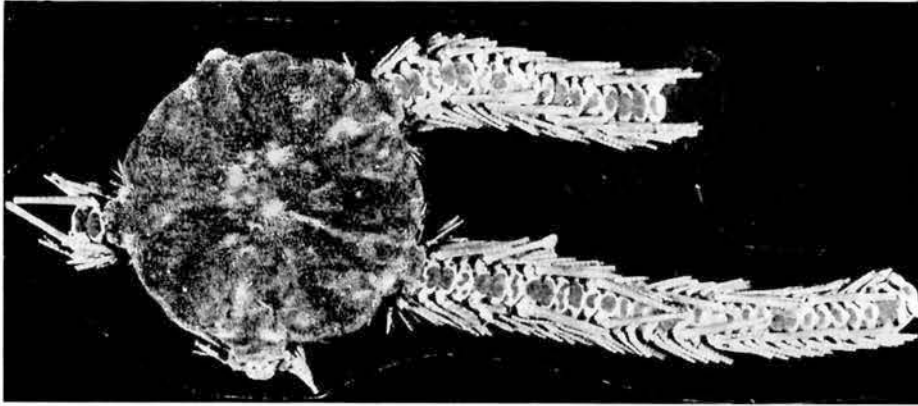


Fig. 13. *Ophiomastix koehleri*, MCZ 1795, Paratype, Zanzibar, 25 mm d.d. Upper side.

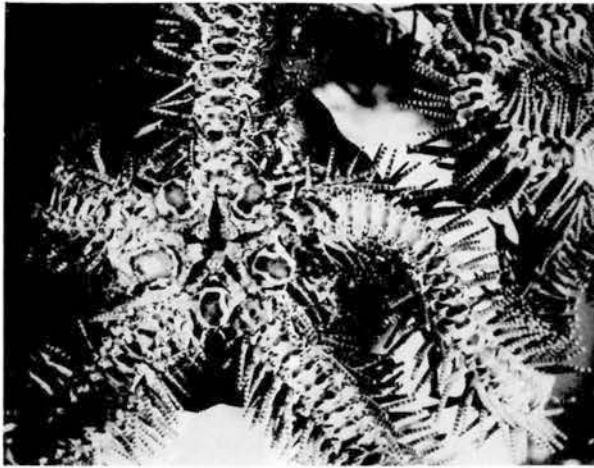


Fig. 14. *Ophiomastix koehleri*, BMNH Reg. no. 1965–6–1–451, Holotype, Zanzibar, 23 mm d.d. Lower side.

#### DISCUSSION

The following discussion reviews some of the major characters of *Ophiomastix koehleri* based upon specimens 22 to 25 mm in disc diameter.

**DISCOVER.** The disc is covered above with rounded granules 89 to 177 microns in diameter by 101 to 202 microns high. The granule height can be less than, equal to, or slightly more than the diameter. In the latter case they are less than twice as high as broad. A series of granules rather conical in shape occur along the interradial edge of

the genital openings. One to four similar granules are found at the distal end of an oral shield.

**TENTACLE SCALES.** Two scales occur regularly on each side of the first 8 to 15 proximal arm segments, and they can occur irregularly to segment 25. A single scale covers the greater part of the arm.

**ARM SPINES.** The arm spine sequences for the first five segments are, in frequency of occurrence: 3-3-3-3-4; 3-3-3-3-3; 3-3-3-4-4. Modified claviform or clavifurcate upper arm spines are present (Figs. 13, 15, 16).

**PIGMENTATION.** The arm spines are distinctly banded dark and light, except the upper modified spines which show traces of annulations mostly near the tip. The basic disc color is blackish brown and the arms are irregularly variegated with dark and light (Figs. 13, 14, 15).

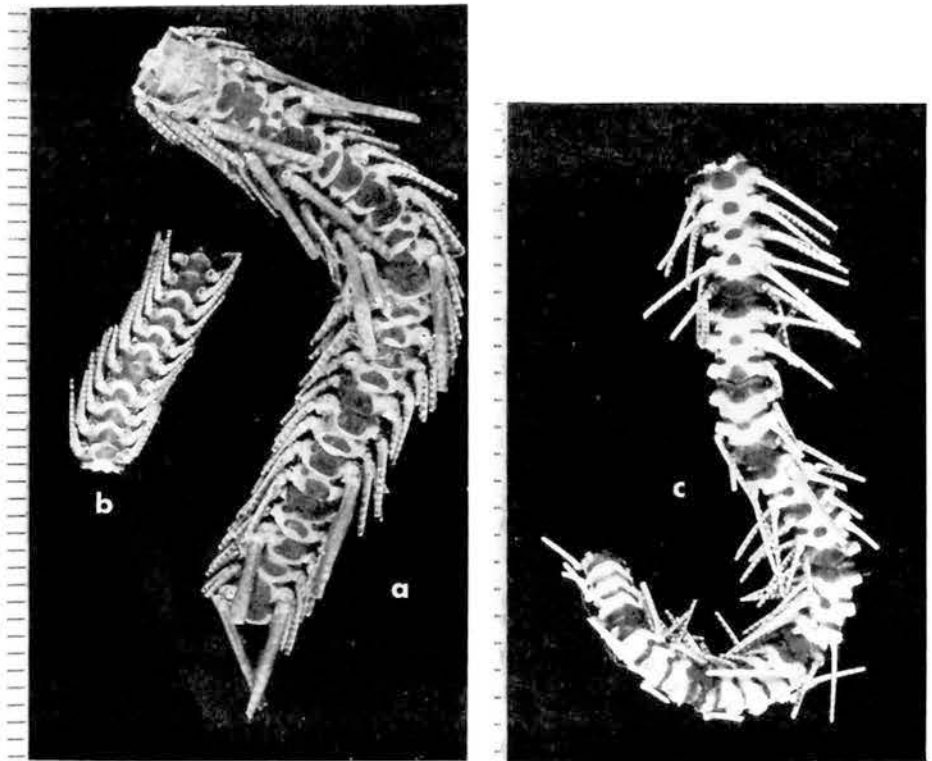


Fig. 15. *Ophiomastix koehleri*, MCZ 1795, Paratype. (a) Upper arm plates from arm base to segment 27. (b) Lower arm plates from broken portion, farther out on arm. (c) BMNH Holotype, upper arm plates from broken portion, some distance out from disc.

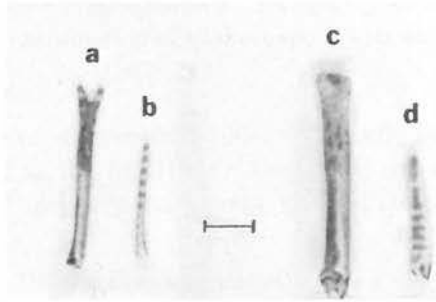


Fig. 16. *Ophiomastix koehleri*, BMNH Reg. no. 1965-6-1-451. (a) Third uppermost arm spine from segment 88 with bifurcate tip. (b) Third uppermost unmodified arm spine from segment 89. (c) Fourth uppermost modified arm spine from segment 14. (d) Third (next uppermost) arm spine in same row from segment 14.

**RELATIONSHIPS.** The presence of both granules and clavifurcate upper arm spines combine the characters of *Ophiocoma* and *Ophiomastix* respectively. Low, rounded granules, absence of disc spinules, and alternation of arm spines present in *Ophiomastix koehleri* are characteristic of the Scolopendrina group of *Ophiocoma* (Devaney, 1970). The presence of enlarged upper arm spines, with the tips forked, is diagnostic of *Ophiomastix*. Likewise, the presence of two arm spines on some of the distal segments is also known in several species of *Ophiomastix* (e.g., *O. flaccida*, *O. variabilis*, *O. palaoensis*) but this is a feature I have noted only on *Ophiocoma wendti* (formerly *O. riisei*) from the West Indian region. This species is also the only *Ophiocoma* which has two arm spines regularly on a proximal segment (segment one). In addition, *O. wendti* often reveals considerable enlargement and elongation of the upper arm spines in which some spines may be swollen centrally and have the tips flattened and slightly expanded (Figs. 17b, c) somewhat like *Ophiomastix koehleri*. Unlike many species of *Ophiomastix* however, the spines of *Ophiocoma wendti* do not have the tips forked.

It is possible, even quite probable, that specimens of *Ophiomastix koehleri* smaller than those examined would lack clavifurcate arm spines. However, Koehler's (1907) figure of this species, with a disc diameter approximately 16-17 mm, clearly shows these. The absence of claviform or furcated arm spines in small specimens of other species of *Ophiomastix* has been noted in this paper and by others (Lütken, 1869; H. L. Clark, 1921).

*Ophiomastix koehleri* can be separated from *Ophiomastix asperula*, another species which shows a granular disc cover (p. 285) by the following:

a) *O. koehleri* has relatively shorter and more widely spaced low and rounded disc elements, none of which are spinules; *O. asperula* has both granules and spinules, closely packed, tapering, and frequently with the upper half dark while the lower half is light colored.

b) *O. koehleri* has enlarged modified upper arm spines beginning near the disc, some with forked tips, continuing a long way out on the arm; *O. asperula* has elongated, swollen upper arm spines limited to a small part of the arm beginning from

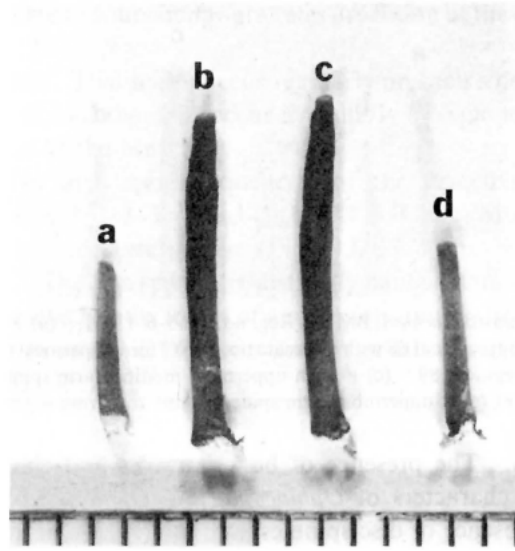


Fig. 17. *Ophiocoma wendti*, from Bermuda, 27 mm d.d. (a) Unmodified third uppermost arm spine from opposite sides of segment 10. (b) Modified elongate fourth uppermost arm spine. (c) Modified elongate fourth spine from segment 22. (d) Unmodified third arm spine from segment 22.

about the twenty-second to thirtieth segment and these are only rarely known to have the tip forked or otherwise modified.

c) In contrast to *O. koehleri*, *O. asperula* is characterized by being darkly pigmented with very consistent fine wavy white rings of color around the arms, a pattern which is repeated on the mouth plates (Figs. 4a, b). However, both species have the arm spines banded.

d) *O. koehleri* has only three arm spines on segment three; two specimens of *O. asperula* examined from Mer Island (Torres Strait) and Fiji have four arm spines on each side of segment three.

e) *O. koehleri* is known from the western Indian Ocean exclusively, while *O. asperula* is not confirmed from the Indian Ocean.

I have been unable to determine the type locality of Koehler's (1907) specimen(s) of *Ophiomastix koehleri* which he included as *Ophiocoma wendti* from several Indo-West Pacific localities. The fact that both the MCZ and BMNH specimens are from Zanzibar suggests that one or more of Koehler's six specimens from Fernando Velosa, Mozambique, probably represent *O. koehleri*. However, Dr. Cherbonnier kindly sent me one of the six specimens from that locality deposited in the Muséum National d'Histoire Naturelles, Paris. This specimen appears to be *O. palaoensis* Murakami (see p. 337) a species recorded previously only from the central Pacific. The taxonomic status of Koehler's other specimens from Fernando Velosa still remains in doubt, as well as those from the other localities he listed (Fiji, Seychelles, New Ireland). Dr. Cherbonnier (pers. comm.) informed me that he is unable to tell which of the specimens



recorded as *O. wendti* by Koehler resembles the figure given by Koehler (1907) as all are bleached out. Critical examination of all these specimens will help clarify this situation.

#### ADDENDUM

Additional specimens reported by Koehler (1907) as *Ophiocoma wendti* have recently been located at the MNHP. Of these, two are examples of *Ophiomastix koehleri*: Seychelles, 1 spec. dry d.d. 17 mm; no loc., 1 spec. alc. d.d. 20 mm.

#### *Ophiomastix marshallensis* n. sp.

Figs. 18–20

*Ophiomastix mixta* Lütken: A. H. Clark, 1952:296.

ETYMOLOGY: Named after the general type locality and after Marshall J. Youngbluth who made collections of ophiuroids available to the author, including the type specimens of this species.

TYPE LOCALITY: Enewetak Atoll, Marshall Islands. Type specimen: BPBM W1529.

#### MATERIAL EXAMINED AND LOCALITIES

MARSHALL ISLANDS—**Bikini Atoll**: 18 July 1946, Namu Island, intertidal, Fred C. Ziesenhenné, dry, 12 mm d.d. (1 AHF 722.1, labeled *Ophiomastix elegans* Brock). **Enewetak Atoll**: late August, or early September 1965, Enewetak Island, quarry area, shallow sublittoral, Darrell R. Stokes, dry, 16.5 mm d.d. (gonads ripe, male), (1 BPBM W1487); 9 Aug. 1965, Enewetak Island, quarry area, from *Pocillopora* sp. (coral), Darrell R. Stokes, dry, 13–15 mm d.d. (1 BPBM W1492); 7 Sept. 1966, Enewetak Island, depth 1 m, coral rubble and sand, Marshall J. Youngbluth, 15 mm d.d. (1 BPBM W1529, HOLOTYPE); locality data same as Holotype, 15–16 mm d.d. (gonads ripe, male), (1 BPBM W1527, PARATYPE); locality data same as Holotype, 6.5 mm d.d. (1 BPBM W1528, PARATYPE); locality data same as Holotype, 12.5 mm d.d. (1 BPBM W1530, PARATYPE). 2 June 1946, Pujiyoru (Rujoru) Island, ocean reef, Morrison and Cali, 10 and 11 mm d.d. (2 USNM E7321, reported as *Ophiomastix mixta* by Austin H. Clark, 1952). Eight specimens from various localities at Enewetak (Engebi, Japtan, Rigili, Aaraanbirn, and Parry) and one specimen from Enyu Island, Bikini Atoll, deposited in the Mid-Pacific Marine Laboratory (MPML, formerly known as the Enewetak Marine Biological Laboratory), size 6 to 17.5 mm d.d.

#### DESCRIPTION OF HOLOTYPE

(BPBM W1529). Disc diameter 15 mm; maximum arm length 65 mm.

Upper side of disc covered with numerous small granules which taper toward thin tip and a large number of more widely spaced spinules (400–660 microns high) about five times as high as broad and tapering to acute tip; small pits in disc scales evident

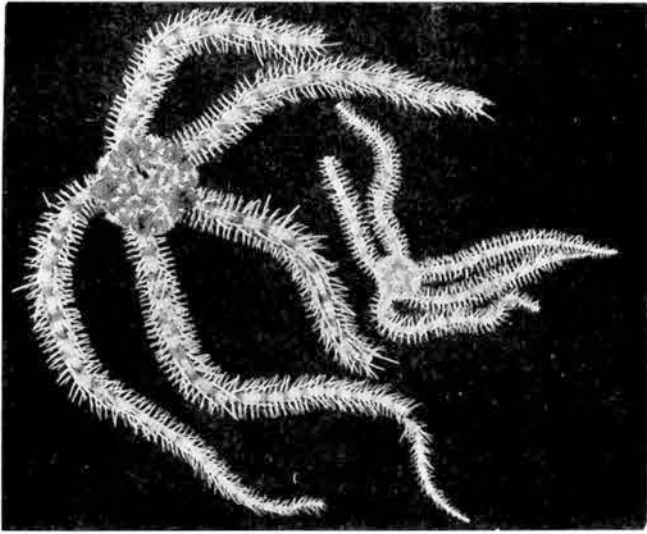


Fig. 18. *Ophiomastix marshallensis*, BPBM W1527 and W1528, Paratypes, Enewetak, 15 and 6.5 mm d.d. Upper sides.

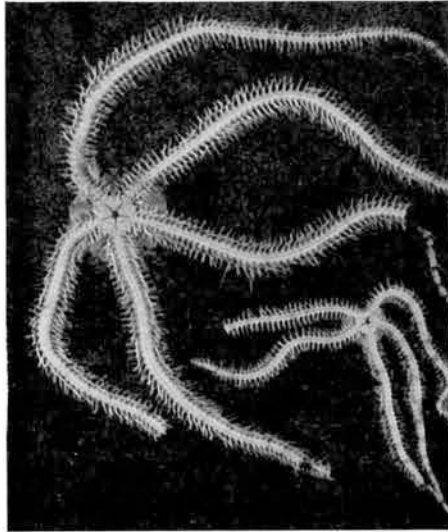


Fig. 19. *Ophiomastix marshallensis*, BPBM W1527 and W1528, Paratypes, Enewetak, 15 and 6.5 mm d.d. Lower sides.

where spinules occur. From ambitus orally, number of granules and spinules diminish leaving only V-shaped central area covered, with exposed scales on each side and to oral shields. One or two small cone-shaped granules placed on distal edge of oral shield plus a series of similar granules along interradial edge of genital opening. No integument obscuring disc or arms.

Oral shields noticeably longer than broad (L 1.3, B 1.0) with greatest width distal to middle of shield, narrowing inward to form nearly straight inner edge; madreporite shield with slight central depression otherwise similar. Small space between distal part of oral shield and first lateral arm plate. Adoral shields widely separated within by oral shield, with inner radial border concave, abutting against outer part of buccal tentacle scale; outer radial angle in contact with ventral shield.

Three oral papillae on each side; outer papilla widest and bearing a distal projection; inner papillae more elongate. Buccal tentacle scale contiguous with both adoral and ventral shields, projecting inward under outer oral papilla.

Seven to nine dental papillae to each jaw; two innermost at side of lower tooth. Three or four teeth, wide, with blunt, truncated and hyalinated tip.

Lower arm plates broader than long, slightly convex along sides with nearly rounded distal edge, sometimes slightly truncated centrally; arm plates contiguous until near distal part of arm where lateral plates separate them.

Upper arm plates broadly fan-shaped, narrowing, with proximal edge about one-third of maximum breadth; obvious truncation of lateral border of upper arm plates where upper arm spine encroaches at irregular intervals; from disc to mid part of arm, plates are 2 to 2.4 times broader than long.

Beyond disc margin lateral arm plates with irregular alternating series of three and four arm spines located along distal portion of plates.

First ten segments with following sequence of arm spines: 3-3-4-4-4 or 5-4 or 5-5-4 or 5-3-4 or 5-4 or 5; rarely 5 spines beyond segment ten, and irregular alternation of 3 and 4 spines on opposite or adjacent sides beginning beyond segment ten. Upper (fourth) spine long and tapering with no swelling or furcation of tip; in some cases these upper spines may be about the same thickness along distal one-third of length and have rounded blunt tip; in middle of arm elongated upper arm spines may equal six segments in length and toward the arm tip, five segments in length. In contrast where only three spines occur on a side, the upper is not much longer than next lowest and is only about three segments in length. Only three arm spines on distal-most segments. Arm spines smooth, curved, being slightly concave along distal margin and somewhat compressed rather than cylindrical, except for elongated upper arm spines.

Two tentacle scales on each side of arm segment regularly from segment one to segment fifty-five or fifty-seven, then only single acutely tapering scale; outer scale largest and tapering; toward middle of arm scale with more acute tip.

Pigmentation: basic color brown, tan and light cream with following pattern: disc aborally variegated with brown and some tan; near radial margins of disc are two darker curved lines from arm base inward about one-half way to disc center, these lines curve along inner part of radial shields; outside of, and adjacent to, each line is a small light tan area. Scales, granules and spinules brown or tan color; very little evidence of banding of disc spinules. Upper arm plates characteristically with narrow median dark brown stripe running through all plates to tip of arm; at intervals of three to five segments one or two consecutive upper arm plates nearly all dark brown but not as dark as stripe; other arm plates light tan. Arm spines dark along upper side with some

faint evidence of light and dark pattern near the tip but no annulation evident. Orally color much lighter than above; with exception of brown spots in center of oral shields and along adoral shields, mouth region otherwise is very light tan to white. From first lower arm plate to end of arm a series of one to four nearly contiguous small brown spots in center of each plate; these begin to run together near middle of arm and continue distally giving appearance of narrow dark stripe; sometimes an irregularly placed dark spot away from middle of arm plates. Oral surface of lower arm spines especially, very light color; oral part of disc light, including spinules and granules.

#### VARIATIONS

**TENTACLE SCALES.** Four specimens, including the smallest (BPBM W1528) and largest (BPBM W1487) were compared for the maximum number of arm plates carrying two tentacle scales on each side (Table 4).

Table 4. Tentacle scales, *Ophiomastix marshallensis*.

Disc Diameter (mm)	No. Arm Segments with Two Tentacle Scales
6.5	29 to 33
10.5	60 to 63
14.0	61 to 65
16.5	65 to 72 (with three scales on all sides of segment 1)

**ARM SPINES.** While the number of arm spines is quite constant on each side of the first four segments (3-3-4-4), there is an increase in the number of arm spines beyond segment four as specimens become larger. For example in the smallest specimen (6.5 mm d.d.) five arm spines are found only on segments five and six. In an intermediate sized specimen (10.5 mm d.d.), five spines alternate with four spines from segment five out to segment twelve, and in the largest specimen (16.5 mm d.d.), four and five spines occur from segment five out to segment sixteen. An irregular alternation of three and four spines occurs beyond the segments carrying four and five spines.

**DENTAL PLATE.** The dental plates were dissected from two specimens (BPBM W1492, disc diameter ca. 14 mm and BPBM W1527). These plates (Fig. 20a, b) show the typical *Ophiomastix* features, with thin compressed complete septa between the teeth, two or three foramina and thirty per cent (range: 29-33%) of the total length of the plate occupied by the dental papillae region. The length: breadth ratio of two dental plates is 2.4-2.5:1.

**PIGMENTATION.** The overall color may be darker than that noted in the holotype resulting in a less distinct appearance of the dark midcentral line on the upper side of the arms (USNM specimens). There may also be a tendency for the disc spinules and arm spines to be more distinctly banded than noted in the type specimen. In no case were the arm spines noted to be claviform, and in the smallest specimen none of the upper spines are even thickened.

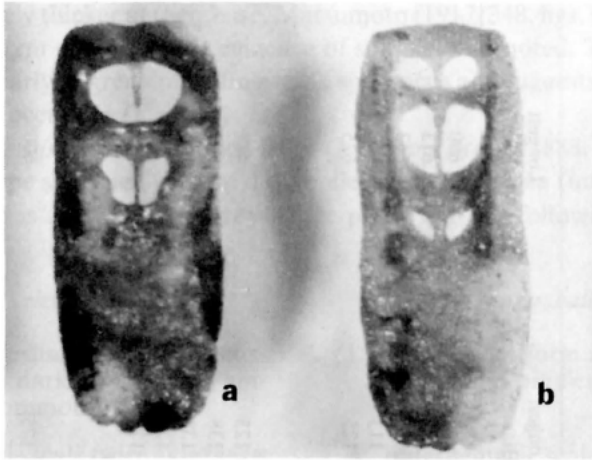


Fig. 20. *Ophiomastix marshallensis*, BPBM W1492, Dental plates. (a) Front surface. (b) Back surface.

#### RELATIONSHIPS

The new species, *O. marshallensis*, compares closely with those in the genus having both granules and spinules well developed on the disc. These species include *O. elegans*, *O. mixta*, and *O. stenozoneula*, the latter described from southeastern Polynesia. Both *O. marshallensis* and *O. mixta* were collected from the same habitats at several Enewetak localities. This allowed comparative examination of these two species based on syntopic specimens.

The most obvious difference between the two species is in pigmentation. *O. mixta* is characterized when alive by a deep claret color. This pigment is lost, however, very rapidly upon preservation in either alcohol or formalin and leaves a bleached out, dirty white color. In contrast, the well marked pigmentation and color pattern remain unchanged in preserved specimens of *O. marshallensis*.

Another difference between the two species is in the relative size of the disc granulation. In each species, granules are more abundant than spinules in specimens larger than 8 mm d.d. An analysis was made of a random assortment of granules (with sample sizes ranging from 13 to 17) from five specimens of *O. mixta* and five specimens of *O. marshallensis* collected at Enewetak (Table 5). Granules 63 to 100 microns ( $\bar{Y} = 81$ ) in diameter and 63 to 150 microns ( $\bar{Y} = 98$ ) in height were measured from *O. marshallensis*, whereas granules 88 to 138 microns ( $\bar{Y} = 106$ ) in diameter and 100 to 190 microns ( $\bar{Y} = 143$ ) in height were measured from *O. mixta*. Yet even though all but one specimen of *O. mixta* was smaller than the specimens of *O. marshallensis*, the analysis shows granules of *O. mixta* are larger than those of *O. marshallensis*.

A comparison of the longest spinules for the two species (Table 5) indicated that the length of these is variable for each species, but that they have about the same maximum length and distribution over the disc. In *O. marshallensis*, the spinules are generally more uniform in length and there is an indication that the spinules of *O.*

Table 5. Relative size of granules and longest spinules in *Ophiomastix marshallensis*, *O. mixta*, and *O. stenozonula*.

BPBM No.	Disc Diameter (mm)	<i>Ophiomastix marshallensis</i>			
		Average Granule Diameter ( $\mu\text{m}$ )	Average Granule Height ( $\mu\text{m}$ )	Longest Spinule Diameter ( $\mu\text{m}$ )	Longest Spinule Height ( $\mu\text{m}$ )
W1530	12.5	83	103	88	600
W1492	14.5	81	103	125	613
W1529	15.0	76	96	125	663
W1527	15.5	78	80	113	462
W1487	16.5	86	103	125	625
		$\bar{Y} = 81$	$\bar{Y} = 98$		
<i>Ophiomastix mixta</i>					
W1524	8	98	120	125	487
W1490	11	103	148	138	525
W1502	11.5	100	128	138	450
W1489	12	103	146	125	725
W1525	14.5	120	161	175	675
		$\bar{Y} = 106$	$\bar{Y} = 143$		
<i>Ophiomastix stenozonula</i>					
W1907	12.5	90 <sup>a</sup>	125 <sup>b</sup>	175 <sup>c</sup>	600 <sup>d</sup>
		a:n=9 w=75-113	b:n=9 w=100-175	c:n=18 w=88-175	d:n=18 w=225-600

*mixta* are relatively thicker at their base. Matsumoto (1917:348, figs. 97a, b) described the disc of *O. mixta* in which little evidence of spinules was noted. This reduction in spinules is not nearly as great in the Enewetak specimens and suggests the intraspecific variation which occurs in *O. mixta*.

*O. marshallensis* can be separated from *O. elegans* Brock, 1888, a species known only from the type specimen (16 mm d.d.) collected at Amboina (unfortunately, this unique specimen is apparently destroyed, see p. 297), in the following ways:

*O. elegans*

1. granules of disc glasslike, transparent with dark spot on tip; spinules not common.
2. outer tentacle scale twice as large or larger than inner scale.
3. basic color dark brown; borders of lower arm plates marked by light lines, one dividing each plate diagonally into two equal halves; similar color on upper arm plates but these more irregularly marbled with light lines and dots; arm spines finely and regularly alternating in light and dark rings; mouth shields finely dark and light marbled.

*O. marshallensis*

1. granules uniform in color, dark to light tan; spinules quite common on disc.
2. outer tentacle scale only about half again as large as inner scale.
3. basic color brown and light tan; disc with evident radial lines and lighter areas at arm base; conspicuous stripe down middle of upper arm plates; lower arm plates light tan with prominent series of spots forming a central stripe along length of arm; upper arm spines darker on upper side, lighter on lower, somewhat broadly banded toward tip; mouth shields with one to several dark spots centrally on very light background.

*Ophiomastix marshallensis* is known only from the northern Marshall Islands (Enewetak and Bikini Atolls) at depths less than 4 m and in coral rubble or live coral habitats.

A 14 mm d.d. specimen (W1492) has the gonads well developed with thin roundish calcareous bodies surrounding these gonads.

*Ophiomastix mixta* Lütken

Figs. 21, 22

*Ophiomastix mixta* Lütken, 1869:42–44 (Fiji, Samoa, description in key); Lyman, 1882:174 (in key), 175 (Fiji), 298 (Levuku Reefs, Fiji), 312, 325; Brock, 1888:497 (Amboina), 504 (modification of upper arm spine), 505 (in key to species on basis of arm spines), 506 (disc elements key to species); Bell, 1899 (Loyalty Islands); Koehler, 1905:68–69, Pls. VI, fig. 15, XV, fig. 1 (description, review type, Indonesia); 1922:330–331 (Philippines, 22 m); 1927:5 (Marshall, Gilbert, Fiji

Ids.); H. L. Clark, 1911:256, figs. 126a-c (So. Japan); 1915:296; 1921:133 (disc cover), 134 (in key to species), 135 (Torres Strait, color, habitat) Pl. 14, fig. 2 (color); 1946:249 (habitat, color, Barrier Reef); Matsumoto, 1917:348-349, figs. 97a-c (Misaki, Japan as northern limit, disc cover and arm spines); Murakami, 1942:34 (Izu, Japan, littoral); 1943a:165 (Palau intertidal reef habitat), 199; 1943b:220 (Ryukyu littoral); 1944:260, 277 (color described, habitat, disc granules); 1963:27 and Pl. III, fig. 10 (dental plate), 30 and Pl. VII, fig. 25 (oral plate); Edean, 1956:126, 134 (habitat Low Is., Great Barrier Reef); Utinomi, 1961:112, Pl. LVI, fig. 7 (color, size); A. M. Clark and Rowe, 1971:86-87 (distribution), 120 (key to species).

non *Ophiomastix mixta*: Loriol, 1893a:414 (= *O. annulosa* according to Koehler, 1905:68; A. H. Clark, 1952:292 (= *O. marshallensis*, this paper).

#### MATERIAL EXAMINED AND LOCALITIES

**FIJI ISLANDS—Viti Levu:** 20 Feb. 1972, south side of Mahuluva Island outside of Lauthala Harbor (18°11.7'S, 178°31.6'E), depth 1-12 m under boulder in surge channel, D. M. Devaney; 15 mm d.d. (1 BPBM W2251).

**SAMOAN ISLANDS—Tutuila:** 5 Mar. 1947, Leloaloe, intertidal, F. C. Ziesenhenné; 4 mm d.d. (1 dry AHF 720.1). 5 May 1974, cove on west side of Siufagalele Pt., under rock on sand, depth 26 m, D. M. Devaney; 8.5 mm d.d. (1 BPBM W2285). West side of Nuuosina Rock on west part of Fagasa Bay, under rock on sand, depth 27 m, D. M. Devaney; 11 mm d.d. (1 BPBM W2284).

**MARSHALL ISLANDS—Enewetak Atoll:** August-September 1965, Quarry, D. R. Stokes; 12 and 16 mm d.d. (2 BPBM W1488, W1489). July-August 1966, northeast end of Quarry, coral rubble, sand, depth 1 m, Marshall J. Youngbluth; 10 and 12.5 mm d.d. (2 BPBM W1502, W1503). 7 Sep. 1966, Enewetak Islet, M. J. Youngbluth; 8, 14, 17 mm d.d. (3 BPBM W1524-1526). 5 Feb. 1973, seaward reef slope between Rigili and Giriinien Islets, rubble, depth 15-21 m, D. M. Devaney; 7 and 10 mm d.d. (2 BPBM W2253). 4 Dec. 1976, southeast of Biken Islet, seaward lee reef slope, under rubble, depth 21 m, D. M. Devaney; 2.5 mm d.d. (1 BPBM).

**RYUKYU ISLANDS—Okinawa:** 30 May 1975, north side of Sesoko Islet, lagoon reef, depth 8 m, J. E. Randall; 13 mm d.d. (1 BPBM).

#### DISCUSSION

*Ophiomastix mixta* appears to be a well defined and strikingly pigmented species which, until the recent discovery of two related species (*O. marshallensis* and *O. stenozonula*), stood together with *O. elegans* as the only species in the genus with a disc cover combining granules and short spinules. A few of the significant characters of *O. mixta* and its relationships to the other species follow.

**SIZE.** H. L. Clark (1946) stated that large specimens of *O. mixta* have a disc diameter from 15 to 28 mm. The largest specimen I am aware of is that figured by Matsumoto (1917), approximately 20 mm. None of the specimens I examined exceeds 17 mm.



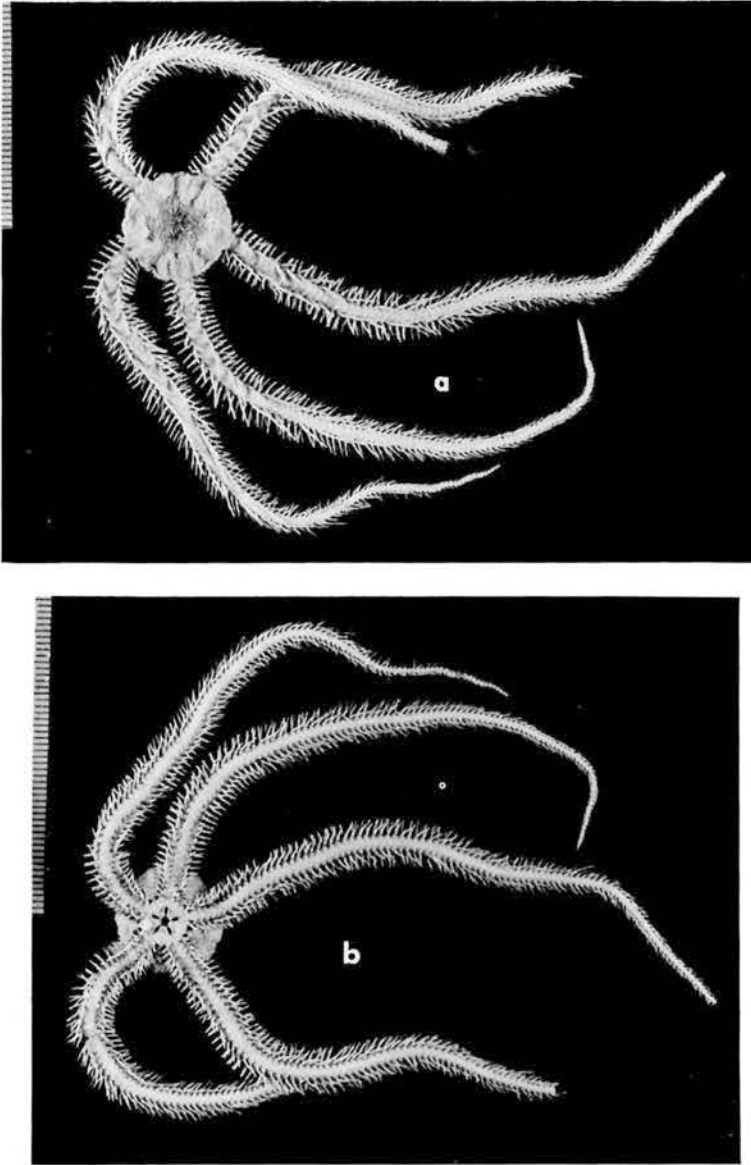


Fig. 21. *Ophiomastix mixta*, BPBM W1526, Enewetak, 17mm d.d. (a) Upper side. (b) Lower side.

An arm length between four and six times the disc diameter has been found.

DISCOVER. A comparison of the dimensions (diameter and height) of granules and spinules has been presented for *O. mixta*, *O. marshallensis* and *O. stenozonula* (Table 5). The number of granules and spinules varies and Matsumoto (1917) noted Japanese specimens with fewer spinules than those recorded from East Indian specimens.

The longest spinule I measured was about 800  $\mu\text{m}$  where these occurred in some number on the Fiji specimen (15 mm d.d.), and Lütken noted these up to 1 mm in length.

A row of conical granules occurs along the border of the genital openings and the granules appear at a size between 5 and 7 mm d.d., being absent in smaller specimens. Likewise a pair of more similarly shaped tapering granules occurs at the base of the oral shields by approximately the same size.

Only the central interradiation region on the lower side of the disc has disc elements; the lateral portions show only the scales.

**TENTACLE SCALES.** An increase in the number of arm segments bearing two tentacle scales occurs with increasing size (Table 6). Likewise, a greater proportion of the arm length has two scales with increasing size: at 2.5 mm, 15% of the length; at 7 mm, 30%; at 8–11 mm, 50–70%; at 15 mm, 65%.

Table 6. Tentacle scales, *Ophiomastix mixta*.

Specimen Deposition	Disc Diameter (mm)	No. Arm Segments with Two Tentacle Scales
BPBM	2.5	3–4
AHF 720.1	4	11–12
BPBM W2253	7	16
" W1524	8	32–34
" W1503	10	36–38
" W2284	11	45
" W1502	12.5	41–46
" W1488	16	53–55

The outer scale is the largest and first formed. H. L. Clark (1911) mentioned and illustrated the unusual occurrence of three tentacle scales on the basal segment of a specimen from Japan.

**ARM SPINES.** The number of arm spines on the Enewetak specimens examined was quite constant on the first four proximal segments: 3–3–4–4. Beyond this, there appeared to be an increase in the number of spines, at least through segment 10, with increase in size. The 2.5 mm d.d. specimen showed no segments with five spines while the 7 mm specimen had five spines alternating with four on segments five and six, on segments five to eight on an 8 mm specimen, on segments five to ten on a 12.5 mm specimen, on segments five to eight on a 16 mm specimen. The two specimens from Fiji and Okinawa (15 and 13 mm d.d.) had a 3–3–3–4–4 sequence predominating while those from Samoa (8.5 and 11 mm d.d.) had 3–3–4–4–4 for the proximal five segments. An irregular alternation of three and four spines occurred farther out on the arm, but towards the tip three spines were most common regardless of the locality.

While Koehler (1905) considered any alteration of the tip of the elongated upper arm spines as proof that a specimen was not *O. mixta*, there is no doubt that a rather special modification of some of these spines does occur. Brock (1888) first pointed this

out by referring to the "spatelforming" or strongly flattened and expanded end of these spines. Matsumoto (1917) showed this in his figure of a Japanese specimen. Among those examined from Enewetak, only the 16 mm specimen showed the spatulate development of the upper spine tips. However, the 17 mm specimen from that same locality had the spines only slightly flattened and most were rather rounded to a blunt point. The Okinawa specimen (13 mm d.d.) revealed the modified spatulate upper spines over a long distance of the arm (Fig. 22). In this specimen also, some of the spines



Fig. 22. *Ophiomastix mixta*, BPBM Okinawa, 13 mm d.d. Portions of broken arms showing spatulate upper arm spines.

showed the end to be slightly bilobed. I was unable to find spatulate spines in specimens less than 13 mm. Brock may have been correct in considering the development of these spines to be a size related feature, although their appearance in large specimens is not uniform. The modified spines (spatulate or not) almost invariably occur as the fourth upper spine and not as the upper spine where only three spines occur in a row. The elongated spines reach up to five segments in length.

Many of the specimens examined have the lower arm spine distinctly curved.

**PIGMENTATION.** This species and *O. flaccida* are two in the genus which lose their natural color upon preservation. The fugaceous nature of the claret-red color of *O. mixta*, color change in preserved specimens, and consideration that no correlation could be found between the natural pigmentation and habitat of this species were reviewed by H. L. Clark (1921) based upon his field experiences at Mer, Torres Strait.

**RELATIONSHIPS.** It has been pointed out (Devaney, 1974:171) that *Ophiomastix mixta* is closely allied with *O. stenozonula* from southeast Polynesia and "an undescribed species of *Ophiomastix* from the Marshall Islands" (described herein as *O. marshallensis*). These three species have a similar type of disc cover with both granules and spinules interspersed, a similar shape of mouth and arm plates, two tentacle scales occurring regularly on proximal segments, and the number of segments with two scales increases with increasing size.

Specific differences among these allied species are presented below.

	<i>O. mixta</i>	<i>O. marshallensis</i>	<i>O. stenozonula</i>
1. Conical granules along genital slits and base of oral shield.	+	+	-
2. Relative size of disc granules and spinules (Table 5).	largest	smallest	medium
3. Dental plate (with) or (without) complete upper interforaminal septum.	with	with	without (or very narrow)
4. Maximum modification of upper arm spine tip.	flattened, spatulate; rarely also bilobed	blunt point	bi- or tri-furcate
5. Relative number of segments bearing two tentacle scales at given size (Tables 4 and 6 and Devaney, 1974: 169, Table 4).	++	+++	+
6. Pigmentation	claret-red; fugaceous	dark midcentral line on upper arms; color fast	narrow dark band on distal end of upper arm plates; color fast
7. Distribution	East Indies, N. Australia (Barrier Reef), Central Pacific, Ryukyu and S. Japan	Central Pacific (Marshall Ids.)	South Pacific (Society Ids., Tuamotu Ids.)

Differences between *O. mixta* and *O. elegans*, the latter known only from the type specimen collected at Amboina in the East Indies, were given under the latter.

**HABITS AND HABITAT.** H. L. Clark (1921) reported *O. mixta* as fairly common in the dead portion of several coral genera at Mer (Torres Strait) on one section of the reef flat and also under rocks. In 1946 H. L. Clark also reported it from the reef flat at High Island in the Frankland group, Great Barrier Reef. Endean (1956: 126, 134) recorded *O. mixta* together with *O. asperula* from a particular habitat "amongst dead coral" at Low Island, Great Barrier Reef. Other shallow water records include Lyman's (1882) Fiji reefs, the intertidal areas at Palau and Amakusa Japan (Murakami 1943a, 1944). Additional shallow water reef collections are evidenced by some of the material from Enewetak herein.

Sublittoral records in the present material from various Pacific localities are from depths of 7.6 to 30 m from rubble or under rocks on sand. Koehler's (1922) small specimen—5 mm d.d.—from the Philippines was from a depth of 22 m.

*Ophiomastix ornata* Koehler

Fig. 23

*Ophiomastix ornata* Koehler, 1905: 71–72, Pl. VI, figs. 13–14; H. L. Clark, 1915: 296; 1921: 134 (in key), 138.

*Ophiomastix bispinosa* H. L. Clark: A. H. Clark, 1952: 296 (pt.).

**MATERIAL EXAMINED AND LOCALITIES**

**MARSHALL ISLANDS—Bikini Atoll:** (Reported as *Ophiomastix bispinosa* by A. H. Clark, 1952), 13 April 1946, Western half of lagoon, 25–30 fms (46–55 m), dredged, bottom coral and algae and algal sand, L. Schultz, Sta. no. S-46-93; 7 and 4.5 mm d.d. (2, USNM E7327).

**INDONESIA—Borneo:** (Type specimen), Siboga Expedition Sta. 81, 14 June 1899, Pulu [Ile] Sebang Katan, banc de Borneo, 19 fms (35 mm), coral and *Lithothamnion*, 9 mm d.d. (1, ZMA).

**DISCUSSION**

It was indeed fortunate to find two additional specimens from Bikini deposited in the National Museum of Natural History which can add information to this previously little known species. While the two specimens from Bikini are somewhat smaller than Koehler's type, the resemblance is remarkable and leaves no doubt as to their taxonomic position. Examination of the Siboga type specimen confirms this.

**SIZE.** Koehler's type of *O. ornata* has a disc diameter of 9 mm, but the arms are broken, having a maximum length of 21 mm from the disc edge. The longest attached arm of the 7 mm d.d. dry specimen from Bikini is 32 mm, the arm not broken too far from the tip. Thus an arm length: disc diameter ratio of 5:1 is reasonable. The arms of

the smaller 4.5 mm specimen are broken too close to the disc to make a comparison.

**DISC COVER.** The unique disc spinules are precisely as Koehler described and figured for all of the specimens. The compressed spindle-shaped ("fusiformes") elements with very small longitudinal grooves ("stries") have the narrower basal portion attached, and the distal portion broadened (Fig. 23a). These spinules are fairly widely separated and appear most distinctly on the upper side of the disc. On the lower side, the spinules diminish in size and number, becoming less fusiform and more evenly elongated. Here they occur only in the central part, leaving a portion of the disc bare out to the genital openings and oral shields. However, at the base of the oral shields there are a pair (rarely three or four) of sharply tapering granules (Fig. 23b). In both Bikini specimens, just beyond the oral shields, there is also a series of low genital papillae occurring along half the length of the genital slits (the Borneo type specimen was not examined for this character).

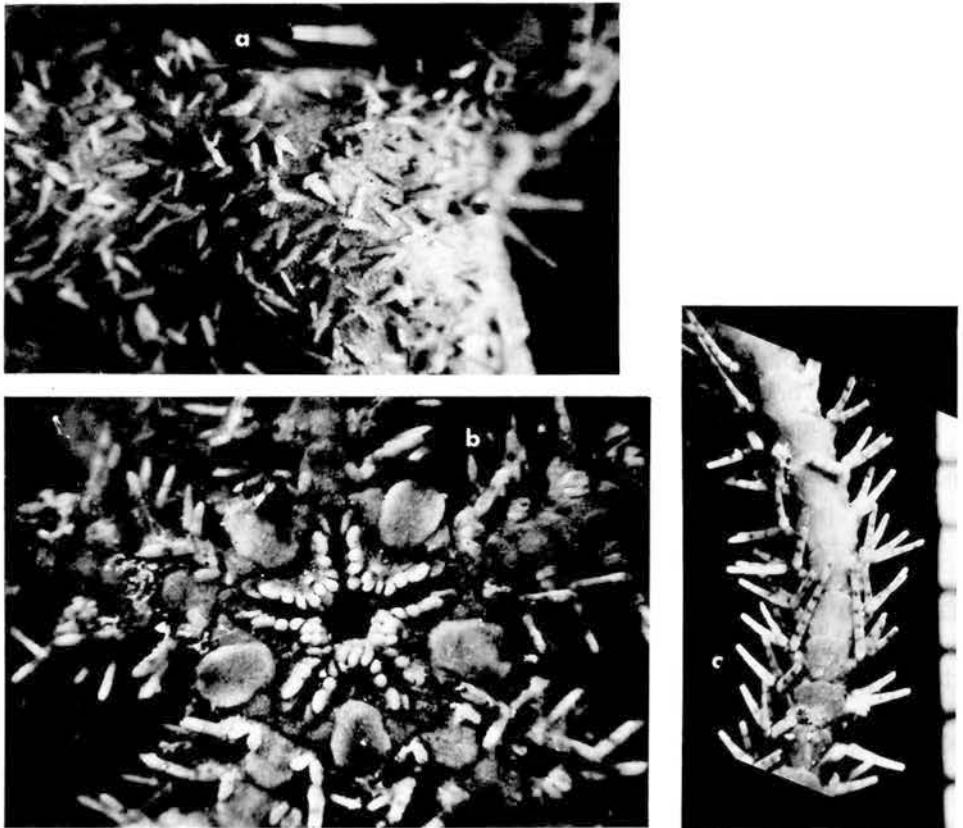


Fig. 23. *Ophiomastix ornata*, USNM E7327, Bikini, 7 mm d.d. (a) Upper side of disc with spindle-shaped spinules. (b) Mouth region and proximal arm segments. (c) Upper mid-arm sector showing arm spines.

TENTACLE SCALES. Koehler reported two tentacle scales on the proximal pairs of tentacle pores with a single large scale on segments beyond the disc edge. In Fig. 14 of Koehler's original description, two rays are shown with two scales out regularly to segment 5. The Bikini specimens show multiple (two) scales on the following segments as shown below:

d.d. (mm)	Segment Number									
	1	2	3	4	5	6	7	8	9	10
7	10	10	10	10	10	10	7	1	1	(number of sides)
4.5	10	10	8	4	3					

(all sides examined in both specimens)

ARM SPINES. The arm spines are very atypical of *Ophiomastix*, being slender, elongate, and tapering without any trace of terminal swelling or furcation (Fig. 23c). In contrast to Koehler's original description, I find nowhere that the upper spines are rather thick and cylindrical ("assez epais, cylindriques. . ."). Rather, these spines are quite slender and slightly compressed. Another significant point is that all the arm spines are distinctly hollow with a well defined lumen. In this respect and their fragile slender form they resemble the spines of *Ophiocoma pusilla* (Brock).

The sequence of arm spines was determined for the 7 mm Bikini specimen (Table 7).

Table 7. Arm spine sequence, *Ophiomastix ornata*.

Arm	Segment No.																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	3	3	3	3	4	4	4	3	4	3	4	3	4	3	4	3	3	4	3	4
	3	3	3	3	4	4	4	3	4	3	4	3	4	3	4	3	3	4	3	4
2	3	3	3	3	4	4	4	3	4	3	4	3	3	4	3	4	3	4	3	4
	3	3	3	3	4	4	3	4	3	4	3	4	3	4	3	4	3	3	4	3
3	3	3	3	3	3	4	3													
	3	3	3	3	3	4	4	4	3											
4	3	3	3	3	4	4														
	3	3	3	3	4	4	3	4												
5	3	3	3	3	3	4	3	4	3	4										
	3	3	3	3	3	4	3	4	3	4										

It is evident that a definite alternation in the number of spines occurs on segments beyond the disc. A fairly regular pattern of alternation occurs, with the same number of arm spines (three or four) on opposite sides of the same segment, only occasionally

three and four spines on opposite sides of the same segment. This results in the lateral sides of most upper arm plates being even (the lateral sides of arm plates on segments with four arm spines on each side are narrower, i.e., more truncated than those with only three spines on each side). The alternating three-four pattern was noted as far as segment 35 after which three spines occur distally. The poor condition of the smaller Bikini specimen precluded an accurate assessment of the spine sequence, however the alternating three-four pattern is evident out to segment 13 (of at least 34 segments where the tips are all broken).

#### DISCUSSION

Despite the absence of modified (enlarged or claviform) upper arm spines, two characters (the presence of disc spinules, unique in their shape, and the evident alternation of arm spines) support the contention that *Ophiomastix ornata* should be retained in that genus. However, the fragile nature of the arm spines, with a definite hollow interior rather than a more solid core, is peculiar to *O. ornata* and it is a feature shared by *Ophiocoma pusilla*, a member of the Pica group of *Ophiocoma* (Devaney, 1970). The fact that the arm spines alternate quite regularly from segment to segment (often three or four spines on each side of the same arm segment) rather than irregularly, suggests that this species is somewhat further removed from the Scolopendrina group of *Ophiocoma* than the other species of *Ophiomastix*. Until more material of *Ophiomastix ornata* is available, allowing examination of the internal skeletal features (dental and oral plates), it is best to defer further phylogenetic considerations of this species.

This species appears to be a relatively deep sublittoral form with a known depth range of 35 to 55 m and a habitat substratum preference of coral and coralline algae. While the type specimen is known from the southeast coast of Borneo in the Makassar Strait (2°13'S, 117°24'E) the other two specimens are from the central Pacific Marshall Island of Bikini, (11°31'N, 165°34'E); the distance between these locations is some 3400 miles (ca. 5470 km).

#### *Ophiomastix palaoensis* Murakami

Figs. 24-31

*Ophiomastix palaoensis* Murakami 1943a:199-200, figs. 17A-C (Palao, Caroline Islands, shallow); 1963:27, Pl. III, fig. 11 (dental plate), Pl. VII, figs. 23, 24 (oral plate); A. M. Clark and Rowe, 1971:86-87, 119 (in key).

*Ophiocoma wendti* Müller and Troschel: 1842. Koehler, 1907:327-328 (pt.).

*Ophiomastix bispinosa* H. L. Clark, 1932:207-208; A. H. Clark, 1952:296-297 (Bikini Lagoon all specimens except USNM E7327 which are redetermined as *Ophiomastix ornata* Koehler); Edean, 1957:245.

?*Ophiomastix asperula* Lütken: Burfield, 1924:153 (see p. 345 of the present report for details).

?*Ophiocoma parva* H. L. Clark: Domantay and Domantay, 1966:53-54.



## MATERIAL EXAMINED AND LOCALITIES

MARSHALL ISLANDS—**Bikini Atoll**: (Reported as *Ophiomastix bispinosa* by A. H. Clark, 1952), lagoon, 9–23 m; 6 to 13 mm d.d., dry, (6 USNM E7322, E7323, E7324, E7326, E7624). **Enewetak Atoll**: 3 September 1957, Rigili Islet, near red buoy, depth 7.6 m, R. Nishioka; 14 mm d.d. (1 EMBL collection). 28 August 1965, Enewetak Islet, lagoon side, on coral mound, depth 7.6 m, just off sunken destroyer, D. R. Stokes; 22 mm d.d. (1 BPBM W1728). 7 September 1966, Enewetak Islet, shallow sublittoral, M. J. Youngbluth; 21.5 mm d.d. (1 BPBM W1534).

AMERICAN SAMOA—**Tutuila**: 5 May 1974, cove on west side of Siufagatele Pt., under rock on sand, depth 23 m, D. M. Devaney; 18 mm d.d. (1 BPBM W2282). 5 May 1974, west side of Nuuosina Rock on west side of Fagasa Bay, depth 21 m under rock on sand, D. M. Devaney; 15 mm d.d. (1 BPBM W2283).

SOLOMON ISLANDS—**Guadalcanal**: 14 July 1973, 11 km west of Honiara, reef near wreck of Japanese ship, depth 34 m, J. E. Randall; 12.5 mm d.d. (1 BPBM W2257). **Malaita**: 25 July 1973, Alite reef, outer reef slope, depth 37 m, J. E. Randall; 16 mm d.d. (1 BMNH).

MOZAMBIQUE—**Fernando Velosa**: 20–25 m, H. Heurtel coll. 1886, R. Koehler, det. 1907 (MNHP specimen described by Koehler, 1907a as *Ophiocoma wendti* according to Dr. G. Cherbonnier); 13 mm d.d.

LOCALITY UNKNOWN—15 April 1950, from boat towed from unknown western Pacific area to dry dock in Pearl Harbor, Oahu, Hawaiian Islands, coll. by C. H. Edmondson; 10 to 21 mm d.d. (7 BPBM W1198).

## DISCUSSION

A good series of specimens has been available and the new material compares well with Murakami's (1943a) description but requires some comment regarding intraspecific variations together with new characterization. Unfortunately, none of Murakami's original specimens (18 reported) have been available and attempts to locate these at the Amakusa Marine Biological Laboratory (where they were reportedly deposited) and elsewhere has been unsuccessful. According to Dr. Kikuchi at Amakusa (pers. comm.), these and other species described by Murakami were probably destroyed in World War II.

SIZE. The largest specimen of *O. palaoensis* at my disposal has a disc diameter of 22 mm (BPBM W1728 from Enewetak). This is an unusual hexamerous specimen. Two other specimens also exceed 20 mm d.d. while Murakami (1943a) records a size of 16 mm. The smallest specimen examined with a disc diameter of 6 mm (USNM E7326) has all the arms broken. Arms, measured from the disc edge, are six to eight times the disc diameter in length.

DISC COVER. Murakami (1943a) stated that the disc was "covered with thick skin, which carries numerous fine spines. . .".

The specimens I have examined, above 7 mm d.d. in size, have short disc spinules forming a relatively dense uniform covering over the disc surface (Figs. 24a, 26a) and extending into the interradial region nearly to the oral shields (Figs. 24b, 26b). In contrast, the disc spinules of the 6 mm specimen from Bikini (USNM E7326) are fairly widely spaced and somewhat less uniform in length (Fig. 27a). A series of spinules were measured from this latter specimen and from a 14.5 mm specimen (BPBM W1198) to determine the limits of size (Table 8).

Table 8. Measurements of disc elements, *Ophiomastix palaoensis*.

USNM E7326 d.d. 6 mm ( $\mu\text{m}$ )		BPBM W1198 d.d. 14.5 mm ( $\mu\text{m}$ )	
length	breadth	length	breadth
$\bar{Y} = 358$	80	224	76
$W = 173-480$	58-115	113-330	60-100
$n = 5$		20	

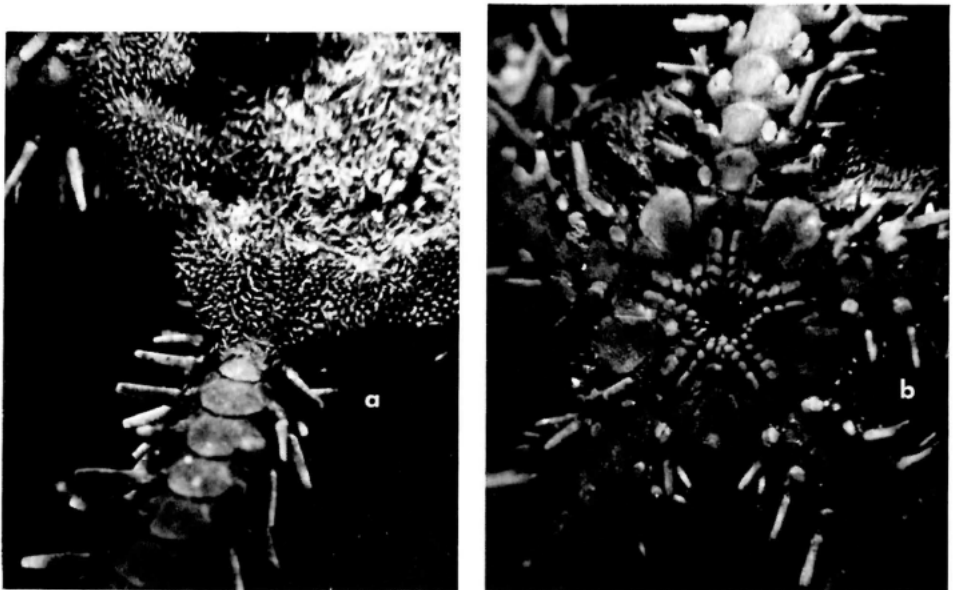


Fig. 24. *Ophiomastix palaoensis*, USNM E7324, Bikini, 8 mm d.d. (a) Upper side of disc and proximal arm sector. (b) Lower side of disc and proximal arm sector.

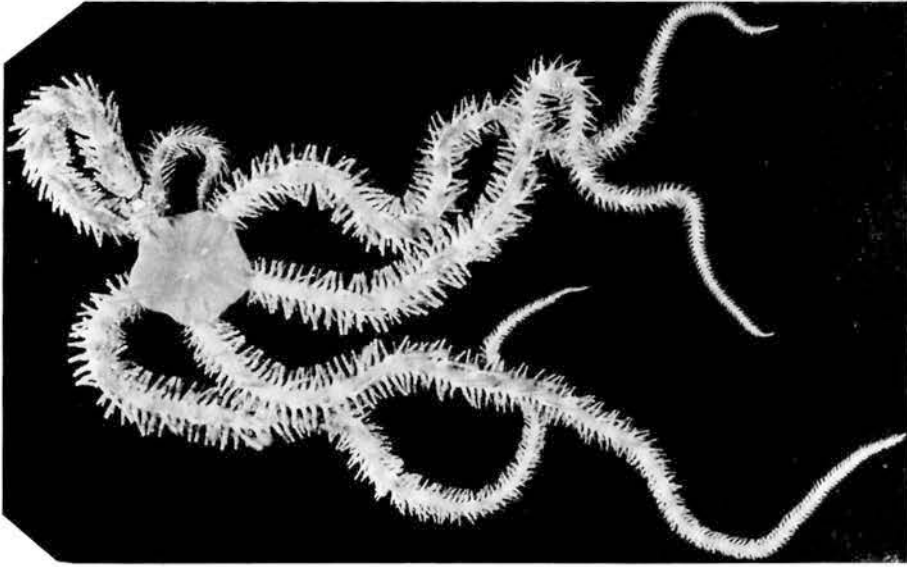


Fig. 25. *Ophiomastix palaoensis*, BPBM W2282, Am. Samoa, 18 mm d.d. Upper side.

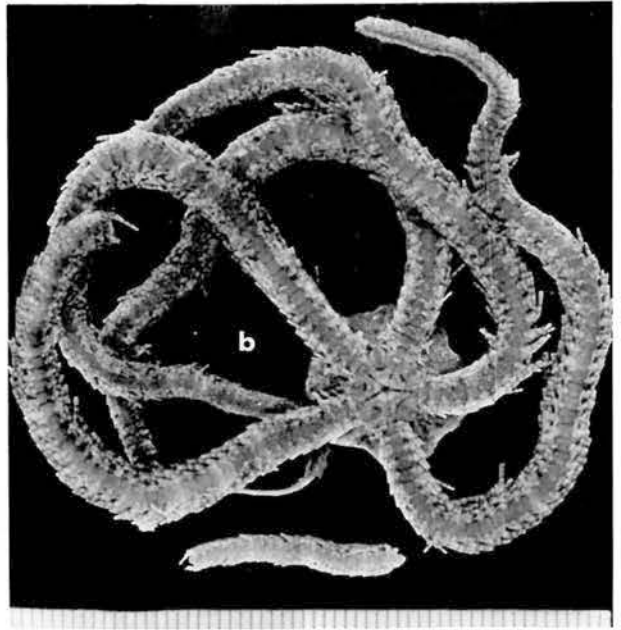
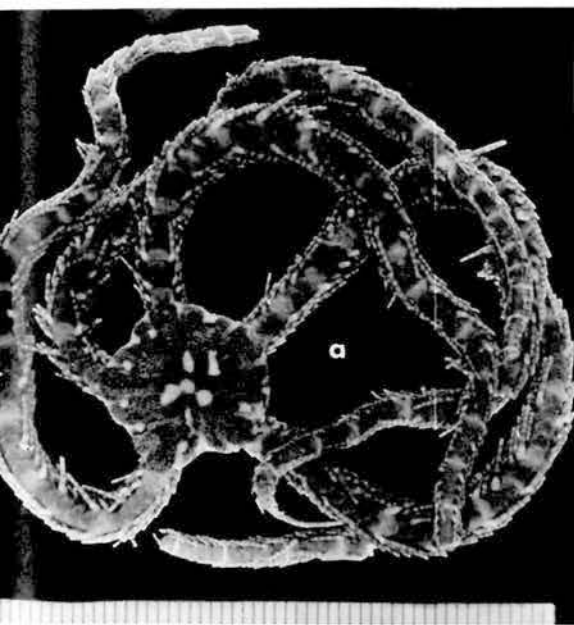


Fig. 26. *Ophiomastix palaoensis*, BMNH, Solomon Ids., 15 mm d.d. (a) Upper side. (b) Lower side.

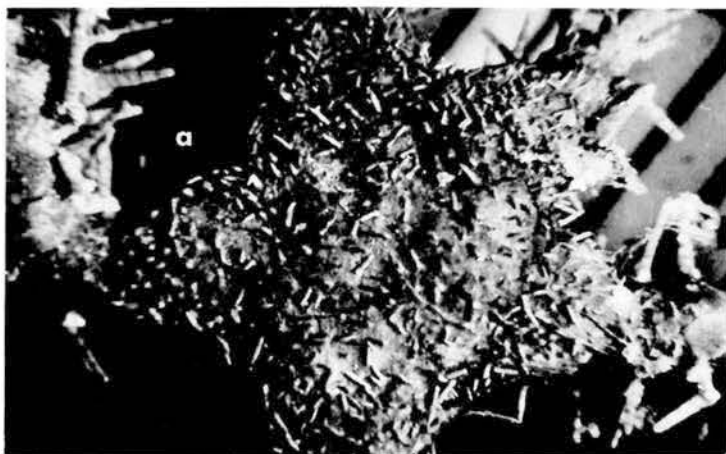


Fig. 27.



Fig. 28.

The spinules of the 6 mm specimen were three to four times longer than broad while those of the 14.5 mm specimen were two to three times longer than broad. The spinules in both cases were minutely serrated laterally as far as the bluntly pointed tip. In no example was there evidence of an acutely prolonged tip so characteristic of *Ophiomastix variabilis*.

In several specimens, pointed granules occur along the genital aperture beginning near the oral shields, becoming more widely spaced or disappearing farther along the aperture. This modifies Murakami's remark that spinules are absent near the genital slits and oral shields, since it is now apparent that there is individual variation in this feature which does not appear to be dependent on either size or location in my material. Also in some specimens a conspicuous pair of these pointed granules may occur on either side of the oral shield (Figs. 24b, 27b) and in one case two pairs were noted (Fig. 28).

Table 9. Number of sides of proximal segments bearing two tentacle scales, *Ophiomastix palaoensis*.

Specimen Number	Disc Diameter (mm)	Segment Number														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
E7326 (Bikini)	6	10	8	4	(number of sides)											
E7323 ( " )	9.5	10	10	10	6	4										
E7323 ( " )	10	7 <sup>a</sup>	10	10	6	4	4	3	1	3	2					
W1198 ( ? )	12	10	8	2												
MNHP (Mozambique)	13	10	2	0	1	1										
W1198 ( ? )	14.5	10	10	6												
W1198 ( " )	15	10	10	10	10	9	9	4	2	1						
WAM 346-77 (Torres Strait)	16	7	0	1 <sup>d</sup>												
<sup>b</sup> BMNH (Barrier Rf)	15	10														
W2283 (Samoa)	15	10	1													
W2247 (Solomon)	15	10	9	1												
W2282 (Samoa)	18	10	7	4	1	1										
W1198 ( ? )	21	10	10	8	1											
W1534 (Enewetak)	21.5	10	6	3												
<sup>c</sup> W1728 ( " )	22	12	12	12	12	12	11	11	9	7	3	7	7	3	2	4

<sup>a</sup> Three tentacle scales on the other three sides of segment one.

<sup>b</sup> Data from A. M. Clark; specimen as *O. bispinosa* reported by H. L. Clark (1932).

<sup>c</sup> Hexamerous specimen.

<sup>d</sup> Three tentacle scales on other side of segment three.

**TENTACLE SCALES.** Murakami (1943a) simply stated that the tentacle scales were "generally single, but sometimes two, large rounded." An examination of specimens at my disposal indicates the variable occurrence of two tentacle scales found only on the proximal segments. With the exception of one specimen, two scales are

Fig. 27. *Ophiomastix palaoensis*, USNM E7326, Bikini, 6 mm d.d. (a) Upper side. (b) Lower side.

Fig. 28. *Ophiomastix palaoensis*, BPBM W1534, Enewetak, 21.5 mm d.d. Mouth region and proximal arm sector.

restricted to the first ten segments. Segment one always was found bearing multiple scales, and in only one case was a single scale found on segments two and beyond. The data are presented in Table 9.

There appears to be no correlation between the number of segments having multiple scales and size of the specimen nor is there correlation in that number with specimens from the same locations or geographic regions. The Barrier Reef specimen (BMNH) with multiple scales limited to segment one is that reported by H. L. Clark (1932) as *Ophiomastix bispinosa*.

**ARM SPINES.** In his original description Murakami (1943a) stated that there were three and four arm spines on each side of the arm for *O. palaoensis*. A more critical examination of the new material suggests that more quantitative determinations may be made concerning the number of spines. The sequence of arm spines on the first five proximal segments is given in Table 10. It is quite obvious that the 33333 sequence of arm spines is most characteristic for *O. palaoensis* with only the 6 mm specimen from Bikini (USNM E7326) having a preponderance of two arm spines on these segments. The presence of four arm spines on the third to fifth segments while lacking in the four smaller specimens (6–10 mm d.d.), cannot be attributed to increased size as larger specimens also lacked four spines on these segments. Segments six to eight were nearly always found with four and/or three arm spines on each side; beyond segment eight, an irregular alternation of three and four spines occurs in specimens 10 mm or larger. Two, three, or four arm spines were also noted to alternate irregularly on a few segments in larger specimens. Specimens smaller than 10 mm sometimes reveal a two and three spine alternation. The alternation may be on opposite sides of the same segment or the same side of adjacent segments.

Five arm spines were noted on one side of the sixth and ninth segments in two separate specimens (10–12 mm d.d.) but the presence of five spines is considered exceptional.

The shape and size of the arm spines is of some importance. Murakami considered the majority of the spines as "about twice or more than twice as long as a joint, thick, cylindrical, and blunt at the tip; the uppermost spine of every two or three joints is exceedingly large, about three times as long as a joint, or even longer than that, forming a club-spine." My examination of the arm spines showed that it is only the upper fourth spine in the series which becomes greatly enlarged in thickness and length. This is the most evident from just beyond the disc edge to the middle of the arm. The shape of these enlarged spines (Figs. 29a, b; 30a, b) shows the swollen portion below the tip and some variation of the tip itself. It is usually blunt, either rounded and truncated or slightly expanded and compressed. In the latter case a depression along the midlateral side of the spine may be evident. No knobs or furcation of the tip have been noted. Epithelial thickening was evident on the tips of enlarged spines for the 18 mm specimen from Samoa, giving these spines a definite swollen appearance. A comparison of one of these spines from segment 27 and another from segment 24 which has been denuded of tissue is shown in Fig. 29b. The upper enlarged spines of the 6 mm specimen are somewhat elongated and thickened but only taper gradually to a blunt tip (Fig. 30c).

Table 10. Proximal arm spine sequence (segments 1 to 5), *Ophiomastix palaoensis*.

No. of Arm Spines										Location & Deposition	d.d. (mm)
22233	23232	23233	23323	23333	33333	33334	33343	33344	33434		
										Bikini, Marshall Islands USNM	
1	1	3	1	4						E7326	6
					8					E7624 <sup>a</sup>	8.5
					10					E7323	9.5
					8					E7323 <sup>b</sup>	10
					8	2				E7322	13
										Enewetak, Marshall Ids. BPBM	
					2	7	1			W1534	21.5
					4	5		1	1	W1728 <sup>c</sup>	22
										American Samoa BPBM	
					10					W2283	15
					10					W2282	18
										Solomon Ids. BPBM	
					10					W2257	15
										Great Barrier Reef BMNH <sup>d</sup>	13
					6					Mozambique MNHP	13
					10					Original Locality? BPBM	
						3		1		W1198 <sup>e</sup>	12
						4		1		W1198 <sup>f</sup>	21

<sup>a</sup> One ray with only four segments, 3333x.<sup>b</sup> One ray broken at base.<sup>c</sup> Hexamerous specimen, 5 1/2 rays examined.<sup>d</sup> Three rays examined by A. M. Clark.<sup>e</sup> Two rays examined.<sup>f</sup> Two and one-half rays examined.

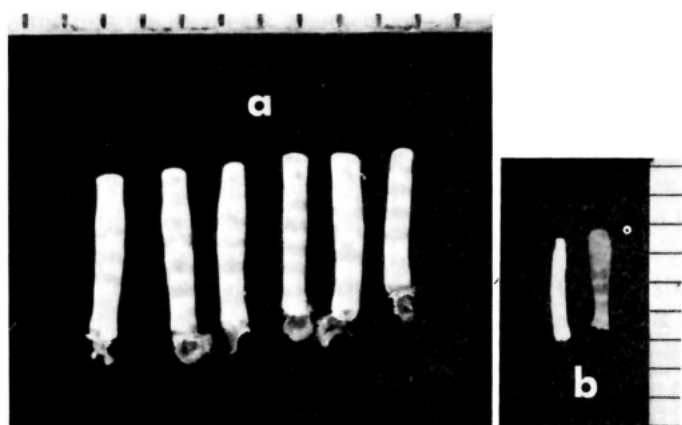


Fig. 29.

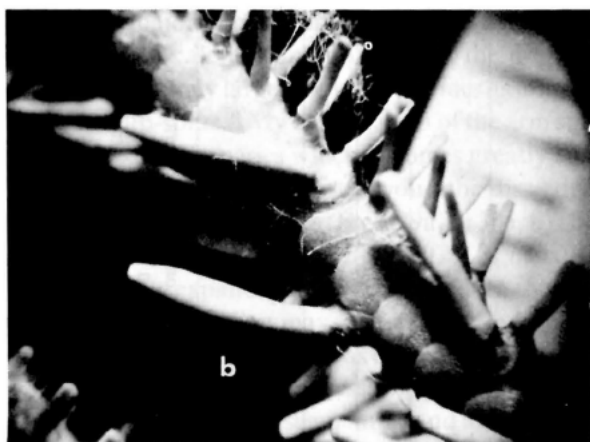
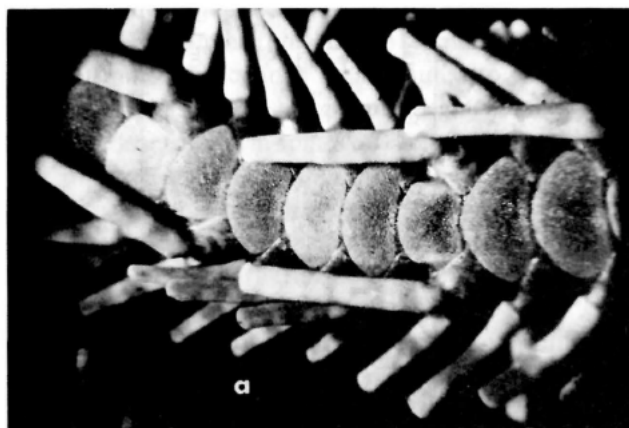


Fig. 30.



**PIGMENTATION.** The specimens examined generally have disc and disc spinules of a uniform brown color. The upper arm plates in most specimens have a characteristic alternation of color with a greater number of the plates of dark tan or brown and fewer plates of a light color. This is especially true of those plates well past the middle of the arm. Counts were taken of the number of dark and light colored segments for thirty consecutive segments from the midpart of arms from each of three specimens. Between 68 to 83 percent of the segments were found to be dark. Usually from one to six dark plates are separated by one or two light plates in irregular fashion (Figs. 25, 26a). The hexamerous specimen from Enewetak shows a much lower proportion of light colored plates than other specimens, and except for the distal portion of the arms, the banding of the arms is very indistinct. As Murakami (1943a) pointed out, the distal part of the arms are annulated with white lines which cover the proximal or middle part of a few widely spaced plates. All of the specimens examined have the arm spines distinctly annulated with brown and light tan or white.

A Solomon Island specimen and the two specimens from Samoa have irregular blotches of white near the center and interradian edges of the predominately brown disc (Figs. 25, 26a). This, together with distinct white portions of single spaced plates distally on the Solomon Island specimen, reminds one of the pigmentation noted in *Ophiomastix variabilis*, except in the latter species the arm annulations begin much closer to the disc.

**RELATIONSHIPS.** Murakami (1943a) considered *Ophiomastix palaoensis* "very near *O. variabilis* Koehler" but differing from that species by having more disc spines, a uniform coloration of the disc without peripheral white markings, arm striations limited to distal parts of the arm, and a larger body size. I agree with Murakami in considering *O. palaoensis* and *O. variabilis* closely allied. However, the new material available makes it possible to present additional criteria by which the two species can be distinguished.

*O. palaoensis*

1. Disc spinules typically short and closely packed, tapering to a blunt point, with minute serrations along edges out to the tip.
2. Upper modified arm spines elongate, 3-4 segments long, thickened below a tip which is either

*O. variabilis*

1. Disc spinules generally longer, often distinctly separated, basal portion cylindrical, only at tip tapering acutely into slender point (Figs. 34a, 38a).
2. Upper modified arm spines usually relatively short, seldom more than two segments long, more or less

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Fig. 29. *Ophiomastix palaoensis*. a) BPBM, Enewetak, from 20 mm specimen. Enlarged upper arm spines. b) BPBM W2282, Am. Samoa, from 18 mm specimen. Enlarged upper denuded spine from segment 24 (left) and spine with epithelium from segment 27 (right).

Fig. 30. *Ophiomastix palaoensis*. a) BPBM W1534, Enewetak, 21.5 mm d.d. Portion of upper arm sector. b) MNHP, Fernando Velosa, 14 mm d.d. Portion of upper arm sector. c) USNM E7326, Bikini, 6 mm d.d. Portion of upper arm sector.

- |  |  |
|--|--|
| <p>truncated or slightly expanded and compressed (Figs. 29a, 30a, b).</p> <p>3. Typical sequence of arm spines on segments one through five is 3-3-3-3-3 (Table 10).</p> <p>4. Multiple (usually two) tentacle scales usually present on segments one through three, often on a few other proximal segments (Table 9).</p> <p>5. Maximum size, 22 mm disc diameter.</p> <p>6. Ground color of disc is generally brown without any lighter color; narrow bands of white (if present) only on distal part of arms; arm spines, including often upper modified, are banded light and dark (Figs. 26a, 29b, 31).</p> <p>7. Body epithelium not well developed enough to obscure oral and adoral shields.</p> | <p>cigar-shaped with a rather rounded tip (Figs. 34c, 40a).</p> <p>3. A sequence of 3-3-3-3-3 is uncommon; presence of two arm spines on the first two segments is typical (Table 11).</p> <p>4. Multiple scales typically limited to segment one (Table 12).</p> <p>5. Maximum size not exceeding 15 mm disc diameter.</p> <p>6. Ground color of disc dark brown to black often with some pattern of lighter color; narrow bands of white begin on segments close to disc; arm spines may be spotted, not typically banded, especially upper modified (Figs. 34a, c; 40a).</p> <p>7. Body epithelium often thick enough to obscure outlines of oral and adoral shields.</p> |
|--|--|

According to A. M. Clark (pers. comm.), after comparison with a specimen of *O. palaoensis* sent to her, the specimen reported as *O. bispinosa* by H. L. Clark (1932) from the Barrier Reef, Australia, is better considered as *O. palaoensis* although as shown in Table 9, the lack of two tentacle scales beyond the basal segment is unique.

Domantay and Domantay (1966) reported an 8 mm d.d. ophiuroid as *Ophiocoma parva* collected at Jolo, Sulu Archipelago in the southern Philippines. The description of this specimen, having three to four slightly banded arm spines is quite unlike *O. parva* (= *Ophiocomella sexradiata*) known through previous descriptions (H. L. Clark, 1915, 1921; Devaney, 1970; A. M. Clark and Rowe, 1971). During the summer of 1968, Professor Jose Domantay informed me that the above specimen and several others from his 1966 publication could not be located. They were apparently misplaced. Later that year Mr. A. Geronimo, one of Prof. Domantay's assistants, found and sent a photograph said to have been of *Ophiocoma parva*. The figure shows an *Ophiomastix*-like ophiuroid with a strong resemblance to *O. palaoensis* which could be seen in the shape and color of the arm spines and in the narrow banding of the distal portion of the arms (Fig. 31). The patches of light coloring on the disc recalls a similar condition noted most evidently on a Solomon Islands specimen (Fig. 26a). However, Domantay and Domantay (1966:53) stated that the Jolo specimen of *Ophiocoma parva* was "homogenous dark brown" in disagreement with the photographed specimen. Regardless of this, it appears that *Ophiomastix palaoensis* does occur in the southern Philippines, if the specimen photographed is truly from that region.

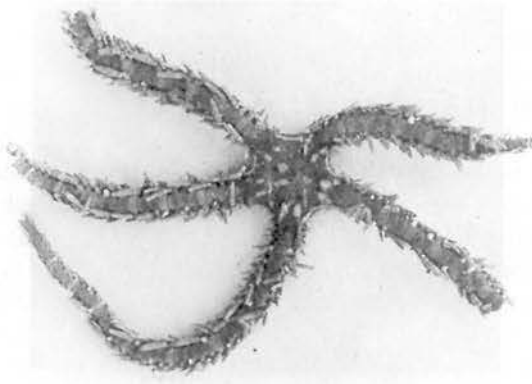


Fig. 31. *Ophiomastix palaoensis*, Philippine specimen (Courtesy of A. Geronimo).

**HABITAT AND DISTRIBUTION.** *Ophiomastix palaoensis* is known from several western Pacific localities, the Great Barrier Reef (H. L. Clark, 1932), and off Mozambique in the western Indian Ocean. Specimens have been recovered from the shallow sublittoral to a depth of 37 m. At Samoa, the specimens were found under rocks on sand. H. L. Clark's (1932) Barrier Reef specimen was taken at a depth of 35 m with shell, gravel and an abundance of *Halimeda*.

***Ophiomastix stenozonula* Devaney**

Figs. 32, 33

*Ophiomastix* n. sp. Devaney, 1973:359, 361, 362 (distribution S. E. Polynesia).

*Ophiomastix stenozonula* Devaney 1974:164-171, figs. 15-20.

**MATERIAL EXAMINED AND LOCALITIES**

**TUAMOTU ARCHIPELAGO—Anaa Atoll:** 27 Oct. 1967, northeastern side of the northeast point, in coral rubble at base of vertical shelf, depth 18-21 m, D. M. Devaney; 11 mm d.d. (Holotype BPBM W1906). Under loose live coral head; 4.5 mm d.d. (Paratype USNM).

**SOCIETY ISLANDS—Tahiti:** 4 Sept. 1967, outside Passe de Teavaroa, in *Pocillopora* coral, depth 21-27 m, D. M. Devaney; 4 mm d.d. (Paratype WAM). 12 Sept. 1967, off Passe de Teavaroa, southeast side in coral and coral rubble, depth 12-15 m, C. Walters and J. E. Randall; 12.5 mm d.d. (Paratype BPBM W1907). 1 Nov. 1967, east of Passe de Teavaroa at outer fringe of reef, from live head of purplish blue coral, depth 1-5 m, D. M. Devaney; 3.5 mm d.d. (Paratype BPBM W1908). **Huahini:** 19 Mar. 1971, off Passe Avamoa, north of Pte, Teffaa, in branches of dead *Pocillopora* coral, depth 21-24 m. D. M. Devaney; 7 mm d.d. (Paratype BPBM W1909).

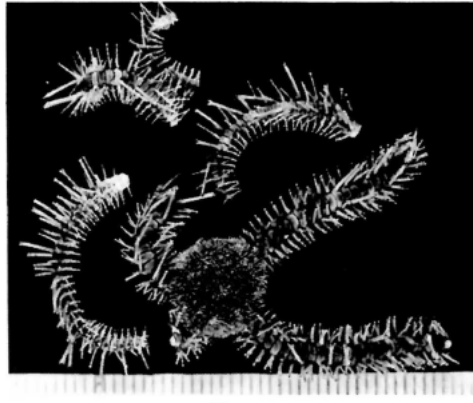


Fig. 32.

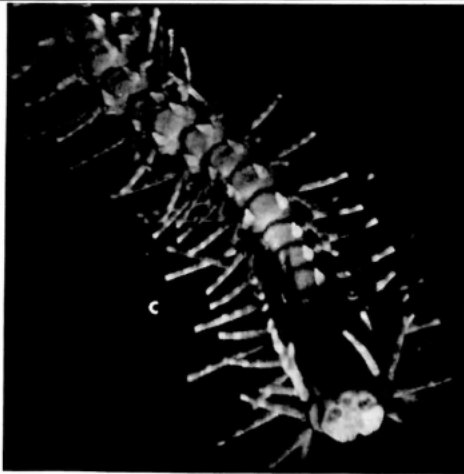
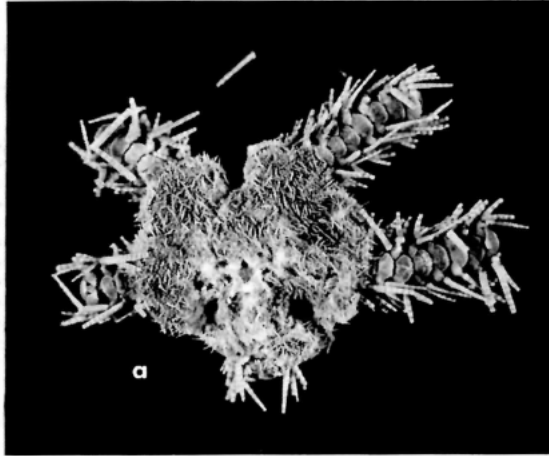


Fig. 33.



## DISCUSSION

*Ophiomastix stenozoneula* has already been compared with two species with which it is most closely allied, *O. marshallensis* and *O. mixta* (see Table 5 and p. 317). A third species, *O. elegans*, appears related to *O. stenozoneula* and the other two species in having both granules and spinules as disc elements. Comparing *O. stenozoneula* with *O. elegans* we must take into account that the largest specimen of the former is only 12.5 mm while the description of the latter was based upon a 16 mm specimen.

**DISC COVER.** *O. stenozoneula* has been found with more spinules as compared to granules than has *O. elegans* (but this may be to some degree a reflection of the difference in size). The size of the granules and longest spinule was measured for the largest specimen of *O. stenozoneula* (Table 5, p. 318).

**ARM SPINES.** Modified upper spines, beginning from the fourth through the twenty-third free segment beyond the disc, have been found on the holotype of *O. stenozoneula*, but such modified spines are not evident on the 12.5 mm paratype or smaller specimens. For *O. elegans* (according to Brock), modified spines occur on segments 19 to 22 but only on two of the arms. Both species have the upper modified spines five to six segments in length.

**PIGMENTATION.** *O. stenozoneula* has a narrow dark brown band on the very distal edge of the upper arm plates, a feature that has not been found on *O. elegans*.

*Ophiomastix stenozoneula* seems to be an easily recognizable species known thus far from only a portion of southeastern Polynesia. Based on collection data, it is associated with coral reefs in rubble as well as live or dead coral in the shallow sublittoral to about 30 m.

***Ophiomastix variabilis* Koehler**

Figs. 34–40

*Ophiomastix variabilis* Koehler, 1905:69–71, Pl. VI, fig. 16, Pl. XVI, figs. 3–4; 1930:202–203 (Indonesia, Kei Ids.); H. L. Clark, 1915:296; 1921:134 (in key), 138; Murakami, 1943a:165 (intertidal zone, Palau) 201; 1963:27, Pl. III, fig. 12 (dental plate), 30, Pl. VII, figs. 21–22 (oral plate); A. M. Clark and Rowe, 1971:86–87 (distribution), 121 (in key with notes); Devaney, 1973:359, 361, 363 (distribution, S. E. Polynesia); 1974, 114 (in key), 171–174 (review and variations); A. M. Clark and Courtman-Stock, 1976, pp. 105, 122, 176 (diagnosis), Fig. 192 (side view of arm segments).

*Ophiomastix bispinosa* H. L. Clark, 1917:442–443, Pl. II, figs. 1–2; 1921:134 (in key), 138; 1946:250; Murakami, 1943a:165, 197–198; Endean, 1957:245; A. M. Clark and Rowe, 1971:86–87 (distribution), 120–121 (in key with notes), figs. 39a–d (of holotype); McKnight, 1972:38; A. H. Clark, 1954:261.

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Fig. 32. *Ophiomastix stenozoneula*, BPBM W1906, Anaa, 11 mm d.d. Holotype. Upper side with lateral views of broken arms.

Fig. 33. *Ophiomastix stenozoneula* BPBM W1907, Tahiti, 12.5 mm d.d. Paratype. (a) Upper side. (b) Mouth region. (c) Lower surface of broken arm. (d) Dental plate.

- non *Ophiomastix bispinosa* A. H. Clark, 1952:296–297 (reexamined: USNM E7327, two specimens are *Ophiomastix ornata*, all other specimens are *O. palaoensis*); H. L. Clark, 1932:207 (= *Ophiomastix palaoensis*).
- Ophiomastix notabilis* H. L. Clark, 1938:337–338, fig. 27; 1946:248 (in key), 250; A. H. Clark, 1954:261; Balinsky, 1957:25 (in key), 27; A. M. Clark and Rowe, 1971:120 (considered synonym of *O. bispinosa*), figs. 54a–c (mouth region of holotype).
- Ophiomastix asperula* Lütken: Döderlein, 1896:290, Pl. XV, figs. 9a–b.

#### MATERIAL EXAMINED AND LOCALITIES

- INDIAN OCEAN—**Madagascar**: 22 Oct. 1964, NW coast, cont. shelf between Nosy Be and Banc du Geysier, depth 44 m, IIOE Anton Bruun Cruise 8 Sta. 412D; 9 mm d.d. (1 BPBM). **Mauritius**: 3 Nov. 1973, lagoon side of Flamand Islet, depth 7–18 m, J. E. Randall; 10 mm d.d. (1 BPBM).
- AUSTRALIA—**Western Australia**: 20–22 Aug. 1929, Cape Leveque (16°24'S, 122°56'E), within coral colony, H. L. Clark (Type, *Ophiomastix notabilis*; 13 mm d.d. (MCZ 5247).
- INDONESIA—**Timor**: 27–28 Apr. 1899, Haingsisi, Samau Island, reefs, depth 23 m, Siboga Sta. 60; 7.5 mm d.d. (1 ZMA Paralectotype *Ophiomastix variabilis*). **Tawi—Tawi Islands**: 24–25 June 1899, Sulu Archipelao, Pulu Sanguisiapo, *Lithothamnion*, sand and coral, depth 12 m, Siboga Sta. 93; 5.5 mm d.d. (1 ZMA Lectotype *O. variabilis*). **Banda**: Nov. 22–Dec. 1, 1899, no further details; between 5 and 8 mm d.d. (disc distorted) (1 ZMA Paralectotype *O. variabilis*).
- MARIANA ISLANDS—**Saipan**: 13 May 1949, lagoon west of island, P. E. Cloud, Jr.; 5 mm d.d. (1 USNM E7809).
- MARSHALL ISLANDS—**Enewetak Atoll**: 11 Dec. 1976, probably leeward side of atoll, seaward drop-off Biken Islet (specimen found on seawater table with corals soaked overnight); 9 mm d.d. (1 MPML with one arm at BPBM).
- GILBERT ISLANDS—**Onotoa Atoll**: 10 Aug. 1951, ca. 2.6 km N. 18°W. from Tabuarorae Maneaba, depth 5 m at low tide, P. E. Cloud, Jr., Sta. G.O.C.-35; 3 mm d.d. (1 USNM E8560). 23 Aug. 1951, ca. 5.2 km N. 31°W. from Tabuarorae Maneaba near center of Te Rawa ni Bao pass in south part of leeward reef, collected from thickly set coral masses rising from 4.6 m depth to within 2.4–3 m of surface at low tide, P. E. Cloud, Jr., Sta. G.O.C.-51; 6 and 6.5 mm d.d. (2 USNM E8559). July 1951, extensive shallow sand flats near shore, A. H. Banner, Sta. B-1; 8.5 mm d.d. (1 USNM E8074). Reported as *Ophiomastix bispinosa* by A. H. Clark (1954) but catalogued as *O. notabilis* in USNM collection.
- COOK ISLANDS—**Aitutaki**: 8 Mar. 1971, south of Arutanga Passage directly off wreck of ALEXANDER, seaward side, 20–23 m depth, coral and boulder rubble, D. M. Devaney; 7 mm d.d. (1 BPBM).

SOCIETY ISLANDS—**Tahiti**: 23 Mar. 1971, Hitiaa, seaward edge, coral reef, depth 4.6–11 m, D. M. Devaney; 4 mm d.d. (1 BPBM).

TUAMOTU ARCHIPELAGO—**Makemo Atoll**: 19 Oct. 1899, "Albatross" station, no further data; 5 mm d.d. (1 USNM E694 Type, *Ophiomastix bispinosa*).

RAPAN AND AUSTRAL ISLANDS—**Rapa**: 16 Feb. 1971, south point of island, SW side of Karapoo Iti, in limestone crevice against lava boulder, depth 15–18 m, D. M. Devaney; 7.5 mm d.d. (1 BPBM). **Raivavae**: 25 Feb. 1971, southeast of Passe Tearoa, directly off Motu Haha, in attached live or dead coral, depth 30–32 m, D. M. Devaney; 5 mm d.d. (1 BPBM). **Ilot de Bass**: 20 Feb. 1971, WNW side of southeastern Ilot, from base of attached coral head in crevice, depth 6–11 m, D. M. Devaney; (1 BPBM).

#### DISCUSSION

Details regarding characteristics of *Ophiomastix variabilis* based on essentially the same material listed above with the exception of the specimens from Mauritius and Madagascar was presented recently (Devaney, 1974). Only information not set forth in that publication is presented below together with several illustrations of type specimens or comparative examples.

SIZE. Notification by A. M. Clark that H. L. Clark's (1932) specimen of *Ophiomastix bispinosa* from the Great Barrier Reef, Australia, is in fact an example of *O. palaoensis* reduces the maximum recorded size of *O. variabilis* from 15 mm to 14 mm, based on Balinsky's (1957) Mosambique specimen. An arm length of seven to ten times the disc diameter has been noted.

TENTACLE SCALES. Two tentacle scales sometimes occur on segment one but have not been observed further out on the arm (Table 11).

Table 11. Number of sides of first proximal segment bearing two tentacle scales, *Ophiomastix variabilis*. Segments two through five have no tentacle scales.

Location	Disc Diameter (mm)	Number of Sides Bearing Two Tentacle Scales
Gilbert Ids.	3	0
" "	6	1
" "	6.5	0
" "	8.5	1
Tawi-Tawi Ids.	5.5	1
Banda	5–8	7 to 9
Timor	7.5	9 to 10
Kei Islands (Koehler, 1930)	11.5	1
Macclesfield Bank	10	1
Mosambique <sup>a</sup>	14	0

<sup>a</sup> Data from Dr. Balinsky, the specimen was from Inhaca Island.

Table 12. Proximal arm spine sequence (segments 1 to 5), *Ophiomastix variabilis*.

No. of Arm Spines														Location	d.d. (mm)					
12332	22222	22223	2222x	22232	22233	2223x	22322	22323	22332	22333	23232	23323	23333	23334	33233	332xx	33333	333xx		
				5				5											INDIAN OCEAN	
																			Mosambique <sup>a</sup>	14
																			Madagascar	9
	6				1		1	1	1										RED SEA	
																			Sudan <sup>b</sup>	10
				3				2											SOUTH CHINA SEA	
																			Macclesfield Bank <sup>b</sup>	10
														1					W. AUSTRALIA	
																			Cape Leveque	13
				1				2			1								INDONESIA	
																2	2	1	Tawi-Tawi Ids.	5.5
																			Banda	5-8
																			Timor	7.5
																			CENTRAL PACIFIC	
			1		2	1			1										Mariana Ids.	5
					1								3						Gilbert Ids.	3
														1					" "	6
					1			3					3						" "	6.5
					1		1	1	1	1									" "	8.5
																			S. E. POLYNESIA	
1				1	3		1	2	2										Aitutaki	5
				3	3			1	4										Tahiti	4
	1								4					2					Makemo	5
					1				2										Raivavae	5
									1										Ilots de Bass	ca. 6
				2	1			4	1										Rapa	6.5

<sup>a</sup> Data from Dr. Balinsky on specimen from Inhaca Island; sequence is said to vary between 22233 and 22333.<sup>b</sup> Data from A. M. Clark, BMNH.



**ARM SPINES.** The proximal arm spine sequence for nineteen specimens is given in Table 12. It is evident that with the exception of two Indonesian specimens and one from Sudan, the majority of sequences for the proximal five segments falls between 22232 and 22333.

**HABITAT AND DISTRIBUTION.** Records of *O. variabilis* are from littoral and sublittoral habitats to a depth of 60 m (Koehler, 1930). Field observations show that this species inhabits crevices well back into solid limestone or attached coral (Devaney, 1974). The species is widespread throughout the Indo-West Pacific region. I include new records from Mauritius and northern Madagascar, and I recently examined a specimen deposited in WAM from the Solomon Islands.

A. M. Clark (A. M. Clark and Rowe, 1971: 120) mentions that the color pattern of the specimens reported by Döderlein (1896) from Amboina, and by Burfield (1924) from the Sudanese Red Sea as *Ophiomastix asperula* recalled a similar pigmentation known for *O. bispinosa* and *O. notabilis*. Data supplied by A. M. Clark on Burfield's specimen in the BMNH suggests that it has atypical features for *O. variabilis*. First, there is an arm spine sequence of 22222 on six sides of the first five proximal segments which is not characteristic of *O. variabilis* (see Table 12). Second, the first four proximal segments carry two tentacle scales on five sides of segment 1; eight sides of segment 2; seven sides of segment 3; and four sides of segment 4, unlike the condition known for *O. variabilis* where only the first segment sometimes has two scales. This latter character is more typical of another related species, *O. palaoensis*.

Döderlein's figure of *O. asperula* from Amboina and his mention that it lacked two tentacle scales on any segments suggest that it may indeed be a specimen of *O. variabilis*.

A reexamination of the 9 mm specimen reported by Koehler (1905) under his description of *O. variabilis* taken from Siboga Station 273 (near Aru Islands, 12 m depth) reveals it to be quite obviously an example of *Ophiarthrum*, cf. *O. elegans*, and the lack of disc elements as noted by Koehler is typical of that genus. In contrast to Koehler, I did not find two tentacle scales on any sides of the basal segment.

**LECTOTYPE DESIGNATION.** Koehler (1905) failed to designate a Holotype when he described *Ophiomastix variabilis*. His illustrations are rather diagrammatic and show the upper side of the rather atypical specimen from the Timor area (Pl. XVI, fig. 3) as well as the upper disc and basal arm segments (Pl. XVI, fig. 4) and lower disc portion (Pl. VI, fig. 16) of unspecified specimens. The specimen from Siboga Sta. 322 was said to be missing when I requested and received the other type specimens of *O. variabilis* from ZMA.

The specimen from Siboga Station 93 appears to be the more representative specimen from the type series, showing an intermediate degree of disc spination (Fig. 34a) and quite typical arm spine development (Fig. 34c). A photo of the oral region is also given (Fig. 34b) of this specimen which is herein designated as the Lectotype of *Ophiomastix variabilis*. The specimens from Banda and Siboga Station 60 are considered Paralectotypes.

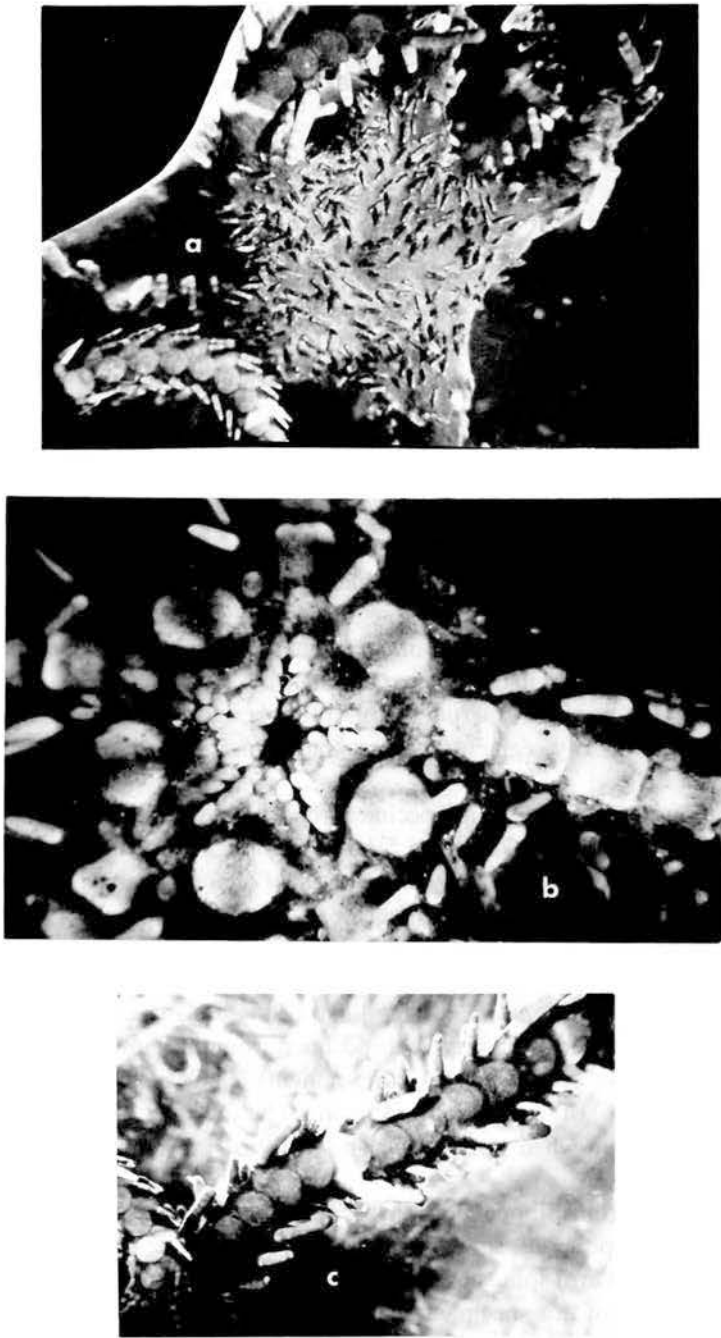


Fig. 34. *Ophiomastix variabilis*, ZMA Siboga Sta. 93, Lectotype, Indonesia, 5.5 mm d.d. (a) Upper side of disc. (b) Mouth region. (c) Portion of upper arm.



Fig. 35. *Ophiomastix variabilis*, ZMA Siboga Sta. 60, Paralectotype, Indonesia, 7.5 mm d.d. (a) Upper side of disc. (b) Mouth region.

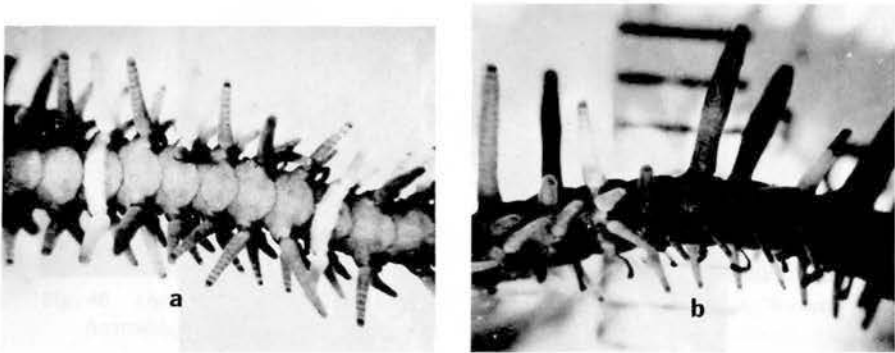


Fig. 36. *Ophiomastix variabilis*, ZMA, Siboga Sta. 60.- (a) Portion of upper arm. (b) Lateral view of arm and spines.



Fig. 37. *Ophiomastix variabilis*, ZMA Siboga Sta. "Banda," Paralectotype, ca. 18 mm d.d. Upper side of disc.

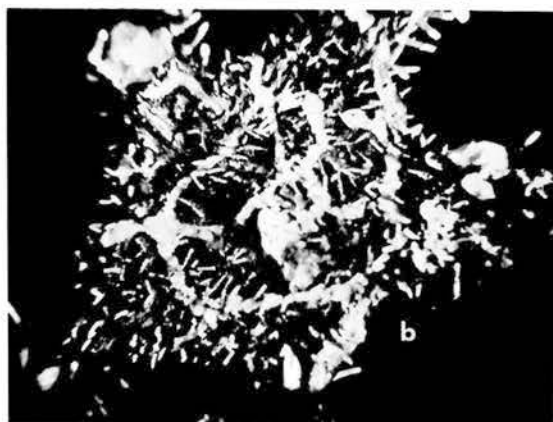


Fig. 38. *Ophiomastix variabilis*. (a) USNM E8574, Gilbert Ids., 3 mm d.d. Upper side of disc. (b) USNM E8074, Gilbert Ids., 8.5 mm d.d. Upper side of disc.

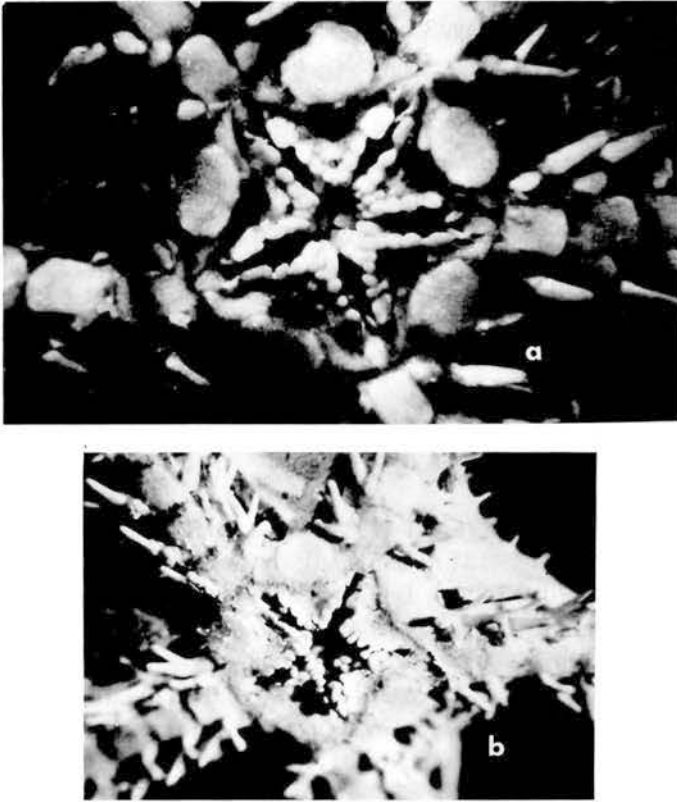


Fig. 39. *Ophiomastix variabilis*. (a) USNM E8559, Gilbert Ids., 6 mm d.d. Mouth region. (b) USNM E694, Type *Ophiomastix bispinosa*, Makemo, 5 mm d.d. Mouth region and proximal arm segments.

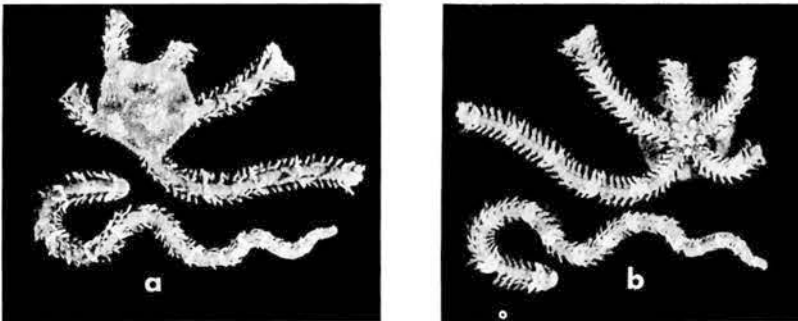


Fig. 40. *Ophiomastix variabilis*, MCZ 5247, Type *Ophiomastix notabilis*, Western Australia, 13 mm d.d. (a) Upper side. (b) Lower side.

Photographs of the unusual specimen from Station 60 are given showing the upper disc surface elements (Fig. 35a), upper surface of a portion of a separated arm (Fig. 36a), oral region of the disc (Fig. 35b), and lateral view of the arm spines (Fig. 36b) which Koehler described as “. . . deviennent nettement claviformes à partir du douzième article: on observe en général quatre de ces piquants claviformes de chaque côté sur chaque bras et se montrent de trois en trois articles.” The size of these spines is certainly greater than usual for *O. variabilis* although Balinsky (1957) reported his East African specimen to have very definite club-shaped spines two to three arm segments in length. In a photograph taken of the Banda specimen (Fig. 37), a single large light colored disc spinule, similar to those so conspicuous in the center of the disc of the Siboga Station 60 specimen, is seen among the more common shorter spinules covering the discs.

*Ophiomastix venosa* Peters

Figs. 41, 42

- Ophiomastix venosa* Peters, 1851:464; 1852:83; Lyman, 1865:92 (MCZ specimens, Zanzibar); Lütken, 1869:41 (disc naked); Brock, 1888:502–503 (nature of upper arm spines), 506 (disc cover); Ludwig, 1899:548–549 (Zanzibar, nature of disc scales); Koehler, 1904b:73–74, figs. 28–29 (oral plates, claviform spines, tentacle scales, size); 1907:329 (Madagascar, Zanzibar); McIntosh, 1910:161–162 (Mergui Archipelago); H. L. Clark, 1915:296; 1921:134 (in key), 138; 1923:349 (Mosambique); Balinsky, 1957:27–28 (habitat Mosambique, disc cover, size, arm spines, color); A. M. Clark and Rowe, 1971:88–89, 91 (distribution, new records: Aldabra, Rodrigues), 120 (in key, color, upper arm spines, disc cover, tentacle scales). A. M. Clark and Courtman-Stock, 1976:105, 122, 176 (diagnosis), Fig. 191 (upper side of arm segments with modified spines).
- non *Ophiomastix venosa*: Bell, 1902:229 (= *Ophiomastix annulosa* according to A. M. Clark in, A. M. Clark and Spencer Davies, 1965:599; Koehler, 1922:331 (= *Ophiarthrum pictum*, Philippines).

MATERIAL EXAMINED AND LOCALITIES

EAST AFRICA—**Mozambique**: no details, received from J. B. Balinsky; 21 mm d.d. (1 BPBM W1586). **Zanzibar**: Cooke collection, no further details; 22 and 26 mm d.d. (2 MCZ #1805).

DISCUSSION

*Ophiomastix venosa*, by being the only member of the genus known to lack disc elements with some consistency (*O. flaccida* rarely has the disc devoid of any spinules), reflects a character reserved for *Ophiarthrum* among the Ophiocominae. It seems reasonable to look at *O. venosa* in terms of *Ophiomastix*- and *Ophiarthrum*-like characters as well as its own specific limits.

**SIZE.** *Ophiomastix venosa* reaches a considerable disc diameter relative to other members of the genus. A size of 35 mm has been reported and specimens over 20 mm are common. The arms, while rather stout, appear to be only about five times the disc diameter in length.

**DISC COVER.** A few widely scattered spinules may be distributed over the disc of *O. venosa* in an irregular arrangement (Fig. 41a). Several instances of no disc elements have been reported (Lütken, 1869; Brock, 1888; Koehler, 1904a; H. L. Clark, 1923; Balinsky, 1957) and this is evident for the BPBM specimen. The MCZ specimen (No. 1805, 26 mm d.d.) has only two nubby spines along the midperipheral upper side of the disc and McIntosh (1910) recorded his from the Mergui Archipelago with several stout blunt spines. A fairly noticeable epithelium covers the disc masking any scales much as one finds for *Ophiarthrum*.

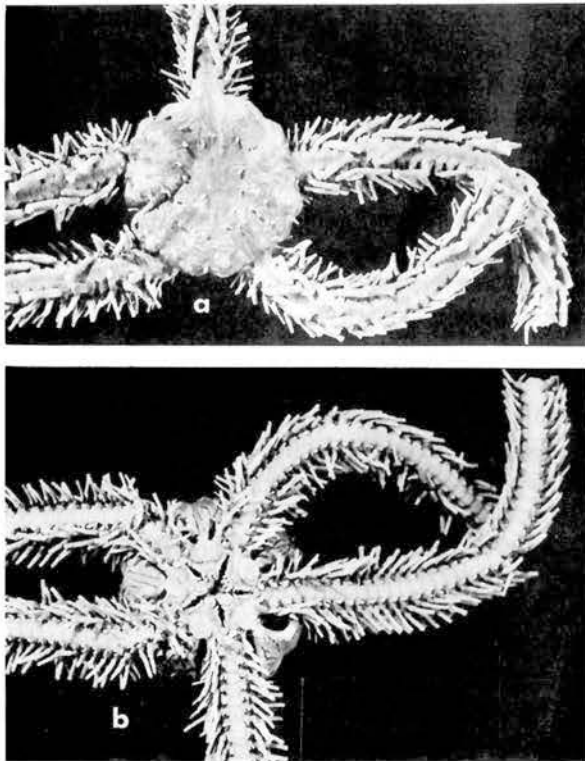


Fig. 41. *Ophiomastix venosa*, MCZ 1805, Zanzibar, 22 mm d.d. (a) Upper side. (b) Lower side.

**TENTACLE SCALES.** *O. venosa* has two equal-sized scales on each side of proximal segments out to a maximum of twelve to fifteen (Koehler, 1904a) yet McIntosh (1910) reported two for two-thirds the arm length. *Ophiarthrum elegans* and *O. pictum* typically have only a single scale. [The specimen Koehler (1922), reported as *Ophiomastix venosa*, has only a single scale on all segments.] While Loriol (1893b: 35)

described the type specimen of *Ophiarthrum lymani* (21 mm d.d.) as having a single scale on each pore; his figure (Pl. XXIV, fig. 2a, with the caption reading *Ophiarthrum robillardi*) shows two similar sized scales over each side of the first two segments.

**ARM SPINES.** Very characteristic clavifurcate upper arm spines occur on *O. venosa* that are at least 20 mm or larger in disc diameter. These spines are cloven-shaped with the tip drawn out into several extensions (Fig. 41a) and may appear digitate. The modified spines begin near the disc border and are spaced within a few segments of one another over half of the arm length. Balinsky (1957) mentioned the absence of such modified clavifurcate spines on a specimen 10 mm d.d. while Lütken (1869: 105) had reported them missing from adult specimens. The modified arm spines are about three segments in length. Clavifurcate spines are also absent from species of *Ophiarthrum* although in *O. pictum* and especially *O. lymani* the upper spines may be elongate.

An arm spine sequence of 2,2 or 3,3 is evident on the three examples of *O. venosa* examined for the proximal three segments. The specimen determined as *Ophiomastix venosa* by Koehler (1922) from the Philippines with a disc diameter of 13 mm has a sequence of 2,2,2, similar to that noted on several specimens of *Ophiarthrum pictum* from the same locality. Likewise other specimens of both *O. pictum* and *O. elegans* from various localities and deposited in the BPBM, USNM, and MCZ have a quite typical 2,2,2 sequence. However, an examination of the type specimen of *Ophiarthrum lymani* shows a 2 or 3,3,3 sequence.

**DENTAL PLATE.** The length of the dental plate occupied by the dental papillae is about twenty percent of the total length (Fig. 42a) as compared to approximately thirty percent for *Ophiarthrum pictum* and fifteen percent for *O. elegans*.

**ORAL SHIELDS.** As described by Peters, these plates are heart-shaped and wider than long for *O. venosa*. However, Koehler (1904b) indicated these to be longer than wide. The BPBM specimen (21 mm d.d.) has one oral plate equally as long as wide (3.2 mm) and another slightly longer (3.0 mm) than wide (2.8 mm).

**OTHER INTERNAL PLATES.** The oral plates as well as radial shield, genital scale and genital plate have been dissected from a portion of *O. venosa* (BPBM specimen) and are shown (Figs. 42b-f).

**PIGMENTATION.** The upper side of the disc is typically marked with narrow dark lines which tend to radiate irregularly from the radial shields. These dark meandering lines also are present on the lower side of the discs. The ground color ranges from grey to brown and the arm spines often have a dark line running their length. In the BPBM specimen, there is a rather broad dark line running down the center of the upper arms. The lower side is paler and uniform in color. The very distinctive color pattern of *Ophiarthrum pictum*, including the narrow dark line down the upper midline of each arm, is evident on the specimen described as *Ophiomastix venosa* by Koehler from the Philippines.

**HABITAT AND DISTRIBUTION.** Balinsky (1957) recorded a single small (d.d. 10 mm) specimen of *O. venosa* together with *Ophiocoma scolopendrina* beneath an algal mat near the shore margin. It appears to occur along the East African coast from



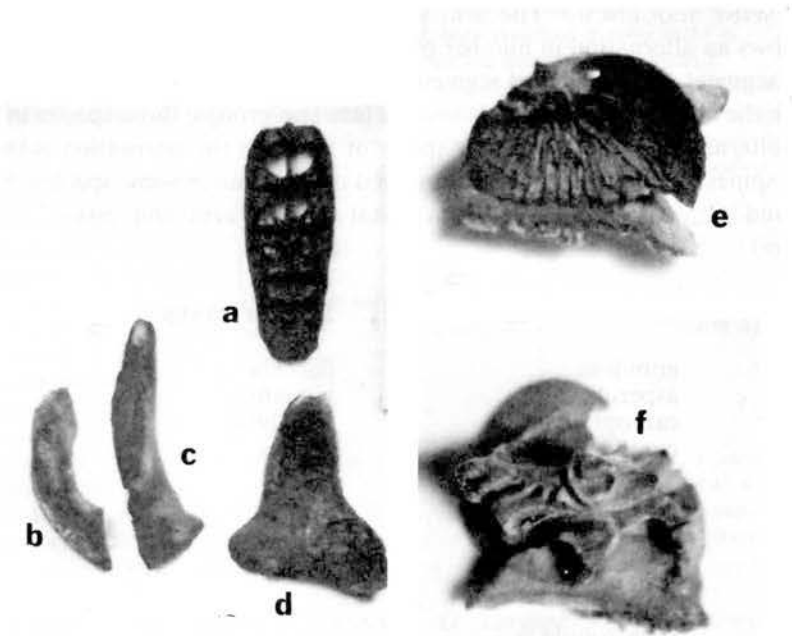


Fig. 42. *Ophiomastix venosa*, BPBM W1586, Mozambique, 21 mm d.d. (a) Dental plate. (b) Genital scale. (c) Genital plate. (d) Radial shield. (e) Abradial view of oral plate. (f) Adradial view of oral plate.

Inhaca Island northwards to Zanzibar and is known from Madagascar. Recently, A. M. Clark and Rowe (1971) report *O. venosa* from two other western Indian Ocean islands, Aldabra and Rodrigues. While Bell's (1902) record of *O. venosa* from the Maldives has been found to be a misidentification, that from the Mergui Archipelago by McIntosh (1910) appears valid but needs to be verified. [Attempts to locate McIntosh's material has proved futile. The specimens are not to be found in the BMNH, the Royal Scottish Museum nor the Gatty Marine Laboratory, Scotland (A. M. Clark, G. Smaldon and M. S. Laverack, pers. comm.)]. This would be the farthest east *O. venosa* occurs, since my reexamination of the specimen reported from the Philippines by Koehler (1922) shows it to be *Ophiarthrum pictum*. It is interesting to note that both *Ophiarthrum lymani* and *Ophiomastix venosa* occur in the Mascarene Islands, the former known only from Mauritius the latter from Rodrigues, while both *O. venosa* and *Ophiarthrum elegans* occur on the east African coast.

### Relationships

A literature review and examination of specimens of many species of *Ophiomastix* have made it apparent that all species in this genus are most closely related morphologically to the Scolopendrina group of *Ophiocoma*. The following evidence supports this consideration.

ARM SPINE SEQUENCE. The arm spine sequence of all known *Ophiomastix* species shows an alternation in number of arm spines either on opposite sides of the same arm segment, or on adjacent segments which occur beyond the disc margin. We may divide the known species of *Ophiomastix* into two groups: those species in which the usual alternation is three and four spines or in which the alternation is two and three arm spines. (A 2/3 alternation is observed on occasion in some specimens of *O. koehleri* and *O. palaoensis*, usually on distal part of arm and mixed with 3/4 alternation.)

## 3/4 ARM SPINES

annulosa  
asperula  
caryophyllata  
corallicola  
elegans  
koehleri  
marshallensis  
mixta  
ornata  
palaoensis  
stenozoneula  
variabilis

## 2/3 ARM SPINES

flaccida  
janualis  
variabilis  
venosa

Each species also has its own typical sequence of arm spines on the proximal segments and these sequences can be used with other criteria to help distinguish troublesome specimens. In Table 13, the most frequent number of spines occurring on the first three segments is given.

DISC COVER. Those species of *Ophiomastix* with a 2/3 arm spine alternation also tend to have a thicker epithelium covering most of the scales on the disc and the upper arm plates and have only widely placed spinules. In contrast, those species with a 3/4 alternation have the disc scales more or less exposed, and have either disc spinules alone, spinules and granules, or just granules (*O. koehleri*).

DENTAL PLATE. Information concerning the oral and dental plates of several ophiocomid species has been recorded including species of *Ophiomastix* (Murakami, 1963). It has already been pointed out that several characteristics of the dental plate suggest differences between the proposed groups of *Ophiocoma* (Devaney, 1970) which are positively correlated with other characters differentiating the groups in that genus. Murakami (1963:27) stated, "The dental plate of *Ophiomastix* belongs to the same category as that of *Ophiocoma*, but the foramina on the upper portion number three, each of them being completely divided". In the case of *Ophiocoma* and *Ophiomastix*, however, the number of foramina varies on plates in the same individual, is governed by the position of the teeth in each radius of the jaw, and is also a function of growth (i.e., fewer in smaller individuals). Although it was not mentioned by Murakami, the septa dividing the teeth formina in *Ophiomastix* are narrow and compressed. A comparison of Murakami's figures and my examination of the dental

Table 13. Most common number of arm spines on proximal segments, *Ophiomastix* species. Those species of *Ophiomastix* which have been examined in more detail in regard to the proximal arm spine sequence are indicated by an asterisk.

<i>n</i>	Species	Segment 1	Segment 2	Segment 3
5	<i>annulosa</i>	2	2 or 2 and 3	2 and/or 3
3	<i>asperula</i>	3	3	4
31	* <i>caryophyllata</i>	2 and/or 3	3	3 (rarely 4)
2	<i>corallicola</i>	3 (rarely 2)	3	3 or 4
0	<i>elegans</i>			
15	<i>flaccida</i>	1 and 2 or only 2	2	2
16	* <i>janualis</i>	2	2	2 or 2 and 3
3	* <i>koehleri</i>	3	3	3
9	<i>marshallensis</i>	3	3	4
15	<i>mixta</i>	3	3	4 or 3
1	<i>ornata</i>	3	3	3
14	* <i>palaoensis</i>	3 or 2 and 3	3	3 (rarely 2 or 4)
6	<i>stenozonula</i>	3	3 or 3 and 4	4 or 4 and 3
19	* <i>variabilis</i>	2 and/or 3	2 and/or 3	3 and/or 2
3	<i>venosa</i>	2	2 or 2 and 3	3 (rarely 2)

plates of *Ophiomastix mixta*, *O. annulosa*, *O. caryophyllata*, *O. stenozonula*, *O. marshallensis*, *O. palaoensis*, and *O. venosa* has verified that the form of the septa is within the limits found in all of the species of *Ophiocoma* in the Scolopendrina group examined.

The length to breadth ratio (L/B) for the dental plate of each of Murakami's specimens of *Ophiomastix* and the percent of the total length occupied by the dental papillae (indicated by the dental bosses or projections) were analyzed. In addition, I have added data on *O. venosa*, *O. marshallensis*, *O. stenozonula*, *O. flaccida*, and *O. palaoensis*. The data are presented below. Numbers in parentheses are mine.

Species	L/B Ratio	% Dental Papillae of Total Length
<i>O. annulosa</i>	2.9:1	31
<i>O. asperula</i>	2.8:1	32
<i>O. caryophyllata</i>	2.8:1	28
<i>O. flaccida</i>	(2.8-3.0:1)	(28-36)
<i>O. janualis</i>	2.8:1	33
<i>O. marshallensis</i>	(2.4-2.5:1)	(29-33)
<i>O. mixta</i>	2.6:1	33
<i>O. palaoensis</i>	2.8:1 (2.2-2.4:1)	18 (18)
<i>O. stenozonula</i>	(2.2-2.4:1)	(27-30)
<i>O. variabilis</i>	2.6:1	26
<i>O. venosa</i>	(2.8:1)	20

The length to breadth ratio is generally within the same range as that noted for specimens of *Ophiocoma* in the Scolopendrina group. Considerable variation was found with regard to the length (percent) occupied by the dental papillae. *Ophiomastix*

*palaoensis* and *O. venosa* (Fig. 42a) have a percentage well below that noted in the Scolopendrina group, whereas the other species have this character within the limits of that genus. The dental plate of *Ophiomastix venosa* is shaped much like that of *Ophiarthrum pictum*. However, in the latter, the dental papillae occupy a far greater portion of the length of the plate (approximately 30%).

**ORAL PLATE.** The oral plate of *Ophiomastix annulosa*, *O. janualis*, *O. mixta*, and *O. palaoensis* resembles *Ophiocoma erinaceus* and *O. scolopendrina* in the form of the indentations (scars) on the abradial side (Murakami, 1963) and no significant differences were noted between these plates and those of *Ophiomastix flaccida* (Figs. 10a, b), *O. marshallensis*, *O. stenozonula*, and *O. venosa* (Figs. 41e, f), which I examined.

**ORAL PAPILLAE.** I have found that three oral papillae plus the buccal tentacle scale which extends partially beneath the outer oral papilla is typical in *Ophiomastix*. Most often the outer oral papilla is the largest. The number and relative size of these elements are similar to those in species of *Ophiocoma* in the Scolopendrina group.

**SUMMARY:** Evidence presented on the basis of the arm spine sequence, dental and oral plates, and characteristics of the oral papillae, indicates a close relation between species of *Ophiomastix* and the Scolopendrina group of *Ophiocoma*. Furthermore, the disc cover of *Ophiomastix koehleri* is quite *Ophiocoma*-like while the disc cover of *O. asperula* with granules and spinules combines this feature for both genera. There is no fossil evidence to indicate which taxon is the older, but the greater diversity and presumed specialization in the shape and number of the upper arm spines and in the disc elements suggest that *Ophiomastix* is probably derived from the Scolopendrina line of *Ophiocoma*. Species of *Ophiomastix* are limited to the Indo-West Pacific area, whereas species in the Scolopendrina group of *Ophiocoma* are found pantropically, suggesting a more ancient history for the latter.

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