

# Coral Reef Asteroids of Palau, Caroline Islands

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**Abstract.**—A collection of nearly 600 specimens of Asteroidea from Palau, representing 24 species in 18 genera and 8 families is reported herein.

A new species, *Asterina corallicola*, is described and the following 9 species are recorded from Palau for the first time: *Celerina heffernani*, *Fromia milleporella*, *Gomophia egyptiaca* (?), *Neoferdina offreti*, *Ophidiaster robillardi*, *Asterina anomala*, *Mithrodia clavigera*, *Echinaster callosus*, and an undetermined species of *Nardoa*.

## Introduction

The asteroids of Palau were previously studied by Hayashi (1938b) who reported on sixteen species collected in the vicinity of Koror Island. The present collection does not cover a much greater geographical area but includes species from deeper water, obtained by snorkel and scuba diving.

Two species, *Nardoa tumulosa* and *Asteropsis carinifera*, recorded by Hayashi, are not represented in the present collection. Also absent are members of the families Luidiidae and Astropectinidae, possibly due to the limited sampling of soft substrates; nearly all the species are more or less associated with coral reefs.

A new species, *Asterina corallicola* is described and the following nine species are recorded from Palau for the first time: *Celerina heffernani*, *Fromia milleporella*, *Gomophia egyptiaca* (?), *Neoferdina offreti*, *Ophidiaster robillardi*, *Asterina anomala*, *Mithrodia clavigera*, *Echinaster callosus*, and an undetermined species of *Nardoa*, bringing the number of asteroids recorded from Palau to twenty-six species.

The greater part of this collection (566 specimens of 21 species) was made by Dr. Masashi Yamaguchi and colleagues from the University of Guam during their studies of the larval development of certain species of asteroids in Palau in 1974 and 1975; 29 additional specimens of 12 species were collected by the author during a visit to Palau in 1974 and two specimens of two additional species from the Bishop Museum collection are included, making a total of 597 specimens of 24 species in 18 genera and 8 families.

The bulk of the Yamaguchi collection is now housed in the National Museum of Natural History, Washington, U.S.A. but where possible representative material is deposited in the Western Australian Museum, the University of Guam and the Palau Biological Institute. Specimens collected by, and for, the author are housed in the Western Australian Museum.

Alternative ways of spelling Palauan place names are used by Palauan, Japanese and American authors. The spelling used here follows the U.S. Navy hydrographic chart.

The author wishes to extend her warmest thanks to Dr. M. Yamaguchi for making his extensive collection of Palau asteroids available for study and to participants in the International Symposium on Indo-Pacific Tropical Reef Biology who kindly added specimens to the author's collection in Palau, 1974. I also wish to thank Dr. D. M. Devaney of the Bernice P. Bishop Museum for allowing the inclusion of two species, loaned by the Bishop Museum.

#### ABBREVIATIONS

##### Institutions

AM—Australian Museum, Sydney, New South Wales

BPBM—Bernice P. Bishop Museum, Honolulu, Hawaii

MMDC—Micronesian Mariculture Demonstration Center

USNM—National Museum of Natural History, Smithsonian Institution, Washington, D.C., U.S.A.

WAM—Western Australian Museum, Perth, Western Australia

##### Measurements

br—breadth of the arm, at the base, unless otherwise specified

R—the major radius, from mouth to end of the ambulacral furrow

r—the minor radius, from mouth to interradial margin

vh—vertical height

#### SYNOPSIS OF ASTEROIDEA

Asteroid species found in Palau, based on Hayashi (1938b) and the present collection. The species known to date can be keyed out in Clark and Rowe (1971).

##### ARCHASTERIDAE

*Archaster typicus* Müller and Troschel

##### OREASTERIDAE

*Choriaster granulatus* Lütken

*Culcita novaeguineae* Müller and Troschel

*Protoreaster nodosus* (Linnaeus)

##### OPHIDIASTERIDAE

\**Celerina heffernani* (Livingstone)

*Fromia indica* Perrier

\**Fromia milleporella* (Lamarck)

*Fromia monilis* Perrier

\**Gomophia egyptiaca* Gray

+*Linckia guildingi* Gray

*Linckia laevigata* (Linnaeus)

*Linckia multifora* (Lamarck)

*Nardoa tuberculata* Gray

*Nardoa tumulosa* Fisher

\**Neoferdina offreti* (Koehler)

\**Nardoa* sp.

*Ophidiaster granifer* Lütken

\**Ophidiaster robillardi* de Loriol

#### ASTEROPSEIDAE

†*Asteropsis carinifera* (Lamarck)

#### ASTERINIDAE

\**Asterina anomala* H. L. Clark

\**Asterina corallicola* n.sp.

‡*Patiriella pseudoexigua* Dartnall

#### ACANTHASTERIDAE

*Acanthaster planci* (Linnaeus)

#### MITHRODIIDAE

\**Mithrodia clavigera* (Lamarck)

#### ECHINASTERIDAE

\**Echinaster callosus* von Marenzeller

*Echinaster luzonicus* (Gray)

\* species recorded here for the first time.

+ recorded as *L. diplax* Müller and Troschel by Hayashi (1938b).

† formerly *Asterope carinifera*.

‡ probably the species recorded as *P. exigua* by Hayashi (1938b).

### SYSTEMATIC ACCOUNT

#### ARCHASTERIDAE

##### *Archaster typicus* Müller and Troschel

Müller and Troschel, 1840: 104; 1842: 65, pl. 5, fig. 2; Hayashi, 1938b: 419-421, pl. 2, figs. 1, 2, 3.

MATERIAL EXAMINED AND LOCALITIES: Arakabesan, coll. M. Yamaguchi, G. A. Heslinga and R. S. Rideout, 28. V. 1975, eight specimens, R/r from 54/11 mm, br 11 mm to 67/12 mm, br 14 mm. Three had 63/13 mm with br of 13 mm; Peleliu I., coll. C. Otto, 20. VI. 1966, on sand, 3 spec., R/r 38/10 mm, br 10 mm, 36/9 mm, br 9 mm and 36/9 mm, br 8.5 mm.

REMARKS: The Arakabesan specimens (dried) are yellowish cream in color with small patches sometimes forming indistinct bands of dark orange on the arms.

They vary in the occurrence of spines on the superomarginals, four specimens have none, three have none on some rays and up to five on others, while two have from 2 to 10 on some rays. There is a single flattened inferomarginal spine per plate except near the base of the ray where there are sometimes two. The dorso-lateral paxillae bear 4 spinelets, occasionally up to eight. The carinals have 10-14 spinelets with extremes of 7 to 15.

The Peleliu specimens all have 1 spine per inferomarginal (two on a few proxi-

mal plates) and lack spines on the superomarginals. The dorsolateral paxillae bear 3–5 spinelets, the carinals 7–10. Hayashi has given a detailed description with figures of this species and notes that it is common in the Arakabesan and islets region.

## OREASTERIDAE

### *Choriaster granulatus* Lütken

Fig. 1.

Lütken, 1869: 35; Goto, 1914: 604–610, pl. 17, fig. 263, pl. 18 figs. 264–269; Hayashi, 1938b: 424.

MATERIAL EXAMINED AND LOCALITIES: Ngerameayus I., coll. L. M. Marsh, 30. VI. 1974, on sandy lagoon slope of coral reef, 2–3 m, 1 spec. R/r 100/38 mm.

REMARKS: This species is usually found below low tide level, but in the bay behind Kwannon island on the south side of Koror several specimens were seen exposed at low tide on a sand and coral covered flat.

Specimens were a dusty pink with the papulae darker.

This species is found from the Red Sea to the East Indies, extending into the South Pacific as far as Fiji and to Nukuoro Atoll in the eastern Caroline Islands in the North Pacific (records based on specimens in the W.A.M.).

### *Calcita novaeguineae* Müller and Troschel

Müller and Troschel, 1842: 38; Livingstone, 1932: 265–273, pls. 14–17; Hayashi, 1938b: 422–424, pl. 1, figs. 4, 5, 6.

MATERIAL EXAMINED AND LOCALITIES: South passage, Iwayama Bay, coll. M. Yamaguchi, 19. VI. 1975, 1 spec. R/r 45/26 mm; Malakal I., coll. M. Yamaguchi, 15. VIII. 1974, 1 spec.



Fig. 1. *Choriaster granulatus*, Ngerameayus I., R = 100 mm.

under rock, R/r 32/18 mm; Ngerameayus I., coll. L. M. Marsh, 30. VI. 1974, on sand near coral reef, 1 m, 2 spec. R/r 104/64 mm and 95/57 mm.

REMARKS: Both of Yamaguchi's specimens are juveniles, one is pale green-grey, darker interradially while the other is light brown with cream areas interradi-ally.

Little need be added to Hayashi's description of a juvenile except to note that the present specimens have six furrow spinelets instead of 4-5.

Adult *Culcita novaeguineae* were common on sand near coral patches on the south side of Auluptagel I. and near Ngerameayus I. Both the adult specimens have a rather uniform distribution of small conical spinelets over the papular areas and skeletal network. The papular areas are fairly discrete in both specimens.

### *Protoreaster nodosus* (Linnaeus)

*Asterias nodosus* Linnaeus, 1758: 661.

*Protoreaster nodosus* Döderlein, 1916: 420. fig. G.H.; Hayashi, R., 1937: 177-186, pls. 4, 5; 1938b: 421-422.

MATERIAL EXAMINED AND LOCALITIES: Arakabesan, coll. G. A. Heslinga, -. VI. 1975, 1 spec. at low tide, R/r 58/23 mm, br 24 mm; Cocktail Cove at Peduliaes Pt, Ngargol I., coll. R. Strong, 1 spec. from 35-40 ft (11-12 m), R/r 148/48 mm, br 48 mm; bay behind Kwannon I., south side of Koror, coll. L. M. Marsh, 2. VII. 1974, 1 spec. on sand, 0-1 m, R/r 75/28 mm; outside barrier reef west of Aulong I., coll. H. Schmidt, 1. VII. 1974, 1 spec. on sandy mud at 20-30 m, R/r 125/48 mm.

REMARKS: The Arakabesan specimen is a uniform orange color when dry while the Ngargol specimen is cream with light brown tubercles and arm ends, a small area around each tubercle is orange. The other two specimens are cream interradially with the remainder of the abactinal surface deep orange.

Hayashi (1937) made a detailed study of the external morphology of this species in Palau and noted that it was common in the Arakabesan region. The present author saw numerous specimens in sandy shallows, among algae and coral, in the lee of Kwannon Island on the south side of Koror but *Protoreaster* was not found at other collecting sites sampled by the author.

## OPHIDIASTERIDAE

### *Celerina heffernani* (Livingstone)

Fig. 2.

*Ferdina heffernani* Livingstone, 1931: 306-307, pl. 24, figs. 1-5.

*Celerina heffernani* (Livingstone), A. M. Clark, 1967b: 193-194, pl. 6, figs. 4 and 5.

MATERIAL EXAMINED AND LOCALITIES: Denges Passage, south west of Koror I., coll. L. Marsh, 4. VII. 1974, 1 spec. under ledge on reef front, 16 m, R/r 28/5 mm, br 5.5 mm.

DESCRIPTION: The disc is small and flat, the arms rather convex and tapering with a prominent, though somewhat irregular carinal series of enlarged plates. The whole surface is finely granulated with slightly enlarged granules in the center of most of the raised plates. The anus is central, closed by six large granules; the

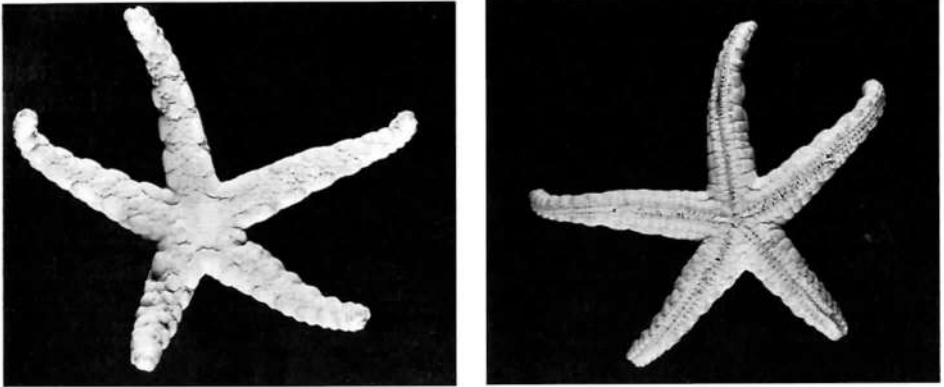


Fig. 2. *Celerina heffernani*, Denges Passage, R=28 mm. a abactinal, b actinal.

madreporite is circular, elevated and 1.2 mm in diameter. Enlarged supermarginals alternate with small flat plates and a single series of up to eight intermarginal plates lies on each side of the arm angle. The inferomarginals do not regularly alternate in size but have a few small intercalated plates between the larger ones. The single series of actinal plates extend to the 10th or 12th inferomarginal with a few plates of a second series in one arm angle. The actinal plates and most of the adambulacrals have a central group of enlarged granules but on one ray the adambulacrals have instead a single conical spinelet. Proximally there is a pair, distally a single, tapering, pointed furrow spine, on each adambulacrals plate; the spines interlock across the furrow. The papulae are single and occur abactinally on the disc and arms with a few intermarginally but none below the inferomarginals.

The disc, arm ends and granules between the plates were red, the enlarged marginals cream while the rest of the abactinal and marginal plates were dusky purple. The color has faded on drying.

REMARKS: *Celerina heffernani* resembles *Fromia monilis* in size, color and general appearance and may be easily confused with the latter in the field. They are readily distinguished, however, by the adambulacrals armature which consists of a single series of pointed furrow spines in *C. heffernani* while *F. monilis* has two series of flattened blunt ended spines. *C. heffernani* also differs in having intermarginal plates in the arm angle, in lacking actinal papulae and in having more prominent carinal plates.

*C. heffernani* is an uncommon species, found amongst corals, sometimes with *Fromia monilis*. It is so far known only from the South China Sea to the Santa Cruz Islands (north of the New Hebrides).

#### *Fromia indica* Perrier

*Scytaster indicus* Perrier, 1869: 255.

*Fromia indica*: Perrier, 1875: 441; Koehler, 1910: 140, pl. 17, figs. 7, 8; Hayashi, 1938a: 59-62, pl. 4, figs. 1-4; 1938b: 428-430, pl. 2, figs. 7, 8.

**MATERIAL EXAMINED AND LOCALITIES:** South passage of Iwayama Bay, Koror I., coll. M. Yamaguchi, 17. VIII. 1974, 1 spec., in dead coral thicket, R/r 25/7 mm, br 7 mm; Arakabesan pass., coll. M. Yamaguchi, 8. VII. 1975, 1 spec. coll. by snorkel, R/r 18/5 mm, br 5 mm; Ngargol I., coll. R. S. Rideout and G. A. Heslinga, -. VI. 1975, 15 spec., R/r from 18/4.5 mm to 28/7 mm; barrier reef N.W. of Koror I., coll. J. Demond, 1. VII. 1974, lagoon side of reef near Aulong I., 3-4 m, 1 spec. R/r 28/7 mm, br 6.5 mm; barrier reef N.W. of Koror, coll. G. Chan, 1. VII. 1974, 2 spec. from reef front, 3-4 m, R/r 25/6 and 26/6.5 mm; barrier reef N.W. of Koror, coll. A. Child, 1. VII. 1974, channel west of Aulong I., 50-60 ft (18 m), 1 spec. R/r 31/7 mm, br 7 mm.

**REMARKS:** Hayashi (1938b) concluded that "*Fromia indica* seems to be very diverse in its external features, and the two sea-stars, *F. andamanensis* and *F. elegans* are to be referable to a forma of a single species, *F. indica*". He referred the Palau specimens to *F. indica* forma *andamanensis* Koehler.

The specimen from the south passage of Iwayama Bay has plump arms with scattered, raised plates and thus resembles *F. indica* abactinally while the actinal surface has groups of short spinelets characteristic of *Fromia elegans* Clark. All the other specimens have slender arms with a more or less developed double row of raised abactinal plates and short actinal spinelets as in *F. elegans*.

I am therefore inclined to agree with Hayashi, provisionally, that no hard and fast line can be drawn between the three species, *F. indica*, *F. andamanensis* and *F. elegans*, at least in this part of the world.

The author is making a study of a large series of specimens from a number of Indo-Pacific localities in the hope of resolving the problem.

*Fromia milleporella* (Lamarck)

Fig. 3.

*Asterias milleporella* Lamarck, 1816: 564.

*Fromia milleporella* Gray, 1840: 286; de Loriol, 1885: 44, pl. 16, figs. 2-4; Clark and Rowe, 1971: 34, 63, pl. 8, fig. 10.

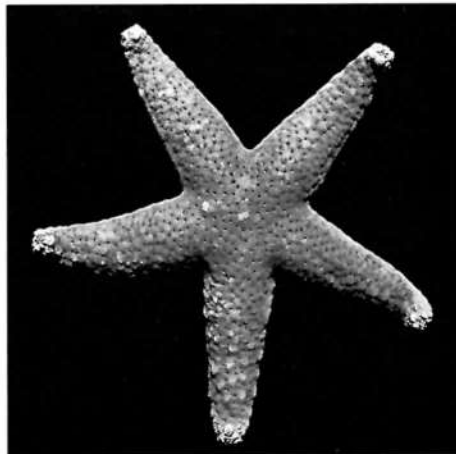


Fig. 3. *Fromia milleporella*, Ngadarak reef, R=30 mm.

MATERIAL EXAMINED AND LOCALITIES: South passage of Iwayama Bay, Koror I., coll. M. Yamaguchi, 17. VIII. 1974, 2 spec. coll. by snorkel under dead coral thicket. R/r 28/8 mm, br 8 mm and 28/7.5 mm, br 8 mm. Ngadarak Reef, coll. M. Yamaguchi, 21. VI, 1975, 2 spec. coll. by snorkel, R/r 30/9 mm, br 10 mm and R/r 28/8 mm, br 8 mm; Auluaptagel I., coll. M. Yamaguchi, 23. VI. 1975, 1 spec. coll. by snorkel, R/r 28/7 mm, br 8 mm.

DESCRIPTION: The specimens all have five regular short, plump rays,  $R=3.3$  to 4 r and 3.0 to 3.5 br. There is a single madreporite and anus in each. The skeleton is composed of small, irregularly arranged plates, with crystal bodies (minute hemispherical glassy beads on the surface of the skeletal plates), with or without a distinct carinal series. There are about 14 superomarginal and about 16 inferomarginal plates, usually fairly regular, lying opposite one another except at the upturned ends of the rays. The actinal plates are in three series at the base of the rays, with a few plates of a fourth series in the arm angle. The disc and rays are covered in a uniform coat of polygonal granules in some specimens while others have enlarged granules in the center of some plates, particularly on the distal part of the rays. Papulae are single, evenly scattered over the upper and lower surface of the disc and rays with a few intermarginally.

The furrow spines are flattened, blunt tipped, two or three to a plate, set obliquely so that where there are three, one group overlaps the next. There are 1–2 short blunt subambulacral spines distinctly set off from the adjacent granules of the actinal plate. The oral plates carry 4–5 furrow spines, the innermost 1 or 2 at least, curved and pointed. Behind these is a similar curved suboral spine followed by a pair of shorter spines in line with the subambulacrals, sometimes with a few additional smaller spines.

The specimens are dark red-brown abactinally, orange along the furrows, shading to red-brown at the margin.

REMARKS: *Fromia milleporella* appears to be rather uncommon in Palau whereas it is one of the most common species in some parts of the Western Pacific, for example Fiji (pers. obs.). It is found from the Western Indian Ocean to the central Pacific with the easternmost record from Palmyra Island (Marsh, 1974).

#### *Fromia monilis* Perrier

Perrier, 1875: 443; H. L. Clark, 1921: 46–48; Hayashi, 1938b: 425–427, text fig. 2.

*Fromia japonica* Perrier, 1881: 14; Fisher 1919: 373–375, pl. 105, fig. 4, pl. 106, fig. 2, pl. 107, figs. 1, 7.

*Fromia major* Koehler, 1895: 399, pl. 9, figs. 3, 4.

MATERIAL EXAMINED AND LOCALITIES: Eang, Koror, coll. H. Sabino, 28. XII. 1962, on sand close to coral, 1 m, 1 spec. R/r 40/6.5 mm, br 6 mm; Ngadarak reef, coll. M. Yamaguchi, 21. VI. 1975, 1 spec. R/r 43/10 mm, br 10 mm; MMDC, Malakal I., coll. M. Yamaguchi, 14. VI. 1975, 1 spec. by snorkel, R/r 50/10 mm, br 9 mm; MMDC, Malakal I. coll. M. Yamaguchi, 31. V. 1975, 2 spec. by snorkel, R/r 40/8 mm, br 7 mm and 30/5.5 mm, br 6 mm; MMDC, Malakal I., coll. R. S. Rideout, 31. V. 1975, 1 spec. by scuba, R/r 20/5 mm, br 4.5 mm; Malakal I., coll. S. Jameson, 15. VIII. 1974, 1 spec. under rock, R/r 43/8 mm, br 8 mm; Malakal I., coll. M. Yamaguchi, 14. VIII. 1974, 1 spec. boulder zone, 2 m below low spring tide, R/r 48/9 mm, br 9 mm; Cocktail Cove, Peduliaes Pt., Ngargol I., coll. R. Strong, —1.1974, 2 spec., R/r 58/11 mm, br 12 mm



and ca 30/6 mm (all rays broken); Arakabesan, coll. M. Yamaguchi, 8. VII. 1975, 2 spec. by snorkel, R/r 42/8 mm, br 8 mm and 13/3.5 mm, br 3 mm; Iwayama Bay, coll. R. S. Rideout, G. A. Heslinga, 7. VI. 1975, 3 spec., R/r 46/9 mm, br 8.5 mm, 32/8 mm, br 7 mm, 22/5.5 mm, br 5.5 mm; south passage, Iwayama Bay, coll. M. Yamaguchi, 19. VI. 1975, 1 spec. by snorkel, R/r 42/9 mm, br 8.5 mm; Augulpelu Reef, coll. R. S. Rideout, 27. VI. 1975, 1 spec. coll. by scuba, R/r 37/8 mm, br 7 mm; Ngargol I., coll. R. S. Rideout, 13. VI. 1975, 1 spec. R/r 26/5 mm, br 5 mm; Ngargol I., coll. R. S. Rideout and G. A. Heslinga, 9. VI. 1975, 22 spec., at low tide, R/r from 15/3.5 to 38/7 mm; Urukthapel I., coll. R. S. Rideout and G. A. Heslinga, 10 spec., R/r from 18/5 mm to 45/7.5 mm; Ngerameayus I., coll. L. M. Marsh, 30. VI. 1974, on dead coral, 0-1 m, 1 spec. R/r 30/7 mm, br 7 mm; barrier reef west of Aulong I., coll. G. Chan, 1. VII. 1974, reef front at 3-4 m, 1 spec. R/r 37/8 mm, br 8 mm.

REMARKS: Little need be added to Hayashi's detailed description and observation of growth changes in this species. The 52 specimens examined range from R/r of 13/3.5 to 58/11 mm, with R: r of 4.8: 1 and R: br of 5.0 ranging from 3.6 to 6.2 and 4.0 to 6.7 respectively. There are three series of abactinal plates at the base of the rays in specimens up to 35 mm in R and five series in larger specimens. Those of <30 mm in R have few alternating small plates between the large superomarginals while they are absent altogether in specimens of <20 mm in R.

The color of the superomarginal and abactinal plates on the proximal half of the rays varies from beige to apricot or orange while the disc and outer half of the arms and the granules between the plates varies from orange-red to rust red, scarlet, carmine and in one case purple in the dry specimens.

This species is fairly common in Palau, particularly at Ngargol Island and Urukthapel Island.

cf. *Gomophia egyptiaca* Gray

*Gomophia egyptiaca* Gray, 1840: 286; Clark, A. M., 1952: 206, pl. 32; 1967a: 39, 54; 1967b: 176-178, 181; Clark and Rowe, 1971: 36-37, 64, pl. 8, fig. 4.

MATERIAL EXAMINED AND LOCALITY: Augulpelu Reef, coll. W. A. Starck, G. R. Allen and J. Condit, 26. I. 1972, 1 spec., BPBM, coll. by rotenone, scuba at 125-150 ft. (38-46 m) on drop off, R/r 40/6.5 mm, br 6.5 mm.

DESCRIPTION: The specimen has a small disc with five rays tapering evenly to a fine point. The abactinal skeleton of the rays is rather open and consists of a carinal series with 2 or 3 enlarged plates, the remainder being fairly small. The dorsolateral series are small and connected to the superomarginals and carinals by bar shaped ossicles. The plates are covered by a thin bare skin.

The madreporite is small, circular, with the striations eroded, half way between the center and the edge of the disc.

There are two prominent superomarginals on each side of the arm angle, thereafter the superomarginals are small and inconspicuous. On each side of the arm angle there are two large intermarginal plates, then a series decreasing in size, corresponding to the superomarginals, extending to about two thirds of the arm length or to about the 12th inferomarginal. The inferomarginals are prominent and there is a single row of actinal plates. The furrow spines number four to each plate and radiate slightly from one another, and are followed by three subambulacral

spines. Each oral plate bears 7 furrow spines and about four smaller spines on its actinal surface.

REMARKS: The specimen is so badly decalcified that it is not possible to determine the species with any degree of certainty.

The shape and size of the specimen resembles *Heteronardoa carinata* but this species lacks intermarginal plates, has a more compact abactinal skeleton and has more furrow spines.

The shape and size are also similar to *Gomophia egyptiaca* although the arms taper to a finer point. The furrow, subambulacral and oral spines agree with *G. egyptiaca* as does the structure of the abactinal skeleton. The intermarginal plates are similar although those in the arm angle are more prominent than in other specimens of *G. egyptiaca* examined.

The characteristic nipple shaped tubercles and granulated surface of *G. egyptiaca* are completely absent but it is believed that these have been lost by decalcification.

Allowing for differences in appearance caused by decalcification of the specimen it agrees in major structural features with *Gomophia egyptiaca* and is tentatively identified as this species, not previously recorded from Palau but widely distributed through the Indo-Pacific.

#### *Linckia guildingi* Gray

Gray, 1840: 285; Hayashi, 1938b: 437, pl. 4, fig. 1 (as *L. diplax* Müller and Troschel).

MATERIAL EXAMINED AND LOCALITIES: South passage of Iwayama Bay, Koror, coll. M. Yamaguchi, 17. VIII. 1974, 2 spec. under coral thicket, by snorkel, R/r 104/7 mm, br 7 mm, and R 60 mm (comet); South passage, Iwayama Bay, coll. M. Yamaguchi, 19. VI. 1975, 1 spec. by snorkel, R/r 88/6.5 mm, br 7 mm; Augulpelu Reef, coll. R. S. Rideout, 27. VI. 1975, 1 spec. by scuba, R/r 196/12 mm, br 13 mm.

REMARKS: This species is relatively uncommon in Palau and was not found by the present author. Hayashi's material identified as *L. diplax*, should from his description and figure, be referred to *L. guildingi*.

The specimens show little variation in color; they are either cream or pale grey mottled with grey-brown and purple or with light and dark purple-brown.

Three of the specimens have five rays, one has six; all have two madreporites and one has two anal apertures.

#### *Linckia laevigata* (Linnaeus)

*Asterias laevigata* Linnaeus, 1758: 662.

*Linckia laevigata* Hayashi, 1938b: 434-435, pl. 3, fig. 4.

MATERIAL EXAMINED AND LOCALITIES: South passage of Iwayama Bay, Koror, coll. M. Yamaguchi, 17. VIII. 1974, 12 spec., under rocks, R/r from 40/6 mm, br of 5.5 mm to 85/12 mm, br of 11.5 mm; same data, 19. VI. 1975, 9 spec. R/r from 43/7 mm, br of 7 mm to 86/12 mm, br of 12 mm; Kasao Reef, coll. R. Strong, inside reef flat, 1 m, 2 spec. R/r 138/18 mm, br 17 mm and 112/17 mm, br 17 mm; Arakabesan, coll. M. Yamaguchi, 8. VII. 1975, 1 spec. by snorkel, R/r 51/9 mm, br 9 mm; Ngadarak Reef, coll. M. Yamaguchi, 21. VI. 1975, 5 spec. by snorkel, R/r from 41/7 mm, br of 7 mm to 51/9 mm, br of 9 mm; Ngerameayus I., coll. L. M. Marsh, 30. VI. 1974,

1 spec. on reef top, 0-1 m, R/r 125/18 mm, br 19 mm; bay behind Kwannon I., south side of Koror, coll. L. M. Marsh, 2. VII. 1974, 2 spec., sand and coral, 0-1 m, R/r 137/19 mm, br 20 mm and 125/28 mm, br 18 mm.

REMARKS: Of the 32 specimens examined, 28 have five rays, with a single madreporite and anus; a four and a six rayed specimen each have two madreporites and two anal apertures while one five rayed specimen has three madreporites and two anal apertures and another has two madreporites and a single anus. The R:r ratio ranges from 5.7 to 7.7:1 and R:br from 5.7 to 8.1:1.

*L. laevigata* shows a remarkable variation in color in Palau, from bright blue and greenish blue with an apricot colored oral surface to deep apricot color on both surfaces. Of the thirty two specimens collected five were bright blue, four grey-blue, eight greenish blue aborally, often apricot colored orally, thirteen were predominantly apricot colored while one specimen was grey-brown with patches of cinnamon brown and one was a dull brownish blue with splashes of vivid orange-red. Many of the specimens had flecks or splashes of brown, bright blue or orange.

In specimens of less than 70 mm in R the apricot color often predominates but adult specimens tend to be bright blue or greenish blue, the latter often apricot colored orally, while a few large apricot colored specimens occur in the population.

No morphological differences were observed in the variously colored specimens.

### *Linckia multifora* (Lamarck)

*Asterias multifora* Lamarck, 1816: 565.

*Linckia multifora*, Hayashi, 1938b: 435-436; pl. 3, figs. 7, 8.

MATERIAL EXAMINED AND LOCALITIES: Ngargol I., coll. R. S. Rideout and G. A. Heslinga, 106 specimens collected in two hours at low tide, R/r from 17/3 mm to 44/5 mm; South passage of Iwayama Bay, coll. R. S. Rideout, G. A. Heslinga and M. Yamaguchi, 19. VI. 1975, 8 spec., coll. by snorkel, R/r from 26/3 mm to 50/6 mm; near MMDC, Malakal I., coll. M. Yamaguchi, 13. VIII. 1974, 9 spec. coll. by snorkel. R/r from 27/3 mm to 41/4.5 mm; near MMDC, Malakal I., coll. M. Yamaguchi, 14. VIII. 1974, 4 spec. coll. by snorkel from wall of wharf, R/r 34/4, 41/4 mm and two small comets; Arakabesan, coll. M. Yamaguchi, 8. VII. 1975, 2 spec. coll. by snorkel, R/r 31/4 mm (6 rays) and a 5 rayed specimen with 3 madreporites and all rays regenerating; South passage of Iwayama Bay, Koror, coll. M. Yamaguchi, 17. VIII. 1974, 3 spec. coll. by snorkel, under coral thicket, R/r from 19/2.5 mm to 46/3 mm; near MMDC, Malakal I., coll. M. Yamaguchi, 31. V. 1975, 3 spec. R/r 26/2 mm to 30/3 mm; Malakal-Koror causeway, coll. M. Yamaguchi and S. Jameson, 15. VIII. 1974, 7 spec., coll. by snorkel, R/r from 29/3 mm to 60/5 mm; Palau, coll. M. Yamaguchi, R. S. Rideout and G. A. Heslinga, -VI. 1975, 8 spec., R/r from 40/6 mm to 46/5 mm; Auluptagel I., coll. R. S. Rideout and G. A. Heslinga, 23. VI. 1975, 13 spec., R/r from 18/2.5 mm to 53/6 mm; Ngadarak Reef, coll. M. Yamaguchi, 21. VI. 1975, 1 spec. by snorkel, R/r 40/5 mm; Ngerameayus I., coll. L. M. Marsh, 30. VI. 1974, 2 spec. under coral ledges 2-3 m, R/r 32/3 mm, 32/5 mm, 3 spec. under dead coral on reef top, R/r 18/2 mm to 27/3 mm; barrier reef west of Aulong I., coll. G. Chan, 3 spec. on reef front, 3-4 m, R/r 25/3 mm to 35/3.5 mm, Denges Passage, south of Koror, coll. L. M. Marsh, 4. VII. 1974, 1 spec. on reef front among dead coral, 12 m, R/r 62/4 mm (comet).

REMARKS: Of the 173 specimens examined, 148 (85.5%) have five, usually

unequal rays, 6 (3.5%) have four and 9 (5.2%) have six rays while there are 10 single rays without any sign of regeneration; 42 of the five rayed specimens are comets. 143 (82.7%) have two madreporites, 4 (2.3%) have three and 5 have a single madreporite, while in 21 of the comets the madreporite is undeveloped. There are usually two anal apertures, occasionally one or three.

All are of fairly small size, from R/r of 17/2.5 mm to 60/5.0 mm, R/r varies from about 7 to 12:1 (excluding comets). The background color of the dry specimens is cream, light buff or pale to deep salmon pink finely freckled with orange, red, rust, red-brown or brown, the papular areas are usually brown and the arm tips grey or grey-blue. The specimens with a single madreporite and anus may be distinguished from juvenile *L. laevigata* by their color and the shape of the arms, which taper in *L. multifora* and are more cylindrical and blunt ended in *L. laevigata*.

Granules between the furrow spines are evident in the smallest specimen, with R of 17 mm, in contrast to material from eastern Polynesia in which granules between the spines were not observed in specimens with R of less than 20 mm.

This species is common in several areas of Palau and abundant at Ngargol Island. No specimens were found in the inner parts of Iwayama Bay.

#### *Nardoa tuberculata* Gray

Gray, 1840: 287; Hayashi, 1938b: 430-432, pl. 3, figs. 1, 2.

*Nardoa tuberculata* forma *pauciforis* (v. Martens), Hayashi, 1938b: 432, pl. 3, fig. 3.

MATERIAL EXAMINED AND LOCALITIES: MMDC, Malakal I., coll. M. Yamaguchi, -. VI. 1975, 3 spec. coll. by snorkel, R/r 127/15 mm, br 18 mm, 108/15 mm, br 15 mm, 120/15 mm, br 17 mm; MMDC, Malakal I., coll. M. Yamaguchi, 11. VII. 1975, 1 spec. coll. by snorkel, R/r 118/15 mm, br 15 mm; south passage, Iwayama bay, coll. M. Yamaguchi, 19. VI. 1975, 1 spec. coll. by snorkel, R/r 80/11 mm, br 11.5 mm; Arakabesan, coll. M. Yamaguchi, 8. VII. 1975, 2 spec. R/r 116/15 mm and 95/15 mm; Malakal I., coll. M. Yamaguchi, -. VI. 1975, 9 spec. coll. by snorkel, R/r from 83/12 mm to 115/15 mm; bay behind Kwannon I., south side of Koror I., coll. L. M. Marsh, 2. VII. 1974, 3 spec. among rock, sand and coral, 0-1 m, R/r 62/10 mm, br 10 mm, 92/14 mm, br 14 mm, 95/13 mm, br 14 mm.

REMARKS: The nineteen Palau specimens range in size from R/r of 62/10 mm to 127/15 mm, R: r varies from 6.2: 1 to 9.2: 1. They are clearly all referable to one species but show a gradation from strongly tuberculate forms, (typical *N. tuberculata*) to specimens with smaller plates and lacking tubercles (typical *N. pauciforis*). The Palau specimens have been compared with material of *N. tuberculata* from Indonesia and the Philippines and of *N. pauciforis* from Queensland and the only character which was found to vary with the degree of tuberculation was the number of abactinal plates across the base of the ray. Specimens of *N. tuberculata* from Indonesia and the Philippines have 8-13, with a mean of 10 (N=8), plates, *N. pauciforis* specimens from Queensland have 11-14 with a mean of 13.2 (N=5) while the Palau specimens have 10-13 with a mean of 12.04 (N=11). The latter are thus intermediate in the number of plates across the base of the rays and are nearly equally divided between those that are nearer *N. tuberculata* in tuber-

ulation and size of plates and those nearer to *N. pauciforis*.

The evidence may be interpreted as either that *N. pauciforis* is merely a non tuberculate form of *N. tuberculata* (as Hayashi concluded) or that the Palau population shows hybridization between *N. tuberculata* and *N. pauciforis*.

The dry specimens have a cream or light pink ground color usually with brown papular areas and granules between the plates. The arms usually have 4 or 5 bands of brown or deep salmon pink. Some specimens lack bands of color on the arms. In color the two forms are indistinguishable.

*Neoferdina offreti* (Koehler)

Fig. 4.

*Ferdina offreti* (pars) Koehler, 1910: 143-147, pl. XVI, figs. 2, 3 (non 4-5, see A.M. Clark, 1967).

*Ferdina intermedia* Djakonov, 1930: 248-251, pl. 13, fig. 6.

*Neoferdina offreti* Livingstone, 1931: 307; Jangoux, 1973: 778-783, figs. 2, 3, 5; pl. IV, figs. 2-6.

MATERIAL EXAMINED AND LOCALITY: Augulpelu Reef, coll. R. S. Rideout, 27. VI. 1975, one spec. by scuba, R/r 28/7 mm, br 7 mm.

DESCRIPTION: This small starfish has five, more or less equal, convex, tapering rays with a R: r ratio of 4: 1.

The abactinal surface is uniformly granulated (10-12/mm) except for raised, bare marginal and some carinal and dorsolateral plates.

The bare plates on the abactinal surface vary in arrangement from one ray to another, there are none on the disc. On some rays they are irregularly arranged while on others there tends to be a carinal series; on two rays there are three to four distinct transverse series of bare plates consisting of a large carinal plate with a smaller bare plate on either side. The bare plates are slightly convex but not hemispherical.

Nearly all the superomarginal plates are enlarged and bare; there is no alterna-



Fig. 4. *Neoferdina offreti*, Augulpelu reef, R=28 mm.

tion of large and small plates although a few plates are reduced in size varying the number of superomarginals from 10–12 on different rays; the superomarginals are much longer than wide. There are 15 inferomarginals, many of which are partly bare, while some of the distal inferomarginals have a small central tubercle.

The actinal plates nearest the furrow extend from three quarters of the arm length on some rays nearly to the arm end on others. The second row extends to about half the arm length, the third row is represented by three or four plates at the base of the ray and there is an incipient fourth row represented by a pair of plates in the arm angle.

The furrow spines are in a single series, two per plate, subequal, flattened, truncate. The oral spines are similar but slightly larger. The anus is closed by four enlarged granules; the madreporite is circular, convex, with pores and short slits rather than sinuous grooves. The terminal plate is fairly large and pointed, bearing one or two small tubercles. There are 5 or 6 plates across the base of the rays.

The granules covering the flat plates of the disc and arms are rose colored. Those of the papular areas and between the plates are a dull orange while the raised bare plates are magenta with pale cream granules around the base. The granules of the inferomarginal and actinal plates are cream except interradially where they are rose colored. The granules between the plates are very pale orange on the rays and dull orange on the disc.

REMARKS: This specimen has rather more raised bare plates on the abactinal surface than most specimens of *N. offreti* but considering the great variability of the species of *Neoferdina* and particularly that of *N. offreti*, described by Jangoux (1973) I believe that the present unique specimen should be referred to this species. It differs from the *cumingi* group in lacking the alternation of large bare and small granule-covered superomarginals. *N. offreti* has previously been recorded from the Andaman I. (Koehler), Seychelles (Jangoux), Okinawa (Djakonov) and New Caledonia (A. H. Clark). Two specimens from the Philippines, in the W. A. Museum collection are also referable to this species.

### *Nardoa* sp.

Fig. 5.

MATERIAL EXAMINED AND LOCALITY: MMDC, Malakal I., coll. M. Yamaguchi, 27. VI. 1975, 1 spec. coll. by snorkel, R/r 110/11.5 mm, br 12 mm.

DESCRIPTION: Disc small, convex; five long cylindrical rays tapering in their outer half to a narrow tip, R/r=9.6:1, R: br=9.1:1. The arm angles are acute. The abactinal and actinal plates are pale beige except for three bands of rust orange on the arms, the papular areas and granules between the plates are chocolate brown.

The compact abactinal skeleton is composed of large and small plates, wider than long on the proximal two thirds of the rays and longer than wide distally. About twenty of the larger plates on the inner two thirds of each ray are hemispherical, measuring 3.5 to 4 mm in diameter. There are five plates across the base of

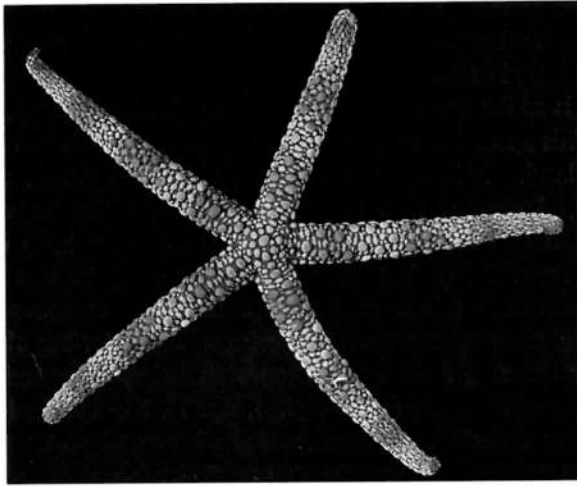


Fig. 5. *Nardoa* sp., Malakal I., R = 110 mm.

the rays but no distinct longitudinal series except for a series of small plates (about two to each of the larger superomarginals) extending to two thirds or three quarters of the arm length above the superomarginals. These plates are conspicuous in the arm angle when viewed from above.

The granules on the abactinal plates are larger in the center than near the margin of the plates and are rounded to polygonal, convex and number 16–19/mm<sup>2</sup> in the center of the plates. Between the plates and in the papular areas the granules are well spaced and conspicuously smaller, numbering 35–45/mm<sup>2</sup>. The actinal plates have very coarse granules, about 9/mm<sup>2</sup> in the center of the plates decreasing towards the edge but the granules between the plates are not as small as those of the abactinal surface.

In the superomarginal series of 38–40 plates, large, slightly convex plates tend to alternate with smaller ones on the distal half of the arms. There are no intermarginal plates. The inferomarginals number 37 to 40, regularly decreasing in size on the outer half of the arms. The terminal plate is covered in coarse granules and on two rays have, in addition, one to three spinelets.

The papular areas are fairly small with up to 12 pores abactinally, nine intermarginally and only an odd group of two or three pores actinally, between the inferomarginal and actinal plates.

One series of actinal plates extends to three quarters of the arm length and a second series consists of two plates on each side of the arm angle. The ambulacral plates bear four furrow spines all of nearly the same length, three subambulacral spines, the middle one of which is the stoutest, and one to three enlarged granules on the outer part of the plate, distinct from the granulation of the adjacent actinal plates.

There are seven oral spines and four stout suboral spines continuing the furrow

and subambulacral series. There are no pedicellariae.

The madreporite lies nearer the margin than the center of the disc and equals the smaller disc plates in size.

This species is so far known only from Palau and North Queensland.

REMARKS: This specimen represents a new species which has also been found in North Queensland. It is being described by F. W. E. Rowe, of the Australian Museum Sydney, Australia, who is currently revising the genus *Nardoa*. This species and *N. tumulosa* recorded by Hayashi (1938b) are both represented by a single specimen from Palau but they seem to belong to two distinct species. Hayashi's specimen had short, rapidly tapering rays compared with the long gradually tapering arms of the present specimen. The former also had relatively large plates near the arm ends and lacked alternating large and small marginal plates. From Hayashi's figure (1938b, pl. 4, fig. 7), the enlarged abactinal plates appear to be rather crowded, not interspersed with small plates as in the present specimen.

#### *Ophidiaster granifer* Lütken

Lütken, 1872: 276; H. L. Clark, 1921: 81-82, pl. 7, fig. 1, pl. 29, figs. 3, 4; Hayashi, 1938b: 437-439, pl. 2, figs. 9, 10.

*Ophidiaster trychnus*, Fisher, 1913: 215; 1919: 390-393, pl. 84, fig. 5, pl. 95, figs. 6, 6a-d, pl. 103, figs. 2, 3, pl. 107, fig. 6.

MATERIAL EXAMINED AND LOCALITIES: South passage, Iwayama Bay, Koror I., coll. M. Yamaguchi, 17. VIII. 1974, 2 spec. coll. by snorkel, under dead coral thicket, R/r 25/5 mm, br 5.5 mm, R/r 20/4 mm, br 4.5 mm; south side of Auluptagel I., coll. L. M. Marsh, 1. VII. 1974, 3 spec. under rocks on reef crest, R/r 33/6 mm, br 6 mm, 30/6 mm, br 6.5 mm, 12/2.5 mm, br 3 mm.

REMARKS: The ground color of four of the specimens is beige, blotched with brown or dark grey. One specimen is pale grey with violet markings and arm tips. This species is characteristic of the under stone fauna of intertidal reefs and shallow sublittoral, with moderate wave action, and is more common in Palau than the material at hand suggests.

#### *Ophidiaster robillardii* de Loriol

Fig. 6

Loriol, P. de 1885: 24-27, pl. 15, figs. 1-5; H. L. Clark, 1921: 84; Marsh (in press).

*Ophidiaster lorioli*, A. H. Clark, 1952: 287.

MATERIAL EXAMINED AND LOCALITIES: Malakal I., coll. M. Yamaguchi, 15. VIII. 1974, 1 spec. coll. by snorkel, R/r 24/3 mm, br 3 mm; Ngadarak reef, coll. M. Yamaguchi, 21. VI. 1975, 1 spec. coll. by snorkel, R 26 mm (comet); south passage of Iwayama Bay, coll. M. Yamaguchi, 17. VIII. 1974, 6 spec. coll. by snorkel, R/r from 16/2.5 mm to 25/4 mm; south passage of Iwayama Bay, coll. M. Yamaguchi, R. S. Rideout and G. A. Heslinga, 19. VI. 1975, 26 spec., R/r from 13/2.5 to 30/4 mm; Auluptagel I., coll. R. S. Rideout and G. A. Heslinga, 23. VI. 1975, 16 spec., R/r from 19/3 mm to 45/4 mm; Ngargol I., coll. R. S. Rideout and G. A. Heslinga, 13-14. VI. 1975, 149 spec., coll. at low tide in 2 hours, R/r from 17/3.5 mm to 39/4 mm; bay behind Kwannon I. on south side of Koror I., coll. L. S. Cieresko, 2. VII. 1974, from base of hydroid, 0-1 m at low tide, R 20 mm (comet).



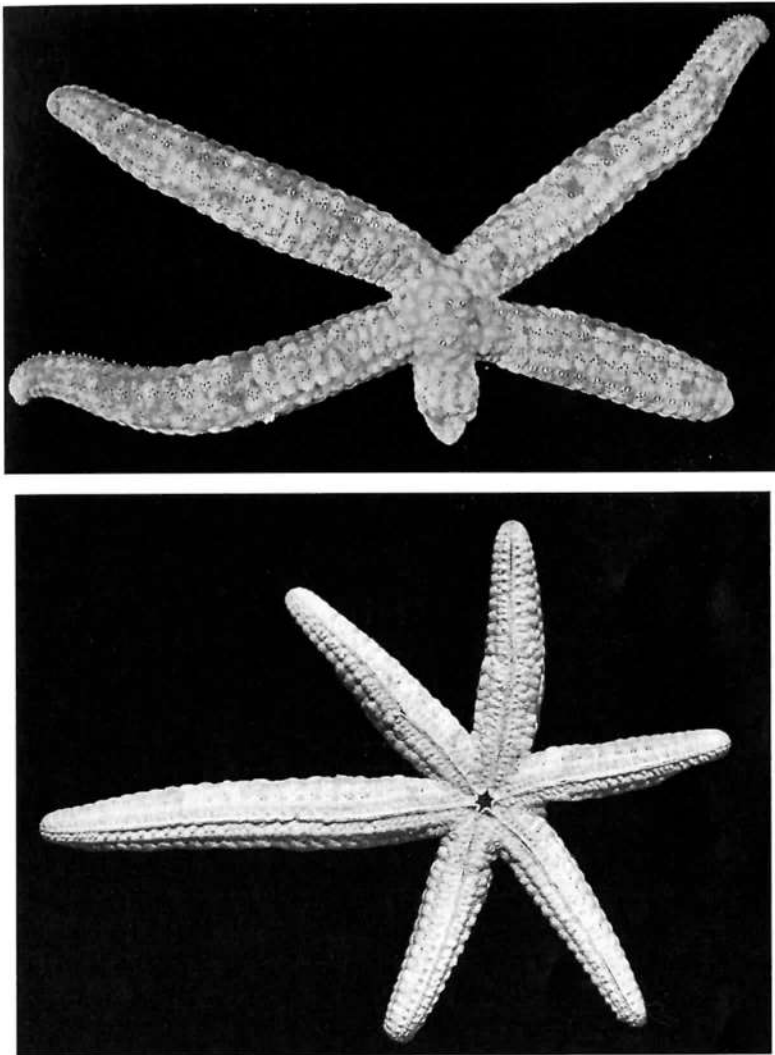


Fig. 6. *Ophidiaster robillardi*, Ngargol I. *a* abactinal, R=35 mm., *b* actinal, R=29 mm.

**DESCRIPTION:** A small *Ophidiaster*, usually five rayed but with arms of irregular length due to asexual reproduction by autotomy; comet forms are very common. The arms are often slightly constricted at the base, widest in the middle and taper to the tip; R/r from 5.2 to 11.3: 1. Two madreporites and two anal apertures are usual.

The skeletal plates of the arms are subcordate and imbricate slightly, the narrower proximal end of one plate overlapping the broader distal end of the previous one. The papular areas are fairly small with calcareous grains in the skin. Papulae are in 8 rows with 4 to 6 pores per area in specimens of 30 mm R and 8

pores in the largest specimen of 45 mm R. They decrease to one or two per area near the ends of the rays. The single series of actinal plates almost reaches the tip of the ray, two actinal plates corresponding to each inferomarginal. The adambulacrals each bear two blunt subequal furrow spines and proximally an oval subambulacral spine; distally the subambulacral spines are usually on every second plate but there is some irregularity. The oral and suboral spines are undifferentiated from the furrow and subambulacral spines.

The skeleton is covered by a granulose skin, the granules larger in the center of the plates (9–10 per mm) than near their edges or in the papular areas, where there are 15 per mm in specimens of 35–40 mm R. Granules near the furrow and on the actinal plates tend to be squamous, particularly in large specimens. As in *Linckia laevigata* the actinal granules partly cover the outer side of the furrow spines making the furrow armature appear granuliform. Granules occur sporadically between the furrow spines, either between pairs or between individual spines. They are often absent from part or all of a furrow, particularly in specimens of less than 20 mm R.

Pedicellariae are large, excavate, with 5–8 teeth fitting into sunken toothed alveoli. They occur near the anus, in the papular areas above the superomarginals, below the inferomarginals and in the actinal interradiial areas.

Living specimens are generally dark colored, mottled with brown, purple, deep rose pink and beige. The madreporite is often orange. The actinal surface is lighter, paling to cream along the furrow. Dry specimens retain their mottled appearance but the colors change to pink, orange and yellow after formalin preservation.

REMARKS: 200 specimens of *O. robillardi* were examined ranging in size from R/r of 13/2.5 to 45/4 mm, most are between 20 and 40 mm in R. R:r varies from 5.2 to 11.3:1. 174 of the specimens (87%) have 2 madreporites, five have one, three have three and one has four (a duplication of each of the two madreporites). The remainder are single rays or comets in which the madreporite is not yet developed. Most specimens have 2 anal apertures, one has a single one and one has three. The species reproduces asexually by autotomy so that a symmetrical specimen is rare (14 of the 200) but five rays is the normal number, there are six six-rayed specimens and one with four rays. Fifty-two, (26%), of the specimens are comets in various stages of regeneration.

The comet with the smallest developing rays has R of 24 mm (the primary ray) two developing lateral rays of 1.5 mm and two median rays of 1.2 mm R, with only partially developed furrows. A madreporite is beginning to develop in the arm angle on each side of the main ray and two anal apertures are beginning to differentiate; there is a distinct mouth. A specimen with developing rays 3 mm in R has a clearly differentiated madreporite on each side of the main ray in the arm angle and two distinct anal apertures, one on each side of the first radial plate. Papular pores are not visible on arms of 3 mm but are distinct at 5 mm. Pedicellariae near the anus are present when R is 9 mm or more; they appear on the

actinal surface, interradially, at R of 10 mm and a few on the arms above the superomarginal plates at 13 mm; at R of 15 mm a series of pedicellariae is usually present above the superomarginal plates. The two lateral rays tend to develop slightly faster than the two middle rays and are still 1 mm longer at R of 20 mm in most cases. Occasional granules between the furrow spines first appear at R of about 12 mm. The specimens agree closely with de Loriol's description except where he states that the abactinal granules are all of equal size. However his Pl. 15, fig. 2a shows the granules larger in the center of the plates, as they are in the present specimens.

Palau specimens were compared with examples of *O. robillardi* from Mauritius (the type locality) and from North Western Australia and agree closely with them, although six rayed specimens are more common among the Western Australian material. *Ophidiaster robillardi* is also known from Guam (Yamaguchi, 1975). It is possible that a specimen from Japan tentatively identified as *O. lorioli* Fisher by Hayashi (1938c) should be referred to as *O. robillardi*. Specimens from the Ogasawara Islands identified as *O. cribrarius* Lütken (Hayashi, 1938a) also appear from the description and figures to belong to *O. robillardi* and not to *O. lorioli* as suggested by Marsh (1974). A specimen from Enewetak Atoll (USNM E7517) identified as *O. lorioli* by A. H. Clark (1952) has been examined by the author; it has five tapering arms of unequal length and two madreporites and is considered by the author to represent *O. robillardi* rather than *O. lorioli*.

The distribution of *O. robillardi* is thus extended from the Indian Ocean to the Western Pacific while *O. lorioli* seems to be confined to the islands of Polynesia.

*O. robillardi* may be distinguished from *O. lorioli*, its nearest congener, principally by the shape of the rays and its habit of asexual reproduction. The former has tapering, pointed rays usually of irregular length due to autotomy while *O. lorioli* has regular, cylindrical, blunt ended rays except in very large specimens in which they taper slightly. *O. robillardi* usually has two madreporites and two anal apertures while *O. lorioli* less frequently has two. In twenty specimens of *O. lorioli* examined (Marsh, 1974) there was no evidence of asexual reproduction despite the presence of two madreporites in some specimens. *O. robillardi* has a convex disc with irregularly arranged plates centrally while *O. lorioli* of the same size has a nearly flat disc with regularly arranged plates. However very large specimens have a more convex disc with some irregularity in the plate arrangement centrally.

The two species appear to differ in color, *O. robillardi* dark and mottled, while the specimens of *O. lorioli* examined (dry) were all unicolorous; deep orange in the largest specimens to white in the smallest. Hawaiian specimens are yellowish (Fisher, 1906).

In other respects, R/r ratio, abactinal granulation, number of papulae per area, granules between the furrow spines and pedicellariae both species show the same range of variation.

Flattening of the arms in *O. robillardi*, used in Clark's (1921) key is probably an artifact of preservation since all the specimens examined, including one from

Mauritius have the rays circular in section.

*O. cribrarius*, another fissiparous species, of similar appearance to *O. robillardi*, was distinguished from the latter by de Loriol (1885) by its more numerous small pedicellariae with few teeth in larger papular areas with 10–12 pores. I have compared the BMNH specimen of *O. cribrarius* from Tonga, the type locality, (ex Goddefroy Museum), with specimens of *O. robillardi* of the same size and find little difference in the size of the papular areas but the pedicellariae are narrower and much less conspicuous; there are 2–3 to most papular areas in the lower three series, few in the abactinal papular areas. The alveoli of the pedicellariae are narrower than those of *O. robillardi* and swollen instead of flat surfaced; they are slightly shorter and the jaws have about 3 (2–4) irregular teeth in contrast to the 5–8 claw-like teeth of the pedicellariae of *O. robillardi*.

## ASTERINIDAE

### *Asterina anomala* H. L. Clark

Fig. 7.

Clark, H. L., 1921: 95–96, pl. 7, fig. 8, pl. 23, fig. 5, pl. 26, figs. 2, 3; Clark and Rowe, 1971: 68; Marsh, 1974: 92.

MATERIAL EXAMINED AND LOCALITIES: Ngargol I., coll. R. S. Rideout and G. A. Heslinga, -. VI. 1975, six specimens, R/r from 8/4 mm to 10/5 mm; Ngadarak Reef, coll. M. Yamaguchi, 21. VI. 1975, 4 spec. coll. by snorkel, R/r from 6/3.5 mm to 7/4 mm.

DESCRIPTION: A small fissiparous species of *Asterina* with 6–8 rays, often four large and three or four regenerating rays. The rays are convex aborally, flat orally and R: r varies from 1.7: 1 to 2: 1 in the Palau specimens.

The abactinal skeleton is composed of imbricating plates, the exposed portion of which is crescentic, usually with a single papular notch. A few plates are four lobed with two notches. The papulae are in six rows on the larger and four on the smaller rays with scattered papulae on the disc. The larger abactinal plates bear a crescentic row of about ten thorny spinelets and the actinal plates a group

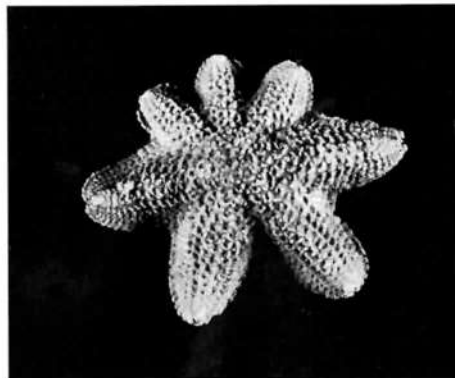


Fig. 7. *Asterina anomala*, Ngargol I., R = 8 mm.

of three or four. The actinal plates are in five series in the largest specimens, the one nearest the furrow extends to the arm tip, the second nearly to the arm end, the third to about two thirds of the arm length, the fourth to one third, and the fifth consists of a few plates in the arm angle.

The furrow spinelets are in webbed fans of 6-8 flattened spinelets, broader near the tip than the base and with a rough surface. The oral plates bear 6-8 oral spines, the innermost longest and widest, the remainder gradually decreasing in size. They are flattened and rough surfaced like the furrow spines. The subambulacral spinelets are in groups of 3-5 and thorny, like the actinal spinelets. The oral plates bear a curved series of three, thorny, suboral spines larger than the subambulacrals. There are two, occasionally three madreporites.

REMARKS: The specimens agree in most respects with the description of the holotype but differ in the number of madreporites and rows of actinal plates. However, the specimens match material from Lord Howe Island (Australia), in the Western Australian Museum, identified by H. L. Clark. Some of these, larger than the type, have three madreporites and five series of actinal plates. The number and form of the furrow spines agree but the Lord Howe specimens have a few more spinelets on the abactinal plates than the Palau specimens.

Clark and Rowe (1971) suggest that *A. anomala* may be conspecific with the syntype of *A. burtoni* which has five madreporites and was therefore potentially fissiparous. Until the nomenclature is definitely resolved it seems better to retain the name *A. anomala* for the small fissiparous Pacific species.

*Asterina corallicola* n.sp.

Figs. 8, 9.

Holotype and type locality: One dry specimen, USNM: coll. R. S. Rideout, G. A. Heslinga, and M. Yamaguchi, at 10 m. on a patch reef north of Koror I., Palau, Caroline Islands, 9. II. 1971.

Paratypes: thirteen specimens, data as above, disposed as follows: USNM, BMNH, WAM No. 877-76 (3), AM No. J10257 (2), BPBM No. W2508 (2).

Etymology: Lat. corallium-coral; colo-to inhabit.

DESCRIPTION OF HOLOTYPE: A very small stellate *Asterina* with a convex disc and six rather narrow pointed, strongly convex rays. The lower surface is flat to concave. R/r 7/3.3 mm, R: r=2.1: 1, br at base of ray is 3.47 mm, vh at base of ray and at the center of the disc is 2.1 mm. The R measurement (above) is of the longest ray; the remainder measure 6.0, 5.7, 5.1, 4.9 and 4.5 mm in R; R: br=2.0: 1. There are five madreporites, irregular in shape and rather sunken between the plates in the interradii. Two small anal apertures lie on either side of the central disc area. Papular pores are large and conspicuous on the rays but are not in distinct rows. They are absent from the central area of the disc, the arm ends and the lower lateral and interradiial areas.

The plates of the central disc are small, oval, circular or irregular in shape and size. Surrounding these and extending on to the radial and interradiial areas are

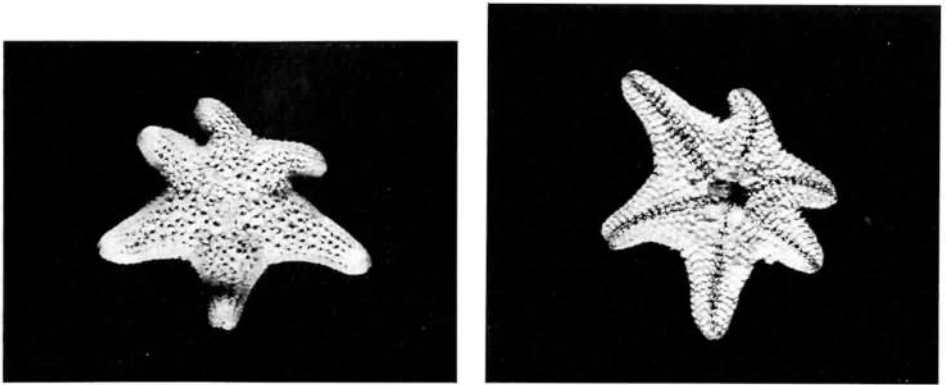


Fig. 8. *Asterina corallicola*, Holotype, Koror lagoon, R=7 mm. a abactinal, b actinal.

relatively large imbricating stellate plates, deeply notched for papulae (Fig. 9a). Laterally and distally they give way to smaller squarish or rectangular plates with a single notch at their upper edge; because of the imbrication of the plates the exposed parts appear crescentic. The abactinal plates are densely covered in tapering, rough tipped spinelets (Fig. 9b) which are easily dislodged and are lost from many of the plates in the Holotype. The largest plates carry up to 15 spinelets.

The carinal series of plates, consisting of 15 plates on the longest ray, and two lateral series on either side reach the terminal plate. A third series extends nearly to the arm end, the next two rows reach to less than half the arm length and a sixth series is represented by a few plates interradially. All the plates have minute crystal bodies (hemispherical glassy beads on the surface of the skeletal plates). The terminal plate is rounded, convex and bare in the holotype but granule covered in one of the paratypes.

The superomarginals are rounded to squarish, fairly prominent and number 17 on one side of the longest ray. Each carries a group of 4 to 7 tapering spinelets. The inferomarginals are imbricating, crescentic plates which project slightly beyond the superomarginals, particularly near the arm ends. They correspond in number with the superomarginals, are opposite them near the arm end but tend to alternate with them midway along the arm. Each bears 6 to 8 tapering spinelets.

The actinal plates are rounded, slightly imbricating, each with 2 or 3 tapering, slightly rough tipped spinelets (Fig. 9c). The series next to the adambulacra extends to the 13th or 14th inferomarginal, the next row to the 10th or 11th, the third row to the 6th, the 4th to the 5th inferomarginal and the 5th consists of a few interradiial plates extending to the second inferomarginal.

The slightly webbed furrow spines are in a fan of four flattened, straight-sided spinelets with five proximally and three distally. The thorny subambulacral spines are in groups of three, sometimes four, proximally and two distally (Fig. 9d). Each oral plate bears six flattened, blunt-ended furrow spines, the two innermost nearly equal in size and considerably larger than the remaining four, each of which is smaller

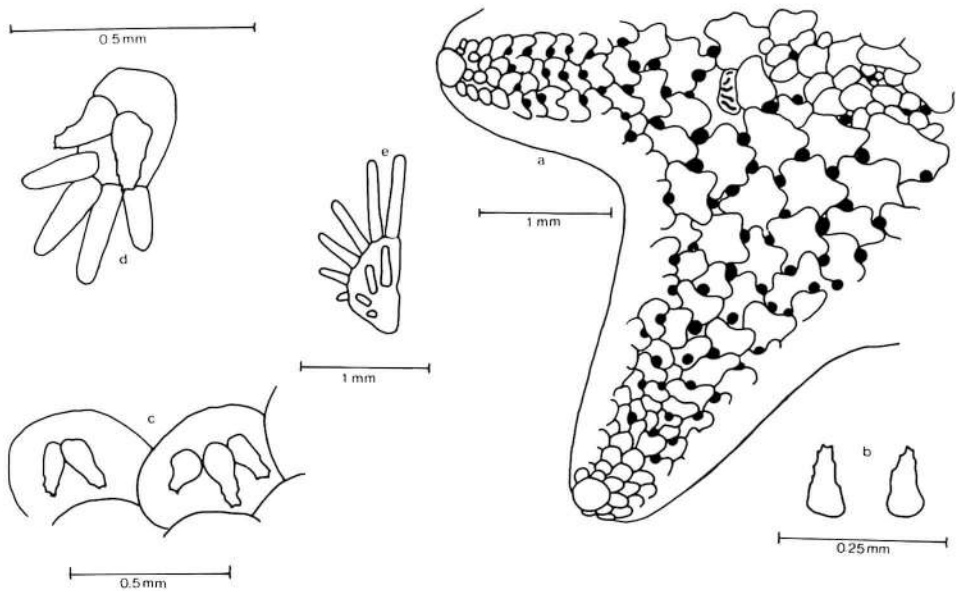


Fig. 9. *A. corallicola*, Holotype. a part of denuded abactinal surface; b abactinal spines; c actinal interradial plates; d an adambulacral plate showing furrow and subambulacral spines; e a single oral plate.

than the previous one. The surface of the plate bears a curved series of four blunt-tipped, slightly tapering suboral spines (Fig. 9e).

The species is apparently mature at a small size since a specimen with R of 5 mm had mature ovaries.

There is no record of the color in life.

This small subtidal asterinid is known only from the type locality, a patch reef north of Koror, Palau, where large numbers were found feeding on coral (*Acropora echinata*) at a depth of about 10 meters.

**VARIATIONS:** The thirteen paratypes show some variation in the number of rays but only a single specimen is five rayed (Table I). Six rays may be regarded as the normal number, found in eleven of the fourteen specimens.

R/r varies from 7/3.3 to 3.1/1.9 mm and R:r from 1.55 to 2.12:1; R:br varies from 1.55 to 2.33:1. There are from three to five madreporites but in several specimens they could not be distinguished without denuding the plates so remain uncounted in those examples.

One of the paratypes has small rough granules on the terminal plate of one ray. They are lost from the holotype and other paratypes.

Eight specimens have three rays shorter than the remainder, the rest have the rays equal or nearly equal in length. The species is therefore regarded as fissiparous.

The small specimens have fewer actinal plates than the holotype, in only three series, the third consisting of one or two plates in the arm angle. Furrow spines are reduced to three (four proximally) in small specimens and the subambulacrals

Table 1. Variation in *Asterina corallicola* n.sp.

	max. R mm	max. r mm	R: r	br mm	vh (center)	No. of madreporae	No. of rays	
Holotype	7.0	3.3	2.12	3.5	2.1	5	6	3 rays shorter
Paratype	5.4	2.8	1.93	3.1	1.6	3	5	rays equal
"	5.35	2.8	1.91	2.3	2.3	4	6	" "
"	5.3	2.7	1.96	2.3	1.6	—	7	3 rays shorter
"	5.0	3.0	1.66	2.3	1.8	5	6	rays equal
"	4.5	2.7	1.66	2.5	1.5	4	6	" "
"	4.3	2.3	1.87	2.2	1.8	3	6	rays subequal
"	4.3	2.2	1.95	2.2	1.6	4	6	3 rays shorter
"	4.3	2.1	2.05	2.2	1.7	3	6	3 " "
"	4.0	2.0	2.0	2.2	1.5	4	6	3 " "
"	3.8	2.2	1.73	2.2	1.3	—	6	3 " "
"	3.4	2.2	1.55	2.2	1.3	3	6	3 " "
"	3.3	2.1	1.57	2.0	1.0	—	6	3 " "
"	3.1	1.9	1.63	1.9	1.3	—	7	rays subequal

Table 2. Comparison of three fissiparous species of *Asterina*.

<i>A. anomala</i>	<i>A. heteractis</i>	<i>A. corallicola</i>
Rays 6–8, usually 7	Rays 6–7	Rays 5–7, usually 6
Max. recorded R=12.5 mm R=1.7 to 2.0 r	Max. recorded R=7 mm R=1.75 r	Max. recorded R=7 mm R=1.55 to 2.12 r
Rays narrow, high, blunt ended	Rays narrow, high, blunt ended	Rays narrow, high, pointed
Abactinal plates crescentic imbricated usually with 1 papular notch.	Abactinal plates irregular, imperfectly imbricated.	Abactinal plates stellate or crescentic often with 2 or more papular notches.
Abactinal spinelets numerous, thorny, partly glassy.	Abactinal plates with 3–4 low blunt spinelets, not thorny, opaque, not glassy.	Abactinal plates with numer- ous, tapering thorny spinelets, partly glassy.
3–5 series of actinal plates each with 3–5 thorny spine- lets.	3 series of actinal plates with 1–3 (usually 2) short sharp spinelets, not thorny.	3–5 series of actinal plates with 2–3 (occ. 4) slightly rough spinelets.
6–8 (4–5 in the type) flattened furrow spines, broadest at the tip.	3–4 short blunt furrow spines.	4 flattened furrow spines, not widest at tip.
3–5 (3 in the type) thorny subambulacral spines.	3 subambulacral spines set at an angle.	3 thorny subambulacral spines.
6–8 oral spines, larger ones widest at the tip.	4 large opaque spines, inner- most not much larger than the others.	5–6 oral spines, two innermost larger, flattened, not wider at the tip than at the base.
3 thorny suboral spines.	1–2 suboral spines, not thorny.	3 tapering suboral spines, not thorny.
2–3 madreporites (1 in the type).	1 madreporite	3–5 madreporites
Habitat—under intertidal rocks and in coral crevices	under rocks on sand	feeding on coral, sublittoral.
Color—red, green, rust	color salmon pink	color not recorded.



reduced to two. There are five oral and three suboral spines in most of the paratypes.

REMARKS: *Asterina corallicola* is very closely related to two other small fissiparous species, *A. anomala* Clark and *A. heteractis* Clark.

Although the differences between them are rather minor (Table II) the species can be separated by the character of the abactinal plates and spinelets, the furrow spines and particularly the oral and suboral spines. The most obvious difference is one of gross morphology, *A. corallicola* usually has six rather pointed rays while *A. anomala* has seven or eight blunt rays.

Probably the most important difference is ecological; *A. anomala* is a secretive species usually found intertidally under coral boulders or in coral crevices while *A. corallicola* is a gregarious species found feeding on the surface of living coral subtidally. *A. heteractis* lives under rocks resting on sand and is known only from Lord Howe Island, Australia.

It is with some hesitation that I have described this little *Asterina* as a new species but it seems to be distinct from *A. anomala* also found in Palau.

#### *Patiriella pseudoexigua* Dartnall

Dartnall, 1971: 43–45, pl. 3(a).

*Patiriella exigua*, Fisher, 1919: 416–417, pl. 109, figs. 3.4; ? Hayashi, 1938b: 439–440, pl. 3, figs. 5, 6.

MATERIAL EXAMINED AND LOCALITY: Koror I., coll. T. R. Fisher, 25. X. 1968, BPBM No. W1780, under rocks on landward edge of mangroves near high tide mark, R/r 18/10 mm.

REMARKS: The single specimen is pentamerous, R: r=1.8: 1. The abactinal plates bear granule-like spinelets; the actinal plates near the margin each have one spine while many others are bare; there are two furrow spines and one subambulacral on each adambulacral plate; each oral plate has three oral spines and one suboral spine; the innermost oral spine is flattened and truncate. The gonopores open abactinally.

Dartnall (1971) has divided *Patiriella* of the "exigua" species group into true *exigua* from temperate waters, with actinally directed gonopores and a new species, *pseudoexigua*, with abactinally directed gonopores, found north of 28°S in Australia and in Borneo, the Philippines, Solomon Islands and the New Hebrides.

A. J. Dartnall has kindly examined the present specimen and confirmed that it is *P. pseudoexigua*. It is probable that the specimen recorded by Hayashi (1938b) as *exigua* should also be referred to this species.

#### ACANTHASTERIDAE

##### *Acanthaster planci* (Linnaeus)

*Asterias planci* Linnaeus, 1758: 823.

*Acanthaster planci* Verrill, 1914: 364; Hayashi, 1938b: 442–444, pl. 4, figs. 3, 4.

MATERIAL EXAMINED AND LOCALITY: MMDC, Malakal I., coll. G. A. Heslinga, 31. V. 1975, 1 spec. coll. by snorkel, R/r 55/24 mm.

REMARKS: A single specimen is included in the present collection. The author observed one on the reef at Ngerameayus Island but none was seen at the other localities visited. Hayashi (1938b) found *Acanthaster* to be common in the Arakabesan region.

The distribution and abundance of *Acanthaster planci* in Palau during the years 1969 to 1972 has been recorded by Chesher (1969), Tsuda (1971) and Marsh and Tsuda (1973).

## MITHRODIIDAE

### *Mithrodia clavigera* (Lamarck)

Fig. 10.

*Asteairs clavigera* Lamarck, 1816: 562.

*Mithrodia clavigera* Perrier, 1875: 378; de Loriol, 1885: 13, pl. 11, figs. 1a-d; Hayashi, 1938d: 216-218, text fig. 1, pl. 2, figs. 8-10.

MATERIAL EXAMINED AND LOCALITIES: South passage, Iwayama Bay, coll. M. Yamaguchi, R. S. Rideout and G. A. Heslinga, 19. VI. 1975, 3 spec. coll. by snorkel, R/r 108/11 mm, br 11 mm, 106/11 mm, br 12 mm, 90/10 mm, br 10 mm; Ngadarak Reef, coll. M. Yamaguchi, 21. VI. 1975, 1 spec. by snorkel, outer reef flat, R/r 98/9 mm, br 9 mm.

DESCRIPTION: The disc is small with five unequal cylindrical rays, slightly constricted at the base and tapering to the tip. The reticulate skeleton and papular areas are covered by granulose skin with small slightly pointed granules and larger pointed granules scattered amongst them. The papular areas are large with about 30 pores to an area. One specimen has numerous small tubercles on the skeletal meshes, topped with six peripheral and a central pointed granule; the other specimens have few or no tubercles.

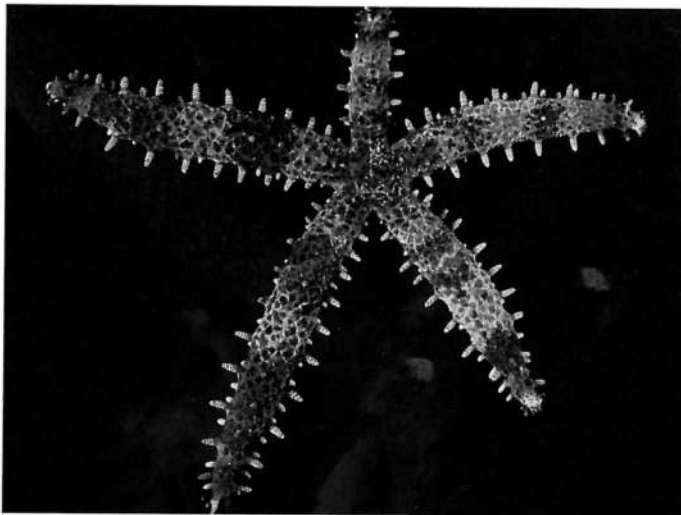


Fig. 10. *Mithrodia clavigera*, Iwayama Bay, R = 108 mm.

There are cylindrical, or slightly tapering, blunt spines, covered in large scale-like granules, on the carinal, supero and inferomarginal, and actinal plates and occasionally on the dorsolateral area. The carinal spines, shorter than those of the superomarginals, vary in number from three to ten on different rays of the largest specimen (108 mm R). There are eleven superomarginal and eighteen inferomarginal spines on the longest rays. The actinal spines approximate the inferomarginals in number and alternate with them.

Each adambulacral plate has a fan of 7-11 furrow spines, the four central ones nearly equal in length, the remainder successively decreasing in size. There is a large subambulacral spine on each plate, bare on its inner face and scale covered on its outer side. The oral and suboral spines are undifferentiated from the furrow and subambulacral spines. Pedicellariae are of variable occurrence, in a series outside the subambulacral spines. Each pedicellaria has a cluster of five, occasionally six, curved teeth as illustrated by Hayashi (1938d).

REMARKS: *Mithrodia clavigera* must be regarded as very uncommon in Palau. No specimens were found by Hayashi or the present author and only four by Yamaguchi despite intensive collecting.

All the specimens are yellow-brown in color with varying amounts of dark brown on the disc and arms, sometimes in 2-3 bands. The papular areas are brown to black.

*M. clavigera* has a wide distribution, from East Africa through the Indo-Pacific to Japan and the western Pacific (Clark and Rowe, 1971).

## ECHINASTERIDAE

### *Echinaster callosus* von Marenzeller

Fig. 11.

von Marenzeller, 1895: 531-532, 1 pl. Fisher, 1919: 428-429, pl. 112, fig. 2; pl. 122, figs. 4, 5; pl. 132, figs. 5a-e.

MATERIAL EXAMINED AND LOCALITY: Ngargol I., coll. R. S. Rideout, 22. VI. 1975, 1 spec. by snorkel, R/r 122/12 mm, R 10.2 r, br 12 mm.

DESCRIPTION: The disc is small with five more or less equal rays, slightly constricted at their base, then tapering evenly to a narrow tip. The madreporite is circular, 2.5 mm across, with radiating striations. The skeleton is a very open meshwork with large papular areas but only about 10 papulae to an area. Tapering, pointed spines occur at the angles of the meshes, the largest barely 2 mm long. The marginal plates are almost actinal in position with a group of intermarginal plates in the arm angles. There is a 2 mm spine on about every fourth inferomarginal plate and more widely spaced smaller spines on the superomarginals. The furrow armature consists of a curved spine deep in the furrow and a larger tapering spine, 2.5 mm long, on the furrow edge. Near the mouth an unpaired actinal intermediate plate bears a spine similar in size to those of the inferomarginals.

REMARKS: The specimen agrees closely with the description and figures of *E. callosus* except that the abactinal spines are rather shorter. It differs from *E.*

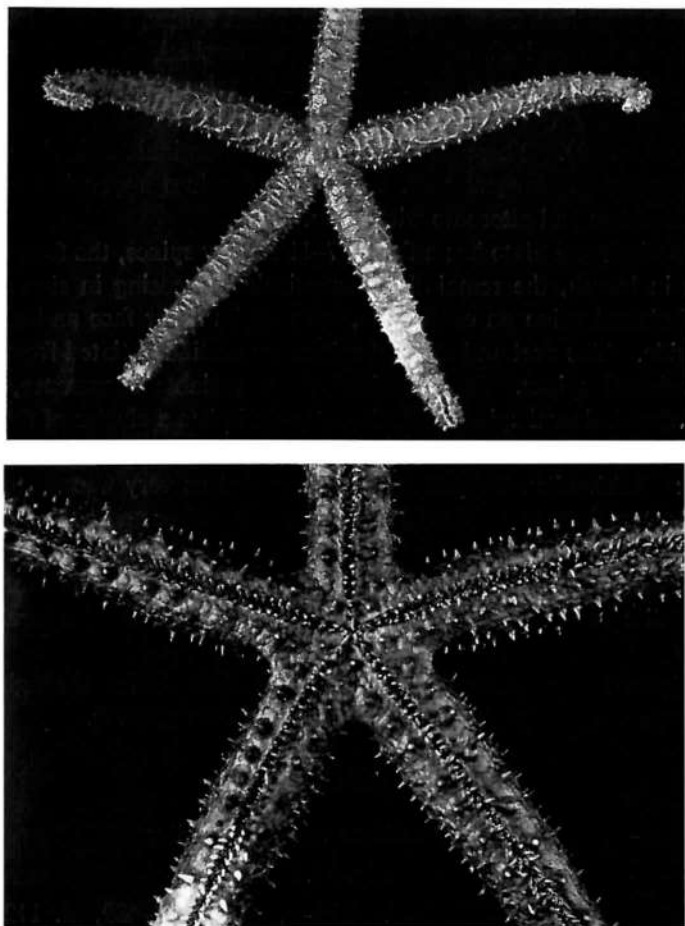


Fig. 11. *Echinaster callosus*, Ngargol I., R=122 mm. a abactinal, b actinal.

*stereosomus* Fisher in having the arms sharply set off from the disc and in the furrow armature.

*E. callosus* is distributed from East Africa (Bell, 1903) through the East Indies to the Solomon Islands (von Marenzeller, 1895).

#### *Echinaster luzonicus* (Gray)

*Othilia luzonica* Gray, 1840: 282.

*Echinaster luzonicus*, Müller and Troschel, 1842: 23; Hayashi, 1938b: 440–442, pl. 3, figs. 5, 6.

MATERIAL EXAMINED AND LOCALITIES: Auluaptagel I., coll. R. S. Rideout, 23. VI. 1975, 1 spec. R/r 96/11 mm; Palau, coll. R. S. Rideout, -. VI. 1975, 2 spec. R/r 62/7 mm and 55/10 mm; Arakabesan, coll. M. Yamaguchi, 8. VII. 1975, 1 spec., coll. by snorkel, R/r 28/4.5 mm; Malakal I., coll. M. Yamaguchi, 31. V. 1975, 1 spec. R/r 36/6 mm; Malakal I., coll. M. Yamaguchi, 13. VIII. 1974, 3 spec. on soft bottom near boulders, R/r 30/7 mm, 29/4.5 mm and 30/5 mm;

Ngargol I., coll. R. S. Rideout and G. A. Heslinga, -. VI. 1975, 4 spec., R/r from 14/3.5 mm to 62/8 mm; Malakal I., coll. M. Yamaguchi, -. VIII. 1974, 5 spec. coll. by snorkel, R/r from 40/6 mm to 70/8 mm; Malakal I., coll. R. S. Rideout and G. A. Heslinga, -. VI. 1975, 10 spec., coll. by snorkel, R/r from 30/6 mm to 107/12 mm; MMDC, Malakal I., coll. M. Yamaguchi, 28. VI. 1975, 5 spec. coll. by snorkel, R/r from 52/8 mm to 65/9 mm; Ngerameayus I., coll. L. M. Marsh, 30. VI. 1974, 1 spec. on coral, 1-2 m, R/r 60/10 mm.

REMARKS: There are 33 specimens in the present collection ranging in size from R/r of 14/3.5 mm to 107/12 mm giving a R:r ratio from 4.0 to 8.9:1. Six rayed specimens are the most common (19 specimens), eleven have five rays and three have seven rays. Two madreporites are usual (30 specimens) while 3 have a single madreporite (including the 7 rayed specimen).

In the dry state all the specimens are red-brown but color notes with the Malakal specimens indicate that some were bright orange and others dark green when alive.

*E. luzonicus* seems to be moderately common on the Palau reefs.

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