Sea Stars of Families Ophidiasteridae and Goniasteridae (Echinodermata: Asteroidea) from the Mesophotic Zone of the Ogasawara Islands, Including Two New Species

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Five species of sea stars of the families Ophidiasteridae and Goniasteridae including two new species, Bathyferdina caelator sp. nov. and Fromia labeosa sp. nov., were collected by dredging from the mesophotic zone of the Ogasawara Islands, Japan. Bathyferdina caelator is distinguished from B. aireyae Mah, 2017 by the presence of glassy bosses (crystal bodies) on actinal and adambulacral plates and the absence of them on marginal plates. Fromia labeosa has large, elliptical pedicellariae on the actinal plate and is further distinguished from its congeners based on characters of the abactinal and superomarginal plates, granules, actinal papulae, furrow spines, and the subambulacral spines. We also provide descriptions for three mesophotic species, Fromia eusticha Fisher, 1913, Ogmaster capella (Müller and Troschel, 1842), and Tama-ria tenella (Fisher, 1906), which are poorly studied in Japanese waters.

Key Words: Bonin Islands, Valvatida, starfish, marine invertebrates, new species, Japan.

Introduction

The Ogasawara Islands are oceanic islands located approximately 1000 km south of Japan’s mainland. The islands are in the subtropics and inhabited by tropical/subtropical marine animals (Imajima 1970). The sea star fauna of the Ogasawara Islands was first reported by Hayashi (1938), who described six shallow-water species. Subsequent reports on the marine diversity further recorded shallow-water sea stars from this region (Imajima 1969; Shigei 1970; Amemiya and Yanagisawa 1991). However, these reports provide no morphological description, pictures, or information on preserved specimens of each species. Pope and Rowe (1977) described a single individual of Thromidia catalai Pope and Rowe, 1977 from Chichi-jima Island of the Ogasawara Islands. Saba (2011) listed ten species occurring in the islands with photographs and short notes on their morphological characters. Fujita et al. (2015) recorded fourteen species from the islands with images of live individuals and vouchered specimens. All studies of asteroids from this region were conducted primarily in shallow water (<45 m), with only a single deep sea record (550 m) in this region by Kogure and Tachikawa (2009), who described Astroceramus boninensis Kogure and Tachikawa, 2009 from east of Haha-jima Island.

In this study, we sampled sea stars from a previously unstudied depth ranging 50–160 m with biological dredges. This depth range corresponds to the mesophotic zone, which is often recognized as depth range from 30 to 150 m (Baldwin et al. 2018). The mesophotic zone is known to harbor characteristic fauna differentiated from neighboring communities in shallower reef or deep water for fish, scleractinian corals, and other invertebrate taxa including echinoderms (Laverick et al. 2017; Semmler et al. 2017; Baldwin et al. 2018). Although there has been no study explicitly mentioning the significance of sea stars in the mesophotic zone, Mah (2003) suggested high possibility of finding new sea star species from the depth range of 60–200 m, which is difficult to explore because of the depth limit of conventional SCUBA diving and steep, rocky substrate to prevent dredging. Several new or rarely found taxa of sea stars have been reported thereafter from the subtropical/tropical mesophotic zone with various sampling methods such as mixed-gas diving, manned and unmanned submersibles, or dredging (Mah 2003; Pawson 2007; Kogure and Fujita 2012). Here we describe five species of sea stars of the families Ophidiasteridae and Goniasteridae, expanding knowledge of the sea stars occurring in the mesophotic zone of the Ogasawara Islands.

Materials and Methods

The examined specimens were collected from the Ogasawara Islands, Japan, using biological dredges lined with 5 mm mesh operated by three vessels: R/V Koyo of Tokyo Metropolitan Ogasawara Fisheries Center, TR/V Shinyo-maru of the Tokyo University of Marine Science and Technology, and R/V
Table 1. Locality, coordinates, depth, date, and substrate of sampling stations. Prefix of the stations represents the vessel as follows. KY: R/V Koyo, SY: R/V Shin’yo-maru, KT: R/V Tansei-maru.

| Station | Locality                  | Latitude     | Longitude    | Depth (m) | Date           | Substrate     |
|---------|----------------------------|--------------|--------------|-----------|----------------|---------------|
| KY-08-21| East of Chichi-jima        | 27°3.84’N    | 142°15.44’E  | 95–98     | 29 October 2008| Sand          |
| KY-08-25| West of Nishi-jima         | 27°7.31’N    | 142°7.70’E   | 127–129   | 30 October 2008| Sand, coral, shell |
| KY-09-21| Northwest of Ototo-jima    | 27°13.09’N   | 142°9.19’E   | 135.5–135.8| 15 July 2009   | Mysis shell   |
| KY-10-31| West of Hutami Port, Chichi-jima | 27°5.18’N | 142°8.48’E   | 96.5–96.8 | 9 July 2010    | unknown       |
| KY-16-06| Northwest of Ototo-jima    | 27°13.104’N  | 142°9.091’E  | 135–137   | 11 July 2016   | unknown       |
| KY-16-09| East of Chichi-jima        | 27°3.836’N   | 142°15.353’E | 90.5–94.6 | 11 July 2016   | Pebble, Sand  |
| KY-16-14| East of Ototo-jima         | 27°9.407’N   | 142°12.163’E | 56.6–62.9 | 12 July 2016   | Boulder       |
| KY-17-24| West of Minami-jima        | 27°1.182’N   | 142°7.269’E  | 147–149   | 20 July 2017   | Pebble        |
| SY-09-21| West of Ototo-jima         | 27°12.80’N   | 142°5.13’E   | 159–161   | 18 November 2009| Sand         |
| KT-09-2-TW1-1| West of Chichi-jima   | 27°1.40’N    | 142°7.41’E   | 138.6–145.2| 19 March 2009  | unknown       |

Fig. 1. Sampling stations. See Table 1 for the detailed information on each station.

**Taxonomic Accounts**

Family **Goniasteridae** Forbes, 1841

Subfamily **Ferdininae** Mah, 2017

Genus **Bathyferdina** Mah, 2017

[New Japanese name: Koyo-akamon-hitode-zoku]

**Diagnosis (emended).** Body flat on both sides, disc broad with five short arms. Abactinal plates homogenous in size. Marginal plates significantly larger than abactinal plates, and gradually decrease in size toward the arm tip. Abactinal, marginal, actinal and adambulacral plates covered with skin containing granules. Skin absent on circular or quadrate bare areas on marginal plates. Either or both abactinal, marginal, actinal and adambulacral plates have glassy bosses (crystal bodies) on their surface. Furrow spines arranged in a single longitudinal series. Actinal surface of adambulacral plates covered with skin and granules, but devoid of spinelets, enlarged granules or other accessories.

**Remarks.** This diagnosis is emended from Mah (2017) to include presence of glassy bosses on actinal and adambulacral plates. For details see remarks under *B. caelator* sp. nov.

**Type species.** *Bathyferdina aireyae* Mah, 2017

**Species included.** *Bathyferdina aireyae; B. caelator* sp. nov.
Fig. 2. Abactinal view of the live specimens (A–D) and ethanol-preserved specimen (E). A, Bathyferdina caelator sp. nov., NSMT E-8265, holotype; B, Fromia eusticha, NSMT E-10595; C, Fromia labeosa sp. nov., NSMT E-9297, holotype; D, Ognaster capella, NSMT E-9312; E, Tamaria tenella, NSMT E-9277. Scale bars: 10 mm.
Bathyferdina caelator

[New Japanese name: Koyo-akamon-hitode]

(Figs 2A, 3)

Bathyferdina sp.: Arai et al. 2018: 194–196.

Material examined. Holotype: NSMT E-8265, KY-09-21, Northwest of Ototo-jima Island, 135.5–135.8 m. Paratypes: NSMT E-8266, 1 individual, KT-09-2-TW1-1, West of Chichi-jima Island, 138.6–145.2 m; NSMT E-8267, 1 individual, dry, locality unknown.

Diagnosis. A species of Bathyferdina with glassy bosses on abactinal, actinal and adambulacral plates. Disc broad with R/r 2.0–2.3. Abactinal plates are homogeneous in size and shape. Superomarginal plates rectangular to barrel-like in outline, and regularly decreasing in size from the interradius to the tip of arms. Glassy boss/ridge present on abactinal and actinal plates. One or two glassy bosses on the center of each adambulacral plate. Three furrow spines on each adambulacral plate.

Description of holotype. R=23.2 mm, r=9.9 mm, R/r=2.3, width of arm is 11.1 mm at base, 6.6 mm at half of R, and 3.1 mm at 1/10 R from the tip. Body is flat on both abactinal and actinal sides. Arms are five and tapering more greatly near the disc than near the arm tip (Fig. 3A).

Abactinal plates are polygonal to elliptical in shape, not lobed, variable in size, and tessellated so that only small spaces are left for papulae around the corners of these plates (Fig. 3B). Those on the disc are about 1.5–2.0 times larger than those on the arms. The arrangement of abactinal plates is regular, and median rows of plates are conspicuous. Between two upper interradial corners of first superomarginal

Fig. 3. Bathyferdina caelator sp. nov., NSMT E-8265, holotype. A, actinal side; B, abactinal side, abactinal plates partly denuded. Arrows indicate pedicellariae on superomarginal plates; C, arm tip, lateral view. Arrow indicates terminal plate; D, SEM picture of a denuded abactinal plate at proximal portion of the arm; E, pedicellaria on actinal interradial plates; F, actinal, adambulacral and oral plates, partly denuded. Arrow indicates glassy boss on adambulacral plate. Scale bars: 10 mm (A), 1 mm (B, F), 5 mm (C), 0.5 mm (D, E). Abbreviations: ab, abactinal plates; sm, superomarginal plates; im, inferomarginal plates; ac, actinal plates; ad, adambulacral plates; op, oral plates.
plates on a ray, there are seven to nine abactinal plates. The entire abactinal surface of abactinal plates is rough with glassy bosses which are circular around the center of the plate and elongated around the periphery (Fig. 3D). Madrepore is single, 1 mm in diameter, flat and pentagonal with rounded corners; gyri extend radially from the central area where nine discontinuous, short gyri lie in parallel to one another. Terminal plates are conical with a broad base and a narrow rounded apex, smaller than the distalmost marginal plates, smooth and bare without skin or granules (Fig. 3C).

Superomarginal and inferomarginal plates correspond in number and size. There are six (seven on one arm) plates to each side of an arm. Superomarginal plates are rectangular in outline, longer than width, rounded at corners, and conspicuous on the abactinal side; first superomarginal plates are about 3 mm in length and 2 mm in width on the abactinal surface. They gradually decrease in size toward the arm tip where the distalmost superomarginal plates are more squarish, measuring about 1–1.5 mm in both length and width. No glassy boss was observed on any marginal plates.

Actinal plates are quadrangular, regularly arranged, and normally flat except several small plates slightly convex between larger actinal plates (Fig. 3F) and inferomarginal plates are slightly convex. The surface of actinal plates is rough with glassy bosses when denuded of granular skin.

Adambulacral armature is composed of three (distally two) furrow spines on each adambulacral plate (Fig. 3F). Furrow spines are truncated at the tip, prismatic, and quadrangular or triangular in a cross section. The adambulacral plates are rectangular with slightly rounded corners. On the proximal first to tenth adambulacral plates, there are one or two glassy bosses at the center of the plates.

Abactinal, actinal and adambulacral plates are covered with a thin skin concealed by fine granules. On the marginal plates, the skin and granules are limited at the periphery, leaving the rest of the plate surface exposed (Fig. 3B). Papulae are isolated, confined around the abactinal plates except in the abactinal interradial areas where they are absent. There are no papulae on the actinal surface. Most papulae occur in spaces where corners of three abactinal plates meet. These papulae are consistent with the complex pattern of glassy bosses on abactinal, actinal and adambulacral plates.

Japanese name. Koyo is taken from R/V Koyo, the vessel which collected the holotype, and akamon-hitode comes from the Japanese name of Neoferdina cumingi (Gray, 1840), another species of Ferdininae which occurs commonly in Japanese waters.

Fromia eusticha Fisher, 1913
[Japanese name: Nameraka-juzuberi-hitode]
(Figs 2B, 4)

Fromia eusticha Fisher, 1913: 213–214; Fisher 1919: 375–377; Domantay and Roxas 1938: 220; A. H. Clark 1952: 286; Jangoux 1978: 294–295; A. M. Clark 1993: 331; Arai et al. 2018: 194, 196.

Material examined. NSMT E-9298, 1 individual, KY-10-31, West of Hutami Port, Chichi-jima Island, 96.5–96.8 m. NSMT E-10595, 1 individual, KY-17-24, West of Minamijima Island, 147–149 m.

Description. R = 34.1 mm, r = 7.8 mm, R/r = 4.4, width of arm is 8.8 mm at base, 5.5 mm at half of R, and 3.0 mm at 1/10 R from the tip in NSMT E-9298. R = 26.1 mm, r = 5.8 mm, R/r = 4.5, width of arm is 7.1 mm at base, 4.6 mm at half of R, and 2.6 mm at 1/10 R from the tip in NSMT E-10595. Abactinal surface is flat and actinal surface...
is arched. Arms are five, slender, and tapering to blunt tips (Fig. 4A, B).

Abactinal plates are polygonal with rounded corners and weakly developed lobes. The plates are arranged in five regular, staggered longitudinal rows at the base of arms (Fig. 4C). The median row extends toward the tip of arms. The two adjacent rows terminate at 2/3R from the center of the disc, and the outermost two rows at 1/4R. The entire surface of abactinal plates is rough with numerous hemispherical glassy bosses (crystal bodies). Madreporite is circular, not conspicuously elevated from the abactinal surface, and about 1.2 mm in diameter (Fig. 4E). Gyri partly radiate from, but absent at, the center. Anal aperture is surrounded by four enlarged ossicles in NSMT E-10595; none are present in NSMT E-9298. Terminal plates are conical and truncated at the tip. The surfaces of the plates lack granules, and are smooth, except the basal portions where glassy bosses occur (Fig. 4D).

Superomarginal plates are block-like, rounded, and larger in diameter than neighboring abactinal plates. There are fifteen superomarginal plates on each side of the arm with $R = 32.7$ mm in NSMT E-9298. They are not alternating in size but diminishing toward the tip of arms. Inferomarginal plates also decrease in size toward the tip of arms, but they are smaller than the adjoining superomarginal plate.

Actinal plates are polygonal, mostly quadrangular, lack-

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**Fig. 4.** *Fromia eusticha*, NSMT E-9298. A, abactinal side; B, actinal side; C, proximal portion of a partly denuded arm, abactinal view; D, arm tip, lateral view. Arrow indicates terminal plate; E, madreporite, F, proximal portion of a partly denuded arm, actinal view; G, pedicellariae on actinal plates (arrow); H, adambulacral spines. Scale bars: 10 mm (A, B); 5 mm (C, D, F); 1 mm (E), 500 µm (G, H). Abbreviations: sm, superomarginal plates; im, inferomarginal plates; fs, furrow spines; ss, subambulacral spines.
Sea Stars from Ogasawara Islands

Pedicellariae occur on some actinal plates and adambular plates followed by smaller granules on the abradial side (Fig. 4H). The number of furrow spines is two or four on a relatively small number of plates, and more plates are likely to bear only two furrow spines near the tip of arms (ca. 1/5R from the tip). Most furrow spines are truncated at and widening toward the tip, flattened, and constricted at the base. The proximal furrow spines on some plates are slightly tapering toward the tip. Subambular plates tapering toward the blunt tip, conical or pyramidal, and flattened but thicker than furrow spines. The granules abradial to the subambular plates are identical in size and shape to those on actinal plates, thus these granules and the subambular plates are discontinuous in size. Pedicellariae occur among the ossicles on a small number of plates. Tubefeet are biserial and with a sucking disc.

Each oral plate bears five oral spines and four to five suboral spines in NSMT E-9298; there are five to six oral and three to four suboral spines in NSMT E-10595. The remaining abradial portion of the plate is covered with granules. Oral spines are conical, tapering toward the pointed tip, slightly curved, and longer than furrow spines. Those near the center of the mouth are more slender and longer than the distal ones. Suboral spines are similar to oral spines in size and shape near the mouth. However, they are shorter in the abradial portion of plates, and a few of them are intermediate in size between oral spines and granules. The granules are slightly larger and coarser than those on actinal plates.

The abactinal, marginal, and actinal plates are covered with a skin on which granules occur. There are 125 granules per square millimeter on abactinal plates at the base of arms. Superomarginal plates only slightly convex, not alveolate. Distribution. Sulu Archipelago, 44 m (Fisher 1913). Puerto Galera, Mindoro Island, Philippines, depth unknown (Domantay and Roxas 1938). Bikini Atoll, 55 m (A. H. Clark 1952). Obi Islands, Indonesia, on the beach and reef (Jangoux 1978). Ogasawara Islands, Japan, 96.5–149 m (this study).

**Japanese name.** *Nameraka* means smooth, referring to its fine granules and graduating superomarginal plates. *Juzuberi-hitode* is a Japanese name for the genus *Fromia*.

**Fromia labiosa** sp. nov.

[New Japanese name: Ogasawara-juzuberi-hitode]

(Figs 2C, 5)

*Fromia sp.*: Arai et al. 2018: 194, 196.

**Material examined.** Holotype: NSMT E-9297, KY-16-14, East of Ototo-jima Island, 56.6–62.9 m. Paratypes: NSMT E-9293, KY-08-25, West of Nishi-jima Island, 127–129 m; NSMT E-9294 and E-9295, KY-16-06, Northwest of Ototo-jima Island, 135–137 m; NSMT E-9296, KY-16-09, East of Chichi-jima Island, 90.5–94.6 m; 1 individual each.

**Diagnosis.** A species of the genus *Fromia* with a small disc and slender, slightly arched arms. At R = 31.3 mm, abactinal plates arranged in five longitudinal rows at base of arms. Superomarginal plates only slightly convex, not alternating but regularly decreasing in size toward the tip of arms. Coarse granules enlarged at center of plates. Papulae single and confined on the abactinal surface. Adambular plates bear three (rarely two or four) furrow spines and five to nine thicker subambulacral granules graduating in size toward those on neighboring actinal/marginal plates. Oral plates bear five oral spines on the margin and four to six suboral spines on the rest of the plate. Large, elliptical pedicellariae on many actinal plates with their major axis oblique to the ambulacra.

**Description of holotype.** R = 31.3 mm, r = 8.6 mm, R/r = 3.6, width of arm is 9.0 mm at base, 5.4 mm at half of R, and 2.9 mm at 1/10 R from the tip. Body is slightly arched at both sides, and the abactinal interradial areas are sunken. Arms taper to blunt tips.

Abactinal plates are polygonal, weakly lobate, arranged in staggered longitudinal series where there are five rows at the
base of arms (Fig. 5C). Hemispherical glassy bosses (crystal bodies) occur on the abactinal plates. Madreporite is single, circular, and about 0.9 mm in diameter, located at about one half r from the anal aperture. Gyri do not regularly radiate from the center of the madreporite. The anal aperture is single and surrounded by six slightly larger ossicles. Terminal plates are conical, truncated at the tip. Several tubercles encircle the top of terminal plates.

Superomarginal and inferomarginal plates are block-like, rectangular, only slightly convex and not alternating but regularly decreasing in size toward the tip of arms. There are sixteen superomarginal and seventeen inferomarginal plates on one side of the ray when skin and granules are removed. The second to fourth superomarginal plates average 1.7 mm in length.

Actinal plates are polygonal, without lobes, and leave no space in between. No glassy bosses occur on actinal plates. These are arranged in three longitudinal series at the base of a denuded arm with a few odd plates on the interradial area.

Adambulacral plates bear three (exceptionally two or four), slender, flattened, cylindrical and bluntly pointed furrow spines and five to nine thicker, more sharply pointed subambulacral granules (Fig. 5F). The latter are not in regular rows parallel to the ambulacrum, and are grading in size

Fig. 5. *Fromia labeosa* sp. nov., NSMT E-9297, holotype. A, actinal surface of the disc; B, abactinal surface of interradial area showing a madreporite (arrow); C, abactinal surface of a denuded arm; D, pedicellaria on the actinal plate; E, proximal portion of a partly denuded arm, actinal side. Arrows indicate pedicellariae; F, adambulacral armature on proximal adambulacral plates. Scale bars: 5 mm (A, C), 1 mm (B, E), 500 µm (D, F). Abbreviations: fs, furrow spines; ss, subambulacral spines.
to the granules on neighboring actinal or marginal plates. Tubefeet are biserial with a stouter terminal disc.

Each oral plate bears five oral spines on the adoral margin and four to six suboral spines on the rest of the plate. Oral spines are conical or pyramidal, larger than furrow spines. Suboral spines are similar to oral spines in the adradial portion but abradially grading into actinal granules.

The abactinal, marginal, and actinal plates are concealed with a skin which is covered coarsely with granules (Fig. 5B). These granules are domed at the top, polygonal in shape, and slightly enlarged at the center of plates, but never spinous. The diameter is ca. 260–340 μm at center and ca. 140–200 μm on periphery. There are 20 granules per square millimeter on abactinal plates at the base of arms and actinal interradial plates. The papular pores are isolated and confined around actinal plates except on the interradial areas and tips of arms, where the pores are absent.

Many actinal plates possess a large elliptical pedicellaria (Fig. 5D). It is typically 1 mm in length and 400 μm in width. The pedicellariae are loosely arranged in a parallel series to an ambulacrum on arms, and their major axis is often oblique to the ambulacrum (Fig. 5A, E).

Color in life is vermilion with white granules and terminal plates (Fig. 2C).

Notes on paratypes. The difference in the numeric characters among type specimens is shown in Table 2. R/r generally increases and the number of granules per square millimeter decreases as R increases. Other characters in the paratypes are consistent with the description of holotype.

DNA sequence. A partial sequence of COI (655 bp) was obtained from NSMT E-9295 and deposited in DDBJ (Acc. No. LC427074).

Remarks. The present species is distinguished from its congeners by the following characters: superomarginal plates regularly decreasing in size toward the arm tip in F. labeosa sp. nov. while they are alternating large and small, in F. indica (Perrier, 1869); abactinal granules are granular in F. labeosa while they are spinuous in F. armata Koehler, 1910; they are also coarse (20/mm²) in F. labeosa while they are fine (80–90/mm²) in F. haddaracantha H. L. Clark, 1921; papulae are lacking on the actinal surface in F. labeosa while there are two rows of actinal papulae in F. balansae Perrier, 1875 and F. ghardaqana Mortensen, 1938. Five to nine subambulacral tubercles continuous in size and not arranged in definite rows in F. labeosa while subambulacral spines are conspicuously larger than outer granules on the adambulacral plate, and arranged in a straight row in F. eusticha. In addition to these differences, large elliptical pedicellariae on actinal plates are specific to F. labeosa.

Distribution. Ogasawara Islands, 56.6–137 m (this study).

Etymology. The species epithet, *labeosa*, is a Latin feminine adjective meaning having large lips and referring to the large pedicellariae on the actinal surface.

Japanese name. *Ogasawara* is taken from the type locality and *juuzuberi-hitode* is a Japanese name for the genus *Fromia*.

**Ogmaster capella** (Müller and Troschel, 1842)

*Goniaster capella* Müll and Troschel, 1842: 61.

*Goniaster* (Ogmaster) *capella* Martens, 1865: 359–360.

*Ogmaster capella*: Sladen 1889: 261; Koehler 1910: 79; Fisher 1919: 262, 305; Döderlein 1935: 101–102; Guille and Jangoux 1978: 53; A. M. Clark 1993: 267; Liao and A. M. Clark 1995: 94; A. M. Clark and Mah 2001: 337; Arai et al. 2018: 194, 196.

*Dorigona reevesii* Gray, 1866: 7.

*Goniaster muelleri*: Lütken 1871: 248–250.

Material examined. NSMT E-9312, 1 individual, dry, KY-08-21, East of Chichi-jima Island, 95–98 m.

Description. R=16.5 mm, r=6.9 mm, R/r=2.4, width of arm is 8.5 mm at base, 4.8 mm at half of R, and 1.9 mm at 1/10 R from the tip. Abactinal and actinal surface are flat. Arms are five, tapering toward a pointed tip (Fig. 6A).

Abactinal plates are polygonal, mostly pentagonal to hexagonal, and arranged in a regular tessellate manner leaving only small spaces around the corners. The plates on the interradial area are larger than those on the median of arms,
and those neighboring the superomarginal plates are smaller (Fig. 6B). The plates are covered with a very thin skin without any granules, thus giving a naked appearance. The surface of the plates is rough with numerous glassy bosses. Papulae are confined to the proximal portion of the abactinal radial area. They are isolated, and occur at the corners of abactinal plates. Madreporite is circular, domed, and about 1.0 mm in diameter; gyri radiate from the center. Anal aperture lies at the center of the disc, and is surrounded by five granular ossicles.

Terminal plates are bell-shaped (Fig. 6C). They have a smooth surface and lack any appendages except two plates bearing a single cylindrical, blunt spine at either side of the tip, suggesting that each terminal plate should bear a pair of such spines.

Marginal plates are block-like, and regularly decreasing in size from the interradius toward the arm tip. There are nine superomarginal plates on each side of arms. The distalmost four plates are in contact with their counterparts on the other side of the arm, though there are small rhomboidal abactinal plates inserted at the median of arms between sixth and seventh superomarginal plates (also between seventh and eighth on two arms). The inferomarginal plates correspond to the superomarginal plates in shape, size and number.

Actinal plates are polygonal, mostly quadrangular or pentagonal, and arranged in a regular tessellate manner leaving no space in between. The surface of the plates is smooth with a skin lacking granules. A few low, faint glassy bosses occur on some of the plates.

Adambulacral plates bear four to five furrow spines and two to five subambulacral tubercles (Fig. 6D). Furrow spines are cylindrical or conical with a blunt tip, and arranged on the curved adradial margin of adambulacral plates. The most distal spine on each plate is about two times wider at the base than the others, and tapering more rapidly toward the tip with the same width as the others. The subambulacral spines are hemispherical, irregular in size, and mostly arranged in a straight line at the abradial side of the plate. On the distal plates corresponding to the final two to three inferomarginal plates, the number of furrow spines decreases to 1–3 including the larger distal spine, and the subambulacral ossicles disappear. Tubefeet are biserial and with a terminal disc. No pedicellariae occur on adambulacral plates or other plates.

Oral plates have a semicircular and domed abactinal surface. Each oral plate bears six oral spines at the margin and six to eight suboral tubercles on the abactinal surface. Oral spines are conical, slightly depressed with flanking spines. The most adradial one is the largest and about two times larger than the most abradial one which is almost identical with the neighboring furrow spines.
Sea Stars from Ogasawara Islands 17

Color in life is dull pink with red lines between plates on the abactinal surface and white on the actinal surface (Fig. 2D).

**DNA sequence.** A partial sequence of COI (655 bp) was obtained from NSMT E-9312 and deposited in DDBJ (Acc. No. LC427075).

**Remarks.** The specimen from the Ogasawara Islands is small but generally agrees with all the past descriptions. Pedicellariae are lacking on adambulacral plates in the present specimen unlike larger specimens with R around 30 mm (Döderlein 1935; Guille and Jangoux 1978). Additionally, the present specimen differs from the original description since none of its plates covered with granules. According to Döderlein (1935), who examined the type specimen, the original description by Müller and Troschel (1842) misinterpreted the crystal bodies (glassy bosses) as granules. In the present specimen, the surface of all the abactinal plates and some of the actinal plates shows numerous glassy bosses.

Liao and A. M. Clark (1995) suggested that *Stellaster septemtrionalis* Oguro, 1991, which was described from 105 m deep in the East China Sea (Oguro 1991), may be a junior synonym of *O. capella* although they did not give a detailed description or comparison of the two species. The two species are indeed very similar in having 5–6 furrow spines, 2–3 short subambulacral spines, and in lacking tubercles or spines on abactinal and marginal plates. However, *O. capella* can be distinguished from *S. septemtrionalis* by the absence of coarse granules on abactinal, marginal, and actinal plates and conical tubercles on actinal plates. We consider that these differences are sufficient to separate the two species and *S. septemtrionalis* should be maintained as valid.

**Distribution.** Southern coast of China, 60–129 m (Liao and A. M. Clark 1995). Kai Islands, Indonesia, 90 m; Timor Island, 112 m; Small Sunda Islands, depth unknown (Döderlein 1935). Seram Island, depth unknown (Guille and Jangoux 1978). Ogasawara Islands, Japan, 95–98 m (this study).

**Japanese name.** *Hadaka-akasuji-hitode* means a bare red-lined sea star, referring to the body hardly covered with granular skin and conspicuous red lines bordering abactinal plates in life.

Family *Ophidiasteridae* Verrill, 1870

_Tamaria tenella_ Fisher, 1906: 1082.

_Ophidiaster_ sp.: McKnight 1975: 56–57.  
_Tamaria tenellus_: McKnight 1993: 172–173.  
_Tamaria tenella_: H. L. Clark 1921: 88, 91; A. M. Clark 1993: 354; McKnight 2001: 176–177; Arai et al. 2018: 198–199.

**Material examined.** NSMT E-8285, 1 individual, coll. by Dr. Minoru Imajima in 1969, labeled as "Hyotan-jima, Ogasawara Islands, intertidal" but probably a mislabeled specimen collected by a coral fisherman Akio Kiwara around Ani-jima, Chichi-jima, Haha-jima or Yome-jima Island in depth ranging from 150 to 160 m (see Imajima 1970: 190). NSMT E-9277, 1 individual, SY-09-21, West of Otojima Island, 159–161 m.

**Description.** R = 30.0 mm, r = 6.2 mm, R/r = 4.8, width of arm is 7.3 mm at base, 4.6 mm at half of R, and 3.0 mm at 1/10 R from the tip in NSMT E-8285. R = 26.0 mm, r = 5.4 mm, R/r = 4.8, width of arm is 6.7 mm at base, 3.6 mm at half of R, and 2.1 mm at 1/10 R from the tip in NSMT E-9277. Body is arched on the abactinal side and flat on the actinal side. Arms are five and tapering toward the tip evenly from the base (Fig. 7A).

Abactinal plates are four-lobed and arranged in three regular longitudinal rows which reach the tip of arms. The rows are partly disrupted at base of an arm of NSMT E-8285, and the shortest arm of NSMT E-9277. Five to six carinal plates in the middle of arms and a few distal actinolateral plates are devoid of skin and granules in an elevated circular area at the center (Fig. 7F). Madreporite is circular, not elevated from the abactinal surface of disc; gyri radiate from the center in a complex pattern. Tube feet are biserial with a terminal disc. Terminal plates are spherical, devoid of granules, and bearing about ten tubercles at the apex in NSMT E-9277 (Fig. 7F). In NSMT E-8285, the tubercles are very low and faint, and the number is about three.

Superomarginal and inferomarginal plates are similar in shape and size to abactinal plates, and arranged in two regular longitudinal series. Distal superomarginal plates (twelve to thirteen plates from the arm tip in NSMT E-9277 and seven to nine in NSMT E-8285) are devoid of a skin and granules like some of the abactinal plates (Fig. 7F). More distal plates have a larger, more swollen and more elliptical naked area. In NSMT E-8285, three to four distalmost inferomarginal plates are denuded and swollen like distalmost superomarginal plates.

Actinal plates are rectangular and arranged in three longitudinal series at the base of arms: the innermost series reach about 3/4 R, the outer 1/2 R, and the outermost 1/6 R in NSMT E-8285 (in NSMT E-9277, there are two series reaching 2/3 R and 1/4 R respectively, and a few interradial plates).

Each adambulacral plate bears two furrow spines and a subambulacral spine (Fig. 7D). Furrow spines are truncated, flattened, and polygonal but rounded at corners and slightly concave at the furrow surface. Each plate carries a pair of subequal spines. Subambulacral spines are obovate but more circular in the distal part of arms. Between two furrow spines and a subambulacral spine, there are granules one of which is occasionally larger than the surroundings to appear like a tubercle.

Oral plates are covered with granules like actinal plates. A plate bears five to six oral spines and a suboral spine (Fig. 7B). They are identical in shape to furrow spines and subambulacral spines respectively.

The entire body is overlaid with a skin except some abac- tinal plates and distal superomarginal plates as mentioned above. The skin is covered with fine granules homogenous in size (Fig. 7B, C). The number of granules per square millimeter is 379 on proximal carinal plates and 167 on proximal actinal plates in NSMT E-9277; 281 and 295 respectively in NSMT E-8285.
A papular area bears one to three pores on the disc and one to five on the arms. The areas occur between carinal, abactinolateral, superomarginal and inferomarginal plates but never below the inferomarginal plates. They are arranged in six longitudinal series although the numbers of pores change irregularly.

Pedicellariae presents on superomarginal plates (from the base to the middle of arms), abactinal interradial plates, and exceptionally on an abactinolateral plate in NSMT E-9277, on actinolateral, superomarginal, and inferomarginal plates in NSMT E-8285. Each pedicellaria with two valves, which fit in an entrenched piece of ossicle with an alveolus at the center (Fig. 7E). The ossicle is merged with the subjacent plate. The valve is gradually broadening from the base to form a smooth, unserrated, and slightly curved contour.

Color in life is unknown. The ex-ethanol specimens show brown transverse bands on arms with darker papular areas and transverse lines between plates on the abactinal surface.

**DNA sequence.** A partial sequence of COI (655 bp) was sequenced from NSMT E-9277 and deposited in DDBJ (Acc. No. LC427076).

**Remarks.** Fisher (1906) described two closely similar species, *Ophidiaster sclerodermus* Fisher, 1906 and *O. tenellus*, distinguishing them by the length of arms, granulation, thickness of skin, number of papular pores in each area, and number of pedicellariae. Both species were subsequently transferred to the genus *Tamaria* by H. L. Clark (1921). The present Ogasawara specimens resemble these two species, but show discordance in some characters from each species. *Tamaria scleroderma* has a larger number of papu-
lar pores (9–14) and shorter arms (R/r = 4.8) than *Tamaria tenella*. The Ogasawara specimens are consistent with *T. tenella* in the number of papular pores (1–3) while it has longer arms (R/r = 6.9). The New Zealand specimens of *T. tenella* described by McKnight (1975, 2001) differ from the Ogasawara specimens in the proportion of arms, number of papulae, distribution of pedicellariae, and spines on actinal plates. The rays are longer in proportion to the disc: R/r = 5.5 at R = 22 mm and 7.5 at R = 48 mm. All the papulae are isolated, and the pedicellariae occur on actinal plates. In the larger specimen with R = 48 mm, spines similar to the sub-ambulacral ones occur on some actinal plates. In addition to these differences, the Ogasawara specimens also have a central naked area on the distal carinal and superomarginal plates which is not present in the Hawaiian or New Zealand specimens. The present specimens are temporarily considered to be *T. tenella*, based on the small number of papular pores per area. However, we believe that these species require a detailed revision in regard to morphological variation with a greater number of specimens.

**Distribution.** Hawaii Islands, 238–276 m (Fisher 1906). Three Kings Rise and Norfolk Ridge, New Zealand, 403–503 m (McKnight 1993, 2001). Ogasawara Islands, Japan, 159–161 m (Arai et al. 2018; this study).

**Japanese name.** Birodo means velvet, referring to the smooth skin with minute granules. Hime-hokiboshi means a small comet.

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**Table 3.** Sea stars reported from the coasts of the Ogasawara Islands and adjacent waters. References as follows: ¹Hayashi (1938); ²Imajima (1969); ³Shigei (1970); ⁴Pope and Rowe (1977); ⁵Amemiya and Yanagisawa (1991); ⁶Kogure and Tachikawa (2009); ⁷Saba (2011); ⁸Fujita et al. (2015); ⁹Arai et al. (2018); ¹¹this study.

| Order                | Family                | Species                                  | References |
|----------------------|-----------------------|------------------------------------------|------------|
| Valvatida            | Acanthasteridae       | *Acanthaster planci* (Linnaeus, 1758)    | b          |
| Asterinidae          | *Aquilonastra anomala* (H. L. Clark, 1921) | g, h, i                                 |
|                      | *Aquilonastra sp.*    |                                         | i          |
|                      | *Pseudospanthia briareus* (Bell, 1894) | e, g, h, i                               |
| Asterodiscididae     | *Asterodiscides japonicus* Oguro, 1991 | i                                      |
| Chaetasteridae       | *Chaetaster moorei* Bell, 1894 | e, g                                   |
| Goniasteridae        | *Astroceramus bominensis* Kogure and Tachikawa, 2009 | f          |
|                      | *Bathyferdina caelator* sp. nov. | i, j                                    |
|                      | *Promia eusticha* Fisher, 1913 | i, j                                    |
|                      | *Promia indica* Perrier, 1869 | a, e, h, i                              |
|                      | *Promia labeosa* sp. nov. | i, j                                    |
|                      | *Promia monilis* Perrier, 1869 | e, g                                    |
|                      | *Promia pacifica* H. L. Clark, 1921 | h                                      |
|                      | *Nardoa* sp.          |                                         |            |
|                      | *Neoferdina cumingi* (Gray, 1840) | e                                      |
|                      | *Ogmaster capella* (Müller and Troschel, 1842) | i, j                                   |
| Mithrodiidae         | *Mithrodia clavigera* (Lamarck, 1816) | e, g, h                                 |
|                      | *Thromidia catala* Pope and Rowe, 1977 | d, g, h                                 |
| Ophidiasteridae      | *Leiaster coriaceus* Peters, 1852 | h                                      |
|                      | *Linkia gildingi* Gray, 1840 | e, g, i                                 |
|                      | *Linkia laevigata* (Linnaeus, 1758) | b, e                                    |
|                      | *Linkia multifora* (Lamarck, 1816) | a, c, e, g, h, i                       |
|                      | *Ophidiaster cribrarius* Lütken, 1871 | a, h, i                                 |
|                      | *Ophidiaster hemprichi* Müller and Troschel, 1842 | e                                      |
|                      | *Tamaria tenella* (Fisher, 1906) | i, j                                    |
| Oreasteridae         | *Choriaster granulatus* Lütken, 1869 | e                                      |
|                      | *Culcita novaesinucae* Müller and Troschel, 1842 | g, h                                    |
|                      | *Proteraster nodosus* (Linnaeus, 1758) | f                                      |
| Poraniidae           | *Marginaster paecepinus* Fisher, 1913 | i                                      |
| Solasteridae         | *Lophaster* sp.       |                                         | i          |
| Spinulosida          | Echinasteridae        | *Echinaster luzonicus* (Gray, 1840)     | a, c, e, g, h |
| Forcipulatida        | Asteridae             | *Coronaster paecepinus* Jangoux, 1984    | g, h       |
|                      |                       | *Coscinasterias acutispina* (Stimpson, 1862) | a, h       |

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**Discussion**

Five species of sea stars from the Ogasawara Islands are described in this study; two are new to science. Summarizing the published records of sea stars in the Ogasawara Islands and this study, we recognize 31 species of 23 genera in 10 families (Table 3). It should be noted that most of the historical records were not verified by specimens, images, or other data. This number of asteroid species is lower than those in the neighboring subtropical/tropical islands such as the Nansei Islands and the Mariana Islands, which are...
49 species and 34 species, respectively (Paulay 2003; Saba 2011). Arai et al. (2018) argued that relatively lower diversity of valvataid sea stars in the Ogasawara Islands than in the Nansei Islands is possibly due to the sampling density, small coastal area and isolated location.

In the Ogasawara Islands, the five species described in this study occurred only in the mesophotic zone between 56–161 m. None of them have ever been reported from the shallower zone (0–30 m) of the Ogasawara Islands (Arai et al. 2018). This suggests that the mesophotic zone has a unique sea star fauna in the Ogasawara Islands. Moreover, the five species have not been recorded from shallower water in any localities save for Fromia castischa, which is known from 0–55 m of Philippines, Indonesia and Marshall Islands (Fisher 1913; Domantay and Roxas 1938; A. H. Clark 1952; Jangoux 1978). Tamaria tenella is reported from deeper waters below the mesophotic zone in the Hawaii Islands and New Zealand (Fisher 1906; McKnight 1993, 2001).

The two new species, Bathyferdina cadator sp. nov. and Fromia laboea sp. nov., were collected only in the Ogasawara Islands, and it is possible that they are endemic to the islands. There is only a single species of sea star currently known to be endemic in the Ogasawara Islands: Astrocera mus boninensis. This species has never been reported from other localities since the original description. Extensive surveys in the neighboring islands such as the Izu Islands are required to clarify the geographic distribution of these species and to understand diversity and endemism of the sea stars of the Ogasawara Islands.

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References

Amemiya, S. and Yanagisawa, T. 1991. [Change in abundance and current status of Echinoderms in the Ogasawara Islands]. Pp. 297–308 In: Ono, M., Kimura, M., Miyashita, K., and Nagami, M. (Eds) Report of the Second General Survey on Natural Environment of the Ogasawara (Bonin) Islands. Tokyo Metropolitan University, Tokyo. [In Japanese]

Arai, M., Tanaka, Y., Miyazaki, T., and Fujita, T. 2018. Valvataida (Echino-dermata: Asteroidea) of the Ogasawara Islands, Japan. Memoirs of the National Museum of Nature and Science 52: 191–203. [In Japanese]

Baldwin, C. C., Tornabene, L., and Robertson, D. R. 2018. Below the mesophotic. Scientific Reports 8: 4920.

Clark, A. H. 1952. Echinodermata from the Marshall Islands. Proceedings of the United States National Museum 102: 265–303.

Clark, A. M. 1993. An index of names of recent Asteroidea—Part 2: Valvataida. Pp. 187–366. In: Jangoux, M. and Lawrence, J. M. (Eds) Echino-derm Studies 4. A. A. Balkema, Rotterdam.

Clark, A. M. and Downey, M. E. 1992. Starfishes of the Atlantic. Chapman & Hall, London, xxiv + 663 pp., 113 pls.

Clark, A. M. and Mah, C. 2001. An index of names of recent Asteroi-dea—Part 4: Forcipulatida and Brisingida. Pp. 229–347. In: Jangoux, M. and Lawrence, J. M. (Eds) Echino-derm Studies 6. A. A. Balkema, Lisse.

Clark, H. L. 1921. The Echinoderm Fauna of Torres Strait: Its Composi-tion and Its Origin. Carnegie Institution of Washington, viii + 223 pp., 38 pls.

Dörderlein, L. 1935. Die Asteriden der Siboga-Expedition. III. Oreat-eridae. Siboga-Expedition 46(3): 71–110.

Domantay, J. S. and Roxas, H. A. 1938. The littoral Asteroidea of Port Galera Bay and adjacent waters. The Philippine Journal of Science 65: 203–237.

Fisher, W. K. 1906. The starfishes of the Hawaiian Islands. Bulletin of the United States Fish Commission 23: 987–1130.

Fisher, W. K. 1913. New starfishes from the Philippine Islands, Celebes, and Moluccas. Proceedings of the United States National Museum 46: 201–224.

Fisher, W. K. 1919. Starfishes of the Philippines Seas and adjacent wa-ters. United States National Museum Bulletin 100(3): 1–712.

Forbes, E. 1841. A History of British Starfishes, and Other Animals of the Class Echinodermata. John Van Voorst, London, xx + 267 pp.

Fujita, Y., Irimura, S., Kogure, Y., Okanishi, M., Michonneau, F., and Baldwin, C. C., Tornabene, L., and Robertson, D. R. 2018. Below the mesophotic. Scientific Reports 8: 4920.

Gray, J. E. 1866. Synopsis of the Species of Starfish of the British Museum. John Van Voorst, London, iv + 18 pp., 16 pls.

Guille, A. and Jangoux, M. 1978. Astérides et Ophiurides littorales de la région d’Amboine (Indonésie). Annales de l’Institut Océ-anographique 54: 47–74.

Hayashi, R. 1938. Sea-stars of the Ogasawara Islands. Annotationes Zoologicae Japonenses 17: 59–69.

Hoareau, T. B. and Boissin, E. 2010. Design of phylum-specific hybrid primers for DNA barcoding: addressing the need for efficient COI amplification in the Echinodermata. Molecular Ecology Resources 10: 960–967.

Imajima, M. 1969. [Marine organisms in the Ogasawara Islands]. Pp. 145–177. In: Tokyo-to Kensei-kyokudo Koenryokukaihcho. Ed.) Ogasawara Shotou Shizenkeikan Chousa Houkokusho [Report on the landscape of the Ogasawara Islands]. Tokyo. [In Japanese]

Imajima, M. 1970. [Marine organisms]. Pp. 179–196. In: Tuyama, T.
Jangoux, M. 1978. Biological results of the Snellius Expedition XXIX. Echinodermata, Asteroidea. Zoologische Mededelingen 52: 287–300, 3 pls.

Kogure, Y. and Fujita, Y. 2012. A new species of Neoferdina and three new records of sea stars (Echinodermata: Asteroidea) collected from Kumejima Island, southwestern Japan. Zootaxa 3367: 252–260.

Kogure, Y. and Tachikawa, H. 2009. A new species of Astroceramus (Echinodermata, Asteroidea, Goniasteridae) from the Ogasawara Islands, Japan. Biogeography 11: 77–82.

Laverick, J. H., Andradi-Brown, D. A., and Rogers, A. D. 2017. Using light-dependent scleractinia to define the upper boundary of mesophotic coral ecosystems on the reefs of Utila, Honduras. PLoS ONE 12: e0183075.

Mah, C. L. 2003. Astrosarkus idipi, a new Indo-Pacific genus and species of Oreasteridae (Valvatida: Asteroidea) displaying extreme endoskeletal reduction. Bulletin of Marine Science 73: 685–698.

Mah, C. L. 2017. Overview of the Ferdina-like Goniasteridae (Echinodermata: Asteroidea) including a new subfamily, three new genera and fourteen new species. Zootaxa 4271: 1–72.

McKnight, D. G. 1975. Some echinoderms from the Northern Tasman Sea. NZOI Records 2: 50–76.

McKnight, D. G. 1993. Records of echinoderms (excluding holothurians) from the Norfolk Ridge and Three Kings Rise north of New Zealand. New Zealand Journal of Zoology 20: 165–190.

McKnight, D. G. 2001. Superfamilies Goniasteroidea (excluding Goniasteridae), Odontasteroidea, Ganoidea, Ophiasteroidea, Oreasteroidea. Pp. 141–308. In: Clark, H. E. S. and McKnight, D. G. The Marine Fauna of New Zealand: Echinodermata: Asteroidea (Sea-stars). Order Valvatida. NIWA Biodiversity Memoir 117. NIWA, Wellington.

Martens, E. 1865. Ueber ostasiatische echinodermen. Archiv für Naturgeschichte 31(1): 345–360.

Müller, J. and Troschel, F. H. 1842. System der Asteriden. 1. Asteriae. 2. Ophiuriae. Friedrich Vieweg und Sohn, Braunschweig, xx + 134 pp.

Oguro, C. 1991. Asteroidea. Pp. 41–110. In: Imaoka, T., Irimura S., Okutani, T., Oguro, C., Oji, T., and Kanazawa, K. Echinoderms from Continental Shelf and Slope around Japan Vol. II. Japan Fisheries Resource Conservation Association, Tokyo.

Paulay, G. 2003. The Asteroidea, Echinoidea, and Holothuroidea (Echinodermata: Asteroidea) of the Mariana Islands. Micronesica 35–36: 563–583.

Pawson, D. 2007. Narcissia ahearnae, a new species of sea star from the Western Atlantic (Echinodermata: Asteroidea: Valvatida). Zootaxa 1386: 53–58.

Paulay, G. 2003. The Asteroidea, Echinoidea, and Holothuroidea (Echinodermata: Asteroidea) including a new subfamily, three new genera and fourteen new species. Zootaxa 4271: 1–72.

McKnight, D. G. 1975. Some echinoderms from the Northern Tasman Sea. NZOI Records 2: 50–76.

McKnight, D. G. 1993. Records of echinoderms (excluding holothurians) from the Norfolk Ridge and Three Kings Rise north of New Zealand. New Zealand Journal of Zoology 20: 165–190.

McKnight, D. G. 2001. Superfamilies Goniasteroidea (excluding Goniasteridae), Odontasteroidea, Ganoidea, Ophiasteroidea, Oreasteroidea. Pp. 141–308. In: Clark, H. E. S. and McKnight, D. G. The Marine Fauna of New Zealand: Echinodermata: Asteroidea (Sea-stars). Order Valvatida. NIWA Biodiversity Memoir 117. NIWA, Wellington.

Martens, E. 1865. Ueber ostasiatische echinodermen. Archiv für Naturgeschichte 31(1): 345–360.

Müller, J. and Troschel, F. H. 1842. System der Asteriden. 1. Asteriae. 2. Ophiuriae. Friedrich Vieweg und Sohn, Braunschweig, xx + 134 pp.

Oguro, C. 1991. Asteroidea. Pp. 41–110. In: Imaoka, T., Irimura S., Okutani, T., Oguro, C., Oji, T., and Kanazawa, K. Echinoderms from Continental Shelf and Slope around Japan Vol. II. Japan Fisheries Resource Conservation Association, Tokyo.

Paulay, G. 2003. The Asteroidea, Echinoidea, and Holothuroidea (Echinodermata: Asteroidea) of the Mariana Islands. Micronesica 35–36: 563–583.

Pawson, D. 2007. Narcissia ahearnae, a new species of sea star from the Western Atlantic (Echinodermata: Asteroidea: Valvatida). Zootaxa 1386: 53–58.

Paulay, G. 2003. The Asteroidea, Echinoidea, and Holothuroidea (Echinodermata: Asteroidea) including a new subfamily, three new genera and fourteen new species. Zootaxa 4271: 1–72.

McKnight, D. G. 1975. Some echinoderms from the Northern Tasman Sea. NZOI Records 2: 50–76.

McKnight, D. G. 1993. Records of echinoderms (excluding holothurians) from the Norfolk Ridge and Three Kings Rise north of New Zealand. New Zealand Journal of Zoology 20: 165–190.

McKnight, D. G. 2001. Superfamilies Goniasteroidea (excluding Goniasteridae), Odontasteroidea, Ganoidea, Ophiasteroidea, Oreasteroidea. Pp. 141–308. In: Clark, H. E. S. and McKnight, D. G. The Marine Fauna of New Zealand: Echinodermata: Asteroidea (Sea-stars). Order Valvatida. NIWA Biodiversity Memoir 117. NIWA, Wellington.

Martens, E. 1865. Ueber ostasiatische echinodermen. Archiv für Naturgeschichte 31(1): 345–360.

Müller, J. and Troschel, F. H. 1842. System der Asteriden. 1. Asteriae. 2. Ophiuriae. Friedrich Vieweg und Sohn, Braunschweig, xx + 134 pp.

Oguro, C. 1991. Asteroidea. Pp. 41–110. In: Imaoka, T., Irimura S., Okutani, T., Oguro, C., Oji, T., and Kanazawa, K. Echinoderms from Continental Shelf and Slope around Japan Vol. II. Japan Fisheries Resource Conservation Association, Tokyo.

Paulay, G. 2003. The Asteroidea, Echinoidea, and Holothuroidea (Echinodermata: Asteroidea) of the Mariana Islands. Micronesica 35–36: 563–583.

Pawson, D. 2007. Narcissia ahearnae, a new species of sea star from the Western Atlantic (Echinodermata: Asteroidea: Valvatida). Zootaxa 1386: 53–58.

Paulay, G. 2003. The Asteroidea, Echinoidea, and Holothuroidea (Echinodermata: Asteroidea) including a new subfamily, three new genera and fourteen new species. Zootaxa 4271: 1–72.