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Two new records of *Heterometra* comatulids (Echinodermata: Crinoidea: Comatulida: Himerometridae) from Okinawa-jima Island, southwestern Japan

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Abstract: Two himerometrid comatulids from Okinawa-jima Island are reported as new to the Japanese crinoid fauna. *Heterometra quinduplicava* (Carpenter, 1888) was found on a shallow sandy bottom of a closed bay, which was previously considered as an unsuitable habitat for comatulids. The specimens on hand are much larger than previously known specimens, and differ in the extent of carination on proximal pinnules. *Heterometra sarae* AH Clark, 1941, was collected from a coral reef area. These records extend the geographic ranges of both species northward.

Introduction

The genus *Heterometra* AH Clark, 1909, is the largest genus in the order Comatulida, and includes 26 species widely distributed in shallow waters of the Indo-western Pacific region (AH Clark 1941). In Japan, the only one species, *Heterometra schlegelii* (AH Clark, 1908), has previously been recorded from the Ryukyu Islands (Kogo 2002; Kogo & Fujita 2005), and this record is regarded as the northern limit of the genus.

Members of the genus exhibit great morphological variation. AH Clark (1941) defined the genus as having moderately long cirri with aboral spines or tubercles on distal segments that are not longer than proximal ones, more than 10 arms, and enlarged proximal pinnules, usually increasing in the length from the first to the third. However, this genus includes some species that deviate from this definition, and the borders between each member are ambiguous ("ill-defined" according to AM Clark & Rowe 1971). This genus is actually an assemblage of species unable to be placed in related genera such as *Craspedometra* and *Amphimetra* (AH Clark 1941), and likely includes some synonyms (Messing 1998). AH Clark (1941) prepared two keys for members of this genus, and mentioned that they were the most difficult of all comatulids to identify.

This paper reports on two *Heterometra* species recently found in the coastal area of Okinawa-jima Island, Ryukyu Islands, southwestern Japan, each

collected from a different environment: *Heterometra quinduplicava* (Carpenter, 1888) from a sandy bottom environment (Oura Bay), and *Heterometra sarae* AH Clark, 1941, from a coral reef at a more exposed area. We report on these new records for the Japanese comatulid fauna.

Materials and Methods

General terminology for description mainly follows Messing (1997) and Rankin & Messing (2008). Following Kogo (1998), comparative lengths of pinnules are represented using inequality signs. The terms for ecological notes follows Meyer & Macurda (1980). Abbreviations are as follows:

R: radius; length from center of centrodorsal to longest arm tip, measured to the nearest 5 mm.

c: cirral; segment of cirrus, numbered from the base.

L/W, W/L: length-to-width and width-to-length ratios of skeletal ossicles.

Br: division series numbered from the ray base by Roman numeral (e.g. IIBr2 indicates second division series composed of two ossicles).

br: brachial; individual ray ossicle, numbered from the base of each division series or arm.

+: articulation joined by syzygy (e.g., br₃₊₄ indicates br₃ and br₄ jointed by syzygy).

P: pinnule, numbered from the most proximal. P_{II} indicates pinnule on IIBr₂. P_m and P_d on middle and distal arms, respectively.

The examined specimens were deposited in the Osaka Museum of Natural History (OMNH) and the University Museum Fujyukan, the University of the Ryukyus (RUMF).

Taxonomic account

Family Himerometridae AH Clark, 1907

Genus *Heterometra* AH Clark, 1909

***Heterometra quinduplicava* (Carpenter, 1888)**

[New Japanese Name: Oura-Hane-Umishida]

(Figs. 1, 3A & B)

Antedon clemens Carpenter, 1888: 229, pl. 39 fig. 5; Hartlaub 1891: 37; AH Clark 1911: 541; 1912: 34; 1918: 76.

Antedon anceps Carpenter, 1888: 262, pl. 35 figs 1–3; Hartlaub 1891:17; Koehler 1895: 420; AH Clark 1911: 541; 1912: 33, 35, 40, 74; 1913: 80; 1918: 76.

Antedon quinduplicava Carpenter, 1888: 262, pl. 4 figs 1a–d, pl. 47 fig. 4, 5; Hartlaub 1891: 18; AH Clark, 1912: 35; Gislén 1928: 4.

Himerometra anceps. — AH Clark 1907: 356; 1908: 214.

Himerometra clemens. — AH Clark 1907: 356.

Himerometra quinduplicava. — AH Clark 1907: 356; 1908: 214.

Amphimetra anceps. — AH Clark 1909a: 7; 1913: 23; Gislén 1928: 4; 1934: 16.

Craspedometra aliena AH Clark, 1909b: 31 (part).

Heterometra quinduplicava. — AH Clark 1909a: 11; 1909c: 162, 163, 193; 1912: 35, 130; 1913: 27; 1918: 76, 81, 272; 1941: 245, pl. 26 fig. 107, pl. 34 figs 149–151; Gislén 1928: 4; 1934: 24, 27; AM Clark & Rowe 1971: 8, 21; Rowe & Gates 1995: 154.

Craspedometra anceps. — AH Clark 1911: 541; 1912: 33–35, 120.

Materials examined. **OMNH-Iv5368**, R 195 mm, Oura Bay, Nago, Okinawa-jima Island, Ryukyu Islands, Japan, 15 m depth, fine sandy bottom, 19 Dec. 2010, coll. M. Obuchi. **OMNH-Iv5369**, R 225 mm, Oura Bay, Nago, Okinawa-jima Island, Ryukyu Islands, Japan, 9.5 m depth, fine sandy bottom, 5 Dec. 2010, coll. R. Yanagisawa. **OMNH-Iv5370**, R 105 mm, Oura Bay, Nago, Okinawa-jima Island, Ryukyu Islands, Japan, between 10–20 m depth, fine sandy bottom, 20 May 2011, coll. T. Fujii. **RUMF-ZE-1398**, R 255 mm, Oura Bay, Nago, Okinawa-jima Island, Ryukyu Islands, Japan, 18 m depth, fine sandy bottom, 29 Jun. 2011, coll. M. Obuchi. **RUMF-ZE-1399**, R 150 mm, Oura Bay, Nago, Okinawa-jima Island, Ryukyu Islands, Japan, 15 m depth, fine sandy bottom, 19 Dec. 2010, coll. M. Obuchi.

Diagnosis. A slender, large species with arms reaching more than 200 mm long. Cirri tapering, approximately 20% of arm length, composed of subequal segments; longest cirral as long as broad; distal segments more or less carinate aborally but never bearing spines or tubercles; opposing spine minute. Arms 10–26 (usually 15–20) in number; brachials short but not exceedingly so. Enlarged proximal pinnules with prominent basal keel on side toward arm tip, and mid-aboral ridge on middle

and distal segments; mid-aboral ridge thickened and notched in proximal segments in large specimens, while smooth and less developed in small individuals.

Description. Centrodorsal small, low hemispherical, 4.3–6.5 mm across (Fig. 1A); polar area smooth without papillae, 49–71% of centrodorsal diameter; cirrus sockets arranged into two crowded marginal rows.

Cirri slender, tapering, XXIII–XXXIV, 31–47 mm long (18–22% of R), composed of 35–56 segments (Fig. 1B); proximal cirrals short, cylindrical, increasing in length distally; succeeding cirrals (after c5–c6 in OMNH-Iv5368) except distal ten almost subequal, L/W 1.0–1.2; distal cirrals decreasing in lengths, laterally compressed, aborally angular with median crest not projecting like keel; penultimate with minute opposing spine; terminal claw curved, sharply pointed distally, longer than penultimate.

Radials entirely concealed by centrodorsal (Fig. 1A). Division series smooth; IBr composed of 2 ossicles; IIBr composed of 4(3+4) ossicles, with slight outer lateral expansion; IIIBr present on inner side of bifurcation, always composed of 2 ossicles; first ossicles in each division series fused with each other, second ossicles perfectly separated; slight synarthrial tubercles present on each synarthry between br₁ and br₂; rays well separated (Fig. 1A).

Arms 11–20 in number, 145–250 mm long (R up to 255 mm), smooth except massive and rugged proximally. Brachials short but not exceedingly so; middle and distal arms with W/L 2.5 and 3.5, respectively; distal ends unmodified. First arm syzygy at br₃₊₄; second between br₉₊₁₀ and br₂₂₊₂₃; following at intervals of 6–10 muscular articulations.

Comparative lengths of pinnules $P_{II} \leq P_1 < P_2 \leq P_3 > P_4 > P_5 = P_m \leq P_d$. Proximal pinnules, especially P₂–P₄, enlarged, stiff with flagellate tips (Fig. 1C); P₂ longest in arms arising directly from IBr, while P₃ longest in arms arising from IIBr and IIIBr; distinct keel present on side of proximal segments, gradually diminishing and disappear on middle segments (at 6th–7th in OMNH-Iv5368); another ridge present along mid-aboral line of middle to distal segments (from 3rd in OMNH-Iv5368); in earlier segments, this ridge thickened, heavily notched, formed into discrete tubercles; basal keel and mid-aboral ridge gradually diminishing and disappearing on middle pinnules. In OMNH-Iv5368, P_{II} 7.5–8.0 mm long, composed of 22–28 segments; P₁ 8.5–11.3 mm, 20–22 segments; P₂ 11.0–13.5 mm, 20–22 segments;

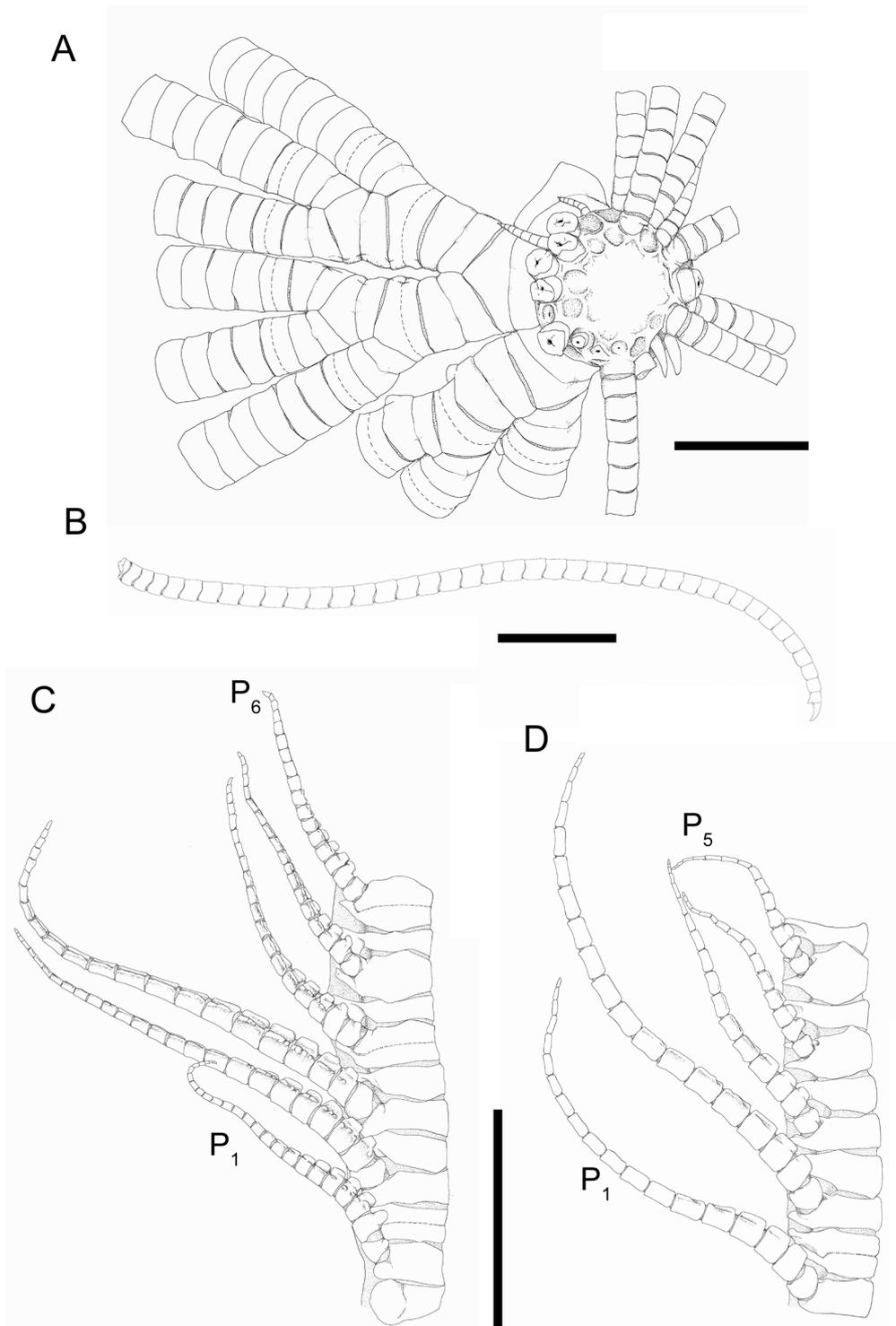


Fig.1. *Heterometra quinduplicava*. A, centrodorsal and division series (OMNH-Iv5368); B, cirrus (RUMF-ZE-1399); C, proximal pinnules of large specimen (OMNH-Iv5368); D, proximal pinnules of small specimen (OMNH-Iv5370). Scale bars 5 mm.

図1. オオウラハネウミシダ (新称) *Heterometra quinduplicava*. A, 中背板と分岐板列 (OMNH-Iv5368); B, 巻枝 (RUMF-ZE-1399); C, 大型個体 (OMNH-Iv5368) の口部羽枝; D, 小型個体 (OMNH-Iv5370) の口部羽枝. スケールは 5 mm.

P₃ 11.5–13.9 mm, 18–22 segments; P₄ 8.5–9.7 mm, 18–19 segments; P₅ 6.0–7.0 mm, 16–17 segments;

P_m 6.0–7.1 mm, 17–19 segments; P_d 7.0–8.5 mm, 20–23 segments.

Disk flat, stellate, 12.0–14.0 mm across, smooth, with no nodules; mouth central; anal cone subcentral.

Notes on young specimen (OMNH-Iv5370). Morphologically similar but with meristic characters outside ranges found in specimens described above, and differing in carination on proximal pinnules.

Centrodorsal 3.0 mm across; polar area 43% of centrodorsal diameter. Cirri XX, 19–22 mm long, of 28–31 segments; longest cirrals L/W 1.3. Arms 18 in number, 100 mm long. Comparative pinnule length $P_{II} < P_1 < P_2 > P_3 > P_4 = P_5 < P_m = P_d$. Enlarged proximal pinnules with weaker carination (Fig. 1D); lateral keel on basal segments lower; aboral ridge on middle to distal segments narrow, gable-like, not thickened in proximal segments.

Coloration. Two main patterns in living animals: 1) uniformly light to dark purple; proximal arms and centrodorsal sometimes faded, almost white (Fig. 3A; OMNH-Iv5369, RUMF-ZE-1398 and RUMF-ZE-1399); 2) overall body color ivory; distal few segments of cirri graded from yellow to brown; dark brown pinnules scattered; lappets of ambulacral grooves light brown (Fig. 3B; OMNH-Iv5368 and OMNH-Iv5370).

Habitat. Exposed during the day on fine sand at the bottom of the bay where sea pens *Cavernulina* sp. and sea grass *Harophila* spp. are found. Usually lying directly on the bottom or sometimes clinging to small rubble with cirri. Most arms spread upward as a partial radial fan, with some arms touching and often bent along the bottom (Fig. 3A, B).

Distribution. The holotype was collected off Mindanao Island, Philippines (Carpenter 1888). The species was previously known from northeast Queensland, Australia (Rowe & Gates 1995), eastward to the Andaman Islands and northward to Mindanao Island (AH Clark 1941); this study extends the range further north to the central Ryukyu Islands. Bathymetrical range: 9–80 m (AH Clark 1941).

Remarks. The specimens from Okinawa-jima Island reported upon here are characterized by large body size, with R reaching more than 200 mm, no aboral processes on distal segments of cirri, and proximal pinnules with one lateral keel on basal segments and a mid-aboral ridge on middle to distal segments. According to the keys to *Heterometra* species by AH Clark (1941) and AM Clark & Rowe (1971), *Heterometra* with tapering cirri lacking distinct aboral processes can be identified as *H. quinduplicava*. The examined specimens agree with this species in general morphology, such as having

a minute opposing spine on cirri, distal brachials short but not exceedingly so, and length ratio of cirri to arms approximately 20%. However, the specimens are much larger than those previously identified as *H. quinduplicava*, which have arm lengths up to 145 mm (mostly less than 100 mm), cirri numbering XVIII–XX with 25–36 segments (AH Clark 1941). Additionally, the carination on the proximal pinnules seem to be more distinct than in previous specimens, which are described as having “smooth” or “slightly carinate” basal segments (AH Clark 1941: 226). Nevertheless, the specimens from Okinawa-jima Island are identified as *H. quinduplicava* here, because the smallest one, OMNH-Iv5370, agrees morphologically with the holotype described by Carpenter (1888). In this smallest specimen, lateral keels and mid-aboral ridges on proximal pinnules are less developed than in the others. This morphological variation among the present specimens suggests that this species reaches larger sizes than previously thought, and that the carination on proximal pinnules is likely to develop with growth. To confirm the latter, further examination of more specimens is needed. The diagnosis shown here was emended from AH Clark (1941), to cover variation of the arm length and of differences in the carination on the proximal pinnules.

If the potential for modification with growth is excluded, the examined specimens, excepting the smallest (OMNH-Iv5370), might be similar to *Heterometra crenulata* (Carpenter, 1882). This species has a wide range of variations related to geographical distribution: individuals are rugged on the North Australian coast and become more slender moving northward to Vietnam (AH Clark 1941; Lane et al. 2000). Some specimens of the slender form of this species lack distinct aboral processes on the cirrus segments (AH Clark 1941), although the keys referred to above do not mention this feature. Such specimens used to be considered a single species together with *H. quinduplicava* (AH Clark 1909b; 1941). Now, *H. crenulata* is distinguishable by the characteristically crenulate profile of the enlarged proximal pinnules, in which a mid-aboral ridge extends as a rounded projection at the distal end of each segment, even higher than lateral keel (AM Clark & Rowe 1971, fig. 17h). Although the proximal pinnules of the present specimens have crenulate profiles, the crenulation is restricted to the basal segments and derives from lateral keels rather than the mid-aboral ridge. However, the validity of this difference needs to be reviewed, as it is possible that the extent of the

carination changes with growth.

In the coastal area of the Ryukyu Islands, where approximately 40 species of comatulids are distributed (Obuchi, personal observation), no other species have been observed inhabiting sandy bottoms. Generally, comatulids are most common in coral reefs or hard bottom areas, and adjacent soft sediment bottoms are ignored as their habitat. However, recent papers have disclosed the presence of comatulid fauna peculiar to soft-bottoms (Stevens & Connolly 2003; Messing et al. 2006). In addition, many species of diverse taxa have been newly reported from the sandy slopes or muddy bottoms of the present sampling site, Oura Bay (e.g., Matsuda et al. 2010; White & Reimer 2012; Fujii & Naruse 2012; Uyeno 2013). Intensive research in such environments is needed to reveal local biodiversity.

***Heterometra sarae* AH Clark, 1941**

[New Japanese name: Fukure-Hane-Umishida]
(Fig. 2, 3C)

Heterometra sarae AH Clark, 1941: 318; AM Clark & Rowe 1971: 8, 21; Rowe & Gates 1995: 154; Putchakarn & Sonchaeng 2004: 419; Keesing et al. 2011: 291.

Materials examined. OMNH-Iv5371, R 155 mm, Horseshoe Cliff, Onna, Okinawa-jima Island, Ryukyu Islands, Japan, 33.2 m deep, 11 April 2013, coll. M. Obuchi. OMNH-Iv5372, R 125 mm, same data (except for depth 34.0 m) as OMNH-Iv5371. RUMF-ZE-1400, R 145 mm, same data (except for depth 28.0 m) as OMNH-Iv5371. RUMF-ZE-1401, R 155 mm, Horseshoe Cliff, Onna, Okinawa-jima Island, Ryukyu Islands, Japan, 27 m deep, 29 December 2011, coll. M. Obuchi.

Diagnosis. Medium sized species with exceedingly short, discoidal and aborally swollen brachials, especially in proximal arms. Cirri stout, curved inward, approximately 20% of arm length, composed of short segments, longest segment not longer than broad; distal segments gradually developing small carinate dorsal spine. Arms 10–19 in number (no IIIBr series), up to 150 mm long. Enlarged proximal pinnules with low keel on basal segments, and gable-like ridge on middle to distal segments that is notched and forms a line of tubercles on proximal segments.

Description. Centrodorsal, hemispherical, 6.2–8.0 mm across (Fig. 2A); polar area shallowly concave, smooth, 30–57% of centrodorsal diameter; cirrus sockets crowded in two rows or a partial

third.

Cirri stout and curved, XXIV–XXXIV, 24–34 mm long (17–23% of R), composed of 28–36 segments (Fig. 2B); all cirrals cylindrical, wider than long; longest middle cirrals (c7–c12 in OMNH-Iv5371) L/W 0.8–0.9; cirrals in distal half (after c13 in OMNH-Iv5371) decreasing in length, with aboral process gradually better developed distally and strongest on antepenultimate; opposing spine straight; terminal claw curved, sharply pointed distally, longer than penultimate.

Radials entirely concealed by centrodorsal (Fig. 2A). Division series ossicles smooth, discoidal, aborally swollen; articulations narrow and deep; IBr of 2 ossicles; IIBr of mostly 4(3+4), rarely 2 ossicles, with slight lateral expansion; no IIIBr; first ossicle of each division series fused laterally; second ossicle perfectly separated; rays well separated from each other (Fig. 2A).

Arms 10–19 in number, 120–140 mm long (R up to 155 mm). Brachials exceedingly short, discoidal, with each margin almost parallel, aborally swollen especially in proximal arms (Fig. 2A); distal ends usually unmodified, sometimes slightly projected aborally in proximal arms; distal brachials with W/L 6.0. First arm syzygy at br₃₊₄; second between br₁₀₊₁₁ and br₂₂₊₂₃; following at intervals of 8–20 muscular articulations.

Comparative lengths of pinnules $P_{II} < P_1 < P_2 \leq P_3 > P_4 > P_5 < P_m = P_d$. Proximal pinnules, especially P₂–P₄, enlarged, stiff, with flagellate tips (Fig. 2C); P₂ longest in arms arising directly from IBr, while P₃ longest in arms arising from IIBr and IIIBr; low keel on side of proximal segments toward arm tip, distinct in earlier segments, gradually diminishing and disappearing on middle segments (7th–9th in OMNH-Iv5371); another gable-like ridge present along mid-aboral line of middle to distal segments (from 6th in OMNH-Iv5371), developing distally, often notched and divided into line of discrete tubercles on proximal segments; both basal keel and mid-aboral ridge gradually diminishing and disappearing on middle pinnules. In OMNH-Iv5371, P_{II} 10.8–12.0 mm long, composed of 30–31 segments; P₁ 8.8–12.1 mm, 24–34 segments; P₂ 11.3–14.0 mm, 24–31 segments; P₃ 13.1–13.6 mm, 23 segments; P₄ 10.1–11.0 mm, 21 segments; P₅ 7.5–9.8 mm, 20–23 segments; P_m 8.5–12.0 mm, 23–26 segments; P_d 9.5–10.1 mm, 23–25 segments.

Disk flat, stellate, 13.5–16.0 mm across, smooth with no nodules; mouth central; anal cone subcentral.

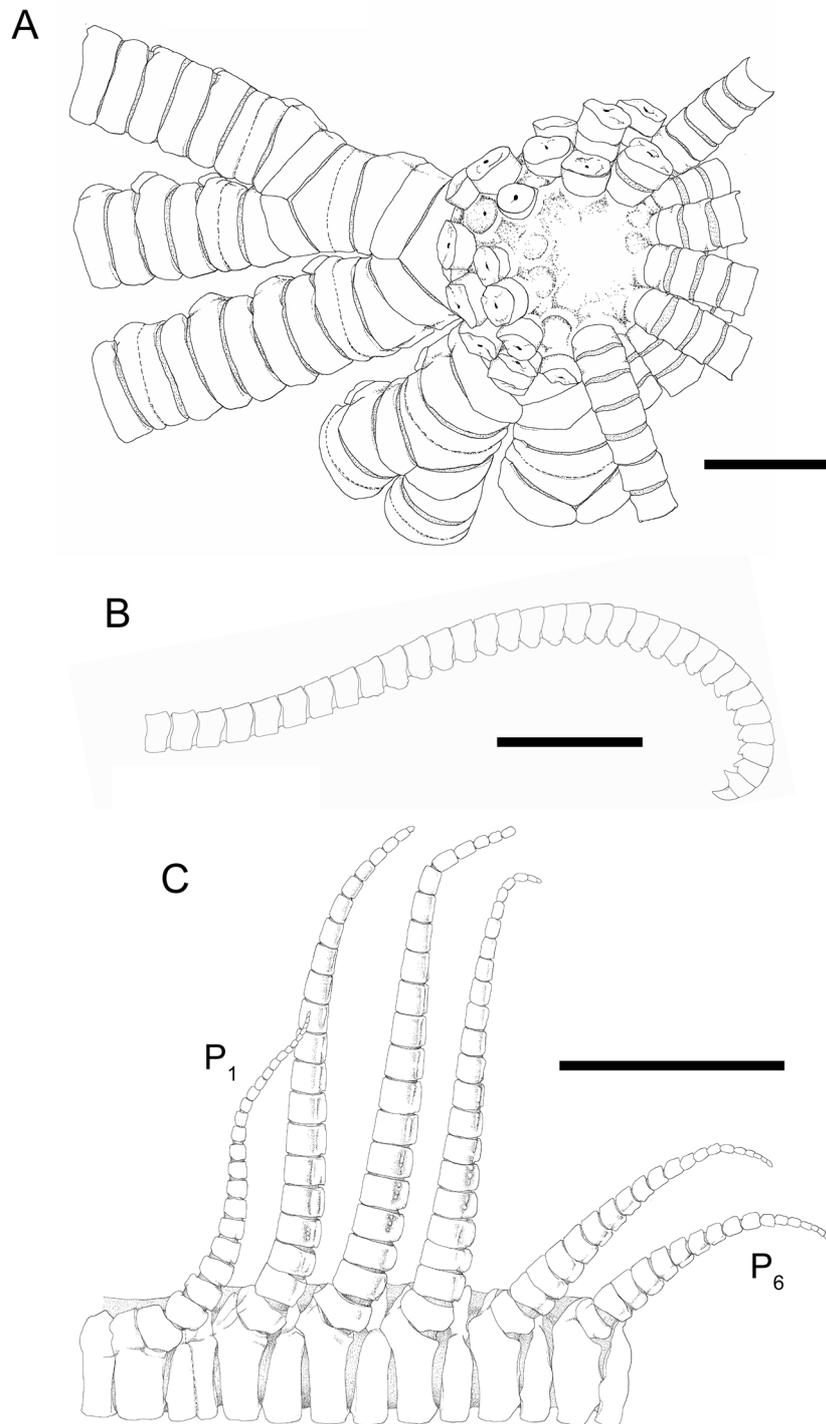


Fig.2. *Heterometra sarae* (OMNH-Iv5371). A, centrodorsal and division series; B, cirrus; C, proximal pinnules. Scale bars 5 mm.

図2. フクレハネウミシダ (新称) *Heterometra sarae* (OMNH-Iv5371). A, 中背板と分岐板列; B, 巻枝; C, 口部羽枝. スケールは 5 mm.

Coloration in life. Centrodorsal, division series, and arm brachials pale purple, often with blurry dark and light bands; cirri dull yellow, sometimes

brown on oral side and at tip; pinnules white, often banded with dark yellow; extent of banded pinnules variable among individuals (Fig. 3C).

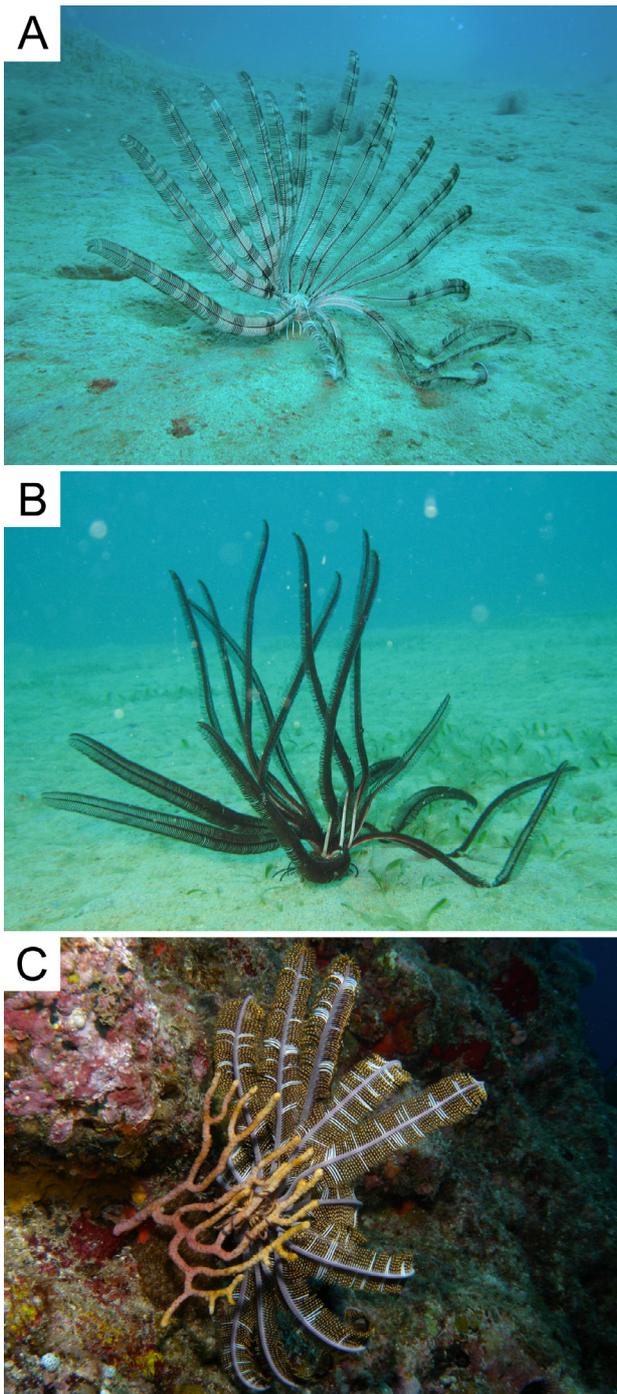


Fig.3. Coloration and feeding posture of living animals. A, B; *Heterometra quinduplicava* (A, OMNH-Iv5369, photographed by R. Yanagisawa; B, OMNH-Iv5368); C, *H. sarae* (RUMF-ZE-1400).

図 3. 2 種のウミシダ類の生時の色彩と接地姿勢。A, B, オオウラハネウミシダ (A, OMNH-Iv5369, 柳澤涼子氏提供; B, OMNH-Iv5368) ; C, フクレハネウミシダ (OMNH-Iv5372).

Ecology. Fully exposed in the day, often perching on pinnacles or sessile organisms such as sea fans and branched sponges with arms spread into a radial fan (Fig. 3C). This species is often

found with other species having the same feeding posture, such as *Colobometra perspinosa* (Carpenter, 1881) and *Cenometra bella* (Hartlaub, 1890).

Distribution. The type locality is Ambon Island, Indonesia (AH Clark 1941). This species was previously recorded from the Timor Sea (Rowe & Gates 1995; Keesing et al. 2011), and the Andaman Sea (Putchakarn & Sonchaeng 2004). This study extends the range northward to the central Ryukyu Islands, Japan. This species occurs in shallow waters less than 40 m deep.

Remarks. The specimens are morphologically identical to the original description of *H. sarae* by AH Clark (1941), in having cirri with gradually developing aboral spines, exceedingly short and swollen brachials free from distinct ornamentation, and a low keel on the basal segments of the proximal pinnules. The combination of such characters is unique to the species. The specimens from Okinawa-jima Island are larger than the holotype, which had 12 cirri of 24–34 segments; however, cirrus morphology is the same. In the diagnosis upon here, emended from AH Clark (1941), such size variation and also a detailed description on the carination of the proximal pinnules were added.

In the genus *Heterometra*, there are eight species having exceedingly short brachials as seen in the present specimens, and four of them occur in the Western Pacific: *Heterometra philiberti* (Müller, 1849), *Heterometra parilis* (AH Clark, 1909), *H. schlegelii* and *H. sarae*. They are easily distinguishable from each other. *Heterometra philiberti* has more arms: usually more than 20, and IIIBr with 4(3+4) ossicles, even when the arm length is less than 100 mm. *Heterometra parilis* is the most similar to *H. sarae*; its proximal brachials are not roundly swollen but their proximal border is raised, and the basal keel on proximal pinnules is more strongly developed into conspicuous carination (AH Clark 1941). *Heterometra schlegelii* has previously been the only species of this genus recorded from Japanese waters (from the Ryukyu Islands), and is endemic to Japan (AH Clark 1941; Kogo 2002; Kogo & Fujita 2005). This small and delicate species has arms not exceeding 100 mm long, and a distinct and sharp aboral spine on the distal cirrals, which develops abruptly.

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沖縄島沿岸から得られた国内初記録のハネウミシダ科2種について

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要旨. 沖縄島沿岸から得られた2種のハネウミシダ類を国内初記録として報告した. オオウラハネウミシダ (新称, 大浦羽海羊歯) *Heterometra quinduplicava* (Carpenter, 1888) は, 浅海産ウミシダ類としては珍しく, 内湾の細砂底から得られた. 沖縄島産の標本は, これまで知られる本種の標本に比べて大型で, また, 口部羽枝基部のキールが発達がより顕著であった. フクレハネウミシダ (新称, 膨れ羽海羊歯) *Heterometra sarae* AH Clark, 1941 はサンゴ礁域から得られた. 本報告により, これら2種の分布域は北側に拡大された.

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