

Redescription of an Euryalid Brittle Star, *Astroceras coniunctum* (Echinodermata, Ophiuroidea, Euryalida)

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Abstract *Astroceras coniunctum* Murakami, 1944 is redescribed based on two newly discovered specimens from the Pacific coast of Japan. To clarify the relationship of *Astroceras coniunctum* to a closely related species, *Astroceras spinigerum*, a detailed description of internal ossicles as well as external features is provided.

Key words: Taxonomy, Euryalidae, *Astroceras*, brittle star, Japan.

Introduction

The genus *Astroceras* (Ophiuroidea, Euryalida, Euryalidae) was erected by Lyman (1879) based on *Astroceras pergamenum* Lyman, 1879. At the present the following 14 species are included in *Astroceras*: *A. annulatum* Mortensen, 1933, *A. aurantiacum* Stöhr, 2011, *A. calix* Murakami, 1944, *A. compar* Koehler, 1904, *A. compressum* Döderlein, 1927, *A. coniunctum* Murakami, 1944, *A. elegans* (Bell, 1917), *A. kermadecensis* Baker, 1980, *A. mammosum* Koehler, 1930, *A. nodosum* Koehler, 1930, *A. paucispinum* Murakami, 1944, *A. pergamenum* Lyman, 1879, *A. pleiades* Baker, 1980 and *A. spinigerum* Mortensen, 1933 (Mortensen, 1933a, b; Murakami, 1944; Baker, 1980; Stöhr, 2011).

Prior to this publication, *Astroceras coniunctum* was known only from the holotype. In the original description Murakami (1944) compared the single specimen *Astroceras coniunctum* with *A. pergamenum*, which he considered the most closely related species. Actually, *Astroceras spi-*

nigerum is more closely related to *A. coniunctum* because they are the only species of *Astroceras* to possess a row of three or four tubercles on each radial shield (Mortensen, 1933a, b; Murakami, 1944), and in fact there are no external characters to distinguish *A. coniunctum* from *A. spinigerum*. However, it has been reported that the proximal vertebrae of *A. spinigerum*, *A. aurantiacum* and *A. compar* lack an oral bridge that is present in most other species of *Astroceras* (Mortensen, 1933b). Therefore, in order to clarify the systematic relationship between *A. spinigerum* and *A. coniunctum* it is necessary to determine whether or not the latter species has proximal vertebrae with an oral bridge.

In this study, we redescribe *Astroceras coniunctum* based on newly discovered specimens from off Kochi Prefecture and Mie Prefecture, central Japan. In addition, we distinguish between *A. coniunctum* and *A. spinigerum* based on an examination of its external morphology and of SEM preparation of isolated internal ossi-

cles, including the proximal vertebrae.

Materials and Methods

The two specimens used in this study are deposited in the National Museum of Nature and Science, Tsukuba (NSMT). A specimen from off Kochi (NSMT E-7474) was air-dried immediately and another specimen from off Mie (NSMT E-7475) was fixed in formalin and preserved in 70% ethanol, except for one arm tip that was preserved in 99% ethanol for future molecular analysis.

The external surface of NSMT E-7474 was observed and photographed with a digital microscope Keyence VHX 1000. Ossicles of NSMT E-7475 were isolated by immersion in domestic bleach (approximately 5% sodium hypochlorite solution), washed in deionized water, dried in air, and mounted on SEM stubs using double-sided conductive tape. The preparations were sputter-coated with gold-palladium and examined with a SEM Hitachi S-4300.

Terminology used to describe anatomical features of ophiuroids is defined in Stöhr *et al.*

(2012) and Okanishi and Fujita (2011). Familial level systematics follows Okanishi and Fujita (2013). In the previous papers, various terms have been used for superficial granular ossicles embedded in the skin, *e.g.* 'granules' (Okanishi and Fujita, 2011), 'granule-shaped dermal ossicles' (Okanishi and Fujita, 2009), 'granule-shaped external ossicles' (Okanishi and Fujita, 2014). In this study, we simply use 'granules' for the ossicles.

Taxonomy

Family Euryalidae Gray, 1840

Genus *Astroceras* Lyman, 1879

Astroceras coniunctum Murakami, 1944

[New Japanese name: Oni-tsuno-moduru]

(Figs. 2–4)

Astroceras coniunctum Murakami, 1944: 243–244, figs. 7–8.

Material examined. NSMT E-7474, 1 dried specimen, attached to a colony of red coral *Paracorallium japonicum* (Kishinouye, 1903) (Cnidaria, Anthozoa, Gorgonacea, Corallidae) col-

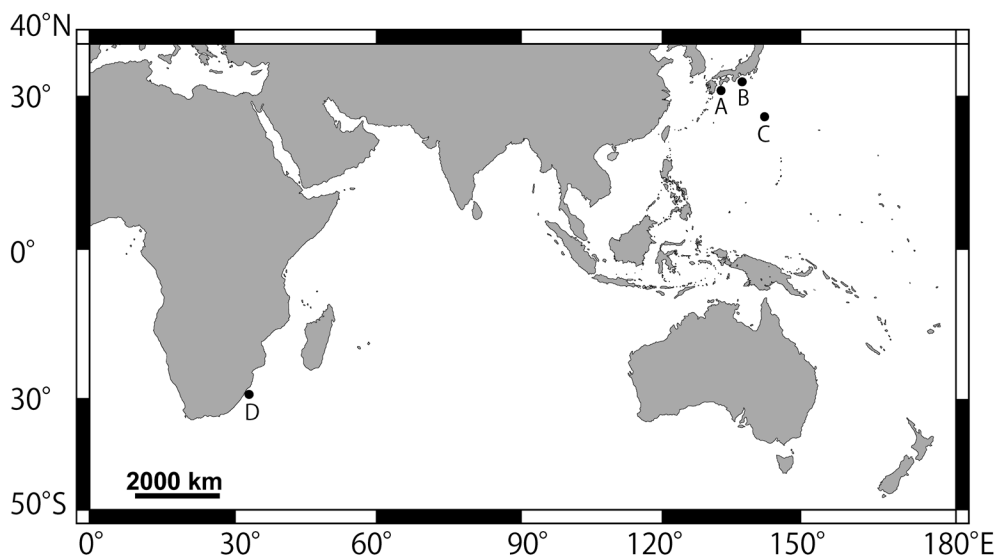


Fig. 1. Distribution of *Astroceras coniunctum* Murakami, 1944 (A–C) and *A. spinigerum* Mortensen, 1933 (D). — A, off Kochi Prefecture (NSMT E-7474); B, off Mie Prefecture (NSMT E-7475); C, off Ogasawara Islands (type locality, Murakami, 1944); D, off Durban (type locality, Mortensen, 1933b).

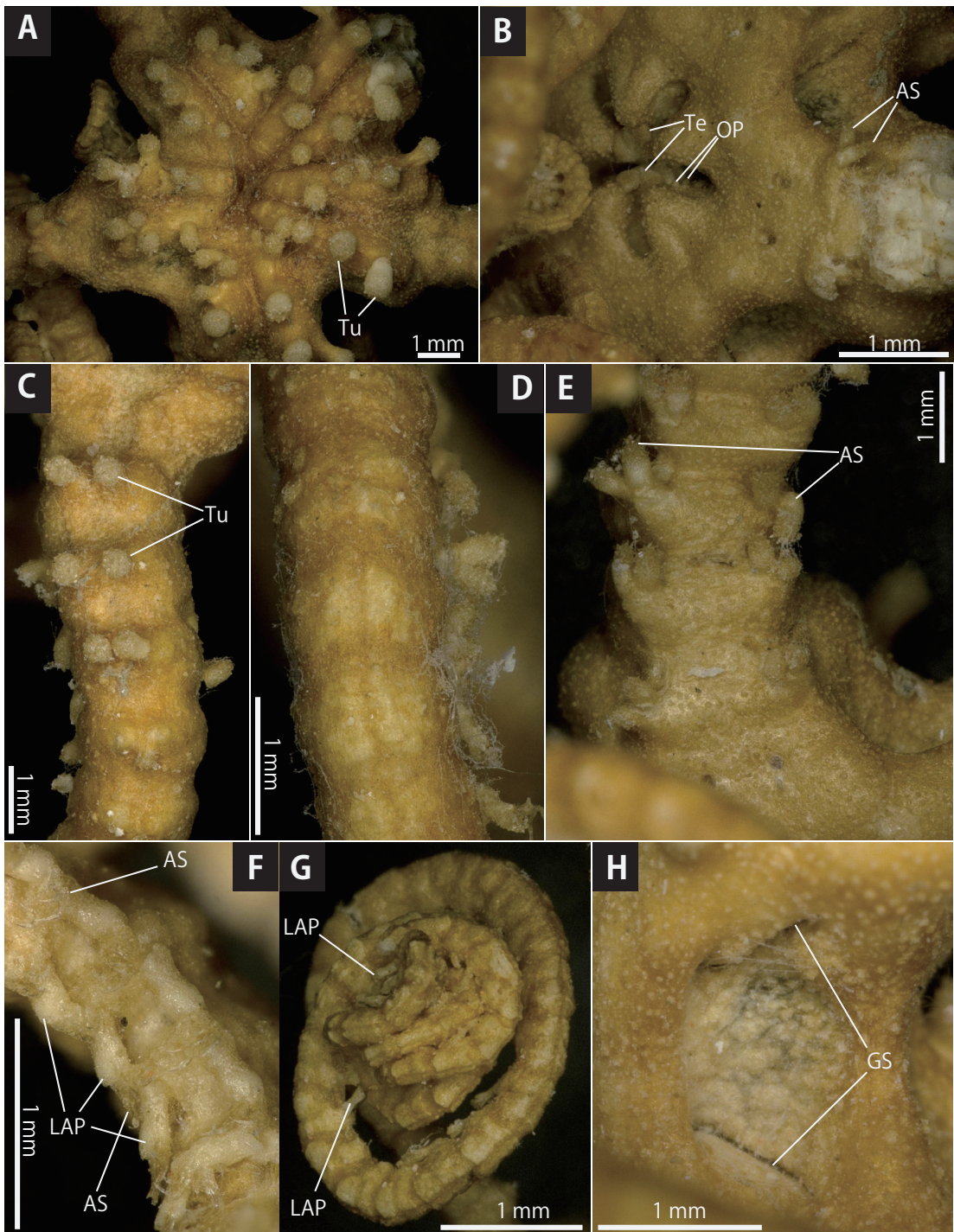


Fig. 2. *Astroceras coniunctum*, NSMT E-7474. — A, aboral disc and proximal portions of arms; B, oral disc; C, aboral proximal portion of an arm; D, aboral middle portion of an arm; E, oral proximal portion of an arm; F, oral middle portion of an arm; G, aboral and lateral views of distal portion of an arm; H, lateral disc. Abbreviations: AS, arm spine; GS, genital slit; LAP, lateral arm plate; OP, oral papilla; Te, teeth; Tu, tubercle.

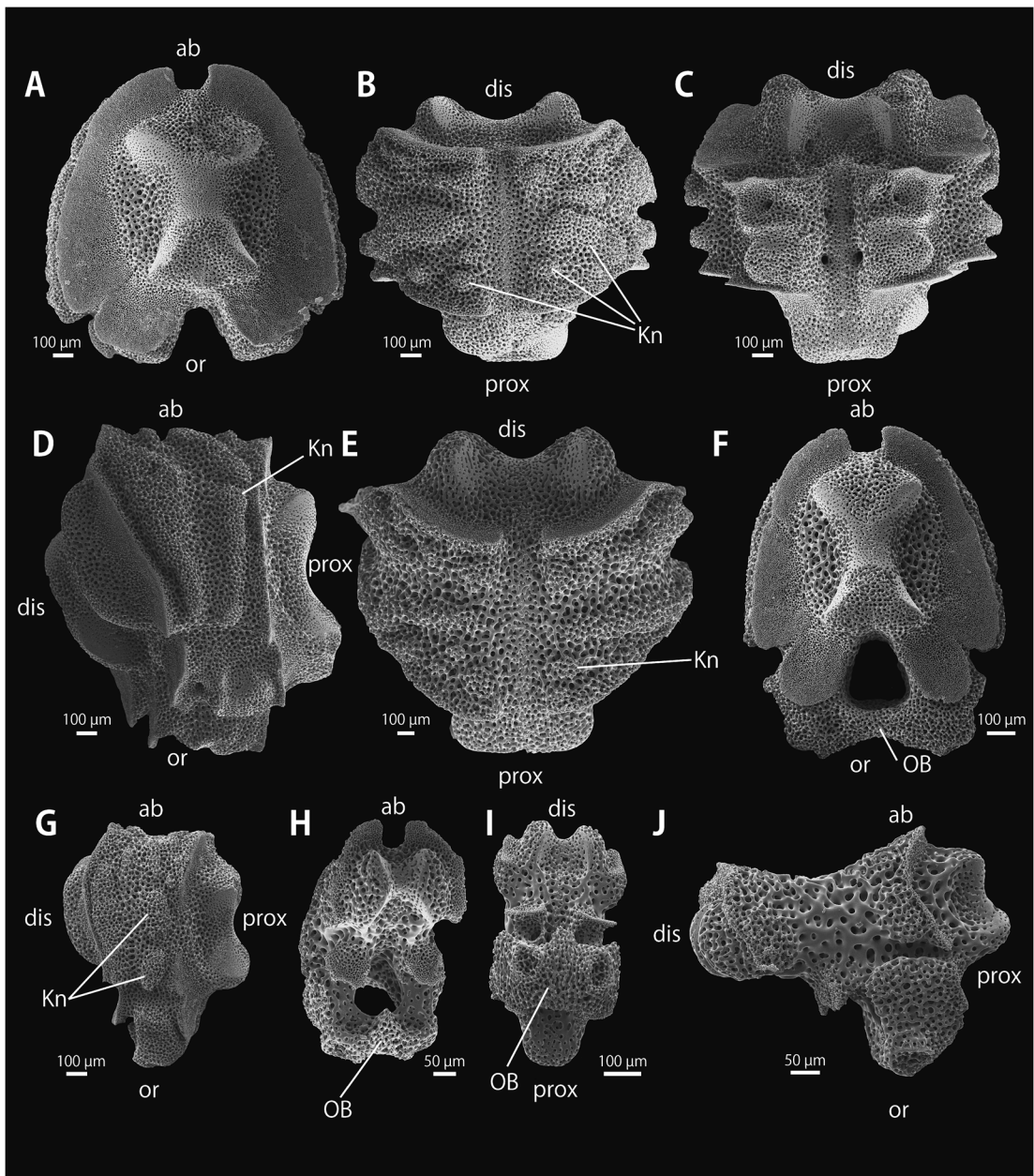


Fig. 3. *Astroceras coniunctum*, NSMT E-7475. SEM photographs of vertebrae from proximal (A–D), from middle (E–G) and from distal portion of an arm (H–J). — A, F, proximal view; B, E, aboral view; C, I, oral view; D, G, J, lateral view; H, distal view. Abbreviations: Kn, knob; OB, oral bridge. Orientations: ab, aboral side; dis, distal side; or, oral side; prox, proximal side.

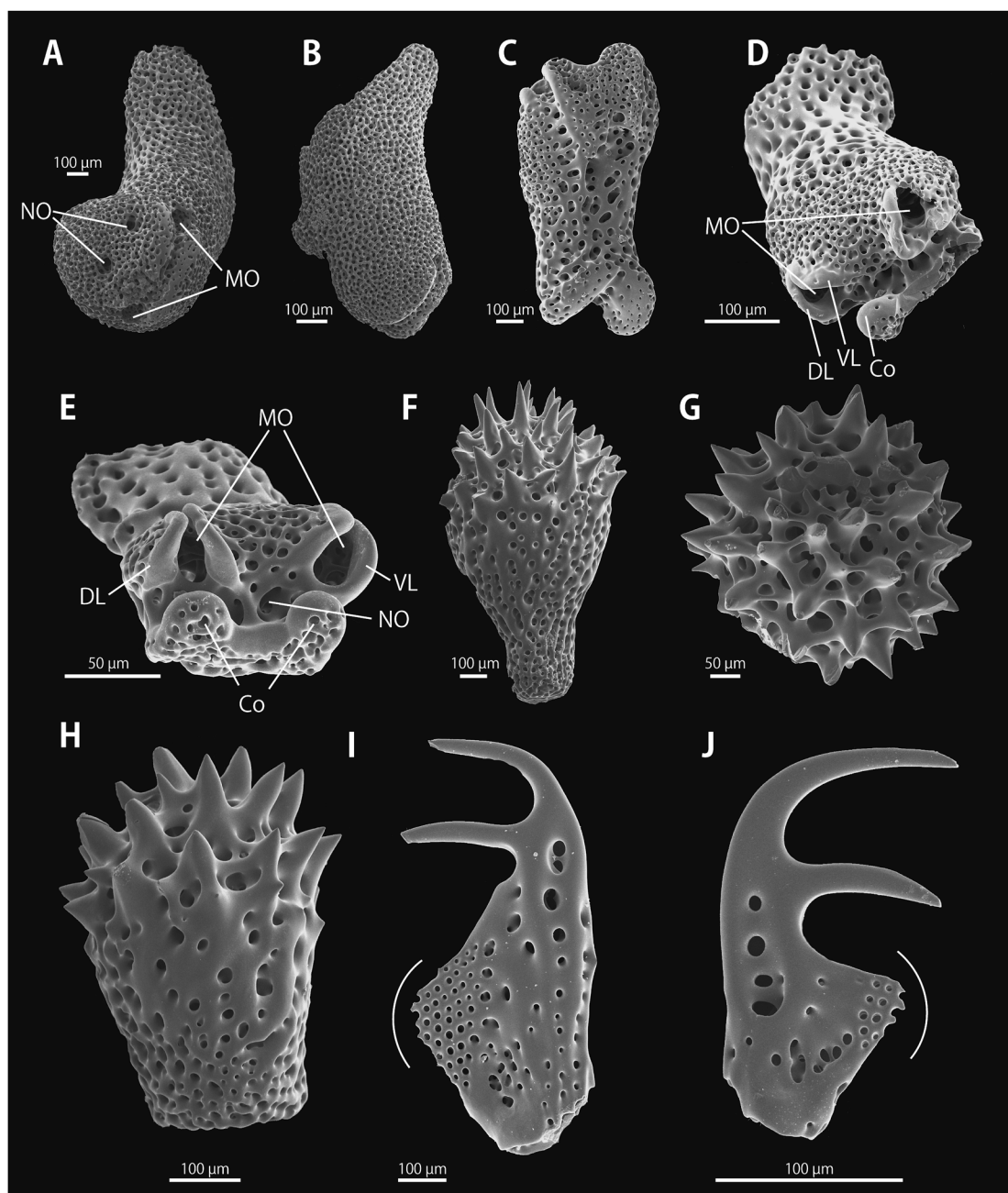


Fig. 4. *Astroceras coniunctum*, NSMT E-7475. SEM photographs of lateral arm plates (A–E), tubercles (F–G) and arm spines (H–J). — A–B, G–H, from proximal portion of an arm; C–D, I, from middle portion of an arm; E, J, from distal portion of an arm; F, from a radial shield. A, D, external view; B, oral view; C, aboral view; E, distal view. Abbreviations: Co, condyle; DL, dorsal lobe; MO, muscle opening; NO, nerve opening; VL, ventral lobe. Arcs indicate smooth lamina (I–J).

lected by coral fishery, at approximately 90–140 m depth, off Ashizuri-misaki Cape, Tosashimizu-shi, Kochi Prefecture, Japan, during October to December 2013. NSMT E-7475, 1 alcohol specimen, collected at approximately 80 m depth with shark net, 11 km south of Goza, Shima-shi, Mie Prefecture, Japan, February 2012 (Fig. 1).

Description of NSMT E-7474 (Fig. 2). Disc pentagonal with notched interradii edges (Fig. 2A). Aboral surface of disc covered by skin and evenly scattered granules of *ca.* 50 μ m in diameter. Radial shields tumid *ca.* 4.0 mm long and 0.6–1.2 mm, each bearing four to five club-shaped tubercles arranged in single file. Tubercles *ca.* 450–700 μ m in diameter and 550–700 μ m in height. Radial shields completely covered by skin, granules and tubercles. Interradius covered by skin with evenly scattered granules of *ca.* 50 μ m in diameter (Fig. 2A).

Oral surface of disc covered by skin and granules, *ca.* 30–60 μ m in diameter, which are evenly scattered (Fig. 2B). At least four horizontally arranged spear head-shaped teeth forming a vertical row on dental plate. Three to five domed oral papillae along each jaw edge (Fig. 2B). Lateral interradii surface of disc nearly vertical, covered by skin and granules, 70–100 μ m diameter (Fig. 2H). Two genital slits in each interradius, 0.9 mm long and 0.01 mm wide (Fig. 2H).

Arms simple, five in number, covered by skin, gradually tapering distally, lacking an abrupt proximal expansion containing gonads (Fig. 2C–G). Proximal portion of arms 1.7 mm wide and 1.9 mm high (Fig. 2C), slightly oblong in cross-section. From middle to distal portion of arms, aboral surface arched and oral surface flattened.

Each proximal arm joint bearing two club-shaped tubercles, *ca.* 480 μ m long and 630 μ m high (Fig. 2C). Aboral surface covered by granules of *ca.* 30 μ m in diameter. Oral surface covered by granules of *ca.* 60 μ m in diameter, which are evenly scattered and less densely distributed than those on aboral surface of the arm (Fig. 2C, E). Middle to distal arm joints bearing few or no tubercles and granules (Fig. 2D, F–G).

First to third tentacle pores lacking arm spines; two arm spines from fourth pore until end of arm (Fig. 2B, E). On proximal third of arm, arm spines ovoid and cylindrical (Fig. 2E). From middle to distal portion of arm, arm spines hook-shaped (Fig. 2F). Adradial and abradial arm spines equal length, about half as long as corresponding arm segment (Fig. 2B, E–F).

Lateral arm plates on proximal portion of arms concealed by skin and granules. From middle to distal portion of arms where skin is thinner, lateral arm plates project more distinctly from the arm's oral surface (Fig. 2F–G).

Color. Uniformly yellowish brown except for tubercles and arm spines, which are white (Fig. 2).

Ossicle morphology of NSMT E-7475 (Figs. 3–4). Vertebrae with streptospondylous articulations (Fig. 3A, F, H). From proximal to middle portion of arms, knobs present on lateral side (Fig. 3B, E, G) decreasing in number toward arm tip and absent near arm tip (Fig. 3J). Knobs on lateral side of vertebrae elongate (Fig. 3B, D–E, G). From middle to distal portion of arms, oral bridges present on oral side (Fig. 3F, H–I).

Lateral arm plates elongated in shape (Fig. 4A–D) with two pairs of muscle and nerve openings, and each of them associated with an arm spine articulation (Fig. 4A, D–E). Dorsal and ventral lobes beside muscle openings contact each other (Fig. 4D–E). A condyle present between each muscle and each nerve opening (Fig. 4D–E).

Tubercles club-shaped, *ca.* 600 μ m wide on radial shield (Fig. 4F) and 600 μ m wide on proximal portion of arms (Fig. 4G).

Arm spines ovoid and cylindrical, *ca.* 400 μ m wide and 500 μ m long on proximal portion of arms (Fig. 4H), hook-shaped with smooth lamina, *ca.* 330 μ m wide and 600 μ m long on middle portion of arms (Fig. 4I), *ca.* 130 μ m wide and 60 μ m long on distal portion of arms (Fig. 4J).

Distribution. Known from off the Ogasawara Islands, southern Japan, the type locality (Murakami, 1944), off Goza, *ca.* 165 m depth, central Japan (this study) and off Ashizuri-misaki

Cape, ca. 90–140 m depth, western Japan (this study) (Fig. 1).

Remarks

Astroceras coniunctum and *A. spinigerum* possess three or four tubercles on each radial shield (Lyman, 1879; Murakami, 1944). Moreover, our detailed examination revealed that the proximal vertebrae of *A. coniunctum* lack an oral bridge (Fig. 3A, C) similarly to *A. spinigerum* (Mortensen, 1933a). Thus, *A. coniunctum* and *A. spinigerum* are identical in nearly all characters that have been examined, and might be viewed as synonyms. However, we here refrain from synonymizing at the present time because so few specimens of either species have been examined.

The holotype of *Astroceras coniunctum* is presumed lost, based on survey of the specimens in the Amakusa Marine Biological Laboratory of the Kyushu University with which Murakami was affiliated (T. Fujita, unpublished data), and additional specimens have never been collected from the type locality. The only known specimen of *A. spinigerum* is the holotype. The examination of additional materials of *A. coniunctum* from the type locality and the holotype of *A. spinigerum* might be helpful to clarify the systematics of these extremely similar species.

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