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First Record of the Deep-Sea Sea Spider *Bathypallenopsis californica* (Arthropoda: Pycnogonida) From the Northwestern Pacific, With a Note on an Attached Crinoid

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We report the first record of the pallenopsid pycnogonid species *Bathypallenopsis californica* (Schimkewitsch, 1893) from the northwestern Pacific. Based on one male specimen collected from 1987–2007 m depth off the southeastern coast of Hokkaido, Japan, we redescribe the species and present its cytochrome *c* oxidase subunit I (COI) sequence for use in future DNA barcoding. We found a cystidean-stage crinoid on the leg-1 femur of the sea spider, representing the first record of a cystidean found on a sea spider. BLAST searches for COI and 28S sequences revealed that the crinoid was *Florometra asperrima* (Clark, 1907).

Key words: bathyal zone, Crinoidea, epibiotic, DNA barcode, Pallenopsidae, Pantopoda, Pycnogonida

INTRODUCTION

Bathypallenopsis Stock, 1975 is one of two genera in the family Pallenopsidae Fry, 1978. With 21 species, *Bathypallenopsis* has been reported from depths of 100–5650 m and from most oceans of the world: Pacific, Atlantic, Indian, and Antarctic (see Supplementary Table S1; Supplementary Figure S1). Stock (1975) proposed three species groups based on proboscis shape: the *tydemani* group, with a styliform proboscis that expands at the middle and then narrows toward the tip; the *longirostris* group, with a proboscis that is the widest at the tip; and the *mollissima* group, with a "normal" proboscis that has almost parallel lateral margins but is slightly wider in the middle.

Bathypallenopsis californica (Schimkewitsch, 1893), one of the largest species in the genus, is distinguished from congeners in having a *tydemani*-group type proboscis and a large most-proximal heel spine that is half the length of the claw. It was originally described from syntype specimens from the Gulf of California and the Gulf of Panama (subtropical to tropical eastern Pacific; Schimkewitsch, 1893), and subsequently reported from off Cape Point, South Africa (southeastern Atlantic; as *Pallenopsis oscitans* (Hoek, 1881), Barnard, 1954), the Mozambique Channel (southwestern Indian Ocean; Turpaeva, 1991, 1992; Stock, 1994), off Oregon, USA (northeastern Pacific; Child, 1994), and the Hikurangi Trough, New Zealand (southwestern Pacific; Child, 1998) (Fig. 1). Its known depth range is 1510–3655 m. Stock (1975) provided a partial redescription of this species based on one of the syntypes.

One *B. californica* male was collected at a depth of 1987–2007 m off the southeastern coast of Hokkaido, Japan, in 2022. This represents the first record of the species in the northwestern Pacific. On a leg of the sea spider, we found one cystidean-stage crinoid that is sessile, has a stalk and calyx, but lacks arms (cf. Kohtsuka and Nakano, 2005). This is the first example of a cystidean attaching to a sea spider. Here, we describe the morphology of the *B. californica* specimen, present a partial sequence for its cytochrome *c* oxidase subunit I (COI) gene, describe the morphology of the attached cystidean, and present partial 28S rRNA and COI sequences for it.

MATERIALS AND METHODS

The pycnogonid (see "Material examined" in the description below for relevant collection information) was fixed in 80% ethanol and then preserved in 99% ethanol. Appendages were detached from the trunk by using chemically sharpened tungsten needles. Body parts and appendages were observed with a Nikon SMZ 1500 stereomicroscope. The distal part of the left oviger comprising five articles was detached, mounted in glycerin on a glass slide, and observed with an Olympus BX51 microscope; after observation, it was preserved in 99% ethanol. Illustrations were prepared with Adobe Illustrator 2021 and Adobe Photoshop 2021 (Adobe, USA) from draft line drawings made with a drawing tube. Morphological terminology follows Child (1979), except that the term "article" is used instead of "segment" for all appendages (Hosoda and Kakui, 2020). The cephalon, with a proboscis, ocular tubercle, chelifore, palp,

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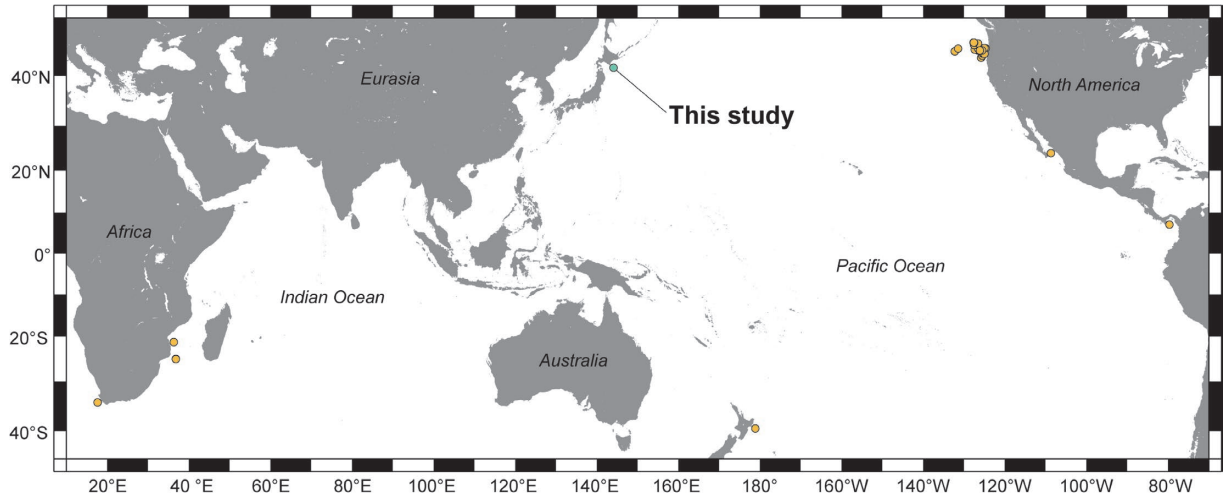

Fig. 1. Map showing the global distribution of *Bathypallenopsis californica* (Schimkewitsch, 1893). The map and plots were generated with GMT6 software (Wessel et al., 2019). Sources and the raw data for the plots are available in Supplementary Table S1.

oviger, and leg 1, represents the first trunk segment; trunk segments 2–4 bear legs 2–4, respectively. Measurements (presented in millimeters) were made axially (dorsally for the trunk; laterally for the proboscis and abdomen; posteriorly for coxae 1–3, the femur, and the cement gland tube; and anteriorly for the other parts of left leg 3). Trunk length was measured from the base of the chelifore to the posterior end of the fourth lateral process. Body width was measured as the distance across the distal ends of the second lateral processes. The specimen studied has been deposited in the Invertebrate Collection of the Hokkaido University Museum (ICHUM), Japan.

The cystidean on the fixed pycnogonid was photographed and then detached from the pycnogonid with needles. The detached cystidean in ethanol was mounted on a glass slide with a pair of thin spacers and observed and photographed at different focal planes through an Olympus BX53 microscope. The serial images were assembled by using CombineZM (Hadley, 2008). The cystidean was cut into three parts (calyx, stalk, and attachment plate); the stalk was used for DNA extraction and the other parts were preserved in ethanol.

DNA was extracted from muscle tissue from the femur of left leg 3 of the sea spider and the stalk of the cystidean by using a NucleoSpin Tissue XS Kit (Macherey–Nagel, Germany). For the sea spider COI gene, primers LCO1490 and HCO2198 (Folmer et al., 1994) were used for PCR amplification and cycle sequencing. For the cystidean 28S gene, newly designed primers Cri_28F (TCAGTAGCGGCGAGTGAAGC) and Cri_28R (CTTTCGGGTCCTAACGCACAC) were used for PCR, and primers 28S-Rd4.2b, 300F, 300R, and 900F (Whiting, 2002; Lockyer et al., 2003) for cycle sequencing. For the cystidean COI gene, newly designed primers Cri-COIF (TACTTTGTATTTTCTTTTTGGWGCTTG) and Cri-COIR (AACATGAGAAATCATACCAAAWCCA) were used for PCR and cycle sequencing. PCR amplification conditions for COI and 28S with KOD ONE PCR Master Mix (Toyobo, Japan) were 45 cycles of 98°C for 10 s, 56°C (COI) or 59°C (28S) for 5 s, and 68°C for 1 s (COI) or 5 s (28S). All nucleotide sequences were determined with a BigDye Terminator Kit ver. 3.1 and a 3730 DNA Analyzer (Life Technologies, USA). Fragments of sea spider COI were concatenated by using GeneStudio Professional Edition ver. 2.2.0.0. (GeneStudio, Inc.) and those of cystidean 28S and COI were concatenated by using MEGA7 (Kumar et al., 2016). The sequences we determined were deposited in the International Nucleotide Sequence Database (INSD) through the DNA Data Bank of Japan. Similarity searches of the INSD for sequences most similar to those we determined were conducted with BLAST (Altschul et al., 1990).

RESULTS

Taxonomy

Family **Pallenopsidae** Fry, 1978
Genus ***Bathypallenopsis*** Stock, 1975

Pallenopsis (*Bathypallenopsis*) Stock, 1975, p. 1032.
Bathypallenopsis: Bamber, 2007, p. 309 (elevated to genus rank).

Remarks. Stock (1975) and Bamber (2000) listed five species in the *tydemani* group, but our literature survey found three additional species having a styliform proboscis: *B. bicuspidata* (Stock, 1968), *B. longimana* (Stock, 1991), and *B. profundis* (Hilton, 1942) (Stock, 1968, 1991: fig. 49; Bamber, 2002a: figs. 9, 10), all of which we assigned to the group. The *tydemani* group thus currently contains eight species: *B. bicuspidata*, *B. californica*, *B. longimana*, *B. profundis*, *B. richeri* (Bamber, 2000), *B. stylirostris* (Hedgpeth, 1949), *B. tritonis* (Hoek, 1883), and *B. tydemani* (Loman, 1908).

Bathypallenopsis californica (Schimkewitsch, 1893)
[New Japanese name: Takageta-kaginote-umigumo]
(Figs. 2, 3)

Pallenopsis californica Schimkewitsch, 1893, pp. 39–41, figs. 11, 18–23; Hilton, 1942, p. 40.
Pallenopsis (*Bathypallenopsis*) *californica*: Stock, 1975, pp. 1036–1038, figs. 33, 34.
Bathypallenopsis californica: Lörz et al., 2012, p. 44.

Material examined. One male (ICHUM8982), 1 jar, Station A0 (41°31.358′N, 144°08.595′E to 41°30.974′N, 144°08.167′E), cruise KH-22-8, R/V *Hakuho-maru* (Japan Agency for Marine-Earth Science and Technology; JAMSTEC), off southeastern Hokkaido, Japan, northwestern Pacific, 1987–2007 m depth, 2 October 2022, beam trawl, collected by Keiichi Kakui.

Description. Trunk (Figs. 2; 3A, B) elongate, naked,

Fig. 2. *Bathypallenopsis californica* (Schimkewitsch, 1893), male (ICHUM8982). Dorsal view of the ethanol-fixed specimen.

fully segmented; lateral processes well separated by 0.7 (between 1–2), 0.9 (between 2–3), and 0.6 (between 3–4) times their basal diameter, twice as long as their basal diameter; lateral processes 1 and 3 each with dorsal seta. Cephalon slightly shorter than trunk segments 2–3 combined; ocular tubercle anterior, dome-like, with paired small papillae on top and four eyes; posterior eyes smaller than anterior ones. Proboscis styliform, extending anteroventrally, with several short distal setae; mouth triradiate. Abdomen naked, extending posteriorly and slightly dorsally, past distal margin of coxa 2 of leg 4; base narrow, gently widening posteriorly.

Chelifore with biarticulate scape and chela. Scape 1 with few setae from middle to distal regions. Scape 2 with setae from proximal to distal regions. Chela (Fig. 3C) slender; palm with several setae; fingers curved, gaping, tips crossing.

Palp uniarticulate, small, knob-like.

Oviger (Fig. 3D, E) with 10 articles and terminal spine. Article 1 with endal row of sparsely arranged short setae. Articles 2–4 with endal and ectal rows of sparsely arranged short setae. Articles 5–8 and 10 with long setae densely in ectal region. Article 9 covered with uneven setae. Article 6 with six strong endal spines pointing proximally; article 10 with nine strong endal spines and terminal spine.

Leg 3 (Fig. 3F–I) coxae 1–3 with several setae; coxa 2 with distoventral tubercle bearing genital pore at tip (Fig. 3F, arrowhead); coxae 2 and 3 with several distoventral setae. Femur gently arched, with several long setae sparsely arranged and two distoventral long setae, slightly swollen at cement gland; cement gland observable inside femur at mid-length (shaded area in Fig. 3F); cement gland tube ventral, meandering, length nearly half femoral diameter. Tibia 1 with several rows of long setae, two distoventral long setae, and several distodorsal short setae. Tibia 2 gently arched, with several rows of long setae and several distal spines. Tarsus with several short setae and large ventral spine. Propodus gently arched, with dorsal row of short setae, several anterior and several anterodistal setae, and distodorsal spine; distal margin protruding, forming pointed corner; on ventral margin, two long heel spines and row of short, uneven spines; proximal heel spine 2.6 times as long as distal heel spine, and half as long as claw. Claw elongate. Auxiliary claws present, vestigial.

Similar to leg 3, genital pore present on leg 4; cement gland tubes present on legs 1, 2, and 4.

Measurements (mm). Length of trunk 10.60; width across second lateral processes 6.70; length of proboscis 6.37; proboscis width at base 1.18, middle (maximum) 1.57, tip 0.84; length of cephalon 4.10; maximum width of cephalon 2.32; height of ocular tubercle 0.56; length of abdomen 5.81; width of abdomen at base 0.63. Chelifore: lengths of scapes 1, 2 are 3.93, 2.77; lengths of palm, movable finger 0.87, 2.03. Oviger: lengths of articles 1–10 are 1.20, 2.67, 1.23, 2.84, 1.90, 1.48, 1.45, 1.45, 0.96, 1.07. Leg 3: lengths of articles (from coxa 1 to propodus), claw, auxiliary claw 1.43, 4.56, 1.88, 15.85, 13.50, 19.90, 0.46, 3.11, 3.02, 0.38; length of ventral large tarsus spine 0.90; lengths of proximal and distal heel spines 1.31, 0.50; length of spines on ventral margin of propodus 0.05–0.21.

Genetic Information. A partial COI sequence (658 bp; INSD accession no. LC858671) was determined. The

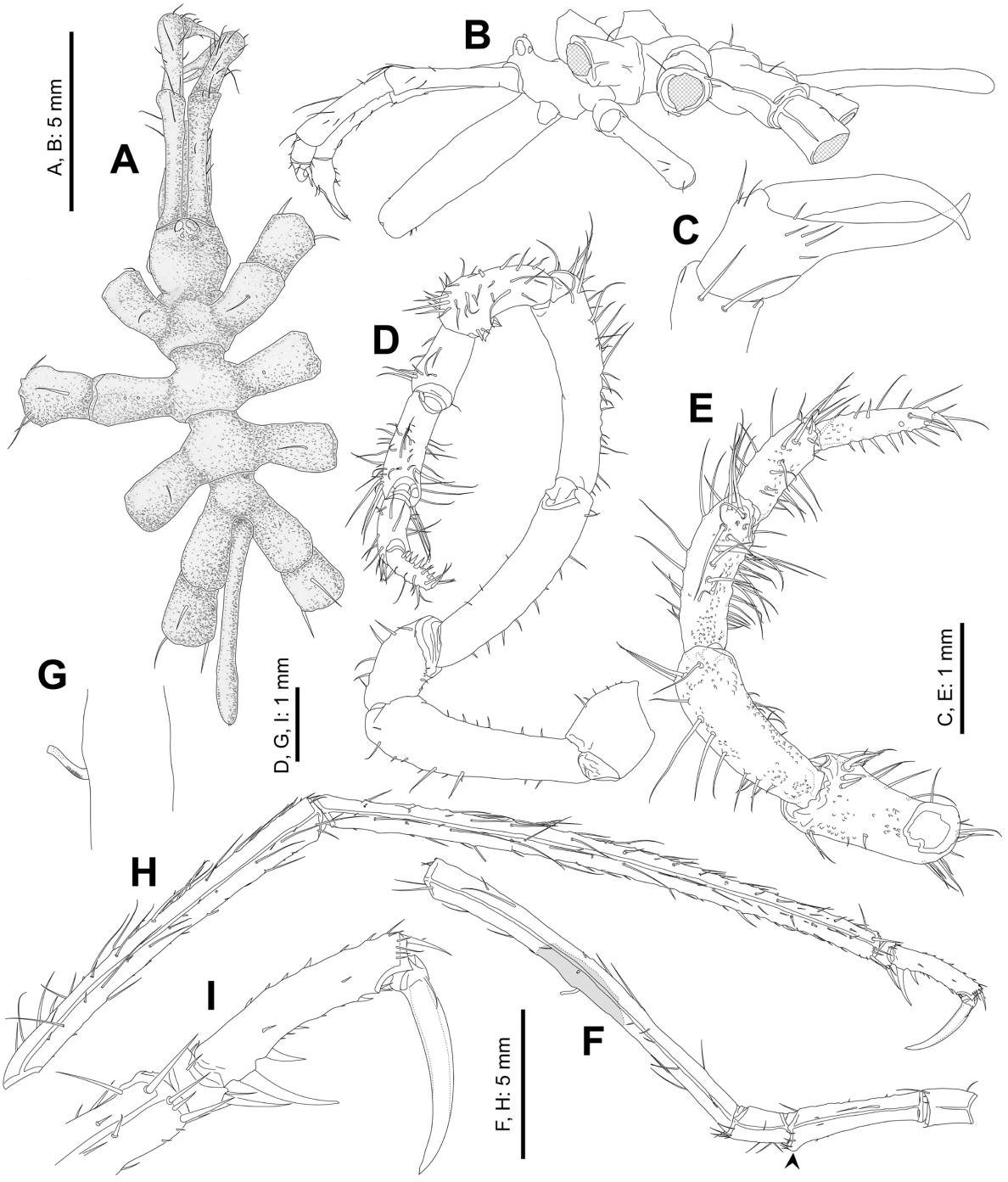

Fig. 3. *Bathypallenopsis californica* (Schimkewitsch, 1893), male (ICHUM8982). **(A)** Body, dorsal view. **(B)** Body, lateral view. **(C)** Left chela. **(D)** Left oviger. **(E)** Left oviger, distal five segments. **(F)** Left leg 3, coxa 1 to femur, posterior view (arrowhead, position of genital pore; shaded area, cement gland). **(G)** Cement gland tube of left leg 3, posterior view. **(H)** Left leg 3, tibia 1 to claw, anterior view. **(I)** Left leg 3, tarsus to claw, anterior view.

sequence in the INSD most similar to ours, as determined by a BLAST search, was from *Pallenopsis patagonica* (Hoek, 1881) from 188 m depth, western Antarctic Peninsula (62°56.004′S 61°28.751′W) (KT982316, identity score 85%, query cover 96%; Harder et al., 2016).

Epibiotic crinoid. One cystidean-stage crinoid (Figs. 4, 5) was attached to the anterior surface of femur of right leg 1 of the sea spider. The length from the attachment plate to the tip of the calyx was 1.7 mm; the calyx length was 0.4 mm. Five oral and five basal plates and at least 13 columnar stalk ossicles were observed; the attachment plate was circular (Figs. 4; 5A, B, E). Partial 28S (911 bp; INSD accession no. LC858672) and COI (672 bp, encoding 223 amino acids; LC858670) sequences were determined for the crinoid. The 28S and COI sequences in the INSD most similar to ours, as determined by BLAST searches, were both from *Florometra*

asperrima (Clark, 1907) collected at 1116 m depth, northeastern Pacific (54.184°N 133.921°W) (28S, KC626828, identity score 100%, query cover 80%; COI, KC626548, identity score 100%, query cover 90%; Hemery et al., 2013). In addition to the crinoid, bryozoan and hydrozoan epibionts were observed.

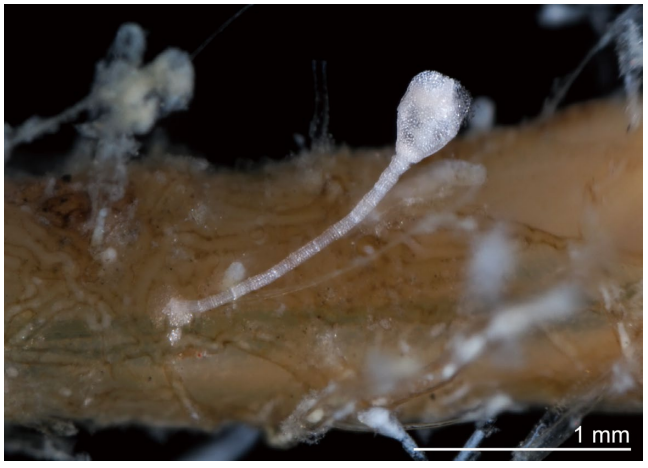

Fig. 4. Crinoid cystidean on leg-1 femur of male *Bathypallenopsis californica* (Schimkewitsch, 1893), ethanol fixed specimen.

DISCUSSION

We identified our male pycnogonid as *B. californica* because it has a styliform proboscis (*tydemani*-group type), fingers twice as long as the palm, the abdomen slightly longer than trunk segments 2–4 combined, and a long most-proximal heel spine (half as long as the claw). The morphology of our specimen concurred well with the previous descriptions of syntypes from the northeastern Pacific (Schimkewitsch, 1893; Stock, 1975). Published morphological information is lacking for specimens from regions other than the North Pacific.

Our record of *B. californica* expands its currently known distributional range to the northwestern Pacific, in addition to the northeastern Pacific, southwestern Pacific, southeastern Atlantic, and southwestern Indian Ocean; the depth of our specimen (1987–2007 m) falls within the previously known depth range (1510–3655 m). Given that *Bathypallenopsis* belongs to Pallenopsidae, species in which show direct development, hatching as an advanced postlarva (Brenneis et al., 2017), the innate dispersal ability of *B. californica* is likely low. Its wide distribution may thus result from passive dispersal through biotic/abiotic factors and is possibly mediated by bathypelagic scyphozoan and/or hydrozoan medusae. Two congeners, *B. scoparia* (Fage, 1956) and *B. calcanea* (Stephensen, 1933), were observed in situ

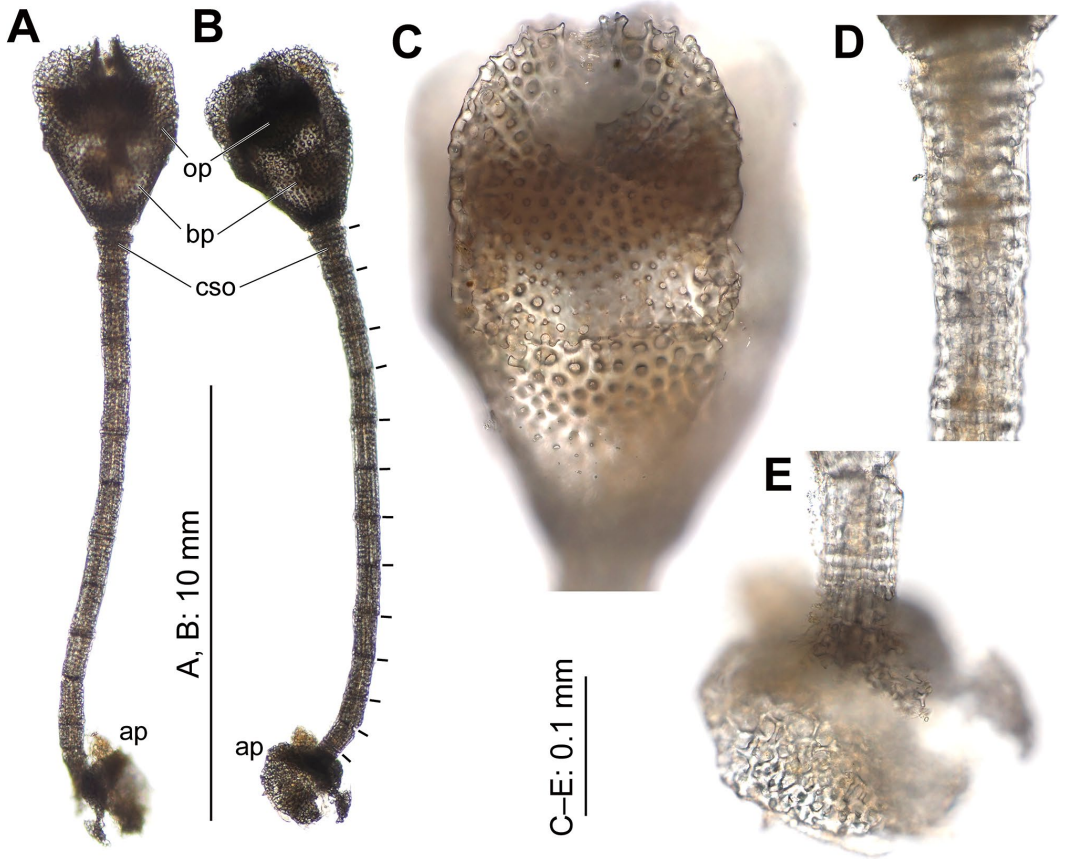

Fig. 5. Crinoid cystidean, ethanol fixed specimen. **(A, B)** Habitus, from two different angles; black dash marks indicate junctions between columnar stalk ossicles. **(C)** Oral and basal plates of calyx. **(D)** Columnar stalk ossicles. **(E)** Attachment plate. Abbreviations: ap, attachment plate; bp, basal plate; cso, columnar stalk ossicle; op, oral plate.

attached to bathypelagic scyphozoan and hydrozoan medusae, respectively (Child and Harbison, 1986; Gasca and Browne, 2018). Individuals of *B. calcanea* and *B. tritonis* associated with bathypelagic hydrozoan medusae have been found in plankton samples (Hedgpeth, 1962; Pagès et al., 2007). *Bathypallenopsis calcanea*, *B. juttingae* (Stock, 1964), *B. mollissima* (Hoek, 1881), *B. scoparia*, and *B. tritonis* have been reported from various midwater samples (Gordon, 1932; Stephensen, 1933; Hedgpeth, 1948; Turpaeva, 1957, 1971; Clark, 1958; Stock, 1964, 1986; Clark and Carpenter, 1977; Mauchline, 1984; Bamber, 2002a, b). Although *B. californica* has not yet been observed or collected with bathypelagic scyphozoan or hydrozoan medusae, these previous examples suggest that it may achieve long-distance dispersal via attachment to them.

We report the first example of a crinoid epibiotic on a sea spider. Our crinoid was identified molecularly as *Florometra asperrima*, previously reported from the northeastern Pacific (California), southern Bering Sea (Aleutian Islands), Okhotsk Sea, and northwestern Pacific (Japan) at depths of 79–1574 (?1941) m (Clark and Clark, 1967). Cystidean-stage crinoids have previously been reported as epibionts on a wide range of organisms, including hydroids, bryozoans, adult crinoid cirri, dead corals, hexactinellid sponges, macroalgae, and seagrasses (Thomson, 1865; Holland, 1991; Barthel, 1997; Obuchi et al., 2009; Kohtsuka, 2011), with additional reports from abiotic substrates such as underwater experimental instruments (e.g., Schiaparelli and Aliani, 2019; Meyer-Kaiser et al., 2021). Holland (1991) stated that crinoid larvae probably choose certain substrates in preference to others. Sea spiders provide attachment or egg-laying sites for various organisms, including algae, diatoms, foraminiferans, ciliophorans, sponges, hydrozoans, bryozoans, brachiopods, entoprocts, polychaetes, leeches, gastropods, barnacles, and tunicates (Kakui and Sekiguchi, 2024). Though we cannot rule out that our cystidean individual on a sea spider was an exceptional occurrence, our study demonstrates that sea spiders may provide settlement sites for crinoid larvae on deep-sea bottoms.

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COMPETING INTERESTS

We declare no competing interests.

AUTHOR CONTRIBUTIONS

SS observed the morphology of the sea spider. KK collected the sea spider and observed the morphology of the cystidean. SS and KK conceived and designed the study and conducted the molecular analysis. SS, HK, and KK wrote the manuscript, and read and approved the final draft.

SUPPLEMENTARY MATERIALS

Supplementary materials for this article are available online. (URL: https://doi.org/10.2108/zs250004)

Supplementary Table S1. Occurrence records of *Bathypallenopsis* sea spiders and published sources.

Supplementary Figure S1. Maps showing the reported locations of 21 *Bathypallenopsis* species.

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