Description of three species of Ophioplinthacids, including a new species, from a deep seamount in the Northwest Pacific Ocean (#55728)

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Description of three species of Ophioplinthacids, including a new species, from a deep seamount in the Northwest Pacific Ocean

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Five specimens of brittle star were collected from a deep-sea seamount in the Northwest Pacific, and identified into three species. One of which is new to science, *Ophioplinthaca grandisquama* n. sp., can be easily distinguished from its congeners by the distinctly elongated and stout tentacle scales, stout and long disc spines, capitate with typically elongate to flaring head bearing numerous distinct thorns, radial shields roughly triangular and contiguous distally. One specimen was identified as *Ophioplinthaca semele* (A.H. Clark, 1949), which had been reported in Hawaii seamounts, is a new record of this species in the Northwest Pacific. The remaining specimen was an unknown species of *Ophioplinthaca*, with some different characteristics from other species of *Ophioplinthaca*. However, we, herein, prefer not to attach a name to this specimen until more morphological characteristics are available. The finding of this new species and two new records further enriches the distribution of *Ophioplinthaca* in the seamount of Northwest Pacific, providing useful information for marine protection in the cobalt-rich area.

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Abstract

Five specimens of brittle star were collected from a deep-sea seamount in the Northwest Pacific, and identified into three species. One of which is new to science, *Ophioplinthaca grandisquama* n. sp., can be easily distinguished from its congeners by the distinctly elongated and stout tentacle scales, stout and long disc spines, capitate with typically elongate to flaring head bearing numerous distinct thorns, radial shields roughly triangular and contiguous distally. One specimen was identified as *Ophioplinthaca semele* (A.H. Clark, 1949), which had been reported in Hawaii seamounts, is a new record of this species in the Northwest Pacific. The remaining specimen was an unknown species of *Ophioplinthaca*, with some different characteristics from other species of *Ophioplinthaca*. However, we, herein, prefer not to attach a name to this specimen until more morphological characteristics are available. The finding of this new species and two new records further enriches the distribution of *Ophioplinthaca* in the seamount of Northwest Pacific, providing useful information for marine protection in the cobalt-rich area.

Introduction

Ophioplinthaca Verrill, 1899 is a genus in the family Ophiacanthidae Ljungman, 1867 which is distinguished from other Ophiacanthid genera by the deep interradial incisions into the disc which are lined distally by enlarged disc plates (O'Hara & Stöhr, 2006). *Ophioplinthaca* is a widely distributed genus, and thirty-one valid species are known around the world. Among which, twenty-one species have been found occurring in the Indo-Pacific Ocean, six in the West Indian Ocean, and seven in the Atlantic Ocean. Recently, it was suggested that *Ophioplinthaca* is one of the dominant groups of megafauna ~~in~~ seamounts (O'Hara, Rowden & Williams, 2008;

Ch[illegible]008). The northwest Pacific region has the highest number of seamounts globally (Yesson et al., 2011), and many of the seamounts are covered with cobalt-rich ferromanganese crusts, which is a valuable mineral (Hein et al., 2009). However, few studies of Ophiuroid in this area ~~were~~ reported (Litvinova, 1981; Zhang et al., 2018; Na et al., 2019).

In 2019, several *Ophioplinthaca* specimens were collected from a seamount in the Northwest Pacific by a Remotely Operated Vehicle (ROV). Three specimens were determined to be a new species of genus *Ophioplinthaca* which we described herein. The other two specimens, identifed as *Ophioplinthaca semele* and an unknown species, were described here as new records of Ophioplinthacids in the Northwest Pacific Ocean. This study provides biodiversity information of seamounts in the cobalt-rich area, which may be useful for marine protection from future deep-sea mining.

Materials & Methods

Ophiuroid specimens from a seamount in the Northwest Pacific Ocean were collected during cruise DY56 using an ROV *HAILONG III*. Sampling sites are shown in Fig. 1. Specimens were fixed in 90% ethanol on board and deposited in the sample Repository of the Second Institute of Oceanography (RSIO), Ministry of Natural Resources, Hangzhou, China.

Specimens were examined and photographed using a stereoscopic microscope (Zeiss Axio Zoom.V16). Arm skeletal elements were obtained after submerging in commercial bleach (2.5% NaOCl), until all soft issue dissolved, washed in distilled water, air-dried and then mounted on stubs, imaged using a Hitachi TM1000 scanning electron microscope.

Genomic DNA was extracted from arm tissue using DNeasy® Blood & Tissue Kit (QIAGEN) following the manufacturers' protocols. The mitochondrial COI sequences were amplified with primers listed in Table 1. PCR reactions were performed using 50 μL volumes containing: 5 μL 10 x Buffer (containing Mg^{2+}), 10 mM of each dNTP, 0.1 mM of each primer, 37.5 μL of ddH_2O, 2.5 U of Taq DNA Polymerase (Vazyme, China), and 2 μL of DNA template. PCR products were purified with QIAquick PCR purification kit (QIAGEN) following the protocol supplied by the manufacturer. Sequencing was performed by Sangon Biotech (Shanghai, China) on an ABI 3730XL DNA analyzer (Applied Biosystems).

To date, only 10 COI sequences of *Ophioplinthaca* are available from the Genbank and BOLD database (Table 2). In this study, we included another two COI sequences of *O. defensor* from a recent study (Na et al., in press). ~~Totally,~~ 19 COI sequences (Table 2), including 5 new sequences and 2 sequences from *Ophiacantha* as outgroup, were used for phylogenetic analysis. COI sequences were aligned using Geneious Prime 2019 with default settings. Phylogenetic analysis was conducted by RAxML (Stamatakis, 2014), with a 1000-replicate bootstrap support value for each node and a GTR+I+T substitution model. Pairwised genetic distance (K2P) were calculated for COI sequences in MEGA6 (Tamura et al., 2013). The Automatic Barcode Gap Discovery (ABGD) analysis (Puillandre et al., 2012) was carried out on the web interface (https://bioinfo.mnhn.fr/abi/public/abgd/abgdweb.html) to establish molecular operational taxonomic units (MOTUs) from COI gene sequence data. The Kimura (K80) model (Kimura, 1980) with a TS/TV of 2.0 (K2P), Pmin = 0.001, Pmax = 0.1, 10 steps and a relative gap width of 1.0.

Nomenclatural acts

The electronic version of this article in Portable Document Format (PDF) will represent a published work according to the International Commission on Zoological Nomenclature (ICZN), and hence the new names contained in the electronic version are effectively published under that Code from the electronic edition alone. This published work and the nomenclatural acts it contains have been registered in ZooBank, the online registration system for the ICZN. The ZooBank LSIDs (Life Science Identifiers) can be resolved and the associated information viewed through any standard web browser by appending the LSID to the prefix http://zoobank.org/. The LSID for this publication is: urn:lsid:zoobank.org:pub:A48B7301-0D4B-4280-BF81-639689F923F6. The online version of this work is archived and available from the following digital repositories: PeerJ, PubMed Central and CLOCKSS.

Results

Systematics

Class Ophiuroidea Gray, 1840

Order Ophiacanthida O'Hara, Hugall, Thuy, Stöhr and Martynov, 2017

Family Ophiacanthidae Ljungman, 1867

Genus *Ophioplinthaca* Verrill, 1899

***Ophioplinthaca grandisquama* n. sp.** (Fig. 2-5)

urn:lsid:zoobank.org:act:8509E6DB-E902-4A71-9339-EA40725DD688

Material examined. — St. RC-ROV05, 161.78°E, 15.54°N, 1049m, September 17, 2019, 3 specimens (RSIO56013, RSIO56014, RSIO56060).

Habitat. All three specimens of the new species were attached to a *Calyptrophora* (Fig. 2).

Etymology. The specific name alludes to the large and long tentacle scales.

Description of the holotype. Disc 7 mm d.d., moderately high, five arms ~~and~~ at least six times of the disk diameter in length. Disc incised interradially more than 1/5 d.d. creating five wedge-shaped divisions ~~which~~ in contrast to the sunken centre and interradii of the disc (Fig. 3A). Each division covered by a pair of large radial shields and a number of irregular plates. Radial shields naked, triangular, about 1/4 d.d. in length, one and a half times as long as wide with a truncate distal edge and a sharp proximal angle, broadly contiguous distally (Fig. 3A). Disc plates overlapping, covered with distinctly elongated disc spines, up to 0.8 mm in length, 4-6 times as high as wide. Disc spines stout, bearing numerous distinct thorns on both lateral side and apex, some bifurcated into two prongs at the top, one of the two prongs elongated and inflated. (Fig. 3B). Ventral disc surface covered in small and overlapped plates, few of which bear spines thinner than those on the dorsal surface. Genital slits wide, extending from the oral shields to the dorsal disc surface (Fig. 3C).

Oral shields arrow-head-like shape, with an obtuse proximal angle, rounded laterals and a small obtuse distal lobe~~d~~, 2 times as wide as long, one of which is expanded as madreporite. Adoral plates quadrilateral, 2 times as long as wide, not separating the oral shields from the lateral arm plate. Jaw triangular, wider than long with 1-2 blunt and serrated ~~apical~~ papillae, and 3-4 conical lateral oral papillae longer than wide with pointed tip (Fig. 3C). One oral tentacle scale situated ~~between the gap of two jaws~~, slightly larger than oral papillae, often ~~longer~~ than high with a rounded free edge and covered by distal oral papillae.

Five arms, wide and slightly moniliform. Dorsal arm plates trapezoid to triangular with slightly convex distal edge on proximal segments, contiguous to each other; on distal segments dorsal arm plates change to fan-shaped and just contiguous (Fig. 3D). Basal ventral arm plates trapezoid much wider than long with a short proximal edge, concave and diverging lateral edges, distal margin much wider. The following plates become pentagonal, slightly wider than long, with a sharp proximal angle, diverging lateral sides which are widely excavated by the corresponding tentacle scales, distal margin board and convex, all separated from each other (Fig. 3~~E~~). Tentacle pores covered on the first segments with one or two leaf-shaped scales, and a tentacle; one fusiform or conical tentacle scale from the second segments, elongated and thorny with a ~~trunk~~ base tapering into a blunt point, slightly longer than one arm segment; tentacles long and glassy, longer than the ventral arm plates, ~~absence~~ from the seventh arm segments (Fig. 3C, ~~E~~). Arm spines seven, up to three arm segments in length on proximal arm segments, dorsally four arm spines are thin with distinct lateral thorns, tapering into a sharp point, the second dorsal-most arm spines longest; ventral arm spines shorter and blunt, finely rugose (Fig. 3D). Color in life orange-brown.

Description of the paratype. The two paratypes (RSIO56013, RSIO56014) share the same morphological characteristics with the holotype (Fig. 4A-D, 5A-E). For one of the two paratypes (RSIO56014) (Fig. 4A, B), the oral structure is incomplete with one of five oral plate sets is missing, which may be due to the ~~malfaction~~ or predation. The remaining oral shields are relatively smaller than the holotype, adoral plates are wider. The other paratype (RSIO56013) with stronger disc spines, elongate to flaring head bearing numerous distinct thorns, up to 1.4 mm in length, 4-6 times as high as wide (Fig. 4C, D). Tentacle pores covered, on the proximal arm segments one elongated with a rounded base tapering to a blunt point ~~scales, and one tentacle~~.

Description of the skeletal elements (Paratype: RSIO56014): Oral plates longer than high, only slightly lower in central part than at proximal end, adradial muscle fossa large with finer mesh stereom than remaining ossicle, conspicuous s-curved suture line crosses foot basin (Fig. 5F). A row of three ~~papillae~~ sockets and pores near lower edge of adradial proximal oral plate as articulations of oral papillae (Fig. 5G). Dental plate entire with single column of wide sockets, dorsal and ventral border below the level of middle part of the dental plate, not penetrating (Fig. 5H). Adradial genital plate long, articulation surface with slightly elevated elongated condyle (Fig. 5I, K); abradial genital plate slightly smaller in size than adradial plate and articulating ~~below level~~ ~~of~~ the adradial plate condyle (Fig. 5J). Radial shield longer than wide, with abradial projection and convex radial edge (Fig. 5L). Internally, radial shield with one distal domed condyle and one groove (Fig. 5M).

The vertebrae articulation zygospondylous, wider than long in proximal segments and gradually ~~change~~ to longer than wide from the middle to distal segments (Fig. 5N-R). The aboral groove on the dorsal side is moderately expressed without extension (Fig. 5N). The podial basins on the ventral side are moderate in size (Fig. 5O). Lateral arm plates (LAP) with constriction in proximal part leading to raised distal portion (Fig. 5S). The external surface of the LAP consisted of regularly meshed stereom, mesh size gradually decreasing from the middle to the proximal margin, while in the distal part, mesh size is mostly small but larger ~~in~~ the distal margin (Fig. 5S). Arm spine articulations well developed, volute-shaped, dorsal and ventral lobes merged at their proximal tips, sigmoidal fold present (Fig. 5S). The muscle opening is larger than the nerve opening (Fig. 5S). On the internal side~~,~~ a row of perforations on the distal part, parallel to the arrangement of spine articulation (Fig. 5T)~~. A~~ short ridge ~~continuous,~~ obliquely stretching from the ventral perforations to the middle of proximal edges~~. A~~ prominent knob close to the ventral edge, separated from the ridge (Fig. 5T).

Remark. *Ophioplinthaca grandisquama* n. sp**.** is characterized by the stout disc spines, capitate with typically elongate to flaring head bearing numerous distinct thorns, radial shields roughly triangular, more than 1/5 d.d. in length and contiguous distally, the tentacle scales elongated and stout. The thick tentacle scales in *O. grandisquama* n. sp**.** are elongated with a rounded base tapering to a blunt point and covered in irregular thorns similar to arm spines, which is distinctly distinguished from its congeners and most of them bearing oval or leaf-shaped tentacle scales (Thomson C.W., 1877; Lyman, 1878; Lyman, 1883; Clark H.L., 1900; Koehler, 1904; Clark H.L., 1911; Koehler, 1922; Mortensen, 1933; Clark H.L., 1939; Koehler, 1930; Clark A.H., 1949; John & A.M. Clark, 1954; Cherbonnier & Sibuet, 1972; Guille, 1981; O'Hara and Stöhr, 2006).

The sizes and shapes of radial shields and disc spines have been suggested to be the primary criteria for delimiting species (O'Hara & Stöhr, 2006). *O. hastata* Koehler, 1922 and *O. globata* Koehler, 1922, which resemble the new species mostly, also have stout and capitate disc spines. However, in *O. grandisquama* n. sp**.,** the disc spines are more elongated, 4-6 times as high as wide, bearing numerous distinct thorns all over the whole spine except the basal trunk,~~,~~ whereas the disc spines are only 2-3 times as high as wide, capitate with a convex to flaring head bearing numerous small thorns in *O. hastata*, and are cylindrical to conical with obvious thorns only in the upper half in *O. globata* with similar height-width ratio to *O. hastata* (O'Hara & Stöhr, 2006). Radial shields are relatively small, in *O. hastata* and *O. globata*, with 1/6 d.d. and 1/5 to 1/8 d.d. in length, respectively, and contiguous distally or separate, instead of 1/4 d.d. in length, broadly contiguous distally in the new species. Additionally, dorsal arm plates are also different between the new species and *O. hastata* and *O. globata*. Dorsal arm plates are a little longer than wide or as wide as long, separated from the basal arm segments, instead of contiguous at least on proximal segments in *O. grandisquama* n. sp.

~~Another~~ species, *O. amezianeae* O'Hara & Stöhr, 2006 and *O. rudis* (Koehler, 1897), were described with elongated spines, greater than 3 times as high as wide in this genus. The former is clearly different from *O.grandisquama* n. sp. in having slender disc spines, with a rounded base tapering to a sharp point or terminating in 2-3 small thorns, radial shields separate, oral shields as long as wide. The latter can be distinguished by having needle-like disc spines, long and slender, up to 1.3 mm in length, smooth to finely serrate, pentagonal oral shields, and bottle-shaped to pointed tentacle scales, half as long as the ventral arm plate.

***Ophioplinthaca semele* (A.H. Clark, 1949)** (Fig. 6-8)

Material examined. — St. RC-ROV08, 161.81°E, 15.53°N, 1024m, September 20, 2019, 1 specimen (RSIO56057).

Habitat and Distribution. This specimen was found attaching on a blade-like glass sponge together with a sea lilly (Fig. 6). The holotype and other specimens were collected near Hawaii (537-1250m); this is the first record of this species from a seamount in the Northwest Pacific (1024m).

Description of morphological characteristics. Disc 11.2 mm d.d., ~~moderately~~ high, arms at least six times disk diameter. Disc almost incised interradially 1/3 d.d., creating five wedge-shaped divisions covered by a pair of large, naked radial shields and a number of irregular plates (Fig. 7A). Radial shields triangular, about 1/3 d.d. in length, 1.5-2 times as long as wide with a truncate distal edge and blunt proximal angles, contiguous for 1/3-1/2 of the length (Fig. 7B). Disc plates overlapping, bearing cylindrical swollen stumps, up to 0.5mm high, covered in obvious thorns on the upper half (Fig. 7C, 8A). Disc spines at the distal margin and between radial shields are thinner with less thorns (Fig. 7C). Ventral disc surface covered in small ~~and overlapped~~ plates, without spines. Genital slits long and wide (Fig. 7D).

Oral shields diamond-~~shape,~~ with an obtuse proximal angle, rounded laterals and an obtuse to lobed distal angle, 2 times as wide as long, one of which expanded as madreporite (Fig. 7D). Adoral plates quadrilateral, large and broad, two times as long as wide, not separating the oral shields from the first lateral arm plate. Jaw triangular, as long as wide with 2-3 thin and long apical papillae. Lateral oral papillae 4-5, pointed, up to 3 times longer than wide, and the distal two oral papillae slightly broadened and leaf-shaped, standing ~~vertical by the squeezing of an~~ elongated oral tentacle scale (Fig. 7D).

Five arms, wide and slightly moniliform. First dorsal arm plate wider than long with obtuse proximal angle and straight distal border. Succeeding plates triangular to scallop-shaped with convex distal edge, slightly wider than long~~er~~, separated from each other (Fig. 7B, E, 8B). Ventral arm plates pentagonal with a sharp proximal angle, diverging lateral sides which are very widely excavated by the corresponding tentacle scales, distal side convex, widely separated from each other (Fig. 7F, 8C). Tentacle pores on the first arm segments, covered with one or two scales leaf-like, pointed and spiniform, more than half length of ventral arm plates, decreasing to one scale thereafter until nearly the end of the arm; One glassy tentacle on each tentacle pore, longer than the ventral arm plates, absent from the tenth arm segment~~s~~ (Fig. 7D, F). The proximal arm segments bearing up to eight arm spines, with sharp tip and distinct teeth, almost meeting each other on the dorsal mid-line on the fourth segment~~s~~ (Fig. 7E). The third dorsalmost arm spines are the longest, up to three segments in length, lowermost shortest, one segment in length. As the arm segments reduced distally, arm spines reduced to five. Color in life orange-white.

Description of the skeletal elements. The vertebrae articulation zygospondylous, wider than long in proximal segments ~~and~~ gradually ~~change~~ to longer than wide from the middle to distal segments (Fig. 8D-H). The aboral groove on the dorsal side is moderately expressed without extension (Fig. 8E). The podial basins on the ventral side are moderate in size (Fig. 8F). LAP with constriction in proximal part leading to raised distal portion. Arm spine articulations well developed, volute-shaped, dorsal and ventral lobes merged at their proximal tips, sigmoidal fold present (Fig. 8I). The muscle opening is larger than the nerve opening. On the internal side, a group of small, irregular perforations near kink between central oblique and short ventral ridges (Fig. 8J). A prominent knob close to the ventral edge, separated from the ridge (Fig. ~~8T~~).

Remark. This specimen was identified as *O. semele* (A.H. Clark, 1949) based on the multiple apical papillae, large radial shields contiguous for 1/3-1/2 of the length distally, cylindrical disc stumps with obvious thorns on the top and upper half. It also has some slight differences, having two or three shaped and leaf-shaped tentacle scales on the first tentacle pore instead of three or more broad and spoon-shaped scales in the holotype, adoral plates complete instead of divided into two or more plates in the holotype. Clark (1949) ~~suggested~~ the ~~difference of~~ tentacle scales and lateral oral papillae between two smaller specimens and holotype. Furthermore, tentacle scale is not reliable for species delimitating in the genus *Ophioplinthaca* (O'Hara & Stöhr, 2006). Therefore, with only one specimen of this species in our collection, these differences are ~~possibly~~ inter-species variation rather than ~~the~~ characteristics for taxonomic delimitation.

The cylindrical disc granules with a flaring top of a few thorns are reminiscent of *Ophioplinthaca citata* Koehler, 1904 from the New Caledonia, which ~~can be~~ differed ~~by~~ having narrower radial shields, contiguous dorsal and ventral arm plates and single ventral-most teeth (O'Hara & Stöhr, 2006). ~~Besides,~~ several other species are also close to *O. semele* in the shape of disc spines. *O. lobata* also has cylindrical to conical granules, the upper half covered in obvious thorns, but can be ~~differed~~ in having single ventral-most tooth, ~~togethre with~~ some other differences such as size and shape of radial shieldsand jaws, number of arm spines. ~~*O.*~~ *clothilde* A.H. Clark, 1949 has stumps terminating in flaring irregular crown of a dozen or more spines, and *O. lithosora* (H.L. Clark, 1911) has low cylindrical stumps with two to six tiny thorns near the apex. But they can be distinctly distinguished by size of radial shields and the number of apical papillae.

***Ophioplinthaca* sp.** (Fig. 9-11)

Material examined. — St. RC-ROV08, 161.80°E, 15.52°N, 1146m, September 20, 2019, 1 specimen (RSIO56058).

Habitat. This specimen was found attaching on a *Narella* (Fig. 9).

Description of morphological characteristics. Disc 10.4 mm d.d., moderately high, arms at least seven times ~~of disk diameter~~. Disc incised interradially 1/3 d.d., creating a wedge over each arm base, wedges tumid in contrast to the sunken centre and interradii of disc (Fig. 10A). Radial shields naked, triangular, more than 1/4 d.d. in length, 1.5~2 times as long as wide with a round distal margin and a sharp proximal angle, distally contiguous more than half of the length, and separated proximally by a triangular plate (Fig. 10A). The center of the disc is occupied by small irregular plates, bearing small granules up to 0.25 mm high, 1~1.5 times as high as wide, cylindrical to capitate with a terminal crown of thorns (Fig. 10B). Ventral disc surface covered in small and uneven plates without granules (Fig. 10C). Genital slits long and wide.

Oral shields diamond-shaped, with an obtuse proximal angle, rounded laterals and an obtuse to lobed distal angle, 2 times as wide as long, one of which is expanded ~~as~~ madreporite (Fig.

10C). Adoral plates quadrilateral, 3 times as long as wide, not separating the oral shields from the first lateral arm plate. Jaw triangular, wider than long with 1 blunt apical papilla, and 3 lateral oral papillae swollen and conical, gradually ~~decrease~~ from inside to outside. One large oral tentacle scale situated under the distal oral papillae, conical and atrophic, or elongate, up to 2 mm long (Fig. 10C).

Five arms, wide and slightly moniliform. Dorsal arm plates triangular to scallop-shaped with convex distal edge, separated ~~with~~ each other (Fig. 10D). Ventral arm plates pentagonal, separated from each other, with a small proximal angle, diverging lateral sides which are excavated by the corresponding tentacle ~~scales,~~ and distal side convex (Fig. 10C, E). Tentacle pores on the first arm segments, covered with one or two scales, decreasing to one scale thereafter to the end of the arm~~, and one tentacle~~. Tentacle scales thick and smooth on the basal segments, change to smaller, leaf-like and thorny on the following segments, almost half length of the ventral arm plates; tentacles long and glassy, longer than the ventral arm plates, disappeared from the seventh arm segments (Fig. 10C, E). The proximal arm segments with up to seven spines, of which the dorsally second or third are the longest, three segments in length, lowermost shortest, one segment in length (Fig. 10D). The number of arm spines reduced to four on ~~distall~~ segments.

Description of the skeletal elements. The vertebrae articulation zygospondylous, wider than long in proximal segments and gradually ~~change~~ to longer than wide ~~from the~~ middle to distal segments (Fig. 11D-H). The aboral groove on the dorsal side is moderately expressed without extension (Fig. 11E). The podial basins on the ventral side are moderate in size (Fig. 11F). LAPs with constriction in proximal part leading to raised distal portion (Fig. 11I). Arm spine articulations well developed, volute-shaped, dorsal and ventral lobes merged at their proximal tips, sigmoidal fold present (Fig. 11I). The muscle opening is larger than the nerve opening (Fig. 11I). On the internal side, a group of small, irregular perforations near kink between central oblique and short ventral ridge (Fig. 11J).

Remark. This specimen is characterized by the deep interradial incisions, radial shields twice as long as wide, 1/4 d.d. in length, contiguous for most of their length, the disc spines cylindrical to capitate with a terminal crown of thorns, and jaw wider than long with 1 blunt apical papilla and 3 small lateral oral papillae in each side, gradually ~~decrease~~ from inside to outside.

Ophioplinthaca pulchra Koehler, 1904 is similar to our specimen in the shape of disc spines, but it differs in having some spherical and smooth disc granules, large radial shields, up to 1/3 mm d.d., only contiguous distally, oral shields much longer than wide, and nine pointed to square-shaped oral papillae in each jaw. *Ophioplinthaca pulchra* is quite similar to *Ophioplinthaca plicata* (Lyman, 1878), and can be difficult to distinguish. ~~*O.*~~ *plicata* is highly variable, particularly in the shape of the disc stumps, the position of the radial shields, and the shape of oral shields (O'Hara & Stöhr, 2006). Some features of this specimen fall within the range of variation, such as the broadly contiguous radial shield and small oral shield, but the capitate disc spines and only three small lateral oral papillae ~~in~~ each side of jaws can be distinguished from *O.plicata*. However, the limits of species in genus *Ophioplinthaca* are obscure (O'Hara & Stöhr, 2006) and with only one specimen, it is impossible to provide a full description of the range of variation and stable characteristics for diagnosis, therefore, we prefer not to attach a name to this single specimen.

Phylogeny

The phylogenetic analysis (Fig. 12) supported that *O. grandisquama* n. sp. is clearly distinguished from other species of *Ophioplinthaca*, furthermore, the genetic distance among the three specimens of *O. grandisquama* n. sp. is 0.2%-0.9% (Table 3), ~~supporting~~ that they belong to the same species (Ward et al, 2008). The maximum likelihood tree showed that *O. semele* was clustered with *O. rudis*, whereas *Ophioplinthaca sp*. was clustered with *O. globata*. The genetic distances between *O. semele* and *O rudis* was 3.2%, between *O*. sp. and *O. globata* was 6.3%, which confirm that they are different species. Although *O. semele* was closely related to *O. rudis*, they can be easily differed from each other based on the morphological characteristics, especially in the shape of disc spines, which are needle-like, long and slender in *O.rudis* instead of cylindrical with obvious thorns on the upper half in *O.semele*. ~~*O.*~~ *globata* differs from *O.* sp. in having variable disc spines, many cylindrical to conical, others with only 3 terminal thorns or trifid with bifurcated tips, and radial shields 1/5-1/8 d.d. in length, only contiguous distally or completely separated, whereas in *O.sp*, radial shields 1/4 d.d. in length, contiguous for most of their length, and the disc spines cylindrical to capitate with a terminal crown of thorns. The genetic distances within the other two species, *O. defensor* and *O. plicata*, were very small, 0.1%-2.8% and 0.4%-1.2%, respectively. The genetic distances between the two species in this study and their closest congeners are higher than the intraspecies genetic distances, supporting the results that they are different species. In addition, we used molecular species delimitation method of ABGD delimit species of *Ophioplinthaca*. In total, the ABGD method identified 10 putative species from the COI dataset in this study (Fig. 12). The three *O. grandisquama* n. sp. specimens are identified as one MOTU, the *Ophioplinthaca sp.* and *Ophioplinthaca semele* are delimited as distinct MOTUs from their closely related congeners, which supported the result of morphological identification.

Conclusions

Three species of the genus Ophioplinthaca were recorded and described, including a new species, *Ophioplinthaca grandisquama* n. sp., which can be easily distinguished from its congeners by the shape and size of tentacle scales and disc spines, as well as radial shields. Morphological characteristics of internal skeleton were also described, providing significant information for future taxonomic study of this genus. Phylogenetic study based on COI supported the delimitation of the three species in this study. These findings further enrich the distribution of *Ophioplinthaca* from the seamount in the Northwest Pacific Ocean, filling the knowledge gap of benthic invertebrate in the cobalt-rich area.

Acknowledgements

We thank all the scientists and crew on the RV DAYANGYIHAO and the HAILONG team for their great work in the collection of the specimens. We also appreciate ~~that~~ Dr. Lu Bo and Dr. Shen Chengcheng for their help ~~of~~ providing species information of ~~coral and sponge attached by~~ ophiuroids, Dr. Lin Shiquan for his help ~~of~~ making the sampling map, Dr Zhang Ruiyan for her ~~helping in~~ genetic analysis.

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Figure 1

Map of the study seamount (indicated by the small red block) in the northwest Pacific (A) and sampling sites of specimens of Ophioplinthacids (B).

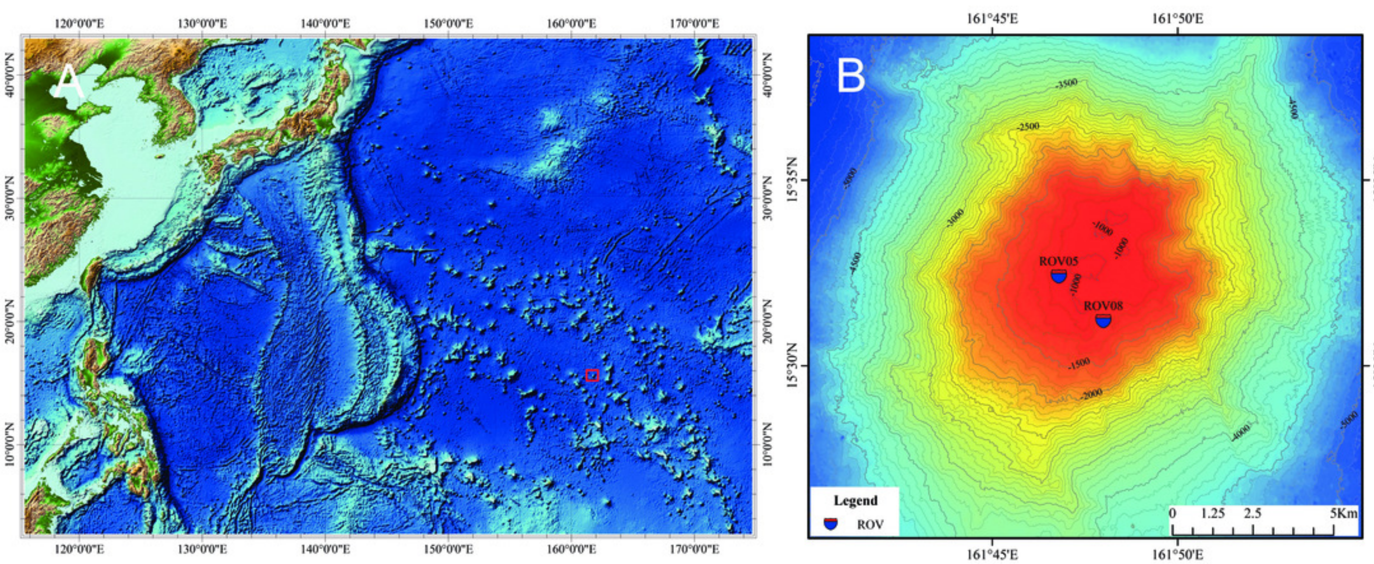

Figure 2

In situ and on board photos of *Ophioplinthaca grandisquama* n. sp.

(A) in situ observations, several specimens attached on a Primnoid. (B-D) photos on board. (B) holotype (RSIO56060). (C) paratype (RSIO56014). (D) paratype (RSIO56013).

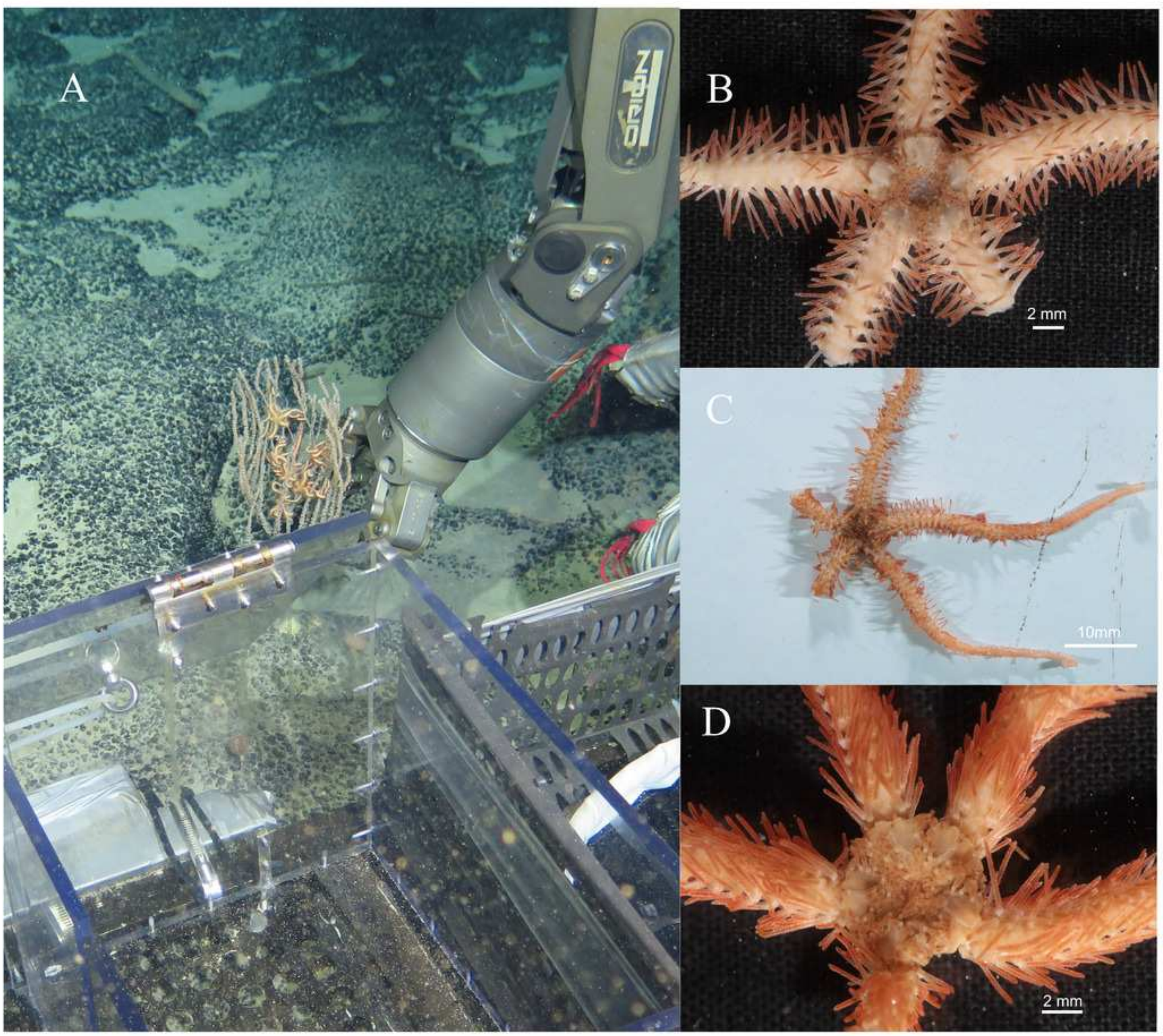

Figure 3

Morphological characters of *Ophioplinthaca grandisquama* n. sp. (Holotype: RSIO56060).

(A) dorsal view of disc. (B) enlarged disc spines. (C) ventral view of disc. (D) dorsal view of arm, proximal part. (E) ventral view of arm, proximal part. Abbreviations: AD, adoral plate; AP, apical papillae; AS, arm spine; DAP, dorsal arm plate; DS, disc spine; GS, genital slits; J, jaw; OP, oral papilla; OS, oral shield; RS, radial shield; VAP, ventral arm plate; TE, tentacle; TS, tentacle scale. Scale bars: 1 mm.

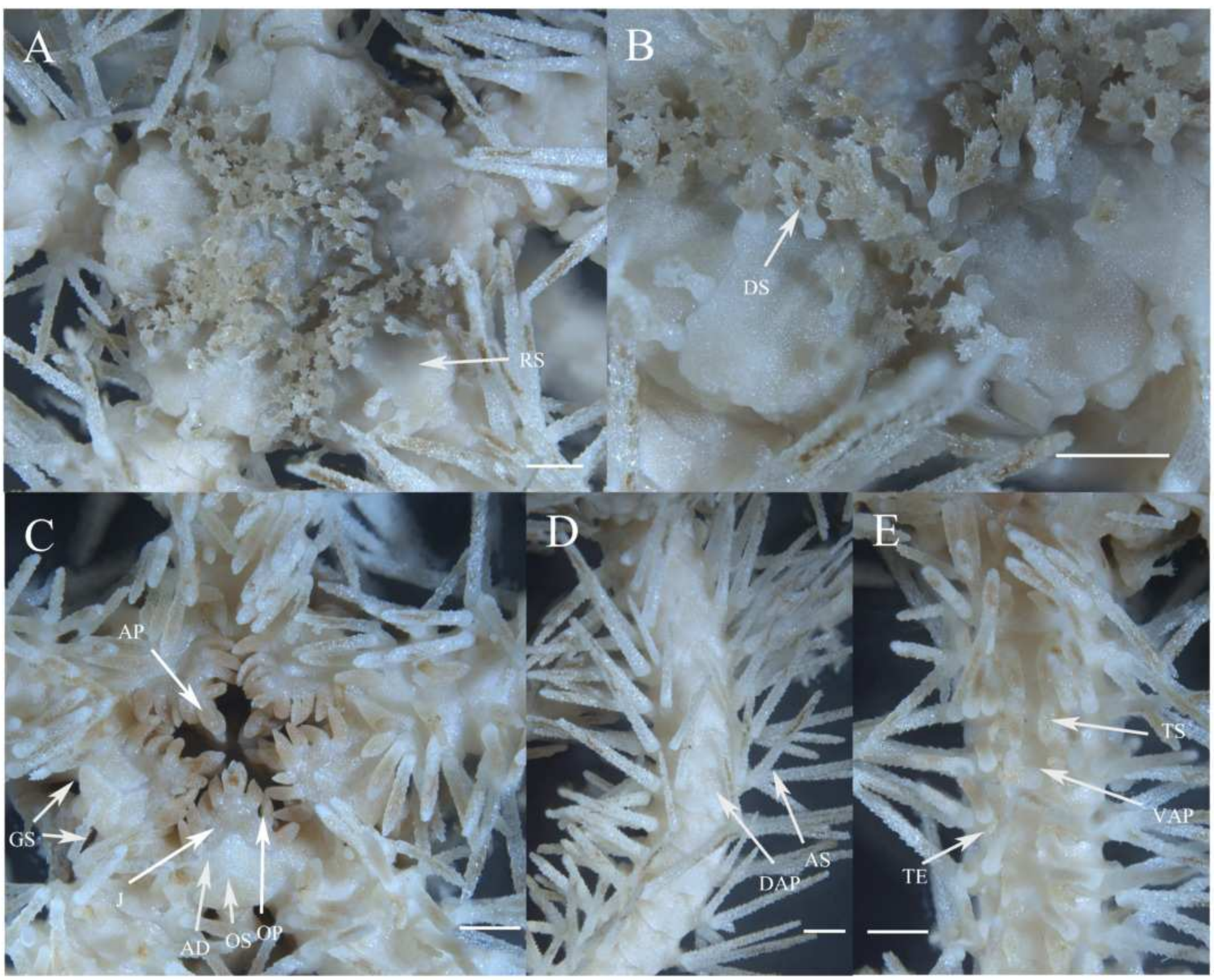

Figure 4

Morphological characters of *Ophioplinthaca grandisquama* n. sp. (Paratype: RSIO56013, RSIO56014).

(A-B) Morphological characters of paratype RSIO56014. (A) dorsal view of disc. (B) ventral view of disc. (C-D) Morphological characters of paratype RSIO56013. (C) dorsal view of disc. (D) ventral view of disc. Abbreviations: AD, adoral plate; AP, apical papillae; AS, arm spine; DAP, dorsal arm plate; DS, disc spine; GS, genital slits; J, jaw; OP, oral papilla; OS, oral shield; RS, radial shield; VAP, ventral arm plate; TE, tentacle; TS, tentacle scale. Scale bars: 2 mm.

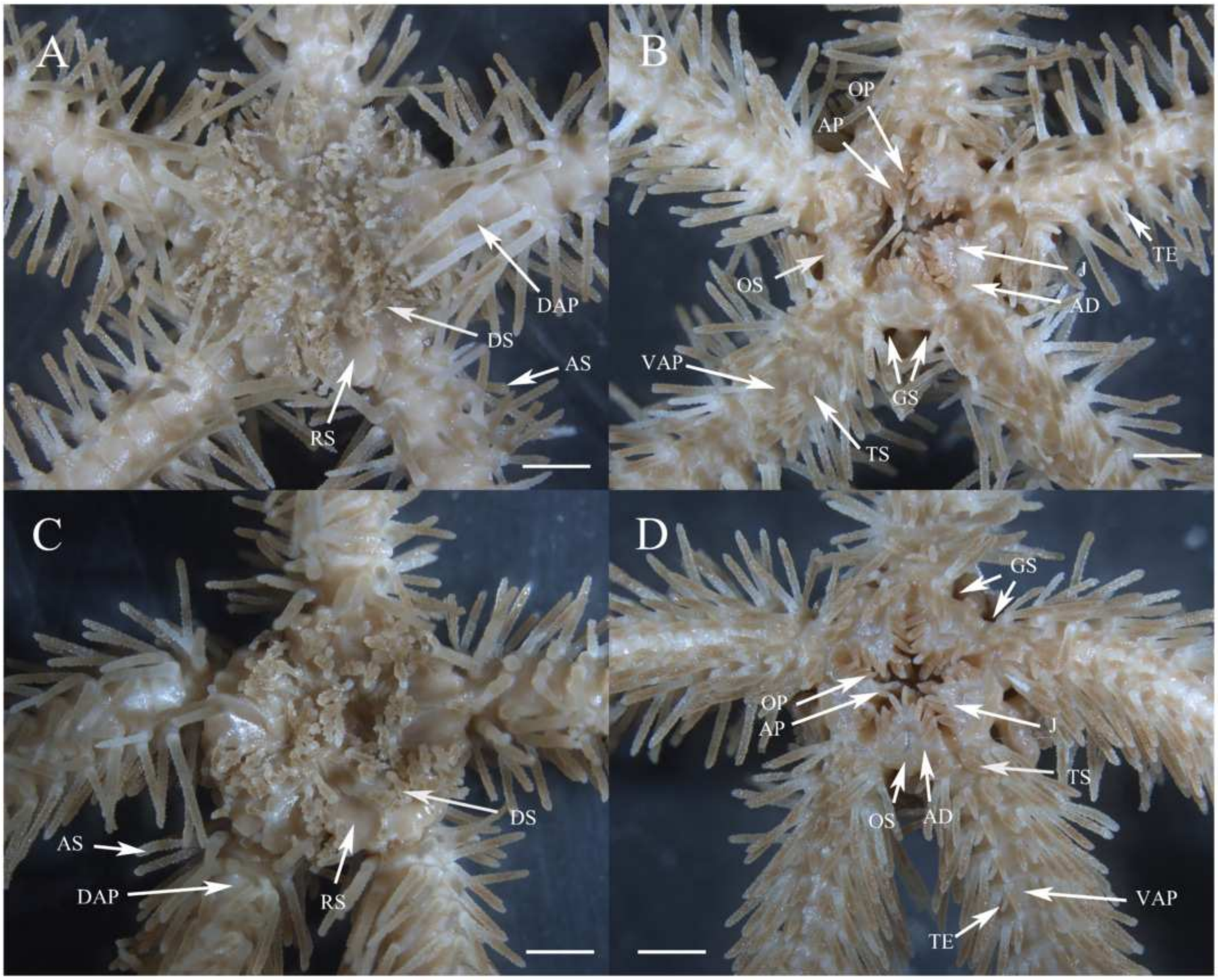
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Figure 5

SEM photographs of skeletons of *Ophioplinthaca grandisquama* n. sp. (Paratype: RSIO56014).

(A) disc spine. (B) ventral arm plate from proximal segment, external view. (C) dorsal arm plate from proximal segment, external view. (D) ventral-most arm spine. (E) dorsal-most arm spine. (F) oral plate, abradial face. (G) oral plate, adradial face, white arrows point to oral papillae sockets and pores. (H) dental plate. (I) adradial genital plate. (J) abradial genital plate. (K) adradial genital plate, distal end. (L) radial shield, external aspect. (M) radial shield, internal aspect. (N-R) vertebrae from proximal portion of arm. (N) dorsal view. (O) ventral view. (P) lateral view. (Q) distal view. (R) proximal view. (S) external view of LAP. (T) internal view of LAP. Abbreviations: AG, aboral groove; dors, dorsal; dist, distal; FB, foot basin; GC, adradial genital plate condyle; K, knob; LR, lateral ridge of the adradial genital plate, attachment area of the abradial genital plate; MO, muscle opening; NO, nerve opening; P, perforations; PD, podial basins; prox, proximal; R, ridge; RC, radial shield condyle; S, suture line; TN, tentacle notch; vent, ventral. Scale bars: 200 µm.

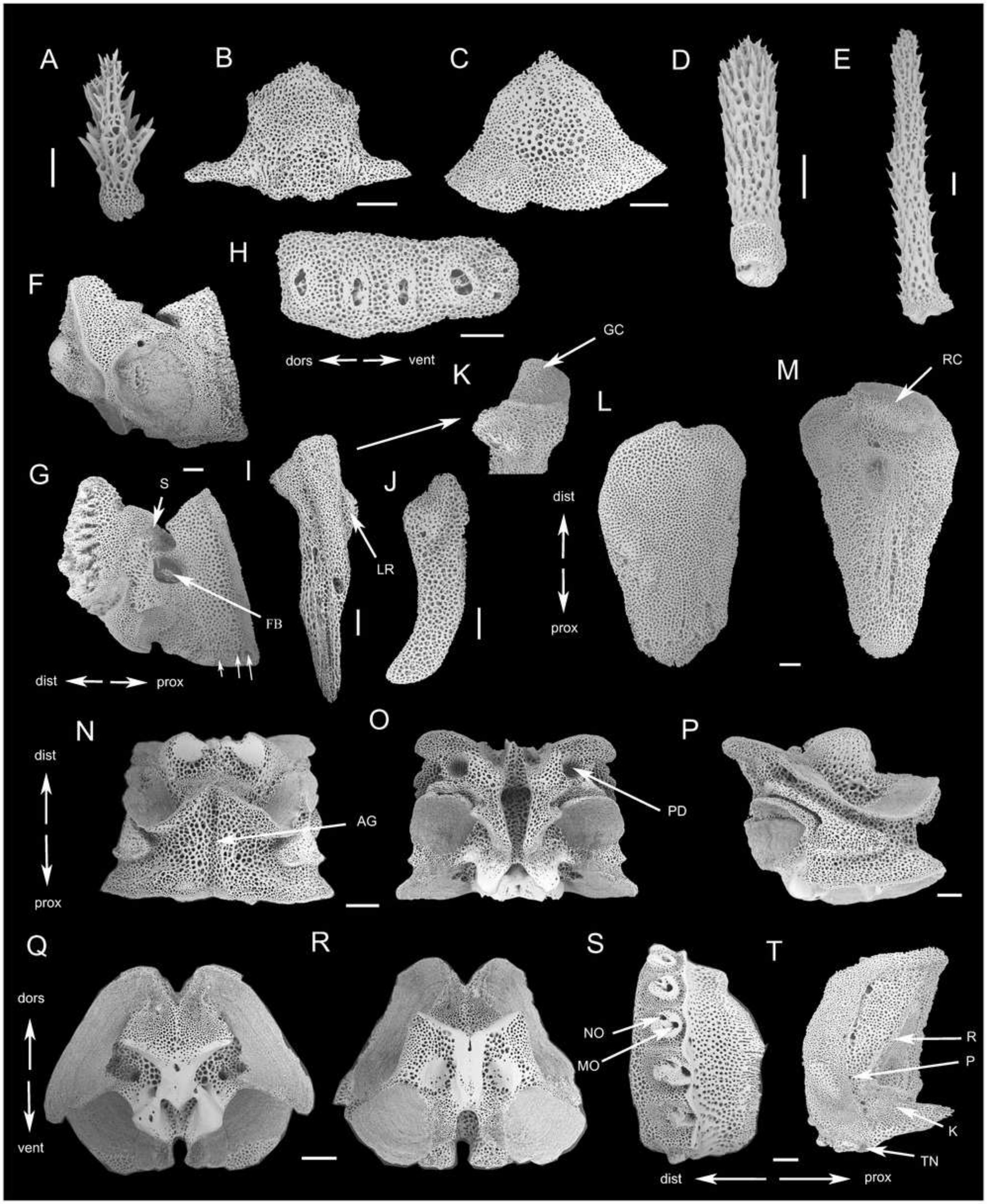
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Figure 6

In situ (A) and on board (B) photos of *Ophioplinthaca semele.*

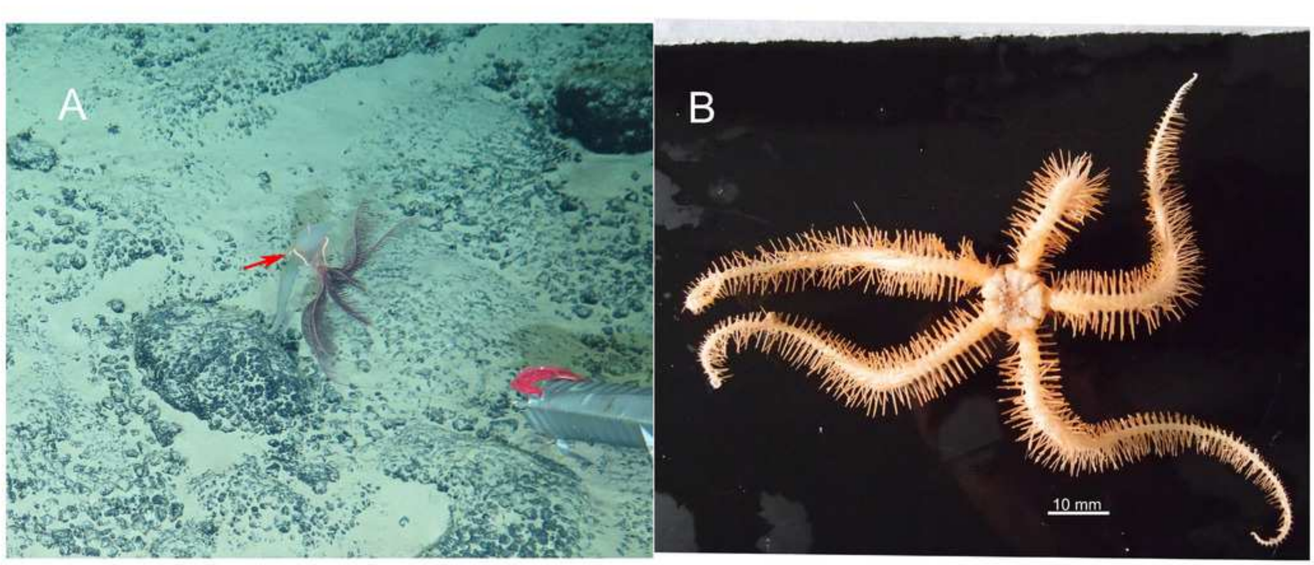

Figure 7

Morphological characters of *Ophioplinthaca semele* (RSIO56057).

(A) dorsal view of disc. (B) radial shields. (C) disc spines. (D) ventral view of disc. (E) dorsal view of arm, proximal part. (F) ventral view of arm, proximal part. Abbreviations: AD, adoral plate; AP, apical papillae; AS, arm spine; DAP, dorsal arm plate; DS, disc spine; GS, genital slits; J, jaw; OP, oral papilla; OS, oral shield; RS, radial shield; VAP, ventral arm plate; TE, tentacle; TS, tentacle scale. Scale bars: 1 mm (B, C), 2 mm (A, D-F).

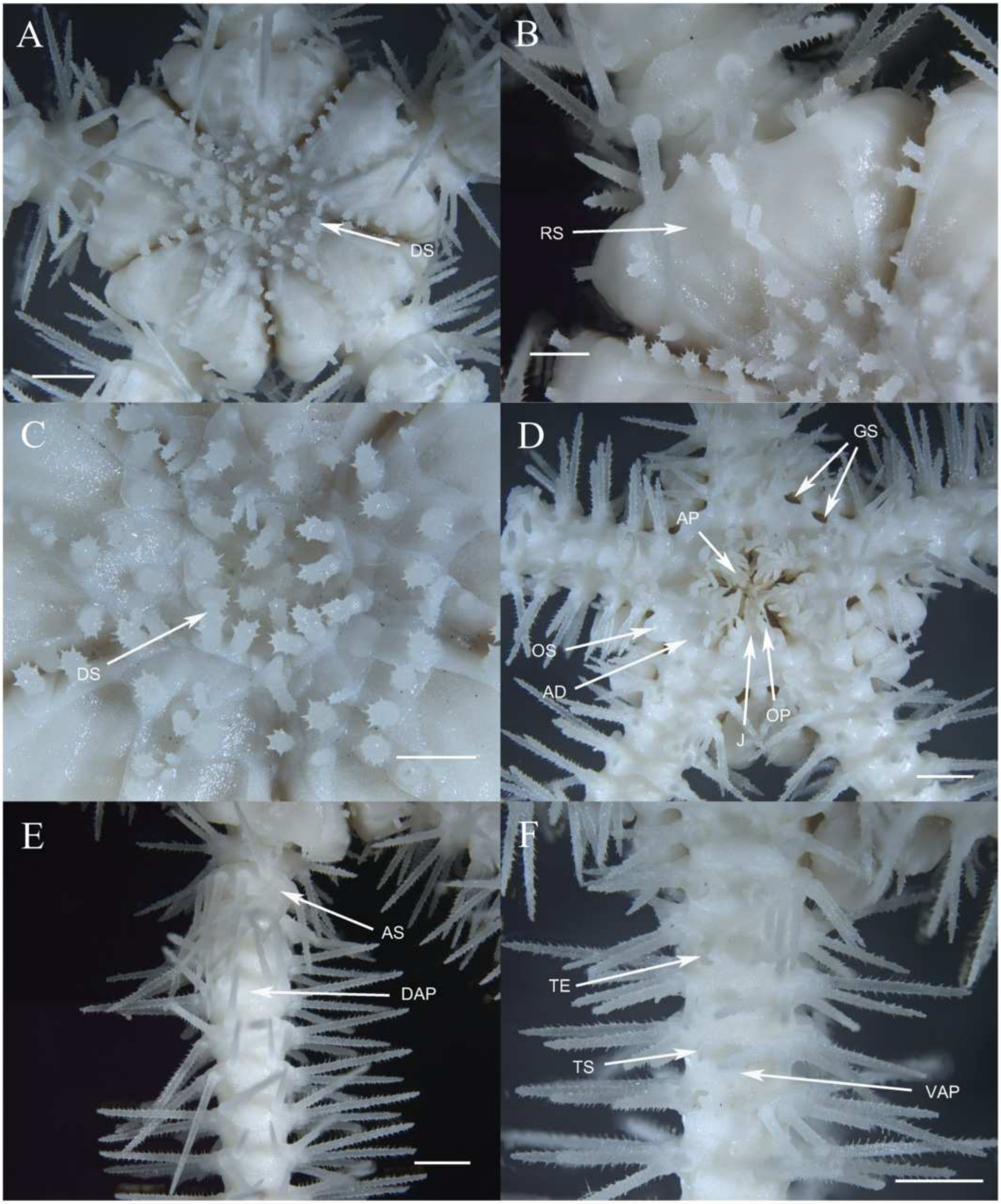
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Figure 8

SEM photographs of *Ophioplinthaca semele* (RSIO56057).

(A) disc spine. (B) dorsal arm plate from proximal segment, external view. (C) ventral arm plate from proximal segment, external view. (D-H) vertebrae from proximal portion of arm. (D) ~~proximal~~ view. (E) dorsal view. (F) ventral view. (G) proximal view. (H) lateral view. (I) external view of lateral arm plate. (J) internal view of lateral arm plate. Abbreviations: AG, aboral groove; dors, dorsal; dist, distal; K, knob; MO, muscle opening; NO, nerve opening; P, perforations; PD, podial basins; prox, proximal; R, ridge; TN, tentacle notch; vent, ventral. Scale bars: 200 µm.

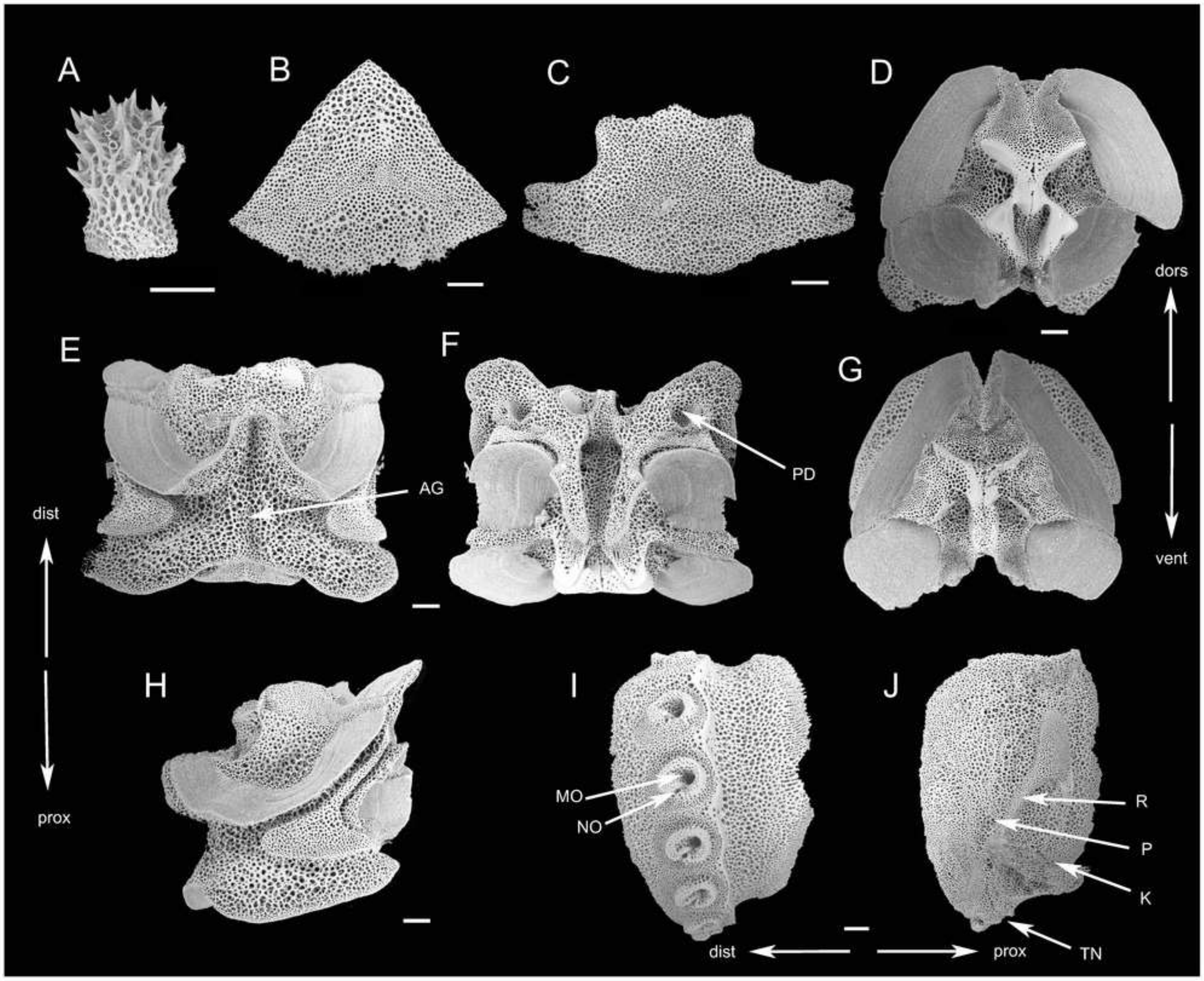
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Figure 9

In situ (A) and on board (B) photos of *Ophioplinthaca* sp.

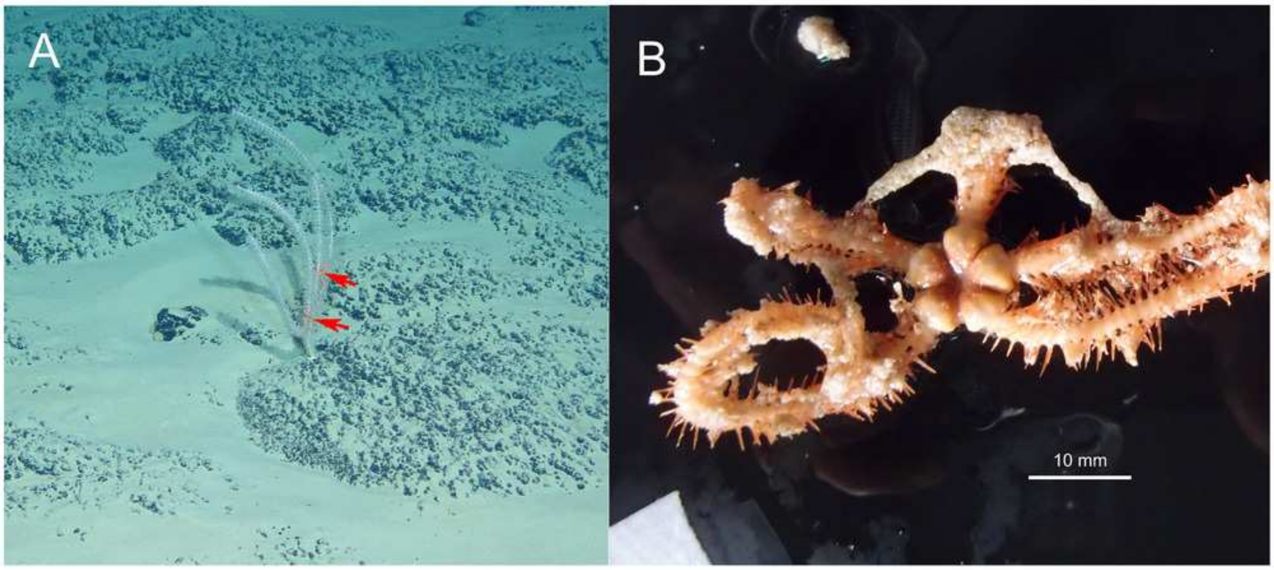

Figure 10

Morphological characters of *Ophioplinthaca sp.* (RSIO56058).

(A) dorsal view of disc. (B) disc spines. (C) ventral view of disc. (D) dorsal view of arm, proximal part. (E) ventral view of arm, proximal part. Abbreviations: AD, adoral plate; AP, apical papillae; AS, arm spine; DAP, dorsal arm plate; DS, disc spine; GS, genital slits; J, jaw; OP, oral papilla; OS, oral shield; OTS, oral tentacle scale; RS, radial shield; VAP, ventral arm plate; TE, tentacle; TS, tentacle scale. Scale bars: 2 mm (A, C-E), 0.2mm (B).

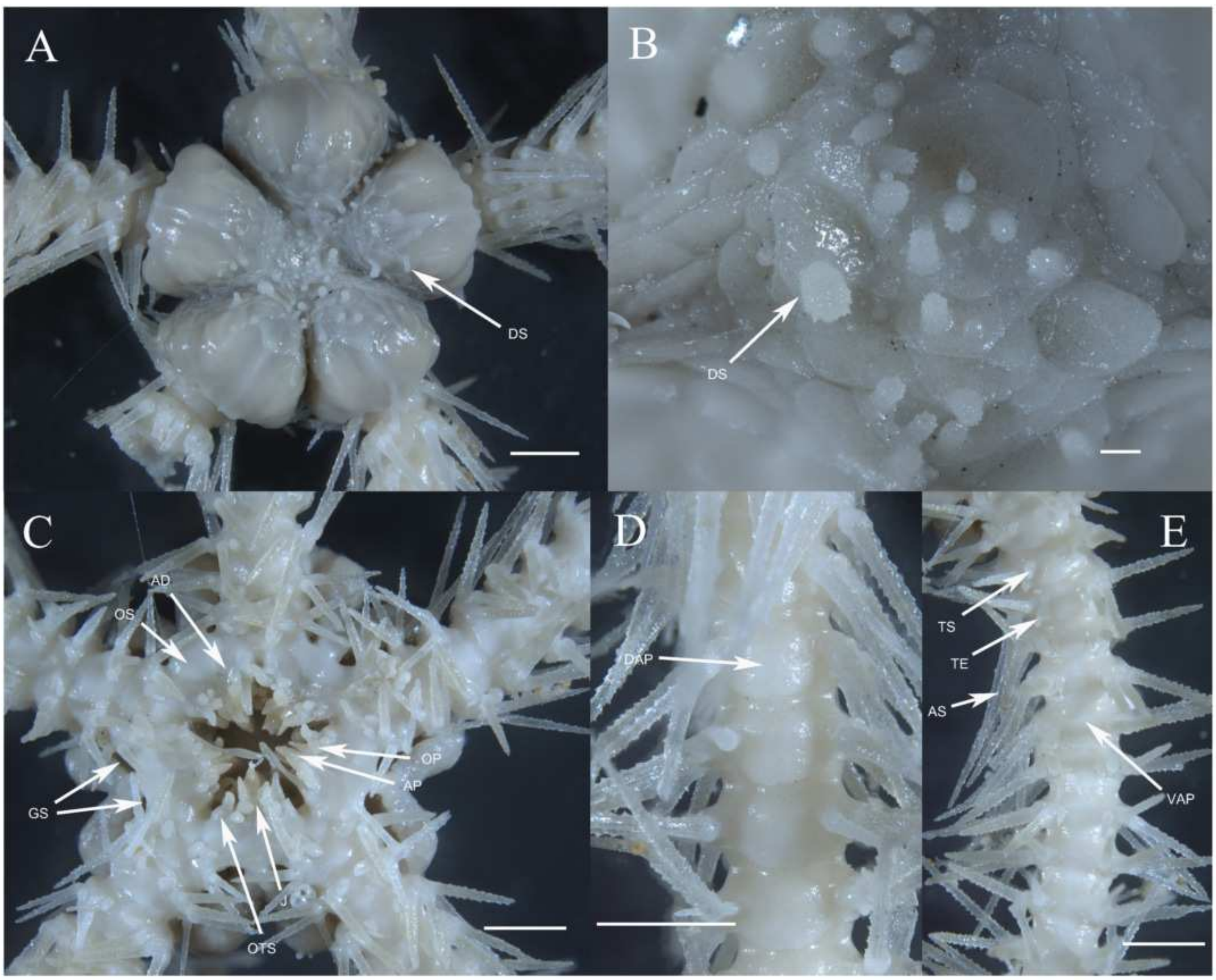

Figure 11

SEM photographs of *Ophioplinthaca* sp. (RSIO56058).

(A) disc spine. (B) dorsal arm plate from proximal segment, external view. (C) ventral arm plate from proximal segment, external view. (D-H) vertebrae from proximal portion of arm. (D) proximal view. (E) dorsal view. (F) ventral view. (G) distal view. (H) lateral view. (I) external view of lateral arm plate. (J) internal view of lateral arm plate. Abbreviations: AG, aboral groove; dors, dorsal; dist, distal; MO, muscle opening; NO, nerve opening; P, perforations; PD, podial basins; prox, proximal; R, ridge; TN, tentacle notch; vent, ventral. Scale bars: 200 µm.

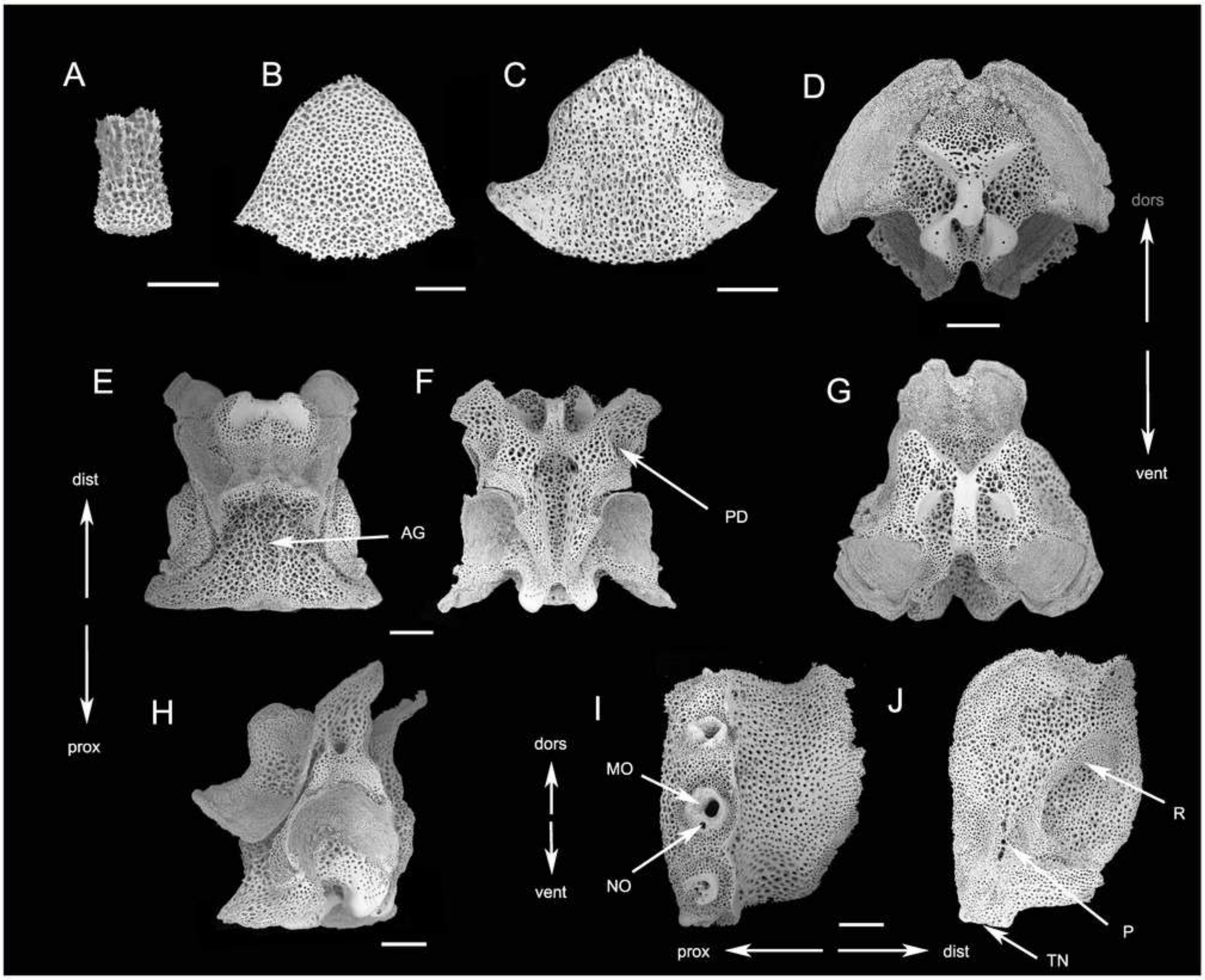
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Figure 12

Maximum likelihood tree of the genus *Ophioplinthaca* based on COI sequences.

Colored bars in red refer to MOTUs in ABGD.

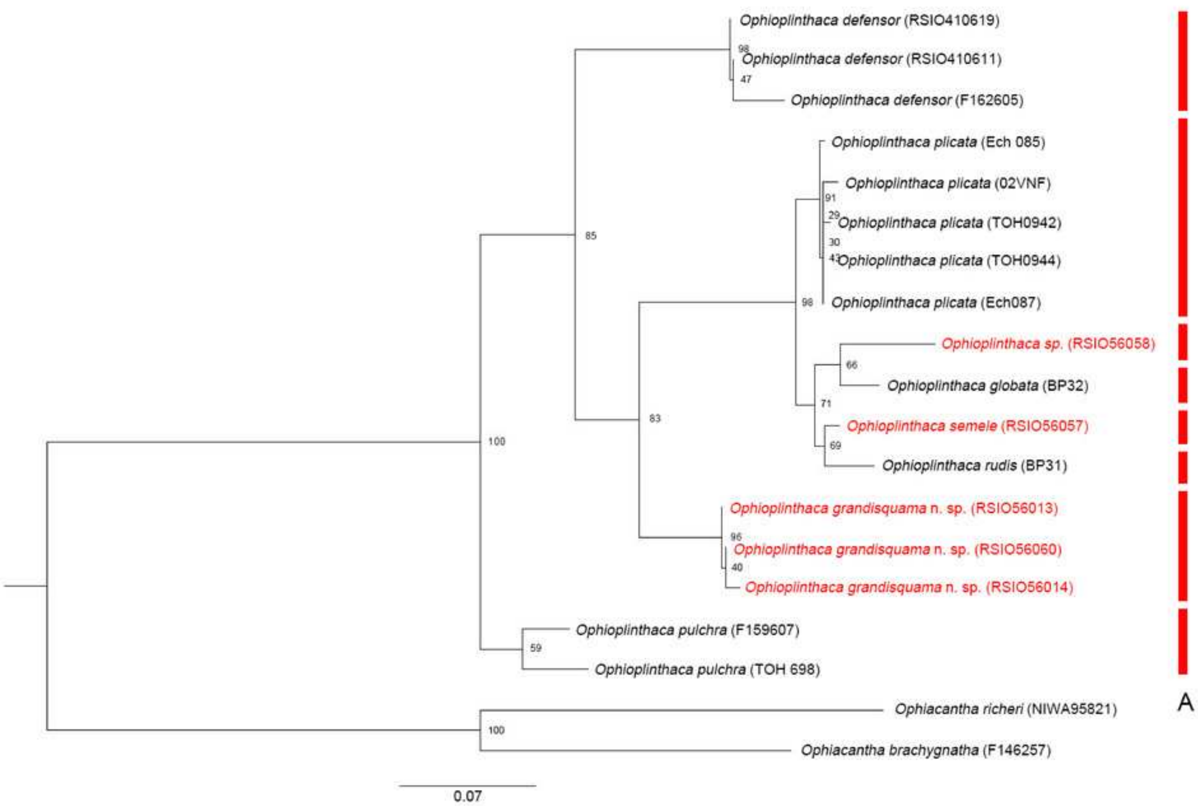

Table 1(on next page)

Information of primers used for PCR programs.

Prime	Sequence
Oph-COI-F	TTTCAACTAATCAYAAGGAYATWGG
Oph-COI-R	CTTCAGGRTGWCCRAARAAYCA
LCO1490	GGTCAACAAATCATAAAGATATTGG
HCO2198	TAAACTTCAGGGTGACCAAAAAATCA

Table 2 (on next page)

~~Information of~~ COI sequences used in phylogenetic analysis.

Taxa	~~Voucher/isolate~~	GenBank accession number/ BOLD sequence ID
Ophioplinthaca grandisquama n. sp.	RSIO56060	MW284982
Ophioplinthaca grandisquama n. sp.	RSIO56013	MW284978
Ophioplinthaca grandisquama n. sp.	RSIO56014	MW284979
Ophioplinthaca semele	RSIO56057	MW284980
Ophioplinthaca sp.	RSIO56058	MW284981
Ophioplinthaca pulchra	~~TOH_698~~	HM400467
Ophioplinthaca pulchra	F159607	KU895136
Ophioplinthaca defensor	~~TOH_0941~~	ECHOZ371-10.COI-5P
Ophioplinthaca defensor	RSIO410611	MT025802
Ophioplinthaca defensor	RSIO410619	MT025808
Ophioplinthaca globata	BP32	KU895134
Ophioplinthaca rudis	BP31	KU895135
Ophioplinthaca plicata	~~Ech085~~	EU869990
Ophioplinthaca plicata	~~Ech087~~	EU869989
Ophioplinthaca plicata	~~02VNF~~	KU895133
Ophioplinthaca plicata	~~TOH_0942~~	ECHOZ372-10.COI-5P
Ophioplinthaca plicata	~~TOH_0944~~	ECHOZ374-10.COI-5P
Ophiacantha richeri	NIWA95821	KU895387
Ophiacantha brachygnatha	F146257	KU895386

Table 3 (on next page)

The genetic distance of COI gene (K2P) of *Ophioplinthaca*.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 *Ophioplinthaca pulchra* (F159607)																		
2 *Ophioplinthaca pulchra* (TOH 698)	0.049																	
3 *Ophioplinthaca sp.* (RSIO56058)	0.157	0.184																
4 *Ophioplinthaca rudis* (BP31)	0.160	0.176	0.078															
5 *Ophioplinthaca semele* (RSIO56057)	0.160	0.156	0.060	**0.032**														
6 *Ophioplinthaca plicata* (Ech085)	0.140	0.148	0.084	0.051	0.036													
7 *Ophioplinthaca plicata* (02VNF)	0.153	0.160	0.085	0.055	0.042	0.012												
8 *Ophioplinthaca plicata* (TOH0942)	0.134	0.145	0.086	0.050	0.030	0.008	0.009											
9 *Ophioplinthaca plicata* (Ech087)	0.137	0.155	0.084	0.050	0.036	0.005	0.008	0.004										
10 *Ophioplinthaca globata* (BP32)	0.146	0.150	**0.063**	0.057	0.050	0.057	0.051	0.032	0.053									
11 *Ophioplinthaca plicata* (TOH0944)	0.125	0.149	0.092	0.054	0.031	0.005	0.003	0.003	0.000	0.000								
12 *O. grandisquama* n. sp.（RSIO56014）	0.123	0.144	0.136	0.125	0.108	0.110	0.115	0.110	0.110	0.107	0.103							
13 *O. grandisquama* n. sp.（RSIO56013）	0.112	0.135	0.141	0.129	0.111	0.114	0.116	0.117	0.114	0.127	0.107	**0.009**						
14 *O. grandisquama* n. sp.（RSIO56060）	0.119	0.148	0.152	0.127	0.108	0.113	0.118	0.120	0.115	0.115	0.117	**0.007**	**0.002**					
15 *Ophioplinthaca defensor* (F162605)	0.111	0.147	0.180	0.174	0.138	0.149	0.152	0.153	0.153	0.097	0.152	0.096	0.091	0.119				
16 *Ophioplinthaca defensor* (RSIO410611)	0.122	0.131	0.176	0.159	0.140	0.148	0.153	0.137	0.146	0.151	0.137	0.104	0.103	0.121	0.025			
17 *Ophioplinthaca defensor* (RSIO410619)	0.119	0.129	0.174	0.156	0.137	0.146	0.151	0.135	0.144	0.151	0.134	0.106	0.106	0.123	0.028	0.001		
18 *Ophiacantha richeri* (NIMA95821)	0.270	0.339	0.393	0.357	0.368	0.387	0.350	0.423	0.399	0.300	0.434	0.366	0.349	0.373	0.369	0.350	0.353	
19 *Ophiacantha brachygnatha* (F146257)	0.278	0.286	0.346	0.311	0.316	0.316	0.304	0.335	0.312	0.280	0.339	0.307	0.309	0.309	0.324	0.303	0.308	0.202