

Two new species of Hexactinellida (Porifera) from the South China Sea

LIN GONG^{1,2}, XINZHENG LI^{1,4} & JIAN-WEN QIU³

¹Institute of Oceanology, Chinese Academy of Sciences, 7 Nanhai Road, Qingdao 266071, China

²Graduate University, University of Chinese Academy of Sciences, Beijing 100039, China

³Department of Biology, Hong Kong Baptist University, Hong Kong, China

⁴Corresponding author. E-mail: lixzh@qdio.ac.cn; Tel.: +86 532 82898771

Abstract

In this paper, two new sponge species, *Semperella jiaolongae* sp. nov. (Amphidiscosida, Pheronematidae) and *Saccocalyx microhexactin* sp. nov. (Lyssacinosida, Euplectellidae) are described based on materials from the South China Sea. *Semperella jiaolongae* sp. nov. is diagnosed mainly by the dermal areas present on both sides of the body, occurring together with atrial areas randomly distributed on one side, and the distinctive shape of micropentactins. *Saccocalyx microhexactin* sp. nov. is characterized by possession of two types of drepanocomes and one of microhexactins. An analysis based on partial sequence of the 16S rRNA gene was undertaken to show the congruence between morphological identification and phylogenetic classification of the two new species.

Key words: Porifera, Amphidiscosida, Lyssacinosida, Pheronematidae, Euplectellidae, *Saccocalyx*, *Semperella*, new species, South China Sea

Introduction

The class Hexactinellida Schmidt, 1870 comprises sponges with a skeleton made of triaxonic siliceous spicules or derivations of that. The class includes two subclasses – Amphidiscophora Schulze, 1886 and Hexasterophora Schulze, 1886. The genus *Semperella* Gray, 1868 (Amphidiscophora, Amphidiscosida, Pheronematidae) lacks an atrial cavity, possesses a columnar body, and their several everted atrial areas constitute units separated from each other by dermal areas (Tabachnick & Menshenina, 2002). It contains ten reported species with different body forms: *S. schultzei* (Semper, 1868), *S. alba* Tabachnick, 1988, and *S. abyssalis* Tabachnick & Lévi, 2000 have several longitudinally directed atrial areas, which are also possibly present in *S. similis* Ijima, 1927, a likely synonym of *S. schultzei* (*sensu* Lévi & Lévi, 1982). *Semperella cucumis* Schulze, 1895 and *S. crosnieri* Tabachnick & Lévi, 2000 have the atrial surface consisting of numerous separated rounded atrial spots, *S. stomata* Ijima, 1896 and *S. spicifera* Schulze, 1904 have the rounded atrial spots bent inwards, *S. varioactina* Tabachnick & Lévi, 2000 has the general sponge surface divided into four longitudinal areas without sieve plates (Tabachnick & Lévi, 2000). *Semperella megaloxea* Vinod, George, Thomas & Manisseri, 2012 has a club-shaped body and is characterized by the presence of very long diactins in addition to pentactins (Vinod *et al.* 2012).

The genus *Saccocalyx* Schulze, 1896 (Hexasterophora, Lyssacinosida, Euplectellidae) is basiphytose, with a long peduncle, usually fixed to rigid substrate. Their atrialia and dermalia are usually hexactins. *Saccocalyx* species distributed widely in the North-central Atlantic, Mid-Atlantic Ridge, Indo-West Pacific, Antarctic Oceans and United States part of the North Pacific Ocean, from 607 m to 3835 m (Tabachnick, 2014; Reiswig, 1999).

Material and methods

Sample collection. The specimens were collected from the South China Sea with “Jiaolong”, the Chinese manned submersible. The specimen of *Semperella jiaolongae* sp. nov. was collected from a muddy bottom at the depth of

1120 m, roughly 200 m below a *Bathymodiolus platifrons* - *Shinkaia crosnieri* community at Jiaolong Cold-Seep No. 1, on 19 June 2013. And the specimen of *Saccocalyx microhexactin* sp. nov. was collected from a volcanic rocky cliff of the Jiaolong Seamount at the depth of 3541 m on 5 July 2013. Both specimens are deposited in the Marine Biological Museum (MBM), Institute of Oceanology, Chinese Academy of Sciences, Qingdao (IOCAS).

Spicule analysis. Spicules were isolated by digesting a small piece of sponge tissue using concentrated nitric acid at 60 °C overnight, and observed using scanning electron microscopy (SEM) and light microscopy (LM). For SEM, the spicules were concentrated onto a cover glass (11 mm × 11 mm) attached to a SEM stub, coated with gold, and observed using a Hitachi S-3400N. For LM, spicules were observed using an Olympus DSX500 Opto-digital microscope and measured using the manufacturer's image analysis software. The measurements are provided in Table 1 and Table 2.

TABLE 1. Measurements of the spicules of *Semperella jiaolongae* sp. nov. (in µm); “n” = number of spicules measured; “s.d.” = standard deviation.

	n	mean	range	s.d.
Dermalia, pinule				
pinular ray length	30	408.9	270.1–592.2	64.7
tangential ray length	30	106.9	49.8–198.8	36.8
Atrialia, pinule				
pinular ray length	25	276.2	206.7–326.2	30.7
tangential ray length	25	108.5	39.5–108.5	30.9
Choanosomalia, pinule				
pinular ray length	30	1433.5	265.8–4000.1	853.3
tangential ray length	30	1376.7	216.6–4217.9	808.2
Uncinate				
length	21	2071.4	927.9–3293.7	522.8
width	21	12.3	6.6–19.6	3.0
Micramphidisc				
length	30	20.1	15.1–25.5	10.4
umbel length	30	5.7	4.2–6.9	2.7
umbel diameter	30	6.7	5.6–7.8	0.5
Micropentactin				
tangential ray length	30	60.4	37.9–87.6	12.0
tangential ray width	30	2.7	1.6–4.0	0.5
Microhexactin				
ray length	20	59.3	31.9–79.3	9.9
ray width	20	2.9	1.7–4.2	0.6

Molecular analysis. DNA was extracted from a small piece of tissue using a Tissue DNA Kit (OMEGA, Qingdao, China) according to the manufacturer's instructions. The primer pair 5'-TCGACTGTTACCAAAACATAGC-3' (forward)/5'-YRTAATTCAACATCGAGGTC-3' (reverse) (Dohrmann *et al.* 2008) was used to amplify a 510 bp segment of the 16S rRNA gene using the following PCR protocol: 5 min at 94°C for initial denaturing followed by 30 cycles of 30 s at 94°C, 30 s at 48°C, 1 min at 72°C, and a final extension for 5 min at 72°C. The total reaction volume was 25 µL, containing 12 µL 2x Es Taq MasterMix (CWBIOL, Beijing, China), 9 µL DNase free ddH₂O, 1 µL of each primer, 2 µL DNA. The 16S rRNA sequences are deposited in GenBank with accession numbers KM881702 for *Saccocalyx microhexactin* sp. nov. and KM881703 for *Semperella jiaolongae* sp. nov.

Sequence analysis. For these two species, in order to see whether there was congruence between morphology and phylogeny, an analysis based on 16S rRNA gene was undertaken. 16S rRNA gene sequences of eight species

were downloaded from Genbank: *Euplectella* sp. (accession number AM886336.1), *Pheronema* sp., (AM886323.1), *Saccocalyx* sp. (FM946103.1), *Semperella schulzei* (AM886324.1), *Sericolophus hawaiicus* (AM886325.1), *Acoelocalyx brucei* (AM886333.1), *Malacosaccus coatsi* (AM886334.1), *Hexactinella carolinensis* (AM886330.1). Only one 16S rRNA gene sequence is available for *Saccocalyx* in Genbank. Sequences were aligned by Clustal X 1.8.1 (Thompson *et al.* 1997) under the default parameters and then slightly corrected by hand before analysis. The best-fit 16S rRNA sequence evolution model (GTR+G) was determined by ModelTest (Posada & Crandall, 1998), selected by the AIC (Akaike Information Criterion), and was used for subsequent Bayesian Inference (BI) and Maximum Likelihood (ML) phylogeny analyses. The ML analysis was conducted using PhyML 3.0 (Guindon & Gascuel, 2003) with 1000 bootstrap replicates. The BI analysis was conducted with MrBayes 3.1 (Ronquist & Huelsenbeck 2003). Markov Chain Monte Carlo algorithms were run for 0.2 million generations, sampling every 200 generations. In the BI analysis, the average standard deviation of split frequencies fell below 0.005. The first 10% of trees were discarded as “burn-in”, and a 50% majority-rule consensus tree was obtained from the remaining trees.

TABLE 2. Measurements of the spicules of *Saccocalyx microhexactin* sp. nov. (in µm); “n” = number of spicules measured; “s.d.”= standard deviation.

	n	mean	range	s. d.
Dermal or atrial hexactin				
pinular ray length	30	370.6	245.8–450.6	57.4
tangential ray length	30	246.8	173.6–246.8	63.1
ray directed inside body	30	391.9	188.2–585.8	89.0
Choanosomalia hexactin				
ray length	15	276.7	126.5–355.8	102.9
Diaictin				
length	26	2963.0	2120.3–3557.5	397.4
width	26	8.5	5.3–15.1	2.2
Spirodiscohexaster				
diameter	30	130.5	112.4–149.8	25.1
diameter of primary rosette	30	49.1	27.6–65.9	8.9
Drepanocome I				
diameter	6	286.8	254.4–318.6	22.8
diameter of primary rosette	6	82.1	60.6–107.7	18.8
Drepanocome II				
diameter	7	128.3	123.0–137.5	4.4
Plumicomes				
diameter	17	48.6	35.8–58.5	5.9
Microhexactin				
ray length	33	42.7	21.4–70.3	13.8
ray width	33	4.8	3.3–6.2	0.74

Results

Taxonomy

Class Hexactinellida Schmidt, 1870

Subclass Amphidiscophora Schulze, 1886

Order Amphidiscosida Schrammen, 1924

Family Pheronematidae Gray, 1870

Genus *Semperella* Gray, 1868

Semperella jiaolongae sp. nov.

(Figures 1–2)

Material examined. Holotype: MBM179993, South China Sea ($22^{\circ}7.21'N$, $119^{\circ}18.67'E$), 19 June 2013, 1120 m depth, muddy bottom.

Description. Columnar body is 250 mm long (not including basalia) and 112 mm in maximal diameter. The color is pure white when alive (Fig. 1A), but grey after collection (Fig. 1B–D) due to contamination by mud during sampling. Some pleuralia rows are present on the bottom of lateral surface (Fig. 1C, arrow c). Numerous elongated atrial areas (Fig. 1B, arrow a) are scattered on one side of (side 1) the specimen's surface (Fig. 1C), separated by many dermal areas (Fig. 1B, arrow b). Atrial surface covered by large-meshed latticework with meshes 0.38 to 2.5 mm in diameter (Fig. 1E). The sponge presents two differently organized sides (Fig. 1F): (1) side 1 has dermal areas randomly present together with atrial ones, (2) side 2 only contain dermal areas (Fig. 1D). The dermal areas on side 1 have thinner main hypodermal beams of the meshed latticework than side 2. Meshes on dermal areas consist of two parts: bigger meshes with thicker edges (main hypodermal beams) forming a framework (Fig. 1G), and smaller meshes (minor hypodermal beams) with finer edges dividing bigger meshes into many smaller meshes (Fig. 1H). Dermal areas on side 1 have smaller meshes with diameter 0.26 to 0.81 mm, and bigger meshes of 0.80 to 2.1 mm in diameter. Dermal areas on side 2 have smaller meshes (Fig. 1G) with diameter 0.19 to 0.93 mm, and bigger meshes (Fig. 1H) of 1.5 to 5.0 mm in diameter. Large openings into tissues are present underneath atrial and dermal lattices. The tufts of basalia, more than 110 mm long and 2.6 to 5 mm wide, consist of many small single, basal spicules. Individual shafts of basal spicules are thin, 0.05 to 0.4 mm diameter.

Spicules. Pentactins (Fig. 2A) with smooth rays make up choanosomal skeleton, tangential rays 216.6–4217.9 μm long, proximal rays 265.8–4000.1 μm long. Dermal pentactins mainly occur as two types (Fig. 2F–G): those with sharply pointed or conical pinular rays with straight tangential rays and those with shorter pinular rays and slightly curved, smooth or slightly spined tangential rays. Pinular rays are 270.1–592.2 μm long; tangential rays are 49.8–198.8 μm long. Atrial pentactins similar to dermal pentactins always present (Fig. 2H). Atrial pentactins' pinular rays 206.7–326.2 μm long, and tangential rays 39.5–108.5 μm long. Pentactins (Fig. 2I) with fewer short spines, and similar lengths for all rays are present mainly in the choanosome, but can also be found in dermal and atrial areas. Basalia (Fig. 2B–D) have a spiny shaft and terminal anchor bearing two teeth. Uncinates (Fig. 2K) rare, with small short spines, 927.9–3293.7 μm long. Prostalia are sceptres (Fig. 2E), common to *Semperella*, with shafts mostly smooth, except for their distal part with spines; they are very easily broken.

Microscleres consist of amphidiscs, microhexactins, micropentactins and microstauractins. Amphidiscs are micramphidiscs (Fig. 2N) only, with shafts covered by numerous spines, total length 15.1–25.5 μm , umbel length 4.2–6.9 μm . Microhexactins (Fig. 2L) very rare. Rays straight, 31.9–79.3 μm long, covered by numerous small spines. Micropentactins (Fig. 2J) with a very short and minute spiny pinular ray, and four straight, smooth or spiny tangential rays 37.9–87.6 μm long. Microstauractins (Fig. 2M) are rare.

Etymology. The species is named after the Chinese manned submersible “Jiaolong”.

Remarks. For *Semperella*, the shape of the body and the morphology of the spicules are important for species identification. By the external morphology of *Semperella* species described in Tabachnick & Lévi (2000), *S. jiaolongae* sp. nov. is most similar to *S. crosnieri* Tabachnick & Lévi, 2000. The two species share the same morphological character of having dermal areas present on both sides of the body, and on one side in combination with atrial areas. However, the holotype of *S. crosnieri* differs from *S. jiaolongae* sp. nov. in having a tongue-like body and having many microuncinates. In contrast, *S. jiaolongae* sp. nov. has a cylindrical body shape, and its microuncinates are very rare. In addition, there are other notable differences between the two species: (1) the shape of micropentactins is very different in both species: those in the new species have smooth tangential rays and a very short slightly spined proximal ray, while those in *S. crosnieri* are always covered with numerous, or rarely with sparse spines; (2) micropentactins and microhexactins of the new species are thinner than those of *S. crosnieri*; (3) the umbels of amphidiscs in *S. crosnieri* have sharper teeth than those of the new species; (4) dermal pinules are a

little larger than the atrial pinules in the new species, the contrary of what is seen in *S. crosnieri*. (5) the new species has a pentactine (Fig. 2I) with fewer short spines, and similar lengths for every ray, which is present not only in the choanosome, but also in the dermal and atrial areas, while this kind of pentactin was not reported for *S. crosnieri*.

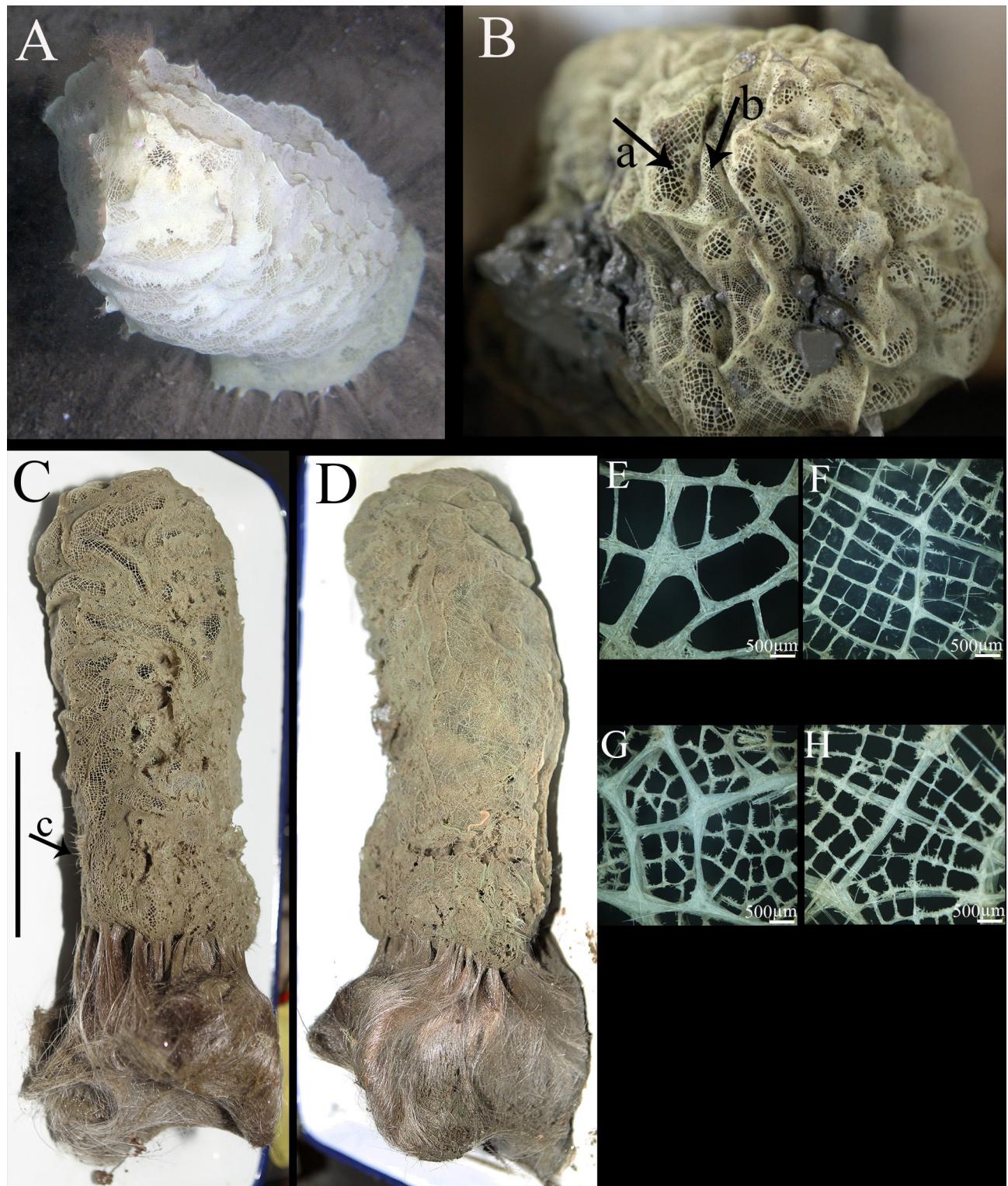


FIGURE 1. *Semperella jiaolongae* sp. nov. A, photograph showing the specimen in its natural habitat. B, the external morphology of atrial areas (arrow a) and dermal areas (arrow b). C, photograph showing side 1 with atrial areas separated by dermal areas (arrow c shows pleuralia), scale bar 10cm. D, photograph showing side 2 with only dermal areas. E, mesh structure of atrial areas. F, mesh structure of dermal areas on side 1 together with atrial areas. G, bigger mesh structures of dermal areas on side 2 with dermal areas only. H, smaller mesh structures of dermal areas on side 2 with dermal areas only.

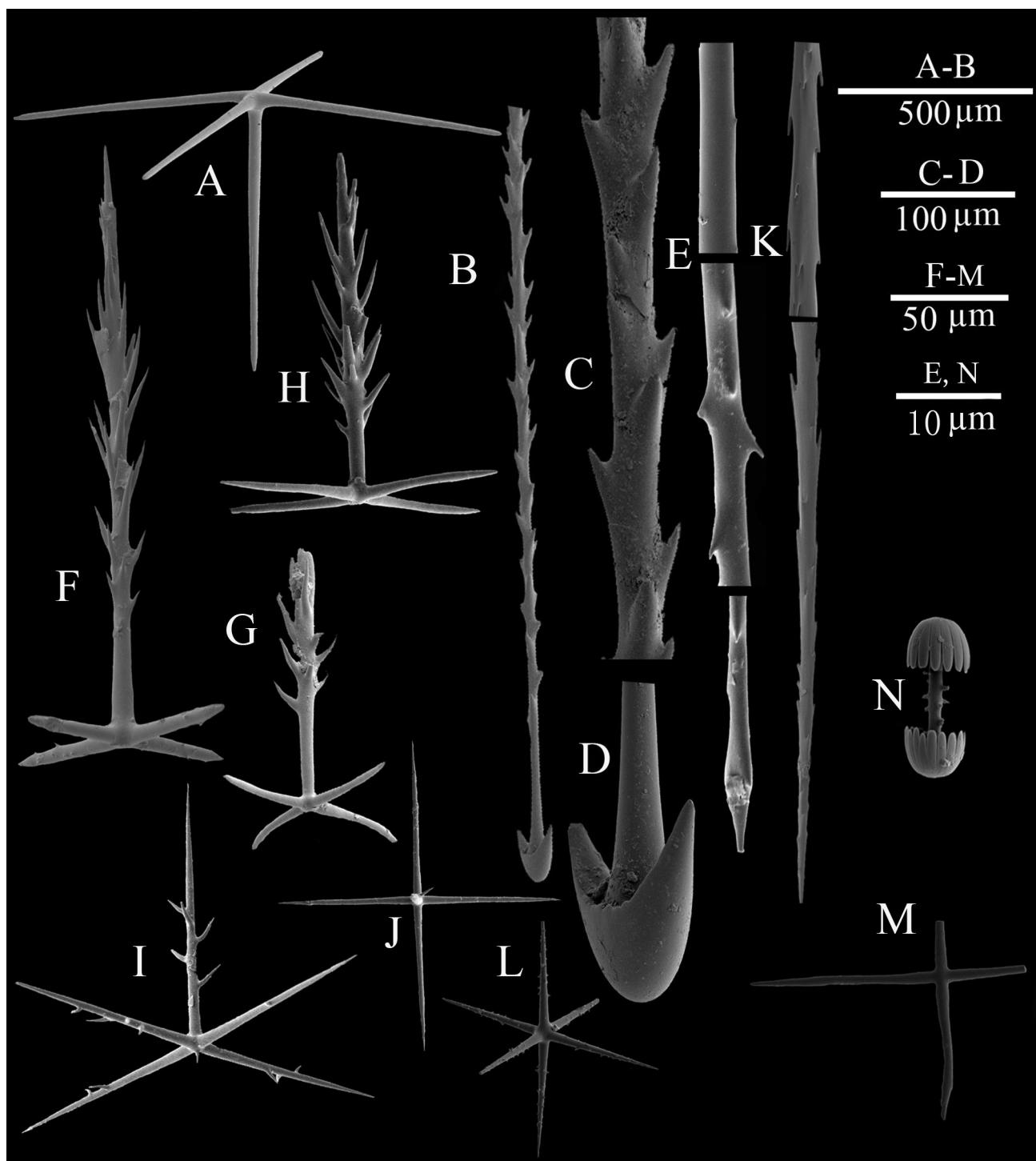


FIGURE 2. *Semperella jiaolongae* sp. nov. SEM images of spicules: A, choanosomal pentactin; B, basalia; C, detail of basalia's shaft; D, detail of basalia's anchor; E, three regions of a sceptre; F–G, dermal pentactin; H–I, atrial pentactin; J, micropentactin; K, details of the tip and middle shaft of an uncinate; L, microhexactin; M, stauractin with two rays broken; N, micramphidisc.

Class Hexactinellida Schmidt, 1870

Subclass Hexasterophora Schulze, 1886

Order Lyssacinosida Zittel, 1877

Family Euplectellidae Gray, 1867

Subfamily Bolosominae Tabachnick, 2002

Genus *Saccocalyx* Schulze, 1896

Saccocalyx microhexactin sp. nov.

(Figures 3–4)

Material examined. Holotype: MBM179994, South China Sea ($17^{\circ}33.95' N$, $117^{\circ}45.67' E$), 5 July 2013, 3542 m depth, hard rock cliff above the mouth of an extinct volcano.

Description. Body is globular with several rows of radially arranged protrusions surrounding a central atrial cavity. The color is white. It looks like a beautiful flower with a long stalk growing on the cliff of a seamount (Fig. 3A). Central atrial cavity is large, with a 100 mm diameter at the upper margin. Roughly 20 suboscula, 10–25 mm diameter open into the central atrial cavity. Radially arranged digitiform protrusions are up to 15 mm long and 10 mm in diameter. A lateral osculum with 5–10 mm diameter is present at the apex of each protrusion. In situ, the body is swollen, with protrusions pointing outward, like a blooming snow lotus herb. After being transported to deck, body with protrusions collapsed. Sponge attached to rock with a long tubular peduncle, 10 mm in diameter, 1 mm thick wall, and at least 250 mm in length.

Choanosomal skeleton solid (Fig. 4O), with some spicules separated from skeleton only after digestion by concentrated nitric acid overnight. Spicules mainly contain hexactins and diactins. Pinular hexactins with rays having sparsely distributed short spines are present in dermalia and gastralria (Fig. 4P), whereas diactins are present in the choanosome. Spirodiscohexasters are numerous and present in the whole body. Drepanocomes occur near dermal and gastral surfaces.

Spicules. Megascleres consist of diactins and hexactins. Diactins are smooth, 2120.3–3557.5/5.3–15.1 μm , usually with four tubercles in middle (Fig. 4H). Dermalia and atrialia are similar in size and shape. Dermalia or atrialia (Fig. 4A) pinular rays (Fig. 4I) are 245.8–450.6 μm long, tangential rays are 173.6–246.8 μm long, proximal rays are 188.2–585.8 μm long. Choanosomal hexactins ((Fig. 4O) are relatively less than diactins, they have short spines in terminal, rays are 126.5–355.8 μm . The skeleton of the peduncle (Fig. 4N) is composed of diactines fused to each other by numerous synapticulae.

Microscleres consist of spirodiscohexasters, drepanocomes, plumicomes and microhexactins. Drepanocomes are in two types. Drepanocomes I (Fig. 4B) 254.4–318.6 μm in diameter, with 6 clusters of 8 hook-like secondary rays (Fig. 4J). Drepanocomes II (Fig. 4C) 123.0–137.5 μm in diameter, with 6 clusters (Fig. 4K) of 4–6 hook-like secondary rays. Structure of drepanocomes easy to destroy during digestion, and hard to isolate completed ones. Spirodiscohexasters (Fig. 4D) 112.4–149.8 μm in diameter, formed by 6 spirally twisted clusters of roughly 8–12 terminal rays ending in discs (Fig. 4L) with approximately 18 marginal teeth. Plumicomes (Fig. 4E) have six shield-like primary termination, one on the top and one on the bottom, the other four are in the middle area. A single sheild (Fig. 4M) have approximately 70 marginal sigma-like secondary rays. Each sigma-like secondary rays has prominent teeth on the inside curve. The diameter of Plumicomes is 35.8–58.5. Microhexactins (Fig. 4F–G) with rays covered short and minute spines, rays are 21.4–70.3 μm long.

Etymology. “*mikros*”, Greek, small; “*hex*”, Greek, six; “*aktis*”, Greek, ray, light beam. Microhexactin is a kind of sponge microscleres. The specific name refers to the presence of microhexactins in the new species.

Remarks. Only two species of *Saccocalyx* are known in the world: *Saccocalyx pedunculatus* Schulze, 1896 and *Saccocalyx careyi* (Reiswig, 1999). The main difference between the two species is that all pinular rays of *S. careyi* are clavate, while only part of the pinular rays of *S. pedunculatus* are clavate. However, since these spicules have a big variety in size and shape, and their ranges overlap, *S. careyi* was considered a doubtful species and could be a junior synonym of *S. pedunculatus* (Tabachnick, 2002). Because there are no described microsclere structure details available for *S. pedunculatus*, we cannot tell what other differences between both species there may be. But our specimen has two distinctive characteristics which are different from the two known species: (a) presence of drepanocomes II, (b) presence of microhexactins. Both types of microscleres have not been found in the other two species of *Saccocalyx*. The new species has all pinular rays clavate as reported for *S. careyi*. However, there are other differences: *S. microhexactin* sp. nov. has less terminal discs in spirodiscohexasters, and more marginal sigma-like secondary rays in plumicomes than *S. careyi*.

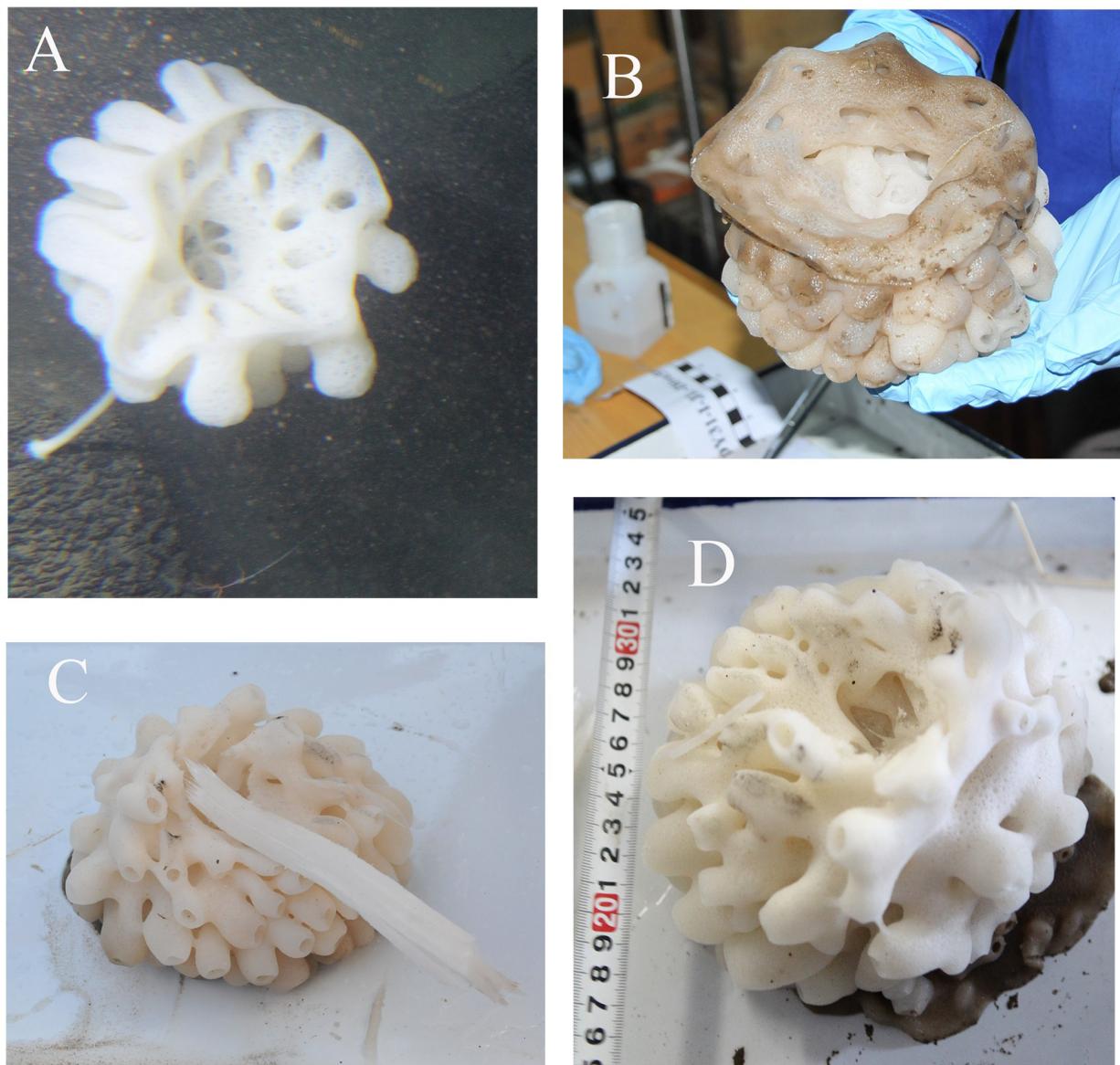


FIGURE 3. *Saccocalyx microhexactin* sp. nov. A, photograph showing the specimen in its natural habitat; B–D, external morphology on deck.

Molecular phylogenetic analysis

The ML and BI analyses based on 16S rRNA were highly congruent, with support values >70 (Fig. 5). *Semperella jiaolongae* sp. nov. is nested within the clade containing members of Pheronematidae, while *Saccocalyx microhexactin* sp. nov. is nested within the clade containing members of Euplectellidae. All species of Pheronematidae and Euplectellidae form well-supported clades, thus showing a consistency between morphological and molecular results. However, we got a poor confidence in the molecular tree, to cluster *Semperella jiaolongae* sp. nov. and *S. schultzei* together. We believe *S. schultzei* may be misidentified. More studies are needed to show a more confident phylogenetic relationship among species of *Semperella*.

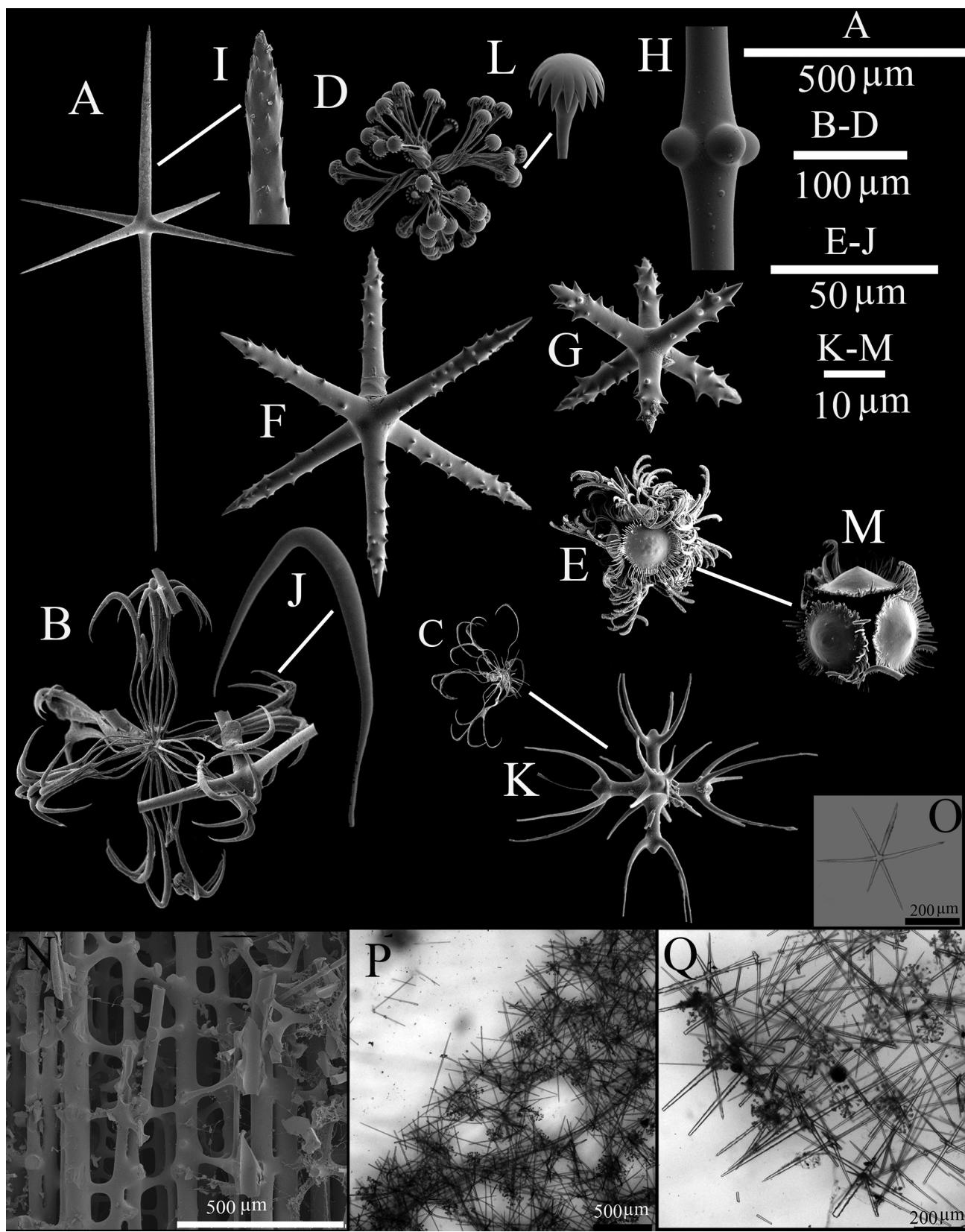


FIGURE 4. *Saccocalyx microhexactin* sp. nov. A–N, SEM images of spicules. A, dermal or atrial hexactin; B, drepanosome I; C, drepanosome II; D, spirodiscohexaster; E, plumicome; F, microhexactin I; G, microhexactin II; H, detail of tubercles in the middle of a diactine; I, detail of the pinular ray of a hexactin; J, detail of the hook-like secondary ray of a drepanosome I; K, detail of the middle part of a drepanosome II; L, detail of the tooth disc of a spirodiscohexaster; M, detail of the whorl of a plumicome; N, spicules of the peduncle; O–Q, LM images of spicule and skeleton; O, choanosomal hexactin; P, tangential view of choanosomal structure; Q, transversal view of choanosomal structure.

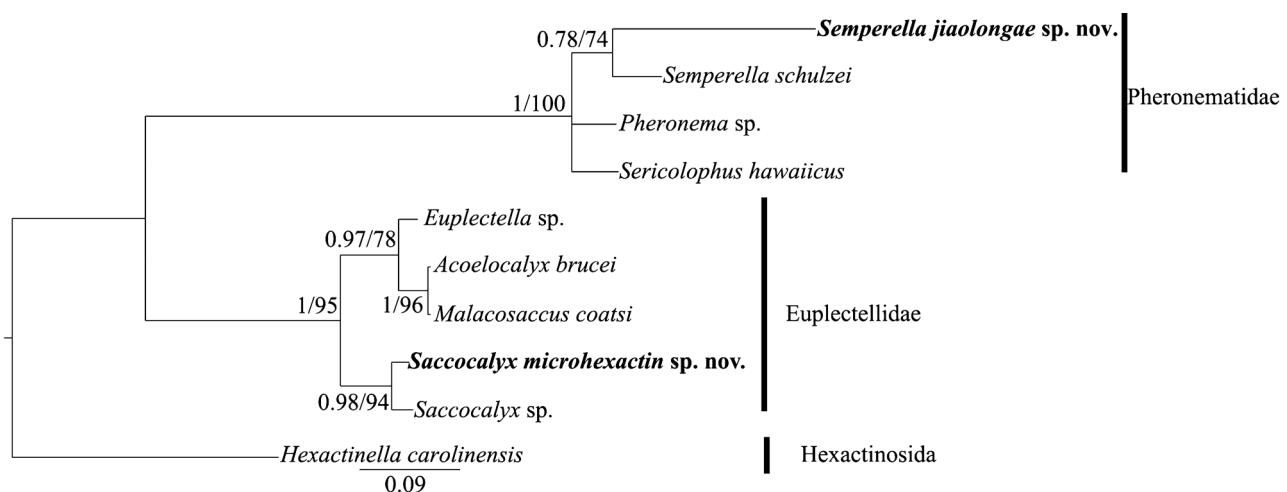


FIGURE 5. Bayesian and ML trees of selected hexactinellid species based on the 16S rRNA sequence data, analyzed with the GTR+G substitution model. Numbers at each node are Bayesian posterior probabilities (left) and ML analysis bootstrap values (right).

Summary

This is the report of *Semperella jiaolongae* sp. nov. and *Saccocalyx microhexactin* sp. nov. from the South China Sea, with photographs showing the natural habitats of both species. Together with *Lophophysema eversa* (Gong *et al.*, 2014), 3 species of hexactinellids are now known in the first scientific cruise of the Chinese manned submersible Jiaolong to South China Sea in June to July 2013. The analysis of the partial 16S rRNA sequence supports the assignment of *S. jiaolongae* sp. nov. to the family Pheronematidae, and *S. microhexactin* sp. nov. to the family Euplectellidae.

Acknowledgements

We are grateful to Konstantin Tabachnick (Institute of Oceanology, Russian Academy of Sciences) for providing useful references and helpful suggestions on the species, Dr. Dorte Janussen (Forschungsinstitut und Naturmuseum Senckenberg) for her suggestion on how to identify the two species. Special thanks are due to the editor, Professor Eduardo Hajdu, and the reviewers for investing their time and helping to improve the manuscript. This work was financially supported by the Strategic Priority Research Program, Chinese Academy of Sciences (No. XDB06010101) and the IOCAS (No. 2012IO060105).

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