



Six new species of *Hyattella* (Porifera: Dictyoceratida: Spongiidae) from the Southern Coast of India

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Abstract

The Sponges of the family Spongiidae have seven genera and occur in a wide variety of forms from low encrusting to upright massive forms. Among these the species of the genus *Hyattella* from India had been described in a very confusing manner. Present work revises the species reported from India. Six new species *Hyattella repandus* n. sp., *Hyattella macrophylla* n. sp., *Hyattella foliata* n. sp., *Hyattella vedalainensis* n. sp., *Hyattella diffusa* n. sp. and *Hyattella oblongus* n. sp. were added to the fauna of India. The *Hyattella macrophylla* n. sp. has uneven surface with folding, less cored primary fibres and smaller diameter of primary fibres. The *Hyattella foliata* n. sp. is like flower petals shape, thicker diameter of primary as well as secondary fibres. *Hyattella vedalainensis* n. sp., is characterised by a small arborescent flat sponge body, small oscules, densely cored primary fibers as compared to other four species. *H. diffusa* n. sp. is an arborescent, small tubular branch and high diameter of the primary fibres. The *H. oblongus* n. sp. is a globate and massive, less diameter of the primary fibres.

Keywords: Diversity, marine sponges, Demospongiae, Gulf of Mannar, *Hyattella*

Introduction

Family Spongiidae Gray, 1867 consists of six valid genera and 91 nominal species. They are characterised by homogenous skeletal fibres and dense fibre skeleton of primary and secondary fibres (Cook and Bergquist, 2002). The first important work on "horny sponges" was by Lendenfeld in 1889 who published a detailed account of the taxonomy, morphology and physiology of this group. Bergquist (1980) described the Horny sponges- mineral skeleton is replaced by collagenous elements which is mainly spongin fibres, reduced to fibrillar collagen which reinforces the sponge matrices. It is interesting to note that the so-called "horny" sponges have been variously grouped at ordinal level as the Keratosa (Grant, 1861; Burton, 1934; De Laubenfels, 1936; 1948; Vacelet, 1959); Monoceratina, Dendroceratina and Myxospongiae (Minchin, 1900), Euceratosa (Dendy, 1905); Dictyoceratida and Dendroceratida (Bergquist and Hartman, 1969; Lévi 1973) Dictyoceratida, Dendroceratida and Verongida (Bergquist, 1978).

Cook and Bergquist (2001) reported that the Genus *Spongia* assigned to Dictyoceratida has the greatest number of species than any genus. Six genera: *Spongia*, *Hippospongia*, *Coscinoderma*, *Hyattella*, *Leiosella* and *Rhopaloeides*, occur in a variety of forms from low encrusting to upright massive forms.

They all have a skeleton of primary, secondary, and distinct fine or pseudo-tertiary fibres. All fibres are unpithed and are homogeneous. Most characteristic of the sponge is the dense secondary fibre reticulum, which dominates the skeleton. The surface of the sponge may be heavily armoured in a dermal crust of sand, foreign spicules and detritus. Unarmoured genera usually have a conulose surface. Choanocyte chambers are diplodal, spherical to oval in shape.

Cook (2007) described that Dictyoceratid Families have fine collagenous filaments-Ircinids, homogenous Skeleton-Spongids, eurypylous choanocyte chambers-Thorectids, diplodal choanocyte chamber, pithed and laminated fibres and absence of fine filaments. The generic characters considered for the species differentiation were skeletal architecture, mucus production, whether they are armoured or not armoured, presence of primary, secondary and tertiary fibres, fascicular fiber and foreign coring. Dictyoceratids have an anastomosing fibre skeleton, usually organised into a hierarchy reflecting size and orientation.

Primary fibres are typically oriented at right angles to the surface; distally they usually end at the sponge surface and support the conules in those species that have them (Bergquist, 1980). They may be simple, coalescing to fascicular. May be axially to fully covered with foreign inclusions e.g: sand, spicule. Secondary fibres: typically interconnect primary fibres (Cook and Bergquist, 2002) in the simple form they look like rungs of a ladder. May be axially to fully cored with foreign materials. Tertiary fibres: interconnect secondary ones (Cook and Bergquist, 2001), uncored, usually very fine-fibres of very small diameter in comparison with secondary fibres. They form a fine mesh-network within the secondary fibre meshes. Pseudo-tertiary fibres: Finer than secondary fibres, not as fine as tertiary fibres (Cook and Bergquist, 2002).

Hyattella is characterised by an unarmoured and conulose surface, lacunose sponge body and commonly cored primary and uncored secondary fibres. They are elastic and compressible. A total of 34 species was described globally, of which 24 are valid. Previous studies indicate that there are around 14 species of *Hyattella* found globally (Lendenfeld, 1889; De Laubenfels, 1936; 1948; 1954; Thomas, 1973; Van Soest, 1978; Bergquist, 1980; Cook and Bergquist, 2002; Van Soest *et al.*, 2020). Recently, nine species of *Hyattella* were recorded off the Chinese coast (Sim and Lee, 2014; Sim *et al.*, 2015). Up to now, seven species of the genus *Hyattella* have been reported from India: *Hyattella cribriformis* (Hyatt, 1877), *Hyattella intestinalis* (Lamarck, 1814), *Hyattella meander* Lendenfeld, 1889, *Hyattella pertusa* (Esper, 1794), *Hyattella sinuosa* (Pallas, 1766), *Hyattella tubaria* Lendenfeld, 1889

and *Hyattella globosa* Lendenfeld, 1889). There exists a great diversity of *Hyattella* around the world especially in the tropical seas. Moreover, the reports from India have been scarce and there are nomenclature issues of the species reported from Indian Ocean (Dendy, 1887; 1889; Burton, 1937; Rao, 1941; Thomas, 1973; 1979; 1985; 1986; Prabhakaran *et al.*, 2013; Sivaleela, 2014; Van Soest *et al.*, 2020; Tarachand *et al.*, 2020; Varsha *et al.*, 2020 a; 2020 b; 2020 c). In this context the present exploration and taxonomic work on the bio-inventorying of Sponge of the Genus *Hyattella* was taken along the Indian coast with special emphasis along the Gulf of Mannar area which is part of the All India Coordinated Project on Taxonomy (AICOPTAX) a new initiative from the Ministry of Environment, Forests and Climate Change, New Delhi to create a database on the inventory of the faunistic diversity of India.

Material and methods

An extensive survey and sampling at selected stations was conducted from both south west and south east coast of India *i.e.*, Muttom, (10.11.2018), Vedalai, (06.05.2019), Mandapam, (21.07.2019) and Chetlat Island (26.09.2019) (Fig.1). Muttom is one of the historical fishing villages located in the south west coast of India characterized by rocky habitat and calm sea wherein the diversity emanates from the Arabian Sea of Indian Ocean. Along the south east coast, Vedalai is an ancient fishing village situated in the south of Gulf of Mannar that lies in the Bay of Bengal Sea. The two coral Islands on both sides of Vedalai makes its unique habitat with vulnerable and threatened species and forms a part of Marine Protected Area of Gulf of Mannar Marine National Park. Mandapam is a coastal town that lies between Gulf of Mannar and Palk Bay of Bay of Bengal Sea. The samples were collected for the present study from the Palk Bay side of the Bay of Bengal Sea. Chetlat Island is a coral island of the Lakshadweep Archipelago. The reef and lagoon are located to the west of the island that has a lagoon area of 3.79 km². It lies between 11° 41' and 11° 43' N latitude and 72° 41' and 72° 43' E longitude having an area of 1.40 km².

Sponges were collected by handpicking, snorkeling and SCUBA diving at various localities at a depth of 0-50 m. Specimens of three species from Muttom - (Field collection numbers: MT 32, MT 53, MT 71, MT 50) two species from Vedalai (VD 12, VD 23) two species from Mandapam (MD 02, MD 13) and specimen from Chetlat (CHT 8) were collected and analysed during the present study. The collected samples were brought to the laboratory and preserved in dry condition and 70% of Ethanol. The sectioning of the samples were done using razor blades and thin sections were preserved. Structural characteristics and length measurements of spicules were noted using the Nikon SMZ 1000 Stereozoom microscope and image analyzing

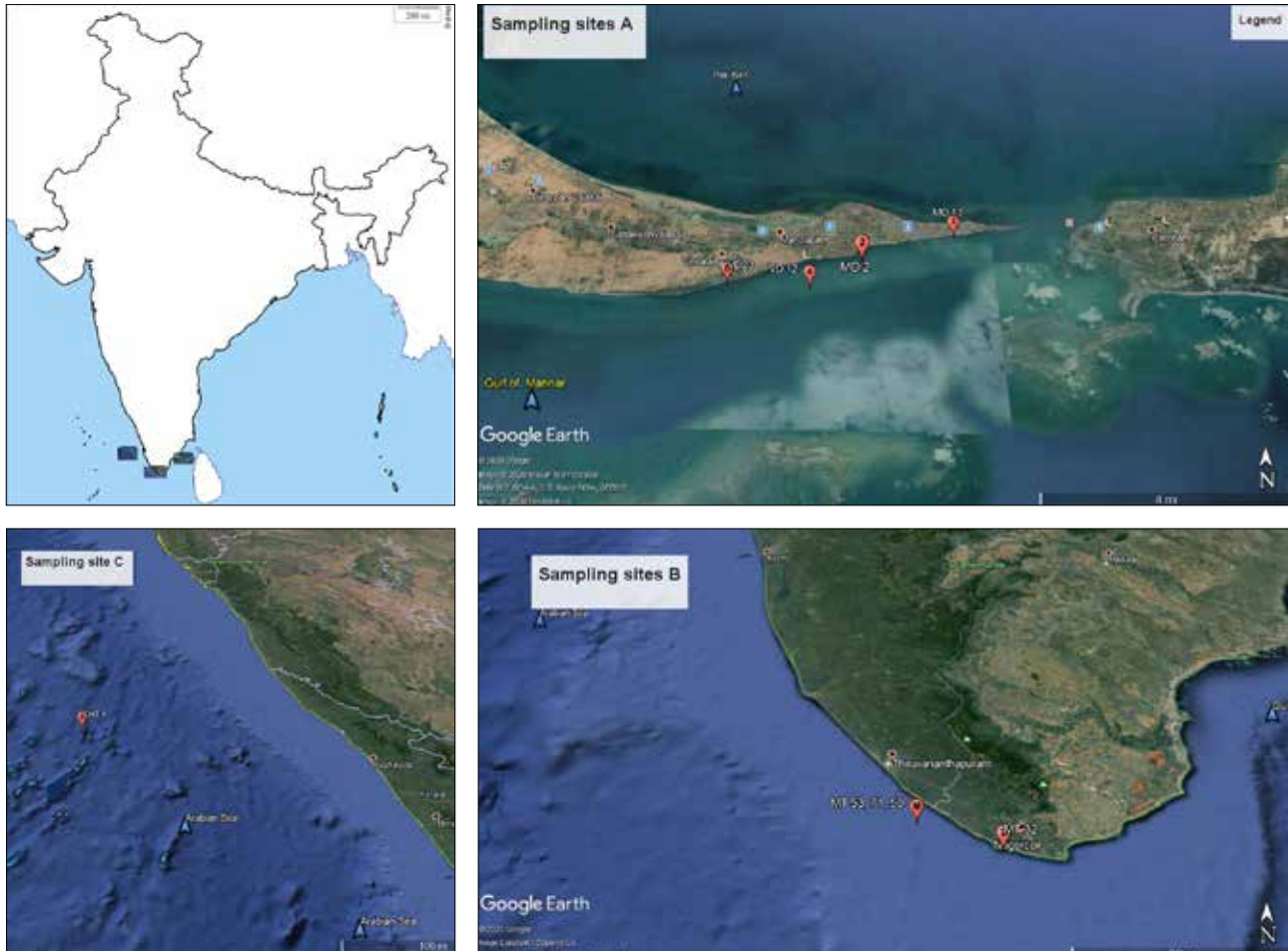


Fig.1. Map showing sampling stations of *Hyattella* species from Gulf of Mannar and Southern Arabian Sea. Site A: VD 12, VD 23, MD 02, MD 13, Site B: MT 53, MT 71, MT 50, MT 32 and site C: CHT 8 are the places where the sampling was done.

software NIS ELEMENTS Version 4.20 (Nikon). The width of the primary fibres were measured and observed the coring pattern and materials. The width of the secondary and tertiary fibres measured in the same way. The sponges were identified as per the detailed diagnostic characters given in the literature (Lendenfeld, 1889; Bergquist, 1980; Bergquist, 1982; Cook and Bergquist, 2001; Cook and Bergquist, 2002; Cook, 2007; Hooper and Van Soest, 2002).

Results

Phylum : Porifera Grant, 1836
 Class : Demospongiae Sollas, 1885
 Subclass : Keratosa Grant, 1861
 Order : Dictyoceratida Minchin, 1900
 Family : Spongiidae Gray, 1867
 Genus : *Hyattella* Lendenfeld, 1888
 Type species : *Hyattella intestinalis* (Lamarck, 1814)

Hyattella intestinalis 1 (Lamarck, 1814)

(Fig. 2-4, 5-7, Table 1)

Synonyms:

Carteriospongia clathrata (Carter, 1881)
Carterispongia clathrata (Carter, 1881)
Hippospongia anomala Poléjaeff, 1884
Hippospongia clathrata (Carter, 1881)
Hippospongia intestinalis (Lamarck, 1814)
Hircinia clathrata Carter, 1881
Hyattella clathrata (Carter, 1881)
Hyattella murrayi Lendenfeld, 1889
Hyattella velata (Hyatt, 1877)
Ircinia clathrata (Carter, 1881)
Spongelia velata Hyatt, 1877
Spongia cariosa Lamarck, 1814
Spongia intestinalis Lamarck, 1814
Spongia tubulosa Lamarck, 1814
Stelospongia kingii Lendenfeld, 1889



Fig. 2. *Hyattella intestinalis* 1 (Lamarck, 1814) CMFRI DNR No. BA.1.1.2.9



Fig. 3. *Hyattella intestinalis* 2 (Lamarck, 1814) CMFRI DNR No. BA.1.1.2.9.2



Fig. 4. *Hyattella intestinalis* 3 (Lamarck, 1814) CMFRI DNR No. BA.1.1.2.9.4

Hyattella intestinalis was originally described by Lamarck (1814) as *Spongia intestinalis*. After a series of genera transfers it was finally assigned in *Hyattella intestinalis*. In 1881, Carter described *Hircinia clathrata* from the Gulf of Mannar ecosystem and renamed as *Cateriospongia clathrata* and *Hyattella murrayi* Lendenfeld 1889 for the sponge collected from East Indies. Several authors, from different parts of the world described the species in different names.

Material examined

1. *Hyattella intestinalis* 1: CMFRI.DNR No. BA.1.1.2.9 (Fig.2) Muttom, Kanyakumari, Tamilnadu (Lat: 8°7'20.07"N, Long: 77°18'45.63"E), 10.11.2018, Gillnet sample (No.MT 53) deposited in the Museum of National Biodiversity Repository, CMFRI, Kochi, India.

2. CMFRI.DNR No. BA1.1.2.9.1 one fragment in Ethanol, deposited in the Museum of National Biodiversity Repository, CMFRI, Kochi, India.

3. *Hyattella intestinalis* 2: CMFRI.DNR No. BA.1.1.2.9.2 (Fig.3) Muttom, Kanyakumari, Tamilnadu (Lat: 8°7'20.07"N, Long: 77°18'45.63"E), 10.11.2018, Gillnet sample (No.MT 71) deposited in the Museum of National Biodiversity Repository, CMFRI, Kochi, India.

4. CMFRI.DNR No. BA.1.1.2.9.2.3, one fragment in Ethanol, deposited in the Museum of National Biodiversity Repository, CMFRI, Kochi, India.

5. *Hyattella intestinalis* 3: CMFRI.DNR No.BA.1.1.2.9.4 (Fig.4), Muttom, Kanyakumari, Tamilnadu (Lat: 8°7'20.07"N, Long: 77°18'45.63"E), 10.11.2018, Gillnet sample (No.MT 50), deposited in the Museum of National Biodiversity Repository, CMFRI, Kochi, India.

6. CMFRI.DNR No. BA.1.1.2.9.5 one fragment in Ethanol, deposited in the Museum of National Biodiversity Repository, CMFRI, Kochi, India.

Description: Sponge with simple, cylindrical branches and hollow body. Overall size of sponge with a height of 8 cm, width of base 6 cm. The finger height 3-6 cm and wall thickness 0.1 -0.3 cm. The wall thickness of lamella is 0.2 cm and wall diameter is 0.8 cm. Hollow tubular with branching ends. Aereolated surface uneven, branching erect with branch length of 2-6 cm. They are attached directly to the substrate. Oscules evenly scattered over the surface producing porous reticulated appearance, mainly on the apex of the sponge digits. Oscule diameters 0.1 -1.0 cm. Ostia minute, dispersed over external surface. Consistency

firm, compressible and difficult to tear, digitiform with large widely tapering surface processes.

Skeleton: Well-developed network of fibres with primary, secondary and tertiary fibres. The main skeleton consists of reticulation of sponge fibres often organised into primary, secondary and tertiary networks. Fibres are homogenous in the cross section.

Hyattella intestinalis 1: Primary fibres are 39.33- 52.0 μm diameter (Fig. 5A-B) cored with small particles of sand. Uncored secondary fibres 14.05-21.9 μm diameter (Fig.5C). The tertiary fibres, 7.3 -11.28 μm in diameter (Fig. 5D).

Hyattella intestinalis 2: Primary fibres are 73.03 -91.72 μm diameter (Fig. 6A) cored with small particles and sand. Uncored secondary fibres, 32.64-52.00 μm diameter (Fig.6B). Tertiary fibres present.

Hyattella intestinalis 3: Primary fibres are 55.66 -93.51 μm diameter (Fig. 7A-B) cored with small particles and sand. Uncored

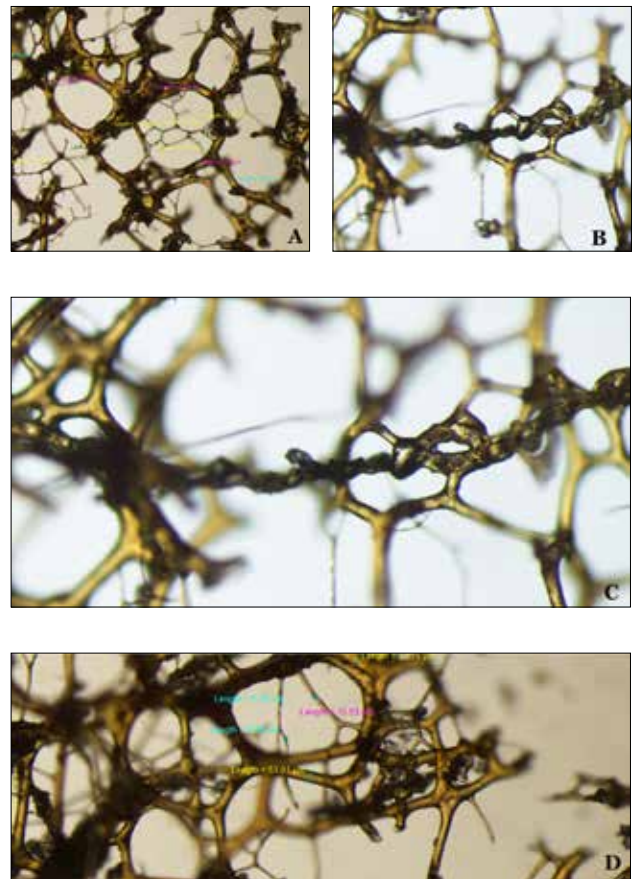


Fig. 5. A. Fibre skeleton (cross section) of *Hyattella intestinalis* 1 B. Cored primary fibres, C. Primary fibres in high power, D. Primary, secondary & tertiary fibres (longitudinal section)

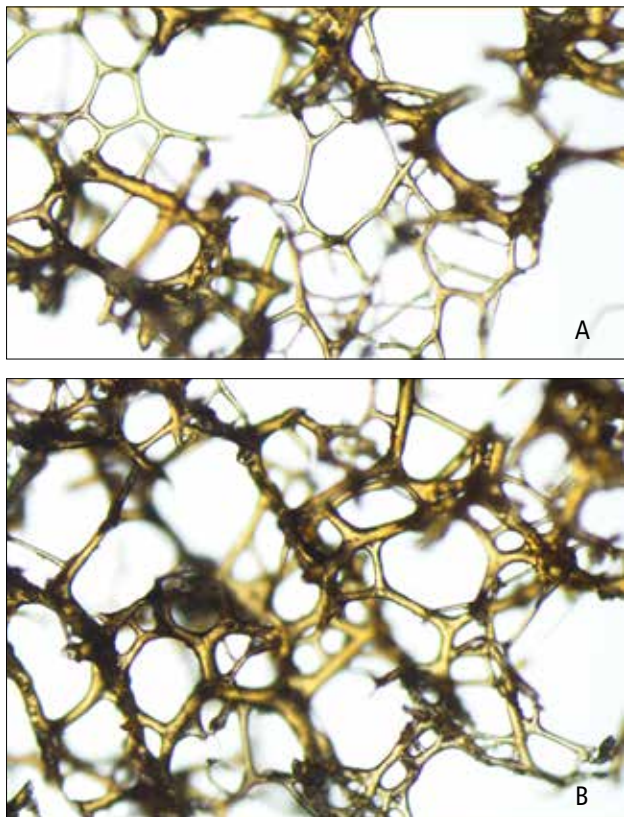


Fig. 6. A. Fibre skeleton (cross section) of *Hyattella intestinalis* 2
B. Fibre skeleton (longitudinal section)

secondary fibres, 16.37-45.77 μm diameter (Fig. 7C-D). Tertiary fibres present (Fig. 7E).

Distribution: Known from Gulf of Mannar, Palk Bay (Thomas, 1986), Mandapam, Vedalai, Shingle Island, Adiaman beach, Manauli Island (Sivaleela, 2014), Muttom (present study) of Tamilnadu state of India.

Remarks: Past literature review revealed that at least three type species i.e. *Hippospongia intestinalis* (Lamarck, 1814), USNM 7689, USNM 8721 (Holotype), Smithsonian National Museum of Natural History, (locality: Indian Ocean), *Spongia intestinalis* Lamarck, 1814, MNHN DT (Holotype) 584, Museum National d'Histoire Naturelle, Paris, (locality: Indian Ocean) and *Hippospongia clathrata* (Carter, 1881) BMNH 1920.12.9.46 (Holotype), British Museum of Natural History, (locality: Indian Ocean) were reported during 1800s. Dendy (1905) collected several samples of *Hippospongia intestinalis* (Lamarck, 1814) with the characters like elongated tubular form, perforated walls, conulose surface, irregular amber coloured skeleton from Gulf of Mannar and Ceylon seas. Later this species were synonymized as *Hyattella intestinalis* (Lamarck, 1814). Dendy (1916) reported species *Hippospongia clathrata* (Carter, 1881) (= *Hyattella intestinalis* (Lamarck, 1814) from Okha (Gujarat,

India) of the Northern Arabian Sea. The present material agrees with the description of *Hyattella intestinalis* (Lamarck, 1814) and the later reports three from the Gulf of Mannar Ecosystem (Dendy, 1905, Thomas, 1986, Sivaleela, 2014). All these studies have been reported the characters like elongated tubular form, walls perforated with openings, irregular, amber coloured fibres, surface is conulose (Dendy, 1905, Thomas, 1986) and minutely conulose, oscules terminal and texture hard (Sivaleela, 2014). Considering the morphological similarities and wide distribution pattern of the species reported from northern Arabian Sea (Okha) and the south-eastern Bay of Bengal (Gulf of Mannar) the present species from Muttom (Southern Arabian Sea) may be *Hyattella intestinalis* (Lamarck, 1814).

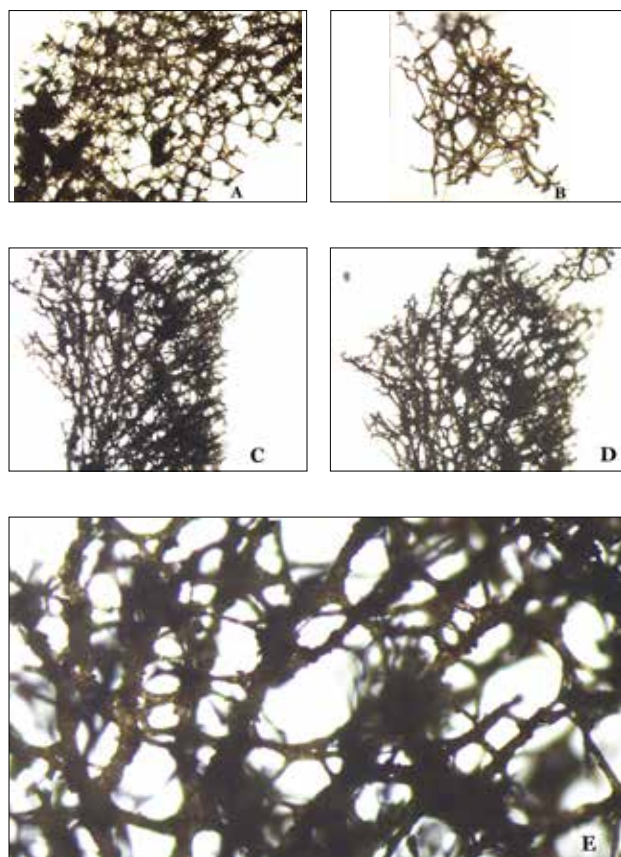


Fig. 7. A & B. Fibre skeleton (cross section) of *Hyattella intestinalis* 3
C & D. Fibre skeleton (longitudinal section), E. Longitudinal section in high power.

Hyattella repandus sp. nov.

(Fig. 8A-C, 9, Table 1)

Material examined

Holotype: CMFRI.DNR No. BA.1.1.2.8 (Fig.8A-C), Vedalai, Ramanathapuram, Tamilnadu (Lat: 9°15'50.33"N, Long: 79°



Fig. 8. A-C. *Hyattella repandus* sp. nov. Holotype, CMFRI DNR No. BA.1.1.2.8

6'24.02"E), 06.05.2019, Hand picking (No.VD 12), deposited in the Museum of National Biodiversity Repository, CMFRI, Kochi, India. ZooBank registration number as per the new Nomenclature Act: <http://zoobank.org/urn:lsid:zoobank.org:act:C5660E6A-6807-4EE9-A5C7-D0EEC46DC27F>.

Paratype: 1. CMFRI.DNR No. BA.1.1.2.8.1, Vedalai, Ramanathapuram, Tamilnadu (Lat: 9°15'50.33"N, Long: 79° 6'24.02"E), 06.05.2019, Hand picking, deposited in the Museum of National Biodiversity Repository, CMFRI, Kochi, India.

2. CMFRI.DNR No. BA 1.1.2.8.2, one fragment in ethanol, deposited in the Museum of National Biodiversity Repository, CMFRI, Kochi, India.

Description: Hollow, tubular with branching ends with a size of 19.5 cm. There are many independent tubes from the base. The colour is brownish. Surface is uneven and irregularly folded. They are attached to the substrate directly. Oscules are distributed all over the body with a diameter of 0.5 cm. Consistency firm, compressible and difficult to tear.

Skeleton: Fibre network is the main skeleton and it has primary, secondary and tertiary fibres. Primary fibres are 79.81- 110.1 μm in diameter and cored (Fig. 9A-B) with small particles and sands. Uncored secondary fibres, 38.8-47.5 μm in diameter (Fig. 9C-D) well developed and make a complex mesh. Tertiary fibres are also present with diameter of 17.39-18.63 μm (Fig. 9 E-F). The distance between two conules is 396.81 μm .

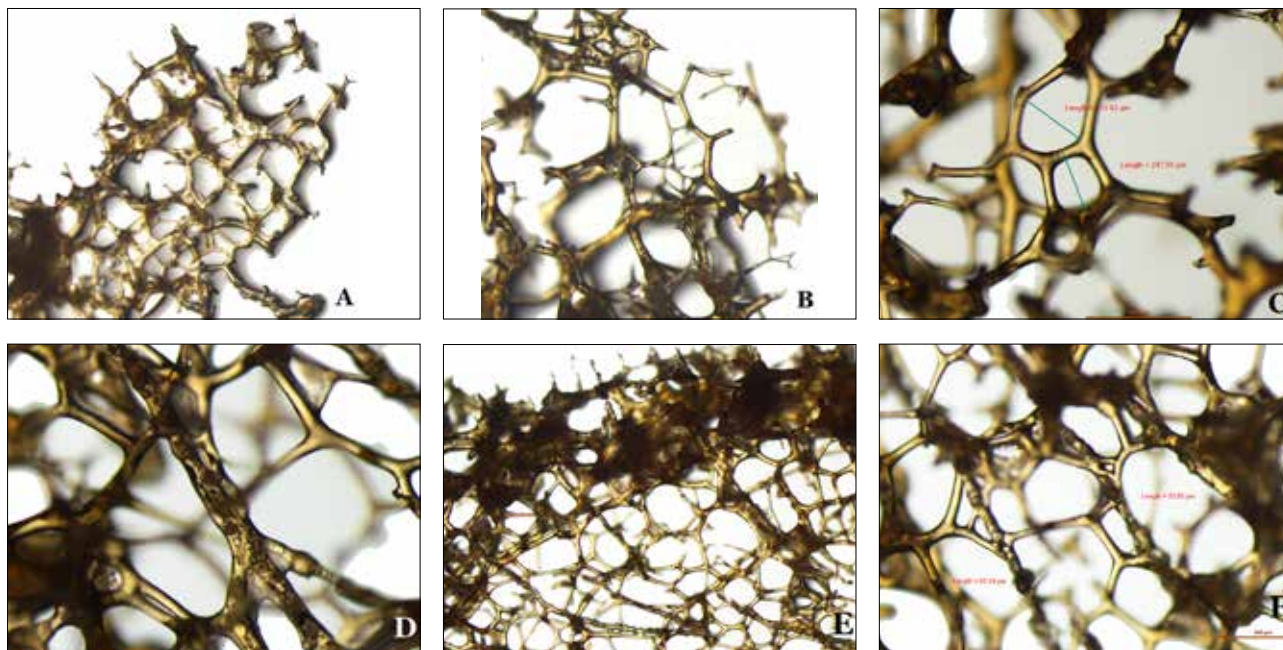


Fig. 9. A. Fibre skeleton (cross section) of *Hyattella repandus* sp. nov, B & C. Cross section in high power, D. Primary fibre, E -F. Longitudinal section

Distribution: Known from Vedalai in Ramanathapuram of Gulf of Mannar of Tamilnadu state of India.

Etymology: The species name *repandus* in Latin refers to curved upwards or turned up shape of the sponge.

Remarks: The morphological characteristics of the original species description of *Hyattella intestinalis* (Lamarck, 1814) agree with those of the present species *Hyattella repandus* n.sp. in the general body pattern only. In general the present species *Hyattella repandus* n.sp., can be grouped *H. intestinalis*, *H. tubaria*, *H. sinuosa* and *H. meander* which are encrusting, pedunculate sponges with a basal mass from which arise irregularly curved cylindrical processes on an average 30 mm thick. But the *Hyattella repandus* n.sp. differ in branching pattern, width of the primary and secondary fibers and thickness of body wall with other congeners. *Hyattella repandus* n.sp. has hollow tubular with branching ends with thicker diameter of fibers but differs in having hollow tubular branches, smaller diameter of fibers in *Hyattella macrophylla* n.sp. has flattened base with narrowing at the tip in *Hyattella foliata* n. sp., arborescent bushy in *Hyattella vedalainensis* n.sp., arborescent bushy and globose massive in *H. oblongus*. n.sp. Considering the extend of internal differences between the other species, a new species *Hyattella repandus* is erected presently from Gulf of Mannar.

Hyattella macrophylla sp. nov.

(Fig.10 A-C, 11, Table 1)

Material examined

Holotype: CMFRI.DNR No. BA.1.1.2.10 (Fig.10A-C), Chetlat, Lakshadweep (Lat: 11°41'28.36"N, Long: 72°42'13.72"E), 26.09.2019, Skin dive collection (CHT 8), deposited in the Museum of National Biodiversity Repository, CMFRI, Kochi, India. ZooBank registration number as per the new Nomenclature Act: <http://zoobank.org/urn:lsid:zoobank.org:act:FBF044EA-A89B-4706-8C7E-E459DE9CDE0F>

Paratype: 1. CMFRI.DNR No. BA.1.1.2.10.1, Chetlat, Lakshadweep (Lat: 11°41'28.36"N, Long: 72°42'13.72"E), 26.09.2019, Skin dive collection, deposited in the Museum of National Biodiversity Repository, CMFRI, Kochi, India.

2. CMFRI.DNR No. BA.1.1.2.10.2, one fragment in ethanol in the Museum of National Biodiversity Repository, CMFRI, Kochi, India.

Description: Encrusting, hollow, uneven shaped, branches arising from the base. They are directly attached to the substratum, encrusting with molluscan shells and corals. The colour is yellowish. The surface is uneven and meandering. Conules are present in the body. The distance between two conules is 962.80 μ m. Oscules distributed all over the body. Consistency tough, slightly compressible and tough to tear.



Fig. 10. A. *Hyattella macrophylla* sp. nov. Holotype, CMFRI DNR No. BA. 1.1.2.10, B & C. Enlarged view of specimen

Skeleton: Fibre network is the main skeleton and it has primary and secondary fibres. Primary fibres are mainly cored and few are uncored (Fig. 11 A). The cored and uncored primary fibre, $36.23 \mu\text{m}$ and $54.31-57.08 \mu\text{m}$ in diameter respectively (Fig. 11 B). Similarly, the secondary fibres also cored and uncored. The cored secondary fibres are $14.86-23.16 \mu\text{m}$ in diameter (Fig. 11 C).

Distribution: Known from Chetlat, Lakshadweep of India.

Etymology: The species name *macrophylla* in Latin refers to similarity with the structure of leaf.

Remarks: *Hyattella macrophylla* sp. nov. is an encrusting sponge, with hollow leaf-like bumps. With uneven surface with folding. This is a similar trait to *Hyattella meander* Lendenfeld, 1889 described as irregular, ramified, horizontally expanding sponge. Although, they differ as the sponge body irregular, surface smooth, presence of small digitate process, fibres close

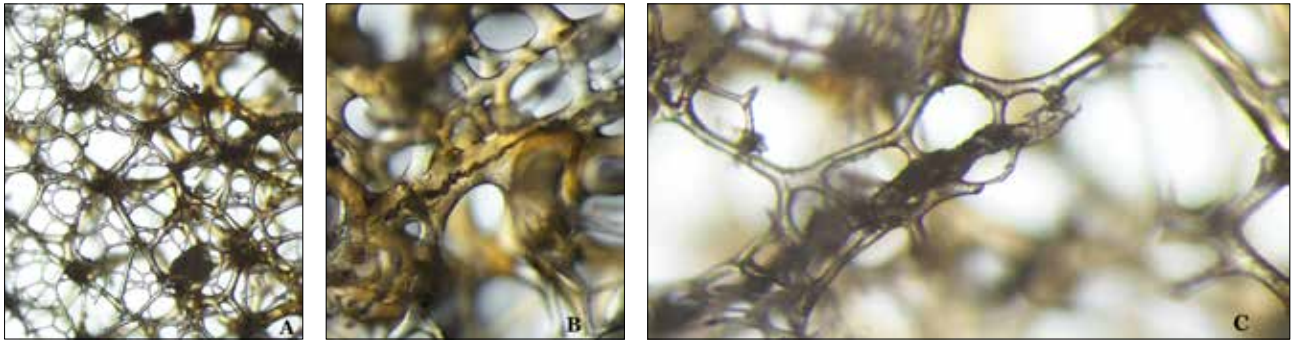


Fig. 11. A & B. Fibre skeleton (cross section) of *Hyattella macrophylla* sp. nov, C. Cross section in high power

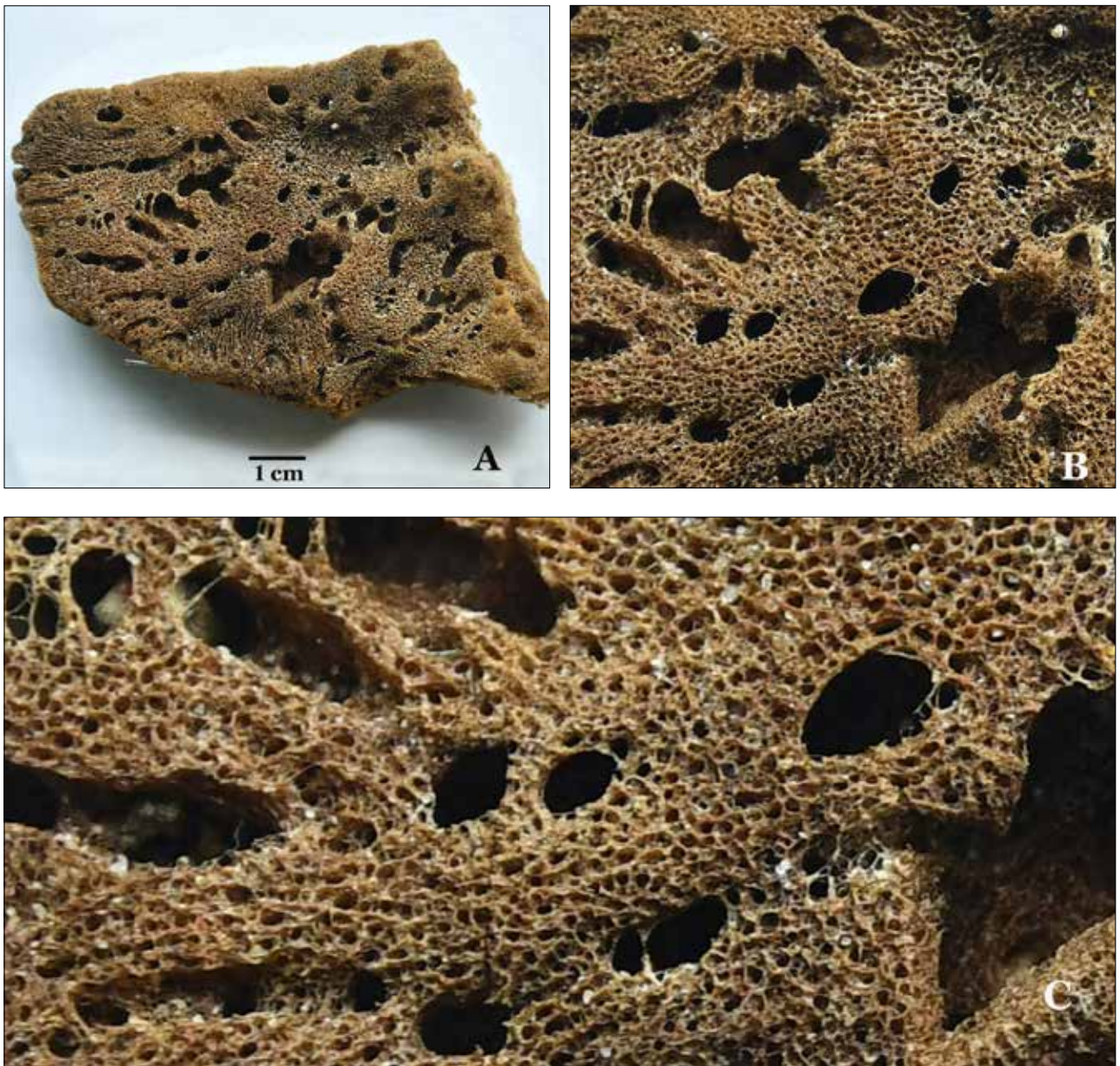


Fig. 12. A. *Hyattella foliata* sp. nov. Holotype, CMFRI DNR No. BA.1.1.2.14, B-C. Enlarged view of specimen

together and form perforated plates, dark amber colour in dry condition in *Hyattella meander*. But in *Hyattella macrophylla* n.sp., sponge arises from the base and expands in the upper part, primary and secondary fibres form polygonal and circular networks, contains plenty of coral parts and shells of molluscs both in the external and internal parts of the sponge body, dull white colour in dry condition.

Hyattella macrophylla n. sp. is distinguished by a network of primary fibres and secondary fibres cored and uncored both in primary and secondaries. The new species also shows thinner width for both primary 36.23 -57.06 μm and secondary fibres 14.86-57.08 μm than the other *Hyattella* spp. Considering the differences from, *Hyattella meander*, we describe *Hyattella macrophylla* as a new species to the genus *Hyattella*.

Hyattella foliata sp. nov.

(Fig. 12 A-C, 13 Table 1)

Material examined

Holotype: CMFRI.DNR No. BA.1.1.2.14 (Fig.12 A-C), Mandapam, Rameswaram, Tamilnadu (Lat: 9°16'17.28"N, Long: 79°7'53.71"E), 21.07.2018, Hand picking (MD 13) deposited in the Museum of National Biodiversity Repository, CMFRI, Kochi, India. ZooBank registration number as per the new Nomenclature Act: <http://zoobank.org/urn:lsid:zoobank.org:act:83E79DF9-E90B-4137-9EDF-F26704F07DA6>

Paratype: 1. CMFRI.DNR No.BA.1.1.2.14.1, Mandapam, Rameswaram, Tamilnadu (Lat: 9°16'17.28"N, Long: 79°7'53.71"E), 21.07.2018, Hand picking, deposited in the Museum of National Biodiversity Repository, CMFRI, Kochi.

2. CMFRI.DNR No.BA.1.1.2.14.2, one fragment in ethanol in the Museum of National Biodiversity Repository, CMFRI, Kochi.

Description: Encrusting sponge with a flattened base and narrowing tips. They are attached directly to the substratum or shells. Sponge has a height of 9 cm and with a base width of 7 cm, wall diameter of 0.6 cm and wall thickness of 0.2-0.4 cm. Specimens are in wood colour. The walls of the sponge hollow. Conules are present in the body. They have small oscules on apex. Small ostia present all over the body. They are tough incompressible and difficult to tear.

Skeleton: They have well developed and strong network of the skeleton, and it has primary fibres, secondary fibres and tertiary fibres (Fig.13A-B). Primary fibres are curved with a width of 46.10-75.61 μm (Fig. 13C) and filled with sand and molluscan parts (Fig.13D). Secondary fibres are also cored with

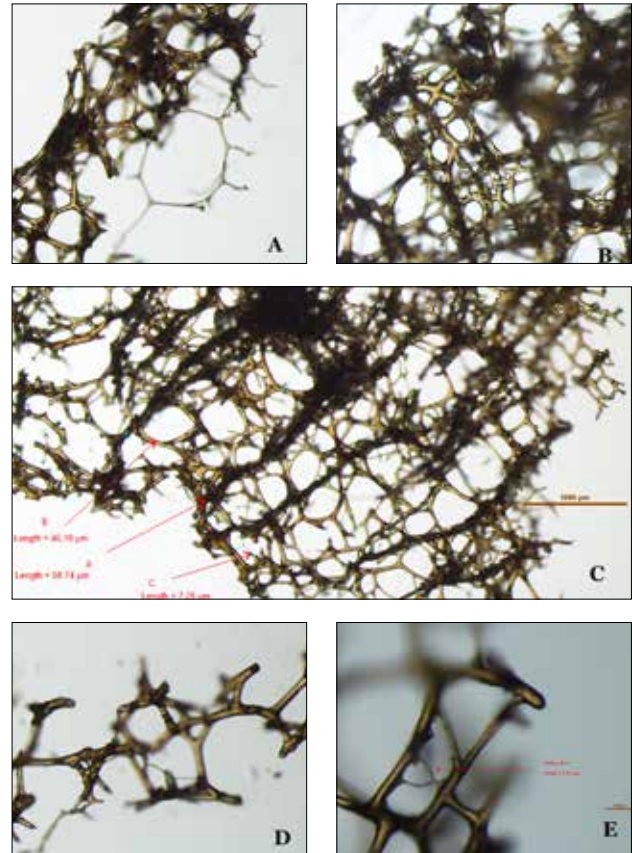


Fig. 13. A-B. Fibre skeleton (cross section) of *Hyattella foliata* sp. nov, C. Fibre skeleton (longitudinal section), D-E. Primary, secondary, tertiary fibres.

a width of 32.43-68.74 μm (Fig.13D). Tertiary fibres present with a width of 6.45-7.26 μm (Fig.13E).

Distribution: Known from Mandapam in Rameswaram of Gulf of Mannar, Tamilnadu, India.

Etymology: The species name *foliata* in Latin refers to similarity of two joined petals of a flower.

Remarks: *Hyattella foliata* n. sp. is distinguished by having a shape of flower petals attached together, while *H. intestinalis* and *H. repandus* n. sp. are encrusting and branched forms. Compared with even surface in *H. intestinalis* the surface in *H. macrophylla* are uneven. The diameter of the primary fibres is thicker in *H. foliata* n. sp. compared with *H. macrophylla* n. sp. The diameter of the secondary fibres is also thicker in *H. foliata* n. sp. Compared with *H. intestinalis*, *H. repandus* n. sp., *H. macrophylla* n. sp. and other species of the genus *Hyattella*, the present species *Hyattella foliata* n.sp. have small oscules on apex. Considering the differences observed in this species, a new species *Hyattella foliata* n. sp. is now being erected from Indian waters.

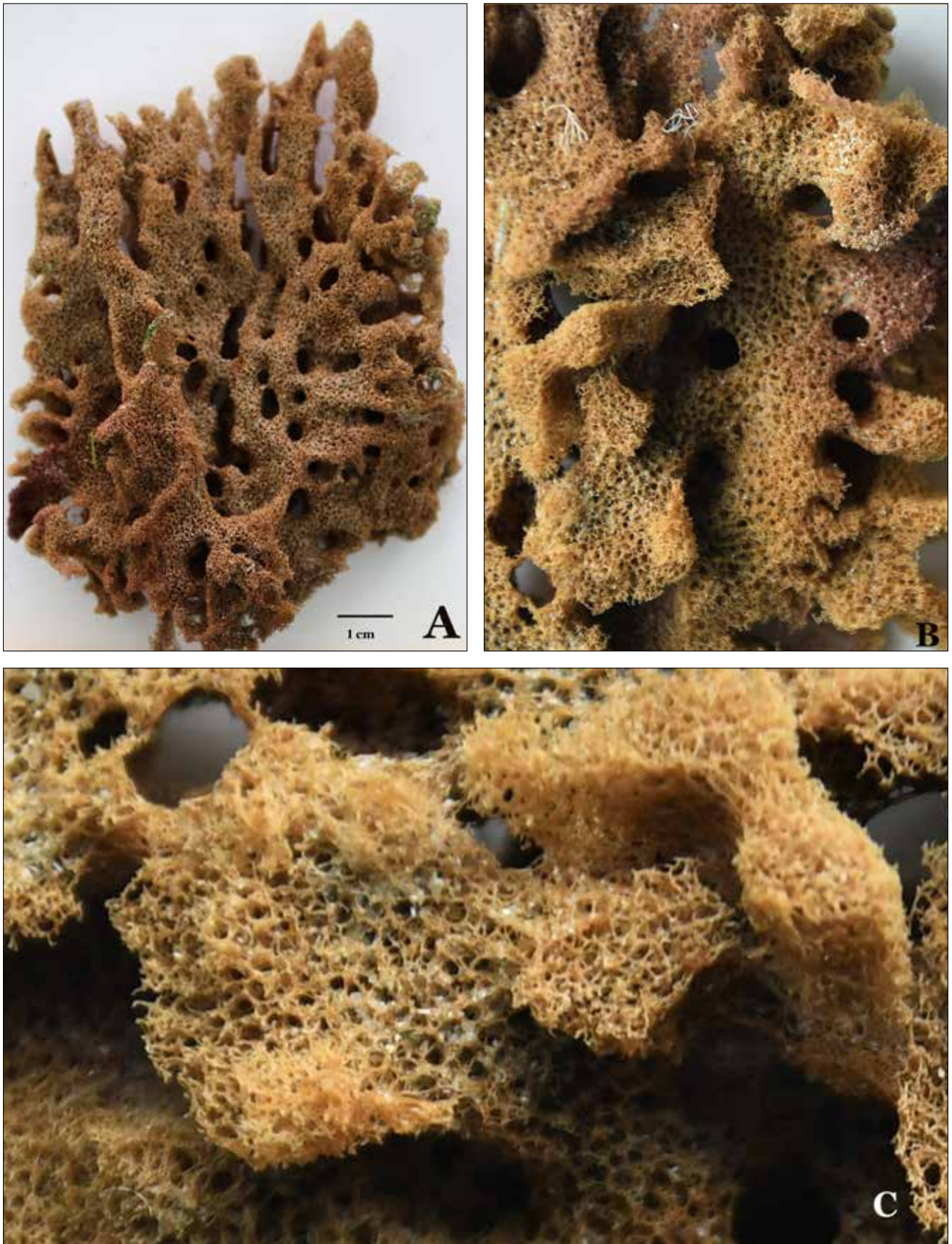


Fig. 14. A. *Hyattella vedalainensis* sp. nov. Holotype, CMFRI DNR No. BA.1.1.2.12, B-C. Enlarged view of specimen

Hyattella vedalainensis sp. nov.

(Fig. 14 A-C, 15, Table 1)

Material examined

Holotype: CMFRI.DNR No. BA.1.1.2.12 (14 A-C), Vedalai, Ramanathapuram, Tamilnadu (Lat: 9°15'48.48"N, Long: 79°6'24.00"E), 21.07.2018, Hand picking (No.VD 23), deposited in the Museum of National Biodiversity Repository, CMFRI, Kochi, India. ZooBank registration number as per the new Nomenclature Act: <http://zoobank.org/urn:lsid:zoobank.org:act:379C39E3-5AAA-4F79-B332-89D8B1ADA269>

Paratype 1: CMFRI.DNR No. BA.1.1.2.12.1, Vedalai, Ramanathapuram, Tamilnadu (Lat: 9°15'48.48"N, Long: 79°6'24.00"E), 21.07.2018, Hand picking, deposited in the Museum of National Biodiversity Repository, CMFRI, Kochi, India.

2. CMFRI.DNR No. BA.1.1.2.12.2, one fragment in ethanol in the Museum of National Biodiversity Repository, CMFRI, Kochi, India.

Description: Encrusting, arborescent with distal tubes arising from the base. Cavernous body which is flattened in shape looks like anastomosing network of tubes. The specimen has a height of 10 cm and basal width of 8 cm. The basal part is

less in width, and it increases to middle and top part of the sponge. They are directly attached to the substrate. The colour is yellowish brown. Conules present in the body. Oscules are distributed all over the body. The oscule diameter is 0.2 cm. They are soft compressible and easy to tear. It is more spongy and elastic.

Skeleton: It has rich fibre network and has primary and secondary fibres (Fig. 15A-B). Primary fibres are heavily cored, 118.07-103.74 μm in diameter (Fig.15C-F). The secondary fibres are 56.84 μm in diameter (Fig.15D). Lots of sand and molluscan soft-shell particles were seen in the choanosome (Fig.15E).

Distribution: Known from Vedalai in Ramanathapuram of Gulf of Mannar, Tamilnadu, India.

Etymology: Species name "*vedalainensis*" in Latin is derived from the locality name Vedalai an ancient fishing village of Ramanathapuram district. Also the word 'Veda' in Sanskrit means knowledge and the four books on Vedas written in BC 1500.

Remarks: This encrusting, arborescent type of sponge is entirely new to the genus *Hyattella*. Unique characters of flattened type body, thicker width of primary fibres, presence of enormous amounts of sand and other particles in the sponge body makes it into a new species.

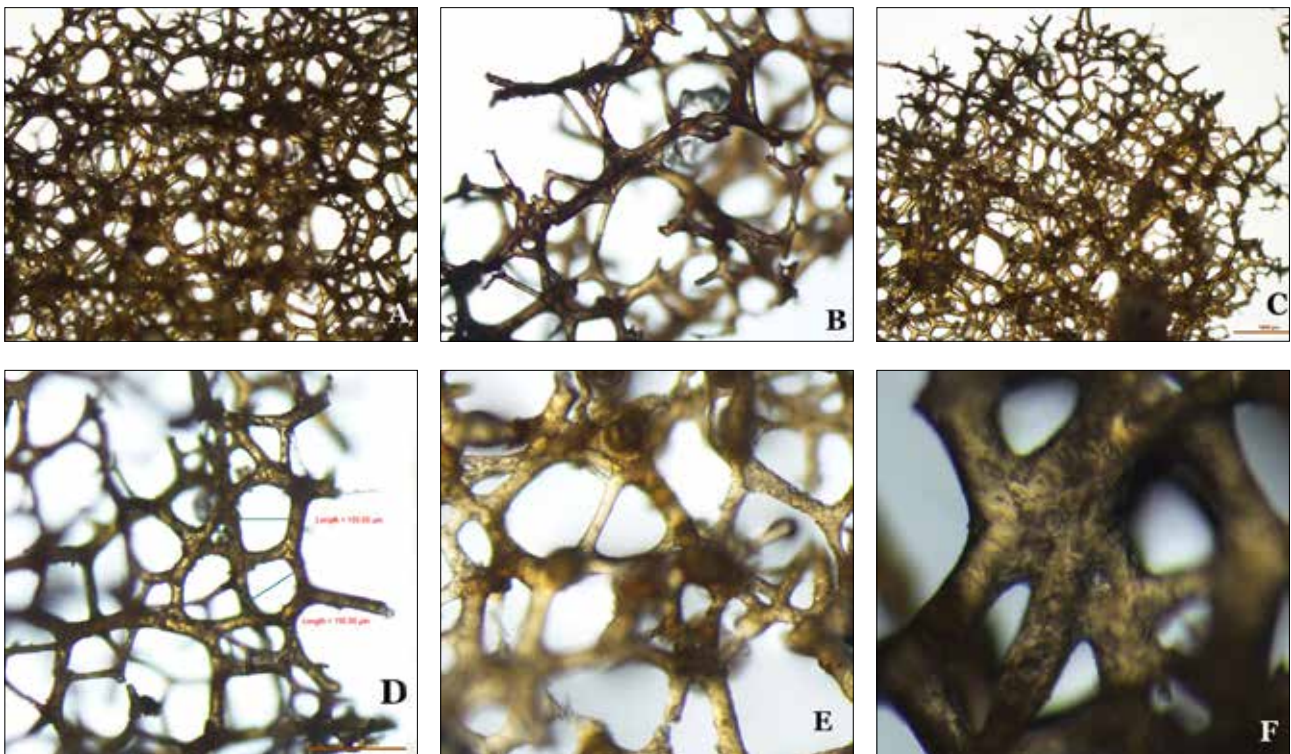


Fig. 15. A. Fibre skeleton (cross section) of *Hyattella vedalainensis* sp. nov, B. Primary fibres, C-D. Fibre skeleton (longitudinal section), E. Cross section in high power, F. Longitudinal section in high power.



Fig. 16. A. *Hyattella diffusa* sp. nov. Holotype, CMFRI DNR No. BA.1.1.2.13, B-C. Enlarged view of specimen

Hyattella vedalainensis n.sp. differ from the other species of *Hyattella* specifically, *H. intestinalis* (Lamarck, 1814), *H. foliata* n.sp., *H. repandus* n.sp. and *H. macrophylla* n.sp. The oscules in *H. vedalainensis* n.sp. are small as well as the cavities of the external and internal body as compared to the other four species. *H. vedalainensis* n.sp. has an oval shaped mesh network while the other four species are nearly polygonal. *H. vedalainensis* n.sp. have thicker fiber diameters as compared to *H. intestinalis* (Lamarck, 1814) and *H. macrophylla* n.sp. *H. vedalainensis* n.sp. has densely cored primary fibers whereas coring is less in the case of *H. macrophylla* n.sp. and *H. foliata* n.sp.

Hyattella diffusa sp. nov.

(Fig. 16 A-C, 17, Table 1)

Material examined

Holotype: CMFRI.DNR No. BA.1.1.2.13 (Fig.16 A-C), Mandapam, Tamilnadu (Lat: 9°16'17.26"N, Long: 79° 7'51.75"E), 21.07.2018, Hand picking (MD 2), deposited in the Museum of National Biodiversity Repository, CMFRI, Kochi, India. ZooBank registration number as per the new Nomenclature Act: <http://zoobank>.

org/urn:lsid:zoobank.org:act:76482035-F13B-4AA8-96AD-EEB7379A85BC

Paratype 1: CMFRI.DNR No.BA.1.1.2. 13.1, Mandapam, Tamilnadu (Lat: 9°16'17.26"N, Long: 79° 7'51.75"E), 21.07.2018, Hand picking, deposited in the Museum of National Biodiversity Repository, CMFRI, Kochi, India.

2. CMFRI.DNR No. BA.1.1.2.13.2, one fragment in Ethanol deposited in the Museum of National Biodiversity Repository, CMFRI, Kochi, India.

Description: Sponge with arborescent or bushy shape, with irregular branches in more than one plane (Fig. 16B). They are cavernous and hollow. Sponge body size decreases from the base to top and it is pointing towards the apex. The sponge height is 14.5 cm, the basal width 13 cm, and wall thickness 0.3 cm. They are directly attached to the substrate and associated with bivalves and gastropod shells. Colour is yellowish brown. The surface is uneven with irregular folding. The oscules are large and circular with a diameter of 1 cm. Minute ostia are present all over the body. They are compressible and easy to tear.

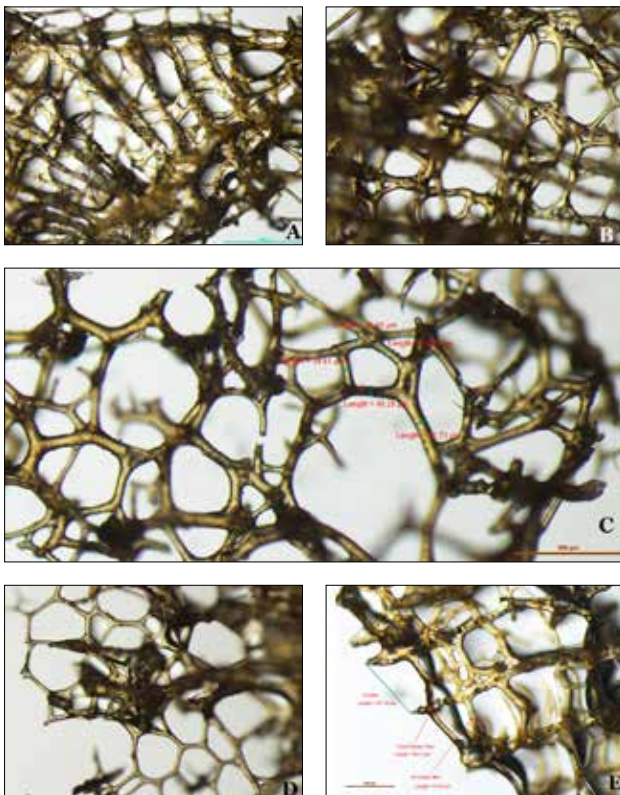


Fig. 17. A-B. Fibre skeleton (cross section) of *Hyattella diffusa* sp. nov., C. Cross section in high power, D & E. Fibre skeleton (longitudinal section)

Skeleton: They are having very rich fibre network which has primary and secondary fibres only (Fig. 17A-B). Primary fibres cored, 95.34-100.46 μm in diameter (Fig. 17C) filled with sand and molluscan shells. Secondary fibres, 34.81-63.6 μm in diameter (Fig. 17E). Tertiary fibres absent (Fig. 17D-E).

Distribution: Known from Mandapam in Gulf of Mannar of Tamilnadu, India.

Etymology: The species name *diffusa* in Latin refers to extending widely and it denotes the spread of small outgrowths throughout the body.

Remarks: Although *Hyattella diffusa* n.sp. shows few similarities with *Hyattella sinuosa* (Pallas, 1766), they are entirely different. The peculiar character of the present species such as arborescent, bushy, irregular branches in more than one plane makes it unique from *H. sinuosa*, which has an encrusting shape with digitate processes. The thicker width of the primary fibres (95-100 μm) also makes it different from *H. sinuosa* that has 28-70 μm (Lendenfeld, 1889). Considering these unique characters of the present species, we describe it as a new species.

Past literature review revealed that several type species i.e. *Spongia sinuosa* Pallas, 1766, BMNH 1882.10.17.35, (locality: Indian Ocean), *Hippospongia sinuosa* (Pallas, 1766), MNHN DT 655, *Hippospongia decudua* (Hyatt, 1877) MCZ, *Hyattella arborea* Lendenfeld, 1889, BMNH and *Hyattella lamarcki* Topsent, 1933 MNHN DT 655 were reported from different localities. Pallas (1766) described *Spongia sinuosa* and later changed through a series of revisions and finally transferred to the present accepted name of *Hyattella sinuosa* (Pallas, 1766). This include the reports of *Hippospongia decudua* (Hyatt, 1877) from Mascarene Islands, described two varieties of *Hippospongia sinuosa* (Pallas, 1766), *Hippospongia sinuosa* var *decudua* Hyatt, 1887 from Seychelles, *Hyattella arborea* Lendenfeld 1889 from Australia, *Hyattella lamarcki* Topsent, 1933 from Ambon, Indonesia and *Hyattella decudua* (Lendenfeld, 1889) from the North American coast and African coast.

H. diffusa n.sp. is an arborescent, small tubular branches compared with *H. intestinalis*, *H. vedalainensis* n.sp., *H. macrophylla* n.sp and *H. foliata* n.sp. The *H. diffusa* n.sp. is compressible and easy to tear as compared to the other five species. The diameter of the primary fibres is more in the *H. diffusa* n.sp. as compared to *H. foliata* n.sp. *H. macrophylla* n.sp. and *H. intestinalis*. Considering the presence of *Hyattella sinuosa* doubtful in the Indian Ocean, the present species we got from Gulf of Mannar may be different one.

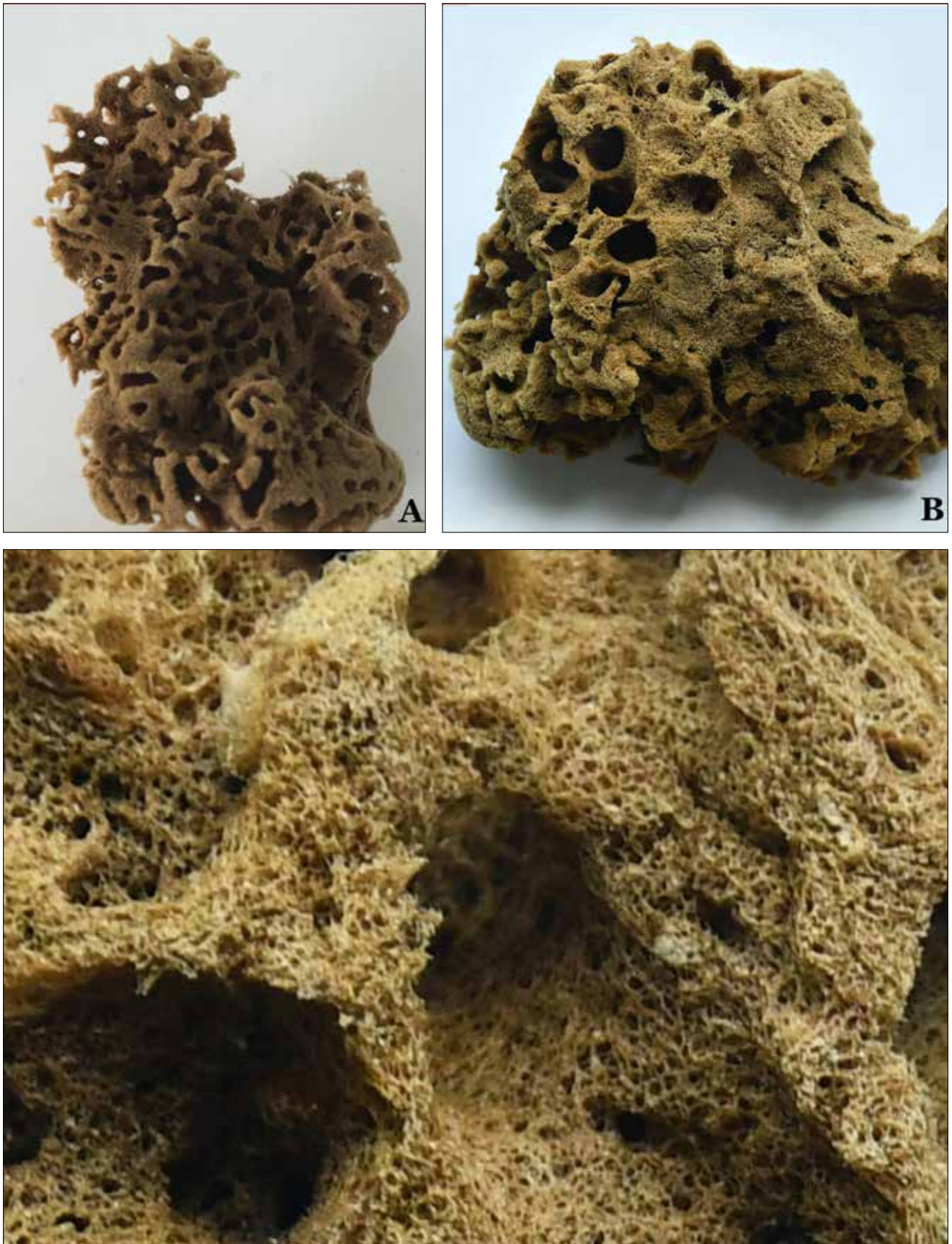


Fig. 18. A-B. *Hyattella oblongus* sp. nov. Holotype, CMFRI DNR No. BA.1.1.2.11, C. Enlarged view of specimen

Hyattella oblongus sp. nov.

(Fig. 18 A-C, 19, Table 1)

Material examined

Holotype: CMFRI.DNR No. BA.1.1.2.11(Fig.18A-C), Muttom, Kanyakumari, Tamilnadu (Lat: 8°72'0.07"N, Long: 77° 18'45.63"E), 17.10.2018, Gillnet sample (MT 32), deposited in the Museum of National Biodiversity Repository, CMFRI, Kochi, India. ZooBank registration number as per the new Nomenclature Act: <http://zoobank.org/urn:lsid:zoobank.org:act:AB32CE3B-A187-4FA6-8823-EC44F3967B51>

Paratype: 1. CMFRI.DNR No. BA.1.1.2.11.1, Muttom, Kanyakumari, Tamilnadu (Lat: 8°72'0.07"N, Long: 77° 18'45.63"E), 17.10.2018, Gillnet sampling, deposited in the Museum of National Biodiversity Repository, CMFRI, Kochi, India.

2. CMFRI.DNR No. BA.1.1.2.11.2, one fragment in ethanol in the Museum of National Biodiversity Repository, CMFRI, Kochi, India.

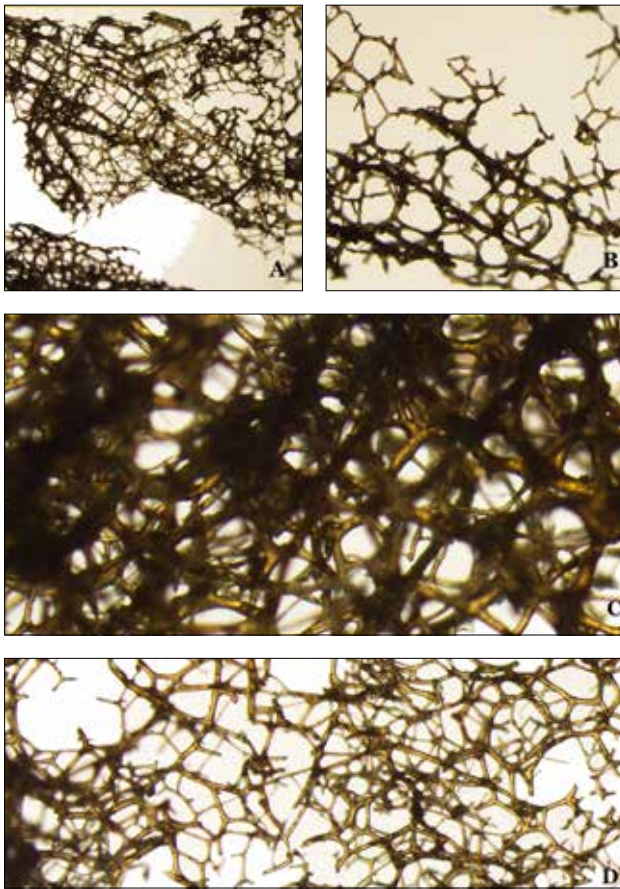


Fig. 19. A-B. Fibre skeleton (cross section) of *Hyattella oblongus* sp. nov, C-D. Fibre skeleton (longitudinal section)

Description: Species with globate and massive body, highly cavernous, whose cavities form irregular folds and small elongated projections. Surface is conulose, colour brownish. Oscules are small, evenly scattered with opening width of 1 cm. Minute ostia scattered evenly on the surface. Consistency firm and barely compressible. Surface aerolated, uneven and opaque.

Skeleton: The main skeleton consists of reticulation of sponge fibres often organised into primary, secondary and tertiary networks. Primary fibres cored, 9.17-10.79 μm in diameter filled with small particles and sand (Fig.19A-B). Secondary fibres are 2.27-3.27 μm in diameter and tertiary fibres absent. Distance between two conules is 41.50 μm (Fig.18A-B). Width of the polygon meshes in the primary fibres 35-45 μm .

Distribution: Known from Muttom in Kanyakumari district of Tamilnadu, India.

Etymology: The species name *oblongus* in Latin refers to shape of the cavities seen externally as well as internally and its elongated in shape.

Remarks: *Hyattella oblongus* n.sp. is very unique and different species from all other congeners already described from the genus *Hyattella*. At the same time several authors allocated it either to *H. cribriformis*, *H. intestinalis* and *H. sinouosa*. However, we examined scrutiny of all these species and finally concluded that it is different from other congeners.

H. oblongus n.sp. is globate and massive in shape as compared to *H. intestinalis*, *H. vedalainensis* n. sp., *H. macrophylla* n. sp., *H. diffusa* n.sp. and *H. foliata* n.sp. The diameter of the primary fibres and secondary fibres are the smallest in *H. oblongus* n.sp. as compared to other six species. They are also the smallest compared to other *Hyattella* species worldwide. The presence of globate massive body makes it different from other members of the group. Small oscules are scattered all over the body with opening of 1 cm, primary fibres with a width of 9-10 μm and secondary fibres (2-3 μm) isolates this from other species. Hence, we describe it as a new species.

Discussion

The present description of six new species of the Genus *Hyattella* from Gulf of Mannar and the South West coast of India contributes to the unexplored species diversity of Indian Ocean. With this six new additions the total number of species from Indian Ocean becomes 12 including the already known *Hyattella intestinalis* (Lamarck, 1814); *Hyattella meander* Lendenfeld, 1889, *Hyattella pertusa* (Esper, 1794); *Hyattella sinouosa* (Pallas, 1766), *Hyattella tubaria* Lendenfeld, 1889 and *Hyattella globosa* Lendenfeld, 1889. The exact species composition of genus *Hyattella* has been

Table 1. Comparisons of different *Hyattella* species obtained in the South west coast of India (present study)

Sl.no	Characters/ Spp.	<i>H.intestinalis</i>	<i>H.repandus</i> n.sp.	<i>H.macrophylla</i> n.sp.	<i>H.foliata</i> n.sp.	<i>H.vedalainensis</i> n.sp.	<i>H.diffusa</i> n.sp.	<i>H.oblongus</i> n.sp.
1	Shape	Simple branch, cylindrical digitate branches	Hollow, tubular with branching ends	Hollow tubular branches	Flattened base with narrowing at the top	Encrusting, Arborescent, tubes	Arborescent, bushy, irregular branches	Globate, massive
2	Attachment	Directly to substrate	Directly to substrate	Directly to substratum	Attached directly to substratum of shells	Directly to substrate	Directly to substrate, association with shells	To substrate insinuating in to cavities
3	Oscule	Small evenly scattered over the surface	Distributed all over the body, diameter 0.5 cm	Distributed all over the body	Small oscules on apex	Diameter- 0.2cm	Terminal oscule, Diameter 1 cm	Small, evenly scattered oscule
4	Consistency	Tough, compressible, difficult to tear	Firm, compressible, difficult to tear	Tough, slightly compressible, tough to tear	Tough, incompressible, difficult to tear	Soft, compressible, easy to tear	Compressible, easy to tear	Firm and barely compressible
5	PF cored width (μ m)	83.94 43.16 39.33 52.00 73.03 83.57 91.72	109.66 110.10 79.81	54.31 57.08 (uncored), 36.23 (cored)	75.61 74.08 46.10	118.07 103.74	98.41 95.34 100.46	9.17
6	SF width (μ m)	45.77 14.05 14.71 21.90 52.64 32.56 38.08	47.99 44.36 47.50 38.80	19.85 14.07 (uncored), 23.16 14.86)	68.74 39.47 32.43	56.84	63.60 55.73 45.00 40.28 34.81	2.27 3.27
7	Remarks	Dense coring Wall thickness- 0.2cm, wall diameter- 0.8cm	Total height-19.5cm	Dry specimen, highly dense secondary network	Total height-9 cm, basal width- 7cm, wall diameter-0.6cm	Densely cored primary fibres	Total height- 14.5cm, basal width- 13cm	Small size of fibre diameters. Width of polygon- 35.45 μ m

confusing and complex due to the misidentification of some of the species (Thomas, 1973; Van Soest *et al.*, 2020). The best characters for the species delineation of the Genus *Hyattella* include the well-developed cored primary and uncored secondary fibers, cavernous body, unarmoured conulose surface which are useful in the taxonomic studies and easy identification of the species (Bergquist, 1980; Cook and Bergquist 2002; Cook, 2007).

In the present study the new species described are *Hyattella repandus* n. sp., *Hyattella macrophylla* n. sp., *Hyattella foliata* n. sp., *Hyattella vedalainensis* n. sp., *Hyattella diffusa* n. sp. and *Hyattella oblongus* n. sp. which enhances the species diversity of the genus in the Indian Ocean. Of these six species, half of them are described from the Gulf of Mannar ecosystem and one species from south west coast and one from Lakshadweep Island. It is interesting to note that *Hyattella repandus* n. sp., *Hyattella foliata* n. sp., *Hyattella diffusa* n. sp. and *Hyattella vedalainensis* n. sp. have been reported from coral associated ecosystem of Gulf of Mannar whereas the *Hyattella macrophylla* n. sp. from the coral reef area of Lakshadweep and *Hyattella oblongus* n. sp. from a rocky habitat of southwest coast of India.

Hence the present investigation is very much significant in the context of the biodiversity conservation and management of Sponge fauna of the Marine Protected Area of the Gulf of Mannar Biosphere Reserve and Lakshadweep area. It assumes significance as Phylum Porifera has been a protected group as per the schedule III of Indian Wildlife (Protection) Act, 1972 and the Aichi biodiversity targets and SDG 14 of the Convention on Biological Diversity.

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