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New distributional records of Indo-Pacific Bryozoans from East and West coast of India

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This study gives a systematic description of six bryozoans species such as *Hippopodina iririkiensis* (Tilbrook, 1999), *Smittipora harmeriana* (Canu & Bassler, 1929), *Drepanophora indica* (Hayward, 1988), *Calyptotheca hastingsae* (Harmer 1957), *Tarsocryptus laboriosa* (Tilbrook, 2006) and *Poricella robusta* (Hinck 1884) supported by Scanning Electron Micrographs, collected from the shallow waters (up to five meters) in Maharashtra coast and Islands of Gulf of Mannar Marine Biosphere Reserve (GoMMBR). These species have not been reported from the Indian waters previously, though they were identified as Indo-Pacific encrusting bryozoans with bio fouling capacities.

[**Keywords**: Gulf of Mannar (GoMMBR), Indo-Pacific bryozoans, Maharashtra coast, Marine Biosphere Reserve]

Introduction

Bryozoans are lophotrochozoan protostomes that commonly form encrusting colonies on rocks, shells and seaweeds. There are also free-living forms having bushy appearance[1]. These organisms are also known as moss animals or sea mats due to their encrusting nature forming thin patches. Similarly due to their association with corals, they are also called 'lace corals'. Bryozoan colonies are observed in fresh water, estuarine and largely in marine habitats. Reports of these marine species have come from the coastline to the ocean depths, including the hydrothermal vents in the deep-sea[2].

The world's most taxonomically diverse Bryozoans seen in the Indo-Pacific region[3] due to the El-Niño–Southern Oscillation that creates sea surface temperature anomalies over the Indian Ocean[4]. These peculiar phenomena which exist only in the Indo-Pacific region, makes it a highest species rich area, next to the Western Atlantic with reference to reef building corals[5]. According to the world list of Bryozoa, there are 5,434 species of living bryozoans reported globally[6], out of which 293 species have been so far reported from India.

First report of bryozoans from Indo-Pacific region was made by Thornely[7] followed by Harmer[8-12] which was the most inclusive accounts of the Indo-West Pacific Bryozoans. Canu & Bassler[13], worked on bryozoans of the Philippines but their work was mostly restricted to the benthic bryozoans and hardly referred to any reef-associated species. Only 284 coral reef-associated bryozoans were included in the global checklist from tropical Australia and its adjoining areas[14]. Major work on bryozoans of Indo-Pacific region has been from Hondt[15], Annandale[16,17], Robertson[18], Liu[19] and Liu *et al.*[20], though it resulted in a massive increase in the bryozoan's records; however these were mostly on deep benthic communities. The first all-inclusive account of the bryozoans of coral reefs was from Tilbrook *et al.*[21]. Recently Gordon *et al.*[22] reported several bryozoan species from the coast of Bangladesh for the first time and a study of fouling bryozoans in Singapore waters was done by Goh[23].

Menon & Nair did a notable work on bryozoans of India[24-26] while Ravindran *et al.*[27] reported fouling bryozoan species of Cochin harbour area and offshore waters of Mumbai, respectively. Badve & Sonar[28] have surveyed bryozoan species, from west coast of Maharashtra. Soja[29] recorded as many as 102 species of bryozoa along the coasts of India and Cochin estuary, of which three were new to science. Swami &

Udhayakumar[30], Nair[31], Goankar *et al.*[32] and Mankeshwar *et al.*[33] have given a paleontological taxonomic report on bryozoan species of South West coast of India. However, bryozoans of the Indian region are still not adequately studied in most of the areas, like shallow-waters, coral reefs and in the intertidal zone. The only studies concerned with the reef-associated bryozoans and intertidal bryozoans are the work by Venkatraman *et al.*[35,36] and Sanjay *et al.*[36] on bryozoans of Gulf of Mannar, Marine Biosphere Reserve (GoMMBR) in the Southeast coast of India, and those from Gujarat and Maharashtra coast, which included 20 new species. Therefore the present work focuses on the least studied areas in India, such as Gulf of Mannar in the coast of Tamil Nadu, Pirotan Island of Gujarat and some areas in Maharashtra, by concentrating on the reef-associated bryozoans and intertidal bryozoans of shallow-waters up to 5 m depth.

Materials and Methods

Bryozoan colonies were collected by resorting to SCUBA diving and snorkelling methods in the intertidal region up to the depth of 5 m. Specimens were collected from reef areas, exposed rocks, floating objects and boat hulls by means of hand picking. Selected portions of colonies of marine bryozoans, or fragments of shells with small colonies, were soaked in 0.5 % commercial sodium hypochlorite solution (liquid domestic bleach) for several hours till organic tissues were dissolved from the zooid surfaces. Distilled water used to wash colony fragments thoroughly and dried prior to carbon and gold-palladium coating for the scanning electron microscopy. The voucher specimens are deposited in the National Zoological Collection (NZC), Zoological Survey of India, Headquarters Kolkata.

Study area (Fig. 1)

Pirotan Island: The Island is known for its biodiversity and scenic beauty and is 12 km away from the coast. Live corals are found in the eastern and northern sides. The major mangrove species are *Avicennia*, *Rhizophora*, *Ceripes* and *Agiocerus*. The island surrounded by sandy beach from all the sides and on the west and central part high tidal mudflat is present. Intertidal mud flats are present in the eastern and western parts.

Kunkeshwar: A small coastal village which is 40 km away from Malvan, is very famous because of the Lord Kunkeshwar temple situated high on the hill near the coast. Collections were made from the rocky areas near the shore.

Vijaydurg: A small coastal village of one kilometre stretch has a good view of the fort at the right and a small plateau with a hut to the left and is 80 km away from Malvan beach. Collections were made near the fort and the beach area.

Pullivasal Island: This Island is a thickly vegetated area with 29.95 ha land having a circumference of 5520 m. It is 5 km away from the Mandapam camp which can be approached from Poomarichan Island by crossing the channel separating the two islands. Fringing reefs seen on the southern side at a distance

Fig. 1 — Study area

of 200 m and a similar patchy reef, in the muddy area on the northern side.

Manoli Putti Island: It is a tiny island of just 2.34 ha and circumference of 940 m, and is 6 km away from the Mandapam camp separated from the nearby Manuali Island by an extensive mud flat fully exposed during low tide. A patchy distribution of massive coral is present at 500 m distance from the shore throughout this island.

Shingle Island: This Island is resplendent with shingles and coral rubbles, along the shore to a height of 0.75 m fully covered by thick vegetation with an area of 12.69 ha and a circumference of 1736 m. It is 4 km away from Pamban. Presence of fringing reefs seen around the island except at the southern side. The most commonly seen corals are of *Acropora* sp. are at a distance of 300 m from the island shore. Boulder corals are also seen scattered around.

Results

The systematic description of six marine bryozoans collected from the inter-tidal regions of Maharashtra coast (west coast) and Gulf of Mannar, Marine Biosphere Reserve (GoMMBR) in the East coast of India, which are new to the Indian waters, given below:

Systematic account of marine Bryozoans

Phylum: Bryozoa (Ehrenberg, 1831)
Class: Gymnolaemata (Allman, 1856)
Order: Cheilostomata (Busk, 1852)

1. *Hippopodina iririkiensis* (Tilbrook, 1999)

Suborder: Flustrina (Smitt, 1868)
Family: Hippopodinidae (Levinsen, 1909)
Genus: *Hippopodina* (Levinsen, 1909)
Hippopodina iririkiensis (Plate 1a – d)

Locality: Paliyar Munai Island, Gulf of Mannar & Vijayadurg, Maharashtra

Substratum: Dead coral rubble.

Description: The encrusting colony is often very extensive, unilamellar/multilamellar. Autozooids generally slightly inflated and rectangular, when superposed, they are arranged in regular longitudinal rows, and separated by grooves that are well-defined.

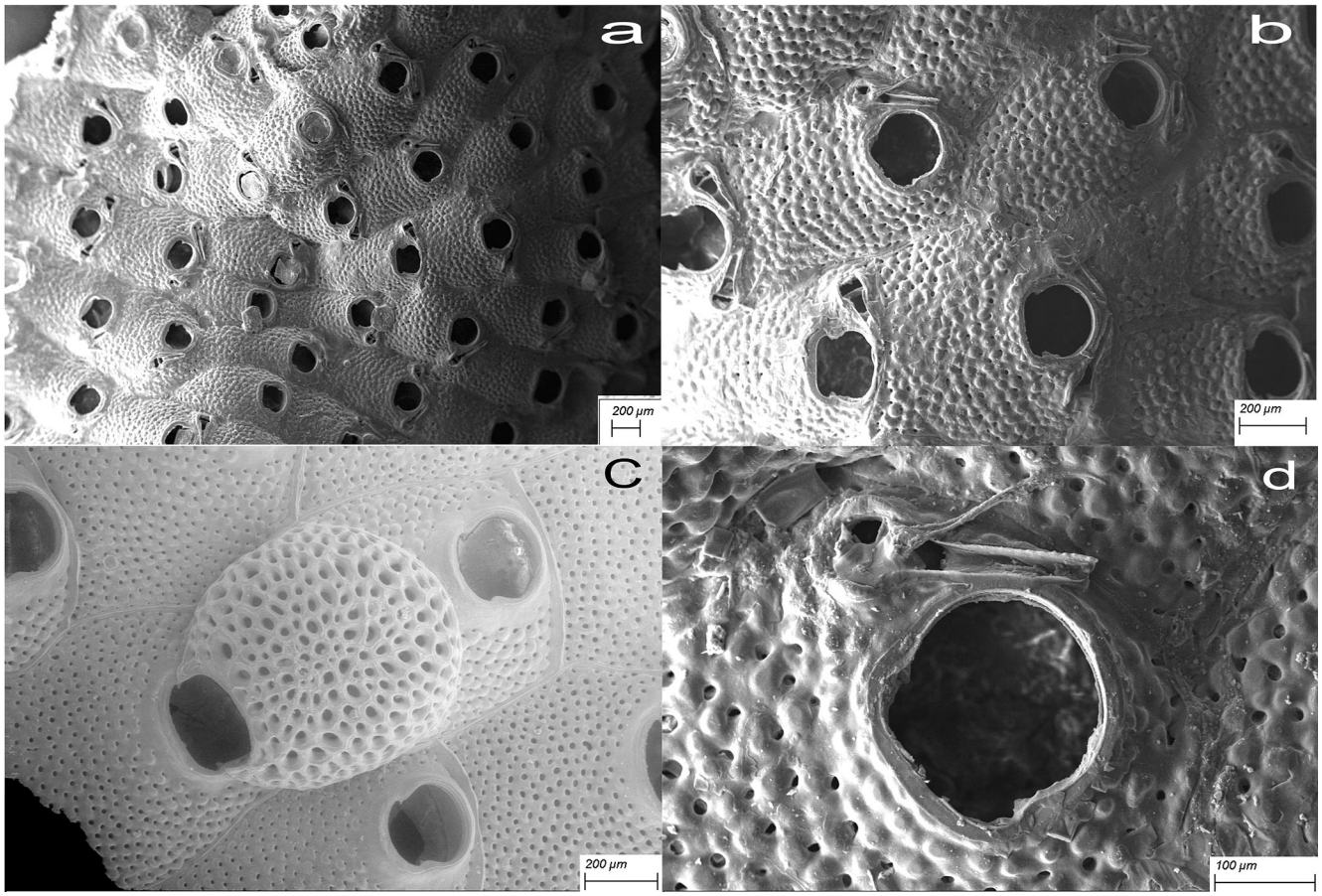

Plate 1 — *Hippopodina iririkiensis* (Tilbrook, 1999): a) Colony, b) Zooids, c) Ovicells, and d) Orifice and adventitious avicularia

Evenly perforated frontal wall is tuberculate and convex. The hoof-shaped primary orifice which is indented with condyles is rounded distally, concave proximally and oriented medially. Adventitious avicularia often paired, single or absent, occupying disto-lateral position towards the orifices. Rostra raised, with complete cross bar. Mandibles acutely triangular, slender with curved tip which is hinged to swing through one plane, it is evidently seen in one of the Zooid. Ovicells when present are very large, rounded, slightly calcified and perforated evenly.

Remarks: *Hippopodina iririkiensis* gets its name from the type location the Iririki Island, Port Vila Harbour, Vanuatu by Tilbrook[37]. *Hippopodina iririkiensis* differs from H. *feegeensis* in its slightly proximally concave primary orifice and adventitious avicularia which is generally short and more lateral towards the orifices.

Distribution: Widely distributed in the Indo- West Pacific tropical region at a depth of 4 m. Range of distribution is from the Vanuatu Islands and north Queensland to Fiji and in west towards Philippines, Singapore, China and recently from Sri Lanka. It was also reported from Mauritius, Red Sea and Mediterranean. It has not been previously reported from the Indian coastal waters until now.

2. *Smittipora harmeriana* (Canu & Bassler, 1929)

Superfamily: Microporoidea (Gray, 1848)

Family: Onychocellidae (Jullien, 1882)

Genus: *Smittipora* (Jullien, 1882)

Smittipora harmeriana (Plate 2a, b)

Locality: Shingle Island, Gulf of Mannar & Piroton Island, Gujarat.

Substratum: Gastropod shell.

Description: Colony flat, encrusting, mostly hexagonal to irregularly polygonal, zooids separated by thin grooves along the thick and greatly raised marginal rim. Front, concave in the centre with translucent membranous frontal membrane covering the coarsely granular depressed cryptocyst. Orifice-opesia large, sub-triangular or bell-shaped, longer than wide. The frontal cryptocyst surrounds the distal half, distal border rounded, with wide edge pointing proximally. The proximal edge is smooth, slightly convex with faintly arching lip dipping slightly at each lateral corner. Operculum smaller than opesia, marginal sclerite lacking. The avicularia smaller than autozooids with slightly narrow, coarsely granular cryptocyst. Its Opesia centrally located, oval, denticulate proximally and smooth distally, a pair of condyles is also present. Mandible if present, short with rachis that are hooked at the tip but it is lost in this specimen. Ovicelen to zooecial, very inconspicuous but the opesia of the fertile zooids are rounded distally and a small cap of granular cryptocyst calcified found distally.

Remarks: Smittipora harmeriana is distinguished by the shape of the opesia and avicularia. It defers from *S. cordiformis* in having a large opesia and a non curved avicularia. *Smittipora harmeriana* defers from *S. philippinensis* in having a large sub-triangular or bell-shaped opesia other than a large D-shaped opesia which is found in *S. philippinensis* and the opesia of

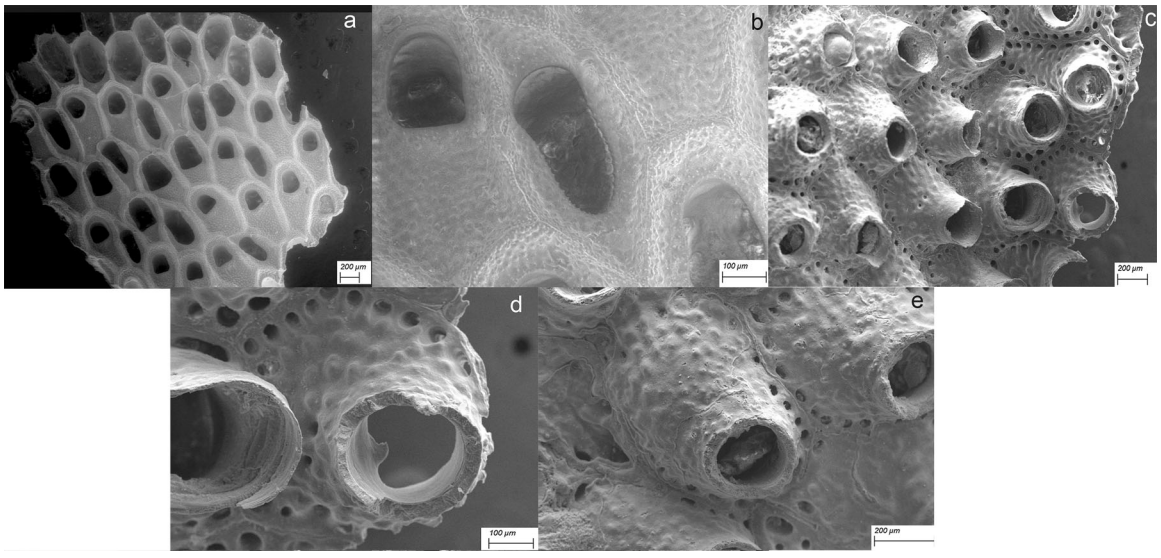

Plate 2 — a, b) *Smittipora harmeriana* (Canu & Bassler, 1929) [a) Colony, and b) Zooid and avicularia]; c, d, e) *Drepanophora indica* (Hayward, 1988) [c) Colony, d) Orifice and adventitious avicularia, and e) Zooid]

the avicularia is centrally located in *Smittipora harmeriana* where as in *S. philippinensis*, it is distally located.

Distribution: Smittipora harmeriana has an Indo-Pacific distribution which is recorded from Indonesia, Torres Strait, Mascerene Island, Solomon Island, Yandina, Mbanika, and Russell Island; and in Indian Ocean from Western Australia to Mauritius. It has not been previously reported from the Indian coastal waters until now.

3. *Drepanophora indica* (Hayward, 1988)

Superfamily: Lepralielloidea (Vigneaux, 1949)

Family: Lepraliellidae (Vigneaux, 1949)

Genus: *Drepanophora* (Harmer, 1957)

Drepanophora indica (Plate 2c – e)

Locality: Pullivasal Island, Gulf of Mannar.

Substratum: Coral debris

Description: The unilamellar colony is encrusting with distinct autozooids which are separated from each other by deep grooves which are oval and convex. Slightly pear-shaped primary orifice is longer than wider, wide distally and broader proximally. On one side, single transversely oriented avicularia with sharply hooked rostrum and a slight constriction on the opposite side. Proximally incomplete peristome; low and thin. The nodular frontal shield has large marginal pores. Ovicell when present is prominent, globular, and recumbent; a large elliptical foramen is angulated towards the frontal plane, on either sides of the midline.

Remarks: The distinguishing character noted in the *Drepano phoraindica* is its ovicell and orificial avicularium.

Distribution: It is found to have tropical distribution. It was first reported from Mauritius and has been recorded from Poanangisu and Gulf of Emirate also. It has not been previously reported from the Indian coastal waters until now.

4. *Calyptotheca hastingsae* (Harmer, 1957)

Superfamily: Smittinoidea (Levinsen, 1909)

Family: Labioporella (Harmer, 1926)

Genus: *Calyptotheca* (Harmer, 1957)

Calyptotheca hastingsae (Plate 3a, b)

Locality: Mandapam group of islands, Gulf of Mannar.

Substratum: Gastropod shell.

Description: Zooecia of primary layer regularly arranged in longitudinal rows, while superposed irregularly oriented, hexagonal and usually very

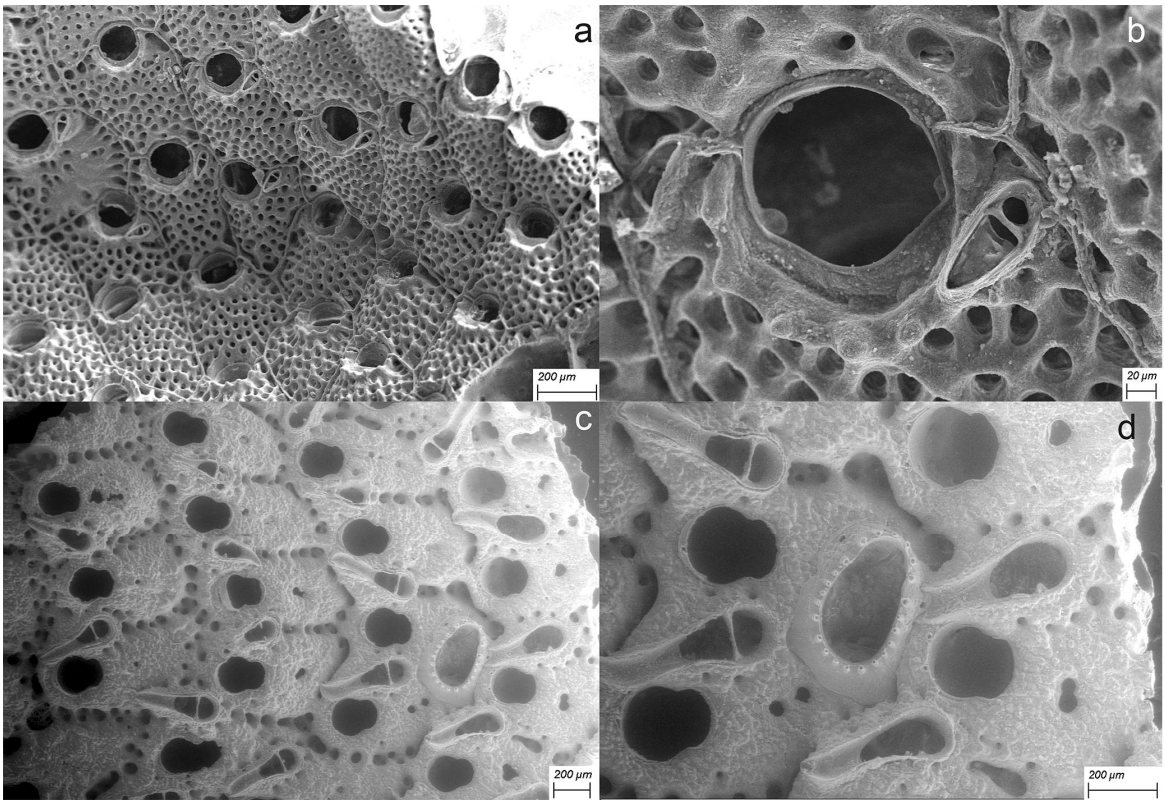

Plate 3 — a, b) *Calyptotheca hastingsae* (Harmer, 1957) [a) Colony, b) Orifice and adventitious avicularia]; c, d) *Poricella robusta* (Hinck 1884) [a) Colony, and b) Zooids and Interzooidal avicularia with Ancistrula in the centre]

regularly disposed, slightly inflated front with advanced calcification and highly convex in the multilamellate zooids. The frontal surface covered with tremocyst which has numerous large pores in between them separated by wide intervals. The frontal surface also contains minute rounded prominent calcification which gives a gritty appearance to the surface. Several umbonate processes found proximal to the orifices. The orifices variable in form, mostly distally semicircular and with wide sinus limited by two small and strong cardelles. Thin operculum with two thin transparent regions at the proximal part present. Peristome absent. Paired or single tear drop shaped avicularia obliquely placed on either side or one side of the orifices either proximo-distally or laterally directed with complete cross-bar. Porous ovicell, hyperstomial and slightly set in the succeeding zooecium but absent in this sample. Spines wanting.

Remarks: Calyptotheca hastingsae can be distinguished by the frontal surface covered with tremocyst which has numerous large pores in between them separated by wide intervals. The tear drop shaped avicularia also serve as a distinguishing feature. In this specimen most of the avicularia are on one side of the orifice, proximo-distally oriented.

Distribution: Indonesia, Philippines, Queensland and Great Barrier Reef Australia. It has not been previously reported from the Indian coastal waters until now.

5. *Poricella robusta* (Hinck 1884)

Superfamily: Arachnopusioidea (Jullien, 1888)
Family: Arachnopusiidae (Jullien, 1888)
Genus: *Poricella* (Canu, 1904)
Poricella robusta (Plate 3c, d)

Locality: Kunkeshwar Beach, Maharashtra.
Substratum: Rocky.

Description: The encrusting colony, multilamellar. Oval autozooids are convex. Orifice longer than wide, slightly tapering proximally, anterior region marked by the presence of two very inconspicuous condyles; two or three distal oral spines present. Marginal pores limit the granular frontal wall, by one to three central foramina which could be large and occluded. Large and mostly spatulate interzooidal avicularia, equally proportionate to autozooids, occasionally asymmetrical, mostly distally directed rearly proximaly. Complete crossbar present with rostrum lightly serrated distal edges; directed distally or disto-laterally. Ovicell when present, finely tuberculate, imperforate, initially prominent but becoming immersed. 2-3 distal pore-chambers present, but this sample was devoid of ovicells.

Remarks: This species is charecterised by large interzooidal avicularia which has an equal number of autozooids which are mostly spatulate. The ansestrula is noted in (Plate 3d).

Distribution: Initially reported from the coast of Myanmar, and has been consequently reported from Sri Lanka, Red Sea, Persian Gulf, and Seychelles.

6. *Tarsocryptus laboriosa* (Tilbrook, 2006)

Suborder: Malacostegina (Levinsen, 1902)
Superfamily: Membraniporoidea (Busk, 1852)
Family: Electridae (Stach, 1937)
Genus: *Tarsocryptus* (Tilbrook, 2011)
Species: *Tarsocryptus laboriosa* (Plate 4a, b)
Locality: Paliyar Munai Island, Gulf of Mannar.
Substratum: Sea grass.

Description: Colony encrusting, with irregular autozooids oval in shape, partitioned by shallow

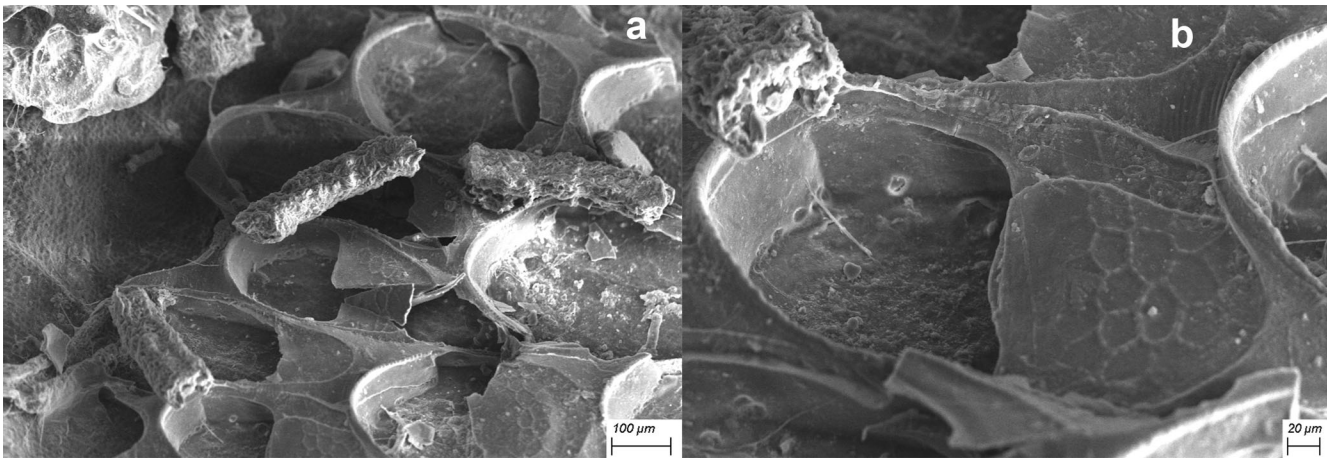

Plate 4 — *Tarsocryptus laboriosa* (Tilbrook, 2006): a) Colony, and b) Zooid

grooves. Gymnocyst reduced, prominent proximally, changing in width, a delicate wall of gymnocyst completely surrounds the cryptocyst, with a slightly raised tubercles on the rim. Cryptocyst extending up to one third to one half of frontal area, extending to a greater or lesser extent on either sides of opesia. Cryptocyst inconspicuous distally, wide proximally, flattened, smooth apart from a raised reticulate pattern of tubercles. Opesia oval or triangular, mostly narrow distally, more wider proximally. In general basal wall is complete, but partly lacking in some autozooids.

Remarks: It was encrusting on a leaf blade of a sea grass, extremely delicate forming a very thin extensive coat over the leaf blade. These have a distinctive relatively large cryptocyst bearing a reticulate. It belongs to a very recently described genus which has never been reported in India so far.

Distribution: Originally described from Vanuatu, also found as a biofouling species in the South China Sea, as well as a species associated with the reefs at Lizard Island on the northern Great Barrier Reef and Indo-Philippine region[38]. It has not been previously reported from the Indian coastal waters until now.

Discussion

The Indo-Pacific area is a geopolitical region that spans across the two Oceans, the Indian Ocean and the Pacific Ocean extending from the western coast of the India to the western coast of United States. Countries that are defined as the "Indo-Pacific" are India, Sri Lanka, Philippines, Singapore, Myanmar, Nepal, Bangladesh, Indonesia, Japan, Fiji, Laos, Malaysia, Maldives, Taiwan, Thailand, Timor, Leste, Vietnam, Australia, Brunei, Cambodia, New Zealand, Papua New Guinea and United States[39]. The bryozoans, which are discussed in this paper, are known as Indo-Pacific species but not yet been recorded from the Indian waters so far. This could be due to lack of study from these regions or they might have been introduced through accidental transport as fouling organisms on commercial ships, recreational boats or aquaculture shipments. Since biofouling species are very resilient towards a variety of environmental conditions, they can establish and become a part of the fauna in that area. In Indo-Pacific, the rising seaborne trade is an indication of growing diversity of fouling organisms especially when intra-regional merchandise trade has been increasing fast, as stated by Anil[40]. The impacts of exotic bryozoans are wide-ranging, with many having no reported impacts, but some species are fouling pests growing on ship hulls, docks and other hard surfaces[41].

H. iririkiensis has recently reported from Colombo port, Sri Lanka, which was found on the artificial settlement by Marasinghe *et al.*[42]. However, in this study, *H. iririkiensis* was found encrusting on dead coral rubble at a depth of 4 m in Pullivasal Island, Gulf of Mannar. The suspected means of introduction is by maritime trade. The port of Tuticorin, India and nearby port of Colombo, Sri Lanka is a busy maritime route separated by only 197 nautical miles[43]. In between the two ports, the Pullivasal Island is located. The discharged water from ships ballast tanks travelling in this route could contain the planktonic forms of *H. iririkiensis*; hence the range of distribution might have extended to India.

Poricella robusta is a known fouling species which has been originally reported from Mergui Archipelago coast of Myanmar and subsequently from Sri Lanka, Persian Gulf and Red Sea[44]. *Poricella robusta* could also be introduced to Kunkeshwar beach in Maharashtra through maritime trade since Mergui is a busy port involved in the coastal trade. The various *Drepanophora* and *Calyptotheca* species also have been recorded as fouling organisms by Cumming & Tilbrook[46]. In this survey, the *Drepanophora indica* was found encrusting on dead coral rubble and *Calyptotheca* was found encrusting on gastropod shell. However, *Smittipora harmeriana* has not yet been reported as a major biofouling agent, but its encrusting nature and diverse distribution around the Indian coast proves its presence in India too, as this (*Smittipora*) species was found on a gastropod shell. *Tarsocryptus laboriosa* is a unique species, which is one and only member belonging to this genus. It was earlier placed under genus *Biflustra*, when it was originally described from Vanuatu as *Biflustra reticulate* by Tilbrook *et al.*[44] and later it was renamed as *Biflustra laboriosa* by Tilbrook[47]. Most recently, it has been assigned to a new genus *Tarsocryptus* due to its extremely distinctive well-developed zooidal cryptocyst covered in a raised reticulate ornamentation and Cyphonautes larvae producing a single ancestrula[47]. Of late, *Tarsocryptus laboriosa* was reported by Gorden[48] as a biofouling species in the Lizard Island on the northern Great Barrier Reef and the South China Sea as a reef associate. In this study, *Tarsocryptus laboriosa* was found encrusting on a sea grass near reef area of Pullivasal Island, southeastern coast of India.

Conclusion

There are 5,434 species of living marine bryozoans reported from all over the world according to the world list of Bryozoa by Bock & Gordon[6], yet only 293 species have been reported from India so far, despite the fact that India is having considerably long coastline. This indicates that Indian bryozoans diversity is quite inadequately studied and there could be rich diversity of fouling bryozoans goes unnoticed, especially when intra-regional maritime trade has been increasing in a fast pace. The present study is just to bring to light a small portion of the Indian bryozoan diversity from unexplored regions of the Indian coastline. Thus, there is a great need for detailed taxonomic and ecological studies of the Indian bryozoans.

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Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Author Contributions

MSS: Conceptualization, methodology, data analysis, and writing - original draft. CV: Funding acquisition, writing - review & editing. SL & JSYK: Writing - review & editing and SS: Investigation.

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