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Research Article

The bryozoan *Amathia verticillata* (delle Chiaje, 1822) fouling harbours of the southeast coast of India: re-evaluating its status

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Abstract

The "spaghetti bryozoan" *Zoobotryon verticillatum* (delle Chiaje, 1822) recently synonymised as *Amathia verticillata* (delle Chiaje, 1822) was first described from Naples, Italy. This ctenostome also occurred in the Bay of Bengal, east coast of India, where it has been long treated as a native species, due to its long presence in the region. However, recent re-appraisal of its global distribution suggests the species was native to the Caribbean region. This study and a literature survey documented the occurrence of this bryozoan along the coast of Tamil Nadu, India, and summarized records of the species from other localities. *Amathia verticillata* has a scattered distribution in the central Indian Ocean and mostly occurs on man modified habitats. Indeed, it appeared to be absent from natural habitats along the coasts of India. Thus we concluded that *A. verticillata* is non-indigenous to the coast of India, where its presence can be attributed to human-mediated dispersal, mainly by shipping.

Key words: spaghetti bryozoan, non-indigenous species, artificial structures, Bay of Bengal

Introduction

Bryozoans are common fouling organisms in marine waters. They are ecologically important as sessile and colonial suspension feeders, as well as habitat providers for a number of associated taxa, such as polychaetes, molluscs, and crustaceans. According to Venkataraman and Wafar (2005), India hosts over 200 bryozoan species, although their real number is probably much higher due to lack of systematic surveys along several extensive coastal stretches.

The "spaghetti bryozoan" *Amathia verticillata* (delle Chiaje, 1822) was originally described from specimens collected in the Gulf of Naples, Italy, as *Hydra verticillata* delle Chiaje, 1822. Before this time, it was considered to be an alga due to epibiontic microalgae, that caused the colonies to appear green (Marchini et al. 2015). *Amathia verticillata* is widely distributed across the world's oceans; it is known from the eastern and western Atlantic, northeastern and southwestern Pacific, and the Indian Ocean (Waeschenbach et al. 2015), in Mediterranean sea (Marchini et al. 2015), and tropical atolls (Knapp et al. 2011).This bryzoan has been transported widely via hull fouling and continues to appear in new regions (Dailianis et al. 2016). Recent discoveries include the subtropical and tropical Macaronesian Islands (the Azores, Madeira, and Canary Islands) in the eastern North Atlantic Ocean, as well as the eastern Mediterranean Sea, Gulf of Oman, Taiwan, the Galapagos Islands, and Palmyra Atoll in the Pacific Ocean (Amat and Tempera 2009; Wirtzand Canning-Clode2009; Knapp et al. 2011; Minchin 2012; Tilbrook 2012; Galil and Gevili 2014; McCann et al. 2015; Dobretsov 2015; Minchin et al. 2016).

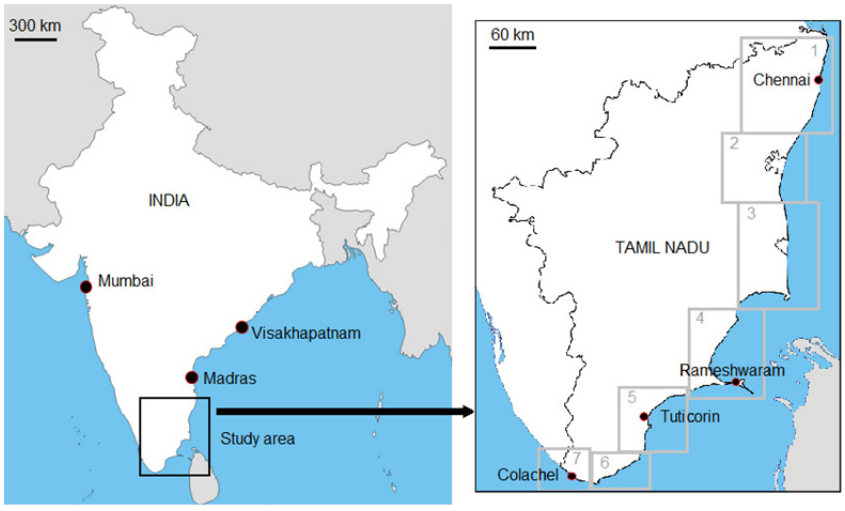

Figure 1. Study Area: The Tamil Nadu coast in southern India; grey squares indicate the 7 sampling zones where the 83 sampling stations were placed (see Supplementary material Table S1 for coordinates). Localities where *Amathia verticillata* was found are indicated in the right panel.

Amathia verticillata is often considered to be a pest in tropical to temperate waters due to its massive colony size and extensive fouling properties (Minchin 2012). *Amathia verticillata* is an erect, uncalcified bryozoan that can form colonies in excess of 2m long (Minchin 2012). A colony is composed of many hermaphroditic zooids, producing large yolky eggs that hatch into lecithotrophic larvae, which are planktonic for short periods (less than a day). The larvae settle on a firm substrate and metamorphose into the first zooid of a colony, the ancestrula. This bryozoan also reproduces asexually. Under favourable conditions, detached fragments may drift and attach elsewhere (Hopkins and Forrest 2008). The dispersal of *A. verticillata* to different locations is facilitated by its capacity as a hull fouling organism (Minchin 2012; Marchini et al. 2015).

Amathia verticillata was considered cryptogenic by Floerl et al. (2009), and its origins were debated by Minchin (2012). Recently, Galil and Gevili (2014) provided evidence that its most likely origin is the Caribbean region. This was based on its occurrence within natural habitats, mainly sea-grass beds, within the Caribbean Sea (Winston 1995), differently from the Mediterranean Sea and elsewhere where it is often restricted to man-modified environments such as harbours (Marchini et al. 2015). Further, its existence in the Caribbean with a co-evolved predator, the nudibranch *Okenia zoobotryon* (Smallwood, 1910), was assumed as an indicator of native status (Ortea et al. 2009; Galil and Gevili 2014). In India, *A. verticillata* was first recorded by Robertson (1921) from Madras Harbour. Subsequently, it was reported by several studies along the estuaries and harbours of the eastern coast of the country (Nair et al. 1992; Gaonkar et al. 2010; Swami and Udhayakumar 2010; Gopalakrishnan and Kelkar 2014; Pati et al. 2015). Previous studies have always perceived *A. verticillata* as endemic to India (Geetha 1994), without including it in the inventory of marine non-indigenous species (Subba Rao 2005). Furthermore the available literature denoted the mere occurrence of the species, while quantitative density assessments are scant (Geetha 1994; Swami and Udhayakumar 2010).

In this study, we carried out an extensive survey for *A. verticillata* along the Tamil Nadu coast (south-eastern India), to assess its current distribution and abundance pattern on natural and artificial habitats. In addition, a literature survey was conducted to assess the previous existence of this global invader in Indian waters and to update the distribution of *A. verticillata* in the central Indian Ocean.

Material and methods

The 1,076 km long coastline of Tamil Nadu lies along the southeastern part of the Indian Peninsula, and forms a part of the Coromandel Coast on the Bay of Bengal and the Indian Ocean. This coastal corridor has 15 marinas and harbours. The entire coastline is occupied by numerous, artificial, low-crested structures and protective groynes that provide habitat for a wide variety of marine organisms.

Biological samples were collected during January, May, and September 2015 along the coast of Tamil Nadu. The coast was divided into seven sampling zones, each including 8 to 18 sampling stations, for a total of 83 sampling stations (Figure 1). Of the 83 sampling stations, three sampling stations were located adjacent to natural rocky outcrops. Investigated habitats

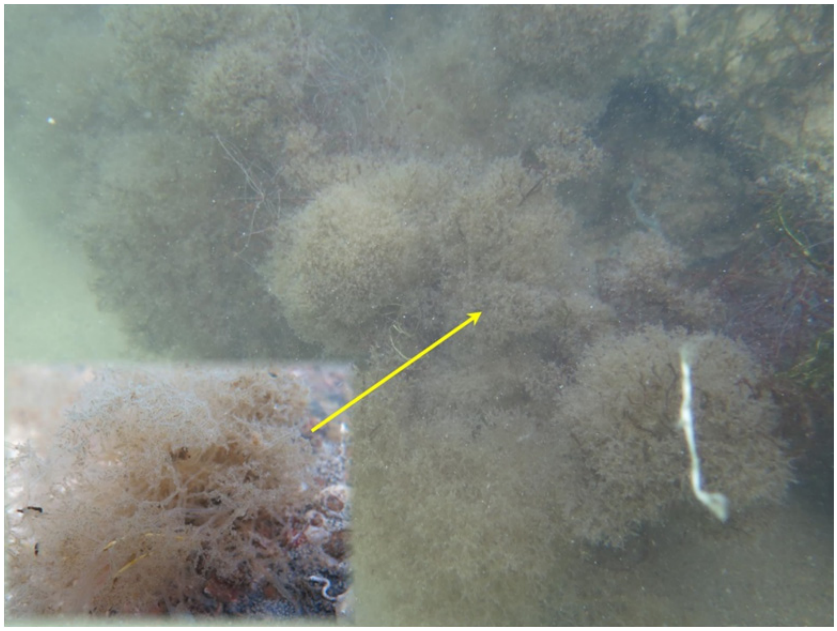

Figure 2. Colonies of *Amathia verticillata* on a breakwater at Colachel Fishing Harbour. Photograph by Ganesan Nandhagopal.

comprised artificial substrates such as boulder piles, groynes, caissons, tetrapods, fishery jetties, pipeline trestles, harbour breakwaters, and natural rocky outcrops along the shoreline.

Surveys were conducted at low tide, depths ranging from 1 to 5 m, by SCUBA diving and snorkelling following Prince Prakash Jebakumar et al. (2015). Density of *A. verticillata* was assessed by means of the semi-quantitative visual technique (counting the stem attached to substratum) using the 10 m belt transect method and a total of three transects (3 to 5 quadrats of 1×1 m per transect) were laid at each site along the submerged portion of the boulders (Megina et al. 2013). A few specimens were also collected and preserved for subsequent taxonomic analysis. Lastly, natural rocky outcrops along the pocket beaches were also searched for the species.

Results and discussion

Amathia verticillata was recorded at five artificial sites: Colachel fishing harbour (CFH), Chennai fishing harbour (CHE-FH), Tuticorin (TECB), Mandapam jetty north (Palk Bay) (MJN), and Mandapam jetty south (MJS) at Rameshwaram. The identity of *A. verticillata* was confirmed by the Zoological Survey of India and voucher material was deposited at the National Zoological Collection with access code ZSI/MBRC/BRY/B-43.

Searches for the bryozoan along the natural rocky shores of Tamil Nadu were always unsuccessful. The species was recorded in high densities in the Colachel fishing harbour during September (Table S1), with a maximum recorded colony length of ~ 60 cm (Figure2), with lower abundances observed in Chennai fishing harbour, Mandapam jetty north, Mandapam jetty south (Ramanathapuram), and Tuticorin. In general, the sheltered habitat of the boulder-pile breakwaters of fishing harbours were the preferred habitat for this bryozoan, with the exception of site north of Mandapam jetty, where *A. verticillata* colonized the concrete pile structures supporting the fishing jetty. The proximity of some fishing harbours like Chennai and Tuticorin to major ports receiving international vessels may explain the occurrence of this species at these sites, as secondary spread from the populations previously introduced to international hubs. The first record of *A. verticillata* in India actually was at Chennai harbour (Robertson 1921), and later on it started to appear in different parts of the Indian coast, mainly on artificial structures (Table 1). Hence, it appears that vessel traffic is a likely vector of introduction and spread of this species similar to reported elsewhere (Marchini et al. 2015).

The majority of the literature records of *A. verticillata* from other localities in the Central Indian Ocean confirmed that *A. verticillata* is usually restricted to man-modified structures (Table 1), consistent with the non-indigenous status of this species. Despite careful searches, the species was not observed from any of the natural habitats surveyed along the Tamil Nadu coast. The ongoing proliferation of artificial

Table 1. Records of *Amathia verticillata* in the Central Indian Ocean.

Locality	Year of record	Habitat/substrate	Reference
Madras	1921	Harbour structure	Robertson (1921)
Visakhapatnam Harbour	1968	Wooden barges and concrete pillars	Ganapathi and Satyanarayana Rao (1968)
Cuddalore	1992	Vellar estuary; sea grass *Halophyla ovalis*	Nair et al. (1992)
Maldives island	1994	Fishing net	Geetha (1994)
Mumbai harbour	2010	Harbour structure	Swami and Udhayakumar (2010)
Mumbai	2012	Breakwater boulder stones	Bhave and Apte (2012)
Visakhapatnam Harbour	2011–2012	Wood and ropes of sunken fishing vessels	Yedukondala Rao and Rakesh Sarma (2013)
Visakhapatnam Harbour	2015	Slipway complex	Pati et al. (2015)

structures along the Tamil Nadu coastal region is creating suitable habitat for opportunistic fouling species such as *A. verticillata* and is expected to further facilitate their spread (Darbyson et al. 2009; Mineur et al. 2012; Dafforn et al. 2015; Megina et al. 2016).

Outside its native range, *A. verticillata* has often been found associated with other non-indigenous invertebrates (Rudman 2004; Farrapeira 2011; Giacobbeand De Matteo 2013; Marchini et al. 2015; Dailianis et al. 2016), whose introduction and establishment are possibly facilitated by this habitat-providing bryozoan. The recent record of the non-indigenous sea slug *Okenia pellucida* Burn, 1967 on *A. verticillata* colonies in Mumbai harbour (Bhave and Apte 2012) may represent a similar type of inter specific facilitation. The native range of the sea slug is unknown, but it is spreading via hull fouling to different parts of the world (Wells et al. 2009).

Ecologic and economic impacts

Several negative ecological and economic impacts of *A. verticillata* have been reported. In San Diego Bay, colonies of the species were found to grow epiphytically on leaves of eelgrass (*Zostera marina* Linnaeus, 1753), often killing the plant and creating gaps in the seagrass canopy, which were later colonized by other algal species (Williams 2007). Although quantitative assessments of its economic impact have not been carried out, *A. verticillata* has long been known to create fouling problems by attaching to the bottoms of ships and harbour structures (Woods Hole Oceanographic Institution 1952; Farrapeira 2011). In Galveston Bay, Texas, major problems were caused by colonies of the bryozoan clogging shrimp-fishing gear (Gossett et al. 2004). Fouling of boats and marinas by *A. verticillata* was also reported in southern California (Johnson et al. 2006) and in the port of Rome, Italy (Ferrario et al. 2016). It has been reported as a pest species for pearl oysters, *Pinctada fucata* (Gould, 1850) farming along the southern coast of Korea and in the mussel maricultures of India (Mahadevan 1980; Je et al. 1988).

Despite this, the ecological impacts of *A. verticillata* have not been regarded as problematic because of the assumption that it is a native species in this region. The high densities observed in Colachel are likely to cause impairment to fishing activities. Moreover, it is possible that this species can favour the settlement of other associated non-indigenous invertebrates, thus contributing to a process of biotic homogenization (Olden et al. 2004), which is an ongoing issue at the global scale. This biotic homogenization of coastal habitats will likely reduce the biodiversity. The current contribution aims to raise awareness of the non-indigenous status of *A. verticillata*, pointing out the need for risk-assessment analyses aimed at evaluating its actual ecological and economic impacts.

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Supplementary material

The following supplementary material is available for this article:

Table S1. Relative abundance of *Amathia verticillata* colonies along the coasts of Tamil Nadu, India.

This material is available as part of online article from:
http://www.reabic.net/journals/bir/2017/Supplements/BIR_2017_PrincePrakashJebakumar_etal_Table_S1.xlsx