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**Rapid Communication**

# First record of the non-native bryozoan *Amathia* (= *Zoobotryon*) *verticillata* (delle Chiaje, 1822) (Ctenostomata) in the Galápagos Islands

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## Abstract

The warm water marine bryozoan *Amathia (= Zoobotryon) verticillata* (delle Chiaje, 1822) is reported for the first time in the Galápagos Islands based upon collections in 2015. Elsewhere, this species is a major fouling organism that can have significant negative ecological and economic effects. Comprehensive studies will be necessary to determine the extent of the distribution of *A. verticillata* in the Galápagos and its effects on native species. The establishment of *A. verticillata* emphasizes the need for regular monitoring of those vectors that could bring additional non-native species to the Archipelago.

**Key words:** introduced species, fouling, ctenostome, transport, shipping

## Introduction

The "spaghetti bryozoan" *Amathia verticillata* (delle Chiaje, 1822) is one of the more infamous bryozoans due to its massive size and extensive fouling propensities. Despite apparently being transported for centuries around the world, it continues to appear in new regions. Recent new records include the subtropical and tropical waters of the Macaronesian islands (the Azores, Madeira, and Canary Islands) in the Western Atlantic Ocean, the eastern Mediterranean, and Palmyra Atoll in the Pacific Ocean (Amat and Tempera 2009; Wirtz and Canning-Clode 2009; Knapp et al. 2011; Minchin 2012; Tilbrook 2012; Galil and Gevili 2014; Ferrario et al. 2014). These regions add to what is regarded as the worldwide, tropical and subtropical, ship-mediated distribution of *Amathia verticillata* (WHOI 1952; Allen 1953; Carlton and Ruckelshaus 1997). The native range of this bryozoan, while variously argued as the Mediterranean (Cranfield et al. 1998) or the Caribbean (Winston 1995; Galil and Gevili 2014), remains uncertain (Cohen and Carlton 1995; Carlton and Eldredge 2007).

We follow Waeschenbach et al. (2015) in treating *Zoobotryon* as a junior synonym of the genus *Amathia*, and thus this species becomes *Amathia verticillata*, leaving behind one of the most familiar genus names amongst bryozoans.

*Amathia verticillata* continues to expand its range within regions where it has long been established, with extralimital excursions (some apparently ephemeral) since the 1990s on both the Atlantic and Pacific coasts of North America as well as on the east coasts of Australia and South America (Cohen and Carlton 1995; Soule et al. 2007; Angione 2008; Farrapeira 2011a; Tilbrook 2012; Carlton 2014). It is likely that all of these new occurrences and range expansions are ship-mediated.

An opportunity for field exploration for non-native marine species in the Galápagos Islands was provided by the convening of the first

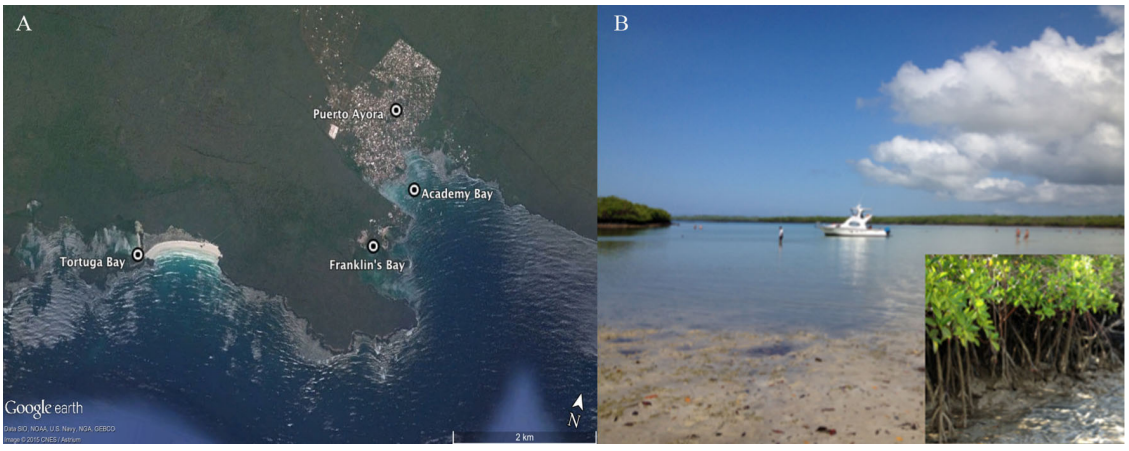


**Figure 1. A:** Satellite image of Santa Cruz Island indicating the location of Tortuga Bay and Franklin's Bay, where *Amathia verticillata* was observed, and the main port of Academy Bay in Puerto Ayora; **B:** Shallow sand flats of Tortuga Bay and (inset) fringing red mangroves. (photos: James Carlton).

**Figure 2.** *Amathia verticillata* colonies on mangrove limbs and roots in Tortuga Bay (photo: Linda McCann).

**Figure 3.** *Amathia verticillata* colonies from shallow waters off the beach in Tortuga Bay (photo: Linda McCann).

International Workshop on Marine Bioinvasions of Tropical Islands at the Charles Darwin Research Station (CDRS) in Puerto Ayora, Santa Cruz Island, during February 2015. Several previously undetected, non-native, species were collected; we report here on the discovery of *Amathia verticillata* in the Galápagos. Prior to this discovery, only two ctenostome bryozoans [*Buskia seriata* Soule, 1953 and *Amathia vidovici* (Heller, 1867)] had been reported from the Galápagos Islands (Banta and Redden 1990; Banta 1991).

## Results and discussion

### *Amathia verticillata* on Santa Cruz Island

Between February 18 and 27, 2015, *A. verticillata* was found near the city of Puerto Ayora (Figure 1A) on Santa Cruz Island. The colonies resembled many of the classic descriptions of *A. verticillata* as long, branching, tangled noodle-like strands (Robertson 1921; Osburn and Soule 1953; Winston 2004; Soule et al. 2007, and whence the common name). *Amathia verticillata* was collected in two locations during this study:

1) ***Tortuga Bay*** (Bahía Tortuga; 0°45.839′S, 90°20.423′W) is a large protected bay (Figure 1B) surrounded by the red mangrove *Rhizophora mangle* L. *Amathia verticillata* was found at shallow depths (< 2 m) nearshore along the northwest edge of the bay. During a shore excursion, *A. verticillata* was first noted in the form of common, large (up to 0.5 m long), tangled mats and sheets draped from mangrove limbs at low tide (Figures 2 and 3). Exploration by snorkelling revealed numerous colonies attached to rocks or shells on the bay floor.

**Figure 4.** *Amathia verticillata* on a pier piling in Franklin's Bay (photo: Inti Keith).

Of interest are the observations of Whitmore et al. (2005) who noted that, in the Gulf of California, *A. verticillata* living in subtidal waters sometimes breaks free and is carried into mangrove forests where they can live for many weeks. We interpret the colonies amongst the mangroves in Tortuga Bay to be linked in a similar manner to colonies on the bay floor proper.

2) ***Franklin's Bay*** (Bahía Franklin; 0°45.310′S, 90°18.760′W) is a small embayment branching off the entrance to Academy Bay; portions of this bay are bordered by red mangroves as well. *Amathia verticillata* was found in small clumps attached to pier pilings (Figure 4) and floats (pontoons) as well as on the bay floor at about 2 m depth.

Voucher specimens of *A. verticillata* were collected to confirm identification and preserved in 95% ethanol for future DNA analyses. This material has been deposited in the invertebrate zoology collection of the CDRS.

## Possible Transport Vectors to the Galápagos

Puerto Ayora receives a large and steady stream of marine traffic, with cargo vessels, naval patrol boats, and recreational vessels arriving from mainland Ecuador. Private vessels from the United States, Mexico, Central America, and South America, and, indeed, from around the world, also visit the Galápagos Islands, often anchoring in Academy Bay as their first port of call. We assume that *A. verticillata* arrived as a fouling organism on vessel hulls in Academy Bay. While our work in February did not provide opportunity for extensive exploration, we examined and did not find it on the upper surfaces of pier pilings at the main Puerto Ayora quay.

Transport through shipping is the most likely vector. *Amathia verticillata* has lecithotrophic coronate larvae of very short planktonic duration (Zimmer and Woollacott 1977). Fragments of *A. verticillata* could conceivably be taken into ballast water systems and survive and, once ejected into a new region, are capable of reattachment (Zirpolo 1924; Robinson and Walters 2003). The species has been recorded from vessel hulls around the world (Neu 1932; Godwin 2003; Carlton and Eldredge 2009; and Table 1) suggesting that hull fouling is the more likely mode of transport to the Islands.

After initial introduction to Puerto Ayora harbour, *A. verticillata* colonies may have been dispersed short distances along the shoreline as rafted masses (Winston 2004), attached to floating debris (Farrapeira 2011b), or transported by local vessels to Tortuga and Franklin's Bays. Tortuga Bay is a popular recreational site, with a small number of speedboats allowed to enter the bay. Franklin's Bay has several public and private docks that are also used by small speedboats, and many daily tours visit the public dock where *A. verticillata* was observed. As noted above, *A. verticillata* has the ability to reattach to substrates, facilitating the colonization of new areas. Drifting *A. verticillata* conceivably could release larvae.

## Source Regions for *Amathia verticillata*

On the nearest continental coast, *A. verticillata* is known from southern California (Robertson 1921; Reish 1968 1972; Soule et al. 2007) to Mazatlán in central Mexico (Soule 1963; Alvarez-Leon and Banta 1984; Tovar-Hernandez et al. 2012). Medina-Rosas and Tovar-Hernandez (2012) remarked that there were no reports from the Pacific coasts of tropical Mexico and Central America. We tentatively regard a report of its occurrence in Central America by Soule et al. (1980) (repeated by Cohen and Carlton 1995, and further noted by Fofonoff et al. 2003) as a mistake because no populations have been reported in recent years from south of Mazatlán in Mexico or Central America. An unpublished record of *A. verticillata* collected in June 1914 from Taboga Island, in the Gulf of Panama (Smithsonian Institution National Museum of Natural History Invertebrate Zoology collections, USNM 6378, James Zetek, collector; database accessed May 2015), may represent a transient

**Table 1.** Potential negative ecological and economic impacts of the ctenostome bryozoan *Amathia verticillata*.

| Impact | Location / References |
|---|---|
| Vessel hull fouling | Tropics (WHOI 1952); Australia (Burn 1967); India: "luxuriant growth" (Ganapati and Rao 1968); Ghana (Edmunds 1975); Brazil (Farrapeira 2011a); Canary Islands (Minchin 2012); Israel (Galil and Gevili 2014) |
| Blocking intake pipes on vessels, industrial plants, commercial salt ponds | Europe (Ryland 1965); South Australia (Bock 1982; Coleman 1999) |
| Fouling commercial fishing gear with subsequent economic loss to fishery, and fouling in shore fishery operations | North Carolina (Angione 2008, flounder fishery); Texas (Hogarth 2000; Gossett and Gonzalez 2004, shrimp fishery); Korea (Je et al. 1988; pearl oyster farms) |
| Blocking turtle exclusion devices (TEDs) | Texas (Hogarth 2000) |
| Eelgrass (*Zostera marina*) mortality by shading and biofouling leading to canopy collapse | California (A. Sewell in Cohen and Carlton 1995; Williams 2007) |
| Spatial dominant in marine communities, with masses growing to 1.5 meters or more in length and 0.6 meters or more in width | California (Robertson 1921; Reish 1968); Baja California (Banta 1980); Florida (Winston 1982, 1995); Japan (Nandakumar 1996) |

occurrence because there are no additional records from the Pacific coast of Panama, despite repeated surveys between 2008 to 2014 near the Pacific entrance to the Panama Canal (Ruiz et al., unpublished). In 2014, however, the first populations of *A. verticillata* in South America were detected at the Salinas Yacht Club located in the province of Santa Elena on mainland Ecuador, 160 km south of Manta, the largest seaport in Ecuador (Priscilla Martinez, personal communication, February 2015).

While the nearest known source populations to the Galapagos Islands are southern California, the Gulf of California, western Mexico south to Mazatlán, and mainland Ecuador, vessel traffic has and continues to arrive in the Islands from around the Pacific Rim. Although a hull inspection program for arriving vessels is in place in the Galápagos Islands, small attached stolons of *A. verticillata* would be easy to miss. Genetic analysis of the new Galápagos colonies may assist in pointing toward possible source regions, especially if linked with known vessel traffic patterns. It is possible that *A. verticillata* represents a global species complex (Soule et al. 2007); if so, and if the Galápagos colonies are found to be members of a specific clade, identifying a specific source region may be less problematic.

## Possible Ecological, Environmental, and Economic Effects

The Galápagos Islands, as with many other tropical islands, are under constant threat from marine bioinvasions due to the global increase in tourism, trade, and coastal development, leading to the concomitant increase in maritime traffic. The appearance of *A. verticillata*, while not unexpected, adds to a growing list of non-indigenous marine species in the archipelago, and, as such, there is strong reason for ecological and economic concern. Despite the ubiquitous and often abundant nature of this species, there appear to be remarkably few quantitative data on the negative impacts of *A. verticillata*, which has been consistently identified as a fouling organism of potentially considerable significance (Table 1). If *A. verticillata* were to become abundant and widespread in the Galápagos Islands, there could be important economic and environmental consequences to shore industries and fisheries, as well as to the structure and function of natural communities. With the recent establishment of *A. verticillata,* additional work is now needed to quantify potential effects on Galápagos' ecosystems and resources. The opportunity exists, prior to extensive spread, to implement a temporal analysis of changes coincident with the spread of this species.

## Monitoring, Eradication, and the Galápagos as a New Dispersal Hub

We suggest that *A. verticillata* is a relatively recent colonizer of the Galápagos Islands, as the species was not detected during surveys of the green alga *Caulerpa* in Tortuga Bay that have been conducted since 2012 by several of us. Our limited surveys suggest that it is already abundant

in this Bay. Critical now will be to determine the full extent of the distribution around the Galápagos to establish a baseline, to monitor spread and seasonal growth, and to determine effects on near shore benthic species. Once it is established, there is a very low likelihood of success for eradication of *A. verticillata* (Gossett and Gonzalez 2004; Amat and Tempera 2009); therefore, we think attempts to eradicate the species from the Galápagos Islands would not be an effective use of limited resources. The likelihood of success in eradication is highest early in an invasion, before the species becomes widespread (Anderson 2005). Furthermore, the establishment of *A. verticillata* emphasizes the need for regular monitoring of those vectors that could bring additional non-native species to the Archipelago. With its establishment, the Galápagos Islands are now a new dispersal center for *A. verticillata*. As such, vessels departing the Galápagos should be advised that they are now potential carriers, and common next-port-of-calls should be advised to watch for *A. verticillata*, if it is not already present.

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