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First record of *Branchiomma bairdi* McIntosh, 1885 (Annelida: Sabellidae) from Madeira Island, Portugal (northeastern Atlantic Ocean)

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Abstract

During a field survey to monitor marine non-indigenous species in several marinas of the Archipelago of Madeira (Portugal), the invasive sabellid polychaete *Branchiomma bairdi* McIntosh, 1885 was detected for the first time on Madeira Island, reaching densities of 238–516 ind.m^{-2}. *B. bairdi* was originally described from the western Atlantic (from Bermuda to Caribbean Sea) but the origin of this species is still unknown. This species has been recorded as an invasive species for the Pacific coast of Panama, Gulf of California, Mediterranean Sea, Canary Islands, and Australia. Hull fouling is the most likely vector for the introduction of the species.

Key words: hull fouling, invasive species, NIS, Madeira Island, hermaphrodite, harbours

Introduction

Introductions of non-indigenous species (NIS) are common in coastal communities. The rate of biological invasions has increased significantly in recent years, in great part due to the transport of alien species on vessels hulls (bio-fouling) and/or in ballast waters. Thus, this phenomenon represents a great threat to the economic and ecological well-being of coastal marine ecosystems (Ruiz et al. 2000; Ruiz et al. 2009; Canning-Clode et al. 2013).

Sabellid polychaetes are commonly known as "fan worms", or "feather-duster worms", a name that refers to their filter feeding radiolar crowns along with a tube of sediment and mucus. *Branchiomma* Kölliker, 1859 is a well-known genus of Sabellidae, with approximately 30 species, that are found in sheltered waters such as harbours, bays, floating docks, buoys, rocks, and on hulls of vessels (Tovar-Hernández and Knight-Jones 2006; Tovar-Hernández et al. 2009a). Most species are circumtropical in distribution (Giangrande and Licciano 2004) and, according to Tovar-Hernández et al. (2009a), at least four species are considered as potential invaders world-wide: *B. luctuosum* (Grube, 1870), *B. boholense* (Grube, 1878), *B. curtum* (Ehlers, 1901) and *B. bairdi* (McIntosh, 1885).

The invasive *Branchiomma bairdi* McIntosh, 1885 is a tube-building sabellid polychaete that was originally described from Bermuda; however, the actual origin of the species is unknown. *B. bairdi* is considered invasive to coastal environments due to its high densities on buoys and hulls of vessels, its feeding mode, and its anti-

predation strategies. It is a simultaneous hermaphrodite species, with male and female gametes occurring in the same segments (Tovar-Hernández et al. 2009b). This species was previously known from the western Atlantic from Bermuda to the Caribbean Sea, and has been introduced to: the eastern Pacific Ocean from the Gulf of California to Panama (Tovar-Hernández et al. 2009a; b; Tovar-Hernández et al. 2011; 2012; in press; Tovar-Hernández and Yáñez-Rivera 2012); the Mediterranean Sea (Çinar 2009; Giangrande et al. 2012; Arias et al. 2013b); the Canary Islands (Arias et al. 2013b); and Australia (Capa et al. 2013). This study provides the first record for the invasive fouling sabellid *B. bairdi* for Madeira Island, north-eastern Atlantic Ocean.

Methods

Madeira is a volcanic island located southwest of continental Europe and 700 km off the Moroccan coast with a surface area of approximately 800 km^2. Historically, Madeira has been an important passage route for many ships between Europe and the African and American continents because of its strategic geographic position in the Atlantic Ocean. Today most of the maritime traffic comes from tourist cruise ships from different parts of the world (APRAM 2014).

This ongoing study was part of an ongoing monitoring program, started in July 2013, for marine NIS in Madeiran waters. Based on the design used by Canning-Clode et al. (2011), we deployed 10 polyvinylchloride (PVC) settling plates (14×14×0.3 cm) horizontally attached to a brick facing downwards and hung at approximately 1 meter depth from pontoons in four marinas of the Madeira Archipelago: Calheta (32°43'N, 17° 10'W), Funchal (32°38'N, 16°54'W), Caniçal (32°44'N, 16°42'W) and Porto Santo Island (33°03'N, 16°18'W) (Figure 1). Communities colonizing the settling plates were analyzed by measuring percent cover of sessile species at three different successional ages: 3 months (October 2013), 6 months (January 2014), and 9 months (April 2014). For each sampling event, settling plates were detached, retrieved from the field, and species identified with the aid of a stereomicroscope (Leica Wild-M3 Heerbrugg). In addition, digital photographs were taken of each settling plate using a Canon A620 camera. Plates were then brought back into the field within 2 hours of each sampling event. Other invertebrate species were present in the settling plates, but, for the purpose of this analysis, we only report the presence of *B. bairdi*. The abundance and tube lengths (to an accuracy of 0.01 cm) of worms were determined for each photographic image with the analysis software CPCe (Kohler and Gill 2006).

Results

Branchiomma bairdi was first detected on PVC plates (Figure 2A) in the marina of Funchal in October 2013, after 3 months of being exposed to colonization. Individuals of *B. bairdi* were also observed growing on the side of pontoons down to 0.5m depth (Figure 2B) and on hulls of vessels that were moored at the marina. To date, *B. bairdi* is only present at the marina of Funchal and specimens were still present after 9 months. This detection represents the first record of this species in Madeira Island.

Branchiomma bairdi (Figures 2C, D) is a filter-feeder organism characterized by the presence of a radiolar crown (Figure 2E), with two types of stylodes on the radioles. The macrostylodes were two to three times longer than the microstylodes (Figure 2F) and this feature agrees with that recorded in the Gulf of California and Mediterranean Sea (Tovar-Hernández et al. 2009 a; b; Arias et al. (2013b); this is an unique character that prevents possible misidentifications with other species within the genus. The colour of the radiolar crown varied from brownish to orange, often with stripes in cream or dark brown. The colour of the body of live specimens observed from the marina of Funchal varied from pale, yellow, olive green to brownish coloration. Three voucher specimens of *B. bairdi*, collected from the marina of Funchal, with estimated body lengths of 4.1 cm, 2.1 cm and 1.7 cm, were deposited at the Museu Municipal (História Natural) in Funchal, Madeira (MMF43135).

The total numbers of worms growing on our settling units were 59, 91, and 28 after 3, 6 and 9 months of colonization, respectively, with a mean (± SD) number of worms per PVC plate were 6.5 ±7.8 (n = 9), 10.1±11.7 (n = 9), and 4.7 ±4.5 (n = 6), respectively. These numbers represented densities of worms growing on the PVC plates of 335 individuals m^{-2}, 516 individuals m^{-2}, and 238 individuals m^{-2} after 3, 6 and 9 months, respectively.

After 3 months (October) the tube lengths ranged between 0.94 cm and 5.56 cm, with mean (± SD) tube size of 1.97 ± 0.82 cm (n = 59); at 6 months (January) the range was 0.73 cm to 5.74

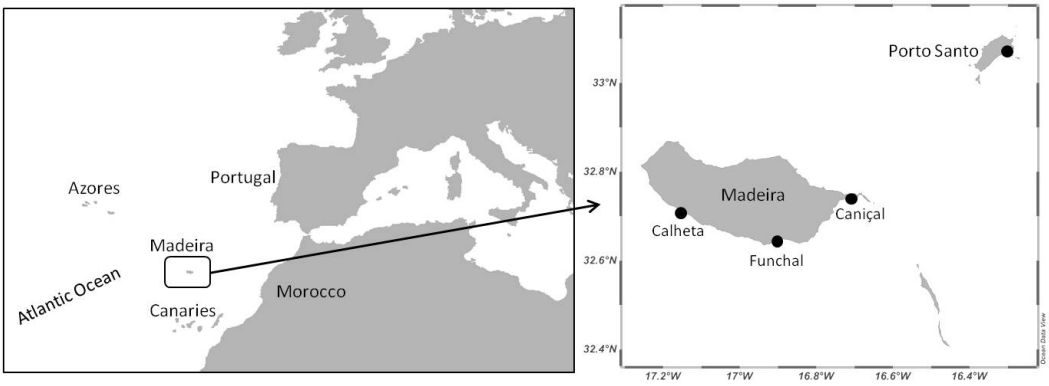

Figure 1. Map of Madeira Archipelago with location of the four stations of the monitoring program for marine NIS.

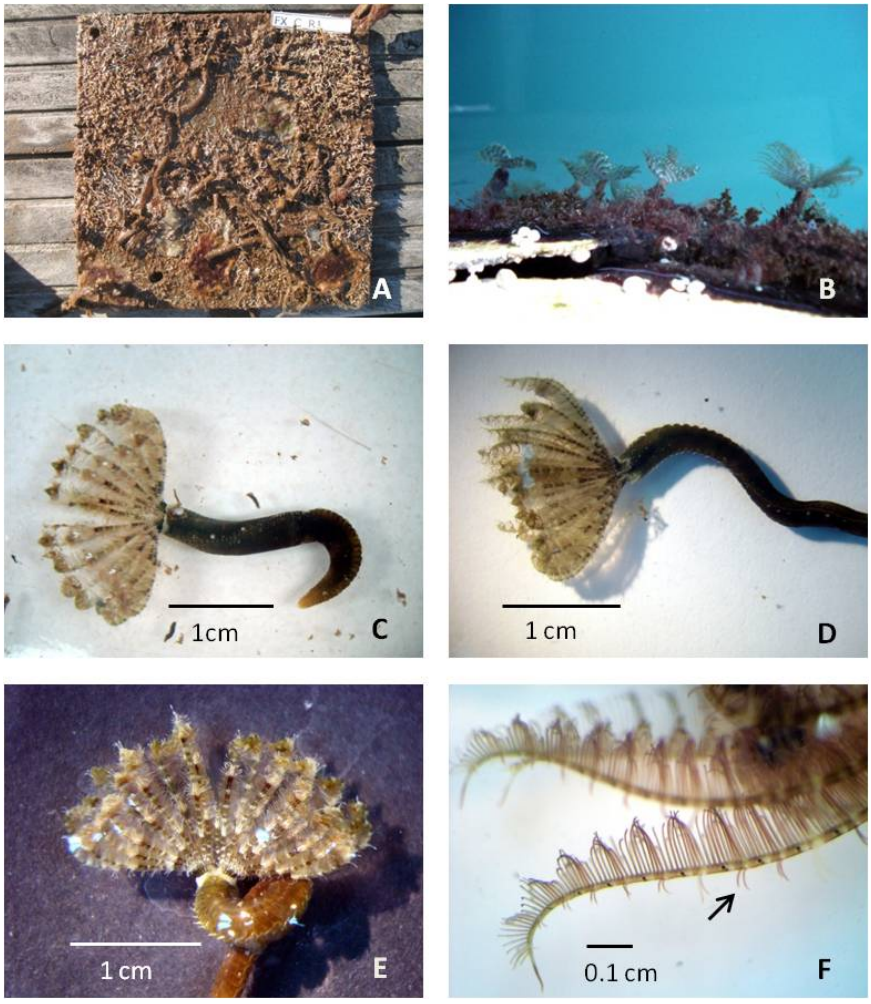

Figure 2. Map *Branchiomma bairdi*, live specimens: (A) growing on PVC plate; (B) attached on the side of pontoon at Marina of Funchal; entire body (C) ventral view; (D) dorsal view; (E) filter-feeding radiolar crown; (F) radioles with macrostylodes and compound eyes (black dots), the arrow show a pair of microstylodes.

cm, with a mean tube size of 2.04 ±1.05 cm (n = 91); and at 9 months (April) the range was from 1.50 cm to 4.89 cm, with mean tube size of 2.68 ±0.71 cm (n = 28).

Discussion

The densities of *B. bairdi* growing on the PVC plates inside the marina of Funchal, Madeira Island, were within the range reported in the Mazatlán port (Mexico) where Tovar-Hernández et al. (2011) found densities >150 individuals m^{-2} throughout the year, a mean annual density of 887 individuals m^{-2}, and temporal variations related to changes in temperature. However, the highest densities (>2500 individuals m^{-2}) at Mazatlán occurred during the warmest months (August and September), months not included in the present study.

The densities recorded in Madeira were at least 15 times greater than the ones recently recorded from Mazarrón harbour (Southern Spanish coast) in May 2012 and on the rocky shores from Las Palmas harbour (Canary islands) in August 2012 where densities were slightly > 15 individuals m^{-2} (Arias et al. 2013b). The estimated densities for Faro Lake (Messina, Italy, Ionian Sea) during the summer months of 2007 were between 2 to 30 individuals per boulder while during the summer of 2011 they had increased to 400 individuals m^{-2} (Giangrande et al. 2012), which is comparable estimated densities in Funchal (this study).

It is difficult to determine when *B. bairdi* arrived on the Madeira coast because there is no routine monitoring along these waters and little is known about the diversity and distribution of fouling NIS in the Madeira archipelago. In fact, only one recent study has investigated NIS diversity in Madeira (Canning-Clode et al. 2013), where the authors found 16 NIS of which 9 constitute new records to Madeira. However, this study was restricted to the marina of Madeira, Caniçal, located southeast of the island.

The most likely introduction pathway of *B. bairdi* to Madeira was "shipping", as a fouling species on the hull of recreational ships.

Branchiomma bairdi has a long history of invading new locations worldwide. This invasive sabellid was initially recorded on the Pacific coast of Panama (Capa and López 2004) and subsequently detected in the Gulf of California in the port of Mazatlán and then spreading to many locations in southern and central Gulf of California (Tovar-Hernández et al. 2009 a; b; Tovar-Hernández et al. 2011; 2012; in press; Tovar-Hernández and Yáñez-Rivera 2012). In Europe, the first finding of *B. bairdi* in the Mediterranean Sea was in the eastern basin, hypothesized to have been introduced on ship hulls through the Suez canal (Çinar 2009). Although the first record is from Girne Harbour (Cyprus) in 1998 as *B. boholense*, (Cinar 2005; Çinar 2009; Arias et al. 2013b), it was probably first introduced through the strait of Gibraltar because since *B. bairdi* was already present in the western and central Mediterranean and had been misidentified as *B. boholense* (Román et al. 2009; Giangrande et al. 2012; Arias et al. 2013a; Arias et al. 2013b) with population densities higher than those found on the eastern basin. Furthermore, the re-examination of specimens collected from Miseno Harbour (Gulf of Naples, Italy) revealed the presence of *B. bairdi* since September 2004, and today it is still spreading throughout the Mediterranean Sea and eastern Atlantic (e.g., Las Palmas harbour, Canary Islands) (Arias et al. 2013b). Taken together, recent findings of *B. bairdi* in the Mediterranean and in the Canary Islands are consistent with the hypothesis of the Strait of Gibraltar being the main pathway of introduction with the Caribbean being the origin of the species. Given that the Canary Islands, Strait of Gibraltar, and the Mediterranean Sea are relatively close to the Madeira Archipelago, we hypothesize that (1) *B. bairdi* arrived into the marina of Funchal from the neighbouring areas of the Mediterranean, Gibraltar and Canary islands; or (2) *B. bairdi* arrived first in Madeira from the Caribbean region and subsequently spread from Madeira to Europe and the Mediterranean. This second hypothesis is supported by the high densities found in Madeira compared to the ones found in the Canary Islands, consistent with a possible earlier introduction and establishment of a thriving population. A focused phylogeographic (genetic) analysis, as suggested by Arias et al. (2013b), would be needed to distinguish between the possible pathways of introduction of *B. bairdi* to the Mediterranean.

Due to the high densities of *B. bairdi* registered in Madeira in the present study, combined with its known invasion history elsewhere, future investigations should be undertaken to assess the potential impacts of this species on the native faunal assemblages. Therefore, we recommend for future studies the use of georeferenced TV underwater devices (e.g. El Haddad et al. 2012), as an valuable tool in field surveys, for the early detection and monitoring of *B. bairdi* and other conspicuous NIS.

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