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Rapid Communication

First report of the invasive species *Branchiomma bairdi* McIntosh, 1885 (Annelida: Sabellidae) along the Tunisian coast (Mediterranean Sea)

Ines Khedhri[1], María Ana Tovar-Hernández[2], Paulo Bonifácio[3], Afli Ahmed[1] and Lotfi Aleya[4,*]

[1] *Laboratoire de Biodiversité et Biotechnologies Marines, Institut National des Sciences et Technologies de la Mer, 28 rue du 2 mars 1934, 2025 Salammbô, Tunisie*

[2] *Universidad Autónoma de Nuevo León, Facultad de Ciencias Biológicas, Laboratorio de Biosistemática, San Nicolás de los Garza, Nuevo León, México*

[3] *UMR 5805 EPOC, CNRS, Université de Bordeaux, Station Marine d'Arcachon, 2 rue du Professeur Jolyet, 33120 Arcachon, France*

[4] *Université de Bourgogne Franche-Comté, Laboratoire de Chrono-Environnement, UMR CNRS 6249, La Bouloie, 25030 Besançon Cedex, France*

**Corresponding author*
E-mail: lotfi.aleya@univ-fcomte.fr

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Abstract

The invasive sabellid polychaete *Branchiomma bairdi* McIntosh, 1885 was collected in the Boughrara Lagoon (southern Tunisian coast) between 2012 and 2013. This species was originally described from Bermuda and has been widely reported in the Caribbean Sea. It has been considered as non-indigenous species on the Pacific coast of Panama and the California Gulf. Recently, *B. bairdi* was recorded along the Italian and Turkish coasts, Australia, Canary and Madeira Islands. It was suggested that the commercial shipping is the most likely vector for the introduction of the species to Mediterranean Sea. A description of the species along with a discussion of its systematic position and ecology are provided.

Key words: Sabellidae, Polychaeta, non-native species, Boughrara Lagoon

Introduction

In Recent years, the number of non-native species in the Mediterranean Sea has increased rapidly (Zenetos et al. 2010, 2012; Gerovasileiou et al. 2016) with at least 1035 alien species recorded in the Mediterranean Sea (Crocetta et al. 2016; Gerovasileiou et al. 2016). It becomes urgent that Alien species should be identified and studied because of their negative economic and ecological impacts on native ones (Tovar-Hernández et al. 2009a; El Haddad et al. 2007). According to Zenetos et al. (2012), shipping and Lessepsian migration are the most responsible and common vectors for the introduction of alien species to the Mediterranean Sea (67.9% and 46.4%, respectively), followed by aquaculture (7.1%) and aquariums (3.6%).

The sabellid polychaetes are commonly known as "fan worms" and are one of the most common groups within marine and coastal areas. The genus *Branchiomma* Kölliker, 1858 comprises a total of 30 species with intertropical distribution (Giangrande and Licciano 2004; Keppel et al. 2015) and are found in harbours, bays, lagoons, docks and on hulls of vessels (Tovar-Hernández and Knight-Jones 2006; Tovar-Hernández et al. 2009b). Until recently, five taxa were considered to be alien (Çinar 2013; Keppel et al. 2015) namely: *B. coheni* (Tovar-Hernández and Knight-Jones, 2006), *B. luctuosum* (Grube, 1870), *B. boholense* (Grube, 1878), *B. curtum* (Ehlers, 1901), *B. bairdi* (Mclntosh, 1885).

According to Keppel et al. (2015), two additional species are considered to be possible non-indigenous species: *B. lucullanum* (Delle Chiaje, 1828) and *B. nigromaculatum* (Baird, 1865), and further investigations are required to confirm their identification and taxonomic position.

The invasive species *B. bairdi*, a tube-building sabellid polychaete (Tovar-Hernández et al. 2009a;

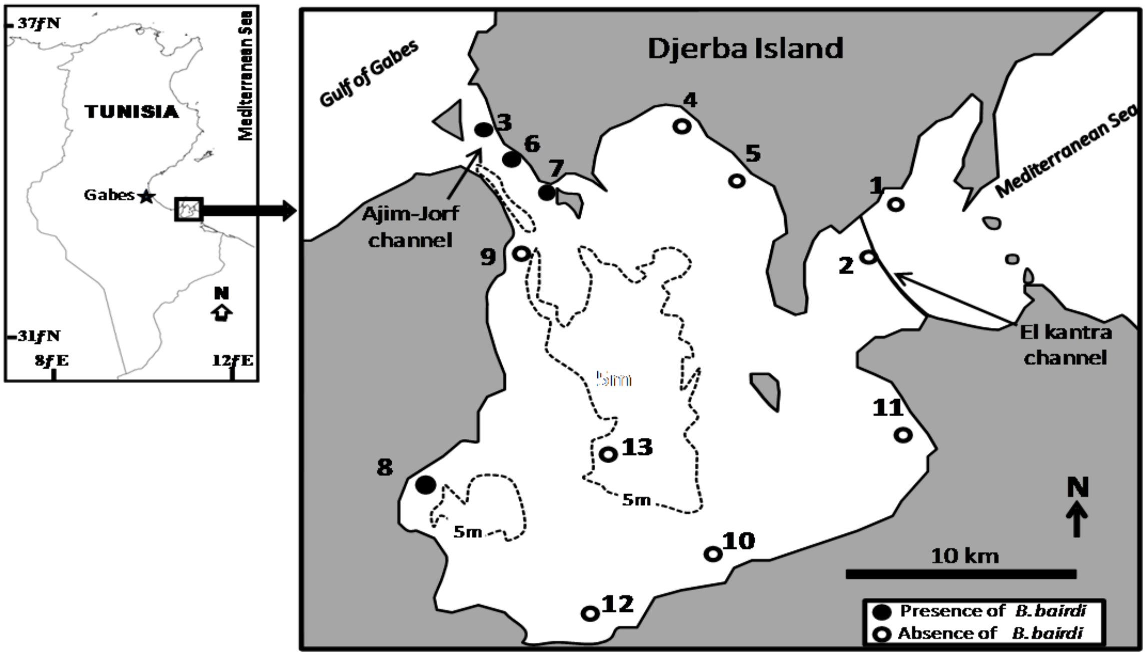

Figure 1. Study area with location of sampling sites and the presence or absence of *Branchiomma bairdi* in Boughrara Lagoon.

Ramalhosa et al. 2014), has been originally described from the Caribbean Sea. According to Tovar-Hernández et al. 2009b, this species is considered as invasive to coastal areas due to its 1) high densities on buoys and hulls of vessels, 2) feeding mode, 3) various strategies of anti-predation and 4) its simultaneous hermaphrodite status (Tovar-Hernández et al. 2009b, 2011; Ramalhosa et al. 2014).

Furthermore, this species was previously recorded in the western Atlantic from Bermuda to the Caribbean Sea. It has been introduced to: the eastern Pacific Ocean from the Gulf of California to Panama (Tovar-Hernández et al. 2009a, b, 2011, 2012, 2014), the Mediterranean Sea (Çinar 2005 (as *B. boholonse*); 2009; Giangrande et al. 2012; Arias et al. 2013a; Corsini-Foka et al. 2015; Lezzi et al. 2016); the Canary Islands (Arias et al. 2013a); Australia (Capa et al. 2013) and Madeira Island (Ramalhosa et al. 2014).

The present paper reports the first record of the invasive and fan worm *B. bairdi* along the southern Tunisian coasts.

Material and methods

Study area

Boughrara Lagoon (500 km^2) is located on the southeastern coast of Tunisia (between 33º28′N and 33º45′N and 10º40′E and 10º57′E), bounded on the North by the Djerba Island and on the other sides by the mainland (Figure 1). The lagoon is connected with the Gulf of Gabes by the Ajim channel (2.2 km width) in the North-West and by the "El-Kantra" channel (Khedhri et al. 2016a, b), which is a narrow connection in the East of around 160 m wide at the mid of the Roman road connecting the Djerba Island to the continent. The variation of the water surface temperature is wide in Boughrara Lagoon; it is on average around 24.7 °C in summer and 11.2 °C in winter, with an increasing North-South gradient (Ben Aoun et al. 2007). The average depth of the lagoon is about 4 m with a maximum of 16 m in the center. The salinity is higher when compared to the salinity of the surrounding sea (Abdenadher et al. 2012), ranging on average from 42.19 to 53.3 PSU (Khedhri et al. 2015) due the evaporative concentration (Khedhri et al. 2016a, b).

Moreover, a considerable amount of organic matter are discharged from the harbours of Boughrara Lagoon and from aquaculture activities, thus making it a vulnerable environment with loaded phosphorus coming from the Gulf of Gabes (Bejaoui et al. 2004; Khedhri et al. 2015, 2016a, b). The restricted water exchange also between the lagoon and the open sea results in blooms of harmful dinoflagellates (Abdennadher et al. 2012) and plays a role in the seasonal fluctuations in a range of environmental variables (Romdhane et al. 1998; Khedhri et al. 2015).

Table 1. Records of *Branchiomma bairdi* in the Boughrara Lagoon. N: number of individuals collected, asterisks indicate absence of data. Sites: see Figure 1.

Sites	Date	Depth (m)	Latitude (N)	Longitude (E)	Abondance (N)	Salinity PSU	% grain (<63µm)	Size (>63µm)
3	November 2013	1.1	10º44′16″	33º43′17″	1	39.7	0.65	99.35
6	August 2012	1	10º44′37″	33º42′59″	5	*	1.42	98.57
	November 2013	1	10º44′37″	33º42′59″	1	37.7	1.42	98.57
7	November 2013	1	10º45′42″	33º41′55″	35	37.6	2.36	97.63
8	March 2012	3.1	10º41′29″	33º32′21″	1	*	0.51	99.49

Material examined

Benthic macrofauna was sampled at 13 stations in Boughrara Lagoon (Figure 1) between 2012 and 2013 during spring (March), summer (August) and autumn (November) seasons, (Table 1). Samples were collected by scuba divers with a quadrat (1 m², 10 cm depth) and sieved through 1 mm mesh. Three replicates were created at each station making a total sampling surface of 0.75 m^{-2}. The remaining fraction was fixed in 7% formalin and later transferred into 70% ethanol. All specimens were examined under a CETI, LCD digital stereomicroscope and one specimen photographed with a Nikon Coolpix P90 camera. Specimens were measured with the NIS-Elements Analysis software (Nikon Instruments Inc., Melville, New York, USA).

Other measurements such as body length, width of the thorax, and the number of thoracic and abdominal chaetigers were made.

Results

Forty three specimens of *B. bairdi* were collected in 2012–2013 from four different sites in the Boughrara Lagoon (Figure 1, Table 1). This species displayed highest abundances in November at station 7 (near to a fish farm) with 35 individuals m^{-2}. Abundances were lower in August and March (max 5 ind.m^{-2}). *Branchiomma bairdi* was collected from harbours (stations 6 and 8).

Systematics

Genus *Branchiomma* Kölliker, 1858
Branchiomma bairdi (McIntosh, 1885) (Figure 2)

Dasychone bairdi McIntosh 1885: 495–497, pl. 30A, Figures 13–15; pl. 39A, Figures 2, 9; Monro 1933: 267; Rioja 1951: 513–516: pl. 1, Figures 1–7 ; Rioja 1958: 370. *Branchiomma cf. bairdi* Capa and López 2004: 370, Figures 5A–I. *Branchiomma bairdi* Tovar-Hernández and Knight-Jones 2006: 13–17, Figures 3A–D, H–K, 9C–D, 10C, 11B; Tovar-Hernández et al. 2009b: 3–8, Figures 2–4. Çinar 2009: 2320, Figure 13 A-B-C. Giangrande et al. 2012: 283–293, Figures 3–0 ; Arias et al. 2013a: 162–171, Figures 2–4 ; Ramalhosa et al. 2014: 235–239, Figure: 2.

Material examined

Central Mediterranean Sea: South Tunisia: Boughrara Lagoon (10º40′ to 10º57′ E; 33º28′ to 33º45′ N; station 7; November 2013; 1m depth; 35 specimens).

Description

Leathery tubes covered by sands and algae (*Caulerpa prolifera* (Forsskål) J.V. Lamouroux, 1809). Specimens up to 25 mm long and 2 mm wide. Body pale brownish with small dark brown spots over whole surface. Radiolar crown united at the base by a short web, and 25 pairs of radioles on each side with apinnate tips and stylodes. Macrostylodes strap-like, two or three longer than the microstylodes to each radiole, randomly alternating and mostly in distal half of radioles (Figure 2A, B). This is a diagnostic character of the species which prevents possible misidentifications with other species belonging to the same genus.

Remaining stylodes digitiform. Up to 15 pairs of stylodes in each radiole. Small eyes, compound, not present between last pair of stylodes and radiolar tip. Collar chaetae slender, weakly geniculate, arranged in compact fascicles. Dorsal collar with lateral separated margins, ventral lappets triangular or rounded are well spaced at mid-line (Figure 2C). Thoracic region with 8 chaetigers. Thoracic uncini avicular with main fang surmounted by 2 rows of teeth, occupying about one third to half of main fang length (Figure 2E). Thoracic notochaetae arranged in irregular oblique rows of superior and inferior chaetae, each superior chaeta is slender and weakly geniculate (Figure 2D).

Abdomen with 75 chaetigers, tori smaller than those in thorax. Abdominal uncini similar to those in thorax. Pygidium rounded.

Distribution

Caribbean Sea, Gulf of California, Mediterranean Sea (Spain, Italy, Greece and Turkey), Canary Islands, Madeira Island and Tunisia (this study) and Australia.

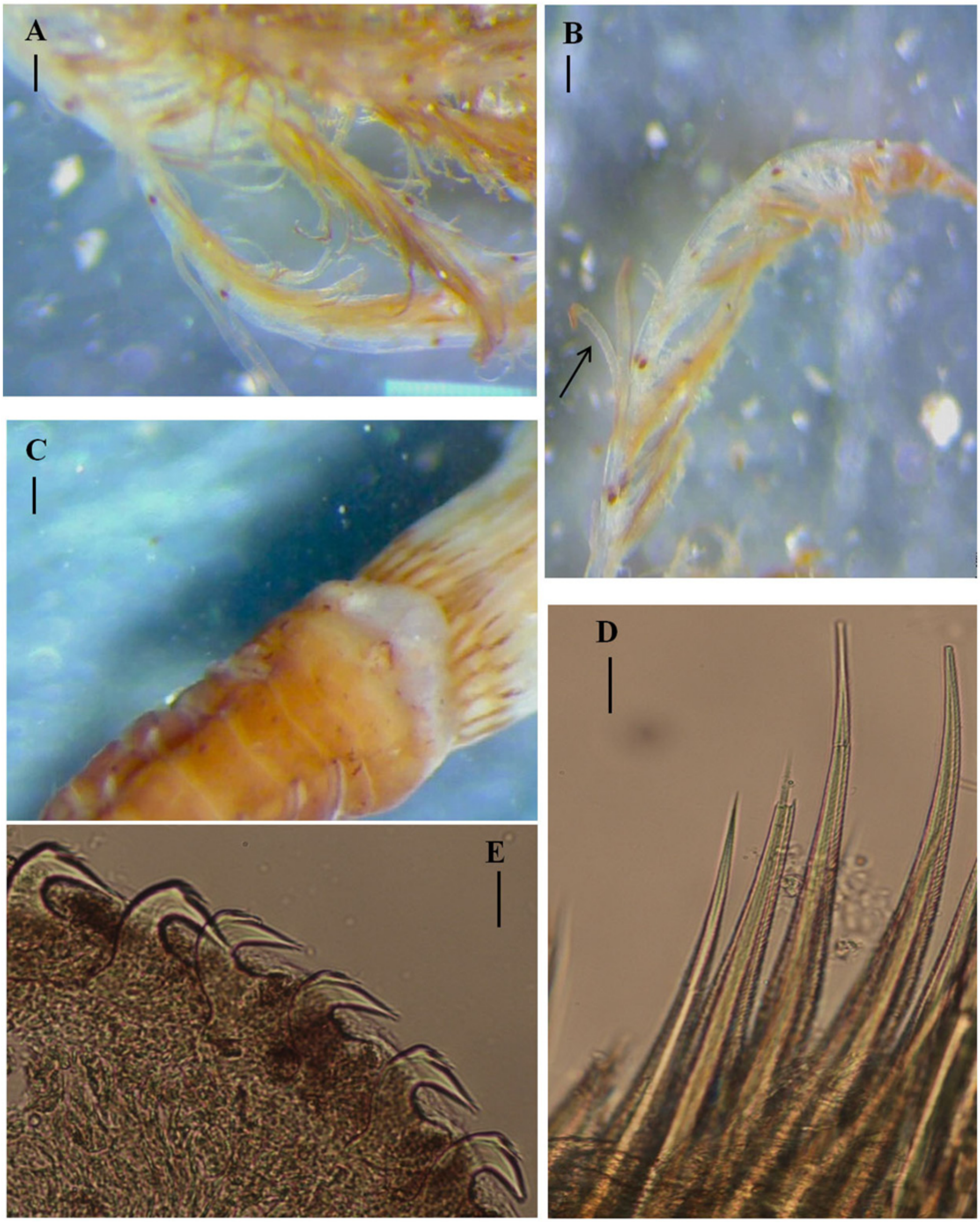

Figure 2. *Branchiomma bairdi*: (A) radioles with more flattened stylodes; (B) radiole with strap-like stylodes, (C) anterior part ventral view; (D) thoracic chaetae; (E) thoracic uncinus. Scale bars: (A-C): 750 µm; (D-E): 1µm. Photomicrographs by I. Khedhri.

Type locality

Bermuda (northwestern Atlantic).

Remarks

Branchiomma bairdi and *B. boholense*, are two alien species fairly common in the Indo-West Pacific and different parts of the Mediterranean Sea (Knight-Jones et al. 1991; Román et al. 2009). Both species have macrostylodes on radioles. According to Tovar-Hernández et al. (2009a), the remarkable differences between these two species is that *B. bairdi* has strap-like macrostylodes and two or three rows of teeth on thoracic uncini, whereas *B. boholense* has one large tooth on thoracic uncini and tongue-like macrostylodes. A recent study of Keppel et al. (2015) shows that the two species have similar uncini, with 2–3 rows of teeth, however the main difference is that *B. boholense* has 1–4 pairs of flattened, tongue-like macrostylodes whereas in *B. bairdi* two pairs of strap-like macrostylodes are present. Therefore, re-examination of specimens reported as *B. bairdi* or *B. boholense* is needed because both species are alien in the Mediterranean Sea and both have distinctive morphological characteristics.

Discussion

The densities of *B. bairdi* (1 to 35 ind.m^{-2}) recorded here in the Boughrara Lagoon were comparable with densities found in Faro Lake Messina, Italy, (Ionian Sea) with about (2 to 30 ind.m^{-2}) during the summer months of 2007 (Giangrande et al. 2012) and greater in the Maltese Island with 1 to 15 ind.m^{-2} during April 2012 (Arias et al. 2013a). However, the estimated densities of *B. bairdi* reported in Mazatlán port (Mexico) was 2500 ind.m^{-2} (Tovar-Hernández et al. 2011) and in the Madeira Island was 500 ind.m^{-2} (Ramalhosa et al. 2014), were at least 72 and 13 times respectively greater than those reported in Boughrara Lagoon.

Branchiomma bairdi is a filter feeder organism and is clearly characterized by high tolerance to several contaminated environmental conditions. In this study, specimens were recorded at four sites classified as polluted (Khedhri et al. 2015): Ajim Harbour (station 6) and Boughrara Harbour (station 8) that support many fishing activities; Gabes Gulf (station 3) which receives industrial waters loaded with phosphate and fish farming (station 7) site which has an important aquaculture activity. These four stations are characterized by high salinity levels (between 37.7 and 47 PSU), muddy sediments, repeated harmful algal blooms (HAB) (e.g. Boughrara Harbour), and by polluted waters (Khedhri el al. 2016b).

Our observations are supported by those of Tovar-Hernández et al. (2009b), Giangrande et al. (2012) and Ramalhosa et al. (2014), who documented the presence of this species with high abundance in confined areas and areas subject to anthropogenic impacts, such as harbours and marinas.

The first finding of *B. bairdi* was initially reported from the Pacific coast of Panama (Capa and López 2004) and later from the Gulf of California in the port of Mazatlán and then the species spread out to other areas/localities (Tovar-Hernández et al. 2009a, b; Tovar-Hernández et al. 2011, 2012). In the Mediterranean Sea, *B. bairdi* has been hypothesized of being introduced on ship hulls through the Suez Canal (Çinar 2009). Shipping via the Strait of Gibraltar is the most likely pathway of introduction of *B. bairdi* to the Mediterranean Sea, despite the first record of this species came from Girne Harbour (Cyprus) in 1998 (as *B. boholense*, Çinar 2005), since *B. bairdi* was already present in the western and central Mediterranean and previously misidentified as *B. boholense* (Román et al. 2009; Giangrande et al. 2012; Arias et al. 2013a, b). Moreover, the occurrence of *B. bairdi* in the Canary and Madeira Islands, in 2012 (Arias et al. 2013a, b) and in 2013 (Ramalhosa et al. 2014) respectively, further supports the shipping hypothesis via the Strait of Gibraltar with the Caribbean being the main pathway of introduction and origin of the species (Ramalhosa et al. 2014).

Ramalhosa et al. (2014), suggest that the most likely introduction pathway of *B. bairdi* to Madeira was "shipping", as a fouling species on the hull of recreational ships. Given that the Tunisian coast is relatively close to the Italian coast (Maltese Island) we hypothesize that *B. bairdi* arrived into the Boughrara Lagoon also by shipping via hull-fouling, it seems that *B. bairdi* is almost everywhere in the Mediterranean Sea. Furthermore, *B. bairdi* was collected at four sites directly connected to the Gulf of Gabes. Certainly, Gabes is an international harbour with a strategic place between the oriental and occidental basins of the Mediterranean Sea. It receives a great deal of traffic from Europe (mainly from Italy), Asia, the USA, and Mexico (Khedhri et al. 2014). Moreover, there is frequent and extensive exchange/passage of crude oil between Italy and Tunisia, especially between Naples and Maltese Island in Italy (where *B. bairdi* occurs; Arias et al. 2013a, b) and Skrika in the Gulf of Gabes. Therefore, maritime transport seems to be the most likely vector of introduction of this species in Boughrara Lagoon.

It is worth noting that in this study *B. bairdi* was abundant at stations exhibiting high salinity and in areas subject to anthropogenic impacts, such as harbours. Moreover, the species has been reported to thrive in low pH conditions, such as those recorded in the Castello CO_2 vent area, Ischia (Arias et al. 2013a). This great capacity to colonize different habitats and substrates, combined with the occurrence of multiple adaptation mechanisms may be further explain how this species is able to spread along different environments in a short time.

Branchiomma bairdi is considered an invader that ecologically harms the environment due to 1) its high capacity of proliferation colonizing for example several areas and ship hulls, 2) its feeding mode, 3) its anti-predation strategies and 4) its hermaphrodite breeding condition throughout the year by using sexual or asexual reproduction (Tovar-Hernández et al. 2011). The anti-predation strategies and the feeding mode of *B. bairdi* justify its classification as an invasive species ecologically impairing the environment (Tovar-Hernández et al. 2009b). The spread of *B. bairdi* via hull-fouling is increasing in the Mediterranean due to shipping traffic and consequently, could already be present in other adjacent areas within the Mediterranean Sea. Therefore, more studies are needed to distinguish between the possible pathways and major factors for the introduction and spread of *B. bairdi* in the Mediterranean by using phylogeographic (genetic) analysis as suggested by Arias et al. (2013b) and to understand the consequences of this invasion on the local biodiversity assemblage.

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