Research Article

Biology and new records of the invasive species *Branchiomma bairdi* (Annelida: Sabellidae) in the Mediterranean Sea

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Abstract

The first observations on the reproductive biology of the alien polychaete *Branchiomma bairdi* (McIntosh, 1885) (Sabellidae) in the Mediterranean Sea are provided as well as additional Mediterranean records of the species, which can help to understand its introduction and spreading. Re-examination of the specimens from Miseno harbour (Tyrrhenian Sea, Italy) revealed the presence of *B. bairdi* in the central-Mediterranean since September 2004. The histological study of individuals collected in Malta revealed that the species is a simultaneous hermaphrodite, developing male and female gametes in the same body segments; embryos are brooded inside the parent tube. However, there is also evidence of asexual reproduction. The species shows a different reproductive pattern from the previously reported population from the eastern-Pacific; this demonstrates its great plasticity and adaptability. *Branchiomma bairdi* has an invasive behaviour, colonizing large areas in relatively short-time, and reaching relatively high densities (c.a. 50 individuals/m^2). Its expansion to several Mediterranean localities is largely a consequence of the high capacity of this species to colonize extremely different habitats and substrates, the occurrence of sexual and asexual reproductive strategies, and the combination of both. Furthermore, *B. bairdi* appears to be particularly abundant in confined areas and areas degraded due to anthropogenic impacts. Finally, our findings strongly suggest that the pathway of introduction in the Mediterranean, previously hypothesized as the Suez Canal (Lessepsian migration), is most likely *via* the Strait of Gibraltar.

Keywords: Polychaetes, Sabellidae, alien species, reproductive biology, brooding, parasite.

Introduction

Introduction of non-native species are threatening the economic and ecological well-being of coastal marine ecosystems (Ruiz *et al.*, 2000; Schwindt *et al.,* 2001). Various vectors are responsible for the introduction of alien species to the Mediterranean Sea: migration through the Suez Canal, also termed 'Lessepsian migration' (Por, 1978); migration through the Strait of Gibraltar (Cattaneo-Vietti & Thompson, 1989); transport on vessel hulls as fouling biota or in ballast waters; intentional introduction (mariculture) and accidental introduction accompanying intentionally introduced species; market discards; escape from aquaria (Zibrowius, 1992). The alien species must be identified and studied because the understanding of their biology would be useful for environmental managers to control or eradicate these non-native species, which is often a considerably less expensive strategy than attempting to restore an area after the introduction of a non-native species (Ricciardi & Rasmussen, 1998).

The Suez Canal has been the largest pathway for the entry of invaders in the Mediterranean Sea, and almost 400 Lessepsian species – principally molluscs, fish, decapod crustaceans, polychaetes and algae - have become established in the Eastern Mediterranean, primarily in the Levantine Basin (Zenetos *et al*., 2012). The rate of these biological invasions has increased in recent decades, and collectively they have significant ecological and economic impacts on the Mediterranean Sea (Galil, 2000). To date, in the Mediterranean Sea the number of non-indigenous marine species recorded is roughly 1,000 (Zenetos *et al.*, 2008; 2010; 2012), but the biological impact of most of them is unknown (Galil, 2007). Other risks associated with introduced species are the transport of foreign pathogens and other associated non-native organisms, which may act as disease carriers (Taraschewski, 2006).

Branchiomma Kölliker, 1858 is a genus of a medium-sized polychaete Sabellidae, characterized by having paired compound radiolar eyes and well-developed

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pairs of stylodes on the outer surface of the radiolar axes. *Branchiomma* is a widespread genus comprising about 30 species, most with an inter-tropical distribution (Giangrande & Licciano, 2004), and only four considered as aliens (Tovar-Hernández *et al.,* 2009a): *B. luctuosum* (Grube, 1870)*, B. boholense* (Grube, 1878)*, B. curtum* (Ehlers, 1901) and *B. bairdi* (Mclntosh, 1885). Currently, two of these species have been reported in the Mediterranean, *B. luctuosum* and *B. bairdi,* both reaching high densities (up to 1300 individuals/m^2 estimated for *B. luctuosum* and 400 individuals/m^2 for *B. bairdi*) (Licciano & Giangrande, 2008; Giangrande *et al.*, 2012). *Branchiomma bairdi,* probably originated from the Caribbean Sea, has recently been introduced to the Gulf of California (Tovar-Hernández *et al.*, 2009a, b; 2011; 2012; 2013) and the coasts of the Mediterranean Sea (Çinar, 2009; Giangrande *et al.*, 2012).

This paper deals with the occurrence of the exotic *Branchiomma bairdi* in the Central Mediterranean Sea, with a special focus on its reproductive biology and ecology. We also report new records and review the current distribution of this species in order to establish its invasive history in European waters, which can help to understand its vector/s of introduction, habitats and substrates colonized, and its expansion dynamics throughout the Mediterranean Sea.

Material and Methods

Reproductive biology

Specimens used to study the reproductive features were sampled in Malta. The Maltese Islands are a small, low-lying archipelago in the Central Mediterranean Sea, about 80 km south of the coast of Sicily (Italy) and at least 340 km north of the coast of Libya. The island of Malta (35°50' N, 14°35' W) is the largest in the archipelago with approximately 167 km of coastline. Survey and sampling of *Branchiomma bairdi* were carried out in March 2011. Thirty specimens of *B. bairdi* were collected from the shallow subtidal rocky areas at Gozo harbour and St. Julians Bay (Fig. 1)

All collected specimens were measured (body length, crown excluded, and width of chaetiger 10 in the thorax). Specimens for the histological study were relaxed in Mg Cl$_2$ isotonic with seawater, fixed in Bouin solution for 24 h and dehydrated in an ascending series of graded ethanol. After that, they were submersed in bencilbenzoato, embedded in paraffin, serially sectioned at 6-7 μm using a Leica microtome, and double stained with Haematoxylin and Eosin to study gametogenesis.

Macrobiota associated with the tubes of Branchiomma bairdi

Tubes of *B. bairdi* from the Maltese rocky shore were randomly removed by a swift hand motion. Each tube was immediately transferred to a plastic bag to minimise the loss of associated motile organisms (Nyberg *et al.,* 2009). External macrofaunal organisms were collected alive and removed using a 1 mm sieve while plant material that covered the tubes was also analysed. Tubes were dissected by hand and tweezers. All organisms were transferred into glass vials and preserved in 70% ethanol for identification.

Re-examination of specimens and new collections

In order to set up the current records of the species in the Mediterranean, the preserved specimens from Miseno harbour 40°47' N, 14.08 E (Gulf of Naples, Italy), collected by M.C. Gambi in September 2004 were re-examined. Moreover, during 2011 and 2012 a series of surveys was carried out at different Italian localities

Fig. 1: *Branchiomma bairdi*: its current distribution along the Mediterranean Sea and the Canary Islands.

from the Tyrrhenian Sea (small harbours and private marinas as Lacco Ameno and Casamicciola, Island of Ischia 40°43'N, 13.90'E, Gulf of Naples) to the South Adriatic Sea (Brindisi harbour 40°38' N, 17º93' E, Apulian coast). Additionally, in May 2012, specimens of this species were obtained in the shallow waters of the Mazarrón harbour (37°36'N, 1º31'W, (Murcia, Spain) and on the rocky shores of Las Palmas Harbour (28°6′N, 15°25′W, Gran Canaria, Canary Islands) (Fig. 1). Lastly, we have also reviewed the previous existing records of this species along the Mediterranean Sea.

The specimens from Malta have been deposited at the Invertebrate Collection of the Department of Biology of Organisms and Systems at the University of Oviedo (Spain). The specimens from Ischia have been deposited in the personal collection of MCG at the benthic ecology laboratory of the Stazione Zoologica of Napoli (Villa Dohrn, Ischia, Naples) and in the collection of AG at the DiSTeBA department of the University of Salento (Lecce, Italy)

Results

Branchiomma bairdi is characterised by the presence of macrostylodes on the radioles which are 2-3 time longer than the microstylodes (Fig. 2A). The macrostylodes are strap-like as well as the microstylodes (Fig. 2B). This character is very clear and unique, and prevents possible misidentifications with other related species within the genus. As regards the morphology on the thoracic avicular uncini, these present a crest surmounted by 2-3 rows of teeth (Fig. 2C). Body colour in live specimens is uniform, pale or brownish with some sparse black spots. The colour of the branchial crown varies from brownish to orange often banded in cream or dark brown (Fig. 2A).

Reproductive biology and features of the Maltese population of Branchiomma bairdi

The size range of specimens of *Branchiomma bairdi* collected in Malta (length excluding the branchial crown) varied from 22 mm to 44 mm, with a medium size of 37.5 mm (N=30; SD = 6.65); the mean thorax width of chaetiger 10 was 4.65 mm (N=30; SD = 0.31). The allometric relationship between the body length and the body width was positive, but the range of variation of the width *vs* length in specimens longer than 30 mm is very low.

The histological study revealed that all individuals of the Maltese population were simultaneous hermaphrodites (Fig. 3). Male and female gametes were allocated simultaneously in the same body segments ranging from chaetigers 6-7 to 35-40. The oogenesis is asynchronous and the oogonia and earlier oocytes appeared to be associated with the wall of small blood vessel networks that irrigate the lateral coelomic cavity and the nephridia (Fig. 3B, C). Vitellogenic oocytes are released into the coelom where they mature assisted by coelomocytes, which act as nurse-cells (Fig. 3D). The mature oocytes reach a medium size of 114 μm (N= 40, SD= 1.32). The estimated number of oocytes in a mature specimen with a volume of about 100 μl (40 mm length, 4 mm wide) is about 1900. Contrarily, early clusters of spermatogonia and spermatocytes arise from the coelomic epithelium arranged in a pair of raceme-like structures located on either side of the dorsal vessel (Fig. 3A). Subsequently, the spermatids were detached from the clusters and continued the spermiogenesis in groups free in the coelom. Mature sperm pass into nephridial chambers being released through the external excretory pores (Fig. 3E, F).

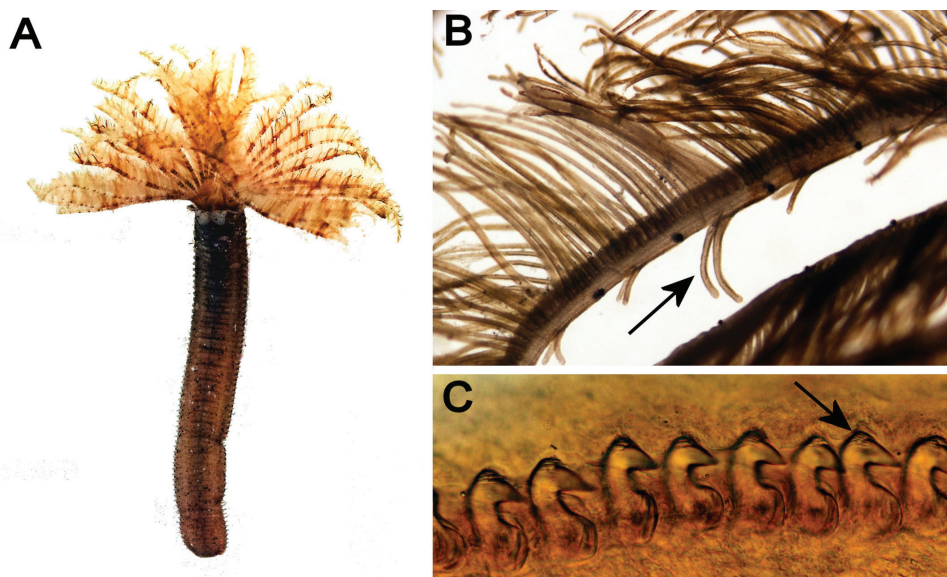Embryos and larvae of *B. bairdi* are brooded inside

Fig. 2: *Branchiomma bairdi*. A - live specimen; B - radioles with stylodes, the arrow shows a pair or macrostylodes; C - a row of thoracic uncini, the arrow shows an uncinus crest surmounted by two rows of teeth.

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the tube of the parent. Larvae are glued to the body wall, to the inter-segmental grooves of the ventral lappets of the collar. The earliest larval stage observed was the earlier trochophore (Fig. 3I). Metamorphosis was observed to the metatrochophore stage (Fig. 3J) externally with three distinct ciliate bands that were added at each segment, and with larval ocelli. Trochophore and metatrochophore larvae were observed simultaneously from individual brood tubes.

27% of the studied specimens show 4-5 thoracic segments, fewer than the usual 8 segments (Tovar-Hernández *et al.*, 2011). Specimens with reduced thoracic segments formed tube aggregates of 4–8 individuals, while specimens with a usual number of thoracic segments were found isolated.

An important finding is the occurrence of parasitic apicomplexan gregarines, observed at several developmental stages (sporozoite, earlier and mature trophozoite) (Fig. 4A-C) in the coelomic cavity of several studied worms. The prevalence of host infected worms was 50%.

Associated macrofauna to the tubes of Branchiomma bairdi from the Maltese population

Specimens of *Branchiomma bairdi* from Malta, Mazarrón and Gran Canaria have leathery tubes covered with green and brown algae and a few shell fragments. By contrast, tubes of *B. bairdi*, in the populations of Ischia are leathery but smooth and without epibionts.

The analysis of the major taxonomic groups of macrofauna living on the tubes of the Maltese population showed that molluscs constituted the largest component (59% of total number of species), followed by echinoderms (14%), arthropods (14%), annelids (9%) and nematodes (4%). Only copepods (Cyclopoida) and nematodes (Oncholaimidae) were found inside the tube, while the majority of the fauna was found on the outer tube surface (Table 1). Most of the species associated to the *B. bairdi* tubes were juveniles (> 50). We also found several specimens of the cryptic species complex of the fireworm *Eurythoe* cf. *complanata* (Pallas, 1766) (*sensu* Barroso *et al.,* 2010) and the trochid gastropod *Stomatella* sp. *E.* cf. *complanata* is considered a cryptogenic species whose alien status is questionable (Zenetos *et al.,* 2011, 2012), while *Stomatella* sp. is a genus up to date known in the Mediterranean with the Lessepsian migrant species *S. impertusa* (Burrow, 1815); however, the identification at species level of our material is still in progress. Nevertheless, both taxa represent new records from the Maltese Islands and the Central Mediterranean, although their definitive taxonomic identification is still ambiguous and is ongoing. Finally, in the Maltese and Mazarrón populations, juveniles of *Mytilus galloprovincialis* Lamarck, 1819 were observed attached near the mouth of *B. bairdi* tubes. This bivalve species, native of the Mediterranean Sea, is however invasive outside this basin.
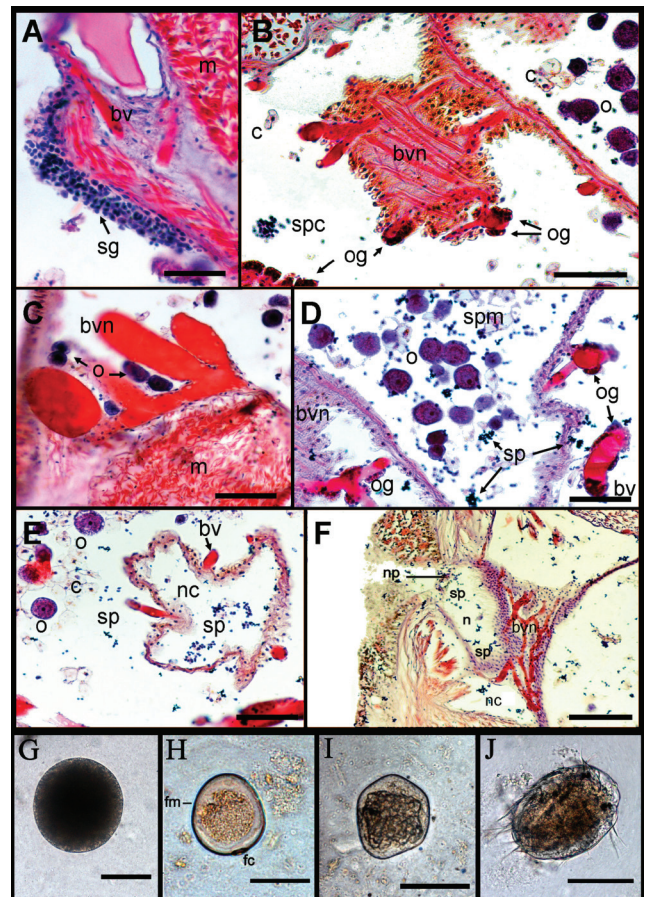

Fig. 3: *Branchiomma bairdi.* Histological sections (A-F). A – Cluster of spermatogonia (scale bar = 100 µm); B – Oogonia associated with blood vessel network (scale bar = 200 µm); C – Earlier oocytes associated with blood vessels (scale bar = 100 µm); D – Vitellogenic oocytes and sperms in the coelomic cavity (scale bar = 300 µm); E – Nephridium chamber with sperms (scale bar = 300 µm); F – General view of nephridium and nephridium chambers (scale bar = 500 µm); G – Mature egg (scale bar =100 µm); H – Fertilized egg (scale bar =150 µm); I – Earlier trochophore (scale bar = 200 µm); J – Metatrochophore (scale bar = 150 µm). bv: blood vessel; bvn: blood vessel network; c: coelomocyte; m: muscle; n: nephridium; nc: nephridial chamber; np: nephridial pore; o: oocyte; og: oogonia; sg: spermatogonia; sp: sperms; spm: spermatids.

New Mediterranean records and ecological considerations

Re-examination of specimens collected from Miseno habour (Gulf of Naples, Italy) revealed the presence of *B. bairdi* in the central Mediterranean since September 2004. The specimens from Miseno were collected at 7-10 m depth on *Posidonia oceanica* (L.) Delile patches and dead matte covered with *Caulerpa prolifera* (Forskal) J.V. Lamouroux and below a mussel (*Mytilus galloprovincialis*) aquaculture system (suspended racks).

Collections around the island of Ischia in summer 2011 and spring-summer 2012 revealed dense populations of the species (more than 50 individuals/m²) in two small touristic harbours of the island (Casamicciola and

Table 1: Species associated with tubes of *Branchiomma bairdi* in Malta.

Taxa	Group	Stages
Chiton olivaceus Spengler, 1797		juveniles
Gibbula divaricata (Linnaeus, 1758)		juveniles
Gibbula rarilineata (Michaud, 1829*)*		juveniles
Stomatella sp.		juveniles; adults
Bittium reticulatum (da Costa, 1778)		juveniles; adults
Cerithiopsis tubercularis (Montagu, 1803)		juveniles; adults
Tricolia speciosa (Mühlfeld, 1824)	Mollusca	juveniles; adults
Trivia monacha (da Costa, 1778)		juveniles; adults
Columbella rustica (Linnaeus, 1758)		juveniles
Mitrella sp.		juveniles; adults
Pisania striata (Gmelin, 1791)		juveniles
Mytilus galloprovincialis Lamarck, 1819		juveniles
Bursatella leachi Blainville, 1817		juveniles
Amphipholis squamata (Delle Chiaje, 1828)		juveniles; adults
Ophiothrix fragilis (Abildgaard, in O.F. Müller, 1789)	Echinodermata	juveniles
Ophioderma longicauda (Bruzelius, 1805)		juveniles
Eurythoe cf. *complanata* (Pallas, 1766)	Annelida	Juveniles; adults
Spirorbis sp.		adults
Cyclopoida (sp.)		juveniles; adults
Gammaridae (sp.)	Arthropoda	juveniles; adults
Pisa sp.		juveniles; adults
Oncholaimidae (sp.)	Nematoda	adults

Lacco Ameno) and in a private marina (Sporting Hotel, Lacco Ameno), all settled on recently placed floating docks (June 2012). At these locations, *B. bairdi* was the dominant fouler species. This sabellid was also frequent in another shallow area of Ischia, the Carta Romana-Castello Aragonese Bay, settled mainly among the macroalgae (mostly *Halopteris scoparia* (L.) Kutzing) and over a dead *Posidonia* matte (1-3 m depth). It is noteworthy that in the latter locality (on the south side of the Castello Aragonese coast) several specimens were found associated to macroalgae settled on a dead Posidonia matte and also the nearby *Posidonia oceanica* meadow, an area of intense CO_2 venting, which causes water acidification and strong lowering of the pH (Kroeker *et al.,* 2011). The species was recently collected in the south Adriatic Sea in the Port of Brindisi (October 2012) as part of the fouling community in association with colonial ascidians. Furthermore, from the Southern Spanish coast, *B. bairdi* was also recorded from Mazarrón Port (in May 2012) on floating docks at densities exceeding 15 individuals/m^2. Finally, in August 2012, *B. bairdi* was observed on the rocky shores from Las Palmas Harbour (Canary Islands) reaching relatively high densities (> 15 individuals/m^2). All these new records and a compilation of overall existing findings for the Mediterranean Sea are summarised in Table 2.

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Table 2: Summary of the findings of *B. bairdi* in the Mediterranean Sea. Density range: Low: 1-15 indv/m²; Medium: 15 -50 indv/m²; High > 50 indv/m².

Locality /Year	Substrate	Relative abundance	Depth	Others features	Reference
Girne Harbour (Cyprus) July 1998 (as *B. boholense*)	Rocky bottom with *Padina pavonica*	Low	1.1 m depth		Çinar, 2005; 2009
Miseno harbour, Bay of Pozzuoli, Tyrrhenian Sea (Italy) September 2004	Dead matte of the seagrass *Posidonia oceanica*, densely covered by the green algae *Caulerpa prolifera*	Medium	7 m depth	Below the local mussel (*Mytilus galloprovinciallis*) shellfish aquaculture structures (suspended raks)	Current work
Iskenderun Bay (Turkey) September 2005	Rocky bottom with *Cystoseira* sp.	Low	0 -1 m depth		Çinar, 2009
Mar Menor Lagoon (Spain) January 2006 (as *B. boholense*)	Rocky bottom	Medium	Midlittoral 0.2 m depth Infralitoral 2 m depth		Roman *et al.*, 2009
Lake of Faro, Ionian Sea (Sicily) July 2007	Soft sediments	Medium	2 m depth	Occurring sympatrically with other sabellids, viz. *Myxicola infundibulum, Branchiomma luctuosum* and *Megalomma lanigera*	Giangrande *et al.,* 2012
Gozo Harbour (Maltese Island)	Rocky bottom	Low	Midlittoral 0.5 m depth	Occurring together with a high diversity of invertebrates, viz. the alien gastropods *Stomatella* sp. and *Bursatella leachii*	Current work
St. Julians Bay (Maltese Island) April 2012	Rocky bottom	Low	Midlittoral 0.5- 1 m depth		
Mazarrón Port, Murcia (Spain) May 2012	Floating docks	Medium	0.5-1 m depth	Occurring sympatrically with the native *Sabella spallanzanii*	Current work
Castello Aragonese, Tyrrhenian Sea Ischia (Italy) July 2011	Dead matte of *P. oceanica,* covered by macroalgae	Low	-3 m depth	At CO_2 vents and acidified water conditions	
Lacco Ameno and Casamicciola harbours, Ischia (Italy) October 2012	Floating docks	High	0.5-1 m depth		Current work
Carta Romana Bay, Ischia (Italy) October 2012	Dead matte of *P. oceanica,* covered by macroalgae	Medium	2-3 m depth	In normal pH conditions	
Brindisi Harbour, Adriatic Sea (Italy) October 2012	On artificial hard substrata	Low	Mid littoral 1 m depth	Embedded within colonial ascidians	

Discussion

The first finding of *B. bairdi* in the Mediterranean Sea was in the Eastern basin (Çinar, 2009), but this species was probably already present in the Western and Central Mediterranean and could have been misidentified as *B. boholense* (Sciberras & Schembri, 2007; Roman *et al.*, 2009; Giangrande *et al.,* 2012). According to Tovar-Hernández *et al.* (2009b, 2011), the main diagnostic features between these related species are the shape of the macrostylodes and the number of teeth in thoracic uncini. In *B. boholense*, macrostylodes differ significantly from all the other stylodes, being tongue-like; while thoracic uncini have a single tooth on top of the large main tooth. In *B. bairdi* the macrostylodes are strap-like (Fig. 2B), both the large and the smaller adjacent ones; and the thoracic uncini have two or three rows of teeth on top of the main large tooth (Fig. 2C).

As regards the reproductive biology, the trade-off between egg size and egg number in *B. bairdi* from Malta differs from that observed in the non-indigenous population from the Gulf of California (Tovar-Hernández *et*

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al., 2009b, 2011). In Malta, *B. bairdi* produced a lower number of eggs with a larger size, while the opposite occurred in the Gulf of California. Both in Malta and in the Gulf of California, *B. bairdi* brooded eggs and embryos inside the tubes where they adhered to the body wall with mucus. However, differences were observed in the development of the brooded larvae. In Malta, broods ranged from earlier trochophore to metatrochophore (with 3-4 segments) (Fig. 3I, J), while in the Gulf of California only earlier trochophores were recorded inside the tubes (Tovar-Hernández *et al.,* 2011). Another difference observed between the two populations, concerns average body length and width. The Maltese specimens are longer (37.5 mm) and wider (4.65 mm) than the Californian ones (mean body length: 16.98 mm; mean thorax width: 2.35) (Tovar *et al.,* 2009b).

The presence of modified in *B. bairdi* nephridial chambers could be evidence of some sort of sperm storage; these chambers probably act as seminal vesicles due to the large quantity of sperm that the species produces. Moreover, in isolated specimens from Malta, the simultaneous occurrence of mature sperm and oocytes may indicate self-fertilization. Another interesting finding in the Malta population of *B. bairdi* is the possible occurrence of asexual reproduction. Several specimens (ca. 27%) in fact showed a lower than (4-5) the usual (7-8) number of thoracic segments; according to Tovar-Hernández *et al.* (2011), when this pattern occurred worms reproduced asexually. This is corroborated by the observation that specimens with reduced thoracic segments appeared in small tube-aggregates of 4–8 individuals. By contrast, isolated specimens (presumably reproduced sexually) showed the usual number of thoracic segments (7-8).

To date, the parasite gregarine apicomplexan had not been described on *Branchiomma* spp. or on other sabellid polychaetes, constituting a newly reported symbiotic association. If this parasite is also an alien species, it may switch to other native worm hosts, with which they have no previous history of association *via* ecological fitting, facilitating the dispersion of the protozoan and representing a potential risk for native marine worms if it also becomes invasive.

Currently, specimens of *B. bairdi* in Maltese waters are large enough for local fishermen to begin harvesting specimens as bait for the common sea bream, *Pagellus bogaraveo* (Brünnich, 1768) (A. Arias, pers. obs.). This fact suggests that the common sea bream could be the first known predator of *B. bairdi.* To date, in fact, there are no known predators of *B. bairdi*, presumably because the species has chemical defences that prevent predation (Kicklighter & Hay, 2007). If the use as fishing bait is generalized, anglers could unintentionally introduce *B. bairdi* to other areas, because a common habit among recreational fishermen is to discard unused or fragmented bait worms into the water (Lau, 1995; Weigle *et al.,* 2005).

As regards the tubes, *B. bairdi* specimens from Malta, Mazarrón and Gran Canaria presented ornamented tubes with foreign material including algae and shell fragments, and even with juveniles of the Mediterranean mussel attached. These little mussels are arranged near the opening of the tube, presumably to take advantage of water currents that are generated by the host sabellid. This great ornamentation observed at these three locations could be an indicator of a long-term colonization of the tubes. On the contrary, the Ischia specimens showed clean tubes due probably to recent substrate colonization by the species and poor fouling development in the artificial substrate.

The large number of species associated with *B. bairdi* tubes (mainly juvenile molluscs and some potentially alien taxa) suggests that *B. bairdi* can also somehow influence local communities. The possible effects include provision of refuge from predators, enhanced habitat/substrate for larval settlement and provision of a suitable habitat for a broad range of fauna mainly small molluscs. These effects have been observed in other tubiculous polychaete species (Woodin, 1981; Bell & Woodin, 1984; Dudley *et al.,* 1989; Zuhlke, 2001). Therefore, when *B. bairdi* reaches high densities it may have important effects on the local community, including alteration of the turbulence and boundary layer features for larvae (Luckenbach, 1987), provision of space for settlement (Bell & Coen, 1982; Bell, 1985), bio-irrigation or nutritional supply (Mayer *et al.,* 1985; Phillips & Lovell, 1999), or incorporation of plant material providing an extra habitat for invertebrates (Thomsen *et al.,* 2010).

From the new records of *B. bairdi* documented in this work (Maltese Islands, Miseno, Ischia and Brindisi), this species seems to be particularly abundant in confined areas and areas subject to anthropogenic impacts, such as harbours and marinas, where the species represent an early fouling colonizer. This feature is consistent with records of the species in the waters off the Gulf of California. In addition, the species has been documented to thrive in low pH conditions (ocean acidification), such as those recorded in the Castello CO_2 vent area, Ischia. This great capacity to colonize different habitats and substrates, combined with the occurrence of multiple reproductive strategies, sexual, asexual, and a combination of both, could be a pre-requisite for its high invasion potential, and may further explain how this sabellid is able to colonize and spread along wide areas in a relatively short time. Although the species was reported only recently for the Italian coast (Giangrande *et al.*, 2012), specimens of Miseno harbour date back to the occurrence of this species along the Italian coast since September 2004. Furthermore, Giangrande *et al.* (2012) confirm the preference of this species for confined water bodies. In their study (based on the Faro Lake population, Ionian Sea), the species showed a similar medium size (ca. 36 mm) as the Malta populations. In Faro Lake, *B. bairdi*
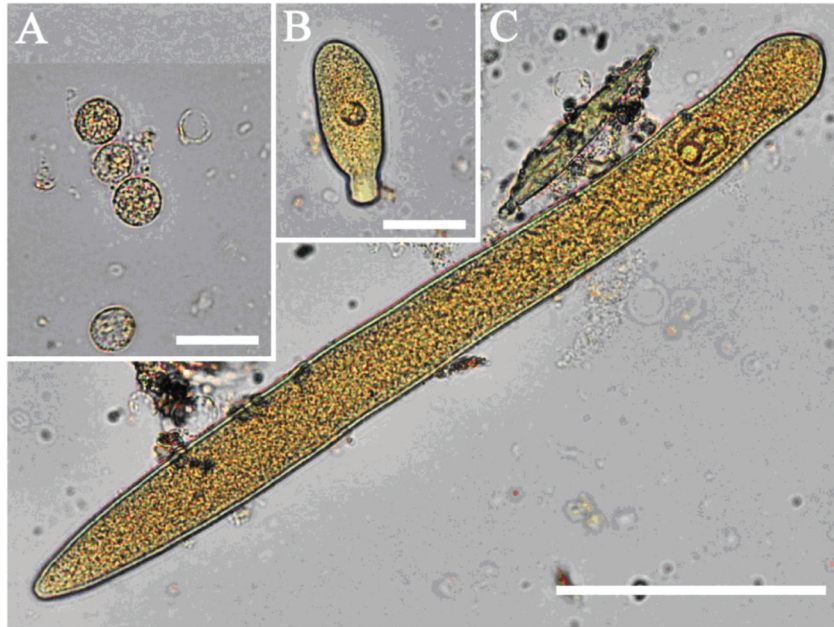
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Fig. 4: Gregarine apicomplexan inside the coelomic cavity of *Branchiomma bairdi*. A – sporozoite stages (scale bar = 5 μm); B – earlier trophozoite stage (scale bar = 10 μm); C – mature trophozoite stage (scale bar = 30 μm).

was found for first time in summer 2007 with a low number of individuals, but in summer 2011 its population dramatically increased reaching 400 individuals/m². The specimens from Faro Lake, settled on hard substrate and were often associated with ascidians (mainly *Ciona* spp.), which covered the basal and middle part of the tube (Giangrande *et al.,* 2012). A similar association with colonial ascidians was observed in the population of Brindisi harbour.

The examination of all current findings of this species in the Mediterranean suggests that *B. bairdi,* hypothesized from the first records to have been introduced on ship hulls through the Suez Canal (Çinar, 2009), was probably first introduced through the Strait of Gibraltar. In fact, although the first record is from Girne harbour (Cyprus) in 1998 (as *B. boholense,* Çinar, 2005; 2009), most of the more recent records are from the western and central Mediterranean basins; and the population densities of the western and central Mediterranean are higher than those of the eastern basin. Recently, Ros and Guerra-García (2012) have proposed the Strait of Gibraltar as the main pathway of introduction to the Mediterranean Sea for a Caribbean alien species, namely, the amphipod caprellid *Paracaprella pusilla* Mayer, 1980. This amphipod is associated with fouling communities, like *B. bairdi*, and is dramatically spreading along the western and central Mediterranean (Ros & Guerra-García, 2012). Moreover, the occurrence of *B. bairdi* in the Canary Islands, considering the Caribbean origin of the species, further supports the hypothesis of the Strait of Gibraltar being the main pathway of introduction. However, multiple ways and times of introduction cannot be excluded, and only a focused phylogeographic (genetic) analysis may clarify this point.

Conclusions

Branchiomma bairdi represents a further case of a species that has been relatively recently introduced into the Mediterranean, which has been underestimated and misidentified. This sabellid displays a highly invasive capacity and great potential for colonization, which is particularly favoured in stressed, low competition habitats. The dense agglomerate of tubes may influence local benthic fauna, while the occurrence of a gregarine apicomplexan parasite represents a further potential risk for other organisms. The invasive potential of the species seems to be favoured by its high biological plasticity and reproductive habits, which include both sexual and asexual reproduction.

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