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First record and establishment of *Branchiomma coheni* (Polychaeta: Sabellidae) in the Atlantic Ocean and review of non-indigenous species of the genus

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Abstract

Sabellidae are among the most visible polychaetes of the hard substrate fouling communities and are colonizing new geographic areas. The fouling community was surveyed in 25 shallow coastal estuaries on the Atlantic and Pacific coasts of the United States with the specific goal of detecting non-indigenous species. During surveys in 2012 and 2014, specimens of *Branchiomma coheni* Tovar-Hernández and Knight-Jones, 2006 were found for the first time in Tampa Bay, Florida, occurring at the same marina site (27°53'7.58"N, 82°32'2.29"W) each year and suggesting it is established here. The species was not detected at other sites surveyed in the United States, and has not been reported from the eastern Atlantic or the Mediterranean basin. Type material of *B. coheni*, specimens from southern Gulf of California, and specimens from the Pacific coast of Mexico, were used to corroborate identification. The transfer of this species by ships via the Panama Canal is a probable mechanism of introduction, based on the current known distribution and shipping traffic patterns. This represents the first record of the species in the Atlantic Ocean. A worldwide update of the records of this species and a list of valid species of the genus *Branchiomma* with notes on introduced populations are provided, as well as recommendations for accurate identification and sampling.

Key words: Sabellid, non-indigenous species (NIS), Panama Canal, biological invasions, shipping, fouling, Gulf of California, Gulf of Mexico, Florida

Introduction

Anthropogenic dispersal and introduction of marine non-indigenous species (NIS) has been known since the opening of transoceanic maritime routes in the 16th Century. It is not by chance that the first case of NIS can be attributed to shipworms (Laidlaw 1952, Edmondson 1962) that took a ride around the world, boring into the hulls of wooden ships. Invasions by NIS have received much attention in recent decades, contributing to increased understanding of the magnitude of species transfers, invasion processes, and consequences for biogeography and invaded communities. For example, over 300 marine NIS are documented and considered established in the Mediterranean Sea (Zibrowius 1991; Galil 2000; Galil & Goren 2014), over 200 NIS are reported to occur in the single estuary of San Francisco Bay, California, USA for invertebrates and algae alone (Ruiz *et al.* 2011) and over 250 NIS are reported for Australia (NIMPIS 2009).

A variety of mechanisms are involved in the NIS transfer in marine environments, including: (i) transport through hull fouling of maritime vessels; (ii) translocation by aquaculture or fisheries; (iii) connecting of waterways through canals; (iv) release of species associated with the pet industries or management practices; and (v) transfer of ballast water and dry ballast of ships (Ruiz *et al.* 1997). On a global scale, ships have been a dominant transfer mechanism for invasions (Hulme 2009), driven by species associated with ballast water and biofouling communities on hulls and underwater surfaces (Carlton 1985; Fofonoff *et al.* 2003). The detection rate of NIS invasions from ships has increased greatly over the past 200 years, coincident with increases in global trade and expansion of shipping through the Suez and Panama Canal.

Expansion of both the Suez and Panama Canals are expected to be completed in 2015, potentially doubling the throughput capacity for ships on each route. This expansion has led to concerns about the associated increase in the delivery and establishment of NIS through these critical corridors (Galil *et al.* 2015a, b; Muirhead *et al.* 2014). Despite the potential effects on regional and global invasion dynamics, there has been remarkably little assessment of the invasion risks and subsequent impacts associated with either canal expansion (Galil *et al.* 2015a, b).

Unlike the Suez Canal, through which at least 350 NIS have arrived to the Mediterranean Sea (Galil *et al.* 2015a), little is known about the effect of the Panama Canal on the distribution of marine biota, despite its operation for 100 years. In general, it appears that the freshwater of Panama Canal may represent a much greater barrier for marine NIS dispersal than Suez Canal, which is a high salinity corridor between ocean basins (Cohen 2006; Miller & Ruiz 2014). Although many marine organisms entering the Panama Canal directly or associated with the hulls of ships are unlikely to survive a transit, it is also increasingly clear that some species have survived transits and successfully invaded the adjacent ocean basin (Ros *et al.* 2014; Schloeder *et al.* 2014; Lohan *et al.* 2015). The overall magnitude of species transfers through the Panama Canal, and their effects on biogeography of many groups, remains poorly understood.

Shelled and tube-forming marine organisms may experience some increased opportunity for surviving transit of the Panama Canal on the hulls of vessels, relative to other unprotected organisms, when controlling for physiological tolerance and other attributes. For example, barnacles, bivalve molluscs, and tube worms may have a temporary refuge exposure to freshwater simply by retreating into their shells or tubes during the 10–12 hours required for a vessel transit.

Members of Sabellidae, a sedentary family of tube-building polychaetes, are among the most visible worms belonging to the fouling community. These polychaetes have in common a branchial crown that has essentially two functions: gas exchange and trophic function, being the filter feeder apparatus. As sessile organisms, they build their own tube, which may provide protection from predators and unfavorable environmental conditions, and they are known to retreat into the tubes when threatened or physically disturbed. Invasions have been reported for at least 19 species of this family (Çinar 2013 & references therein; Capa *et al.* 2014a), resulting from four of the five transfer mechanisms outlined above with the exception of pet trade (iv), although sabellids are likely associated with live coral “rock” in the aquaria trade.

Invasions by sabellids have received widespread attention, due to the arrival of the Mediterranean fanworm *Sabella spallanzanii* (Gmelin, 1791) in Australia. Originally described and known only from the Mediterranean and the Atlantic coast of Europe, *S. spallanzanii* was detected in Australia in the 1990s, likely arriving on the hull of a ship, and it is now widely distributed on the southern coast of the continent (Murray & Keable 2013). More recently the species was found in New Zealand, where it reaches high abundances (Read *et al.* 2011). Except for Australia and New Zealand, and despite the old record (1856) from Brazil (Murray & Keable 2013), it is not known to be introduced in other regions. Invasions by this species have caused concerns, because it (a) competes for space or consumes larval stages of invertebrates, including those of economic importance, affecting their recruitment (Holloway & Keough 2002), and (b) can lead to the habitat modification (Coleman & Williams 2002; Teske *et al.* 2011). *Sabella spallanzanii*, having an invasion history, has been listed by various groups as a pest species with high potential for significant ecological and economic impacts (Currie *et al.* 1998; Lowe *et al.* 2004; Hayes *et al.* 2005; NIMPIS 2013; Fletcher 2014).

Among the sabellids, several invasions have been reported in the genus *Branchiomma* Kölliker. This genus is taxonomically complex and large, with approximately 29 recognized species, having the unique character of paired stylodes (epithelial flaps) on the outer surface of radiolar axes of the crown, considered as an autapomorphy (Capa *et al.* 2014b). The shape and relative size of stylodes are highly variable: they can be digitiform, strap-like, foliose, palmate, dendritic, bifurcate, tongue or paddle-shaped, but they are at the moment diagnostic features used in species identification (after Tovar-Hernández & Knight-Jones 2006). The most recent list of alien polychaete species worldwide includes six species of *Branchiomma* (Çinar 2013). Cases of high phenotypic plasticity in species from Australia and probably all around the world, high infraspecific genetic variability, cryptic species and unexpected cases of translocations of species beyond those previously reported were documented by Capa *et al.* (2013). In addition, the possible presence of invasive hybrids cannot be excluded.

In this study, we report a new translocation of *Branchiomma coheni* Tovar-Hernández and Knight-Jones, 2006 in Tampa Bay, Florida, USA, representing the first record of this species for the Atlantic Ocean. We provide an update of the valid species list for *Branchiomma* and provide information on introduced populations of the species

in the genus around the world. In addition, we include recommendations to accurately identify species of *Branchiommma*. This contribution is part of a large-scale survey of North America, conducted in advance of completion of the Panama Canal expansion. Our results for *B. coheni* suggests that some species in the genus can survive transit of the Panama Canal and colonize new regions via this corridor.

Material and methods

Settlement plates were put out on the Pacific, Atlantic, and Gulf coasts of North America to survey for NIS (Fig. 1) from 2000 until 2014. Embayments were chosen to focus on high salinity communities in relatively large estuaries, in close proximity to major population centers and port systems. For each of the 25 bays, a stratified sampling design was used, selecting approximately ten sites (marinas, ports, bridges, piers and buoys) with salinity >20 PSU. Inside this broader survey, during the summer of 2012 and 2014, Tampa Bay, Florida, USA was sampled in 15 and 10 sites respectively (Fig. 2). 10 sites are common for both the years.

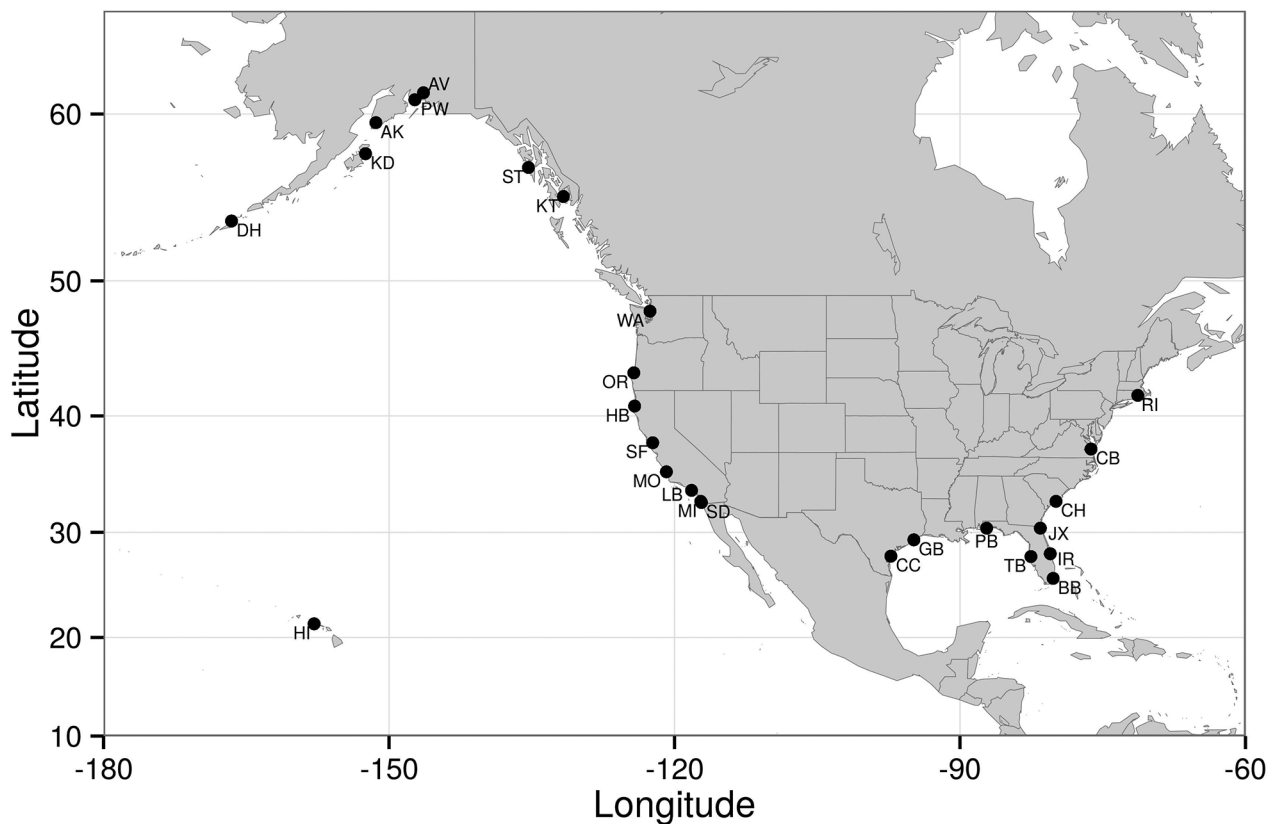


FIGURE 1. Map of the NIS surveys in the Pacific, Atlantic, and Gulf coasts of North America from 2000 through 2014. *Branchiommma coheni* was found only in Tampa Bay (TB), Florida.

Five Poly Vinyl Chloride (PVC) settlement plates (14 × 14 cm), facing the bottom of the sea, were suspended 1 m below mean low water within each of 15 sites. Settling plates were deployed in late spring or early summer and retrieved after three months. Once retrieved, sessile invertebrates were collected live, sorted, and preserved in ethanol for identification. This material is part of the reference collection of the Invasion laboratory at the Smithsonian Environmental Research Center (SERC) in Edgewater, Maryland.

Environmental parameters measured at deployment and retrieval at each site included: depth, temperature, salinity, and turbidity (secchi depth). Temperature was also recorded continuously during the three months deployment. Study sites were as deep as 10 m. Temperature and salinity were fairly stable throughout the water column within each site and did not exhibit stratification. Temperature for all sites ranged from 18–30.5 °C over the three month period of deployment. At the Tampa Harbour site in 2012 (2118), during the panels' deployment, the salinity and temperature were 28.8 PSU and 23.6 °C, respectively, while at the time of panels' retrieval the salinity

was 30.8 PSU, the temperature was 27.8 °C and the dissolved oxygen was 4.2 (mg/l). At the Tampa Harbour site in 2014 (2240) during the panels' deployment the salinity and temperature were 25 PSU and 20.4 °C, respectively, while at the time of panels' retrieval the salinity was 26.2 PSU, the temperature was 29.46 °C and the dissolved oxygen was 4.71 (mg/l).

Additional materials of *Branchiomma coheni* were examined from Colección de Referencia, El Colegio de la Frontera Sur, Unidad Chetumal (ECOSUR), Colección de Referencia de Invertebrados, Instituto de Ciencias del Mar y Limnología, Universidad Nacional Autónoma de México (EMU-ICML) and Colección de Invertebrados Exóticos de Geomare, A. C. (GEOMARE).

For the genus and NIS review the list was reviewed and discussed starting from WoRMS (2015) and its nested database WRIMS (Pagad *et al.* 2015) that is not populated for this genus yet. All the existing literature mainly based upon published scientific papers and books was checked. Potentially undescribed species investigated by Capa *et al.* (2013) or elsewhere were not included here to avoid confusion, although some of these species likely have been translocated in some worldwide localities.

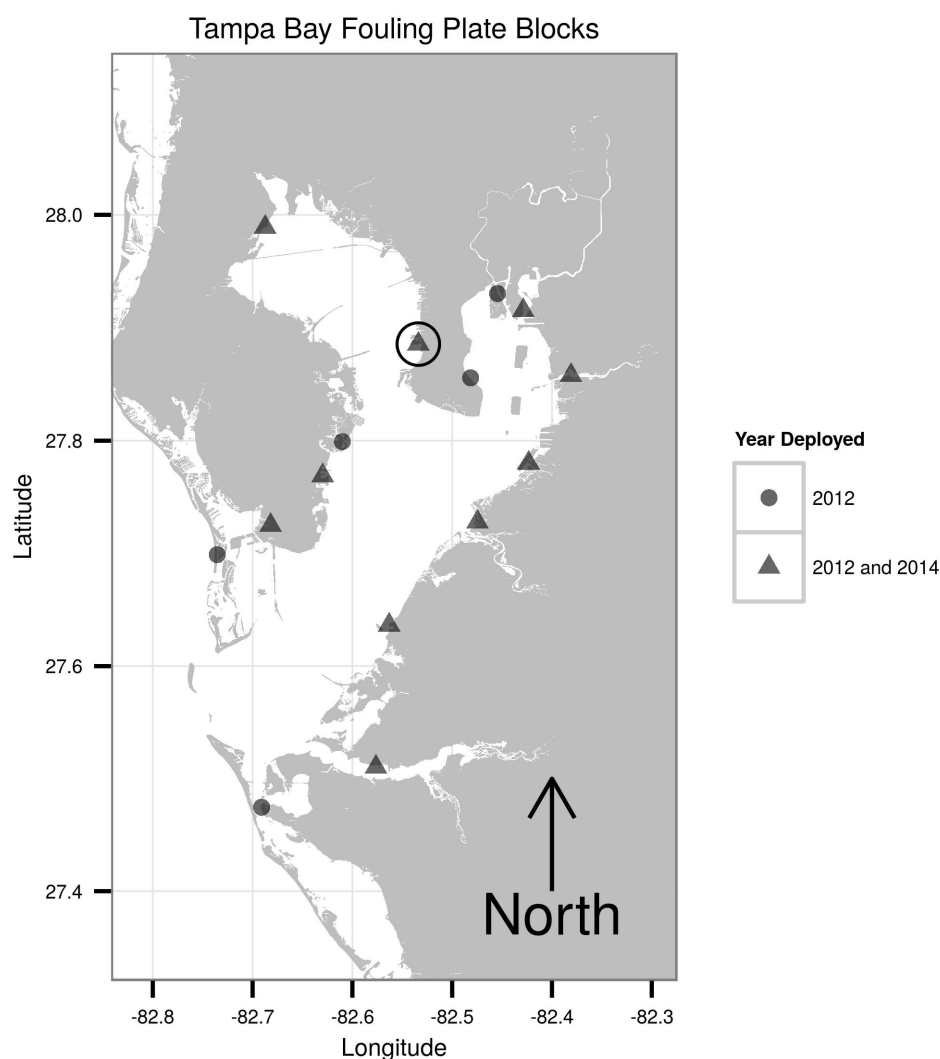


FIGURE 2. Map of Sites in Tampa Bay (Florida). The triangles are sites sampled in both 2012 and 2014, while the full circles were sampled only in 2012. The site indicated by the circled triangle shows where *Branchiomma coheni* was recorded.

Results

Systematics

Order SABELLIDA Latreille, 1825

Family SABELLIDAE Latreille, 1825

Genus *Branchiomma* Kölliker, 1858

Branchiomma coheni Tovar-Hernández and Knight-Jones, 2006: 24–27, Fig. 6A–M, 8A, 9E–G, 10D, 11C.

Examined material. Tampa Bay, Florida, coordinates 27° 53' 07.4" N, 82° 32' 02.7" W (4 specimens). One specimen is from the survey of 2012 and 3 are from 2014 from the same site of 2012, nevertheless the site numbers are different numbers due to the different years, and are from 2 different plates. Site 2118 (2012): plate 15009: vial # 168941 (1 specimen). Site 2240 (2014): Plate 16838: Vial #: 158629 (1 specimen), 199914 (1 specimen); Plate 16829: 158394 (1 specimen). Some tissue was collected from 2 specimens and preserved in 95 Ethanol for possible molecular analysis (158629 and 158394) in order to have the same organism for both the analysis. The four specimens are listed in Table 1 with some size measures and observations on reproductive biology.

TABLE 1. Length and observations on the reproductive biology of *Branchiomma coheni* found in Tampa Bay, Florida. Presence of character or detail indicated by +, absence indicated by -. All plates represented by a single specimen of *Branchiomma coheni*

Year	Block	Plate	Vial	Length (cm)	Molecular specimen	SERC collection Location	Oocytes	Sperm	Notes
2014	2240	16838	158629	3.7	+	Drawer 13 Box 103 B16	+	+	No radioles, broken. Simultaneous hermaphrodite,
2014	2240	16838	199914	3.7	-	Drawer 13 Box 103 C2	+	-	Female, only eggs present, no evidence of regeneration.
2014	2240	16829	158394	5	+	Drawer 13 Box 103 E16	+	+	Simultaneous hermaphrodite. Smaller variation of stylodes
2012	2118	15009	168941	3.8	-	Drawer 11 Box 86 C11	+	+	Simultaneous hermaphrodite. Smaller variation of stylodes

Comparative additional material. Panama, Punta Culebra, Naos, 08° 54.7' N, 79° 31.8' W, intertidal (Paratype ECOSUR 0051).

Gulf of California: Mazatlán, Sinaloa (2009), 23°12' 13" N, 106° 24' 31.4" W, 50 cm depth, buoy fouling (20 specimens EMU-ICML 8703, 8715, 8719, 8724, 8726, 8729); 23°12' 13" N, 106° 24' 30.1" W, 50 cm depth, buoy fouling (23 specimens EMU-ICML 8704, 8707, 8710, 8716, 8720, 8722); 23°11' 48.7" N, 106° 24' 31" W, 50 cm depth, buoy fouling (129 specimens EMU-ICML 8705, 8708, 8711, 8713, 8717, 8721, 8723, 8725, 8727, 8730, 8731, 8733); 23°11' 8.9" N, 106° 24' 55.8" W, 50 cm depth, buoy fouling (8 specimens EMU-ICML 8706, 8709, 8712, 8714, 8718, 8728, 8732, 8734). Topolobampo, Sinaloa (2011), 25°35' 59" N, 109° 03' 29" W, 50 cm depth, dock fouling (13 specimens GEOMARE-POLY-004); El Mavirí (2011), 25° 35' 15" N, 109° 06' 05" W, 30 cm depth, on *Crassostrea gigas* cultures (4 specimens GEOMARE-POLY-005). San Carlos, Sonora (2011), 27° 56' 44.52" N 111° 5' 32.82" W, 30 cm depth, rope (8 specimens GEOMARE-POLY-006). La Paz, Baja California Sur (2011), 24° 9' 17.76" N 110°19' 33.96" W, 50 cm depth, dock fouling (18 specimens GEOMARE-POLY-007); 24°16' 28.62" N 110°19' 51.12" W, hull fouling (11 specimens GEOMARE-POLY-008).

Diagnosis. Body length of four adult specimens varied from 37 to 50 mm. Body dark brown mottled with small brown spots (Fig. 3b). Interramal dark spots, larger on thoracic segments than in abdominal region. Radiolar crown (1/3 of the body length) is usually around 10 mm length. About 21–23 pairs of radioles, each banded with green olive, dark brown bands and one orange band between each pair of eyes. Basal stylodes unpaired, medium length, tongue-like, same size as rachis width. At least three foliose macrostylodes, broadening distally, sometimes

with very uneven distal margins (Fig. 3a–c). Dorsal lips one third length of radioles, triangular with a distinct orange longitudinal ridge (mid-rib), lateral margin olive-green. Body with eight thoracic segments; collar dorsal margin well separated, ventral lappets subtriangular, fleshy and overlapping in reflexed position (Fig. 3b). Thoracic tori extending to sides of brown trapezoidal ventral shields. Avicular uncini with the crest surmounted by two rows of teeth, occupying one quarter of the crest and manubrium short (Fig. 3d).

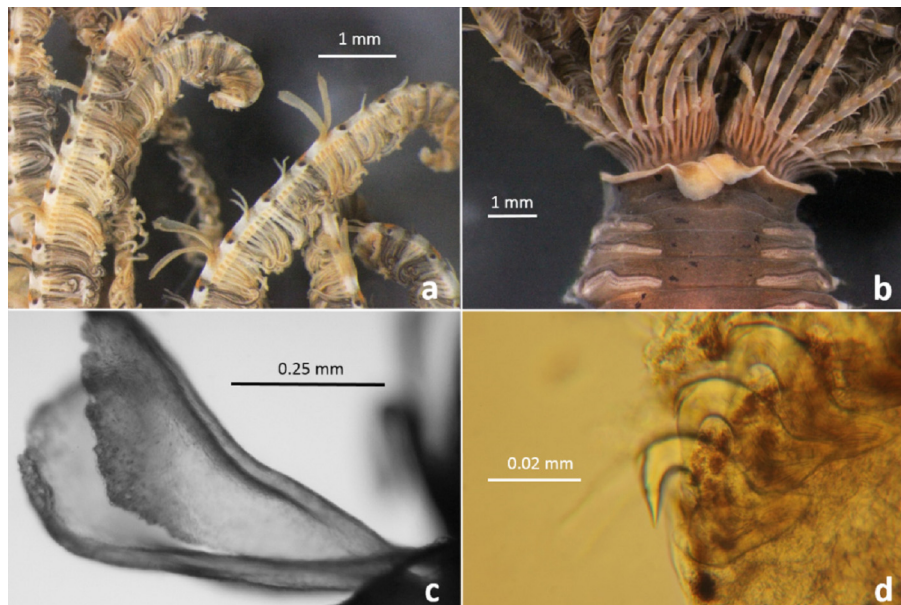


FIGURE 3. *Branchiomma coheni* found in Tampa Bay: a) stylodes; specimen 158394 (2014), b) ventral view showing thorax, collar, lappets and base of radioles; specimen 168941 (2012), c) macrostylodes, specimen 199914 (2014), d) thoracic uncini, specimen 199914 (2014).

Distribution (Fig. 4). Eastern Pacific (Possibly native): Punta Culebra and Balboa (Panama); Mazatlán, Topolobampo, San Carlos and La Paz (Gulf of California).

Western Atlantic (Introduced): Tampa Bay (Florida).

Habitat. Panama: intertidal, on large boulders and rocks buried in sand and associated tide pools, with smaller rocks covered by sponges and additional fouling species (Tovar-Hernández & Knight-Jones 2006).

Gulf of California: inhabiting shallow waters (0.3–0.5 m depth) on buoys, docks, ropes, on vessel hulls and on oyster farms; salinity 32.1–34.8‰; temperature 21.5–31.5°C; dissolved oxygen 3.15–6.66 mg/L; forming part of an assemblages of 12 introduced species: the polychaetes *B. bairdi* (McIntosh, 1885), *Hydroides diramphus* Mörch, 1863, *H. elegans* (Haswell, 1883), *H. sanctaecrucis* Krøyer in Mörch, 1863; the ascidians *Botryllus schlosseri* (Pallas, 1766), *Botrylloides nigrum* Herdman, 1886, *B. violaceus* Oka, 1827, *Didemnum perlucidum* F. Monniot, 1983 and *Polyclinum constellatum* Savigny, 1816; the bryozoans *Bugula neritina* (Linnaeus, 1758) and *Amathia verticillata* (delle Chiaje, 1822); and the copepod *Haplostomides hawaiiensis* Ooishi, 1994.

Florida: on settling panels (present study). *Branchiomma coheni* was found not in the presence of *B. bairdi* but was always found with the sabellid *Parasabella microphthalmia* (Verrill, 1873).

Remarks. According to Camp *et al.* (1998) and Statewide Biological Database (2013), four species of *Branchiomma* are reported along the coast of Florida: *Branchiomma arenosa* (Treadwell, 1924), *B. bairdi*, *B. conspersum* (Ehlers, 1887) and *B. nigromaculatum* (Baird, 1865). However, *B. arenosa* is not valid, it is a junior synonym of *B. conspersum* (Tovar-Hernández & Knight-Jones, 2006). As far as we know, Florida is a natural distribution area for all these three species; the record of *B. coheni* constitutes the first record of an introduced species of *Branchiomma* along the east coast of the US and the entire Atlantic Ocean.

Branchiomma coheni was described from the Pacific coast of Panama in 2006 and the records provided here from Tampa Bay and Gulf of California constitute the first published record since its description. As *B. coheni* was found at the same site in two different years and in 2014 on two different settlement panels of the five investigated in that site, we assume that it represents a case of an early detection of a NIS that appears to be established (*sensu* CIESM 2012).



FIGURE 4. Distribution of the species of *Branchiomma coheni* around the world.

Among the species distributed in Florida, it is easy to differentiate *B. nigromaculatum* from the other species because it is unique in having microstylodes and rachis with a segmented appearance. *Branchiomma bairdi*, *B. conspersum* and *B. coheni* present macrostylodes, but in the first these are strap-like, in *B. conspersum* tongue-like and in *B. coheni* foliose (see Fig. 9 in Tovar-Hernández & Knight-Jones 2006 for the shape of stylodes).

***Branchiomma* species**

The *Branchiomma* species in WoRMS (2015) are not completely updated, in fact, its list reports 34 species but some are not valid names. After our review, we refine the list of *Branchiomma* to 29 confirmed species (Table 2), as some belong to other genera: *B. claparedei* is *Megalomma claparedei* Gravier, 1906 and a Lessepsian migrant species; *B. kumara*, *B. picta* and *B. serratibranchis* are *Pseudobranchiomma* according to Knight-Jones (1994); *B. sanjuanense* is *Sabellastarte magnifica* (Shaw, 1800) according to Hartman (1956: pg. 299) and Jones (1962; pg. 201); and *B. violacea* is *Hypsicomus phaeotenia* (Schmarda, 1861) according to Hartman (1965).

Non indigenous *Branchiomma* species

At least seven species of *Branchiomma* have been reported to date, including six in a recent list of alien polychaetes by Çinar (2013) and one more species in this study: *B. coheni*. Table 2 summarizes the list of all the valid species of this genus with their updated status and distribution. However, we suggest further information is desirable to confirm the status of some species, as reviewed and outlined below in alphabetical order, providing an update of available information as well as directions for future studies. In addition, we provide recommendations to accurately identify them when focusing in early detection and NIS monitoring programs.

TABLE 2. Recognized species of the genus *Branchiomma* worldwide with their NIS status and the native and introduced geographic ranges indicated.

Species name	Synonyms	NIS Status	Possible native Distribution	Introduced Distribution
<i>Branchiomma arcticum</i> (Ditlevsen, 1937)			Arctic Ocean	
<i>Branchiomma argus</i> (Sars, 1862)			North East Atlantic	
<i>Branchiomma bahusiense</i> Johansson, 1927			North East Atlantic	
<i>Branchiomma bairdi</i> (McIntosh, 1885)		NIS	West Atlantic/ Caribbean	Mediterranean, Gulf of California, Australia
<i>Branchiomma boholense</i> (Grube, 1878)		NIS	Indo-Pacific	Mediterranean
<i>Branchiomma bombyx</i> (Dalyell, 1853)			North East Atlantic, Mediterranean	
<i>Branchiomma capense</i> (McIntosh, 1885)			South Africa	
<i>Branchiomma cingulatum</i> (Grube, 1870)	<i>Dasychone japonica</i> McIntosh, 1885; <i>Dasychone maculata</i> Fischli, 1903; <i>Dasychonopsis pallidus</i> Bush, 1905; <i>Sabella havaica</i> Kinberg, 1866		Pacific	
<i>Branchiomma cingulata pererai</i> Silva, 1965			Indian Ocean	
<i>Branchiomma coheni</i> Tovar-Hernández & Knight-Jones, 2006		NIS	Pacific	Gulf of Mexico
<i>Branchiomma conspersum</i> (Ehlers, 1887)	<i>Dasychonopsis arenosa</i> Treadwell, 1924		Gulf of Mexico	
<i>Branchiomma corollifera</i> (Ehlers, 1913)			South Africa	
<i>Branchiomma costaricense</i> Tovar-Hernández & Dean, 2010			Pacific	
<i>Branchiomma curtum</i> (Ehlers, 1901)		NIS	East Pacific	Mexico Atlantic, New Zealand
<i>Branchiomma galei</i> (Augener, 1914)			Indian Ocean	
<i>Branchiomma gravelyi</i> (Aziz, 1938)	<i>B. kumari</i>		Arabian Sea	
<i>Branchiomma iliffei</i> Tovar-Hernández & Knight-Jones, 2006			West Atlantic/ Caribbean	
<i>Branchiomma inconspicua</i> (M. Sars in G.O. Sars, 1872)			North East Atlantic	
<i>Branchiomma infarctum</i> (Krøyer, 1856)	<i>Dasychone decora</i> Sars		Arctic Ocean	
<i>Branchiomma luctuosum</i> (Grube, 1870)		NIS	Indo-Pacific	Mediterranean

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TABLE 2. (Continued)

Species name	Synonyms	NIS Status	Possible native Distribution	Introduced Distribution
<i>Branchiomma lucullanum</i> (Delle Chiaje, 1828)		NIS (?)	Mediterranean	Red Sea
<i>Branchiomma maerli</i> Licciano & Giangrande, 2008			Mediterranean	
<i>Branchiomma moebii</i> Knight-Jones, 1994			Mediterranean	
<i>Branchiomma natalense</i> (Kinberg, 1866)			South Africa	
<i>Branchiomma nigromaculatum</i> (Baird, 1865)	<i>Sabella crispa</i> Kroyer, 1856; <i>Dasychone ponce</i> Treadwell, 1901	NIS (?)	Atlantic/Caribbean	Australia
<i>Branchiomma patriota</i> Nogueira, Rossi & López, 2006			South East Atlantic	
<i>Branchiomma pseudoviolacea</i> (Augener, 1922)			South East Atlantic	
<i>Branchiomma spongiarum</i> Knight-Jones, 1994			North East Atlantic	
<i>Branchiomma wyvillei</i> (McIntosh, 1885)			Caribbean Sea	

***Branchiomma bairdi* (McIntosh, 1885)**

Branchiomma bairdi, originally from the Caribbean, is a recent introduction in the Gulf of California via the Panama Canal (Tovar-Hernández *et al.* 2009a,b) and to the eastern Mediterranean through the Gibraltar Strait (Çinar 2009; Giangrande *et al.* 2012; Arias *et al.* 2013), Australia (Capa & Murray 2015) and the northeastern Atlantic Ocean (Ramalhosa *et al.* 2014).

In the Gulf of California, this species is highly abundant reaching densities of 18,000 ind./m² in perturbed sites (marinas, ports, shrimp and oyster farms), on hard anthropogenic substrates (metal buoys, hulls of vessels, ropes, floating docks, and concrete and wood water gates), and also reported as epibionts on *Crassostrea gigas* (Thunberg, 1793) and *C. sikamea* (Amemiya, 1928), and on natural substrates (rocks and wood) from a marine protect area (Tovar-Hernández *et al.* 2012; 2014).

Çinar (2009) documented *B. bairdi* along the coasts of Turkey (Levantine Sea) in 2005 and found specimens at 0.5 and 8 m depth, associated with ropes, rocks and mud, but in low densities (53 ind. m⁻²). In Lake Faro (Italy), *B. bairdi* has been recorded since 2007 near a mollusc farm, among photophilic algae, on the leaves of a *Cymodocea nodosa* (Ucria) Ascherson patch, and on rocks and boulders used for restoration purposes where the overall estimated density of *B. bairdi* ranged from 35 up to 400 ind. m⁻² (Giangrande *et al.* 2012).

Branchiomma bairdi was also recorded in harbours and ports from Malta, Spain and both coasts of Italy, where it is spreading and overtaking stressed habitats with low species competition, reaching densities of 16,000 ind. m⁻² (Arias *et al.* 2013).

In Cairns, Australia, Capa *et al.* (2013) recorded *B. bairdi* based on morphological and molecular data and more recently in Lizard Island, a marine protected area of the Great Barrier Reef (Capa & Murray 2015). Ramalhosa *et al.* (2014) reported this species on Madeira Island reaching densities of 238–516 ind. m⁻².

Branchiomma bairdi is a conspicuous component of most benthic communities and mostly in confined environments and areas degraded by anthropogenic impacts (Arias *et al.* 2013; Giangrande *et al.* 2014a).

This species also tolerates broad environmental conditions in the Gulf of California: reproductive specimens live in marine waterbodies with temperatures of 18.4–32.1°C (average 26.4°C), salinity ranges from 25.6–38.0 PSU (average 34.2 PSU), and dissolved oxygen concentrations of 3.05–6.66 mg/l (average 4.83 mg/l) (Tovar-Hernández *et al.* 2011). The highest survivorship temperatures (27–33°C) and salinities (40–47 PSU) were recorded in shrimp farms from Gulf of California during culture cycles (Tovar-Hernández *et al.* 2014). In addition, this species tolerates a desiccation period up to 24 hrs (Tovar-Hernández & Yáñez-Rivera, 2012).

The reproductive features, the functional traits and the local environmental conditions are useful to understand and predict the dispersion capability of potentially invasive species (Sarà *et al.* 2013). The reproductive habits of *B. bairdi* include both sexual (simultaneous hermaphrodite), and asexual reproduction (architomy). Its success as an invader could be facilitated by chemical defenses that help reduce attacks by predators (Kicklighter & Hay 2007; Giangrande *et al.* 2014b) especially outside its native range where it lacks native predator. In fact, in Tampa Bay many *B. bairdi* specimens were found with evidence of predation, including regeneration of the crown. Also, tubes of *B. bairdi* are colonized by other marine invertebrate NIS, as demonstrated in the Gulf of California for the NIS ascidians *B. violaceus*, *B. schlosseri* and *P. constellatum* and the bryozoans *A. verticillata* and *B. neritina* (Tovar-Hernández *et al.* 2014); *Mytilus galloprovincialis* is also reported on tubes of *B. bairdi* in Malta (Arias *et al.* 2013).

The risk analysis by Tovar-Hernández & Yáñez-Rivera (2012) classified *B. bairdi* as highly invasive and included it in the Lista de Especies Invasoras de México (CONABIO 2015).

***Branchiomma boholense* (Grube, 1878)**

Branchiomma boholense was originally described from the Phillipines. According to Knight-Jones *et al.* (1991), who examined type material of *B. boholense*, it is a common species in the Indo-West Pacific and occurs in the Mediterranean Sea. It was reported by Çinar (2005) from Turkey but in a later work it was recognized as *B. bairdi* (Çinar 2009). Roman *et al.* (2009) provided the first record of *B. boholense* in the western Mediterranean, as well as the most detailed description and illustrations of morphological features available to date. Surprisingly, this species has not been reported in previous or subsequent papers on sabellid worms in the Mediterranean (Licciano & Giangrande 2008; Giangrande *et al.* 2012), and Çinar (2009) suggested the re-examination of all the Mediterranean material identified as *B. boholense* because these or at least some might be *B. bairdi*. Both species have similar uncini, bearing 2–3 rows of teeth over the main fang, but also a remarkable difference: *B. boholense* has 1–4 pairs of flattened, tongue-like macrostylodes whereas in *B. bairdi* two pairs of strap-like macrostylodes are present (Knight-Jones *et al.* 1991; Roman *et al.* 2009; Tovar-Hernández *et al.* 2009a, b). Consequently, detailed re-examination of specimens reported as *B. bairdi* or *B. boholense* is needed because both species are NIS in the Mediterranean Sea and both have distinctive morphological features.

***Branchiomma coheni* Tovar-Hernández and Knight-Jones, 2006**

Branchiomma coheni was described from the Pacific coast of Panama in 2006 (Tovar-Hernández & Knight-Jones, 2006) and is first recorded in the Atlantic Ocean (Florida) in this study. In the Gulf of California, *B. coheni* is found in marinas and ports (docks, buoys, ropes, all hull fouling) but even in aquaculture facilities (oyster and shrimp cultures) where it is found in relatively low abundance, reportedly in the ratio of 1:100 with *B. bairdi* (Tovar-Hernández, unpublished data). Nevertheless, this species could increase in abundance depending on abiotic and biotic factors of the environment, therefore it is important to maintain monitoring although it is not presently considered a threat to marine ecosystem health.

***Branchiomma curtum* (Ehlers, 1901)**

This species was described from Juan Fernández Island (Chile) in 1901, and it was recorded in New Zealand, Cape Verde Islands and the Mexican Caribbean (Tovar-Hernández & Knight-Jones, 2006). In the latter area, it was reported as abundant living in gregarious clumps among algae and was thought to be introduced by ballast water from ships (Tovar-Hernández & Knight-Jones 2006).

There are no new records of *B. curtum* elsewhere; however, the record by Tovar-Hernández & Knight-Jones (2006) from Caribbean may be erroneous, requiring further sampling, because both syntypes of *B. curtum* and Caribbean specimens were juveniles produced by fission with a low number of thoracic segments (4–6). This is a common reproductive phenomena in species of *Branchiomma* (Tovar-Hernández & Dean 2014).

Materials examined and compared by Tovar-Hernández & Knight-Jones (2006) do not show significant

morphological differences with Ehlers syntypes because juveniles of different species can look all similar. Shape and size of stylodes in juveniles of many species of *Branchiomma* change in adult stages. Additionally, the original description and drawings by Ehlers (1901) emphasized important differences among the nominal species *B. curtum* and specimens reported in from the Mexican Caribbean. The thoracic uncini has one row of teeth, covering 1/4 of the main fang length in *B. curtum* (Ehlers 1901: plate 25, Fig. 13) versus three rows covering 1/2 of the main fang length in Caribbean material. Thus, the status of *B. curtum* as NIS in the Mexican Caribbean, New Zealand and Cape Verde demands a further morphological study using adult forms as well as molecular markers at juvenile-adult stages.

***Branchiomma japonicum* (McIntosh, 1885)**

This species was described from Kobé, Japan in 1885. Carlton & Eldredge (2009) regarded *B. japonicum* as introduced in Hawaii, given its largely harbor and fouling habitat in the Islands and the highly disjunct distribution between Japan and Hawaii. However, confusion arises when trying to track records of *B. japonicum*, a species name which is under a subjective synonym (*B. cingulatum* (Grube, 1870)). In addition, one *Branchiomma* species originally described from Honolulu (*B. havaicum* Kinberg, 1867) was synonymized with *B. cingulatum* by Hartman (1948).

Augener (1914) and Imajima & Hartman (1964) suggested that *B. japonicum* is synonym of *B. cingulatum*, a species described originally from the Fiji islands. However, Augener (1914) and Imajima & Hartman (1964) did not provide any evidence or comments about this consideration and stylodes were not described. Knight-Jones (1994) introduced both names (*B. cingulatum* and *B. japonicum*) as separate species while trying to form groups based on artificial categories, but any indication about the status of both species was not provided. She was reported to be in the process of redescribing *B. cingulatum*, but unfortunately, she died in 2009 without concluding her revision.

Carlton & Eldredge (2009) included under the name *B. japonicum* previous records from Hawaii (*Branchiomma nigromaculata* of Bailey-Brock & Hartman (1987), *Sabella havaica* and *Branchiomma cingulata* of Hartman (1966) and many others studies). However, these attributions were based on a personal communication that Phyllis Knight-Jones had with Carlton & Eldredge in 2000, but not on the examination of specimens.

Branchiomma cingulatum has uncini with two rows of teeth above the crest (Fitzhugh 2002: Fig. 2B) and stylodes are digitiform, proximal stylodes with length same as radial width and more distal stylodes up to two times longer than radial width (Grube 1870: plate 14, Fig. 6a–c; Fitzhugh 2002: Fig. 2A). Although in *B. japonica* the uncini present only one clear tooth above crest and apparently a second short tooth (McIntosh 1885: plate 30A, Fig. 24), stylodes are similar to those described for *B. cingulatum* (McIntosh 1885: plate 39A, Fig. 5).

Thus, the synonymy of these species remains tentative until a revision based on type materials can further clarify the status of species involved. If synonyms are confirmed among these three species, *B. cingulatum* will be the valid name according to Priority Principle of ICZN, having implications about its status as NIS in Hawaii or in other worldwide localities.

***Branchiomma lucullanum* (Delle Chiaje, 1828)**

This species was described and recorded in Naples (Claparède 1868; Lo Bianco 1893; Iroso 1921) as well as in other Mediterranean localities (Arvanitidis 2000; Çinar 2005; Castelli *et al.* 2008; Çinar *et al.* 2014; Mikac 2015): France (Saint Joseph 1906; Fauvel 1927), Málaga, Valencia, Denia, Vinaroz and Mahón (Rioja 1923), Porto Cesareo (Licciano & Giangrande 2008). Outside the Mediterranean, it was reported in La Coruña, Spain (Rioja 1923) and in the English Channel (Dauvin *et al.* 2003).

Licciano & Giangrande (2008) indicated that this species was very common in the past in the Mediterranean, particularly in the Gulf of Naples where it used to be very abundant. Its reduced presence could be due to the arrival of NIS species (or to our improvement in identifying the different species).

Çinar (2013) reported this species as NIS, native from the Mediterranean and introduced in the Red Sea, and he noted the work of Por (1978). In regard to Por (1978), the information is confused: a list of the Mediterranean

species of Indo Pacific and Red Sea origins had reported *B. cingulatum* (as *Dasychone cingulata*) as suspected to be pre-Lessepsian migrants (Por 1978: pg. 31). However, Por (1978) took the original record in Fauvel (1955) from Israel, adding a comment that *B. cingulatum* is a very closely related species to the *B. lucullanum* from the Red Sea (as *Dasychone lucullana*), reporting erroneously the latter as a Red Sea species but suggesting the need of a clarification. Por (1978) in the restricted list with demonstrable Lessepsian migrants did not cite any sabellid species (Por 1978: pg. 93–92, Table 2); but in the table titled “Low probability Lessepsian migrants” he reported all the dubious cases as true Lessepsian migrants and he listed *B. cingulatum*, noting that for Laubier (1966) the separation with the Mediterranean *B. lucullanum* was not clear (Por 1978: pg. 109, table 3). In another table titled “Anti-Lessepsian migrants”, Por finally reported *B. lucullanum*, but still with many doubts, as it was (a) reported inside the Suez Canal (Potts 1929), but even further south in the Red Sea in the locality of Dahlak (Fishelson & Rullier 1969), and it is supposed to be a variant of *B. cingulatum* (Laubier 1966) (Por 1978: pg. 158–159, Table 10). Consequently, the presence of *B. lucullanum* in the Red Sea should be further investigated, but it was not reported before 1929. The species name is valid but there is the need of a neotype, redescription, and detailed comparisons with *Branchiomma* species described originally from the Mediterranean (*B. maerli*, *B. moebii*, *B. bombyx*). It would be also useful to corroborate identification with molecular genetic analysis.

***Branchiomma luctuosum* (Grube, 1870)**

Branchiomma luctuosum was described from the Red Sea and reported as introduced for the first time in the Lucrino Lake (Naples, Tyrrhenian Sea, Italy) by Bianchi (1983). Since this first finding, many records of this species have been reported in the western and central Mediterranean basins (Sordino & Gambi 1992; Licciano *et al.* 2002; Mastrototaro *et al.* 2004; El Haddad *et al.* 2008; Licciano & Giangrande 2008; Giangrande *et al.* 2012), as well as in the eastern Mediterranean (Knight-Jones *et al.* 1991, Arvanitidis 2000; Simbora & Nicolaidou 2001; Çinar 2005; Çinar *et al.* 2006). It was included in the 100 ‘Worst Invasives alien marine species in the Mediterranean’ (Streftaris & Zenetos 2006). Moreover, this species was reported colonizing the Brazilian coast (Nogueira *et al.* 2006; Costa-Paiva *et al.* 2007).

In the Red Sea, this species has been found mainly in the more sheltered areas of coral reefs (Grube 1870). In the Aegean Sea it has been found associated with sponges (Arvanitidis 2000), while its presence in Italian waters has mostly been recorded in lagoon environments (Sordino & Gambi 1992; Knight-Jones *et al.* 1991) or sheltered marine areas (Sordino & Gambi 1992; Licciano *et al.* 2002; Matarrese *et al.* 2004). In Valencia Port, El Haddad *et al.* (2008) found specimens of *B. luctuosum* mostly on rocky substrates, grouped in small aggregates of specimens or more rarely isolated. Specimens were present in practically all orientations of the substrate, but especially on the vertical surfaces of the docks where densities reached 320–370 ind./m². In Lake Faro, it was found in a maximum density of 19 ind./m² (Giangrande *et al.* 2012). In Brasil, it was found on rocky shores where it was the dominant sabellid sharing the space with *B. patriota* Nogueira, Rossi & López, 2006 and *Parasabella microphtalma* (Nogueira *et al.* 2006).

***Branchiomma nigromaculatum* (Baird, 1865)**

This species was first described from the Caribbean Sea, with many records in the Atlantic Ocean. The Australian Check list reports this species for the Pacific Sea (ABRS 2009) but neither Çinar (2013) nor Capa (2013) cited this species or commented on its status. Previous records of *B. nigromaculatum* from Australia were found by Hartmann-Schröder (1986; 1989; 1991), Hutchings & Rainer (1979), and Hutchings & Murray (1994). The last references reported *B. nigromaculatum* as widespread in most estuaries of New South Wales throughout the year, but figures or descriptions were not provided. Capa (pers. comm.) re-examined specimens reported from Australia but identification as *B. nigromaculatum* was not corroborated because specimens were small and morphological traits were not completely developed. Thus, presence of *B. nigromaculatum* in Australia is still in doubt.

Day (1967) reported *B. nigromaculatum* from South Africa, but Tovar-Hernández & Knight-Jones (2006) suggested that it belongs to *B. corollifera* Ehlers, 1913. The Hawaiian record of *B. nigromaculatum* by Bailey-Brock (1987) seems to be *B. cingulatum* (*B. japonicum*), but more studies are needed to clarify its status.

Accuracy in identifying *Branchiomma* species: recommendations for tube removal, anesthetization and fixation

Stylodes (shape, size and distribution) and dentition of thoracic uncini are at the moment the main morphological features for identification in *Branchiomma*.

Other features used previously in keys include: body size (discerning between small or large worms), branchial crown, dorsal lips and thorax length, degree of separation on dorsal margins of collar and gaps among ventral shields and tori; however, these characters are not informative as they are impacted by anesthetics and fixation methods. The number of thoracic uncini does not help in identification because it is highly variable in *Branchiomma* species as they reproduce asexually by fission. Different numbers of uncini are the result of variation of regenerative processes, being typically eight in adults and lower numbers in regenerating individuals. All *Branchiomma* species have spotted bodies but the size of spots are variable in distribution and/or color within a single species; in addition these spots are lost gradually after preservation.

It is easier to identify *Branchiomma* species when they are fixed outside their tubes than within tubes. Otherwise, preservative substances do not completely fill the tubes and tissues may present histolysis. Branchial crowns and other parts of the body can be detached or damaged while removing tubes and appearance of structures (e.g., ventral lappets) may change if worms are fixed inside their tubes.

The best procedure to remove the worms from their tubes while live is to apply some pressure at the basal part of the tubes using flat forceps (or fingers if worms are big), and subsequently move the forceps slowly towards the mouth of tube. Once the worm is expelled, place it in a dish with marine seawater without anesthetic. This will help especially if the purpose is to observe eggs, larvae, embryos or analyze tube epibionts. Fixed worms inside tubes are not desirable.

Misleading results can arise with the shape of stylodes, especially when variation exists between *Branchiomma* species or if specimens are subjected to different anesthetization procedures. Anesthetization with magnesium chloride, menthol crystals, clove oil, refrigeration, fresh water, or gradually incorporating ice is not recommendable for *Branchiomma* species (also see Costa Paiva *et al.* (2007) for effects in morphometrics). These methods promote a high rate of mucous production, the distortion of radioles and stylodes and the detachment of integument from the body. Disruption of the integument can also lead to the loss of parapodial elements (chaetae and uncini). As stylodes and uncini are essential characters for identification, maintaining the worms for about 1 hour in small dishes covered with marine water provides the best results to obtain relaxed worms, and the subsequent use of formaldehyde 4% allows fixation of the branchial crown and body structures, more closely maintaining the form of living specimens. Although fixation with ethanol is recommended for molecular techniques, radioles and stylodes of *Branchiomma* are shrunk by dehydration. Thus, when there is more than one specimen, as usually occurs for the abundant and dense members of *Branchiomma*, it is recommendable to fix some in formaldehyde for identification based on morphology and some in ethanol for molecular studies. As shown by Capa *et al.* (2013) a combined molecular and morphological approach is needed when the morphology in itself is not sufficient or the morphological characters chosen do not allow discrimination of the species.

Discussion

We report the first record of *Branchiomma coheni* for the Atlantic Ocean. Despite on-going surveys across 10 different estuaries along the Atlantic and Gulf coasts of the US, with approximately 10 sites per bay (over 100 sites sampled, including some in multiple years) since 2001, we have only detected the species at one location from 2012. This suggests a recent introduction has occurred. Moreover, based on the previous known distribution, our data suggest transfer of the species via ships transiting the Panama Canal from the northeastern Pacific Ocean. Since the species was described for the first time in 2006 from the Pacific coast of Panama, its origin (i.e., native distribution) should be investigated more thoroughly with a molecular genetic approach.

Ships from Asia are regular visitors to Florida and the Gulf of Mexico, providing a possible mechanism of introduction. Mazatlán and Topolobampo are the most important ports in the Gulf of California in terms of commercial traffic for agricultural, industrial, fishing, automobile, petroleum and derived products. Both have dense connection networks with many ports in the world, and Panama is the most important network (Tovar-

Hernández *et al.* 2009b). The Mazatlán and Topolobampo ports and their associated marinas also receive significant numbers of cruise ships and private sailing boats that connect them with other US ports (Tovar-Hernández *et al.* 2009b). From 2010 to 2014 the number of ship arrivals to Tampa, where one of the last 5 ports of call was Balboa (Panama), has an average of 397 ships per year as reported in Notices of Arrival submitted to the US Coast Guard's National Vessel Movement Center (NVMC).

While freshwater (i.e., Gatun Lake) of the Panama Canal can act as a dispersal barrier for some marine species, this is not the case for some euryhaline species or those with shells or tubes that can reduce exposure (Davidson *et al.* 2008; Schloeder *et al.* 2014; Lohan *et al.* 2015). This appears to be the case for polychaetes in the family Serpulidae, which have calcareous tubes and opercula, which may provide a short-term refuge from hostile environmental conditions, such as freshwater. Specifically, multiple species of serpulids that occur on the hulls of vessels and appear at both the Atlantic and Pacific sides of the Panama Canal are likely to have successfully breached this dispersal barrier. *Ficopomatus miamiensis* (Treadwell 1934), *Hydroides dianthus* (Verrill 1873), *Hydroides mucronatus* (Rioja 1958), and *Hydroides sanctaerucis* (Kröyer in Mörch 1863) are western Atlantic species which have become established on the Pacific side of the canal (ten Hove & Weerdenburg 1978; Bastida-Zavala and ten Hove 2002, 2003; US National Museum of Natural History collections 2015; Fofonoff *et al.* 2015; Ruiz *et al.* unpublished data). *Ficopomatus uschakovi* (Pillai 1960) is an Indo-Pacific species which has colonized the Gulf of Mexico, the Caribbean, the Brazilian coast, and the Pacific side of the Panama canal (de Assis *et al.* 2008; Bastida-Zavala 2012; Liñero-Arana *et al.* 2012; US National Museum of Natural History 2015). *Hydroides diramphus* is cryptogenic; it is unknown if the tropical western Atlantic or the Indo-Pacific is the region of origin for this species.

Our discovery of *B. coheni* in the Atlantic Ocean suggests that some sabellid polychaetes can withstand transits through the Panama Canal, despite the lack of calcareous tube or operculum. This may result from either being euryhaline, or experiencing a refuge from freshwater exposure in their tubes, or both. The relative importance of these mechanisms remains to be tested experimentally. If tubes provide protection to freshwater exposure, this expands the range of this phenomenon to include non-calcareous tube-building species and also underscores the opportunity for species transfer across the Panama Canal, especially with completion of the canal expansion (e.g., Muirhead *et al.* 2014). Larval development and aspects of the reproductive biology (except for the simultaneous hermaphroditism) of this species are not known, therefore at this stage it is not possible to predict how long the larvae can stay in the water and if they can survive in the ballast water. Interestingly, unlike the serpulid examples above, *B. coheni* has not been recorded from the proximity of the Atlantic side of the Panama Canal.

In general, species in the genus *Branchiomma* have multiple attributes that appear to facilitate transfer and invasions. These organisms are common in fouling communities and can be transported as larvae in ballast tanks and underwater surfaces of vessels as juveniles or adults. Several species have been already reported as introduced in some areas around the globe; they share similar biology and ecology being tubicolous worms; some of them present simultaneous hermaphroditism, brooding, gonochorism and asexual reproduction within a single species; some show chemical deterrence to prevent being targeted as desirable choice for consumers; some are tolerant to broad environmental conditions; some are evaluated by risk analysis as highly invasive due to their high potential as vector to transport other invasive species (Tovar-Hernández & Yáñez-Rivera 2012; Arias *et al.* 2013; Giangrande *et al.* 2014a).

More broadly, our review of the genus suggests at least five species (including *B. coheni*) are known as NIS. The present study has added *B. coheni* to the alien list of Çinar (2013), but we have removed *B. japonicum*. Two additional species are considered to be possible NIS, with some uncertainties: *B. lucullanum* and *B. nigromaculatum*. It is doubtful whether *B. lucullanum* is present in the Red Sea, even if it was present in the Suez Canal, and it appears likely that this record could be *B. cingulatum*; however, further investigation is required to confirm the identification and status. This review also illustrates how it is difficult to discriminate species level and NIS status in *Branchiomma*. Moreover this work stresses the importance of good descriptions with figures of specimens images and procedures for their preservation that reduce artifacts, thus enabling more accurate comparative work of taxonomists from different areas around the world.

Beyond the taxa considered in this study, it appears that additional NIS are likely to occur in this genus (e.g. Capa *et al.* 2013), suggesting a relatively high capacity for transfer and invasion by *Branchiomma*. Specifically, additional records for *Branchiomma* spp. have been already reported as new introductions along the west US coast after 2006 (CDFW-OSPR 2014), in San Francisco (Keppel & Ruiz unpublished data 2014), Mission Bay (2013),

San Diego (2013) and Los Angeles (Leslie Harris pers. comm.). The latter have been detected in our recent surveys, and we are now exploring the identification and status of these sabellids. We hypothesize that invasions of sabellids may be much more common than currently known. As with many polychaete groups, it appears likely that many additional NIS remain undetected for this family, in multiple geographic regions around the world, due to both limited sampling and rigorous taxonomic analyses. Given the conspicuous size and abundance of sabellids, we suggest this provides a useful model system to increase understanding of invasion dynamics and effects on biogeography in marine systems.

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References

- ABRS (2009) Australian Faunal Directory. Australian Biological Resources Study, Canberra. Available from: <http://www.environment.gov.au/biodiversity/abrs/online-resources/fauna/afd/index.html> (accessed 27 August 2015)
- Arias, A., Giangrande, A., Gambi, M.C. & Anadón, N. (2013) Biology and new records of the invasive species *Branchiomma bairdi* (Annelida: Sabellidae) in the Mediterranean Sea. *Mediterranean Marine Science*, 14 (1), 162–171. <http://dx.doi.org/10.12681/mms.363>
- Arvanitidis, C. (2000) Polychaete fauna of the Aegean Sea, inventory and new information. *Bulletin of Marine Science*, 60, 73–96.
- Augener, H. (1914) Polychaeta II. Sedentaria. In: Michaelsen, W. & Hartmeyer, R. (Eds.), *Die Fauna Südwest-Australiens. 1905 (5)*. Ergebnisse der Hamburger Südwest-australischen Forschungsreise Gustav Fisher, Jena, pp. 1–170 + pl.1.
- Bailey-Brock, J.H. & Hartman, O. (1987) Phylum Annelida, Fauna In: Devaney, D.M. & Eldredge, L.G. (Eds.), *Reef and Shore Fauna of Hawaii, Section 2: Platyhelminthes through Phoronida and Section 3: Sipuncula through Annelida*, *Bishop Museum Special Publication*, 64 (2–3), pp. 216.
- Bastida-Zavala, J.R. & ten Hove, H.A. (2002) Revision of *Hydroides* Gunnerus, 1768 (Polychaeta: Serpulidae) from the western Atlantic Region. *Beaufortia*, 52 (9), 103–179.
- Bastida-Zavala, J.R. & ten Hove, H.A. (2003) Revision of *Hydroides* Gunnerus, 1768 (Polychaeta: Serpulidae) from the Eastern Pacific Region and Hawaii. *Beaufortia*, 53 (4), 67–110.
- Bianchi, C.N. (1983) Serpuloidea (Annelida, Polychaeta) delle lagune costiere laziali e campane. *Annali del Museo Civico di Storia Naturale di Genova*, 84, 231–243.
- CDFW-OSPR (2014) 2014 Triennial Report on the California Department of Fish and Wildlife's Marine Invasive Species Program, 33 pp. Available from: <https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=91995&inline=true> (accessed 27 August 2015)
- Camp, D.K., Lyons, W.G. & Perkins, T.H. (1998) Checklists of Selected Shallow-Water Marine Invertebrates of Florida. *Florida Marine Research Institute Technical Report TR-3*, 238 pp.
- Capa, M., van Moorsel, G. & Tempelman, D. (2014a) The Australian feather-duster worm *Laonome calida* Capa, 2007 (Annelida: Sabellidae) introduced into European inland waters? *BioInvasions Records*, 3 (1), 1–11. <http://dx.doi.org/10.3391/bir.2014.3.1.01>
- Capa, M. & Murray, A. (2015) A taxonomic guide to the fan worms (Sabellidae, Annelida) of Lizard Island, Great Barrier Reef, including new species and new records. *Zootaxa*, 4019 (1), 98–167. <http://dx.doi.org/10.11646/zootaxa.4019.1>
- Capa, M., Pons, J. & Hutchings, P. (2013) Cryptic diversity, intraspecific phenetic plasticity and recent geographical translocations in *Branchiomma* (Sabellidae, Annelida). *Zoologica Scripta*, 42, 637–655. <http://dx.doi.org/10.1111/zsc.12028>
- Capa, M., Giangrande, A., Nogueira, J.M.M. & Tovar-Hernández, M.A. (2014b) Sabellidae Latreille, 1825. In: *The Handbook of Zoology*. De Gruyter, Germany. Available from: http://www.degruyter.com/view/Zoology/bp_029147-6-62 (accessed 23 November 2015)
- Carlton, J.T. (1985) Transoceanic and interoceanic dispersal of coastal marine organisms: the biology of ballast water. *Oceanography and Marine Biology: An Annual Review*, 23, 313–371.
- Carlton, J.T. & Eldredge, L.G. (2009) Marine bioinvasions of Hawaii. The introduced and cryptogenic marine and estuarine

- animals and plants of the Hawaiian archipelago. *Bishop Museum Bulletins in Cultural and Environmental Studies*, 4, 1–202.
- Castelli, A., Bianchi, C.N., Cantone, G., Çinar, M.E., Gambi, M.C., Giangrande, A., Iraci Sareri, D., Lanera, P., Licciano, M., Musco, L. & Sanfilippo, R. (2008) Annelida Polychaeta. In: Relini, G. (Ed.), Checklist della flora e della fauna dei mari italiani (Parte I). *Biologia Marina Mediterranea*, 15 (Supplement 1), pp. 327–377.
- CIESM (2012) Atlas. Available from: <http://www.ciesm.org/online/atlas/intro.htm> (accessed 21 August 2015)
- Çinar, M.E. (2005) Polychaetes from the coast of northern Cyprus (Eastern Mediterranean Sea), with two new records from the Mediterranean Sea. *Cahiers de Biologie Marine*, 46, 143–159.
- Çinar, M.E. (2009) Alien polychaete species (Annelida: Polychaeta) on the southern coast of Turkey (Levantine Sea, eastern Mediterranean), with 13 new records for the Mediterranean Sea. *Journal of Natural History*, 43, 2283–2328. <http://dx.doi.org/10.1080/00222930903094654>
- Çinar, M.E. (2013) Alien polychaete species worldwide: current status and their impacts. *Journal of the Marine Biological Association of the United Kingdom*, 93, 1257–1278. <http://dx.doi.org/10.1017/S0025315412001646>
- Çinar, M.E., Bilecenoglu, M., Öztürk, B. & Can, A. (2006) New records of alien species on the Levantine coast of Turkey. *Aquatic Invasions*, 1, 84–90. <http://dx.doi.org/10.3391/ai.2006.1.2.6>
- Çinar, M.E., Dağlı, E. & Şahin, G.K. (2014) Checklist of Annelida from the coasts of Turkey. *Turkish Journal of Zoology*, 38, 734–764. <http://dx.doi.org/10.3906/zoo-1405-72>
- Claparede, E. (1868) Les annélides chétopodes du Golfe de Naples. *Mémoires de la Société Physique et d'Histoire Naturelle de Genève*, 19, 313–584.
- Cohen, A.N. (2006) Species Introductions and the Panama Canal Chapter III. In: Gollash, S., Galil, B.S. & Cohen, A.N. (Eds.), *Bridging Divides*. Springer, Dordrecht, pp.127–206.
- Coleman, F.C. & Williams, S.L. (2002) Overexploiting marine ecosystem engineers: potential consequences for biodiversity. *Trends in Ecology and Evolution*, 17, 40–44. [http://dx.doi.org/10.1016/S0169-5347\(01\)02330-8](http://dx.doi.org/10.1016/S0169-5347(01)02330-8)
- CONABIO (2015) Sistema de información sobre especies invasoras en México. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad. Available from: http://www.biodiversidad.gob.mx/especies/Invasoras/pdf/presentes_confinados.pdf (accessed 27 August 2015)
- Costa-Paiva E., Paiva, P.C. & Klautau, M. (2007) Anaesthetization and fixation effects on the morphology of sabellid polychaetes (Annelida: Polychaeta: Sabellidae). *Journal of marine biological Association United Kingdom*, 87, 1127–1132. <http://dx.doi.org/10.1017/S002531540705223X>
- Currie, D.R., McArthur, M.A. & Cohen, B.F. (1998) Exotic Marine Pests in the Port of Geelong, Victoria. *Marine and Freshwater Resources Institute Report*, 8, 72 pp.
- Dauvin, J.C., Dewarumez, J.M. & Gentil, F. (2003) Liste actualisée des espèces d'Annélides Polychètes présentes en Manche. *Cahiers de Biologie Marine*, 44, 67–95.
- Davidson, I.C., McCann, L.D., Fofonoff, P.W., Sytsma, M.D. & Ruiz, G.M. (2008) The potential for hull-mediated species transfers by obsolete ships on their final voyages. *Diversity and Distributions*, 14, 518–529. <http://dx.doi.org/10.1111/j.1472-4642.2008.00465.x>
- Day, J.H. (1967) *A Monograph on the Polychaeta of southern Africa. Part 2. Sedentaria*. British Museum (Natural History), London, 878 pp.
- de Assis J.E., Alonso, C. & Chrystoffersen, M.L. (2008) First record of *Ficopomatus uschakovi* (Pillai, 1960) Serpulidae (Polychaeta: Annelida) for the western Atlantic. *Revista Nordestina de Biologia*, 19 (1), 35–43.
- Edmondson, C.H. (1962) Teredinidae, Ocean Travelers. *Occasional Papers Bishop Museum*, 23 (3), 45–59. [Honolulu, Hawaii]
- Ehlers, E. (1901) Fauna Chilensis. Die Anneliden der Sammlung Plate. *Zoologisches Jahrbücher Jena*, 5 (Supplement), 251–272.
- El Haddad, M., Capaccioni-Azzati, R. & Garcia-Garrascosa, M. (2008) *Branchiomma luctuosum* (Polychaeta: Sabellidae): a non-indigenous species at Valencia Port (western Mediterranean Sea, Spain). *Marine Biodiversity Records*, 1, e61. <http://dx.doi.org/10.1017/S1755267207006604>
- Fauvel, P. (1927) *Faune de France. Polychetes sedentaires: addenda aux errantes, archiannelides, myzostomaires. Vol. 16*. Lechevalier, P., Paris, 492 pp.
- Fauvel, P. (1955) Contribution à la faune des Annélides Polychètes des côtes d'Israël. *Bulletin of the Sea Fisheries Research Station of Israel Haifa*, 10, 3–12.
- Fishelson, L. & Rullier, F. (1969) Quelques Annelides Polychetes De La Mer Rouge. *Israel Journal of Zoology*, 18 (1), 49–117. <http://dx.doi.org/10.1080/00212210.1969.10688275>
- Fitzhugh, K. (2002) Fan worm polychaetes (Sabellidae: Sabellinae) collected during the Thai–Danish BIOSHELF Project. *Phuket Marine Biological Center Special Publication*, 24, 353–424.
- Fletcher, L.M. (2014) Background information on the Mediterranean fanworm *Sabella spallanzanii* to support regional

- response decisions. Prepared for Marlborough District Council. *Cawthron Report*, 2479A, 35 pp.
- Fofonoff, P.W., Ruiz, G.M., Steves, B. & Carlton, J.T. (2003) In ships or on ships? Mechanisms of transfer and invasion for nonnative species to the coasts of North America. *In*: Ruiz, G.M. & Carlton, J.T. (Eds.), *Invasive species: vectors and management strategies*. Island Press, Washington, DC, pp. 152–182.
- Fofonoff, P.W., Ruiz, G.M., Steves, B. & Carlton, J.T. (2015) NEMESIS National Exotic Marine and Estuarine Species Information System. Available from: <http://invasions.si.edu/nemesis/> (accessed 20 August 2015)
- Galil, B.S. (2000) A sea under siege: alien species in the Mediterranean. *Biological Invasions*, 2, 177–186.
- Galil, B.S., Boero, F., Campbell, M.L., Carlton, J.T., Cook, E., Frascchetti, S., Gollasch, S., Hewitt, C.L., Jelmert, A., Macpherson, E., Marchini, A., McKenzie, C., Minchin, D., Occhipinti-Ambrogi, A., Ojaveer, H., Olenin, S., Piraino, S. & Ruiz, G.M. (2015a) ‘Double trouble’: the expansion of the Suez Canal and marine bioinvasions in the Mediterranean Sea. *Biological Invasions*, 17 (4), 973–976.
<http://dx.doi.org/10.1007/s10530-014-0778-y>
- Galil, B.S., Boero, F., Frascchetti, S., Piraino, S., Campbell, M., Hewitt, C., Carlton, J., Cook, E., Jelmert, A., Macpherson, E., Marchini, A., Occhipinti-Ambrogi, A., McKenzie, C., Minchin, D., Ojaveer, H., Olenin, S. & Ruiz, G. (2015b) The Enlargement of the Suez Canal and Introduction of Non-Indigenous Species to the Mediterranean Sea. *Limnology and Oceanography Bulletin*, 24 (2), 43–45.
<http://dx.doi.org/10.1002/lob.10036>
- Galil, B.S. & Goren, M. (2014) Metamorphoses: Bioinvasions in the Mediterranean Sea *In*: Goffredo, S. & Dubinsky, Z. (Eds.), *The Mediterranean Sea: Its history and present challenges*. Springer Science+Business Media, Dordrecht, pp. 463–477.
http://dx.doi.org/10.1007/978-94-007-6704-1_27
- Giangrande, A., Cosentino, A., Lo Presti, C. & Licciano, M. (2012) Sabellidae (Annelida) from the Faro coastal lake (Messina, Ionian Sea), with the first record of the invasive species *Branchiomma bairdi* along the Italian coast. *Mediterranean Marine Science*, 13 (2), 283–293.
<http://dx.doi.org/10.12681/mms.310>
- Giangrande, A., Licciano, M., Lezzi, M., Pierri, C., Caruso, L.P.G. & Stabili, L. (2014a) Allochthonous *Branchiomma* species (Annelida, Sabellidae) in the Mediterranean Sea. A case of study in the Mar Grande of Taranto. *Biologia Marina Mediterranea*, 21 (1), 93–96.
- Giangrande, A., Licciano, M., Shirosi, R., Musco, L., Stabili, L. (2014b) Chemical and structural defensive external strategies in six sabellid worms (Annelida). *Marine Ecology*, 35, 36–45.
<http://dx.doi.org/10.1111/maec.12053>
- Grube, E. (1870) Neue Arten der Gattung *Sabella*. Jahres-Bericht der Schlesischen Gesellschaft für vaterländische Kultur, *Breslau*, 48, 67–68.
- Hartman, O. (1948) The marine annelids erected by Kinberg. With some notes on some other types in the Swedish State Museum. *Arkiv för Zoologi*, 42A (1), 1–137.
- Hartman, O. (1956) Polychaetous Annelids erected by Treadwell, 1891 To 1948, Together With A Brief Chronology. *Bulletin of The American Museum of Natural History*, 109 (2), 243–310.
- Hartman, O. (1966) Polychaetous annelids of the Hawaiian Islands. *Occasional Papers of the B.P. Bishop Museum*, 33 (11), 163–252.
- Hartmann-Schröder, G. (1986) Teil 12. Die Polychaeten der antiborealen Südküste Australiens (zwischen Wallaroo im Westen und Port MacDonnell im Osten). *In*: Hartmann-Schröder, G. & Hartmann, G. (Eds.), *Zur Kenntnis des Eulitorals der australischen Küsten unter besonderer Berücksichtigung der Polychaeta. Mitteilungen aus dem Hamburgischen Zoologischen Museum und Institut*, 83, pp. 31–70.
- Hartmann-Schröder, G. (1989) Teil 14. Die Polychaeten der antiborealen und subtropisch-tropischen Küste Südost-Australiens zwischen Lakes Entrance (Victoria) im Süden und Maclean (New South Wales) im Norden. *In*: Hartmann-Schröder, G. & Hartmann, G. (Eds.), *Zur Kenntnis des Eulitorals der australischen Küsten unter besonderer Berücksichtigung der Polychaeta. Mitteilungen aus dem Hamburgischen Zoologischen Museum und Institut*, 86, pp. 11–63.
- Hartmann-Schröder, G. (1991) Teil 16. Die Polychaeten der subtropisch-tropischen bis tropischen Ostküste Australiens zwischen Maclean (New South Wales) und Gladstone (Queensland) sowie von Heron Island (Groß Barriere-Riff). *In*: Hartmann-Schröder, G. & Hartmann, G. (Eds.), *Zur Kenntnis des Eulitorals der australischen Küsten unter besonderer Berücksichtigung der Polychaeta. Mitteilungen aus dem Hamburgischen Zoologischen Museum und Institut*, 88, pp. 17–71.
- Hayes, K., Silwa, C., Migus, S., McEnulty, F. & Dunstan, P. (2005) *National priority pests: Part II Ranking of Australian marine pests*. An independent report undertaken for the Department of Environment and Heritage by CSIRO Marine Research, 106 pp.
- Holloway, M.G. & Keough, M.J. (2002) An introduced polychaete affects recruitment and larval abundance of sessile invertebrates. *Ecological Applications*, 12 (6), 1803–1823.
[http://dx.doi.org/10.1890/1051-0761\(2002\)012\[1803:AIPARA\]2.0.CO;2](http://dx.doi.org/10.1890/1051-0761(2002)012[1803:AIPARA]2.0.CO;2)
- Hove, ten H.A. & Weerdenburg, J.C.A. (1978) A generic revision of the brackish-water serpulid *Ficopomatus* Southern 1921 (Polychaeta: Serpulinae), including *Mercierella* Fauvel 1923, *Sphaeropomatus* Treadwell 1934, *Mercierellopsis* Rioja 1945 and *Neopomatus* Pillai 1960. *Biological Bulletin*, 154, 96–120.
- Hulme, P.E. (2009) Trade, transport and trouble: managing invasive species pathways in an era of globalization. *Journal of*

- Applied Ecology*, 46, 10–18.
<http://dx.doi.org/10.1111/j.1365-2664.2008.01600.x>
- Hutchings, P.A. & Rainer, S.F. (1979) The polychaete fauna of Careel Bay, Pittwater, New South Wales Australia. *Journal of Natural History*, 13, 745–796.
- Hutchings, P.A. & Murray, A. (1984) Taxonomy of polychaetes from the Hawkesbury River and the southern estuaries of New South Wales, Australia. *Records of the Australian Museum*, 36, 1–119.
- Imajima, M. & Hartman, O. (1964) The polychaetous annelids of Japan. *Occasional Papers of the Allan Hancock Foundation*, 26 (1–2), 1–452.
- Iroso, I. (1921) Revisione dei serpulidi e sabellidi del Golfo di Napoli. *Marine Ecology Pubblicazioni Della Stazione Zoologica Di Napoli I*, 3, 68–85.
- Jones, M.L. (1962) On some polychaetous annelids from Jamaica, the West Indies. *Bulletin of the American Museum of Natural History*, 124 (5), 173–212.
- Knight-Jones, P. (1994) Two new species of *Branchiomma* (Sabellidae) with redescriptions of closely related species and comments on *Pseudobranchiomma* and *Sabellastarte*. In: Dauvin, J.-C., Laubier, L. & Reish, D.J. (Eds.), *Actes de la 4ème Conférence internationale des Polychètes. Mémoires du Muséum National d'Histoire Naturelle*, 162, pp. 191–198.
- Knight-Jones, P., Knight-Jones, W. & Ergen, Z. (1991) Sabelliform polychaetes, mostly from Turkey's Aegean coast. *Journal of Natural History*, 25, 837–858.
- Kicklighter, C.E. & Hay, M.E. (2007) To avoid or deter: interactions among defensive and escape strategies in sabellid worms. *Oecologia*, 151, 161–173.
<http://dx.doi.org/10.1007/s00442-006-0567-0>
- Laidlaw, F.B. (1952) *The history of the prevention of fouling. Marine Fouling and Its Prevention* (Woods Hole Oceanographic Institution) Naval Institute Press, Annapolis, MD, 580, 211–223.
- Laubier, L. (1966) Sur quelques Annélides Polychètes de la région de Beyrouth. *Miscellaneous Papers In The Natural Sciences*, 5, 9–22. [American University of Beirut]
- Licciano, M. & Giangrande, A. (2008) The genus *Branchiomma* (Polychaeta: Sabellidae) in the Mediterranean Sea, with the description of *B. maerli* n. sp. *Scientia Marina*, 72 (2), 383–391.
<http://dx.doi.org/10.3989/scimar.2008.72n2383>
- Licciano, M., Giangrande, A. & Gambi, M.C. (2002) Reproduction and simultaneous hermaphroditism in *Branchiomma luctuosum* (Polychaeta, Sabellidae) from the Mediterranean Sea. *Invertebrate Biology*, 121, 55–65.
- Liñero-Arana, I. & Díaz-Díaz, Ó. (2012) Presence of the exotic polychaete *Ficopomatus uschakovi* (Polychaeta: Serpulidae) in Venezuela: Description and comments on its distribution. *Interciencia*, 37, 234–237.
- Lo Bianco, S. (1893) Anellidi tubicoli del Golfo di Napoli. *Atti dell'Accademia delle Scienze Fisiche e Matematiche*, Napoli, 5, 65–81.
- Lohan, K.M.P., Hill-Spanik, K.M., Torchin, M.E., Strong, E.E., Fleischer, R.C. & Ruiz, G.M. (2015) Molecular phylogenetics reveals first record and invasion of *Saccostrea* species in the Caribbean. *Marine Biology*, 162, 957–968.
<http://dx.doi.org/10.1007/s00227-015-2637-5>
- Lowe, B., Browne, M., Boudjelas, S. & De Poorter, M. (2004) *100 of the world's worst invasive alien species*. The Invasive Species Specialist Group (ISSG) of the World Conservation Union (IUCN), Auckland, New Zealand. Available from: <http://www.issg.org/database/species/search.asp?st=100ss> (accessed 23 November 2015)
- Mastrototaro, F., Petrocelli, A., Cecere, E. & Matarrese, A. (2004) Non indigenous species settle down in the Taranto seas. *Biogeographia*, 25, 47–54.
- Matarrese, A., Mastrototaro, F., D'onghia, G., Maiorano, P. & Cursi, A. (2004) Mapping of the benthic communities in the Taranto seas using side-scan sonar and an underwater video camera. *Chemistry and Ecology*, 20, 377–386.
- McIntosh, W.C. (1885) Report on the Annelida Polychaeta collected by H. M. S. Challenger during the years 1873–76, Report of the scientific results of the voyage of H. M. S. Challenger London, *Zoology*, 12, 1–554.
- Mikac, B. (2015) A sea of worms: polychaete checklist of the Adriatic Sea. *Zootaxa* 3943 (1), 1–172.
<http://dx.doi.org/10.11646/zootaxa.3943.1.1>
- Miller, A.W. & Ruiz, G.M. (2014) Arctic shipping and marine invaders. *Nature Climate Change*, 4 (6), 413–416.
<http://dx.doi.org/10.1038/nclimate2244>
- Muirhead, J.R., Minton, M.S., Miller, W.A. & Ruiz, G.M. (2014) Projected effects of the Panama Canal expansion on shipping traffic and biological invasions. *Diversity and Distributions*, 21(1), 1–13.
<http://dx.doi.org/10.1111/ddi.12260>
- Murray, A. & Keable, S.J. (2013) First Report of *Sabella spallanzanii* (Gmelin, 1791) (Annelida: Polychaeta) from Botany Bay, New South Wales, a northern range extension for the invasive species within Australia. *Zootaxa*, 3670 (3), 394–395.
<http://dx.doi.org/10.11646/zootaxa.3670.3.10>
- NIMPIS (National Introduced Marine Pest Information System) (2009). Web publication. Available from: <http://www.marinepests.gov.au/nimpis> (accessed 7 November 2015)
- NIMPIS (2013) *Sabella spallanzanii* general information, National Introduced Marine Pest Information System. Available from: <http://adl.brs.gov.au/marinepests/index.cfm?fa=main.spDetailsDB&sp=6000011479#generalInfo> (accessed 30 April 2013)
- Nogueira, J.M.M., Rossi, M.C.S. & López, E. (2006) Intertidal species of *Branchiomma* Kolliker and *Pseudobranchiomma*

- Jones (Polychaeta: Sabellidae: Sabellinae) occurring on rocky shores along the state of Sao Paulo, southeastern Brazil. *Zoological Studies*, 45, 586–610.
- Pagad, S., Hayes, K., Katsanevakis, S. & Costello, M.J. (2015) World Register of Introduced Marine Species (WRIMS). Available from: <http://www.marinespecies.org/introduced> (accessed 26 August 2015)
- Por, F.D. (1978) *Lessepsian Migration*. The influx of Red Sea biota into the Mediterranean by way of the Suez Canal. Springer-Verlag, Berlin, 228 pp.
- Potts, F.A. (1929) Zoological Results of the Cambridge Expedition to the Suez Canal. Report on the annelids (Sedentary Polychaetes). *Transactions of the Zoological Society of London*, 22 (5), 693–705.
- Ramalhosa, P., Camacho-Cruz, K., Bastida-Zavala, R. & Canning-Clode, J. (2014) First record of *Branchiomma bairdi* McIntosh, 1885 (Annelida: Sabellidae) from Madeira Island, Portugal (northeastern Atlantic Ocean). *BioInvasions Records*, 3 (4), 235–239.
<http://dx.doi.org/10.3391/bir.2014.3.4.04>
- Read, G.B., Inglis, G., Stratford, P. & Ahyong, S.T. (2011) Arrival of the alien fanworm *Sabella spallanzanii* (Gmelin, 1791) (Polychaeta: Sabellidae) in two New Zealand harbours. *Aquatic Invasions*, 6 (3), 273–279.
<http://dx.doi.org/10.3391/ai.2011.6.3.04>
- Rioja, E. (1923) Estudio sistemático de las especies ibéricas del suborden Sabelliformia. *Trabajos del Museo Nacional de Ciencias Naturales Madrid, Serie Zoológico*, 48, 1–144.
- Román, S., Pérez-Ruzafa, A. & López, E. (2009) First record in the western Mediterranean Sea of *Branchiomma boholense* (Grube, 1878) (Polychaeta: Sabellidae), and alien species of Indo-Pacific origin. *Cahiers de Biologie Marine*, 50, 241–250.
- Ros, M., Ashton, G.V., Lacerda, M.B., Carlton, J.T., Vazquez-Luis, M., Guerra-García, J.M. & Ruiz, G.M. (2014) The Panama Canal and the transoceanic dispersal of marine invertebrates: Evaluation of the introduced amphipod *Paracaprella pusilla* Mayer, 1890 in the Pacific Ocean. *Marine Environmental Research*, 99, 204–211.
<http://dx.doi.org/10.1016/j.marenvres.2014.07.001>
- Ruiz, G.M., Carlton, J.T., Grosholtz, E.D. & Hines, A.H. (1997) Global invasions of marine and estuarine habitats by non-indigenous species: mechanisms, extent and consequences. *American Zoologist*, 37, 621–632.
- Ruiz, G.M., Fofonoff, P.W., Steves, B., Foss, S.F. & Shiba, S.N. (2011) Marine invasion history and vector analysis of California: a hotspot for western North America. *Diversity and Distributions*, 17 (2), 362–373.
<http://dx.doi.org/10.1111/j.1472-4642.2011.00742>
- Saint Joseph, A. (1906) Annélides Polychètes des cotes de France (Ocean et cote de Provence). *Annales des Sciences Naturelles Zoologique*, 9 (III), 1–395.
- Sara, G., Palmeri, V., Rinaldi, A., Montalto, V. & Helmuth, B. (2013) Predicting biological invasions in marine habitats through eco-physiological mechanistic models: a case study with the bivalve *Brachidontes pharaonis*. *Diversity and Distributions*, 19, 1235–1247.
<http://dx.doi.org/10.1111/ddi.12074>
- Schloeder, C., Canning-Clode, J., Saltonstall, K., Strong, E.E. & Ruiz, G.M. (2014) The Pacific bivalve *Anomia peruviana* in the Atlantic: a recent invasion across the Panama Canal? *Aquatic Invasions*, 8, 443–448.
<http://dx.doi.org/10.3391/ai.2013.8.4.08>
- Simboura, N. & Nicolaidou, A. (2001) The Polychaetes (Annelida, Polychaeta) of Greece, Checklist, distribution and ecological characteristics. In: *Monographs on Marine Sciences. 4*. National Centre of Marine Research ed. Attiki, Athens, pp. 1–115.
- Sordino, P. & Gambi, M.C. (1992) Prime osservazioni sulla biologia riproduttiva e sul ciclo vitale di *Branchiomma luctuosum* (Grube, 1869) (Polychaeta, Sabellidae). *Oebalia*, 17 (Suppl.), 425–427.
- Statewide Biological Database (2013) State of Florida. Available from: <http://www.floridadep.org/labs/cgi-bin/sbio/database.asp#lists> (accessed 21 August 2015)
- Streftaris, N. & Zenetos, A. (2006) Alien marine species in the Mediterranean - the 100 ‘worst invasives’ and their impact. *Mediterranean Marine Science*, 7 (1), 87–118.
<http://dx.doi.org/10.12681/mms.180>
- Teske, P.R., Rius, M., McQuaid, C.D., Styan, C.A., Piggott, M.P., Benhissoune, S., Fuentes-Grunewald, C., Walls, K., Page, M., Attard, C.R.M., Cooke, G.M., McClusky, C.F., Banks, S. C., Barker, N.P. & Beheregaray, L.B. (2011) “Nested” cryptic diversity in a widespread marine ecosystem engineer: a challenge for detecting biological invasions. *BMC Evolutionary Biology*, 11, e176.
<http://dx.doi.org/10.1186/1471-2148-11-176>
- Tovar-Hernández, M.A. & Dean, H. (2014) A new gregarious sabellid worm from the Gulf of California reproduced by spontaneous fission (Polychaeta, Sabellidae). *Journal of the Marine Biological Association UK*, 94 (5), 935–946.
<http://dx.doi.org/10.1017/S0025315414000186>
- Tovar-Hernández, M.A. & Knight-Jones, P. (2006) Species of *Branchiomma* (Polychaeta: Sabellidae) from the Caribbean Sea and Pacific coast of Panama. *Zootaxa*, 1189, 1–37.
- Tovar-Hernández, M.A., Méndez, N., Salgado-Barragán, J. (2009a) *Branchiomma bairdi*: a Caribbean hermaphrodite fan worm in the south-eastern Gulf of California (Polychaeta: Sabellidae). *Marine Biodiversity Records*, 2 (e43), 1–8.
<http://dx.doi.org/10.1017/S1755267209000463>

- Tovar-Hernández, M.A., Méndez, N. & Villalobos-Guerrero, T.F. (2009b) Fouling polychaete worms from the southern Gulf of California: Sabellidae and Serpulidae. *Systematics and Biodiversity*, 7, 1–18.
<http://dx.doi.org/10.1017/S1477200009990041>
- Tovar-Hernández, M.A., Villalobos-Guerrero, T.F., Yáñez-Rivera, T.F., Aguilar-Camacho, J.M. & Ramírez-Santana, I.D. (2012) *Guía de invertebrados acuáticos exóticos en Sinaloa*. Geomare, A. C., USFWS, INE–Semarnat, Mazatlán, México, 41 pp.
- Tovar-Hernández, M.A., Yáñez-Rivera, B. & Bortolini-Rosales, J.L. (2011) Reproduction of the invasive fan worm *Branchiomma bairdi* (Polychaeta: Sabellidae). *Marine Biology Research*, 7 (7), 710–718.
<http://dx.doi.org/10.1080/17451000.2010.547201>
- Tovar-Hernández, M.A., Yáñez-Rivera, B. (2012) Ficha técnica y análisis de riesgo de *Branchiomma bairdi* (McIntosh, 1885) (Polychaeta: Sabellidae). Capítulo IX. In: Low Pfeng, A.M. & Peters-Recagno, E.M. (Eds.), *Invertebrados marinos exóticos en el Pacífico mexicano*. Geomare, A.C., INE–Semarnat, México, pp. 167–190.
- Tovar-Hernández, M.A., Yáñez-Rivera, B., Villalobos-Guerrero, T., Aguilar-Camacho, J.M. & Ramírez-Santana, I.D. (2014) Detección de invertebrados exóticos en el Golfo de California. In: Low Pfeng, A.M., Quijón, P.A. & Peters-Recagno, E.M. (Eds.), *Especies invasoras acuáticas: casos de estudio en ecosistemas de México. Segunda parte, distribución de especies invasoras: casos de estudio. Capítulo 16*. Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT), Instituto Nacional de Ecología y Cambio Climático (INECC), University of Prince Edward Island (UPEI). México, D.F., pp. 381–409.
- U.S. National Museum of Natural History (2015) Invertebrate zoology collections database. Available from: <http://collections.nmnh.si.edu/search/iz/> (accessed 21 August 2015)
- WoRMS Editorial Board (2015) World Register of Marine Species. VLIZ Available from: <http://www.marinespecies.org> (accessed 26 August 2015)
- Zenetos, A., Gofas, S., Verlaque, M., Çinar, M.E., Garcia Raso, J.E., Bianchi, C.N., Morri, C., Azzurro, E., Bilecenoglu, M., Froggia, C., Siokou, I., Violanti, D., Sfriso, A., San Martin, G., Giangrande, A., Kataan, T., Ballesteros, E., Ramos-Espla, A., Mastrototaro, F., Ocana, O., Zingone, A., Gambi, M.C. & Streftaris, N. (2011) Alien species in the Mediterranean Sea by 2010. A contribution to the application of European Union’s Marine Strategy Framework Directive (MSFD). Part I Spatial distribution. *Mediterranean Marine Science*, 11, 381–493.
<http://dx.doi.org/10.12681/mms.87>
- Zibrowius, H. (1991) On-going modification of the Mediterranean fauna and flora by the establishment of exotic species. *Mesogee (Bulletin du Museum d’ Histoire Naturelle de Marseille)*, 51, 83–107.