

Research Article

New records of the non-indigenous species *Branchiomma bairdi* and *B. conspersum* (Polychaeta: Sabellidae) on the Pacific coast of North America

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Abstract

Among Sabellidae (polychaetes commonly found in hard substrate fouling communities), the genus *Branchiomma* K lliker is a species-rich group with an expanding global history of invasions. In this paper, we report the first new records of *Branchiomma bairdi* along the Californian and Hawaiian coasts. Moreover, we confirm the first recorded introduction and range extension of *Branchiomma conspersum*. *Branchiomma conspersum* is originally from the Caribbean Sea and is a new non-indigenous species on the Pacific side of Panama and is also present in Hawaii and Australia.

Key words: Sabellid, NIS, biological, invasions, shipping, fouling, California, Hawaii

Introduction

The genus *Branchiomma* K lliker is reported to include 29 valid species names (Keppel et al. 2015), but proper identification is particularly challenging for this group due to morphological variation in taxonomically informative characters at the species level. Consequently, the genus is currently under review using molecular identification techniques (Del Pasqua et al. 2018). Since the contributions of Knight-Jones et al. (1991), it is clear that many records have been misidentified throughout the world, including possibly undescribed species. Knight-Jones was the last expert to work on *Branchiomma cingulatum* (Grube, 1870), and she had begun to write a paper questioning previous reports of the species and trying to re-describe the species that was easily misidentified as *Branchiomma japonica* (McIntosh, 1885). However, taxonomic documents obtained from her original work at the National Museum of Wales, Cardiff are uninformative with regards to taxonomic clarification. As a result, the taxonomic nomenclature is in a state of flux where previous names are being resurrected

and a revision of the genus is needed. For example, a recent paper re-examined all the reports of *B. bairdi* (McIntosh, 1885) in the Mediterranean and led to the re-identification of some specimens as *B. boholense* (Grube, 1878); therefore both are present in the Mediterranean (Del Pasqua et al. 2018). Similar mistakes are common within this genus around the world. Four *Branchiomma* species have been reported to occur outside of their native ranges, as non-indigenous species (NIS), around the world (Keppel et al. 2015): *B. bairdi*, *B. boholense*, *B. curtum* (Ehlers, 1901) and *B. luctuosum* (Grube, 1870). In this paper, we report for the first time new records of *B. bairdi* and *B. conspersum* along the Californian and Hawaiian coasts.

Branchiomma bairdi is native to southern Florida, Bermuda, and the Caribbean, including the coast of Panama, Cura ao, and the Virgin Islands. It has been introduced to the Mediterranean Sea, the Canary Islands (Arias et al. 2013), the Balearic Sea (Cepeda and Rodr guez-Flores 2017), Madeira, Portugal (Ramalhosa et al. 2014), the Tunisian coast (Khedhri et al. 2017), Queensland, Australia (Capa et al. 2013),

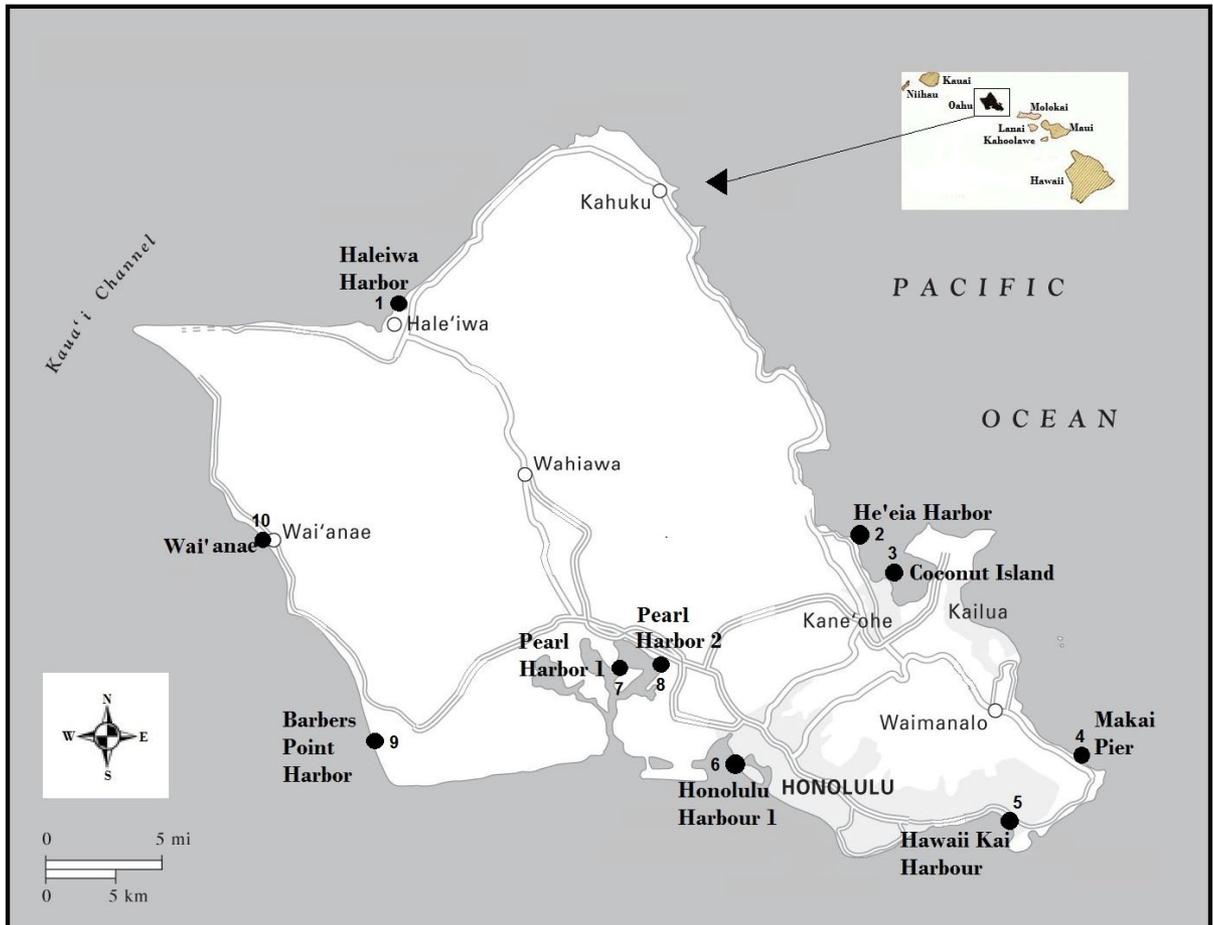


Figure 1. Map of the 10 (plain blank dots) sites sampled in 2015 in Oahu, Hawaii (see details in the Supplementary material Table S1).

the Pacific coast of Mexico (Tovar-Hernández et al. 2009a, b; Bastida-Zavala et al. 2016), and Coiba National Park, Panama, on the Gulf of Montijo, Pacific coast, where it was found in 1998 (Capa and López 2004). The reproductive habits of *B. bairdi* include both sexual (simultaneous hermaphrodite) and asexual reproduction (architomy) (Tovar-Hernández et al. 2011). *Branchiomma bairdi* is considered invasive to coastal environments due to high densities attained on buoys and hulls of vessels, its feeding mode, and its anti-predation strategies (Tovar-Hernández and Yáñez-Rivera 2012; Arias et al. 2013; Ramalhosa et al. 2014; Diario Oficial de la Federación 2016). *Branchiomma conspersum* (Ehlers, 1887) is a Caribbean species and was never reported to be translocated until now.

Here we summarize all the new records of *B. bairdi* and *B. conspersum* in the eastern Pacific, unraveling their identification in California, Hawaii, and Australia.

Material and methods

Settlement plates were deployed on the Pacific, Atlantic, and Gulf coasts of the United States of America to survey for NIS from 2000–2016 (see also Figure 1 in Keppel et al. 2015). Embayments were chosen to focus on high salinity communities in relatively large estuaries that are in close proximity to major population centers and port systems. For each of the 25 bays, a stratified sampling design was used, selecting approximately 10 sites (e.g., marinas, ports, bridges, piers and buoys) with salinities greater than 20 PSU. As a part of this survey, 10 sites were sampled in Oahu, Hawaii in 2015 (Figure 1; Supplementary material, Table S1), and 14 sites were sampled in San Diego, California, in 2000 and 2013 (Figure 2; Supplementary material, Table S1).

Poly-vinyl chloride (PVC) settlement plates (14 × 14 × 1 cm) were deployed in late spring or early

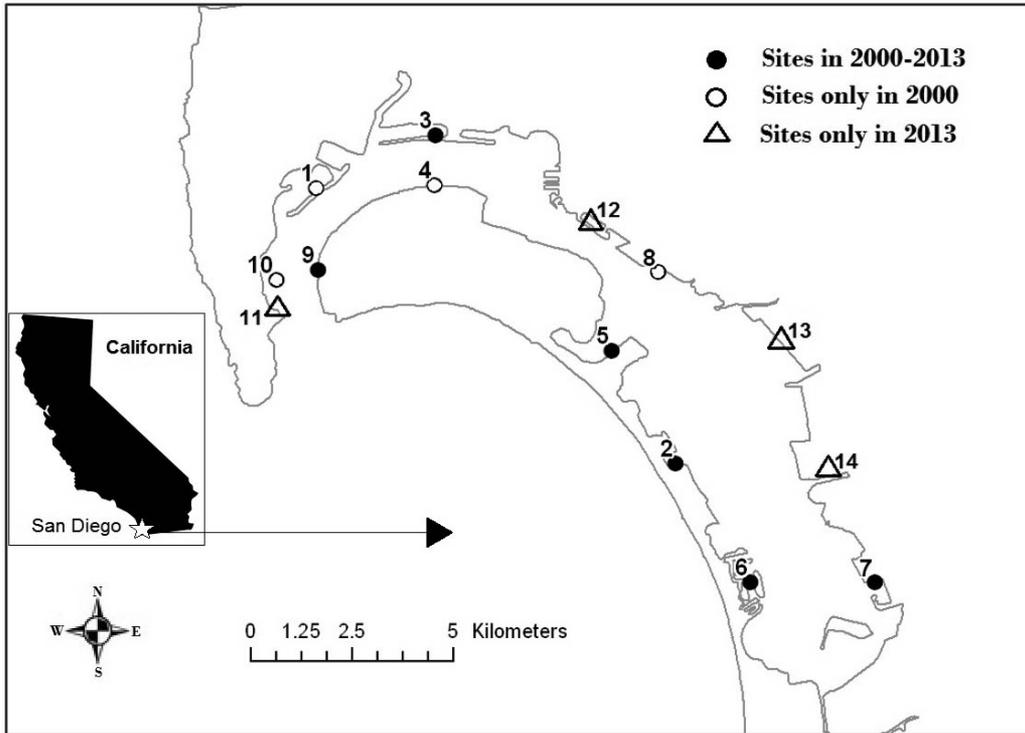


Figure 2. Sites in San Diego bay during the survey in 2000 and 2013: 1. Island Palm Marina, Shelter Island, 2. NAB Fiddlers Cove, 3. Cabrillo Isle Marina, 4. Navy Pier 14, 5. NAB ACU-1 Docks, 6. Coronado Cays Marina, 7. Chula Vista Marina, 8. Crosby St Pier, 9. Navy Ammo Dock, Pier, 10. Bait Dock, 11. Naval Base Point Loma, 12. Marriott Marquis and Marina, 13. Naval Station San Diego, 14. Pier 32 Marina (see details in the Supplementary material Table S1).

summer and retrieved after three months. Five plates were randomly distributed at each site and suspended from docks 1 m below mean low water level. Once retrieved, sessile invertebrates were collected live, sorted, and preserved in ethanol for identification. This material is part of the reference collection of the Marine Invasions Laboratory at the Smithsonian Environmental Research Center (SERC) in Edgewater, Maryland.

Results

Systematics

Order SABELLIDA Latreille, 1825
 Family SABELLIDAE Latreille, 1825
 Genus *Branchiomma* Kölliker, 1858
Branchiomma bairdi (McIntosh, 1885)

Figure 3

Dasychone bairdi McIntosh 1885: 495–497, pl. 30A, figs 13–15; pl. 39A, figs 2, 9.— Monro 1933: 267.— Rioja 1951: 513–516, pl. 1, figs 1–7.— Rioja 1958: 286–287.
Branchiomma cf. bairdi.— Capa and López 2004: 70, figs 5A–I.

Branchiomma bairdi.— Rioja 1960: 308–309, fig. 28.— Tovar-Hernández and Knight-Jones 2006: 13–17, figs 3A–D, H–K, 9C–D, 10C, 11B.— Tovar-Hernández et al. 2009a: 3–8, figs 2–4.— Tovar-Hernández et al. 2009a: 321–322, figs 2a, d–e, h, 3a–b, 4a–b, 5a–b.— Çinar 2009: 2320, fig. 13A–C.— Bastida-Zavala et al. 2016: 406–407, fig. 10A.— Cepeda and Rodríguez-Flores 2017: 2–4, figs 1A–D, 2.

Examined material

San Diego, California, USA. Site Coronado Cays Marina, 32°37'35.52"N; 117°7'51.59"W (2000): plate 1000: SERC vial # 32071 (1 specimen); Chula Vista Marina, 32°37'21.94"N; 117°6'8.65"W (2000): plate 1083: SERC vial # 12410 (1 specimen); Navy Pier 14, 32°42'54.34"N; 117°11'59.35"W (2000): plate 1114: SERC vial # 237765 (1 specimen). Site Pier 32 Marina, 32°39'4.16"N; 117°6'31.55"W (19th August 2013): plate 15941: SERC vial # 190592 (1 specimen); plate 15207: SERC vial # 189393 (1 specimen).

Oahu, Hawaii, USA. Site Honolulu Harbor, 21°19'2.29"N; 157°53'32.48"W (6th December 2015), plate 30106: SERC vial # 227498 (1 specimen), plate 30104: SERC vial # 227490 (1 specimen), SERC vial # 227459 (1 specimen); Site Coconut

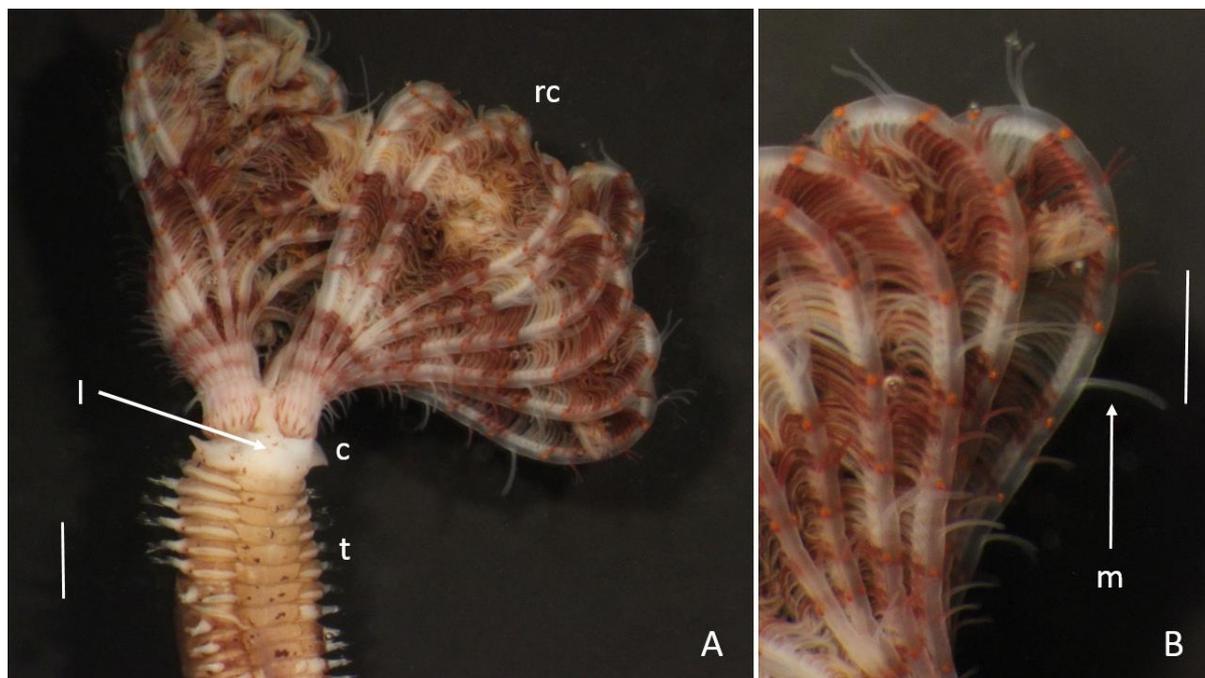


Figure 3. Preserved specimen of *Branchiomma bairdi* sampled in 2015 in Oahu, Hawaii (Vial # 227523); A) ventral view showing thorax (t), collar (c), lappets (l), and radiolar crown (rc); B) radioles with macrostylodes (m). The white bar is 1 mm. Photographs by Erica Keppel.

Island, 21°25'58.00"N, 157°47'19.64"W (7th December 2015); plate 30173: SERC vial # 227523 (1 specimen), SERC vial # 227525 (5 specimens).

Description

Body dark olive-green with small brown and white spots over the whole surface when alive, light brown-violet when preserved (Figure 3A). Interramal dark spots present, larger on first thoracic segments and progressively smaller towards posterior region. Radiolar crown with olive-green bands alternating with white bands around radioles, each band occupying the space of three pinnules and colour extends into pinnules and stylodes. Rachis with orange rhomboid spots. Radiolar crown base bearing longitudinal bands of diffuse brown spots in line with each radiole axil, red to orange radiolar eyes. Mid-rib of dorsal lips olive-green, ventrally not coloured. The measurements depend on the size of the specimens and the contraction during preservation, but in our specimens, the crown length ranges from 0.4 to 1.7 cm, thorax wide from 0.1 to 0.2 cm, thorax length from 0.1 to 0.5 cm, and abdomen length from 0.5 to 2 cm. Radiolar crown united at base by a short web, bearing 10–24 pairs of radioles with apinnulate tips and stylodes. Basal stylode small, unpaired and digitiform. Macrostylodes

strap-like (Figure 3B), up to four times as long as neighbouring pairs, mostly in distal half of the radiole, with remaining stylodes digitiform; all stylodes about one-third width of rachis. Eyes small and compound (with subconical lenses), not present between last pair of stylodes and radiolar tip. Dorsal lips long, about one-third length of radioles and tapering supported by a longitudinal ridge or mid-rib. Ventral sacs or sand sacs prominent. Dorsal collar with free, well separated margins, lateral margins above junction with crown and thorax, ventral lappets triangular or rounded, well-spaced at mid-line but in some cases, slightly overlapped. Thorax with 4–8 segments with inter-ramal dark spots. Ventral shields rectangular, anterior margin of first shield fairly straight (Figure 3A). Collar chaetae spine-like arranged in compact fascicles. Thoracic notochaetae arranged in irregular oblique rows of superior and inferior chaetae; each superior chaeta slender, narrowly-hooded, inferior chaetae spine-like. Thoracic tori abutting ventral shields; avicular uncini with crest surmounted by two rows of teeth (side and profile views), occupying about one-third of crest, with three distinct teeth in anterior row and a few very small teeth. Abdominal tori smaller than those in thorax. Fascicles of abdominal chaetae forming compact tufts, with superior group of narrowly-hooded chaetae and inferior spine-like

chaetae; number of chaetae per fascicle decreases gradually towards posterior end. Abdominal uncini similar to those in thorax. Faecal groove passing around right side of body from last thoracic segment to second segment of ventral abdomen and on to bilobed pygidium.

Remarks

Branchiomma bairdi is already reported for Queensland, Australia (Capa et al. 2013), and it is possibly the *Branchiomma* sp. B reported in Hawaii in Capa et al. (2013) (Capa et al. unpublished data). We hypothesize that that the records from Lizard Island by Capa and Murray (2015) do not belong to this species, as evidenced by Figures 3A–B, which shows great similarity to *B. conspersum*, but molecular analyses are currently underway to test this hypothesis (Capa et al. unpubl. data).

In this study, *B. bairdi* was found in marinas from San Diego, California during an initial survey in 2000 and a subsequent survey in 2013. We therefore assume that the species is now established in Southern California. The record of *B. bairdi* in Hawaii could represent a case of an older establishment, as the same species was present in one of our prior surveys in 2006.

Distribution

Original distribution: Western Atlantic Ocean: Gulf of Mexico and Caribbean Sea. Distribution as NIS: Pacific Ocean: Panama, Hawaii, Australia, San Diego, California, Gulf of California, Southern Mexico; Indian Ocean: Queensland and Lizard Island (doubtful record) Australia; Eastern Atlantic Ocean: Canary Island and Mediterranean Sea.

Branchiomma conspersum (Ehlers, 1887)

Figure 4

Dasychone conspersa Ehlers 1887: 266–270, pl. 54, figs 1–6.
Dasychonopsis arenosa Treadwell 1924: 1–2, figs 1–4.
Branchiomma conspersum.— Knight-Jones 1994: 192.— Tovar-Hernández and Knight-Jones 2006: figs 4A–J, 10E, 11D.

Examined material

Oahu, Hawaii, USA. Pearl Harbor NOAA dock, 21°22'2.55"N; 157°57'51.59"W (10th December 2015), plate 30132; SERC vial # 227707 (1 specimen), SERC vial # 227711 (1 specimen), plate 30129, SERC vial # 227637 (1 specimen); site Hawaii Kai harbor, 21°17'4.00"N, 157°42'30.55"W (16th December 2015), plate 30226, SERC vial # 228624 (1 specimen).

Description

Live specimens with radiolar crown with multiple thin brown bands and orange spots between each pair of black eyes, brown dorsal lips with an orange mid-rib. Body dark brown with small brown spots. Preserved specimens with general dark brownish pigmentation and darker spots (Figure 4). The orange spots on radioles remain for at least some time in most specimens after fixation (Figure 4A, C); sometimes they are not present or disappear in preserved specimens. Radiolar crown with basal lobes semicircular or slightly involuted ventrally. The crown length ranges from 1 to 1.3 cm, thorax wide from 0.2 to 0.35 cm, thorax length from 0.4 to 0.5 cm, and abdomen length from 1.3 to 1.7 cm. Dorsal and ventral basal flanges absent. Basal membrane reduced. Radiolar flanges absent. Paired stylodes present, digitiform, shorter than or similar to the width of rachis, except for macrostylodes (Figure 4B, C) mainly in distal half of radiole, tongue-like, and up to four times as long as neighbouring pairs; unpaired basal stylodes present, also longer than width of rachis. Radioles with paired compound eyes, black, along lateral margins of radioles alternating with stylodes. Dorsal lips with long radiolar appendages and one third the length of crown (Figure 4D); ventral lips and parallel lamellae present; ventral sacs outside or radiolar crown. Posterior peristomial ring collar with well-separated dorsal margins; ventral lappets quadrangular, separated by a mid-ventral incision, and with a distinctive yellow spot on each lappet. Interramal eyespots present in thorax and abdominal chaetigers. Ventral shields conspicuous, in contact with neuropodial tori; first one with M-shaped anterior margin. Collar chaetae spine-like arranged in compact fascicles. Following thoracic chaetigers with notopodia as conical lobes, with superior narrowly-hooded notochoetae, inferior spine-like notochoetae. Thoracic uncini avicular, with two rows of teeth over main fang, occupying about half of main fang, breast well developed, handle very short. Companion chaetae absent. Abdominal neuropodia as conical lobes with superior narrowly-hooded neurochaetae and inferior spine-like neurochaetae arranged in a C-shaped pattern. Uncini avicular, with three rows of teeth above main fang, breast well developed, handle very short. Bilobed pygidium with eyespots on lateral margins.

Remarks

Branchiomma conspersum can be distinguished from other congeners by the presence of an extensive variation in the stylodes and macrostylodes and the colour pattern, with dark brown bodies and conspicuous bright

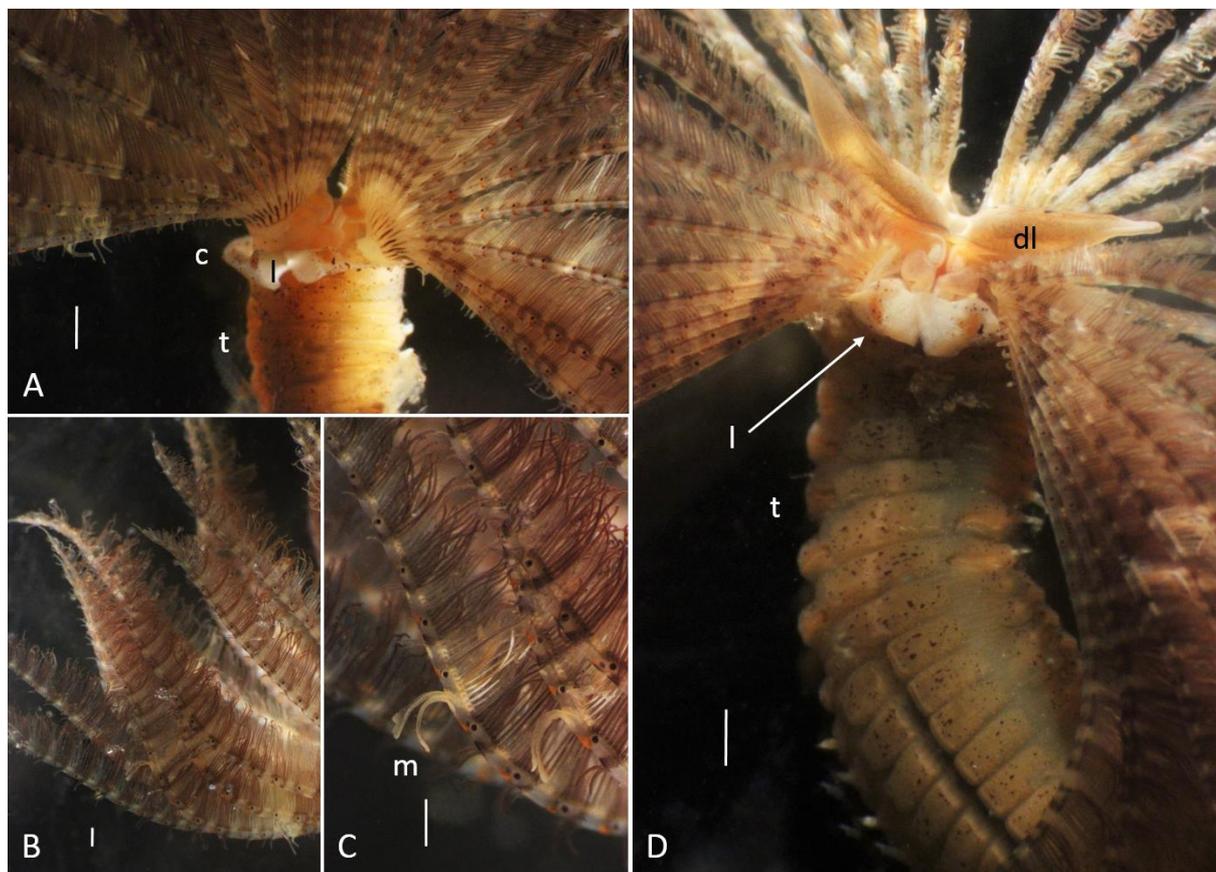


Figure 4. Live specimen of *Branchiomma conspersum* sampled in 2015 in Oahu, Hawaii (Vial # 227637); A) ventral view showing thorax (t), collar (c), lappets (l) and base of radioles; B) radioles; C) detail of radioles with macrostylodes (m), D) ventral view with dorsal lips (dl) visible. Scale bars: A, D 1 mm; B, C 0.2 mm. Photographs by Erica Keppel.

orange spots alternating with radiolar eyes and on the ventral lappets. The species reported as *B. bairdi* from Lizard Island (Capa and Murray 2015; Figure 3 A–B), as well as *Branchiomma* sp. D from Australia and Hawaii (Capa et al. 2013) should be referred to as this species.

Distribution

Original distribution: Western Atlantic Ocean: Gulf of Mexico and Caribbean Sea. Distribution as NIS: Pacific Ocean: Hawaii; Indian Ocean: Lizard Island, Australia.

Discussion

We report new records of *Branchiomma bairdi* and *B. conspersum* for the Pacific coasts of California and Hawaii. *Branchiomma bairdi* is a well-known species, native to the Caribbean Sea, with records

throughout the world. It was already recorded in Australia, but these records were misidentified. It is now present on Hawaii Island, even if the recorded date of its first arrival there is not certain. Since it was recorded in Mazatlán (southern Gulf of California), it was probably able to disperse anthropogenically through shipping across the Panama Canal. It seems to be spreading and expanding its range and appears well-established in southern California, as specimens from San Diego found in 2000 undoubtedly belong to this species. The species was identified most likely under *Branchiomma* sp. A in Southern California (Cohen et al. 2005). The same species is established in the Mediterranean Sea.

Branchiomma conspersum has not previously been recorded as having an introduced population. It is a Caribbean species that dispersed anthropogenically through the Panama Canal to the Eastern Pacific (Tovar-Hernández MA, pers. comm.). After

reviewing some material from Hawaii and Lizard Island, we can say that the species was already present in Hawaii and Australia (Capa et al. 2013), therefore it should be listed as a NIS worldwide. Molecular analysis of Lizard Island specimens reported in Capa and Murray (2015) will be the subject of future work on the species.

In Hawaii, the *Branchiomma* genus was present in 9 out of 10 sites sampled, and the highest abundances were found at the two Pearl Harbor sites, suggesting a possible origin of invasion through fouling on military ships. The most probable pathway for introduction of all the *Branchiomma* species is shipping, specifically as a fouling species on the hulls of ships. No *Branchiomma* species were found at the Makai Pier site. *Branchiomma bairdi* seems to be present exclusively in Honolulu Harbor, He'eia Harbor, Wai'anae Harbor and Barbers Point Harbor Ko'olina Marina. In Hale'iwa, only *B. conspersum* appears to be present. At the Pearl Harbor, Coconut Island and Hawaii Kai Harbor sites, both species are present. Specimens from a previous round of sampling in 2006, belonging to the SERC collection, were checked, and both species were already present in Hawaii at that time. These findings represent NIS arrivals before the Japanese tsunami of 2011 (Carlton et al. 2017).

We suggest that particular care is taken during taxonomic identification for this genus. Ideally, managers and researchers involved in monitoring surveys can review key characters as well as collect voucher material for taxonomic confirmation. Moreover, it is our recommendation that these species are preserved directly in ethanol, even if it would be ideal to fix some specimens in formalin and some in ethanol to allow for the best morphological and molecular examinations. The reasons for primarily using ethanol are two-fold: specimen color can be considered diagnostic and is better preserved in ethanol. Also, a worldwide revision of this genus is needed; fixing and storing specimens in ethanol allows for future molecular analysis of all specimens collected and allows any future reviews of this genus to be more comprehensive.

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Supplementary material

The following supplementary material is available for this article:

Table S1. Details of surveys conducted in 2000-2013-2015 in San Diego and Hawaii: location name, vial number, coordinates, presence of *Branchiomma bairdi* and *B. conspersum*, and native/non-native status.

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