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Research Article

# New records of native and non-indigenous polychaetes (Annelida: Polychaeta) in the Galapagos Islands

Erica Keppel[1,*], Inti Keith[2], Gregory M. Ruiz[1] and James T. Carlton[3]

[1]*Smithsonian Environmental Research Center, P.O. Box 28, 647 Contees Wharf Road, Edgewater, Maryland, 21037, USA*
[2]*Charles Darwin Research Station, Puerto Ayora, Galapagos Islands*
[3]*Maritime Studies Program, Williams College-Mystic Seaport, 75 Greenmanville Avenue, Mystic, Connecticut 06355, USA*
Author e-mails: *keppele@si.edu (EK), inti.keith@fcdarwin.org.ec (IK), ruizg@si.edu (GMR), james.t.carlton@williams.edu (JTC)*
**Corresponding author*

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## Abstract

The biofouling community on Santa Cruz and Baltra Islands, Galapagos, was surveyed in 2016 based on samples from settlement plates deployed in 2015 and 2016 at three different sites. We report numerous new records for the Galapagos fauna: one novel family (Opheliidae), nine novel genera, and 15 novel species records were documented in a total of seven families. Six introduced species were found, the syllid *Myrianida pachycera,* the sabellids *Branchiomma bairdi, Branchiomma* sp. and *Pseudobranchiomma schizogenica*, and the serpulids *Hydroides elegans*, *Hydroides sanctaecrucis*, along with one cryptogenic species, the spionid *Dipolydora armata.* Non-native species come from either the warm waters of the Western Atlantic or Indo-West Pacific Oceans.

**Key words:** biofouling, introduced, NIS, cryptogenic, shipping

## Introduction

The polychaete annelid fauna of the Galapagos Islands is remarkably poorly known. Blake (1991) summarized all known polychaete records. The earliest collections appear to be those from the Swedish frigate *Eugenie* expedition of the 1850s, followed by other research vessel visits in the early decades of the 1900s. Between 1933 and 1938 the *Velero* expeditions of the Allan Hancock Foundation resulted in extensive collections, not all of which have been worked up (Blake 1991). Surprisingly little work ensued for the rest of the 20th century (Blake 1991). Since Blake's excellent summary that listed 192 species, Bastida-Zavala and ten Hove (2003), Nishi et al. (2009) and Blake (2017) added *Hydroides ochotereana* Rioja, 1941, five species of *Chaetopterus*, two species of *Mesochaetopterus,* and *Naineris setosa* (Verrill, 1900). We have found no reports of prior collections of polychaetes from the biofouling communities of Galapagos ports and harbors.

We report here new records of non-indigenous, cryptogenic, and presumably native polychaetes from Santa Cruz and Baltra Islands. No

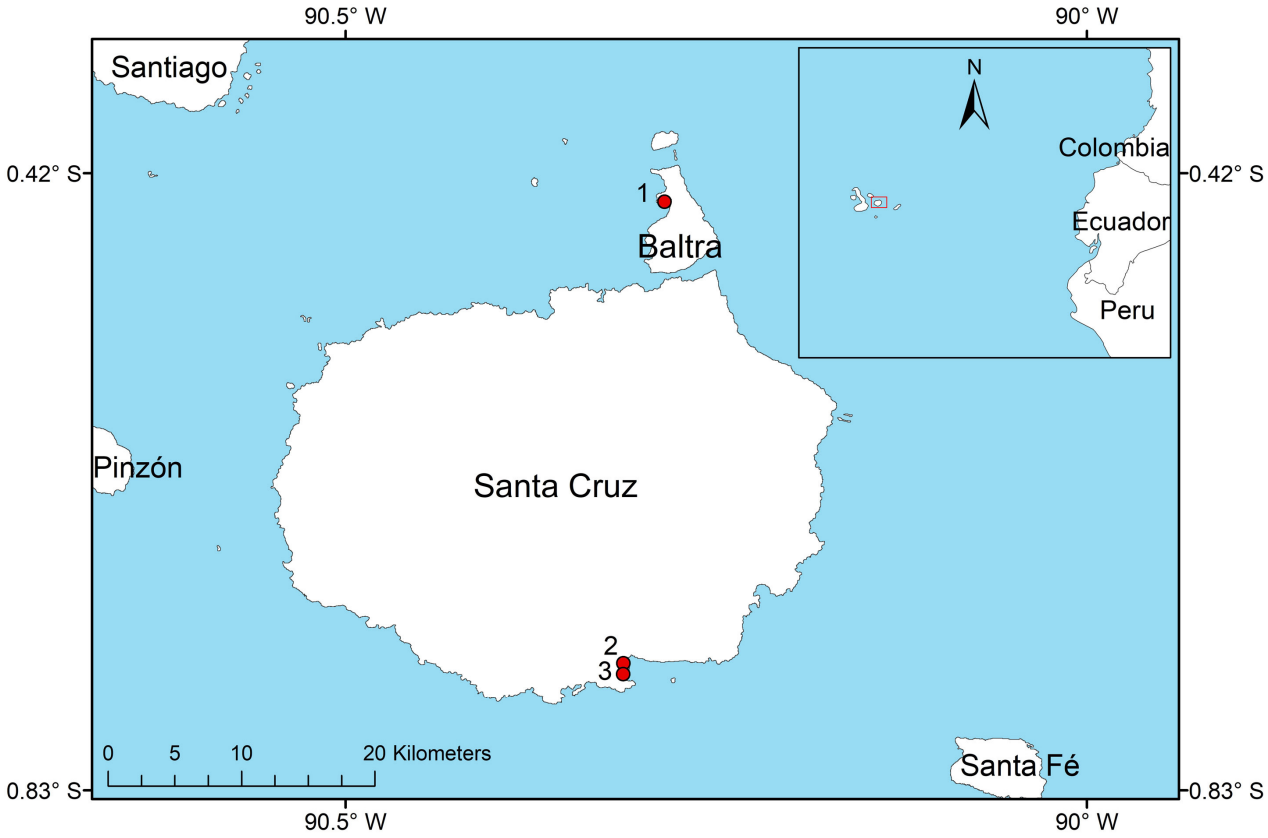


**Figure 1.** Map of Galapagos Islands showing the location of the three sampling sites: 1, Baltra Island Ecuadorian Navy dock; 2, Puerto Ayora Main Passenger dock in Academy Bay and 3, Franklin's Bay dock, both on Santa Cruz Island. Map courtesy of Linda McCann.

previous work on Galapagos polychaetes has reported the presence of non-indigenous species (NIS).

## Materials and methods

Polyvinylchloride (PVC) settlement plates (14 × 14 cm) were suspended horizontally 1 m below mean low water to survey for both NIS and native species in February 2015 and January 2016. Some plates were caged with a 5 mm mesh for predator-exclusion studies but most plates were uncaged; analysis of exposed versus caged experimental panels will be reported elsewhere. In some cases, specimens were collected directly from the rope hanging the plates. Plates were deployed on Santa Cruz Island at two stations, Puerto Ayora's Main Passenger Dock (0°44′52.04″S; 90°18′44.98″W) and in Franklin's Bay (0°45′18.72″S; 90°18′45.56″W), and on adjacent Baltra Island (0°26′9.52″S; 90°17′5.29″W) (Figure 1, Supplementary material Table S1). The plates were retrieved 14 and three months later in April 2016. Temperature and salinity at 1 m depth were measured with a YSI temperature-conductivity meter. Plates were transported in seawater and analyzed at the Charles Darwin Research Station's (CDRS) marine biological laboratory (BioMar) in Puerto Ayora.

All material was preserved in 95% ethanol, and specimens have been deposited in the CDRS invertebrate collections.

## Results

### *Water Parameters*

In April 2016 at the Santa Cruz and Baltra sites, the temperature at 1 m depth ranged from 22.9 to 23.9 °C, and salinity ranged from 33 to 35.3 psu.

### *Systematic Account*

We report numerous new records for the Galapagos fauna: one novel family (Opheliidae), nine novel genera, and 15 novel species records were documented in a total of seven families.

Order Phyllodocida

Family Syllidae Grube, 1850

Subfamily Autolytinae Langerhans, 1879

We report two new records in two genera in the Autolytinae for the Galapagos.

Genus *Myrianida* Milne-Edwards, 1845

#### ***Myrianida pachycera* (Augener, 1913)**

*Autolytus pachycerus* Augener 1913: 257–260, pl. 2, Figures 11, 12, text fig. 40A–C (type locality: Sharks Bay, Western Australia 0.5–9 m, Harbor); Augener 1927: 157–158 (Sydney Harbor, at low tide, on the hydroid *Pennaria*).
*Autolytus purpureimaculata* Okada 1933: 332–338, Figures 6–11; 1937 (Seto and Misaki, Japan, closely attached to oysters); Imajima and Hartman 1964: 100 (Southern Japan).
*Myrianida crassicirrata* Hartmann-Schröder 1965: 119–121, Figures 47–49 (Hawaii, Kaneohe Bay, on coralligenous mud and sponge fauna); Hartman 1966b: 194–195 (Kaneohe Bay, Oahu, Hawaii, USA, in coral mud and in sponge colonies).
*Myrianida pachycera*: Imajima 1966: 79–82, Figure 26A–L (Misaki; Seto; Usa; Amakusa; Notogi, attached to a living oyster, *Crassostrea gigas* or among the ascidians *Halocynthia*); Imajima 1967: 417 (Tsukumo Bay, Mawaki, Japan); Nygren 2004: 143–146, Figures 71A–E (Los Angeles harbor, USA, 33°45′N; 118°16′W, 1 m, epifauna on ship).
*Myrianida pachycerus*: Hartman 1966a: 362–363, Figure 1A–B (Long Reef, New South Wales, in weed-mat, intertidal).

**Material.** Puerto Ayora (3 specimens, 25 April 2016, vial 232806, on caged plate 16465, deployed for 14 months).
**Taxonomic Remarks.** A species with a distinct color patterns, dorsal cirri thick and digitiform. The morphology of our Galapagos material agrees with the detailed description in Nygren (2004).
**Distribution and remarks.** A widespread Indo-West Pacific, to which region it is held to be native. It is considered to be introduced to the Hawaiian Islands and to the northern east Pacific coast, as well as to Florida (Carlton and Eldredge 2009). It could possibly be a complex of cryptic species, but to test this hypothesis molecular analyses are needed.

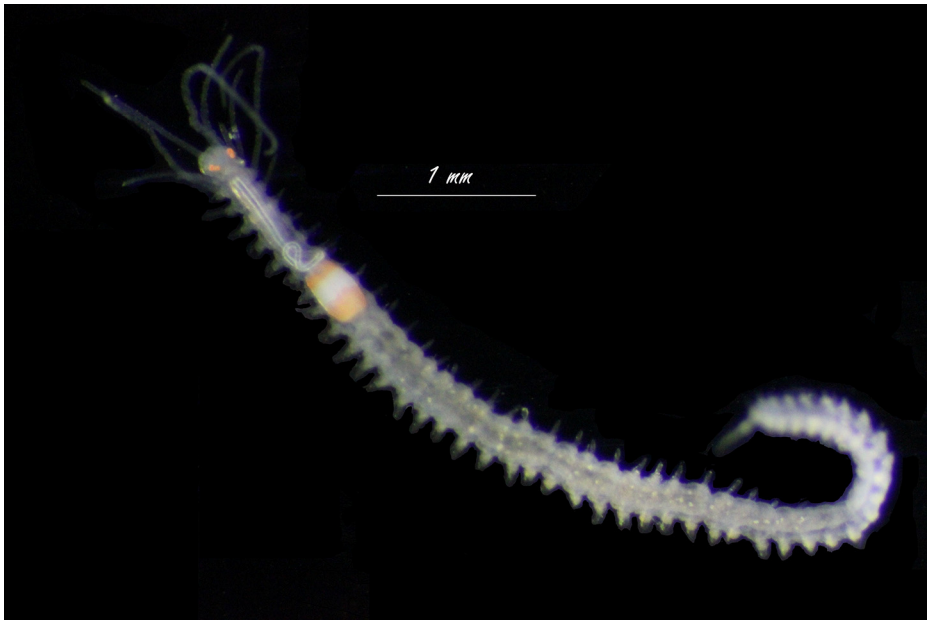


**Figure 2.** Living specimen of *Proceraea* cf. *rubroproventriculata* (photograph by E. Keppel).

Genus *Proceraea* Ehlers, 1864

### *Proceraea* cf. *rubroproventriculata* Nygren and Gidholm, 2001

(Figure 2)

*Proceraea rubroproventriculata* Nygren and Gidholm 2001: 184–187, Figures 2D–E, 5A–E, 6A–D, 7 (holotype (LACMPOLY 1964), paratype (LACM-AHF POLY 1965), type locality: Key Biscayne, Crandon marina, Florida, 25°43.4′N; 80°10.4′W, 0.5–1 m. Bara de Paranagua, west Ihla do Mel, Brazil, 25°34.55′S; 48°19.19′W, 10 m, boulders with epifaunal mat).

*Proceraea rubroproventriculata*: Nygren 2004: 74–75, Figures 27A–E (type locality: Key Biscayne, Crandon marina, Florida, 25°43.4′N; 80°10.4′W, 0.5–1 m. Bara de Paranagua, west Ihla do Mel, Brazil, 25°34.55′S; 48°19.19′W).

**Material.** Puerto Ayora (1 specimen, 25 April 2016, vial 233528, on caged plate 30237 deployed for three months).

**Diagnosis.** Anterior and posterior part of proventricle orange in living specimen (color lost in preserved material), eyes confluent, orange (Figure 2). Trepan in chaetiger 1, but the teeth were not sufficiently visible to count. Proventricle equal in length to 3–4 segments between chaetigers 6–9, with 30–35 rows of muscle cells.

**Taxonomic remarks.** We refer the present material provisionally to *Proceraea rubroproventriculata* because of the characteristic proventicle color pattern (in the red-orange spectrum), but we are unable to verify the trepan teeth number (12 large, 12 small) considered distinctive for this species. Nygren (2004) noted that, "*P. rubroproventriculata* is most similar to *P. paraurantiaca, P. filiformis* and *P. misakiensis,* but may be separated from these taxa on its trepan with 12+12 teeth." Our Puerto Ayora material is neither *P. paraurantiaca* nor *P. misakiensis*, whose color patterns are distinct in the North East Atlantic and North West Pacific respectively (the color of *P. filiformis* from South West Pacific is not known).

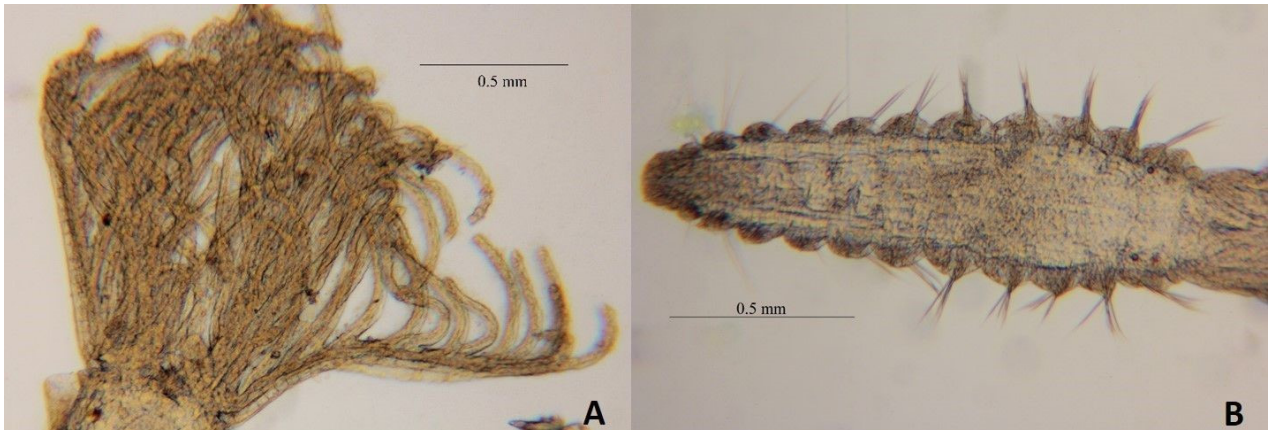


**Figure 3.** Preserved specimens of *Amphicorina* sp.: A) crown; B) body with eyes and statocysts (photographs by E. Keppel).

**Distribution and remarks.** *Proceraea rubroproventriculata* is an Atlantic species, known from Florida, USA to Paranaguá Bay, Brazil (Nygren 2004). If the Galapagos specimens prove to be this species, we would regard it as an introduction from the Atlantic. Westheide (1974) reported two *Proceraea* species from the Galapagos, the Atlantic species *P. fasciata* Langerhans, 1879 (now *P. madeirensis* Nygren, 2004), and *Proceraea* sp. from Academy Bay, Santa Cruz Island. Westheide's description of this second *Proceraea* species was based upon preserved (and thus colorless) material; he reported similar difficulties in viewing the pharynx teeth, but nevertheless reported 11–12 teeth, with the middle teeth apparently shorter than the lateral teeth. Both Westheide's and our material probably represent an undescribed species, as may his *P. madeirensis*, which (unless introduced) would be unlikely to occur naturally in the tropical Eastern Pacific.

Order Sabellida

Family Sabellidae Latreille, 1825

The family Sabellidae in Galapagos has been minimally investigated in the past. Blake (1991) noted that there was only one record of an identified sabellid, *Acromegalomma quadrioculatum* (Willey, 1905) (originally reported from the Galapagos in the 1930s as *Branchiomma mushaensis* Gravier, 1906, although Blake noted that the Galapagos specimens have never been reexamined). We identify three genera here, all new records for the Islands.

Genus *Amphicorina* Claparède, 1864

***Amphicorina* sp.**

(Figure 3)

**Material.** Puerto Ayora (4 specimens, 25 April 2016; vial 237613, on caged plate 16605 deployed for 14 months; vial 233535 from caged plate 30242 deployed for three months; vial 237616 from caged plate 30256 deployed for three months; vial 237617 from uncaged plate 16457 deployed for 14 months.

**Diagnosis.** A small sabellid of a few millimeters in length, body with eight thoracic and five abdominal chaetigers, three pairs of radioles, radiolar skeleton with two rows of cells, radioles with external flanges and palmate membrane (Figure 3A). Eyes present in the peristomium but not visible in the pygidium; a pair of statocysts in the first chaetiger (Figure 3B). Thoracic superior chaetae, with varying but narrow hoods, and an inferior row of smaller, thinned bayonet chaetae. Thoracic uncini acicular, with teeth of unequal sizes in first arc above main fang. Abdominal uncini quadrangular, handles absent, toothed margin with a more or less enlarged basal fang. Abdominal neurochaetae needle-like, elongate.

**Taxonomic remarks.** We are unable to resolve our material to species level. It may be a new species long been present but not detected earlier due to its small size.

**Distribution.** *Amphicorina* species are known from the Mediterranean, the southwest Atlantic, and the Western and Eastern Pacific Oceans.

Genus *Branchiomma* Kölliker, 1858

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

(Figure 4)

*Dasychone bairdi* McIntosh 1885: 495–497, pl. 30A, Figures 13–15; pl. 39A, Figures 2, 9 (type locality: shore at Bermuda).

*Dasychone bairdi*: Monro 1933: 267 (Dry Tortugas, Florida, stns 328 and 347); Rioja 1951: 513–516: pl. 1, Figures 1–7 (Veracruz, Gulf of Mexico).

*Branchiomma bairdi*: Johansson 1927: 167 (new combination); Rioja 1958: 286–287 (Veracruz, Gulf of Mexico); Tovar-Hernández and Knight-Jones 2006: 13–17, Figures 3A–D, H–K, 9C–D, 10C, 11B (Florida, Mexican Caribbean, Panamá and Lesser Antilles, mostly 1 m); Tovar-Hernández et al. 2009: 3–8, Figures 2–4 (Mazatlán port, Sinaloa, Mexico, on floating dock, 0.3–1 m depth); Çinar 2009: 2320, Figure 13 A–C (Iskenderun Bay, Turkey and northern Cyprus, 0.1–8 m, mud and rocks); Ramalhosa et al. 2014: Figure 2A–F (Archipelago of Madeira, Portugal, 1 m); Villalobos-Guerrero and Molina-Acevedo 2014: 106 (Sinaloa, Mexico, checklist); Bastida-Zavala et al. 2016: 406–407, Figure 10A (Baja California, Oaxaca, Mexico, 0–6 m); Cepeda and Rodríguez-Flores 2017: 2–5, Figures 1A–D, 2A–L (Estany des Peix lagoon, Formentera Island, Spain, 0–4 m); Khedhri et al. 2017: 141–143, Figure 2A–E (Boughrara Lagoon, Tunisia, 1 m); Keppel et al. 2018: 3–5, Figure 3 (San Diego, Californian and Oahu, Hawaii); Del Pasqua et al. 2018: 12, 15–16, Figure 8C–D, 9A–F (Madeira, Spain, Mazatlán and Veracruz, Mexico, Galapagos, Ecuador, Tampa Bay and Hawaii USA).

*Branchiomma* cf. *bairdi*: Capa and López 2004: 70, Figures 5A–I (Granito de Oro Island, Panamá; 7°35′30″N; 81°42′30″W, 2 m, dead coral block cryptofauna).

**Material.** Many specimens retrieved in 2016 from Franklin's Bay, Puerto Ayora, and Baltra, on many plates and other substrates.

**Diagnosis.** Dorsal collar with well separated margins, well developed triangular or rounded ventral lappets and rectangular but poorly visible ventral shields. Dorsal lips about one-third the length of the radiole. Crown united at the base by a low web, and 20–26 pairs of radioles on each side. Radioles have apinnulate tips and stylodes. Macrostylodes strap-like, two or three to each radiole, randomly alternating and mostly in distal half of radioles. Remaining stylodes digitiform. Thoracic tori, touching the ventral


**Figure 4.** Living specimen of *Branchiomma bairdi* (photograph by E. Keppel).

shield, composed of avicular uncini with the crest surmounted by 2–3 rows of teeth. Radiolar eyes orange. The colour of the radiolar crown varied from brownish to orange, often with stripes in cream or dark brown. The colour of the body of live specimens varied from pale, yellow, olive green to brownish.

**Distribution and remarks.** *Branchiomma bairdi* is a warm-water Western Atlantic species known from Bermuda and throughout the Caribbean to Panama (Keppel et al. 2015; Del Pasqua et al. 2018). It has been introduced to the Eastern Atlantic, to the Mediterranean Sea, to the Eastern Pacific (California to Panama) and to Australia (Keppel et al. 2018). It was found in 1998 on the Pacific coast of Panama (Capa and Lopez 2004), from where it may have been introduced to the Galapagos. It is a conspicuous component of benthic communities, largely in confined environments and areas degraded

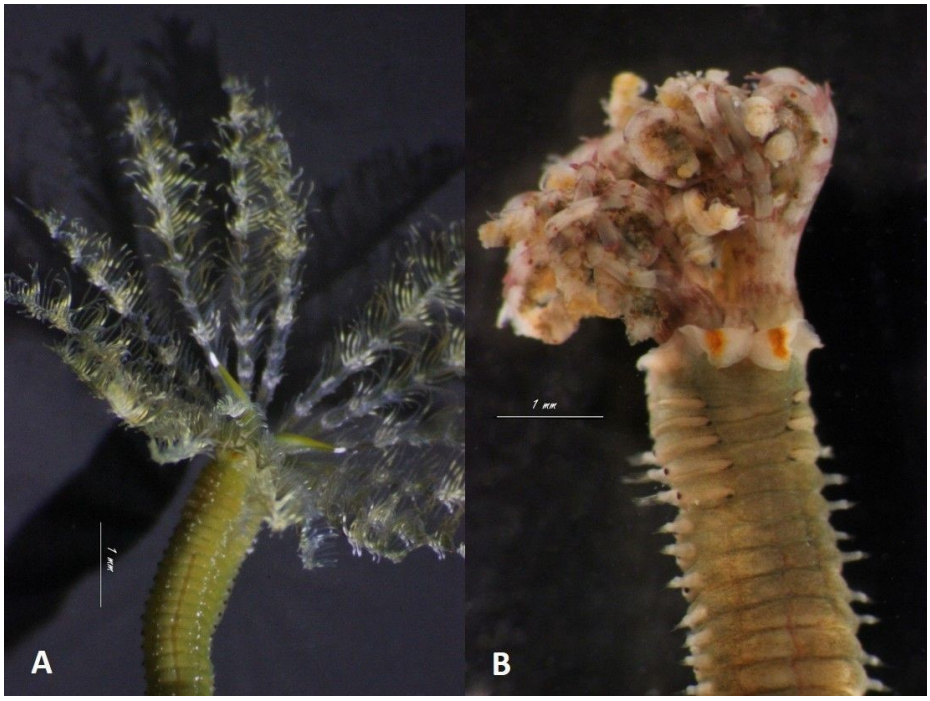


**Figure 5.** *Branchiomma* sp.: A) Live specimen with details of color and dorsal lips; B) Preserved specimen and details of ventral lappets (photographs by E. Keppel).

by anthropogenic impacts (Arias et al. 2013). *Branchiomma bairdi* appears to be abundant and well-established in the Galapagos. The identification was also confirmed from molecular analysis (Del Pasqua et al. 2018).

***Branchiomma* sp.**

(Figure 5)

**Material.** Franklin's Bay and Puerto Ayora (many specimens, 25 April 2016; two specimens were examined, collected in Puerto Ayora from vial 236733, on caged plate deployed for 12 months).

**Diagnosis.** Dorsal collar with well-separated margins, dorsal lips with a distinctive white tip and about 1/3 as long as the radiole (Figure 5A). Ventral lappets well-developed triangular or overlapping with a distinctive internal orange spot that remains after preservation (Figure 5B). Crown united at the base by a low web, and 8–12 pairs of radioles on each side. Radioles have apinnulate tips and stylodes. Stylodes strap-like, radiolar eyes orange. The colour of the radiolar crown varied from olive green to white, often with yellow stripes. The colour of the body of live and preserved specimens is bright green.

**Distribution and remarks.** Further studies are required to determine if this is a described or undescribed species; some specimens have been provided to Maria Capa for DNA analysis. This is likely an introduction and first record for the Galapagos.

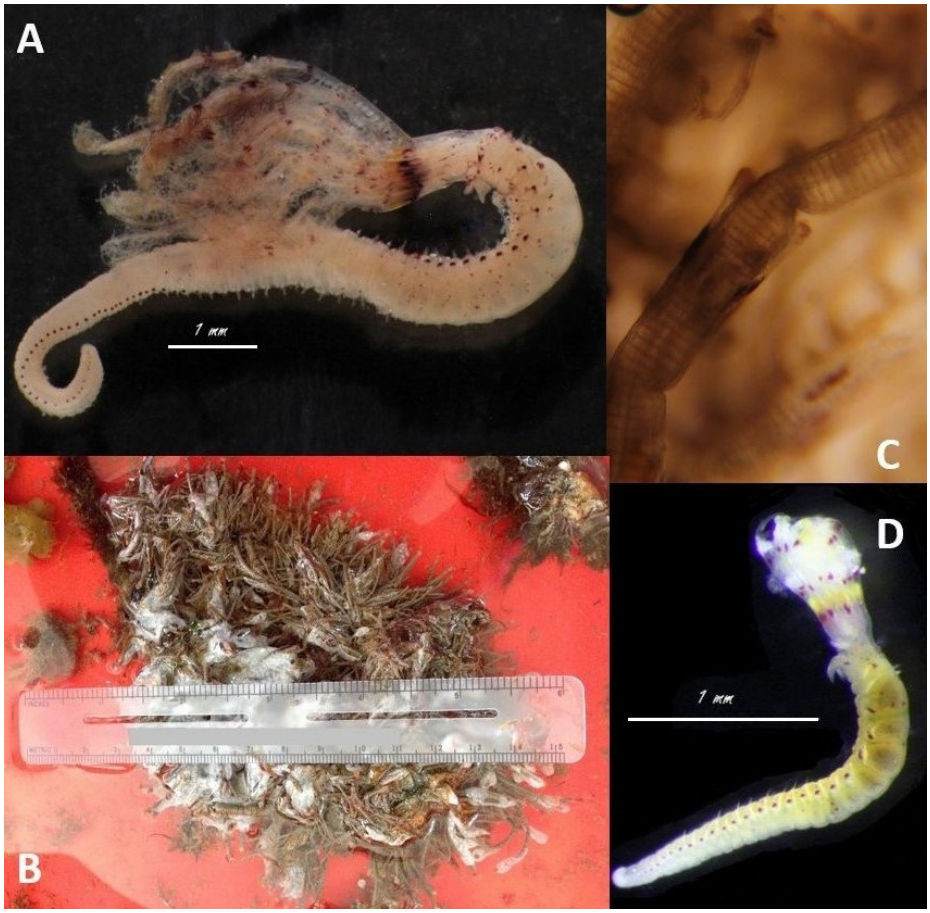


**Figure 6.** *Pseudobranchiomma schizogenica*: A) Preserved specimen; B) size of the colonies. C) Radiolar serration almost unnoticeable under stereomicroscope; D) Living juvenile with color pattern (photographs by E. Keppel).

Genus *Pseudobranchiomma* Jones, 1962

### ***Pseudobranchiomma schizogenica* Tovar-Hernández and Dean, 2014**

(Figure 6)

*Pseudobranchiomma schizogenica* Tovar-Hernández and Dean 2014: 936–945, Figures 1–5 (type locality: La Paz, southern Gulf of California, Mexico, 0.5 m, dock fouling in association with *Branchiomma bairdi*).

*Pseudobranchiomma* cf. *schizogenica*: Capa and Murray 2016: 23–28, Figures 3U–Z, A1, 8–10 (Western Australia, Northern Territory and Queensland, Australia, 3–30 m, Coconut Island, Hawaii, 1 m, coral rubble and epifauna attached to hard substrates).

**Material examined.** Puerto Ayora and Franklin's Bay, 2016, building large colonies (many specimens; vial 233551 from caged plate 30273 deployed for three months; vial 233575 from uncaged plate 16607 deployed for 14 months; vial 233580 from caged plate 16462 deployed for 14 months).

**Diagnosis.** *Pseudobranchiomma schizogenica* is a gregarious sabellid with a short body (Figure 6A, B). Our material matches the original description. Radioles with short, digitiform serrations (Figure 6C) along the entire radiolar length. No radiolar eyes. Lateral margins of collar oblique, covering anterior peristomial ring. Eleven pairs of radioles arranged in two semicircles. Eight pairs of short, digitiform serrations (6–9 pairs) along the

entire length of radioles. Dorsal margins of collar not fused to faecal groove, peristomium exposed dorsally. Ventral lappets triangular, distally rounded, not overlapping. Five thoracic segments: thoracic uncini with four teeth. Body bright yellow in live specimens, anteriorly speckled with few purple spots. Radioles with four or more purple bands separated by orange and translucent bands (Figure 6D). Interramal eyespots purple, larger anteriorly, decreasing gradually towards posterior end.

**Distribution and remarks.** *Pseudobranchiomma schizogenica* was recently described from "dock fouling" in shallow water in the southern Gulf of California. Capa and Murray (2016) have suggested that it may not be native to Mexico, given the discovery of other *P. schizogenica* populations or closely related clades widely distributed around the Pacific (including Australia and Hawaii). It would appear unlikely that this abundant, gregarious sabellid would have been overlooked in Western Mexico (including the Gulf of California) for decades prior to its detection and first collection in 2011 in Baja California Sur. Equally compelling is that among nearly 20 known species of *Pseudobranchiomma*, widely distributed in the Western Pacific and Indo-West Pacific as well as the Atlantic Oceans, *P. schizogenica*, is the only representative of the genus in the Eastern Pacific. Given its strong association with fouling communities, we concur that *P. schizogenica* is not native to the Eastern Pacific.

Family Serpulidae Rafinesque, 1815

Only six serpulid species were previously reported from the Galapagos (Blake 1991; Bastida-Zavala and ten Hove 2003), including two indigenous *Hydroides* species, *H. inermis* Monro, 1933 and *H. ochotereana* Rioja, 1941. Three new records of two different genera are reported here.

Genus *Hydroides* Gunnerus, 1768

*Hydroides elegans* and *H. sanctaecrucis*, treated below, are well-known introduced species; both appear to be undergoing major expansions from Panama to the Pacific Mexican coast (Bastida-Zavala et al. 2016, 2017).

### *Hydroides elegans* (Haswell, 1883)

*Eupomatus elegans* Haswell 1883: 633, pl. 12, Figure 1 (type locality: Port Jackson, Australia).
*Hydroides elegans*: Bastida-Zavala and ten Hove 2002: 164–166, Figures 35A–J, 36 (Florida, Texas, Puerto Rico, Atlantic Panama, Aruba, Curaçao, and Mexico: Veracruz, Campeche and Quintana Roo; 0–7 m; 31–37‰; on coral debris, fouling of wood pier and boats); Bastida-Zavala and ten Hove 2003: 86–87, Figure 11A–S (California and Hawaii; 0–1 m; fouling of marina piers and ship and submarine hulls); Bastida-Zavala 2008: 25–26, Figure 6H (California and Baja California Sur, Mexico; 0–1 m, on PVC plates and hull of boats); Bastida-Zavala et al. 2016: 419–420, Figures 4, 11F–G (Baja California Sur and Oaxaca; Mexico, fouling; 0–1 m).

**Material.** Baltra (21 specimens, 28 April 2016, from caged plates deployed for three months: vial 233609 from plate 30273; 233618 and 233619 from plates 30254; 233622 and 233625 from plate 30269; 233626 from plate 30270; 233641 from plate 30263; vials 233598, 233599 and 233600 from ropes).


**Figure 7.** Operculum of *Hydroides sanctaecrucis* (photograph by E. Keppel).

**Taxonomic remarks.** Our specimens agree in all details with the description in Bastida-Zavala and ten Hove (2003).

**Distribution and remarks.** Widely distributed in tropical-to-warm temperate marine waters. It is presumed to be native to the Indo-Pacific. Of interest is that it appeared in our samples only at the Ecuadorian Navy floating dock on Baltra Island, where the panels were deployed, and where this species was found on ropes as well as on five different plates deployed for three months. Its apparent restriction, at least as of 2016, may be due to a direct introduction from the mainland to the naval base in the Galapagos. The distribution of *Hydroides elegans* is generally limited to polluted harbours and eutrophic lagoons, except in the type locality and a few other locations (ten Hove 1974; Bastida-Zavala 2008).

### *Hydroides sanctaecrucis* Krøyer in Mörch, 1863

(Figure 7)

*Hydroides* (*Eucarphus*) *sanctae-crucis* Krøyer in Mörch 1863: 378–379, pl. 11, Figure 12 (type locality: Saint Croix Island, Lesser Antilles, Caribbean Sea).

*Hydroides sanctaecrucis*: Bastida-Zavala and ten Hove 2003: 101–102, Figure 19P–Q (Oaxaca, Mexico and Panama; salinity 19–25‰; on rocks and floats); Bastida-Zavala 2008: 29, Figure 6R (Huatulco, Oaxaca, Mexico; 0–1 m; on pier pilings); Bastida-Zavala et al. 2016: 426, Figures 6, 12E (Sonora, Baja California Sur and Oaxaca, Mexico; in marinas and harbors, fouling; 0–1 m).

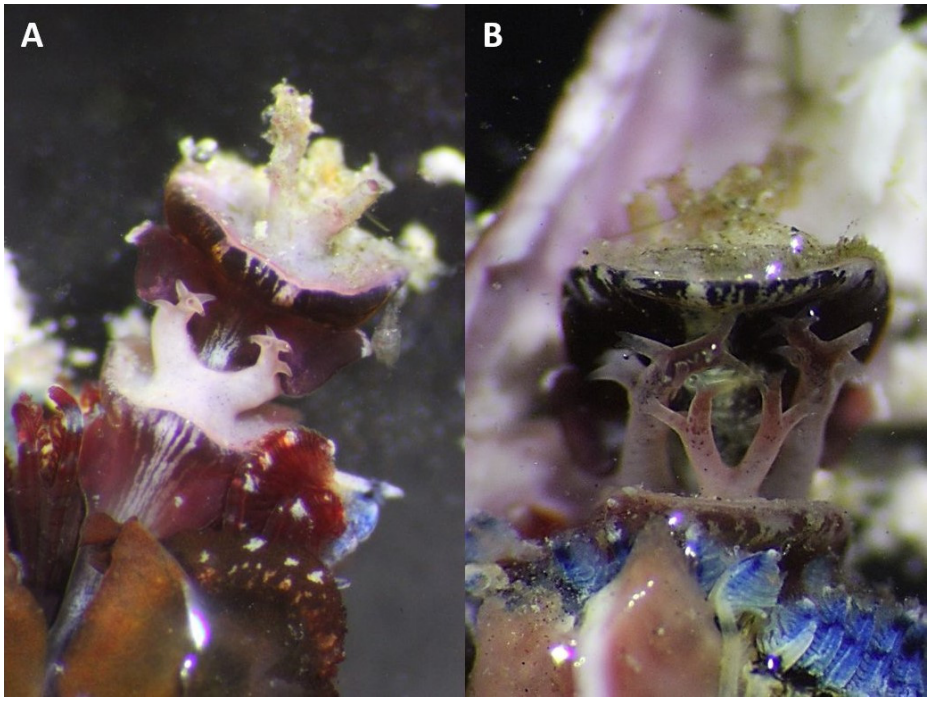


**Figure 8.** Living specimen of *Spirobranchus incrassatus*; the upper is the oldest operculum and the lower the youngest: A) dorsal view, B) ventral view (photographs by E. Keppel).

**Material.** Franklin's Bay (1 specimen, 27 April 2016, vial 233681 from uncaged plate 16424, deployed for 14 months).

**Taxonomic remarks.** The overall morphology and the operculum (Figure 7) agree with the descriptions in Bastida-Zavala and ten Hove (2003).

**Distribution.** Native to the Caribbean Sea and Gulf of Mexico, this species is now established on the Atlantic coast of the United States, the Pacific side of Panama and Mexico, Hawaiian Islands, Australia, Hong Kong and Taiwan (Bastida-Zavala et al. 2016; Ferrario and Minchin, 2017). Our survey produced only one record of this species.

Genus *Spirobranchus* Blainville, 1818

### *Spirobranchus incrassatus* Krøyer in Mörch, 1863

(Figure 8)

*Spirobranchus incrassatus* Krøyer in Mörch 1863: 405, pl. 11, Figures 21–23. Type locality: Western Colombia.

*Spirobranchus incrassatus*: Bastida-Zavala 2008: 49–50, Figure 12C–E (Baja California Sur, Colima, Guerrero and Oaxaca, Mexico, 4–17 m); Bastida-Zavala 2009: 542, Figure 4F (identification key for Tropical America); Bastida-Zavala et al. 2016: 434–435, Figures 8, 13G.

**Material.** Many specimens retrieved on 28 April 2016 from Baltra, on many plates, cage and uncaged, exposed for 3 months.

**Diagnosis.** Tube violet, with prominent longitudinal ridge. Anteriormost section of tube forms robust spine extending over opening of tube, usually this spine and opening are violet, pinkish or bluish in colour; lacking peristomes or alveoli. Opercular peduncle with wide wings. Operculum calcareous, circular or pear-shaped. Opercular surface bears three spines,

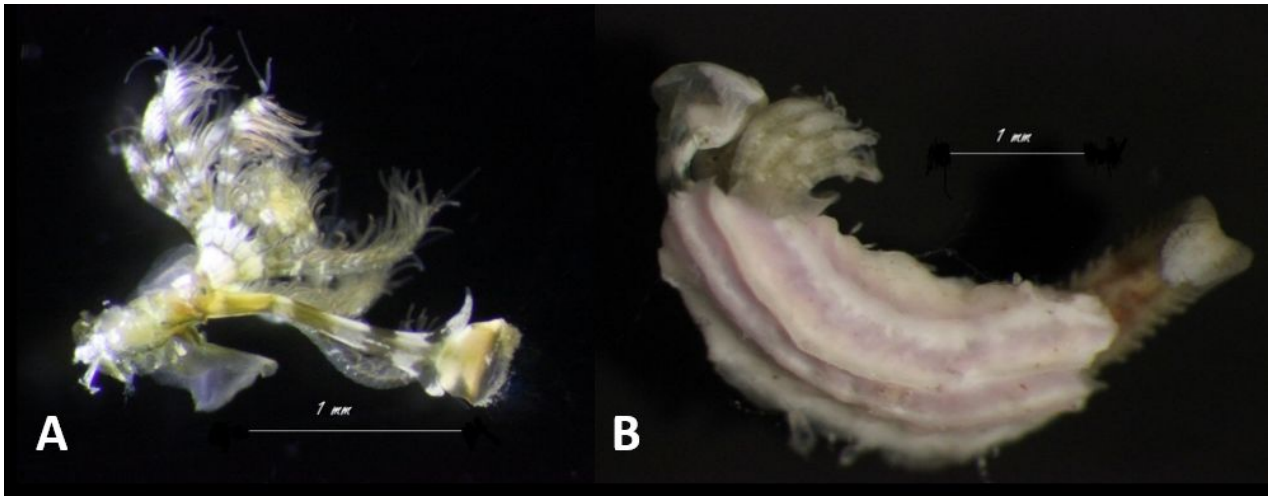


**Figure 9.** *Spirobranchus* sp.: A) alive specimen with operculum; B) preserved specimen in its pink tube (photographs by E. Keppel).

emerging from dorsalmost part of opercular plate. Two latero-dorsal spines thin, with an additional 6–10 spinules and one small and thin basal branch; the medio-ventral third spine widely bifurcated.

**Distribution and remarks.** Tropical Eastern Pacific. Baja California Sur (Mexico) to Panama and Colombia. Galapagos Islands (herein) common, and presumably native, in the Islands. Blake (1991) and all subsequent literature cited only one species of this genus in the Galapagos, misidentified as the Caribbean *Spirobranchus giganteus* (Pallas, 1766). We also found in the present survey an anomalous operculum of *S. incrassatus* (Figure 8), similar to that described for *S. polycerus* var. *augenerii* ten Hove, 1970, where the upper operculum is the oldest and the lower the youngest.

***Spirobranchus* sp.**

(Figure 9)

**Material.** Franklin's Bay (5 specimens, 27 April 2016, vial 237564, from ropes).

**Diagnosis.** Tube violet, with 1–3 longitudinal ridges, lacking peristomes or alveoli (Figure 9). Opercular peduncle with wide wings and smudged with brown-black spots. Operculum with calcareous concave plate. The central longitudinal ridge terminates in a spine projection over the opening.

**Taxonomic remarks.** Our specimens resemble *Spirobranchus minutus* Rioja, 1941 from the Tropical Eastern Pacific (Bastida-Zavala 2008: 31–33; Bastida-Zavala et al. 2016: 435–437), except by the pink colour of the tube and lacks alveoli. It is also similar to *Pomatoleios* sp. in Bastida-Zavala 2008: 33–34, Figures 7P–R, an undescribed species (Bastida-Zavala, *personal communication*, 2017). The present collections are probably also an undescribed species.

**Distribution.** Galapagos Islands (herein).

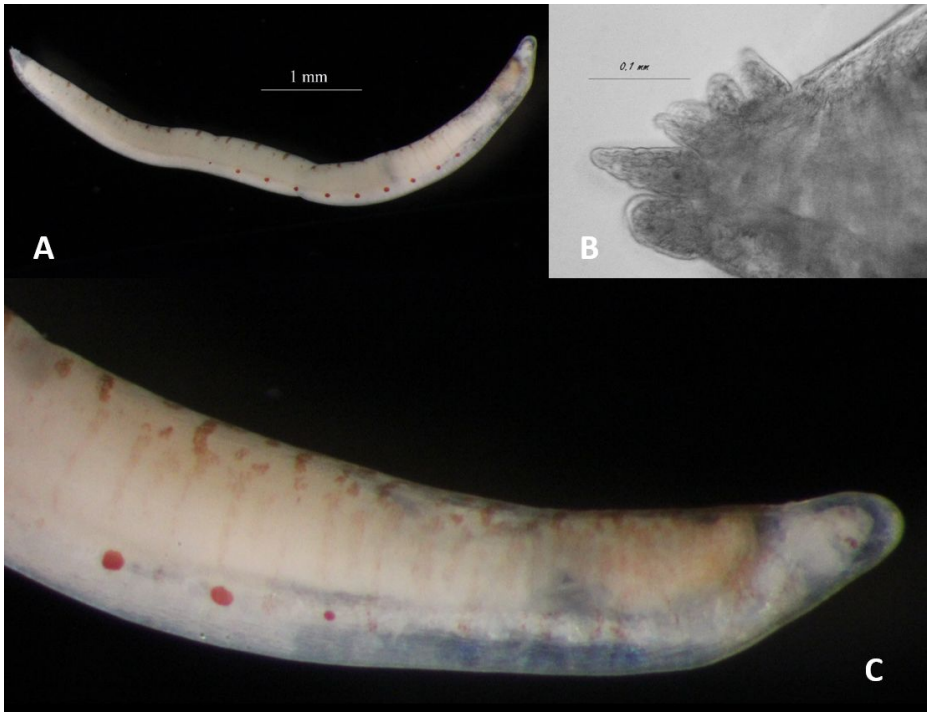


**Figure 10.** Preserved specimen of *Polyophthalmus* cf. *pictus:* A) entire body; B) pygidial papillae; C) close-up of the anterior end (photographs by E. Keppel).

Order Scolecida
Family Capitellidae Grube, 1862
Genus *Capitella* Blainville, 1828

***Capitella* sp.**

**Material.** Baltra (1 juvenile, 28 April 2016, vial 237624 from caged plate deployed for three months).

**Taxonomic remarks.** Remarkably, this is the first record of the genus from the Galapagos, perhaps due to the lack of earlier collections in shallow biofouling habitats, although it is a taxon that should also be present in soft sediment habitats. Our material is a member of the *Capitella capitata* (Fabricius, 1780) complex, but it cannot be assigned to species at this time. Capillary chaetae on the first three chaetigers. This specimen is a juvenile with no genital chaetae, and a missing pygidium.

**Taxonomic remarks.** We provisionally consider *Capitella* to be cryptogenic, based upon its biofouling habitat, and its treatment as cryptogenic in the Central (Carlton and Eldredge 2009) and Eastern Pacific (Cohen and Carlton 1995).

Family Opheliidae Malmgren, 1867
Genus *Polyophthalmus* Quatrefages, 1850a

***Polyophthalmus* cf. *pictus* (Dujardin, 1839)**

(Figure 10)

*Nais picta* Dujardin 1839: 293, pl. 1, Figures 1–12 (type locality: Toulon Bay, France).
*Polyophthalmus agilis* Quatrefages 1850b: 10–11 (type locality: Bay of Biscay, France).

*Polyophthalmus dubius* Quatrefages 1850b: 12, pl. 2 (type locality: Atlantic France).
*Polyophthalmus ehrenbergi* Quatrefages 1850b: 9–10, pl. 2, Figures 1–2–4–6 (type locality: Sicily, Italy).
*Polyophthalmus pictus*: Claparède 1864: 5, pl. l, Figures 1–2 (Port Vendres Harbur, France, associated to algae); Lo Bianco 1893: 7 (Naples, Italy); Monticelli 1896: 35–45, pl. 1 (Porto Torres, Sardinia, Italy, differences in size and coloration); Saint-Joseph 1898: 385 (Guéthary beach, France); Fauvel 1914: 247–248, pl. XXII, Figures 8–9 (Port of Palais, Belle Île, France, Stn. 38, 10 m; Capo Verde, Stn. 1203, 91 m; Grande Salvage, Canary Islands, Stn. 1704, littoral; Red Sea); Southern 1914: 133–134 (Clare Island, Ireland); Fauvel 1927: 137, Figure 48L–N (Plymouth, UK; Atlantic; Mediterranean; Red Sea; Indian Ocean); Imajima and Hartman 1964: 309 (Japan, manual); Day 1967: 579–580, Figure 25.2K–M (KwaZulu-Natal; Mozambique); Imajima and Gamo 1970: 16, Figures 66–67 (Manazuru, Kanagawa Prefecture, Japan); Paik 1982: 815 (Korea); 1989: 500, Figure 198 (Korea); Parapar 2012: 327–328, Figure 155 (manual, mesolittoral rocks associated with algae).
*Polyophthalmus pallidus* Claparède, 1869: 34–35, pl. XXXI, Figure 7 (type locality: Naples, Italy).

**Material.** Baltra (3 specimens, 28 April 2016, from two different uncaged plates deployed for three months: vial 237608 from plate 30278; vial 237639 from plate 30290).

**Diagnosis.** Prostomium short, rounded, two eyes, ventral groove present along the entire body, characteristic dorsal pigmentation with brown streaks and variable spots, branchiae absent. The lateral parapodial eyespots present are very distinct (Figure 10A, C) but another specimen has faintly lateral eyespots. Anal funnel with eight papillae: in one specimen they are long and more or less equal except for the ventral papillae, while another specimen has 6 small papillae and two ventral bigger of different shape, one pointed and one rounded (Figure 10B). The papillae in the present Galapagos material differ from the drawings of Japanese populations in Imajima and Gamo (1970).

**Distribution and remarks.** There are no previous records of Opheliidae in the Galapagos, so this should be the first one. *Polyophthalmus pictus* is reported around the world as a nearly cosmopolitan species, suggesting that it is, in fact, a species complex, with few reliable morphological characters. Although the subject of intensive studies in the Iberian Peninsula, in the Atlantic and the Mediterranean (Monticelli 1896; Rioja 1917, 1931; Alós 1983, 1984; Aguirrezabalaga 1984; Aguirrezabalaga et al. 1984; San Martín and Viéitez, 1984, 1991; Acero and San Martín 1986) the taxonomy of species remains tangled. For Mediterranean populations, Fauvel (1927) described it as variable in pigmentation and number of pygidial papillae. Imajima and Hartman (1964) described Japanese populations as having a pygidium with two lobes each ringed with digitate processes, but provided no illustrations of this feature. Parapar (2012) reported a dorsal transverse line and barely visible lateral eyespots for Mediterranean specimens, but his illustration of the color pattern, as well the anal papillae, differ from our Galapagos material. Choi et al. (2015) reported *Polyophthalmus qingdaoensis* Purschke, Ding and Müller, 1995 from Korea, distinguished by a prostomium with a brain bearing dark pigment-spots, distinct lateral

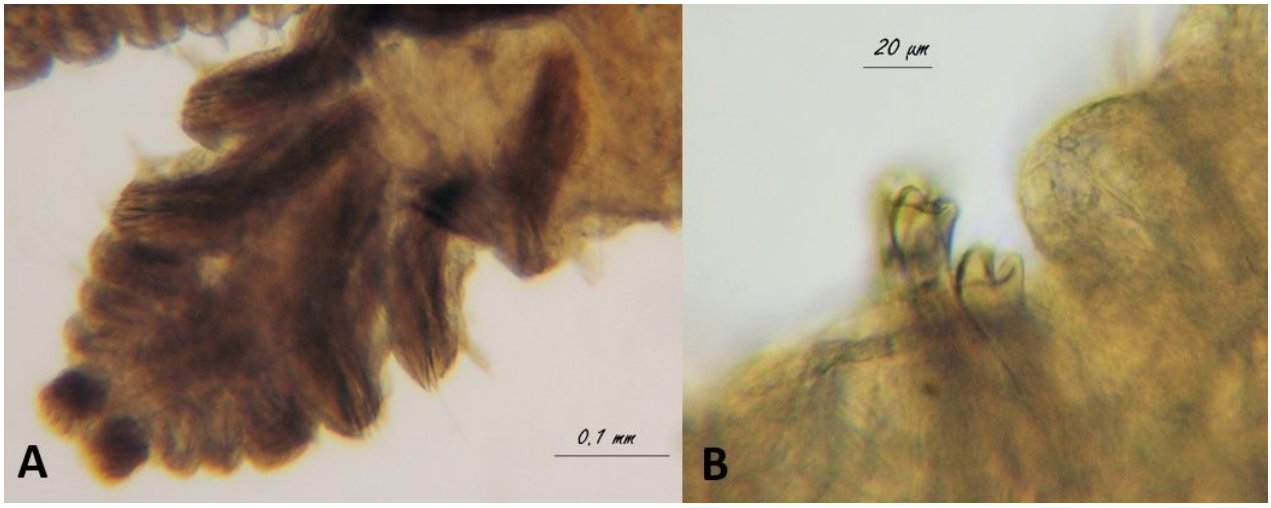


**Figure 11.** *Dipolydora armata:* A) Dorsal view of pygidium and posterior body with acicular notopodial spines; B) Modified chaetae of 5th chaetiger (photographs by E. Keppel).

eyespots, only dark pigment-streaks on the dorsal side of the body, and with papillae represented as 8–10 small cirri on the posterior margin with the dorsal papillae being smaller than ventral papillae. Our Galapagos specimens have the typical dorsal color pattern of *P. pictus*, but with very distinct lateral eyespots in the anterior body and eight pygidial papillae. We suggest that body and lateral eyespot color patterns likely vary too much to be useful for identification. Molecular studies are required to sort out this complex around the world.

Order Spionida
Family Spionidae Grube, 1850
Genus *Dipolydora* Verrill, 1881

### ***Dipolydora armata* (Langerhans, 1880)**

(Figure 11)

*Polydora armata* Langerhans 1880: 93–94, pl. 4, Figure 5A–C (type locality: Madeira, borer of calcareous algae).
*Polydora monilaris*: Ehlers 1904: 43–44, pl. 6, Figures 5–14 (Elmslie Bay, New Zealand).
*Polydora armata*: Fauvel 1927: 55–56, Figure 19A–E (English Channel, Madeira, Naple); Okuda 1937: 230–231, Figure 10 (Seto, Japan, associated with coral, algae, sponge and mollusks); Hartman 1941: 306; 1969: 127, Figures 38–39 (California, intertidal); Woodwick 1964: 14, Figures 1–6 (Marshall Islands, in coral rocks); Day 1967: 466–468 (doubtful record from unknown locality or Morocco), Figure 18.2.I–J; Rainer 1973: 558, Figure 7 (Otago Harbor. New Zealand, 3–4 m); Read 1975: 412–413 (Wellington Harbour, New Zealand, borings in encrusting coralline algae and shells); Blake and Kudenov 1978: 255–256, Figure 43A–G (Victoria, South Australia, revision); Hartmann-Schröder 1979: 134, Figures 299–302 (Australia), 1987: 55 (Australia); Blake 1983: 258–260 (Ecuador, 8–9 m; Chile, 2–180 m; Argentina, 0–80 m; suggesting 2 different species).
*Dipolydora armata*: Blake 1996: 196–198, Figure 4.36 (California, 0–126; Barbados, 1 m); Bick 2001: 178–180–181, Figures 1–2–3 (Ibiza, 1–5 m); Radashevsky and Nogueira 2003: 375–384, Figure 2–4 (Belize, Brazil, Taiwan, and Vietnam).
*Polydora rogeri*: Martin 1996: 161–165, Figures 1–5 (type locality: Bay of Blanes, Spain, 5–20 m).
*Dipolydora* cf. *armata*: Radashevsky and Fauchald 2000: Figure 6F (Belize).

**Material.** Franklin's Bay (14 specimens, 27 April 2016, vial 233671 from the same uncaged plate 16590, deployed for 14 months).

**Diagnosis.** Prostomium incised; caruncle extending to posterior margin of chaetiger 2; eyes and occipital antenna absent; dentate hooded hooks from chaetiger 7; hooks without constriction on shaft, with acute, wide angle (50°) between main fang and secondary tooth. Chaetiger 5 with specialized chaetae about three falcate spines, each with teeth connected by lateral hood or a sub-terminal semicircular cowl-like flange (Figure 11B); branchiae from chaetiger 7, reaching full size by chaetiger 8; posterior acicular notochaetal spines present (Figure 11A); pygidium small, cuff-shaped, with broad dorsal gap and narrow ventral notch (Figure 11A).

**Distribution and remarks.** *Dipolydora armata* has a reportedly world-wide distribution in tropical and boreal seas, including the Mediterranean Sea, North and South Atlantic Oceans, Australia, the Indo-Pacific, Japan, and the Eastern Pacific (Bick 2001; Radashevsky and Nogueira 2003). It is considered a pest of abalone aquaculture and a non-specialized borer of calcareous substrata, perforating coralline algae, corals and mollusk shells (Sato-Okoshi et al. 2015). Blake (1983, 1996) reported *D. armata* in mainland Ecuador, but not in the Galapagos. We consider it cryptogenic in the Galapagos Islands. Although Çinar (2012) proposed an Eastern Atlantic origin (the type locality is Madeira Island), centuries of shipping connecting the Atlantic and Pacific Oceans preclude suggesting an endemic region at this time. This is the first record of the genus from Galapagos.

Genus *Polydora* Bosc, 1802

The presence of *Polydora* in the Galapagos Islands, previously unreported, is supported by the identification of two specimens clearly belonging to two different species: one collected in 1964 and one incomplete specimen from the present survey.

***Polydora* sp. A indeterminate**

(Figure 12)

**Material.** Puerto Ayora (1 specimen, 24 January 1964, California Academy of Sciences 196211, collected by Robert C. Miller, in wood on old boat near Angermeyers Residence).

**Diagnosis.** This very small (1 mm) specimen is in poor condition; it was collected incidentally to excavations in marine wood searching for boring isopods (*Limnoria*). This specimen was found amongst wood particles as isopods were being sorted in 2016 from the sample while on loan to J.T. Carlton. Prostomium weakly bifid, caruncle extending to beginning of chaetiger 3; four eyes; no occipital tentacle. Chaetiger 5 with major spines falcate with weakly lateral flange (Figure 12). Bidentate hooded hooks on neuropodium starting from chaetiger 7 with constriction. Branchiae from chaetiger 7. The pygidium is missing.

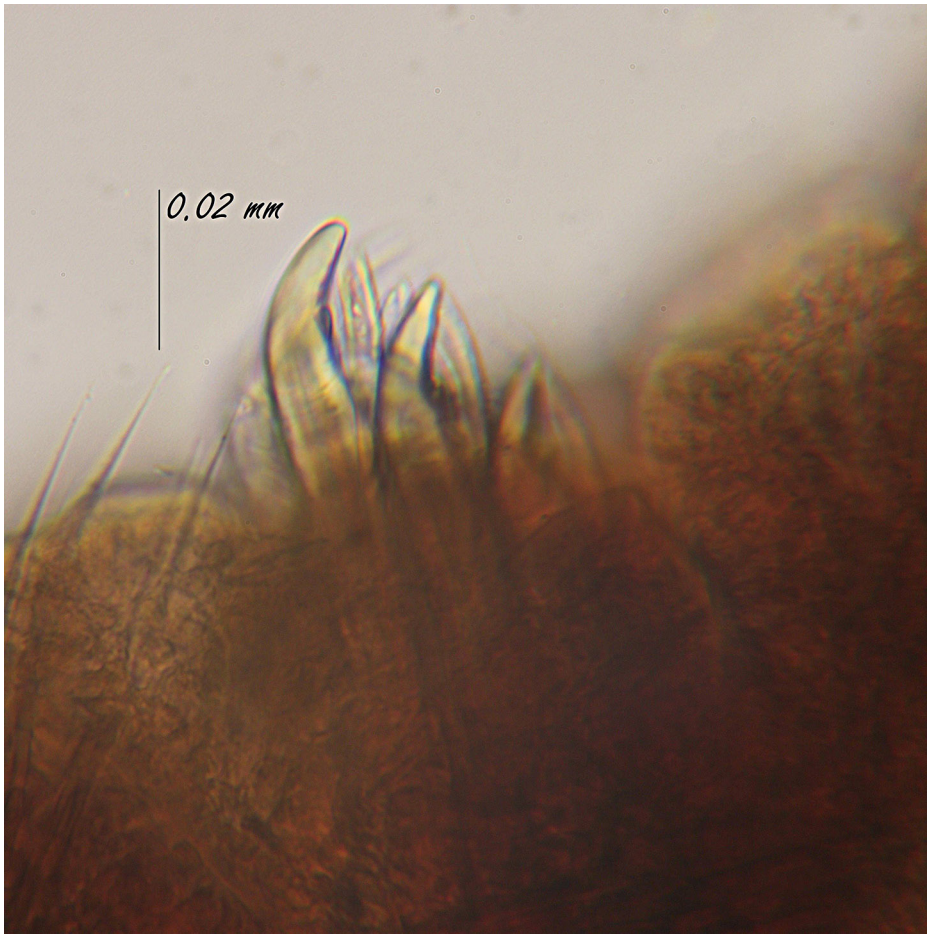


**Figure 12.** Preserved specimen of *Polydora* sp. A indeterminate detail of modified chaetae from 5th chaetiger (photograph by E. Keppel).

**Taxonomic Remarks.** The specimen resembles *Polydora websteri* Hartman in Loosanoff and Engle, 1943 but the flange on the falcate spines is very weak. *P. websteri* is considered a species complex (Blake 1971; Radashevsky 1999; Read 2010). *Polydora hoplura* Claparède, 1868 and *P. websteri* are similar, but the present specimen does not appear to have the heavy recurved spines on the posterior notopodia characteristic of the former species.

### *Polydora* sp. B indeterminate

(Figure 13)

**Material.** Baltra (1 specimen, 28 April 2016, vial 233631; from uncaged plate 30289 deployed for three months).

**Diagnosis.** A second *Polydora* species is in hand, but it is also indeterminate based upon an incomplete specimen (Figure 13). Round prostomium; caruncle reaches the end of chaetiger 3; no scattered small dark spots; no occipital tentacle; major spines on chaetiger 5 with secondary tooth; branchiae and hooded hooks with constriction starting from chaetiger 7; pygidium missing.

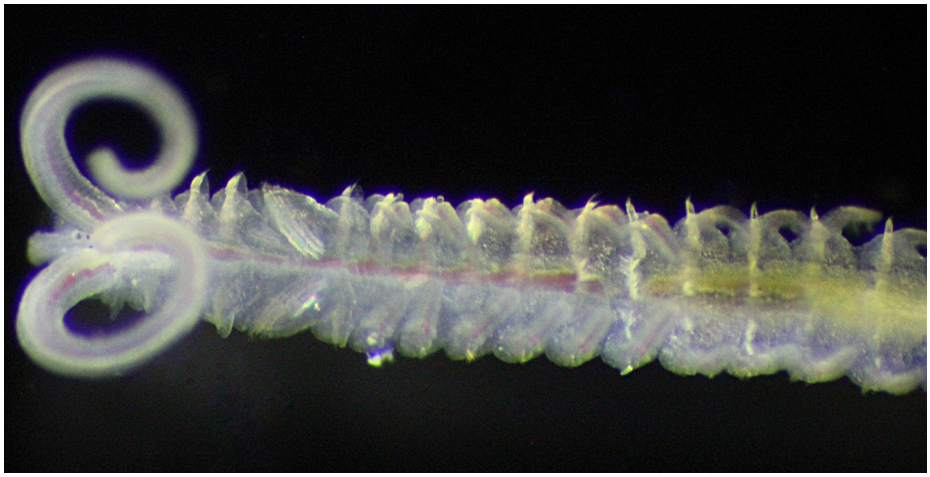

**Figure 13.** Living specimen of *Polydora* sp. B indeterminate (photograph by E. Keppel).


**Figure 14.** Preserved specimen of *Dodecaceria* sp. (photograph by E. Keppel).

Order Terebellida
Family Cirratulidae Carus, 1863

Six genera of cirratulids are known from the Galapagos (Blake 1991); *Dodecaceria* is newly reported here.

Genus Dodecaceria Örsted, 1843

***Dodecaceria* sp.**
(Figure 14)

**Material.** Franklin's Bay (5 specimens, 27 April 2016: vial 237621; vial 233657, both from caged plate 16387, deployed for 14 months).
**Diagnosis.** Live specimens red-green to black; when preserved, these turn dark or brown; prostomium blunt, without eyes; all the specimens have the first segment with a pair of thick grooved palps that are inserted laterally and a pair of slenderer, shorter tentacles (Figure 14). The first chaetiger has

**Table 1.** Introduced and cryptogenic Polychaeta of the Galápagos Islands treated in the present study. Status: I, Introduced; C, Cryptogenic.

| Species | Status | Galápagos collection records | Possible Origin |
|---|---|---|---|
| Syllidae | | | |
| *Myrianida pachycera* | I | 2016 (Puerto Ayora) | Indo-West Pacific |
| Sabellidae | | | |
| *Branchiomma bairdi* | I | 2016 (Santa Cruz, Baltra) | Western Atlantic |
| *Branchiomma* sp. | I | 2016 (Santa Cruz) | unknown |
| *Pseudobranchiomma schizogenica* | I | 2016 (Santa Cruz) | Western Pacific |
| Serpulidae | | | |
| *Hydroides elegans* | I | 2016 (Baltra) | Indo-Pacific |
| *Hydroides sanctaecrucis* | I | 2016 (Santa Cruz) | Western Atlantic |
| Spionidae | | | |
| *Dipolydora armata* | C | 2016 (Santa Cruz) | unknown |

a pair of filamentous tentacles. There are no other tentacles. The pointed setae are delicately serrated along one side. The hooks starts from the 6$^{th}$ and 7$^{th}$ chaetiger. Hartman (1954) notes that the hooks start from the 8$^{th}$ chaetiger, but this character may be size dependent. More posteriorly the neurohooks come to be increasingly stronger and acquire a strong lateral boss.

**Taxonomic remarks.** The specimens resemble *Dodecaceria laddi* Hartman, 1954, a species distinctive for its very limited number of tentacles that could be mistaken for the Chilean *D. gallardoi* Carrasco, 1977, especially relative to the disposition of the hooks, but the latter is distinguished by having two pairs of branchiae on the first branchial segment. The characteristics of our specimens do not fit any described *Dodecaceria* species (Aguilar-Camacho and SalazarVallejo 2011). This is the first record of the genus from Galapagos. The specimens were not boring into calcareous substrates.

## Discussion

The number of new records (one family and nine novel genera and fifteen species) reported here is not surprising, given the absence of previous studies on the polychaetes associated with port and harbor fouling communities in the Galapagos Islands. Thus also not surprising is our discovery of six introduced species not previously reported from the Galapagos (Table 1, Table S1): the syllid *Myrianida pachycera,* the sabellids *Branchiomma bairdi, Branchiomma* sp. and *Pseudobranchiomma schizogenica*, and the serpulids *Hydroides elegans*, *Hydroides sanctaecrucis*, as well as one cryptogenic species, the spionid *Dipolydora armata.* Ship biofouling, either on the hull, in sea chests, or in seawater pipe systems (Fofonoff et al. 2003; Farrapeira et al. 2011; Frey et al. 2014), are likely the primary vectors that brought these species to the Galapagos.

The non-native species have been introduced from either the warm waters of the Western Atlantic or Indo-West Pacific Oceans (Table 1). We do not as yet know the exact sources of Galapagos populations in the

absence of population genetic studies. Thus, it is uncertain whether the Western Atlantic species *Branchiomma bairdi* and *Hydroides santaecrucis* arrived through the Panama Canal (in, for example, as fouling even if ballast water cannot be excluded totally, and thus not exposed as hull fouling organisms during transit through the freshwater Gatun Lake), or from secondary populations that have also been introduced elsewhere in the Pacific Ocean. For species transported through the Canal, and if the sources of Galapagos populations are the Atlantic, it may be that they first became established on the Central or South American mainland, and were then brought to the Islands in hull fouling.

Much remains to be learned about the native, introduced, and cryptogenic polychaetes of the Galapagos Islands. Our samples represent only three stations sampled in April 2016; the striking results suggest that further studies will yield a more complete picture contributing to the history of marine invasions in the Galapagos Islands.

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**Supplementary material**

The following supplementary material is available for this article:

**Table S1.** Occurrences of Polychaeta at sampling locations in the Galápagos Islands, 2015–2016.

This material is available as part of online article from:
http://www.aquaticinvasions.net/2019/Supplements/AI_2019_Keppel_etal_Table_S1.xlsx