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Sipuncula inhabiting the coral *Oculina patagonica* in the western Mediterranean Sea

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Abstract

Background: We analyzed the sipunculan fauna inhabiting the scleractinian coral *Oculina patagonica* in the Marine Reserve of Tabarca Island (western Mediterranean).

Results: Five sipunculan species were collected from 2011 to 2014: *Phascolosoma stephensoni*, *P. granulatum*, *P. cf. agassizii*, *Aspidosiphon misakiensis*, and *Golfingia vulgaris*. All five species were reported for the first time inhabiting *O. patagonica*; with *P. cf. agassizii* being a new record for the Iberian Peninsula. The average abundance of sipunculans inhabiting the coral was 468.75 ± 158.04 ind m^{-2} , representing the second most abundant taxonomic group, in biomass, after Mollusca.

Conclusions: Sipunculan diversity was low comparing with tropical reefs, but species abundances were higher than in soft-bottom nearby areas and community structure appears to be more homogeneous. There may be a considerable contribution to the erosion of the coral skeleton by sipunculans.

Keywords: Sipuncula, *Oculina patagonica*, Associated macrofauna, Coral, Bioerosion, Iberian Peninsula, Mediterranean Sea

Background

Although the Sipuncula community is well characterized in soft-bottoms from our study area (Ferrero-Vicente et al. 2011, 2013a, 2014) (Fig. 1), hard-bottom species are largely unexplored. There are very few works on sipunculan ecology, and niches have not been well defined for the majority of species in this area (Cutler 1994; Ferrero-Vicente 2014). It is well known that some sipunculans are coral reef dwellers and active bioeroders, inhabiting crevices or galleries inside the calcareous skeletons (Reed 1980; Rice & Macintyre 1982; Cutler 1994). Found to be important bioeroders in many coral reefs (Hutchings 1986; Klein et al. 1991; Peyrot-Clausade et al. 1992; Gómez et al. 2013), this taxon can make a significant contribution to the bioerosion of the coral skeleton.

Oculina patagonica De Angelis, 1908 was recorded for the first time in the Mediterranean in 1966. It has been considered as an invasive species widely distributed throughout the Mediterranean coast (Zibrowius & Ramos 1983; Fine et al. 2001; Çınar et al. 2006) and abundant along the Spanish Mediterranean (Zibrowius & Ramos 1983; Ramos 1985; Izquierdo et al. 2007; Rubio-Portillo et al. 2014a, b). Recently, Leydet & Hellberg (2015) questioned the invasive nature of this species, denying a recent entry in the Mediterranean and considering the invasive behavior of the species as a consequence of changes in environmental conditions.

Many animal species live together with *O. patagonica*, including bivalves, gastropods, crustaceans, polychaetes, nemertean, sipunculans and nematodes (Ferrero-Vicente, pers. obs.). Nonetheless, there is a lack of studies identifying which particular species inhabit these coral colonies and, as a result, their associated fauna is practically unknown. The number of sipunculans in the Mediterranean Sea reaches up to 36 different species (Ferrero-Vicente et al. 2012), and several of them are able to bore into coral (Saiz-Salinas

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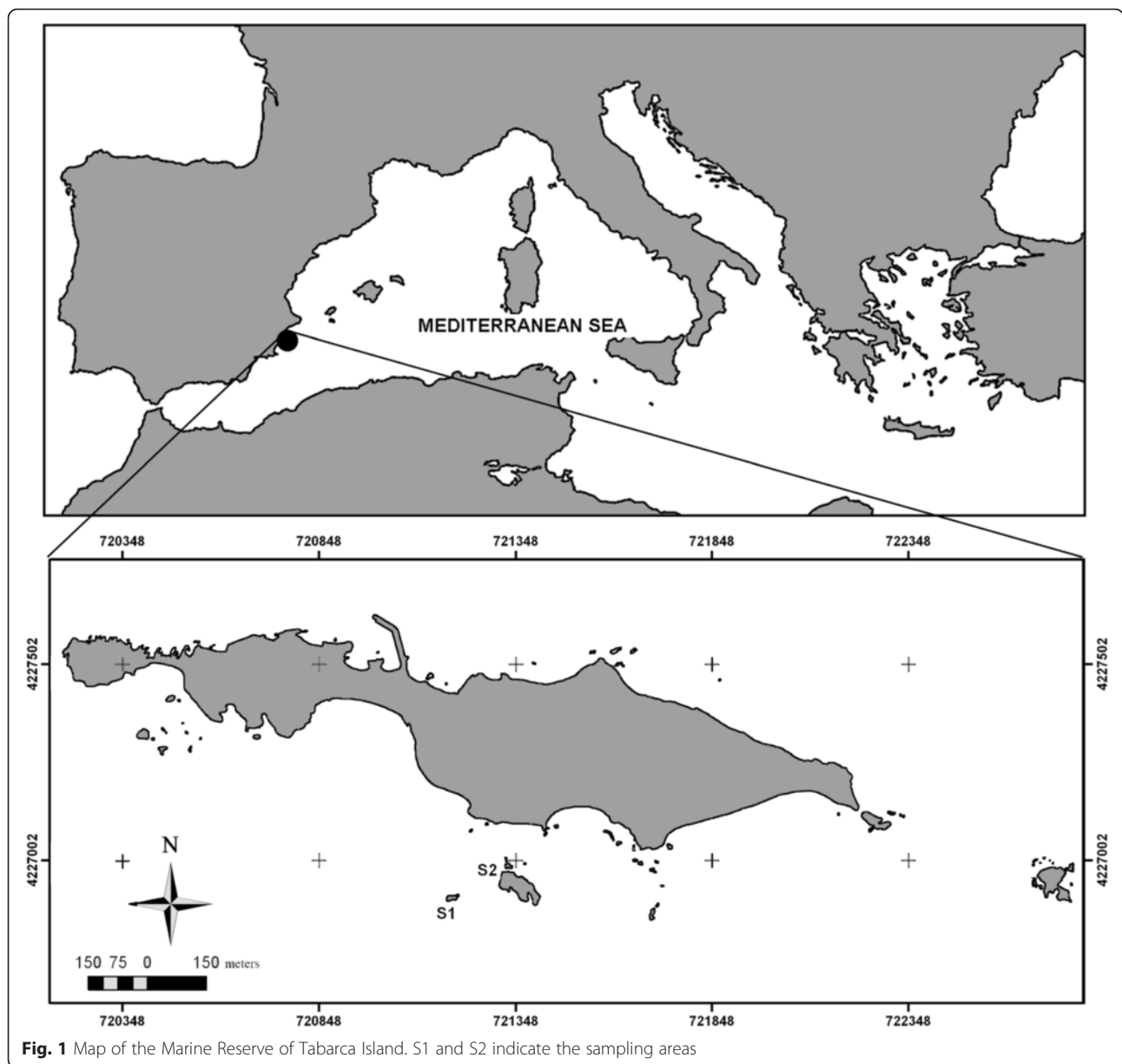


Fig. 1 Map of the Marine Reserve of Tabarca Island. S1 and S2 indicate the sampling areas

1993; Pancucci-Papadopoulou et al. 1999), but this ability is still not adequately documented for most species.

The aim of this study is to characterize the sipunculan community inhabiting *O. patagonica*.

Results

Five different sipunculan species were found inhabiting the coral (Figs. 2, 3 and 4), including *Phascolosoma stephensoni* (Stephen, 1942) as the most abundant one (relative abundance of 65.4 %), followed by *Aspidosiphon misakiensis* Ikeda, 1904 (15.4 %), *P. granulatum* Leuckart, 1828 and *Golfingia vulgaris* (de Blainville, 1827) (both 7.7 %), and finally *P. cf. agassizii* Keferstein, 1866 (3.8 %).

Density of total Sipuncula was $468.75 \pm 158.04 \text{ ind m}^{-2}$ (Fig. 5a), with Polychaeta, Crustacea and Mollusca presenting higher densities ($7\ 343.65 \pm 1\ 264.42 \text{ ind m}^{-2}$, $5\ 156.25 \pm 1\ 425.96 \text{ ind m}^{-2}$ and $2\ 812.50 \pm 458.45 \text{ ind m}^{-2}$ respectively). In terms of biomass, Sipuncula was the second taxon of importance, contributing 17 % to the total ash-free dry weight of fauna associated with *O. patagonica*. The Mollusca was the taxonomic group with the highest contribution to the biomass, with 45 % of the total weight.

Discussion

Four out of the five species reported are new records for the Tabarca Island Marine Reserve: *Aspidosiphon*

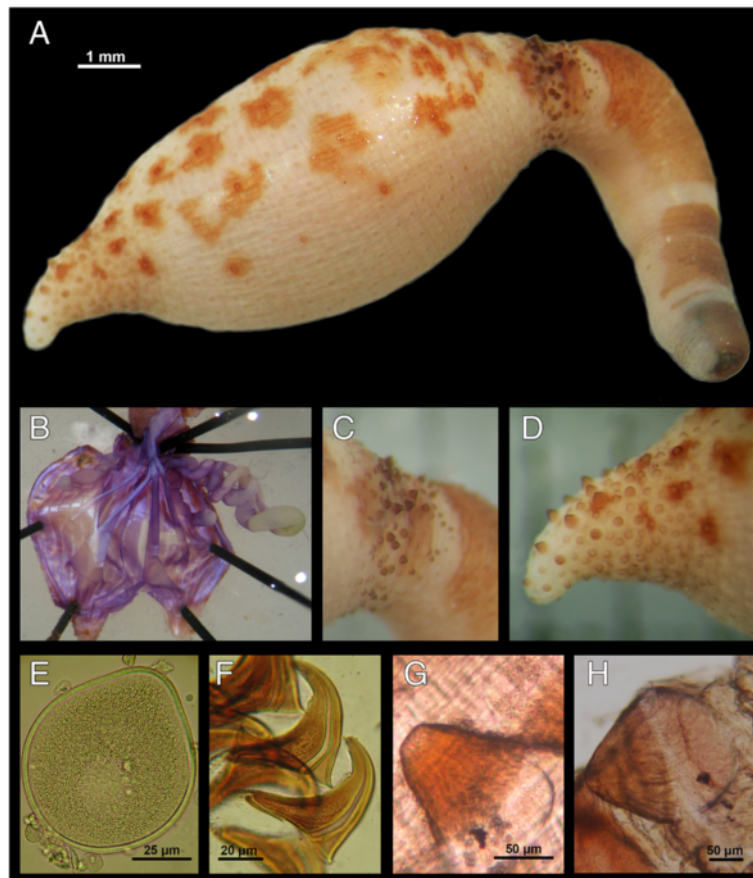


Fig. 2 *Phascolosoma stephensoni*: **a** Specimen with the introvert partially everted; **b** detail of a dissected specimen; **c** amplification of the cone-shaped papillae from the anterior part of the introvert; **d** amplification of the cone-shaped papillae from the posterior part of the introvert; **e** oocyte; **f** hooks from the rings in of the introvert; **g** amplification of cone-shaped papillae from the anterior part of the introvert; **h** amplification of cone-shaped papilla from the caudal part of the introvert

misakiensis, *Phascolosoma* cf. *agassizii*, *P. stephensoni* and *Golfingia vulgaris*. Furthermore, *P. cf. agassizii* is a new record for the Iberian Peninsula. These results are a consequence of the lack of studies on *O. patagonica* associated fauna and sipunculan fauna in general.

Considering Sipuncula is a phylum with a low number of species, approximately 150 (Cutler 1994), the diversity of sipunculans associated with coral ecosystems is relatively high and frequently with several specimens inhabiting a single rock (Rice 1975). In the case of the present study, the five species recorded in *O. patagonica* represent 14 % of the total known species in the Mediterranean Sea (Ferrero-Vicente 2014). This diversity is low compared to other coral reefs in the Caribbean (Gómez et al. 2013).

When comparing sipunculan abundance between different habitats, density in *O. patagonica* (468.75 ± 158.04 ind m^{-2}) was more than 10 times higher than densities recorded in soft-bottoms of nearby areas, which ranged from 10–30 ind m^{-2} and presented a high natural variability between localities and years (Ferrero-Vicente

et al. 2013a). *Oculina patagonica* colonies, which were collected randomly in space and time, appear to be more stable sipunculan communities—in abundance and species richness— compared to the soft-bottom sipunculan community, which is known to present a high spatial and temporal variability, both in abundance and species composition (Ferrero-Vicente 2014). Sipunculan fauna of south-western Caribbean reefs was described by Gómez et al. (Gómez et al. 2013) as relatively homogeneous in terms of abundance and number of species. This hypothesis must be supported by further studies in the case of sipunculans inhabiting Mediterranean hermatypic corals.

All species but *G. vulgaris* belong to the genera *Phascolosoma* and *Aspidosiphon*, species usually associated with hard bottoms and bioerosion on coral skeletons (Cutler 1994). Rock-boring sipunculans are usual inhabitants of both live and dead portions of coral skeletons, presumably in burrows of their own formation, contributing actively to the erosion of such structures by making them brittle (Rice 1975; Rice & Macintyre 1982; Klein et al. 1991; Antonelli et al. 2015).

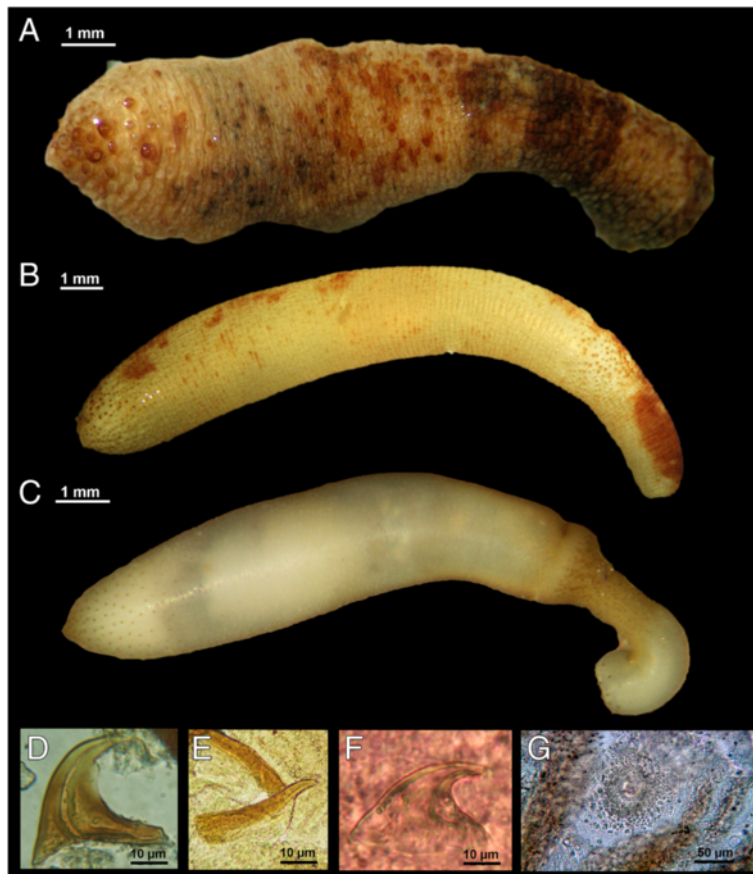


Fig. 3 **a** Specimen of *Phascolosoma* cf. *agassizii* with the introvert partially everted; **b** specimen of *Phascolosoma granulatum* with the introvert partially everted; **c** specimen of *Golfingia vulgaris* with the introvert partially everted; **d** hook of *P. granulatum*; **e** hook of *G. vulgaris*; **f** hook of *P. cf. agassizii*; **g** mid-trunk papilla of *P. cf. agassizii*

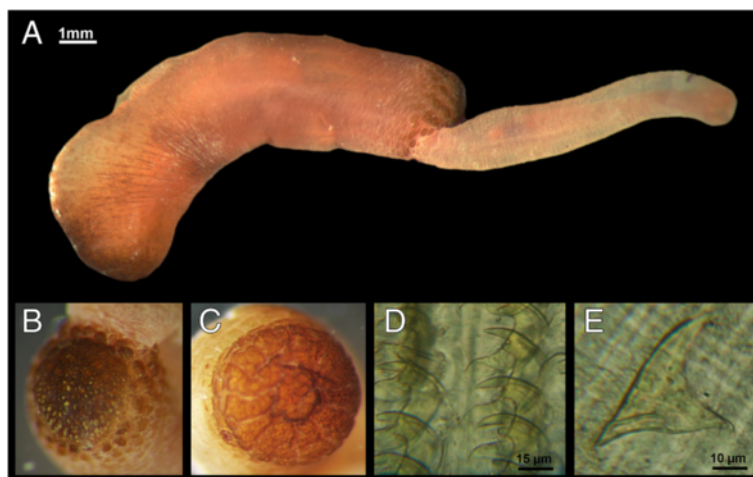
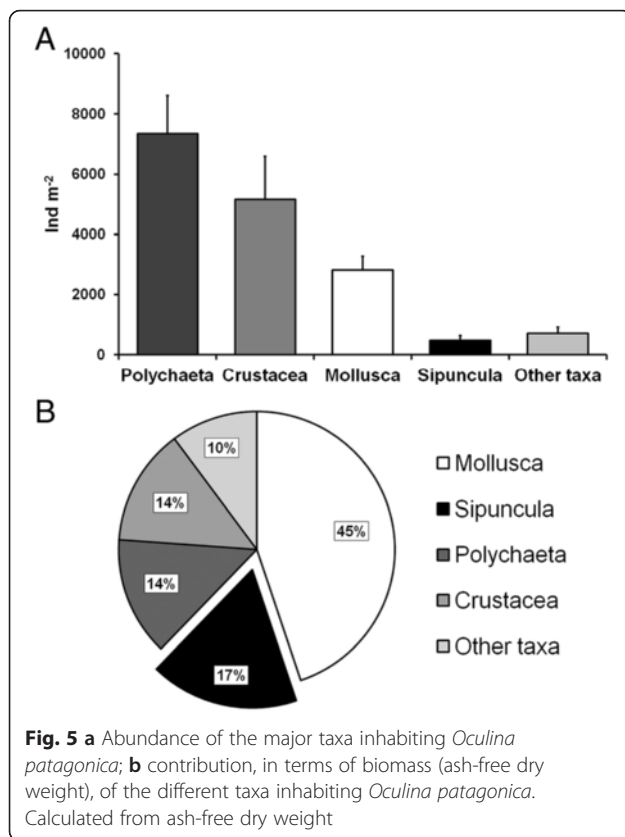


Fig. 4 *Aspidosiphon misakiensis*: **a** Specimen with the introvert partially everted; **b** preanal shield; **c** caudal shield; **d** bidentated hooks from the rings of the introvert; **e** scattered hook from the proximal part of the introvert



The abundance of sipunculans in the coral was much lower than other groups such as Polychaeta, Crustacea and Mollusca (Fig. 5a), which can also contain bioeroders species. Interestingly, Sipuncula was the second most abundant group after Mollusca in terms of biomass (Fig. 5b), likely due to the fact that individual sipunculans were usually much bigger than the mollusks or crustaceans present in the coral. Since 94 % of mollusks were vermetids, without bioerosion capabilities, Sipuncula is most likely the group with the highest contribution to the bioerosion of the *O. patagonica* skeleton. Their importance as bioeroders in many coral reefs was previously reported (Hutchings 1986; Klein et al. 1991; Peyrot-Clausade et al. 1992; Gómez et al. 2013).

Phascolosoma stephensoni is a common species persisting in hard substrata with a worldwide distribution. Despite it being the dominant sipunculan species inhabiting the *O. patagonica* skeleton samples (65.4 % of the total number of individuals) there are just a few records of the species around the Mediterranean Sea (Pancucci-Papadopoulou et al. 1999; Açık 2014). As suggested by Pancucci-Papadopoulou et al. (Pancucci-Papadopoulou et al. 1999), early identifications of *P. stephensoni* might have been misidentified as *P. granulatum*, a common and previously known species in the Mediterranean. On this basis, the distribution of *P. stephensoni* would be wider than expected. It is a common species found in

hard substrata within the study area, appearing in rock crevices, algae rhizoids, seagrass rhizomes or mussel clusters (Ferrero-Vicente, pers. obs.).

Phascolosoma agassizii is not a common species in the Mediterranean, with just a few records. This is the westernmost record of the species in the Mediterranean and a new record for the Iberian Peninsula. Since species identification was on the basis of characters with some variability, such as number of hook rings, it has been identified with caution under the denomination *cf.*

Phascolosoma granulatum is a very common and highly distributed species in the Mediterranean Sea, appearing in a great variety of habitats (Cutler 1994; Pancucci-Papadopoulou et al. 1999). It was the only species previously reported in the marine reserve (Ramos 1985), inhabiting a vermetid reef species *Dendropoma petraeum*.

Golfingia vulgaris is a widespread species found in soft and hard substrata throughout the Mediterranean (Pancucci-Papadopoulou et al. 1999; Açık 2008, 2011; Ferrero-Vicente et al. 2013a). In the nearby areas it is a common and very abundant species in sediment trapped within algae rhizoids in shallow rocky bottoms (Ferrero-Vicente, pers. obs.). Even if species of the genus *Golfingia* are not commonly associated with corals, it seems that *G. vulgaris* can also live in coral skeletons, as evidenced by previous records in *C. caespitosa* (Koukouras et al. 1998; Açık 2008) and in *O. patagonica* in the present study. It is not clear whether this species is able to erode the coral, or if it simply occupies a discarded hole previously drilled by another sipunculan species or other organism.

Aspidosiphon misakiensis is present within just a few scarce records throughout the western Mediterranean, likely due to the lack of studies on sipunculan distribution. *Aspidosiphon misakiensis* is easily discernible from the similar species *A. muelleri*, found to be dominant in soft-bottoms from the studied area (Ferrero-Vicente et al. 2013a, b), by observing differences in the anal shield. In *A. misakiensis* the anal shield is granular (Fig. 4b) while in *A. muelleri* it is grooved. *Aspidosiphon muelleri* has not yet been recorded in *O. patagonica*, but is, by far, the most common species classified in soft substrata within nearby areas, dwelling in gastropod shells or preferably empty tubes of the serpulid polychaete *Ditrupa arietina* (Ferrero-Vicente et al. 2013b, 2014; Ferrero-Vicente 2014). *Aspidosiphon muelleri* has also been previously reported in diverse hard substrate habitats and even drilling activity has been also observed (Por 1975; Antonelli et al. 2015); therefore, its sporadic presence in *O. patagonica* within the studied area cannot be discarded.

Conclusions

The number of sipunculan species inhabiting *O. patagonica* was low compared with tropical reefs, but similar than soft-bottom species in nearby areas. Species abundances were

higher and community structure appears to be more homogeneous than in the soft-bottom community. Sipunculans contribute significantly to the coral skeleton bioerosion.

Methods

The specimens studied were obtained from *Oculina patagonica* colonies in the Marine Reserve of Tabarca Island (Fig. 1, 38.1645° N; 0.4733° W), which is a hot spot for this species in the western Mediterranean. *Oculina patagonica* extends its distribution in the area to 12 m in depth, but the larger formations occur mostly in the shallowest layer (0–5 m) of rocky walls. The species was first documented in the island in 1983 (Ramos 1985), and according to (Izquierdo et al. 2007) it can be found the biggest colonies of the area and off the SE Iberian Peninsula, reaching sizes up to 50 cm in diameter. A total of 8 samplings were randomly carried out (from 2011 to 2014) in three different sites (from 2 areas where most of the colonies are concentrated). Samples from different colonies were randomly collected; 3 for each site and for each sampling day, giving a total of 72 samples.

Pieces of coral, ranging from 50 to 100 cm², were ripped from the rocky substratum by scuba diving, using a chisel and a hammer. We immediately placed the collected pieces in zip-plastic bags prior to processing. Once at the laboratory, samples were fixed in 4 % formaldehyde. Afterward, the sipunculans were removed out of the coral skeleton by carefully crumbling the coral into tiny pieces using a small hammer. In order to identify the species, we observed the specimens under a binocular lens to study external morphology and dissections were conducted to analyze internal anatomy. Structures with taxonomic value such as hooks, skin papillae or oocytes (when present) were observed under a microscope (Fig. 2). Species identification was carried out according to (Saiz-Salinas 1993; Cutler 1994; Pancucci-Papadopoulou et al. 1999; Açık 2008, 2009, 2011; Ferrero-Vicente et al. 2012).

We measured the surface of the sampled colonies using image analysis techniques (carried out with Photo-shop CS5) in order to obtain densities of individuals of the different taxa associated with the coral. Finally, we measured the ash-free dry weight of the different taxa through weight loss on ignition after 4 h at 400 °C inside a muffle furnace. The biomass was previously dried for 24 h at 80 °C in order to get a constant dry weight.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

LFV carried out the laboratory work, statistical analyses and draft the manuscript. ERP carried out the sampling design, field work and helped to draft the manuscript. ARE conceived of the study and helped to draft the manuscript. All authors read and approved the final manuscript.

Acknowledgements

This work has been carried out within the CIESM' project 'Tropical Signals'. The authors wish to thank the MAGRAMA (Fisheries Secretary) and the Tabarca Marine Reserve staff, especially to Felio Lozano, for their logistic and administrative assistance. We are also grateful to Ashley Larson for her altruistic work of reviewing the correct use of English grammar in the manuscript.

Received: 28 January 2016 Accepted: 8 February 2016

Published online: 08 March 2016

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