SERPULID POLYCHAETES FROM CYSTOSEIRA COMMUNITIES IN THE IONIAN SEA, MEDITERRANEAN

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INTRODUCTION

Serpulids are quite distinctive within polychaetes as they are able to produce calcareous tubes to live inside and ensuring the protection of animal soft bodies. However, the achievement of a mineralized skeleton has for counterpart the lost of mobility, and tube worms are permanently attached to a substratum, except for a few genera such as Ditrupa (ten Hove & Kupriyanova 2009). The availability of suitable substrata on which to settle and grow is therefore of paramount importance for the establishment of serpulids. The presence and distribution of rocks, hard biogenic structures and soft vegetation (algal and plant) communities is thus relevant. Following the suggestions of pioneering papers by Bellan (1971), it has been demonstrated that, in shallow water bottoms and mostly in areas where algae dominate, the presence of particular algal species and the importance of algal cover largely influence the composition and distribution of polychaete assemblages (Bellan & Marinopoulos 1981, Abbati et al. 1987, Giangrande 1988). Indeed, some macroalgae species act as engineer taxa and produce habitat complexity favoring colonization by different benthic faunal species (William & Seed 1992, Antoniadou & Chintiroglou 2005). Zonation is not only a function of depth and of physical factors directly or indirectly linked to depth (mainly light penetration and hydrodynamic energy), but results also from more complex interactions between physical and biotic factors, eventually causing a considerable horizontal variability (Giangrande et al. 2003, 2004).

However, so far studies have focused mainly on midlittoral and shallow infralittoral assemblages (Bianchi, 1979a, b; 1980; Bianchi et al. 1988, Abbati et al. 1991, Antoniadou & Chintiroglou 2005, and references therein) often with special emphasis on organisms, which are large-sized and/or easily recognizable by scuba divers. Few papers deal with deep infralittoral assemblages and usually do not focus on serpulids, that are a minor component within polychaete assemblages (see Giangrande et al. 2003, 2004, for instance). Few exceptions include Bellan (1964), Sardà (1991), Morri et al. (1999), and Frascetti et al. (2002), who examine also polychaetes from infralittoral habitats, and especially Càsoli et al. (2016), who focus on how serpulid assemblages are influenced by the occurrence of soft and calcareous algae.

Information on serpulids from the Ionian coasts of Sicily is virtually lacking. Most papers focus on polychaete biodiversity (Cantone 2001, Castelli et al. 2008), or deal with the taxonomy of particular species or groups of species (e.g. Fassari & Móllica 1991, Sanfilippo 2003, 2009a, 2009b, Sanfilippo & Móllica 2000). Few papers deal with serpulids thriving in the coraligenous (Di Geronimo et al. 2001, Rosso & Sanfilippo 2009), precoraligenous (Cantone & Fassari 1980) and cave habitats (Rosso et al. 2013). In contrast, serpulids living in the Biocoenosis of the Infralittoral Algae (IA) largely corresponding to the Photophilic Algae Biocoenosis of Péres & Picard (1964) are essentially known from papers by Tenerelli (1961, 1962), Fassari & Móllica (1989), Sanfilippo (1993), Sanfilippo & Di Geronimo (1993) and Cantone et al. (2003).
However, most of these papers are based on randomly collected samples. The present paper focuses on serpulids thriving in selected Cystoseira communities from the IA biocoenosis, i.e., the C. brachycarpa, the C. sauvageana, and the C. spinosa communities, all listed among those in need of protection within the Barcelona Convention. Samples originate from western Ionian Sea, along Sicily coast, including the Ciclopi Islands Marine Protected Area (CIMPA).

The main goals are: 1) giving preliminary insights on serpulids found within these selected Cystoseira communities; 2) identifying differences (if any) in the composition and abundances of serpulids between Cystoseira communities and/or sampling sites.

MATERIALS AND METHODS

Subvolcanic as well as subaerial and submarine volcanic rocks constitute the coastal area of the northern side of the Gulf of Catania (Corsaro & Cristofolini 1997). These rocks, dissected by faults and dismantled by wave action, produce a belt of blocks, up to a few m-sized, all along the coast and at the base of local shallow cliffs, down to about 15 m and locally to about 40 m. Within blocks gravelly to sandy sediments are trapped. They mostly consist of bioclastic remains but include high percentages of volcanic ashes, produced periodically after the explosive activity of the Etna volcano.

The Biocoenosis of the Infralittoral Algae (IA), largely develops on these rocky outcrops and on the blocks scattered on the bottom.

Six samples were collected in June 2015 in this area within the C. brachycarpa (5 m depth), C. sauvageana (9-10 m depth) and C. spinosa (25-26 m depth) communities (Fig. 1). Three samples, one for each of the above mentioned communities, originate from off Cape Punta Aguzza (CPA), in the southern sector of the CIMPA area, namely CPA.1.Z5 (37°32’52”N; 15°08’44”E, 5 m water depth), CPA.1.Z10 (37°32’52”N; 15°08’45”E, 10 m water depth) and CPA.1.Z26 (32’52”N; 15°08’47”E, 26 m water depth). Three further samples were collected outside the CIMPA area. Two of them come from off Santa Maria La Scala (SM). They are: SM.1.Z5 (37°37’10”N; 15°10’31”E) and SM.1.Z25 (37°37’10”N; 15°10’33”E), collected at 5 m and 25 m depth, respectively. The last sample (ST.1.Z9: 37°38’17”N; 15°10’53”E) originates from off Santa Tecla (ST), at 9 m depth.

The location of the sampling stations was selected based on historical information and on surveys specifically aimed to locate the target communities. Sampling was performed by scuba divers scraping a standard surface of 40 × 40 cm in phisonomically homogeneous surfaces. Samples were preserved in alcohol and examined under a stereomicroscope to pick-up serpulins and spirobins in order to identify species.

Identification of species and low magnification images were taken with a Zeiss Discovery V8A stereomicroscope equipped with an Axiocam and Axiovision acquisition system.

A simple multivariate statistical analysis was performed with PRIMER 6.1.12 software (© Primer-E Ltd.; Clarke and Warwick, 2001). The specimens abundance matrix included all 6 samples and 19 species. Hierarchical cluster analysis (complete linkage clustering) and Non-Metric Multi-Dimensional Scaling Ordination (MDS) were performed, and similarity percentages (SIMPER procedure, one-way analysis) were calculated. The Shannon-Weaver diversity index (H’) was calculated with the DIVERSE procedure.

Material is housed in the Paleontological Collections of the Dipartimento di Scienze Biologiche, Geologiche e Ambientali of the Università di Catania, in the Sanfilippo Collections under the collective code PMC Sanfilippo CIMPA collection I.H.

RESULTS

Serpulids are not obvious in the field and usually also in the samples, unless material is observed under a stereomicroscope. Only few large-sized serpulid specimens were visible at naked eye on the underside of some laminar calcareous algae.

A total of 19 serpulid species have been identified (Table I, Figs 2-3). Serpulinae largely prevail (Fig. 4) with an overall 13 taxa: 12 determined at species rank and one at the genus level. Spirobiniae only include 6 species, but are dominant when specimen abundances are considered. Indeed, the most frequent (found in all samples) and abundant species is Janua (Dexiospira) pagenstecheri, represented by more than one hundred specimens per
sample at shallower depths (samples from 5 and 9-10 m in the *C. brachycarpa* and *C. sauageauana* communities, respectively), and only by slightly lower numbers in the deepest *C. spinosa* community, at 25-26 m. Also other spirorbin species, *i.e.* *simplaria pseudomilitaris* and *pileolaria militaris*, are relatively frequent (found in several samples) and abundant, mostly in samples from the *C. spinosa* community. In contrast, a unique serpulid *Josephella marenzelleri*, reaches high to very high abundances in a couple of samples (ST.1.Z9 and SM.1.Z25)..

Among other serpulines, only *spirobranchus polytrema* is frequent, occurring in five out of six samples, usually with less than a dozen specimens and occasionally with less than a few tens of specimens. All other species are rare, except for the scissiparous *Filograna cf. implexa*, which is occasionally present but with nearly one hundred specimens (SM.1.Z25) most of which damaged. In the absence of opercula these specimens are cautionary identified as *F. cf. implexa*, because some authors consider operculate and non-operculate forms as separate species within the genus (ten Hove & Kupriyanova 2009: 42 and references therein).

Serpulid assemblages are all poorly diversified (Table I), as indicated by Shannon-Weiner indexes between 1.1 and 1.4, which denotes an oligotypic assemblage...
(Table I). Group 2 includes the two deeper samples (25-26 m depth); the similarity within group is lower (42.55) and due to S. pseudomilitaris and J. (D.) pagenstecheri (contribution: 20 % each). Shannon-Weaver index (2.4 for both samples) reveals a remarkably higher diversity than in group 1.

The total number of species per sample is low in both the C. brachycarpa and C. sauvageauana communities ranging from four to six species per sample (nearly equally distributed between serpulins and spirorbins), whereas it raises significantly in the C. spinosa community reaching 12 and 13 species. This higher species richness is exclusively due to a higher number of serpulin species, which passes from one and three species in shallow sites to nine and ten species in the deep sites. This implies that a relevant number of species, especially belonging to serpulins, were restricted to the deep C. spinosa community. Some of these species, namely Serpula vermicularis, S. concharum, Vermiliopsis striaticeps and V. labiata are shared by both samples collected in the C. spinosa community and have relatively low abundances. In contrast, further species, i.e. the serpulins Hydroides elegans, H. pseudouncinata pseudouncinata, Spirobranchus triquetser, Semivermilia crenata, S. cribrata and Protula sp., together with the spirorbins Spirobranchus cuneatus, are restricted to only one sample (mostly the SM.1.Z25) and are usually rare.

No relevant difference is obvious between the two sampling sites for each of the studied communities, except for the C. spinosa community whose serpulins share seven species, accounting for less than 44 % of the total number of species, but show four and five species restricted to one or the other of the two sampling sites.

Noteworthy, some species in some samples are exclusively represented by juveniles. This has been observed

Spirobinae specimens usually encrust the thalli of a few species of algae on which are often clustered. They have been especially found on *Padina pavonica*, selectively located on the upward-facing side of its convolute laminar fronds; on the geniculate coralline algae *Jania* adherens and in particular *Ellisolandia elongata*, where larger, relatively more aged, specimens were located on the main axial branches and smaller specimens and juveniles on thin branches near the growing tips. Spirorbins occur also on the relatively rigid thallum of *Halopteris scoparia*, with a distribution pattern comparable to that observed on articulate red algae. In contrast, serpulins were found attached to the down-facing side of laminar calcareous algae, mostly in the deepest samples, and subordinately on small gravely-sized volcanic clasts.

**DISCUSSION**

All serpulid species found within the three investigated *Cystoseira* communities are known from the Mediterranean, where they represent common components of shallow water rocky bottoms, either natural and vegetate, either artificial (e.g. Bellan 1971, Bianchi 1979a, Cantone & Fassari 1980, 1982, Cantone 1985, Abbiati et al. 1987, Bianchi & Morri 2000, Antoniadou & Chintiroglou 2005). These species are among the most tolerant to light, even colonizing exposed algal surfaces, but some of them are sciaphilic at different degrees and consequently may extend their distribution also to coralligenous habitats and cave entrances (e.g. Bianchi 1979a, Ben Eliahu & Fiege 1996). In the studied communities, these last species seem to benefit of the shadowing produced within *E. elongata* turfs and *P. pavonica* beds. In contrast, few species, among which the most abundant one, *J. (D.) pagenstecheri*, seem to be comparably photophilic, as they usually reach very high population densities in the shallowest infralittoral horizons also favoured by early supply of larvae close to parental specimens and their gregarious behavior (Pillai 1970). Interestingly, the majority among the most abundant species, and in particular *J. (D.) pagenstecheri*, *S. polytrema* and *J. marenzelleri*, are known as pioneer species (Bianchi 1979b), especially able to colonise new substrates such as those provided by algal fronds. How-
ever, although offering a wide extension of colonizable surfaces, soft algae represent a challenge for skeletonized epibionts. Indeed, algae are flexible and ephemeral, their duration being related to seasonality of the vegetative stages as well as to local hydrodynamic energy, above all at shallower depths. Substrate flexibility and its constant motion, mostly at shallower depths, favour species, which adopt special strategies to cope with these stresses. Spirorbins, growing within closely coiled tubes usually not exceeding 2 mm in diameter, often developing short erect terminal portions (Ippolito & Rzhavsky 2014) but needing a small attaching surfaces, seem to be specially adapted for this challenge. This could explain their high dominance in the studied communities and especially in the C. brachycarpa and C. sauvageauana ones, at 5 and 10 m depth. Spirorbins also have short life-spans and rapid turnover with very prolonged, often all year-round, reproduction periods (Bianchi 1981, Giangrande 1997). This possibly enhances their ability to colonise successfully the ephemeral algal fronds, soon after their growth and before detachment and/or decay during adverse conditions/seasons. These particular habitat and substrata also select serpulins with relatively small and/or light calcified skeletons, such as C. implexa and above all J. marenzelleri, which possesses a minute articulate tube (Sanfilippo 1996). Noteworthy, serpulins are preferentially located on laminar calcareous algae when present, as observed for sample SM.1.Z25. Specimens recognized on soft algae are particularly small and located on the main axial branches. This distribution pattern seems to be forced by the demand of a hard substratum or, at least, a surface rigid as much as possible within those available for colonization.

Reasons outlined above could account for the affinities observed between serpulids from the C. brachycarpa and C. sauvageauana communities, as well as for differences between them and those from the C. spinosa one. The presence, abundance and diversification of serpulins in the last algal community seem mostly related to the presence of hard (both lithic and organogenic) substrata, to the relatively low hydrodynamic energy and to the shadowing, which favour the development of an underlying biogenic concretion hosting species with a certain colonial affinity. Unlike bryozoans (Rosso et al. in press) but roughly comparable with foraminifera and ostracoda (Sciuto et al. in press) serpulid assemblages do not show remarkable differences in species richness and specimen abundance between samples collected inside and outside the Ciclopi Islands Marine Protected Area, except for the a certain difference in composition in the C. spinosa community. The presence of some species in only one or the other of the two samples from this community could result from the major availability of hard substrata in the sample SM.1.Z25, where also isolated specimen of Cystoseira zosteraoides were colonized. Close similarity between all samples is also shown by their position in the cluster and the MDS analyses (Fig. 5), unlike that of the two samples from the C. spinosa community, which are not clustered together.

The total number of species (19) found associated to Cystoseira communities from the Ciclopi Islands area is relatively high compared to numbers reported for the few studied serpulid assemblages from infralittoral algal communities, also taking into account the relatively low number of examined samples. A total of 15 species were found in two different groups of samples originating from the 5-25 m depth range near Otranto (Giangrande et al. 2003, 2004), and 16 species in the 5-35 m depth range at the Giglio Island (Tyrrhenian Sea) by Casoli et al. (2016). Interestingly, differences in the total number of species between these serpulid assemblages and those here examined seem to be accounted for by spirorbin species. The latter are lacking in assemblages collected in the Adriatic Sea (consisting exclusively of serpulin species), and only represented by two species in the assemblages from the Tyrrhenian Sea in spite of the six species reported from the Ionian Sea in the present study. Noteworthy, spirorbins, unanimously referred to as the most photophilic group within serpulids, were not found in those samples and are often lacking in polychaete lists from Mediterranean very shallow bottoms (Abbiati et al. 1987, Giangrande 1988, inter alias) whereas they are dominant on midlittoral to shallow infralittoral environments in north Atlantic communities (Knight-Jones & Knight-Jones 1977, Holthe 1992). This apparent spirorbin absence might be arguably a result of their small sizes making them hardly identifiable rather than of their real exclusion from these environments, but further studies are needed to support one or the other of these hypotheses.

Comparison relating to species composition and abundance can be hardly done because only general lists are usually provided in the scant literature. However, affinities can be traced with serpulids associated to shallow infralittoral algal communities in the Giglio Island (Tyrrhenian Sea) where assemblages were poorly diversified and consisted of an equal number of serpulin and spirorbin species at 5 m water depth (Casoli et al. 2016). Species richness increased at 10 m depth, and above all at 15, 25 and 35 m in the Phyllophora turfs, thanks to the inclusion of 6-to-14 Serpulinae species per sample, notwithstanding the decrease of a Spirorbinae species in samples deeper than 10 m (Casoli et al. 2016).

Comparisons cannot be done at all with past populations associated to algae from the same area because data are very scant (Table II). Serpulid lists are usually included in systematic and/or biodiversity-biogeographic review papers (Tenerelli 1961, 1962, Cantone 1971, 2001, Sanfilippo 1993, Sanfilippo & Di Geronimo 1999), and even when samples derive from accurate sampling designs, only cumulative lists including all detected species from all the collected samples are provided (e.g. Cantone et al. 2003). The only exception is given by Fassari
& Möllica (1989) who examined very shallow (1 and 5 m deep) horizons of the infralittoral. These authors found populations poorer than the present one with completely different structures including from 0 to a maximum of 3 species per sample and a total of 6 serpulid species at 1 m and only 2 at 5 m with a diversity decreasing with depth, a trend opposite to that observed in the present assemblages.

This study raises the total biodiversity of serpulids in the area of 5 species (Table II), including 2 serpulins (*i.e.* *S. cribrata*, plus a representative of the genus Protula), and 3 spirorbins (*i.e.* *Spirorbis marioni, S. cuneatus* and *S. striaticeps*).

Table II. – List of species reported from shallow water vegetate bottoms of the Ciclopi Islands area in northern Gulf of Catania, Ionian Sea; T: Tenerelli; C: Cantone; F-M: Fassari & Möllica; S: Sanfilippo; S-DG: Sanfilippo & Di Geronimo; na: not applicable; 1: as *Hydroides uncinata*; 2: as *Vermiliopsis langueransi*; 3: as *Pomatoceros triqueter*; 4: as *Spirorbis (Dexiospira) corrugatus*.

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**POLYCHAETA**

**Serpulinae**

- *Serpula concharum* Langerhans, 1880
- *Serpula lobianci* Rioja, 1917
- *Serpula vermicularis* Linnaeus, 1767
- *Spiraserpula massiliensis* (Zibrowius, 1968)
- *Hydroides dianthus* (Verrill, 1873)
- *Hydroides elegans* (Haswell, 1883)
- *Hydroides helmita* (Iroso, 1921)
- *Hydroides norvegica* Gunnerus, 1768
- *Hydroides pseud. pseudounicinatus* Zibrowius, 1971
- *Vermiliopsis infundibulum* (Philippi, 1844)
- *Vermiliopsis labiata* (O.G. Costa, 1861)
- *Vermiliopsis monodiscus* Zibrowius, 1971
- *Vermiliopsis striaticeps* (Grube, 1862)
- *Metavermilia multicristata* (Philippi, 1844)
- *Semivermilia crenata* (O.G. Costa, 1861)
- *Semivermilia cribrita* (O.G. Costa, 1861)
- *Filognanula calyculata* (O. G. Costa, 1861)
- *Spirobranchus polytremus* (Philippi, 1844)
- *Spirobranchus triqueter* (Linnaeus, 1767)
- *Spirobranchus lamarkii* (Quatrefages, 1865)
- *Josephella marenzelleri* Caullery & Mesnil, 1896
- *Filograna implexa* Berkeley, 1964
- *Protula* sp.

**Spirorbinae**

- *Spirorbis cuneatus* J.M. Gee, 1964
- *Spirorbis infundibulum* Harris & Knight-Jones, 1964
- *Spirorbis marioni* Caullery & Mesnil, 1897
- *Protolaeospira striata* (Quievreux, 1963)
- *Pileolaria militaris* Claparède, 1870
- *Simplaria pseudomilitaris* (Thriot-Quilervaux, 1965)
- *Janua (Dexiospira) pagenstecheri* (Quatrefages, 1865)
- *Neodexiospira pseudocorrugata* (Bush, 1904)

**Serpulinae**

- *Hydroides* sp.

**Spirorbinae**

- *Spirorbis* sp.

Total number of serpulid species

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<tr>
<th>Serpulinae</th>
<th>5</th>
<th><em>Hydroides</em> sp.</th>
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S. pseudomilitaris). However, all these species were otherwise known from neighboring sectors of the western Ionian Sea (see Castelli et al. 2008).

Sp. marioni is the only species that has been recognized as a NIS (Non Indigenous Species) for the Mediterranean (Zenetos et al. 2010). First recorded within harbors and possibly resulting from accidental transport as ship fouling, this species has been considered as established for a long time in Italian seas (Zibrowius & Bianchi 1981, Octципinti Ambrogi et al. 2011). The occurrence of Sp. marioni in this sector of the western Ionian Sea possibly results from a spreading history through local maritime traffic parallel to that suggested for the bryozoan Catenicella paradoxa discovered in the same Cystoseira communities (Mytilinou et al. 2016).

Serpulids, which live as epibionts on the ephemeral substrates available in the three Cystoseira investigated communities, formed low diversified assemblages characterized by the dominance of a few species. Composition and population structures found in the area at sampling time represent a snapshot of a more complex situation. Indeed, these serpulid fouling assemblages seem to be largely shaped by the occurrence, morphology and persistence of the algal substrata and the canopy they form. These assemblages are expected to change through time, largely in relation to changes in algal vegetative state, as well as to the life-spans and reproductive strategies of involved serpulid species. Further investigation on samples covering different seasons are planned in order to better clarify the distribution pattern of serpulid assemblages on algal substrata, and their dynamic through time.

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