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Sabellaria alveolata (Annelida, Polychaeta) bioconstructions and associated macroalgal community from Portopalo di Capo Passero (SE Sicily)

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Abstract

The shallow-water reef building polychaete *Sabellaria alveolata* is recorded from a new locality in the southeastern corner of Sicily, off Portopalo di Capo Passero. Here, a particular habitat is formed on upper infralittoral rocky bottoms beaten by waves, with *S. alveolata* developing as veneer-like bioconstructions interspersed/covered with a dense macroalgal community including alien *Caulerpa* taxa and dominated by *Ericaria giacconei*. First insights about the development of this particular habitat, as well as observations on possible relationships between *Sabellaria* and the associated algae, are presented.

Keywords: Polychaetes; Sabellariidae; Fucales; *Ericaria giacconei;* infralittoral; bioconstruction; benthic ecology; alien species; Sicily Straits.

Introduction

The habitat-forming tubicolous polychaete *Sabellaria alveolata* (Linnaeus, 1767) is widely distributed in north-eastern Atlantic and the western Mediterranean Sea (e.g., La Porta & Nicoletti, 2009; Bertocci *et al.,* 2017; Sanfilippo *et al.*, 2020). The species occurs from midlittoral to upper infralittoral, where it lives solitary or more frequently aggregated, forming bioconstructions of a huge number of individuals adjacent to each other inside protective tubes built by agglutinating sand grains (Gruet, 1986; Sanfilippo *et al.,* 2019). Depending on environmental conditions, the bioconstructions range from a few cm in thickness (“veneers” *sensu* Gruet, 1982) to *ca.* 50 cm (hummocks or pillows), up to more than 1 meter (reefs), with extensions of few square decimeters to several tens of square meters (Delbono *et al*., 2003; Noernberg *et al*., 2010).

Bioconstructions develop where the worm can catch sand particles suspended by turbulent waters (Gruet, 1972, 1982). For this reason, *Sabellaria* reefs seem restricted in Sicily to the sandy beaches that extensively occur along the southern coast (see Sanfilippo *et al*., 2020).

Owing to its building activity, *S. alveolata* deeply transforms the colonised biotopes, increasing bottom heterogeneity and providing additional substrates, space and shelter, thus promoting species richness (Dubois *et al.,* 2002; Jones *et al*., 2018; Bonifazi *et al.,* 2019, and references therein). However, little is known about associated animal taxa and their possible interactions with *S. alveolata*, especially for Mediterranean reefs. Papers often deal with single taxonomic groups (mostly mollusks, polychaetes and amphipod crustaceans), or even species (e.g., La Porta & Nicoletti, 2009; Iaciofano *et al.,* 2015; Schimmenti *et al.,* 2016), rather than the whole associated communities (Bertocci *et al*., 2017; Bonifazi *et al.*, 2019). Even less is known about the associated flora, with only a few algae mentioned, including *Ulva* Linnaeus, *Cladophora* Kützing (Dubois *et al*., 2006), and *Caulerpa* J.V. Lamouroux (Musco *et al.,* 2014; Vega Fernández *et al.,* 2019). Analogously, the role of *Sabellaria* reefs as available substrate for colonization by algal communities is just mentioned (see Delbono *et al*., 2003).

In the southeastern corner of Sicily, near the village of Portopalo di Capo Passero, *S. alveolata* coexists with a rich algal community forming crustose bioconstructions on shallowly submerged rocky bottoms interspersed with a dense algal vegetation dominated by the rare species *Ericaria giacconei* Serio & G. Furnari. This species has been described from Porto Palo di Capo Passero (Serio &

Furnari, 2021) to replace *Cystoseira hyblaea* Giaccone, in order to solve taxonomic and nomenclatural problems produced by the necessary genus displacement of an invalidly published species.

The present note aims at reporting and characterising these new *Sabellaria* bioconstructions from Portopalo di Capo Passero describing the assemblages they contribute to form, also focusing on macroalgal community and intergrowing algal species.

Materials and Methods

Veneer-like bioconstructions of *S. alveolata* inter growing with dense *Ericaria* community were discovered in September 2018 at the southeastern coast of Sicily, *ca*. 6 km SW of the Portopalo di Capo Passero village (Contrada Guardiana, 36.651056°N, 15.077067°E), in a small rocky shallow-water embayment constantly exposed to strong waves and winds. Cenozoic limestone constitutes both the colonized seafloor and emerged outcrops delimiting the embayment. The rocky bottom is gently sloping and locally covered by biogenic sandy sediments.

Since the first finding of these bioconstructions in 2018, several surveys have been carried out seasonally in the area. On the 2nd half of July 2020, scuba divers took pictures of the seabed through underwater GoPro 8Hero black camera to document the nature of the bottom and the distribution/extension of the *Sabellaria* bioconstructions and the algal cover (Fig. 1). In order to investigate the floristic biodiversity, sampling of macroalgal species growing on the rocky bottom and on *Sabellaria* crusts were carried out at -0.50 m depth in July and October 2020, detaching algae at their base using a small knife. Furthermore, the macroalgal species growing on two large-sized thalli of *E. giacconei* were studied (Table 1). The low number of replicates was forced by the need of minimizing the impact on a rare species.

Using a hammer, two small portions of the *Sabellaria* crust were sampled at the same depth (-0.50 m) in July 2020 to obtain living specimens for species identification and to describe the bioconstruction architecture. The *Sabellaria* samples PCP1 and PCP2 had sizes of *ca*. 8x11x4 cm and *ca*. 7x7x5 cm, respectively. The collected macroalgae and *Sabellaria* samples were preserved in 70% ethanol in seawater solution for subsequent analyses.

In the Palaeoecology laboratory of the Department of Biological, Geological and Environmental Science (BiGeA), *Sabellaria* individuals were extracted from their tubes and identified at species level under a Zeiss Axioplan II stereomicroscope using the morphological characters indicated by Fauvel (1927) and Kirtley (1994). The general architecture of the sampled *Sabellaria* bioconstruction was examined with the naked eye and photographed (Fig. 2). In the Phycology laboratory of the BiGeA, samples were studied for the identification of all macroalgal species under stereomicroscope. Morpho-anatomical observations were performed by optical microscope Zeiss Axioplan. Some specimens were stained with 1% aqueous aniline blue acidified with diluted HCl, which enhances visualization of pit connections. Sections were made by razor blade.

Sabellaria specimens and framework samples are housed in the Palaeontological Museum of the BiGeA (University of Catania). Algal material is housed in the

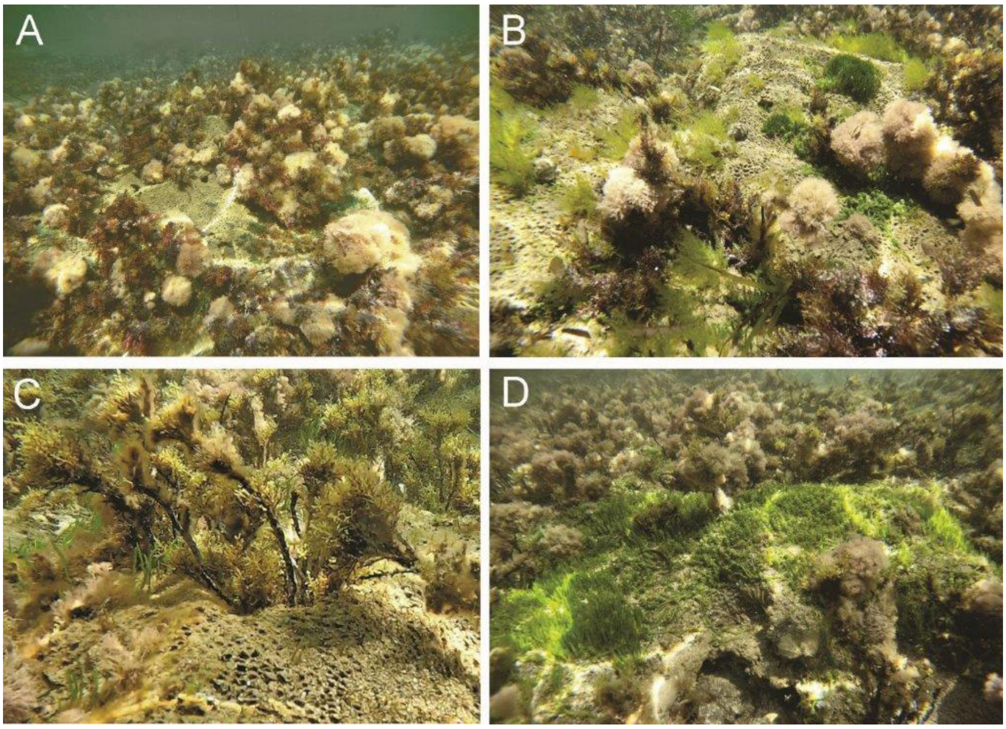

Fig. 1: *Sabellaria alveolata-Ericaria giacconei* habitat from Portopalo di Capo Passero (Sicily): A) Overview of the bottom with *Sabellaria* bioconstructions densely covered by *Ericaria* community. B) *Sabellaria* veneer-like crusts colonized by several thalli of macroalgae (*Laurencia* spp. and *Caulerpa* spp.). C) *Ericaria* thalli encircled by *Sabellaria* crusts. D) Portions of *Sabellaria* crusts covered by the invasive alien species *Caulerpa cylindracea* and *C. taxifolia* v. *distichophylla*.

Table 1. Epiphytic macroalgal species on *Ericaria giacconei* (E) and *Sabellaria alveolata* (S). + = presence; f = female gametophyte; m = male gametophyte; s = sporophyte; j = juvenile stage.

Locality	**Portopalo di Capo Passero (Syracuse)**		
Station	Contrada Guardiana	Contrada Guardiana	
Date	July 2020	October 2020	
Depth (m)	0.50	0.50	
RHODOPHYTA			
Ceramium codii (H. Richards) Mazoyer		+	E
Ceramium comptum Børgesen	+	+	E
Ceramium tenerrimum (G. Martens) Okamura	s		E
Ceramium cfr *brevizonatum* H.E. Petersen	s	+	E
Ceramium circinatum (Kützing) J. Agardh	+	+	E
Ceramium nodosum (Kützing) A.W. Griffiths & Harvey		+	E
Chondria dasyphylla (Woodward) C. Agardh		m	E
Choreonema thuretii (Bornet) F. Schmitz	s		E
Dasya rigidula (Kützing) Ardissone	+		E
Dipterosiphonia rigens (C. Agardh) Falkenberg	+	+	E
Erythrocystis montagnei (Derbès & Solier) P.C. Silva	+	+	E
Gayliella mazoyerae T.O. Cho, Fredericq & Hommersand	+	+	E
Herposiphonia secunda (C. Agardh) Ambronn	s	+	E
Herposiphonia tenella (C. Agardh) Ambronn		+	E
Heterosiphonia crispella (C. Agardh) M.J. Wynne	+	+	E
Hydrolithon boreale (Foslie) Y.M. Chamberlain	+	+	E
Jania pedunculata J.V. Lamouroux var. *adhaerens (J.V. Lamouroux)* A.S. Harvey, Woelkerling & Reviers		+	E
Jania virgata (Zanardini) Montagne	s	+	ES
Laurencia microcladia Kützing	f	+	ES
Laurencia cfr *obtusa* (Hudson) J.V. Lamouroux		+	S
Laurencia intricata J.V. Lamouroux		+	S
Laurenciella marilzae (Gil-Rodríguez *et al.*) Gil-Rodríguez *et al.*	s	fs	S
Lithophyllum pustulatum (J.V. Lamouroux) Foslie	s	+	E
Pneophyllum zonale (P. Crouan & H .Crouan) Y.M. Chamberlain	+	+	E
Polysiphonia sertularioides (Grateloup) J. Agardh		+	E
Rytiphlaea tinctoria (Clemente) C. Agardh	+	+	S
Taenioma nanum (Kützing) Papenfuss		+	E
Womersleyella setacea (Hollenberg) R.E. Norris		+	E
OCHROPHYTA			
Cystoseira compressa (Esper) Gerloff & Nizamuddin		j	S
Dictyota dichotoma (Hudson) J.V. Lamouroux	+	+	ES
Dictyota fasciola (Roth) J.V. Lamouroux	+	+	S
Dictyota mediterranea (Schiffner) G. Furnari	+	+	ES
Padina distromatica Hauck		+	S
Padina pavonica (Linnaeus) Thivy	+		S
Sphacelaria cirrosa (Roth) C. Agardh	+		E
CHLOROPHYTA			
Caulerpa taxifolia (M. Vahl) C. Agardh var. *distichophylla* (Sonder) Verlaque, Huisman & Procaccini	+	+	S
Caulerpa cylindracea Sonder	+	+	S
Cladophora laetevirens (Dillwyn) Kützing	+	+	S
Phaeophila dendroides (P. Crouan & H. Crouan) Batters	+	+	E
Pseudochlorodesmis furcellata (Zanardini) Børgesen	+		E
number of species on *Sabellaria*			11
number of species on *Ericaria*			25
number of species on both *Ericaria* and *Sabellaria*			4
Total number of species			40
Rhodophyta			28
Ochrophyta			7
Chlorophyta			5

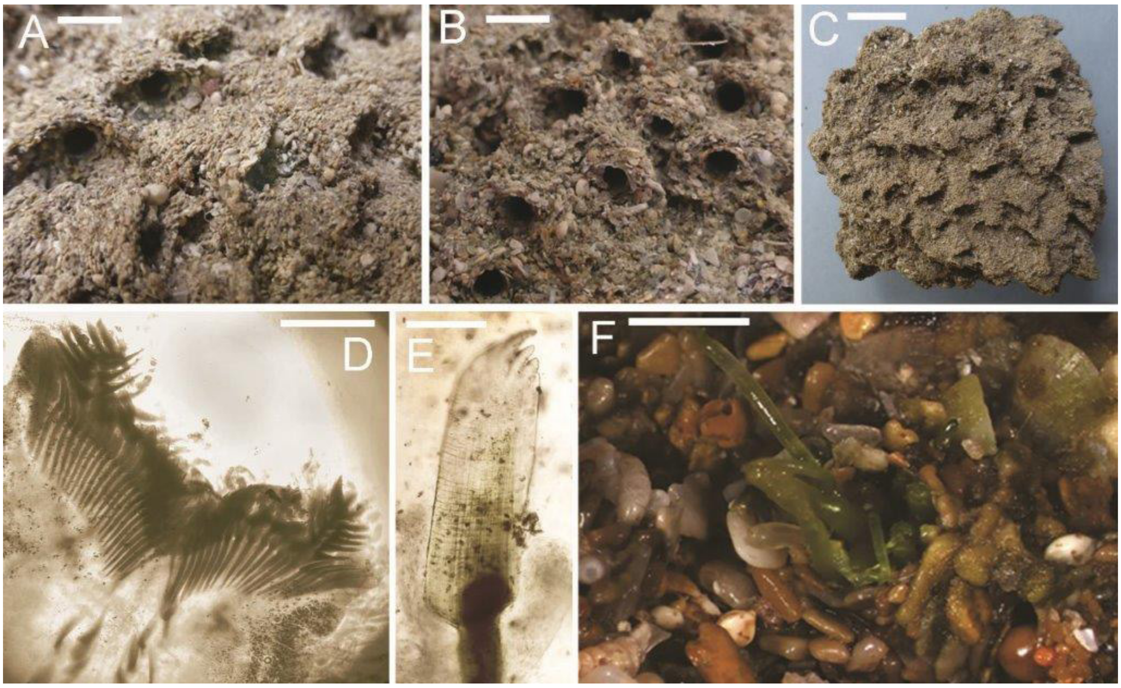

Fig. 2: *Sabellaria alveolata* from Portopalo di Capo Passero (Sicily): A) Outer surface of sample PCP1 showing tubes with intact apertural edges and well-developed rims. Scale bar: 5 mm. B) Outer surface of sample PCP2 with incomplete tubes disrupted in their distalmost part. Scale bar: 5 mm. C) Upper view of the veneer-like bioconstruction with prostrate and dorsally flattened tubes. Sample PCP2. Scale bar: 1 cm. D) Dorsal view of the anterior end of an individual with the opercular crown. Scale bar: 2 mm. E) Outer palea of the chitinous operculum figured in D bearing a smooth central tooth indicative of the species. Scale bar: 0.1 mm. F) Detail of the outer surface of sample PCP1 with a tube distal end hosting a stolon of *Caulerpa cylindracea*. Note the different nature, shape and size of the agglutinated sandy particles. Scale bar: 5 mm.

phycology laboratory of the BiGeA - Plant Biology Section of the University of Catania.

Results

In the study area, the *Sabellaria* bioconstructions cover a narrow rocky area subparallel to the coastline of about 100 square meters, from 0.3 m depth down to 1 m, growing on restricted bottom surfaces interspersed within a dense algal canopy dominated by *E. giacconei* (Fig. 1A). The *Sabellaria* bioconstructions are found below and around the *Ericaria* thalli and are locally colonized by some other algal species on their upper surface (Fig. 1 C-D). *E. giacconei* shows high specific coverage values, with largest thalli being up to 30 cm high.

The floristic study showed a total of 40 species (28 Rhodophyta, 7 Ochrophyta, 5 Chlorophyta) 25 of which found on *E. giacconei*, 11 on *Sabellaria* and 4 on both species (Table 1).

Both floristic study and field observations showed that the geniculate coralline red alga *Jania virgata* is very abundant on *E. giacconei*. Furthermore, numerous thalli of *Laurencia microcladia* and *Laurenciella marilzae,* as well as the invasive alien species *Caulerpa cylindracea* and *C. taxifolia* var. *distichophylla,* grow on the *Sabellaria* bioconstruction (Fig. 1B, D). *Sabellaria* patches no longer occur below one meter depth, where *E. giacconei* has lower coverage values. There, on rocky outcrops it is largely replaced by an association of species of the *Laurencia* complex associated with *Dictyota* spp., *Padina pavonica* and *Gongolaria elegans* (Sauvageau) Molinari & Guiry, which become dominant. At this depth a sandy cover begins to be found on the bottom, hosting *Caulerpa prolifera* (Forsskål) J.V. Lamouroux, *Dasycladus vermicularis* (Scopoli) Krasser and *Posidonia oceanica* (Linnaeus) Delile.

The *Sabellaria* bioconstructions associated with the algal canopy consist of aggregates of adjacent sand-made tubes that form irregularly shaped and discontinuous veneer-like patches, each 5-20 cm thick and up to 60 cm wide (Fig. 1). Owing to their structure, consisting of tubes made by agglutinated sandy particles, these patches are barely noticeable, if not for their distinctive honeycomb-like surface, which derives from the regular pattern of adjacent tube apertures (Fig. 1B, C). Locally, large thalli of *Ericaria* are encircled and become immersed in between the *Sabellaria* crusts for much (up to the upper third) of the cauloid (Fig. 1C). In these sheltered portions below the algal fronds, the *Sabellaria* tubes show intact apertural edges with well-developed rims (Fig. 2A). Conversely, in portions of the bioconstruction exposed to hydrodynamism, unprotected by the *Ericaria* thalli, tubes are incomplete and more or less disrupted in their distalmost part (Fig. 2 B).

Observations performed in the field and on the two *Sabellaria* crust samples show that the bioconstruction corresponds to the veneer-like type, consisting of tubes irregularly bent in their initial part and then growing straight, subparallel to each other and prostrate in their distal part, with isoriented apertures facing landwards (Figs 1C, 2C). Tubes are circular to sub-quadrangular in cross section and up to 7 cm long with a 3-6 mm wide lumen and an outer diameter up to 9 mm at the aperture (Fig. 2B, C). Each tube ends with an infundibular asymmetrical rim, usually much protruding on the flattened dorsal side, forming a sort of roof above the aperture (Fig. 2A, C). The tube wall is *ca*. 2 mm thick and typically three-layered. It is formed by agglutinate sandy particles mainly consisting of carbonate clasts and subordinate lithic grains of different shape and size (Fig. 2F). Living animals found inside tubes demonstrated they unequivocally belong to *S. alveolata* owing to the diagnostic morphology of the chitinous outer paleae of the operculum that show a smooth central tooth (Fig. 2D, E) compared to those of *S. spinulosa* that bear a central denticulate plume (Lezzi *et al.,* 2015: fig. 2).

Discussion and Conclusions

The new finding of *S. alveolata* from the Portopalo di Capo Passero coast integrates the known geographical distribution of the species along the coasts of Sicily. In the study area bioconstructions develop as veneers (see Gruet, 1982; Gruet & Bodeur, 1995, Curd *et al.,* 2019) in contrast to what reported from other Sicilian areas, where hummocks, pillows and reefs have been identified (Schimmenti *et al*., 2016; Bertocci *et al*., 2017; Sanfilippo *et al*., 2019). This crustose bioconstruction, formed by tubes prostrate in their distal ends, and apertures directed towards the coastline, would indicate conditions of high hydrodynamic energy, as evidenced by Gruet & Bodeur (1995). This fits well with the environmental conditions of the investigated coastal sector that is beaten by strong waves and currents that are forced by dominant landwards directed winds (e.g., Ciani *et al*., 2019).

The association of macroalgal species with *Sabellaria* reefs has been very rarely reported (e.g., Dubois *et al.,* 2006) since underwater imaging of these biostructures usually miss algal cover (e.g., Bonifazi *et al*., 2019). Although *Sabellaria* bioconstructions have been considered as biodiversity hotspots, very high values in overall abundances and species richness negatively correlate with the number of “sand crowns” considered as an index of health status for the worm (Bonifazi *et al.,* 2019). Pending for results of ongoing monitoring, it seems that in the Portopalo di Capo Passero bioconstruction worm growth is not negatively affected by the presence of the numerous co-occurring algal species that grow on top and sideway. Instead, a beneficial influence could be suggested for this association because first observations after winter showed that on the upper surfaces of the *Sabellaria* crusts tube apertures are intact close to *Ericaria* fronds but disrupted far from the algal fronds.

The coexistence of *S. alveolata* and *E. giacconei* in the same biotope and their growth relationships deserve to be investigated, including the possible advantage for the perennial portion of *Ericaria* thalli to be encircled by the sandy crust formed by the worm, or likewise the positive effects of the presence of *E. giacconei* and other macroalgae on *Sabellaria* bioconstructions in mitigating too strong hydrodynamic action, thus favoring sediment capture by the worm. Although formally unreported, a similar interaction is visible on underwater photographs in a report of ARPA Sicilia (2014) for some *Sabellaria* bioconstructions located on bottoms *ca*. 100 km west of our study site, where algae seem to be absent but tufts of short *Posidonia oceanica* leaves are surrounded by the tube worm’s aggregates. Seemingly, both *Ericaria* fronds and *Posidonia* leaves may perform the same positive function for *Sabellaria*. Further species found in epibiosis on both *E. giacconei* thalli and directly on the exposed surface of the *Sabellaria* bioconstruction are under examination in order to assess the total algal biodiversity, as well as the occurrence of associated sessile animal species.

Among macrophytes easily registered in the field, the invasive alien species *Caulerpa cylindracea* and *C. taxifolia* var. *distichophylla* are common and highly developed especially in summer months. The presence of stolons of *C. cylindracea*, even within some empty tubes of *Sabellaria* (Fig. 2F), highlights the invasive colonization strategy of this macroalga. Their possible impact on the growth of the *Sabellaria* veneers and/or the protection from dismantlement by environmental energy remains to be investigated, as well as the impact of these algae on the assemblage’s biodiversity.

Although the occurrence of invasive *Caulerpa* species may be highly negative for particular species, such as the frame-builder coral *Cladocora caespitosa* (Linnaeus, 1767) (see Kružić *et al*., 2008), other data point to the beneficial effect of populations of *C. cylindracea* intermixed with other algae on macrozoobenthos dispersion and in attracting some vagile taxa (Sinopoli *et al*., 2020). The presence of *C. cilindracea* and *C. taxifolia* var. *distichophylla* growing on *Sabellaria* tubes does not seem to hinder the crust development. This is also obvious (even not described) for other *Sabellaria* bioconstructions in neighboring areas (Vega Fernández *et al.,* 2019: fig 1) and sabellarids have been considered tolerant worms persisting in *Posidonia* meadows impacted by *C. taxifolia* var. *distichophylla* (Musco *et al*., 2014).

Finally, the rough *Sabellaria* surface seems to favour *Ericaria* settlement and the development of the new germlings. Pons-Fita *et al*. (2020) hypothesized a similar positive interaction between the habitat-forming species *Cladocora caespitosa* and *Treptacantha ballesterosii* (Orellana & Sansón) [corresponding to *Gongolaria montagnei* (J.Agardh) Kuntze] proposing a new habitat to be included in the list of the Spanish Mediterranean habitats. Pons-Fita *et al.* (2021) also assert that the close and long-lasting relationships they found between *Cystoseira s.l.* species and *C. caespitosa* are species- and site-specific, even though they are mainly neutral. The mechanisms that promote this coexistence are yet to be understood, but results by Pons-Fita *et al.* (2021) challenge the theory of competitive exclusion between *C. caespitosa* and fleshy macroalgae in the Mediterranean.

Likewise, *Cladocora*-*Gongolaria*, the *Sabellaria*-*Ericaria* co-occurrence and close intergrowth here first described represents an example of taxa that thrive together in a healty algal community falling in the “Biocoenosis of the Infralittoral Algae" (IA) (Habitat III.6.1 according to SPA/BIO Protocol), or the "Biocoenosis of the Photophilic Algae" (AP) *sensu* Pérès & Picard (1964).

Both the "*Cystoseira* complex" and the *Sabellaria* bioconstructions are protected owing to their vulnerability and the key functional role in coastal ecosystems. They are listed in Annex II ('endangered and threatened species') of the Barcelona Convention, Mediterranean Action Plan of the United Nations, and Annex I of the EC - Council Directive EEC/92/43 on the Conservation of Natural Habitats and of Wild Fauna and Flora, respectively. Consequently, the status and extension of the *Sabellaria-Ericaria* community deserve to be further investigated and monitored in the area, especially in relation to the anthropogenic impact and intense trampling in summer months, as suggested by Plicanti *et al*. (2016) for other bioconstructions.

The preliminary data here reported may constitute a baseline for future studies addressing the interactions between *Sabellaria* bioconstructions and *Ericaria* community through time, and for comparing data from an underway monitoring to investigate seasonal changes produced by human and/or natural disturbance.

Author contribution

RS, AR, DS designed the study. CD contributed to field and laboratory investigation; RS wrote the first draft of the manuscript. All authors interpreted data and wrote the agreed version of the manuscript.

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