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Degradation of a photophilic algal community and its associated fauna from eastern Sicily (Mediterranean Sea)

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Abstract

The status of the “Biocoenosis of the Infralittoral Algae” of the upper infralittoral zone (at 5 m depth) from two selected stations along the eastern coast of Sicily (Ionian Sea, Mediterranean) was studied with a multiproxy approach involving the study of algae and associated protist and animal organisms, including foraminifers, serpulids, molluscs, bryozoans and ostracods. Scraped samples (40x40 cm) were collected at selected seasons during a 2-year period (2015-2016) in order to identify possible seasonal and spatial differences between the two stations, and to compare present data with historical ones. A community made up of the algae Halopteris scoparia, Padina pavonica, Dictyota dichotoma, Ellisolandia elongata and other encrusting coralline algae was found in sites historically colonised by a Cystoseira brachycarpa community, which was not found during our study. These algae presently structure the community and provide substratum for several associated epibiotic species. Hierarchical cluster analysis and Non-Metric Multi-Dimensional Scaling Ordination significantly differentiate the communities between the two stations but show no clear seasonal trend. Differences largely relate to changes in the algal vegetation and the impact produced by the regression of structuring species on epibionts (especially serpulids and bryozoans). Comparison with historical algal data from the area indicates the disappearance of Cystoseira brachycarpa, which was present at least until the late 1990s, and a community degradation with a considerable loss in species richness. This parallels observations in other Mediterranean areas, and could be related to an increase in population density of echinoids and their heavy grazing activity.

Keywords: Marine vegetation; IA Biocoenosis; Cystoseira; encrusting/mobile benthos; Ionian Sea.

Introduction

The “Biocoenosis of the Infralittoral Algae” (IA) (Habitat III.6.1 according to SPA/BIO Protocol), largely corresponding to the “Biocoenosis of the Photophilic Algae” (AP) sensu Pérès & Picard (1964), occurs in shallow-water rocky strongly illuminated habitats and includes most Cystoseira communities.

The genus Cystoseira (Fucales) consists of 45 species (Guiry & Guiry, 2017), and 30 occur in the Mediterranean Sea (Cormaci et al., 2012). Most of these species form habitats from the littoral fringe down to the upper circalittoral zone (Feldmann, 1937; Molinier, 1960; Verlaque, 1987; Ballesteros, 1988, 1990a, 1990b; Giaccone et al., 1994). Cystoseira species have erect, relatively rigid, growth morphologies, form three-dimensional structures, where vegetation stratifies and several microhabitats and ecological niches develop supporting a high biodiversity with plants and animals setting up multiple relationships (Pérès & Picard, 1964; Otero-Schmitt & Perez-Cirera, 1996; Ballesteros & Pinedo, 2004; Christie et al., 1998). For these reasons, Cystoseira habitats have been included in the priority list of the Barcelona Protocol and the EU Marine Strategy Directive (MSFD Descriptor 1).

Cystoseira species are long-living and their status can be used to estimate the possible onset of disturbance and degradation (Giaccone & Bruni, 1973; Ballesteros et al., 2007; Sales & Ballesteros, 2009; Mancuso et al., 2018). They are particularly prone to both natural and anthropogenic environmental changes, including temperature rise and heatwave events, extremes of weather and marine phenomena, and introduction of non-indigenous species.
As a result, *Cystoseira* communities may act as a sentinel in environmental monitoring (Chemello & Milazzo, 2002; Cacabelos et al., 2010).

Loss of *Cystoseira* communities has been recently reported throughout the Mediterranean Sea, caused by habitat destruction, eutrophication and overgrazing by herbivores (Cormaci et al., 2001; Thibaut et al., 2005, 2015, 2016; Serio et al., 2006; Mangialajo et al., 2008; Sales & Ballesteros, 2009; Tsimis et al., 2013; Templado, 2014; Mineur et al., 2015). These pressures usually lead to habitats with lower structural complexity, such as turfs of filamentous algae, or even barren grounds, where sea urchin density is a driver of habitat homogenization (Guidetti & Dulčič, 2007; Mangialajo et al., 2008; Giakoumi et al., 2012).

*Cystoseira* habitats have been unanimously considered well structured along the eastern coast of Sicily, and especially in the northern sector of the Catania Gulf (MSFD subregion “Ionian Sea and the Central Mediterranean Sea”). Consequently, associations from these areas have been used for the phytosociological study of photophilous assemblages of both infralittoral and circalittoral zones (Giaccone et al., 1994). Since 1989, an area of protection has been established (the Ciclopi Islands Marine Protected Area: CIMPA), where the *Cystoseira brachycarpa* community was widespread and in good health at least until the 1990s (Pizzuto, 1999), providing physical and ecological space for algal and animal epibions.

In this paper new data is presented, aiming to: i. highlight possible changes in composition of algal species and their relative abundances since the 1990s; ii. investigate possible seasonal variation using samples collected in three subsequent seasons (late spring, autumn and winter) during a two-year period; iii. contribute first knowledge about associated skeletonised protists (foraminifera) and invertebrates, including serpulids, molluscs, bryozoans and ostracods, on which no data is presently available, except some preliminary information reported by Sanfilippo et al. (2017), Sciuto et al. (2018) and Rosso et al. (in press); iv. provide a good starting point for future investigation and monitoring.

**Material and Methods**

We selected communities within the IA Biocoenosis, which is widespread in the Ciclopi area, along the northeastern Gulf of Catania (Sicily, Ionian Sea) on shallow-water bottoms consisting of subvolcanic rocks (Corsaro & Cristofolini, 1997), partly dismantled to produce a belt of large boulders from sea-level down to 10-15 m depth. Coarse bioclastic sediments and Etna volcanic ash occur within boulders and a veneer of fine sand and silt is often entrapped within the algal canopy.

We investigated two stations: Punta Aguzza (CPA: 37.5464306 N; 15.1452777 E), located inside CIMPA, and Santa Maria La Scala (SM: 37.6185861 N; 15.1754666 E), outside CIMPA (Fig. 1). Localities were chosen based on historical records (Pizzuto, 1999) of a *Cystoseira brachycarpa* community.

In order to evaluate seasonal changes in both flora and fauna biota sampling was carried out in late spring, autumn and winter. Each site was surveyed 5 times during a two-year period: June 2015, October 2015, February 2016, June 2016 and October 2016. For each survey three samples were collected through scuba diving in homogeneous surfaces on contiguous quadrats of 40x40 cm (Fig. 2). The first sample was collected with a mobile sorbon (Fig. 2A) to analyze slightly attached microorganisms (protists and ostracods); the second and third samples by scraping, to analyze plants and associated macrofauna respectively.

Samples were preserved in 70% seawater-ethanol alcohol solution for further study. Voucher algal specimens were deposited in the Herbarium of the Department of Biological, Geological and Environmental Sciences of the University of Catania (CAT). Protist and metazoan material was deposited within the Paleontological Museum of the same Department, in the Rosso, Sanfilippo and Sciuto Collections, respectively for bryozoans (Bryo-CIMPA-Biochange 2015-2016), serpulids (Serp-CIMPA-Biochange 2015-2016), and foraminifers and ostracods (CIMPA-Biochange 2015-2016 Sciuto micro bio). In situ video-photo-documentation was performed using a Go-pro Camera Hero 4.

Identification of algal species was mostly based on diachronic structural and reproductive features observed using stereomicroscope and microscope, following standardized laboratory methods as reported in Cormaci et al. (2003). A cover percentage value expressed according to the scale of Braun-Blanquet (Braun-Blanquet, 1959; Cormaci et al., 2003) was attributed to each species. Species with cover values ≥1% are first reported in Table 1, followed by species with values <1% listed in decreasing order. The reproductive phenology was also reported.

Metazoan identification was performed using a Zeiss Discovery V8A stereomicroscope, which was also used for the acquisition of low magnification photos through

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**Fig. 1**: Location of the sampling area within the Mediterranean (A), and the eastern coast of Sicily (B). C. Santa Maria La Scala D. Punta Aguzza. Sampling stations are indicated with red dots.
an Axiocam and related Axiovision acquisition system. Scanning Electron Microscopy (SEM) in low vacuum modality (Tescan VEGA LMU 2) was also used to identify several associated species, mostly bryozoans, ostracods and foraminifera.

Multivariate statistical analysis was performed with PRIMER 6.1.12 software (© Primer-E Ltd.; Clarke & Warwick, 2001) based on the abundance matrix constructed using specimens collected alive. All samples (observations = 10) and species (variables = 232) were retained. Algal data were introduced in the matrix by replacing the original coverage classes (Cormaci et al., 2003) with the median values of their respective coverage percentage ranges, following the rationale exposed in Boudouresque (1971); subsequently, they were treated as abundance data in the cluster/MDS analysis. The abundance data (except for molluscs, foraminifers and ostracods) were square root transformed in order to downweight highly abundant species (Field et al., 1982).

A triangular Bray-Curtis resemblance matrix provided the base for hierarchical cluster analysis (complete linkage cluster mode) and Non-Metric Multi-Dimensional Scaling Ordination (MDS). Similarity percentages (SIMPER procedure, one-way analysis) were calculated on the community matrix only to reveal species contribution to the total similarity within sampling sites; an analysis of similarity (ANOSIM procedure) was performed on the same matrix to ascertain site separation. Finally, the Shannon-Weaver diversity index ($H'$) was calculated with the DIVERSE procedure with the raw number of species ($S$) and specimens ($N$) per sample as base; as regards algal data, the same index was modified following Boudouresque (1971).

Results

Floristic and vegetation data

A total of 85 taxa were found (Table 1, Fig. 3), determined at specific and infraspecific levels (later referred to as “species” for convenience), including 68 Rhodophyta, 10 Ochrophyta and 7 Chlorophyta. Sixty-nine species (55 Rhodophyta, 9 Ochrophyta, 5 Chlorophyta) were present in the CPA station, and 61 species (49 Rhodophyta, 7 Ochrophyta, 5 Chlorophyta) in the SM station. Twenty-four species (19 Rhodophyta, 3 Ochrophyta, 2 Chlorophyta) were present only at CPA site, whereas 16 species (13 Rhodophyta, 1 Ochrophyta, 2 Chlorophyta) occurred exclusively in the SM site. A bulk of 45 species (36 Rhodophyta, 6 Ochrophyta, 3 Chlorophyta) were shared by both sites.

The highest number of species was recorded in summer (72 species: 61 Rhodophyta, 9 Ochrophyta, 2 Chlorophyta) and the lowest in winter (53 species: 45 Rhodophyta, 6 Ochrophyta, 2 Chlorophyta). Nearly 48.2% of the species were present in all sampling surveys, 13% only in June, 6% only in October and 4.7% only in February.

The mean number of species per sample was 38.5. No significant difference was observed between the two stations (CPA = 40.6 and SM = 36.4) and different sampling periods (41 in June, 36 in October and 39 in February). In addition, diversity values (modified Shannon-Weaver index) showed no spatial or temporal trends, reaching maximum values (1.8-2.1) in both CPA and SM in February and June 2016.

The absence of Cystoseira brachycarpa, historically widespread in the investigated stations and neighbouring areas (Pizzuto, 1999), was noticed. Instead, present-day algal community consisted mainly of Halopteris scoparia, Padina pavonica, Dictyota dichotoma, Jania rubens, Ellisoliandia elongata, and other encrusting coralline algae (Table 1). The presence of Wurdemannia miniata was noteworthy since it is reported from Catania coasts for the first time. It formed tangled turfs and reached high cover values in February and October 2016 inside the MPA.

In some samples (and especially in CPA4 and SM4) the lower layer of the algal mat consisted of erect and poorly branched basal portions of Ellisoliandia elongata, topped by a nearly 1 cm thick turf of filamentous soft algae (e.g. Sphacelaria cirrosa and Centroceras claviulatum) and Jania spp. (Fig. 4). This algal mat had an important role in the entrapment of silt.
Table 1. List of algae species found in the examined algal community within the Ciclopi Islands area. CPA: Punta Aguzza; SM: Santa Maria La Scala; Pr: presence in number of surveys. Cover values follow the Braun-Blanquet scale modified (Cormaci et al., 2003): + < 1%; 1=1-5%; 2=6-25%; 3=26-50%; 4=51-75%; 5=76-100%. Reproductive phenology of species: s: sporophyte; f: female gametophyte; m: male gametophyte. 1, 2, 3, 4, and 5 in the heading refer to sampling surveys.

| Algae                                         | CPA | CPA | SM | SM Total |
|-----------------------------------------------|-----|-----|----|----------|
| **Surveys**                                   | 1   | 2   | 3  | 4        | 5     | Pr  | Pr  | 1   | 2   | 3  | 4   | 5  | Pr  | Pr  |
| Halopteris scoparia (L.) Sauv.                | 4   | 2   | 1  | 2       | 5     | 4    | 2   | 2   | 3   | 3   | 5   | 10  |
| Padina pavonica (L.) J.V. Lamour.            | 2   | +   | +  | 3       | +     | 5    | +   | 3   | +   | 3   | 8   |
| Dictyota dichotoma v. intricata (C. Agardh)  | Grev. | +   | +  | 3       | +     | 4    | +   | +   | +   | +   | 7   |
| Ellisoliandia elongata (C. Ellis & Sol.) K.  | Hind et G.W. Saunders | +   | +  | 3       | 5     | +   | +   | 3   | +   | +   | 5   | 10  |
| Jania rubens (L.) J.V. Lamour. v. rubens      | 3   | 2   | 2  | 4       | 2     | 3    | 2   | 3   | 3   | 5   | 9   |
| Jania adhaerens J.V. Lamour.                  | +   | +   | +  | +       | 4     | +    | +   | +   | +   | +   | +   | 5   | 9   |
| Rhodymenia ligulata Zanardini                 | +   | +   | +  | +       | 4     | 1    | 1   | +   | +   | +   | 1   | 5   | 9   |
| Sphacelaria cirrosa (Roth) C. Agardh          | +   | +   | 1  | 4       | +    | +    | +   | +   | +   | +   | 5   | 9   |
| Wurdelemania miniata (Spreng.) Feldmann &    | Hamel | 3   | 2  | 2       | 0     | 2    |
| Gelidium cf. pusillum (Stackh.) Le Jol.       | 1   | +   | 1  | +       | 4     | +    | +   | +   | 2   | 6   |
| Centroceras clavatum (C. Agardh) Mont.        | +   | +   | +  | 3       | 3    | 1    | 2   | 1   | 1   | 5   | 8   |
| Ceramium comptum Borgesen                     | Is  | 1   | +  | 4       | 2s    | 1    | +   | 3   | 7   |
| Lithophyllum incrustans Phil.                 | s   | +   | +  | 1       | 2     | 5    | 0   | 5   |
| Lithophyllum styctiforme (Aresch.) Hauck     | 2s  | 1   | 2  | 1       | 1     | 3    | 4   |
| Peyssonnelia squamaria Boudour. & Denizot     | +   | +   | +  | +       | 4     | +    | 2   | 3   | 7   |
| Feldmannophycus rayssiae (Feldmann et Feld.- | Maz.) H. Augier & Boudour. | +   | +   | +   | +       | 5    | +    | +   | +   | +   | 5   | 10  |
| Antithamnion cruciatum (C. Agardh) Nägeli    | +   | +   | +  | +       | 5     | +    | +   | +   | +   | +   | +   | 5   | 10  |
| Hydrolithon boreale (Foslie) Y.M. Chamb.     | +   | +   | +  | +       | 5     | +    | +   | +   | +   | +   | +   | 5   | 10  |
| Laurencia chondrioides Borgesen               | s   | +   | +  | +       | +     | 5    | s   | +    | +   | +   | +   | 5   | 10  |
| Stylovena alsidii (Zanardini) K.M. Drew       | +   | +   | +  | +       | 5     | +    | +   | +   | +   | +   | +   | 5   | 10  |
| Asparagopsis armata (C. Agardh) Harv. (sporophyte included) | +   | +   | +  | +       | 5     | +    | +   | +   | +   | +   | 4   | 9   |
| Champa parvula (C. Agardh) Harv.              | +   | +   | +  | +       | 4     | +    | +   | +   | +   | +   | +   | 5   | 9   |
| Herposiphonia secunda (C. Agardh) Ambronnn    | +   | +   | +  | 5       | +    | +    | +   | +   | 4   | 9   |
| Ceramium cincinatum (Kütz.) J. Agardh         | +   | +   | +  | 5       | +    | +    | +   | +   | 3   | 8   |
| Ceramium codii (H. Richards) Feld.-Maz.       | +   | +   | +  | 3       | +    | +    | +   | +   | 5   | 8   |
| Ceramium tenerrimum (G. Martens) Okamura      | +   | +   | +  | 3       | s    | +    | 4   | 7   |
| Gayliella mazayerae T.O. Cho, Fredericq &    | Hommers | +   | +   | +  | 3       | +    | +   | +   | 4   | 7   |
| Heterosiphonia crispsella (C. Agardh) M.J.  | Wynne | +   | +   | +  | 4       | +    | +   | +   | 3   | 7   |
| Monosporres pedicellatus (J.E. Sm.) Solier    | +   | +   | +  | 4       | +    | +    | +   | 3   | 7   |
| Contarinia squamariae (Menegh.) Denizot       | +   | +   | +  | 4       | +    | +    | 2   | 6   |
| Hypoglossum hypoglossoides (Stackh.) Collins  | +   | +   | +  | 3       | +    | +    | +   | 3   | 6   |
| & Herv.                                       | +   | +   | +  | 2       | +    | +    | 3   | 5   |
| Caulerpa cylindracea Sonder                   | +   | +   | 2  | +    | +   | 3   | 5   |
| Dictyota dichotoma (Huds.) J.V. Lamour. v.    | dichotoma | 4   | 2  | 2   | +    | 3   | 5   |
| Osmundea truncata (Kütz.) K.W. Nam & Maggs    | +   | +   | s  | 4    | +    | 1   | 5   |
| Amphiroa rigida J.V. Lamour.                  | +   | +   | +  | 4       | 0   | 4   |
| Botryocladia botryoides (Wulfen) Feldmann     | +   | +   | +  | 3       | +    | 1   | 4   |
| Bryopsis plumosa (Huds.) C. Agardh            | +   | 1   | +  | +    | +   | 3   | 4   |
| Choreonema thureti (Bornet) F. Schmitz        | +   | +   | +  | 4       | 0   | 4   |
| Dasya rigidula (Kütz.) Ardiss.                | +   | 1   | +  | +    | 3   | 4   |
| Herposiphonia tenella (C. Agardh) Ambronnn    | 0   | +   | +  | +    | 4   | 4   |

continued
| CPA | CPA | SM | SM | Total |
|-----|-----|----|----|-------|
|     |     |    |    |       |
| **Surveys** | 1 | 2 | 3 | 4 | 5 | Pr | 1 | 2 | 3 | 4 | 5 | Pr | Pr |
| Hypnea musciformis (Wulfen) J.V. Lamour. | + | + | + | + | + | + | 3 | 4 |
| Laurencia microcladia Kütz. | + | + | f | + | + | + | 3 | 4 |
| Lomentaria chylocladiella Funk | + | + | + | + | + | 3 | 4 |
| Lophosiphonia cristata Falkenh. | + | + | 2 | + | + | 2 | 4 |
| Neogoniolithon brassica-florida (Harv.) Setch. & L.R. Mason | 0 | s | + | + | + | 4 | 4 |
| Nitophyllum microcarpunctatum Funk | 0 | + | + | + | + | 4 | 4 |
| Rhodophyllis divaricata (Stackh.) Papenf. | 0 | + | + | + | + | 4 | 4 |
| Spyridia filamentosa (Wulfen) Harv. | + | + | + | + | + | 4 | 0 |
| Acrosorium ciliosum (Harv.) Kylin | + | + | + | + | 3 | 4 |
| Chylocladia verticillata (Lightf.) Bliding | s | + | + | 3 | 0 |
| Cladophora prolifera (Roth) Kütz. | + | + | 2 | + | 1 | 3 |
| Halopteris filicina (Gratel.) Kütz. | + | + | 2 | + | 1 | 3 |
| Jania virgata (Zanardini) Mont. | + | + | + | 3 | 0 |
| Nitophyllum punctatum (Stackh.) Grev. | + | + | + | 3 | 0 |
| Peyssonnelia bornettii Boudour. & Denizot | + | + | + | 3 | 0 |
| Pneophyllum fragilis Kütz. | 0 | + | + | + | 3 | 3 |
| Polysiphonia dichotoma Kütz. | + | m | + | + | 2 | 3 |
| Stylenoma cornu-cervi Reinsch | + | + | + | 3 | 0 |
| Valonia utricularis (Roth) C. Agardh | + | + | + | 3 | 0 |
| Anotrichium tenue (C. Agardh) Nägeli | 0 | s | s | 2 | 2 |
| Ceramium diaphanum (Lightf.) Roth | + | 1 | m | 1 |
| Chaetomorpha linum (O.F. Müll.) Kütz. | + | + | 2 | 0 |
| Coralliphila cinnabarina (Gratel. ex Bory) R.E. Norris | 0 | + | + | 2 | 2 |
| Dasya ocellata (Gratel.) Harv. | + | 1 | + | 1 | 2 |
| Dictyopteris polyspodioides (DC.) J.V. Lamour. | 0 | + | + | 2 | 2 |
| Dictyota mediterranea (Schiffer) G. Furnari | + | + | 2 | 0 |
| Eupogodon planus (C. Agardh) Kütz. | + | + | 2 | 0 |
| Laurencia sp. | 0 | + | + | 2 | 2 |
| Laurencia obtusa (Huds.) J.V. Lamour. | + | + | 2 | 0 |
| Peyssonnelia heteromorpha (Zanardini) Athanasiadis | + | + | 2 | 0 |
| Wrangelia penicillata (C. Agardh) C. Agardh | + | + | 2 | 0 |
| Anotrichium barbatum (C. Agardh) Nägeli | 0 | + | 1 | 1 |
| Chondria dasyphylla (Woodward) C. Agardh | 0 | + | 1 |
| Dasya hutchinsiae Harv. | 0 | + | 1 |
| Diperosiphonia rigens (C. Agardh) Falkenh. | + | 1 | 0 |
| Discosporangium mesarthocarpum (Menegh.) | Hauck | s | 1 | 0 | 1 |
| Gelidium minusculum (Weber Bosse) R.E. Norris | 0 | + | 1 |
| Halimeda tuna (J. Ellis & Sol.) J.V. Lamour. | 0 | + | 1 |
| Lithophyllum pustulatum (J.V. Lamour.) Foslie | s | 1 | 0 |
| Microdictyon umbilicatum (Velley) Zanardini | 0 | + | 1 |
| Peyssonnelia dubyi P. & H. Crouan | + | 1 | 0 |
| Pleonosporium borreri (J.E. Sm.) Nägeli | 0 | + | 1 |
| Polysiphonia scapulorum Harv. | + | 1 | 0 |
| Spermothamnion repens (Dillwyn) Rosenvinge | + | 1 | 0 |
| Sphacelaria plumula Zanardini | + | 1 | 0 |

**N° of Rhodophyta per sample** | 31 | 30 | 35 | 38 | 33 | 34 | 25 | 30 | 33 | 29 |
**N° of Ochrophyta per sample** | 5 | 5 | 6 | 6 | 4 | 5 | 3 | 5 | 6 | 3 |
**N° of Chlorophyta per sample** | 1 | 4 | 0 | 2 | 3 | 1 | 2 | 2 | 1 | 3 |
**N° of species per sample** | 37 | 39 | 41 | 46 | 40 | 40 | 30 | 37 | 40 | 35 |
Foraminifers

A total of 45 benthic taxa were identified, some at genus level (Table 2, Fig. 5), with specimen abundance often positively correlated to species richness. CPA station was richer in both number of species (40 spp.) and abundance of specimens in comparison to SM (28 spp.). Elphidiidae and some Hauerinidae dominated. Quintaloculina auberiana and Planorbulina mediterranensis occurred in all samples. Few other species, among which Elphidium spp., were also frequent, whereas the majority were rare and sporadic. Shannon-Weaver diversity did not vary over time, and was higher in CPA than in SM samples.

Serpulids

Serpulid assemblages consisted of 14 taxa identified at species level (Table 3, Fig. 5), including 10 Serpulinae and 4 Spirorbinae. Twelve species were present in CPA station and 8 in SM station; 6 species (4 Serpulinae and 2 Spirorbinae) were shared by both stations. Although Serpulinae were more diversified, Spirorbinae dominated in terms of abundance.

The total number of species per sample was low in both CPA and SM sites and serpulins were always poorly diversified. Janua (Dexiospira) pagenstecheri was the most frequent (found in all samples) and abundant spirorbin species, often represented by hundreds of specimens.

Serpulins colonized a few algal species, preferring the largest, most robust and persistent substrata, such as coralline thalli, whereas spirobins usually clustered on soft algae. Spirorbins were mostly located on the upward-facing sides of laminar fronds of Padina pavonica. They also occurred on the coralline algae Ellisolandia elongata and Jania adhaerens, as well as on the brown alga Halopteris scoparia, whose thin branches were preferentially colonised by juveniles. In samples where a double-layered algal mat was developed, specimens of Janua (Dexiospira) pagenstecheri colonising the upper layer formed tubes with particularly elongated, helical, erect distal portions.

The number of specimens showed no significant differences between CPA and SM samples, but it was decidedly higher in February and June (surveys 1, 3 and 4) than in October in both sites, although the number of species was comparable. This temporary increase is mainly due to Janua (Dexiospira) pagenstecheri, which occurred with numerous specimens, mostly juveniles. Shannon-Weaver diversity seemed not related with either site or sampling period; in some instances, it was not calculated due to the occurrence of monotypic assemblages.

Molluscs

Samples from CPA and SM stations yielded 60 mollusc species, 51 of which represented by live specimens.
Table 2. List of Foraminifera species found in the examined algal community, within the Ciclopi Islands area. The number of specimens found for each species in individual surveys is given. CPA: Punta Aguzza; SM: Santa Maria La Scala; Fr: frequency, i.e. the number of surveys out of the total in which the species has been found. 1, 2, 3, 4, and 5 refer to sampling surveys.

| Foraminifera                | CPA | CPA | SM | SM | Total |
|-----------------------------|-----|-----|----|----|-------|
|                             | Surveys | 1 | 2 | 3 | 4 | 5 | Fr | 1 | 2 | 3 | 4 | 5 | Fr | Fr |
| Planorbulina mediterranensis d’Orbigny, 1826 | 12 | 9 | 8 | 4 | 16 | 5 | 4 | 12 | 4 | 2 | 4 | 5 | 10 |
| Planorbulina variabilis (d’Orbigny, 1826) | 5 | 3 | - | - | - | 2 | 3 | - | - | - | - | - | 1 | 3 |
| Asterigerinata mammila (Williamson, 1858) | 16 | 12 | 9 | - | - | 3 | 19 | 7 | 9 | - | 3 | 6 |
| Cibicides refugens (de Montfort, 1808) | - | 3 | 5 | 9 | - | 3 | - | 4 | 5 | - | - | 2 | 5 |
| Discorbina planorbis (d’Orbigny, 1846) | 3 | 1 | - | - | - | 2 | - | - | - | - | - | - | 2 |
| Discorbis bulbosus Parker, 1954 | - | - | 2 | - | 1 | - | - | - | - | - | - | - | 1 |
| Eponides concameratus (Williamson, 1858) | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Rosalina sp. | 7 | 6 | - | 4 | - | 3 | 8 | - | 4 | 8 | - | 3 | 6 |
| Elphidium aculeatum (d’Orbigny, 1846) | 15 | 11 | 4 | 1 | 1 | 5 | 13 | - | 7 | - | 2 | 7 |
| Elphidium adventum (Cushman, 1922) | 3 | 1 | 7 | 1 | 1 | 5 | 7 | 1 | 11 | - | - | 3 | 8 |
| Elphidium complanatum (d’Orbigny, 1839) | 5 | - | - | - | - | 1 | - | - | - | - | - | - | 1 |
| Elphidium crispum (Linnaeus, 1758) | 13 | 8 | 4 | - | - | 7 | 1 | - | - | - | - | - | - |
| Elphidium depressulum Cushman, 1933 | - | - | 3 | 2 | - | 2 | - | - | - | - | - | - | 2 |
| Elphidium macellum (Fichtel & Moll, 1798) | - | - | 3 | - | 1 | - | - | 7 | - | - | 1 | 2 |
| Elphidium sp. | 12 | 12 | - | 11 | 1 | 4 | 7 | - | 3 | 1 | 3 | 7 |
| Adelosina dubia (d’Orbigny, 1826) | - | - | - | 1 | - | 1 | - | - | - | - | - | - |
| Lachnellana variolata (d’Orbigny, 1826) | 2 | 3 | 3 | 1 | 11 | 5 | - | - | - | - | - | - |
| Triloculina dilatata (d’Orbigny, 1839) | - | - | - | - | - | - | - | - | - | 3 | 1 | 1 |
| Flintinoides labiosa (d’Orbigny, 1826) | 13 | 9 | - | - | - | 4 | 2 | - | 1 | 1 | 2 | 4 |
| Mililiolina subrotunda (Montagu, 1803) | - | - | - | 3 | 1 | 1 | 6 | 1 | - | - | 7 | 3 | 4 |
| Mililiolina sp. | - | - | - | - | - | - | - | 11 | - | - | - | - | - |
| Triloculina oblonga (Montagu, 1803) | - | - | 1 | - | 1 | - | - | - | - | - | - | - |
| Pseudotriloculina rotunda (Schlumberger, 1893) | 15 | 8 | - | 9 | 3 | 4 | 10 | - | 3 | 3 | - | 3 | 7 |
| Pseudotriloculina sp. | - | - | - | 2 | 3 | 2 | - | - | - | - | 2 | 1 | 3 |
| Pyrgo mutabilis (Martinotti, 1921) | 1 | 1 | - | - | - | 2 | - | - | - | - | - | - | 2 |
| Pyrgo sp. | - | - | - | - | - | 1 | - | - | 1 | - | - | 1 |
| Quinqueloculina annectens (Schlumberger, 1893) | 2 | 1 | 1 | 1 | 1 | 5 | - | - | - | - | - | - |
| Quinqueloculina auberiana d’Orbigny, 1839 | 3 | 1 | 5 | 10 | 11 | 5 | 6 | 3 | 1 | 2 | 1 | 5 | 10 |
| Quinqueloculina bradyana Cushman, 1917 | - | - | - | - | - | 1 | - | - | - | - | - | - | 1 |
| Quinqueloculina laevigata d’Orbigny, 1839 | 3 | 1 | 5 | 3 | - | 2 | - | - | - | - | - | - |
| Quinqueloculina limatula Cushman, 1876 | - | - | - | 3 | 1 | 12 | - | 1 | - | 2 | 3 |
| Quinqueloculina limbatula d’Orbigny, 1826 | - | - | 3 | 2 | - | 1 | - | - | 1 | - | 1 |
| Quinqueloculina parvula Schlumberger, 1894 | - | - | 1 | 1 | 1 | 3 | - | - | - | - | - | - |
| Quinqueloculina seminula (Linnaeus, 1758) | 5 | 4 | 1 | 1 | 1 | 4 | 4 | - | - | - | 1 | 5 |
| Quinqueloculina vulgaris d’Orbigny, 1826 | 3 | 2 | - | 11 | 8 | 4 | - | - | - | - | - | 4 |
| Quinqueloculina spp. | - | - | - | 3 | 4 | 2 | - | - | - | - | - | 1 | 3 |
| Spirulina ornata d’Orbigny, 1839 | - | - | 3 | 4 | 2 | - | - | - | - | - | - | - |
| Textularia bocci Höglund, 1947 | - | - | - | - | - | 1 | - | - | - | - | - | - | - |
| Triloculina oblonga (Montagu, 1803) | - | - | - | 3 | 1 | - | - | 1 | - | - | 1 |
| Triloculina tricarinata d’Orbigny, 1826 | - | - | 3 | - | 1 | - | - | - | - | - | - |
| Triloculina trigonula (Lamarck, 1804) | 10 | 7 | 3 | 2 | 9 | - | 1 | - | 2 | 4 |
| Vertebratulina striata Cushman, 1917 | 3 | 1 | 4 | 11 | 4 | 20 | - | 18 | 2 | 6 |
| Laevipeneroplis karreri Wiesner, 1923 | - | - | - | 3 | 1 | - | - | - | - | - | - | - |
| Peneroplis planatus (Fichtel & Moll, 1798) | 15 | 11 | 7 | 15 | 21 | 5 | - | - | - | - | - | - | 5 |
| Total specimens | 151 | 97 | 85 | 108 | 112 | 137 | 43 | 52 | 44 | 41 |
| Total species | 21 | 19 | 20 | 26 | 20 | 17 | 8 | 13 | 11 | 9 |

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Table 3. List of animal species (serpulids, molluscs, bryozoans and ostracods) found in the examined algal community, within the Ciclopi Islands area. The number of specimens found for each species in individual surveys is given. CPA: Punta Aguzza; SM: Santa Maria La Scala; Fr: frequency, i.e. the number of surveys out of the total in which the species has been found. Juveniles in brackets.

| Species | CPA Surveys | SM Surveys | Fr | Total |
|---------|-------------|------------|----|-------|
| Serpulidae | | | | |
| Serpula vermicularis Linnaeus, 1767 | - - (1) (2) - 2 - - - - - - - - - 2 | | | |
| Serpula concharum Langerhans, 1880 | - 2 - - - - 1 - - - 5(3) 1 2 | | | |
| Hydrodoidae elegans (Haswell, 1883) | - 5 2 - 2 3 - 2 - - - 1 4 | | | |
| Hydrodoidae pseud. pseudouncinatus Zibrowius, 1971 | - - - - - 3 1 - - - - - - - 1 | | | |
| Hydrodoidae stoichadon Zibrowius, 1971 | - - - - 1 - - - - - - - - - 1 | | | |
| Vermiliopsis striaticeps (Grübe, 1872) | - - - - - 1 - - - - - - - - 1 | | | |
| Vermiliopsis infundibulum (Philippi, 1844) | - - - - - - - - - - - - - 1 | | | |
| Spirobranchus polytrema (Philippi, 1844) | 5 - - - 2 5 2 2 - - - 7 2 4 | | | |
| Josephella marenzelleri Caullery & Mesnil, 1856 | 2 - - - 1 6 1 - 3 - - - 2 2 | | | |
| Filograna cf. impexa Berkeley, 1827 | - - - - - 3 6 - - - 2 2 | | | |
| Spirobranchinae | | | | |
| Pileolaria militaris Claparède, 1870 | - 2 - 6 - 2 - - - - - - - 2 | | | |
| Simplaria pseudomilitaris (Thiriot -Quiévreux, 1965) | 3 - - - - 1 5 - - - - - 1 2 | | | |
| Janua (Dexiospira) pagenstecheri (Quatrefages, 1866) | 90 45 (10) 321 (95) 8(3) 5 20 10 40 900 (600) 40(5) 5 10 | | | |
| Neodexiospira pseudocorrugata (Bush, 1904) | 8 - - - - 1 - - - - - - - 1 | | | |
| Total specimens | 108 10 50 329 20 38 20 40 900 53 | | | |
| Total species | 5 4 5 3 5 5 4 1 1 4 | | | |
| Mollusca | | | | |
| Bivalvia | | | | |
| Afrocardium richardi (Audouin, 1826) | 1 1 - - - 2 - 8 - - - - - 1 3 | | | |
| Anomia ephippium Linnaeus, 1758 | - - - - 1 1 - - - - - - - 1 | | | |
| Arca noae Linnaeus, 1758 | 2 1 1 2 1 5 1 6 1 3 - 4 9 | | | |
| Barbatia barbata (Linnaeus, 1758) | - - - - - 1 1 - - - - - - - 1 | | | |
| Cardita calyculata (Linnaeus, 1758) | 1 - - - - 1 2 5 - - - - - 1 2 | | | |
| Chama glyptoides Linnaeus, 1758 | - 1 1 - - - 2 - - - - - - - - 2 | | | |
| Flexopecten hyalinus (Poli, 1795) | 1 - - - - 1 - - - - - - - - - 1 | | | |
| Hiatella arctica (Linnaeus, 1767) | 1 2 - 1 - 3 - 1 - 11 1 3 6 | | | |
| Iris irus (Linnaeus, 1758) | - - - - - - - - - - - - 1 - 1 1 | | | |
| Lasaea rubra (Montagu, 1803) | - - - - - - - - - - - - 1 - 1 1 | | | |
| Limaria loscombi (G. B. Sowerby I, 1823) | - 1 - - - - 1 4 - 2 1 3 4 | | | |
| Modiolus barbatus (Linnaeus, 1758) | - - - - - - - - - - - - 1 2 2 | | | |
| Modiolus sp. | 2 - 2 - - 2 1 6 - - - - - 2 4 | | | |
| Musculus costulatus (Risso, 1826) | 1 2 - 5 - 3 - 6 2 8 4 4 7 | | | |
| Ostreidae sp. | - 1 - - - - - - - - - - - - - 1 | | | |
| Pinctada imbricata radiata (Leach, 1814) | - - 1 - - - 1 - - - 1 - 1 2 | | | |
| Pseudochama glyptina (Lamarck, 1819) | 1 - - - - 1 - - - 2 - - 1 2 | | | |
| Roccellaria dubia (Pennant, 1777) | - - - - - - 1 - - - - - - - 1 | | | |
| Striarca lactea (Linnaeus, 1758) | - - 2 - 2 1 1 - - - - - 2 3 | | | |
| Gastropoda | | | | |
| Alvania cf. clathrella L. Seguenza, 1903 | - - - - - - - - - - - 1 - 1 | | | |
| Alvania dictyophora (Philippi, 1844) | - 1 1 - - 2 - 1 - 1 - 2 1 | | | |
| continued | | | | |
| Surveys | CPA | CPA | SM | SM | Total |
|---------|-----|-----|----|----|-------|
|         | 1   | 2   | 3  | 4  | 5    | Fr | 1  | 2  | 3  | 4  | 5    | Fr | Fr |
| Alvania dorbignyi (Audouin, 1826) | -   | -   | -  | -  | -    | 1  | -  | -  | -  | -  | 1    | 1  | 1  |
| Aplysidae sp. | -   | -   | 1  | 1  | -    | 2  | -  | 3  | 1  | -  | -    | 2  | 4  |
| Barleia unifasciata (Montagu, 1803) | 2   | -   | -  | 1  | 2    | 5  | 4  | -  | -  | 3  | 4    | 6  |
| Bittium latreillii (P Gayr. de la B.) | 36  | 4   | 1  | 3  | 5    | -  | 20 | -  | 8  | 2  | 7    |    |
| Bittium reticulatum (da Costa, 1778) | 7   | -   | 1  | -  | 2    | -  | 3  | 1  | -  | 2  | 4    |    |
| Bulla striata Bruguère, 1792 | -   | -   | -  | -  | -    | 1  | -  | -  | -  | -  | 1    |    |
| Cerithium renovatum Moner. (1884) | 1   | -   | 1  | 3  | 1    | 2  | -  | 1  | -  | 3  | 6    |    |
| Columbella rustica (Linnaeus, 1758) | -   | -   | 2  | -  | I    | -  | 1  | -  | 2  | -  | 2    | 3  |
| Conus ventricosus Gmelin, 1791 | -   | -   | -  | -  | -    | -  | -  | -  | -  | -  | 1    | 2  |
| Crepidula fornicta (Linnaeus, 1758) | -   | -   | -  | -  | -    | -  | -  | 1  | -  | -  | 1    | 1  |
| Crisella semistriata (Montagu, 1808) | -   | -   | -  | 1  | -    | -  | -  | -  | -  | -  | 1    |    |
| Euthria cornea (Linnaeus, 1758) | -   | -   | -  | -  | -    | 1  | -  | -  | -  | -  | 1    | 2  |
| Fusinus sp. | -   | -   | -  | -  | -    | -  | -  | -  | -  | -  | 1    | 1  |
| Haminorea sp. | -   | -   | 4  | -  | 1    | -  | 1  | -  | 2  | -  | 2    | 3  |
| Mangelia tenuata (Deshayes, 1835) | -   | -   | -  | -  | -    | -  | -  | -  | -  | -  | 1    | 1  |
| Mitrella gervillii (P Gayr. de la B.) | -   | -   | 3  | -  | I    | -  | 1  | -  | 2  | -  | 3    |    |
| Philine catena (Montagu, 1803) | 1   | -   | -  | 1  | 2    | -  | -  | -  | 1  | -  | 3    | 1  |
| Pisina glabrata (Megerle von Mülfeld, 1824) | -   | 1   | -  | -  | -    | -  | -  | -  | -  | 1    |    |
| Pusia savignyi (Payr. de la B.) | -   | -   | 1  | -  | I    | -  | -  | -  | -  | -  | 1    |    |
| Pusia tricolor (Payr. de la B.) | -   | -   | -  | -  | -    | -  | -  | -  | -  | -  | 1    |    |
| Scissurella costata d'Orbigny, 1824 | 1   | -   | -  | 1  | 2    | -  | -  | -  | -  | -  | 2    | 3  |
| Sinezona cingulata (O. G. Costa, 1861) | 2   | 1   | -  | -  | -    | -  | -  | -  | -  | -  | 1    | 2  |
| Thylacodes arenarius (Linnaeus, 1758) | -   | 1   | -  | -  | -    | -  | -  | -  | -  | -  | 1    | 2  |
| Tritia caviieri (Payr. de la B.) | -   | -   | 1  | -  | I    | -  | -  | -  | -  | -  | 1    | 2  |
| Trophonopsis ? sp. | -   | -   | -  | -  | -    | -  | 1  | -  | 1  | -  | 1    | 1  |
| Vitreolina incurva (Bucquoy et al., 1883) | -   | -   | 1  | -  | I    | -  | 1  | -  | 1  | -  | 1    | 2  |
| Williamia gussoni (Costa O. G., 1829) | -   | 1   | -  | -  | I    | -  | 1  | 2  | 1  | 1  | 3    | 4  |
| Polyplacophora | ? Acanthochitona crinita (Pennant, 1777) | -   | -   | -  | -  | -    | -  | -  | -  | -  | -  | 1    |    |
| Polycladophora sp. | -   | -   | -  | 1  | -    | -  | -  | -  | -  | -  | 1    |    |
| total specimens | 20  | 58  | 14 | 25 | 12   | 8  | 14 | 33 | 24 |
| total species | 13  | 14  | 9  | 14 | 9    | 7  | 9  | 12 | 11 |

**Bryozoa**

**Cyclostomatida**

? Annectocyma mayor (Johnston, 1847) | -   | 1   | -  | -  | -    | -  | -  | -  | -  | -  | -    | 1  |
| Crisia fistulosa Heller, 1867 | -   | -   | 6  | -  | I    | -  | -  | -  | -  | -  | -    | 1  |
| ? Crisia pyrula Harmelin, 1990 | -   | -   | 3  | 1  | 2    | 40  | 21 | 3  | 5  | 7    | 4    |
| Crisia ramosa Harmer, 1891 | 4   | -   | -  | -  | -    | 1  | 4  | -  | 2  | -  | 3    | 4  |
| Filicrisia geniculata (Milne-Edwards, 1838) | 19  | 1   | 1  | 5  | 4    | 60  | 9  | 41 | -  | 4    | 8    |
| Patinella radiata (Audouin, 1826) | 4   | 1   | 7  | 5  | 2    | 5  | 154 | 54 | 49 | 22 | 5    | 10   |

**Ctenostomatida**

Pherusella tubulosa (Ellis & Solander, 1786) | -   | -   | -  | -  | -    | -  | -  | -  | -  | -  | -    | 1  |
| Amathia delicatula Souto et al., 2010 | 5   | 6   | 16 | 3  | 4    | 6  | 8  | 8  | 18 | 5    | 9    |
| Walkeria tuberosa (Heller, 1867) | -   | -   | 2  | -  | I    | -  | -  | -  | -  | -  | 1    |    |

**Cheilostomatida**

Aetea anguina (Linnaeus, 1758) | -   | -   | -  | -  | -    | 6  | -  | -  | -  | -  | -    | 2  |
| Aetea truncata (Landsborough, 1852) | 1   | 1   | 1  | -  | -    | 3  | -  | -  | -  | -  | -    | 3  |
| Bugulidae sp. | -   | -   | -  | -  | -    | -  | -  | -  | -  | -  | 1    | 1  |
| Beania hirtissima (Heller, 1867) | 4   | 2   | 19 | 3  | 1    | 5  | -  | 1  | -  | 1    | 6    |
| Beania mirabilis Johnston, 1840 | 2   | -   | -  | -  | I    | -  | -  | -  | -  | -  | 1    |    |
| Collarina sp. | -   | -   | -  | -  | 4    | 4  | -  | -  | -  | 2    | 2    |
Table 3 continued

| Surveys | CPA   | CPA   | SM    | SM    | Total |
|---------|-------|-------|-------|-------|-------|
|         | 1     | 2     | 3     | 4     | 5     | Fr   | 1     | 2     | 3     | 4     | 5     | Fr   |
| ...     |       |       |       |       |       |      |       |       |       |       |       |      |

Ostracoda

| Species                        | CPA | CPA | SM  | SM  | Total |
|--------------------------------|-----|-----|-----|-----|-------|
| Aurila convexa (Baird, 1850)   | 10  | 3   | 21  | 3   | 4     |
| Aurila gr. punctata (Muenster, 1830) | 5   | -   | -   | 8   | 2     | 4     |
| Aurila prasina Barbeito-Gonzalez, 1971 | -   | -   | -   | 4   | 15    | 2     | 5     | 1     |
| Bairdia longevasinata (Müller, 1894) | -   | 3   | -   | -   | 1     | -     | -     | -     | 1     |
| Bairdia mediterranea (Müller, 1894) | 10  | 6   | 4   | 18  | 4     | 9     | 21    | 8     | 8     | 5     | 9     |
| Callistocythere sp.             | -   | -   | -   | -   | -     | -     | -     | -     | -     | -     | -     | -     |
| Loxoconcha bairdi Müller, 1912  | 10  | -   | 25  | 3   | 14    | 4     | 14    | 6     | 4     | 3     | 7     |
| Loxoconcha stellifera (Müller, 1894) | -   | -   | -   | 18  | 8     | 2     | -     | -     | -     | -     | -     | 2     |
| Paradoxostoma atrum (Müller, 1894) | 5   | -   | -   | 11  | -     | 2     | 5     | -     | -     | -     | -     | 2     |
| Paradoxostoma simile (Müller, 1894) | 5   | -   | -   | 17  | -     | 2     | -     | 12    | 3     | 9     | 3     | 5     |
| Propontocypris pirifera (Müller, 1894) | 10  | 14  | -   | -   | 10    | 3     | -     | 16    | 15    | 14    | 4     | 7     |
| Xestoleberis dispar (Müller, 1894) | 20  | 8   | 11  | 13  | 16    | 5     | 14    | 5     | 28    | 9     | 4     | 9     |
| Total specimens                 | 75  | 31  | 64  | 69  | 89    | 28    | 77    | 69    | 50    |       |       |       |
| Total species                   | 8   | 4   | 5   | 7   | 7     | 3     | 6     | 7     | 6     |       |       |       |

Bryozoans

Bryozoans occurred in CPA and SM stations with 15 and 14 species respectively, accounting for a total of 22 species, including 6 shared ones (Table 3, Fig. 5). Cheilostomes (13 spp.) prevailed, followed by cyclostomes (6 spp.) and ctenostomes (3 spp.). However, cyclostomes dominated for colony number and included some of the most frequent species such as the lichenoporid *Patinella radiata* and the crisisid *Filocrisia geniculata* and *Crisia* cf. *pyrula*. The only frequent and common ctenostome was *Amathia delicatula*. In contrast, all cheilostome species were occasional and rare. Species richness per sample was considerably low, ranging from 5 to 9 species (total range 3-11).

CPA samples were very poor in bryozoans (8-39 colonies) in relation to the SM ones (27-281 colonies). Samples collected in October delivered few colonies in relation to those collected in June and February, although they were not necessarily poorer in species number. Shannon-Weaver diversity was quite homogeneous among sites and periods (1.3-1.8) with the only exception of SM5 sample (0.9).

Bryozoans often clustered on a few thalli and usual-
ly colonised *Ellisolandia elongata* (especially basal articles) and subordinately *Halopteris scoparia* and *Jania adhaerens*. Few bryozoan species occurred in the algal mat, exhibiting a certain zonation, with *Filicrisia geniculata* essentially restricted to the upper layer and *Patinella radiata* and *Crisia* spp. to the lower one, whereas *Amathia delicatula* was present everywhere (Fig. 4).

### Ostracods

A total of 12 ostracod species were identified (Table 3, Fig. 5), with 8 species shared by both stations. Species richness was comparable between CPA (11 spp.) and SM (9 spp.) stations. The number of species per sample ranged from 3 to 8 with slightly higher values for CPA than for SM samples, that were sometimes lacking in ostracods. Analogously, the number of specimens was slightly higher in CPA samples. Juveniles were always abundant.

*Xestoleberis dispar* and *Bairdia mediterranea* were the most abundant and frequent species, followed by *Loxoconcha bairdi* and *Propontocypris pirifera*. Shannon-Weaver diversity showed no clear seasonal trend; it was higher in CPA than in SM, except for assemblages sampled in February 2016.

### Community patterns

Both cluster and MDS analyses clearly separated CPA and SM samples at a Bray-Curtis similarity level slightly exceeding 40% (Fig. 6). Conversely, no seasonal grouping was noted because only SM1 (June 2015) and SM4 (June 2016) were linked at about 55% BC for the entire biota. Only serpulids (Fig. 7) showed a clear seasonal pattern, with several samples paired at 60-70% BC. The average similarity between CPA samples was 49.45%; major contributors were the alga *Halopteris scoparia* (4.8%), the serpulid *Janua (Dexiospira) pagenstecheri* (4.19%), the ostracod *Xestoleberis dispar* (4%) and the foraminifer *Peneroplis planatus* (3.96%). The average similarity between SM samples was 50.3%; major contributors were the algae *Jania rubens* (7.3%) and *Halopteris scoparia* (7.23%), and the bryozoan *Patinella radiata* (7.08%). *Janua (Dexiospira) pagenstecheri* stands as the major cause of the dissimilarity between the two sites (4.55%). The ANOSIM test returned a global $R=0.632$ (significance 0.8%), confirming a good separation between the two stations.

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*Fig. 5: Histograms illustrating species richness (A) and specimen abundance (B) for all investigated taxonomic groups from the examined algal community in the whole area (TOT) and in individual sampling stations (CPA, SM). Relationships between low-rank taxonomic groups are shown for some taxa. For serpulids: dark and light nuances refer to Serpulinae and Spirobranchinae, respectively; for molluscs, dark, intermediate and light nuances indicate bivalves, gastropods and polyplacophorans, respectively; for bryozoans dark, intermediate and light nuances indicate cyclostomatids, ctenostomatids and cheilostomatids, respectively; TOT: data for the area as a whole; CPA: Punta Aguzza station; SM: Santa Maria La Scala station. Numbers on each column indicate the total number of species (A) and specimens (B) for the entire group (high) and for lower taxonomic groups (below, separated by commas).*
Field observations and sample analysis proved that during 2015-2016 *Cystoseira brachycarpa* was absent in the investigated area, both inside and outside CIM-PA, although it was present in 1994, locally reaching a 100% coverage at a depth of 3 m (Pizzuto, 1999). The vegetation, thus, appears highly altered and remarkably poorer than previously reported. Indeed, comparison with data published by Pizzuto (1999) shows that *Cystoseira brachycarpa*, a species promoting a high structural complexity, has been replaced by morphologically less complex species, such as *Halopteris scoparia*, *Dictyota dichotoma*, *Padina pavonica* and geniculate coralline algae. These species create a structurally less diversified habitat holding lower plant biodiversity (Cormaci et al., 2001; Alongi et al., 2004; Serio et al., 2006; Bedini et al., 2011).

The comparison with algal species (revised according to modern taxonomy and nomenclature) recorded by Pizzuto (1999) in the same seasons, showed a dramatic reduction in the number of species in the area (from 168 to 85) and at each surveyed station (Fig. 3). A dramatic decrease was recorded for both Lachea Island, inside CIM-PA, passing from 148 taxa reported by Pizzuto (1999) to 69 taxa found in the CPA station in present study, and Santa Maria La Scala (outside CIMPA) lowering from 118 to 61 taxa (Fig. 3). A remarkable change is also evident in the floristic composition with a strong decrease of Chlorophyta, presently accounting for 8.2% against 17.3% of the ’90s. Such changes mainly derive from the lack of *Cystoseira brachycarpa*, which affects both the number of microhabitats and the composition of epibionts.

Separation between CPA and SM stations (Fig. 6) is not accounted for by algae (despite slight differences in total species richness), but by some groups of associated organisms and especially foraminifers and ostracods, which are both more abundant in CPA samples. In contrast, bryozoans and subordinately molluscs are more abundant in SM samples.

Although richness and diversity of algal populations are slightly higher in samples collected in February and June relative to those collected in October, seasonal changes in the community are remarkably less evident nowadays than in the past. Indeed, high seasonal variation was previously produced by the relevant loss of fronds of large sized, habitat-structuring algae, particularly of *Cystoseira brachycarpa*, which affected the persistence of epibiont species (Pizzuto, 1998). The present-day absence of this alga is thus responsible not only for the decrease in biodiversity (see above) but also for habitat homogenization at seasonal scale (Bulleri et al., 2002; Thibaut et al., 2015).

However, diversity indexes of serpulids (Fig. 7), and less obviously of bryozoans (that are higher in February and June) point to relatively richer and most diversified communities in these months. This finding is strictly related to the encrusting life habit of these groups that need suitable substratum for their settlement and growth, and are consequently more strictly linked to algal vegetation cycles. The relative scantiness of these encrusting species in autumn could be caused by the loss of algal fronds representing the main colonisable substratum in the investigated stations. In contrast, abundance of specimens, above all in June, appears related to the increase of colonisable algal fronds following algal flourishing. It is worthy of note that some of the highest values were found in samples where the algal mat developed. Some species appeared to be particularly able to colonise microhabitats produced inside turf, some of which preferring the relatively open spaces between *Ellisolithia elongata* basal articles and others the sediment entangled in the upper layer of densely branching articles (Fig. 4). In this respect, the unusually helically coiled long erect portions of *Janua* (Dexiospira) pagenstecheri could be interpreted as a special adaptation of this species to cope with sediment entrapment progressively elevating tubes’ apertures (Fig. 4). The finding of numerous specimens (including many juveniles) of spirorbins and especially of *Janua*

**Discussion**

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(Dexiospira) pagenstecheri, mostly in June, probably results from its life cycle. Bianchi (1979, 1983) and Kupryanova et al. (2001) documented that this species starts to reproduce from late spring and Kus & Kurt-Şahin (2016) reported high densities of recruits in Cystoseira communities of the Black Sea in summer.

It is worthy of note that both bryozoans and serpulids were essentially associated with those algae (Halopteris scoparia, Padina pavonica and geniculate corallines) which structure the community in the absence of Cystoseira brachycarpa. In fact, parts of their thalli, constitute a persistent portion of the vegetation.

In contrast, all dominant mollusc species, along with several others (e.g. Cardita calyculata, Modiolus barbatus, Pseudochama gryphina, Striarca lactea and Columbella rustica) are known to exploit hard substrata and to be commonly associated with Cystoseira-colonized bottoms (e.g. Milazzo et al., 2000; Chemello & Milazzo, 2002; Pitacco et al., 2014; Piauzzi et al., 2018). Indeed, Piauzzi et al. (2018) found decidedly more diversified molluscs, and especially gastropods, communities in the Cystoseira brachycarpa beds which were analysed from 5 sites (Balearic Islands, Sardinia, Tuscany Archipelago, and coasts of Croatia and Montenegro in the Adriatic Sea) within the Mediterranean Sea. The occurrence of low diversified mollusc associations in the present study points to the ability of the above mentioned species to survive even when the community is altered, after the local disappearance of Cystoseira brachycarpa. However, the relevance of juveniles (202 juveniles out of 305 specimens = 66%) with co-occurring low percentages of adult specimens could mirror the ongoing degradation of the habitat whose resources cannot support mollusc growth to adult stage, and a possible recruitment from neighboring areas.

All foraminifera and most ostracod species have been reported from shallow bottoms colonised by soft algae and/or seagrasses (e.g. Athersuch, 1979; Mateu-Vicens et al., 2010; 2014; Sciuto et al., 2018). Some foraminifers are associated with particular algal species, such as Halopteri scoparia and Padina pavonica, collected at 5-6 m depth, along the shores of the Volcano Island (Southern Tyrrhenian Sea) by Langer (1993). Some ostracods are associated with “filamentous algae” and slender-branched Cystoseira species, as well as “calcareous algae” including Jania rubens (Athersuch, 1979; Sciuto et al., 2018). The scantiness of ostracod populations and the structure of the foraminifer ones point to low algal abundance and an unsuitable environment (see Triantaphyllou et al., 2005). The co-occurrence of phytal and sediment-dwelling species within ostracods fit well with the occurrence of sediment entrapped within the algal mat (see Sciuto et al., 2018).

Data on shallow-water bryozoan populations associated with IA is scant. Present data increase the number of species already known (7 species reported by Campisi, 1973) from the area at collecting depths at the beginning of the ‘70s when Cystoseira communities presumably flourished (see above). However, comparisons are not possible because of different sampling and study approaches. Species richness appears roughly comparable or lower than those reported for algal communities recently collected at comparable depths in other Mediterranean sites where Cystoseira (including C. brachycarpa) occurred (Galluzzo, 1993; Nicoletti et al., 1996; Piauzzi et al., 2018). Piauzzi et al. (2018) found 28 bryozoan taxa (8 to 17 in individual sites) in Cystoseira brachycarpa and/or C. corniculata beds of 5 Mediterranean sites. Higher species richness was reported for Cystoseira brachycarpa beds in the Eolian Islands, with 21 and 22 cheilostome species from Salina and Volcano, respectively, and 9 ad-
ditional cyclostome species from Salina (Galluzzo, 1993; Nicoletti et al., 1996). This points to a significant heterogeneity within geographical localities widely apart and also within sites only a few hundreds metres away (Piazzi et al., 2018). Spatial heterogeneity is also supported by the sharing of a limited number of species (among which Patinella radiata, Haplopora bimicronatum, Aetea spp., Crisia spp., Beania spp.) that are usually generalist and especially adapted to colonise shallow-water habitats. At present knowledge and taking into account that data on bryozoan communities associated with algal turfs is presently unavailable, it is not possible to assess if observed differences fall within the range of variability of bryozoan communities associated with the IA bioecosystem or if they indicate possible long-term fluctuations of bryozoan communities or their deterioration resulting from the decay of the community as a whole.

Comparisons are difficult also for serpulids because data on communities associated with IA are very scant, as well as those on turf-related populations, which have been studied only from deeper habitats (Casoli et al., 2016; Sanfilippo et al., 2017, and references therein). However, diversity of serpulid communities of the CIM-PA stations seem to be comparably high.

The disappearance of the Cystoseira brachycarpa community in the area is probably caused by high increase of water turbidity (and sediment deposition, indicated by silt veneer) and overgrowing by the sea-urchins Paracentrotus lividus and Arbacia lixula. Paracentrotus lividus is known to feed preferentially on Cystoseira spp., while Arbacia lixula grazes on turf and encrusting species, including plantlets, thus preventing new successful settlement (Verlaque & Nedelec, 1983; Verlaque, 1984, 1987; Knoepffler-Peguy et al., 1987; Frantzis et al., 1988; Hereu et al., 2008; Boudouresque & Verlaque, 2013). Both species had high density population in the area in 2000 (Cantone & Beninati, 2004), still increasing in the last decade (MC and DS, personal observations).

At the present state of knowledge and owing to the scantiness of data, it is not possible to assess if the observed status represents a permanent disappearance of Cystoseira brachycarpa. Further studies are needed to understand the ongoing processes, delineate trends, and monitoring local communities over longer time intervals, also including associated organisms for which available information is scant. In this context, the present study provides an important snapshot for future comparisons.

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