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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; Tsiamis *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 & Dulčić, 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 epibionts.

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 San-

filippo *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 northern 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-ethyl 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 GoPro Camera Hero 4.

Identification of algal species was mostly based on diacritic structural and reproductive features observed using stereomicroscope and microscope, following standardised 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 $\geq 1\%$ 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

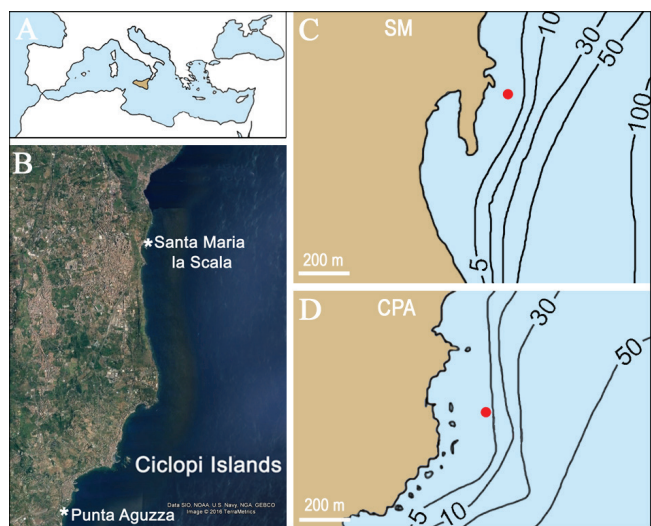


Fig. 1: Location of the sampling area within the Mediterranean (A), and the eastern coast of Sicily (B). C. Santa Maria La Scala. D. Punta Aguzza. Sampling stations are indicated with red dots.

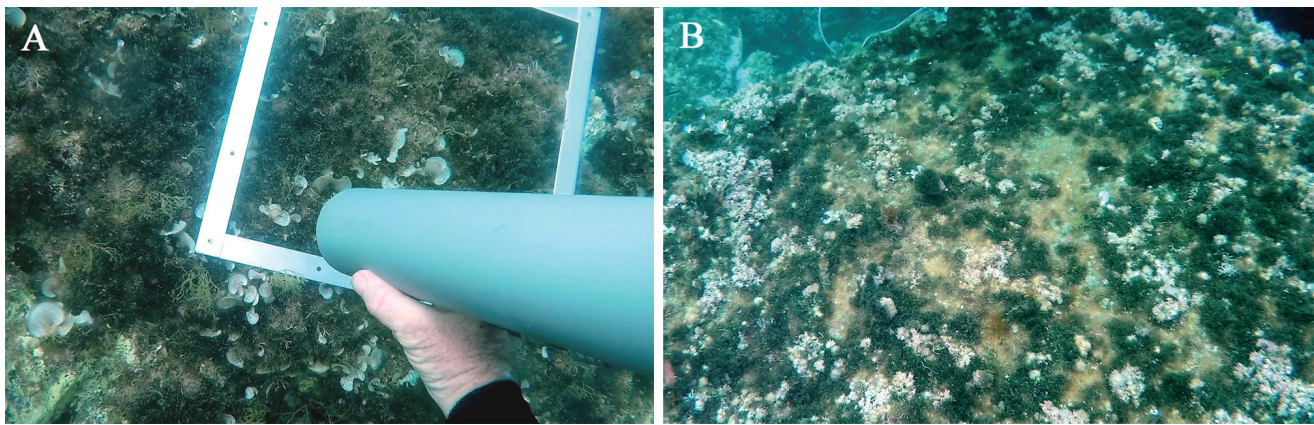


Fig. 2: Underwater images of the sampling stations. A: CPA station; B: SM station, as appeared in June 2015. In A the quadrat frame and the sorbona gear are shown.

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*, *Ellisolandia 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 *Ellisolandia elongata*, topped by a nearly 1 cm thick turf of filamentous soft algae (e.g. *Sphacelaria cirrosa* and *Centroceras clavulatum*) 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.

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

continued

Table 1 continued

| Surveys | CPA | | | | | CPA | | | | | SM | | | | | SM Total | |
|--|-----|----|----|----|----|-----|----|----|----|----|----|----|----|--|--|----------|--|
| | 1 | 2 | 3 | 4 | 5 | Pr | 1 | 2 | 3 | 4 | 5 | Pr | Pr | | | | |
| <i>Hypnea musciformis</i> (Wulfen) J.V. Lamour. | | | + | | | 1 | + | + | + | | | 3 | 4 | | | | |
| <i>Laurencia microcladia</i> Kütz. | | | | + | | 1 | f | | | + | + | 3 | 4 | | | | |
| <i>Lomentaria chylocradiella</i> Funk | + | + | + | | | 3 | | | + | | | 1 | 4 | | | | |
| <i>Lophosiphonia cristata</i> Falkenb. | | + | | | + | 2 | | + | | + | | 2 | 4 | | | | |
| <i>Neogoniolithon brassica-florida</i> (Harv.) Setch. & L.R. Mason | | | | | | 0 | s | | + | + | + | 4 | 4 | | | | |
| <i>Nitophyllum micropunctatum</i> Funk | | | | | | 0 | + | + | + | | + | 4 | 4 | | | | |
| <i>Rhodophyllis divaricata</i> (Stackh.) Papenf. | | | | | | 0 | + | + | + | + | | 4 | 4 | | | | |
| <i>Spyridia filamentosa</i> (Wulfen) Harv. | + | + | | + | + | 4 | | | | | | 0 | 4 | | | | |
| <i>Acrosorium ciliolatum</i> (Harv.) Kylin | | | + | | | 1 | + | | | + | | 2 | 3 | | | | |
| <i>Chylocardia verticillata</i> (Lightf.) Bliding | s | + | | | + | 3 | | | | | | 0 | 3 | | | | |
| <i>Cladophora prolifera</i> (Roth) Kütz. | | + | | | + | 2 | | + | | | | 1 | 3 | | | | |
| <i>Halopteris filicina</i> (Gratel.) Kütz. | | | + | + | | 2 | | | + | | | 1 | 3 | | | | |
| <i>Jania virgata</i> (Zanardini) Mont. | + | + | | + | | 3 | | | | | | 0 | 3 | | | | |
| <i>Nitophyllum punctatum</i> (Stackh.) Grev. | + | + | + | | | 3 | | | | | | 0 | 3 | | | | |
| <i>Peyssonnelia bornetii</i> Boudour. & Denizot | + | | | + | + | 3 | | | | | | 0 | 3 | | | | |
| <i>Pneophyllum fragile</i> Kütz. | | | | | | 0 | + | + | | | + | 3 | 3 | | | | |
| <i>Polysiphonia dichotoma</i> Kütz. | | | m | | | 1 | + | | | | + | 2 | 3 | | | | |
| <i>Stylonema cornu-cervi</i> Reinsch | | | + | + | + | 3 | | | | | | 0 | 3 | | | | |
| <i>Valonia utricularis</i> (Roth) C. Agardh | | + | | + | + | 3 | | | | | | 0 | 3 | | | | |
| <i>Anotrichium tenue</i> (C. Agardh) Nägeli | | | | | | 0 | | | | s | s | 2 | 2 | | | | |
| <i>Ceramium diaphanum</i> (Lightf.) Roth | + | | | | | 1 | m | | | | | 1 | 2 | | | | |
| <i>Chaetomorpha linum</i> (O.F. Müll.) Kütz. | | + | | | + | 2 | | | | | | 0 | 2 | | | | |
| <i>Corallophila cinnabarina</i> (Gratel. ex Bory) R.E. Norris | | | | | | 0 | | | + | + | | 2 | 2 | | | | |
| <i>Dasya ocellata</i> (Gratel.) Harv. | | | + | | | 1 | | | + | | | 1 | 2 | | | | |
| <i>Dictyopteris polypodioides</i> (DC.) J.V. Lamour. | | | | | | 0 | + | | | + | | 2 | 2 | | | | |
| <i>Dictyota mediterranea</i> (Schiffner) G. Furnari | | + | | + | | 2 | | | | | | 0 | 2 | | | | |
| <i>Eupogodon planus</i> (C. Agardh) Kütz. | | | + | | + | 2 | | | | | | 0 | 2 | | | | |
| <i>Laurencia</i> sp. | | | | | | 0 | + | | | | + | 2 | 2 | | | | |
| <i>Laurencia obtusa</i> (Huds.) J.V. Lamour. | | | + | | + | 2 | | | | | | 0 | 2 | | | | |
| <i>Peyssonnelia heteromorpha</i> (Zanardini) Athanasiadis | | | + | + | | 2 | | | | | | 0 | 2 | | | | |
| <i>Wrangelia penicillata</i> (C. Agardh) C. Agardh | + | | | + | | 2 | | | | | | 0 | 2 | | | | |
| <i>Anotrichium barbatum</i> (C. Agardh) Nägeli | | | | | | 0 | | + | | | | 1 | 1 | | | | |
| <i>Chondria dasyphylla</i> (Woodward) C. Agardh | | | | | | 0 | | + | | | | 1 | 1 | | | | |
| <i>Dasya hutchinsiae</i> Harv. | | | | | | 0 | + | | | | | 1 | 1 | | | | |
| <i>Dipterosiphonia rigens</i> (C. Agardh) Falkenb. | + | | | | | 1 | | | | | | 0 | 1 | | | | |
| <i>Discosporangium mesarthrocarpum</i> (Menegh.) Hauck | s | | | | | 1 | | | | | | 0 | 1 | | | | |
| <i>Gelidium minusculum</i> (Weber Bosse) R.E. Norris | | | | | | 0 | | | + | | | 1 | 1 | | | | |
| <i>Halimeda tuna</i> (J. Ellis & Sol.) J.V. Lamour. | | | | | | 0 | | | | | + | 1 | 1 | | | | |
| <i>Lithophyllum pustulatum</i> (J.V. Lamour.) Foslie | | | | s | | 1 | | | | | | 0 | 1 | | | | |
| <i>Microdictyon umbilicatum</i> (Velley) Zanardini | | | | | | 0 | | | + | | | 1 | 1 | | | | |
| <i>Peyssonnelia dubyi</i> P. & H. Crouan | | | | + | | 1 | | | | | | 0 | 1 | | | | |
| <i>Pleonosporium borneri</i> (J.E. Sm.) Nägeli | | | | | | 0 | + | | | | | 1 | 1 | | | | |
| <i>Polysiphonia scopulorum</i> Harv. | | | | + | | 1 | | | | | | 0 | 1 | | | | |
| <i>Spermothamnion repens</i> (Dillwyn) Rosenvinge | + | | | | | 1 | | | | | | 0 | 1 | | | | |
| <i>Sphacelaria plumula</i> Zanardini | | | + | | | 1 | | | | | | 0 | 1 | | | | |
| 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. *Quinqueloculina auferiana* and *Planorbulina mediterraneensis* 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 spirorbins 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

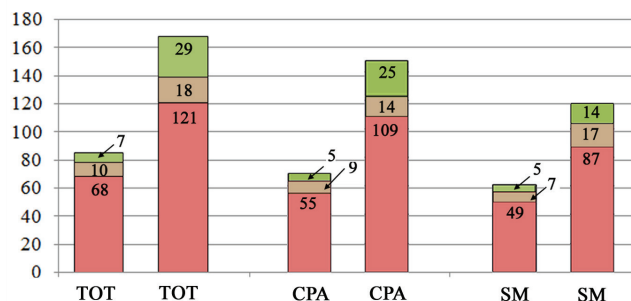


Fig. 3: Floristic richness and relationships between algal taxonomic groups in the examined algal community in the whole study area (TOT) and in individual stations (CPA: Punta Aguzza station; SM: Santa Maria La Scala station). Left columns in each group show present-day situation in comparison with past data (right columns) as reported in Pizzuto (1999). Red: Rhodophyta; brown: Ochrophyta; green: Chlorophyta. Numbers indicate the total number of species for each taxonomic group.

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

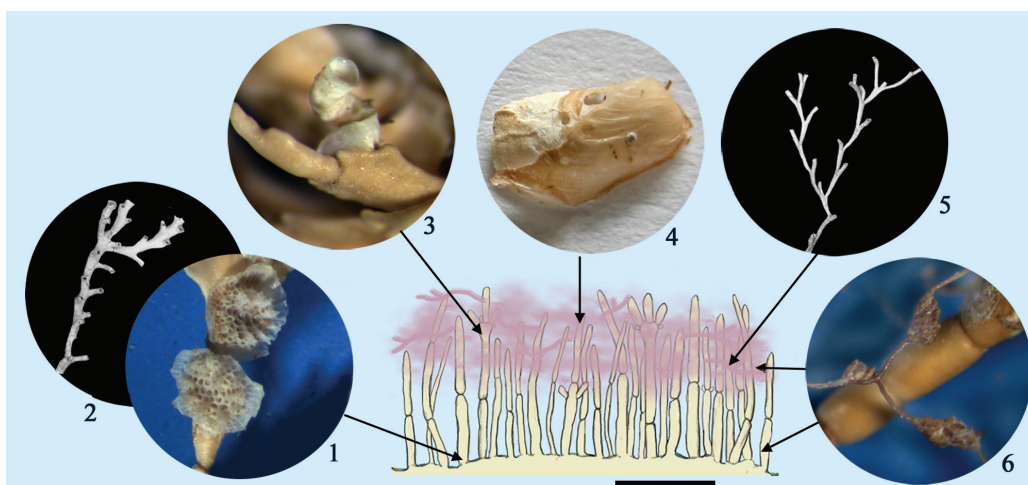


Fig. 4: Double-layered algal mat formed by erect *Ellisolandia elongata* basal portions capped by a thick turf of filamentous soft algae and thin geniculate coralline algae entrapping silt. Few species (depicted in the round inserts) thrive in this algal mat, some showing particular distribution pattern (arrowed) and morphological adaptations. 1: *Patinella radiata*; 2: *Crisia* spp.; 3: *Janua (Dexiospira) pagenstecheri*; 4: *Hyatella arctica*; 5: *Filicrisia geniculata*; 6: *Amathia delicatula*. Scale bar: 1 cm.

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.

| | | CPA | | | | | CPA | | SM | | | | SM | | Total |
|---|---------|-----|----|-----|-----|---|-----|----|----|----|----|---|----|----|-------|
| | Surveys | 1 | 2 | 3 | 4 | 5 | Fr | 1 | 2 | 3 | 4 | 5 | Fr | Fr | |
| Foraminifera | | | | | | | | | | | | | | | |
| <i>Planorbulina mediterranensis</i> d'Orbigny, 1826 | 12 | 9 | 8 | 4 | 16 | 5 | 4 | 12 | 4 | 2 | 4 | 5 | 10 | | |
| <i>Planorbulina variabilis</i> (d'Orbigny, 1826) | 5 | 3 | - | - | - | 2 | 3 | - | - | - | - | 1 | 3 | | |
| <i>Asterigerinata mamilla</i> (Williamson, 1858) | 16 | 12 | 9 | - | - | 3 | 19 | | 7 | 9 | - | 3 | 6 | | |
| <i>Cibicides refulgens</i> (de Montfort, 1808) | - | 3 | 5 | 9 | - | 3 | - | 4 | 5 | - | - | 2 | 5 | | |
| <i>Discorbina planorbis</i> (d'Orbigny, 1846) | 3 | 1 | - | - | - | 2 | - | - | - | - | - | - | 2 | | |
| <i>Discorbis bulbosus</i> Parker, 1954 | - | - | - | 2 | - | 1 | - | - | - | - | - | - | 1 | | |
| <i>Eponides concameratus</i> (Williamson, 1858) | - | - | - | - | - | - | - | - | 1 | - | - | 1 | 1 | | |
| <i>Rosalina</i> sp. | 7 | 6 | - | 4 | - | 3 | 8 | - | 4 | 8 | - | 3 | 6 | | |
| <i>Elphidium aculeatum</i> (d'Orbigny, 1846) | 15 | 11 | 4 | 1 | 1 | 5 | 13 | - | - | 7 | - | 2 | 7 | | |
| <i>Elphidium advenum</i> (Cushman, 1922) | 3 | 1 | 7 | 1 | 1 | 5 | 7 | 1 | 11 | - | - | 3 | 8 | | |
| <i>Elphidium complanatum</i> (d'Orbigny, 1839) | 5 | - | - | - | - | 1 | - | - | - | - | - | - | 1 | | |
| <i>Elphidium crispum</i> (Linnaeus, 1758) | 8 | 5 | 7 | 1 | 1 | 5 | 7 | 1 | 6 | 5 | - | 4 | 9 | | |
| <i>Elphidium depressulum</i> Cushman, 1933 | - | - | 3 | 2 | - | 2 | - | - | - | - | - | - | 2 | | |
| <i>Elphidium macellum</i> (Fichtel & Moll, 1798) | - | - | 3 | - | - | 1 | - | - | 7 | - | - | 1 | 2 | | |
| <i>Elphidium</i> sp. | 12 | 12 | - | 11 | 1 | 4 | 7 | - | - | 3 | 1 | 3 | 7 | | |
| <i>Adelosina dubia</i> (d'Orbigny, 1826) | - | - | - | 1 | - | 1 | - | - | - | - | - | - | 1 | | |
| <i>Lachlanella variolata</i> (d'Orbigny, 1826) | 2 | 3 | 3 | 1 | 11 | 5 | - | - | - | - | - | - | 5 | | |
| <i>Triloculina dilatata</i> (d'Orbigny, 1839) | - | - | - | - | - | - | - | - | - | - | 3 | 1 | 1 | | |
| <i>Flintinoides labiosa</i> (d'Orbigny, 1839) | - | - | 3 | - | 4 | 2 | - | - | 1 | - | 1 | 2 | 4 | | |
| <i>Miliolinella subrotunda</i> (Montagu, 1803) | - | - | - | - | 3 | 1 | 6 | 1 | - | - | 7 | 3 | 4 | | |
| <i>Miliolinella</i> sp. | - | - | - | - | - | - | 11 | - | - | - | - | 1 | 1 | | |
| <i>Triloculina oblonga</i> (Montagu, 1803) | - | - | - | 1 | - | 1 | - | - | - | - | - | - | 1 | | |
| <i>Pseudotriloculina rotunda</i> (Schlumberger, 1893) | 15 | 8 | - | 9 | 3 | 4 | 10 | - | 3 | 3 | - | 3 | 7 | | |
| <i>Pseudotriloculina</i> sp. | - | - | - | 2 | 3 | 2 | - | - | - | - | 2 | 1 | 3 | | |
| <i>Pyrgo mutabilis</i> (Martinotti, 1921) | 1 | 1 | - | - | - | 2 | - | - | - | - | - | - | 2 | | |
| <i>Pyrgo</i> sp. | - | - | - | - | 1 | 1 | - | - | 1 | - | - | 1 | 2 | | |
| <i>Quinqueloculina annectens</i> (Schlumberger, 1893) | 2 | 1 | 1 | 1 | 1 | 5 | - | - | - | - | - | - | 5 | | |
| <i>Quinqueloculina auberiana</i> d'Orbigny, 1839 | 3 | 1 | 5 | 10 | 11 | 5 | 6 | 3 | 1 | 2 | 1 | 5 | 10 | | |
| <i>Quinqueloculina bradyana</i> Cushman, 1917 | - | - | - | - | - | - | 1 | - | - | - | - | 1 | 1 | | |
| <i>Quinqueloculina laevigata</i> d'Orbigny, 1839 | - | - | 5 | 3 | - | 2 | - | - | - | - | - | - | 2 | | |
| <i>Quinqueloculina lamarckiana</i> d'Orbigny, 1839 | 6 | 3 | - | 5 | - | 3 | 10 | - | - | 3 | 3 | 3 | 6 | | |
| <i>Quinqueloculina lata</i> Terquem, 1876 | - | - | - | - | 3 | 1 | 12 | - | - | 1 | - | 2 | 3 | | |
| <i>Quinqueloculina limbata</i> d'Orbigny, 1826 | - | - | 3 | 2 | - | 1 | - | - | 1 | - | - | 1 | 2 | | |
| <i>Quinqueloculina parvula</i> Schlumberger, 1894 | - | - | 1 | 1 | 1 | 3 | - | - | - | - | - | - | 3 | | |
| <i>Quinqueloculina seminula</i> (Linnaeus, 1758) | 5 | 4 | 1 | 1 | - | 4 | 4 | - | - | - | - | 1 | 5 | | |
| <i>Quinqueloculina vulgaris</i> d'Orbigny, 1826 | 3 | 2 | - | 11 | 8 | 4 | - | - | - | - | - | - | 4 | | |
| <i>Quinqueloculina</i> spp. | - | - | - | 3 | 4 | 2 | - | - | - | - | 1 | 1 | 3 | | |
| <i>Spiroloculina ornata</i> d'Orbigny, 1839 | - | - | 3 | - | 4 | 2 | - | - | - | - | - | - | 2 | | |
| <i>Texularia bocki</i> Höglund, 1947 | - | - | - | - | - | - | - | 1 | - | - | - | 1 | 1 | | |
| <i>Triloculina oblonga</i> (Montagu, 1803) | - | - | - | - | 3 | 1 | - | - | - | - | - | - | 1 | | |
| <i>Triloculina tricarinata</i> d'Orbigny, 1826 | - | - | 3 | - | - | 1 | - | - | - | - | - | - | 1 | | |
| <i>Triloculina trigonula</i> (Lamarck, 1804) | 10 | - | - | 3 | - | 2 | 9 | - | - | 1 | - | 2 | 4 | | |
| <i>Vertebralina striata</i> Cushman, 1917 | 3 | - | 4 | 1 | 11 | 4 | - | 20 | - | - | 18 | 2 | 6 | | |
| <i>Laevipeneroplis karreri</i> Wiesner, 1923 | - | - | - | 3 | - | 1 | - | - | - | - | - | - | 1 | | |
| <i>Peneroplis planatus</i> (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 | | | | |

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.

| | CPA | | | | | CPA | SM | | | | | SM | Total |
|---|------------|-----------|------------|-------------|-----------|-----|-----------|-----------|-----------|--------------|-----------|----|-------|
| Surveys | 1 | 2 | 3 | 4 | 5 | Fr | 1 | 2 | 3 | 4 | 5 | Fr | Fr |
| Serpulidae | | | | | | | | | | | | | |
| Serpulinae | | | | | | | | | | | | | |
| <i>Serpula vermicularis</i> Linnaeus, 1767 | - | - | (1) | (2) | - | 2 | - | - | - | - | - | - | 2 |
| <i>Serpula concharum</i> Langerhans, 1880 | - | 2 | - | - | - | 1 | - | - | - | - | 5(3) | 1 | 2 |
| <i>Hydroides elegans</i> (Haswell, 1883) | - | 5 | 2 | - | 2 | 3 | - | 2 | - | - | - | 1 | 4 |
| <i>Hydroides pseud. pseudouncinatus</i> Zibrowius, 1971 | - | - | - | - | 3 | 1 | - | - | - | - | - | - | 1 |
| <i>Hydroides stoichadon</i> Zibrowius, 1971 | - | - | 1 | - | - | 1 | - | - | - | - | - | - | 1 |
| <i>Vermiliopsis striaticeps</i> (Grübe, 1872) | - | - | 1 | - | - | 1 | - | - | - | - | - | - | 1 |
| <i>Vermiliopsis infundibulum</i> (Philippi, 1844) | - | - | - | - | - | - | - | - | - | - | 1 | 1 | 1 |
| <i>Spirobranchus polytrema</i> (Philippi, 1844) | 5 | - | - | - | 2 | 2 | 5 | - | - | - | 7 | 2 | 4 |
| <i>Josephella marenzelleri</i> Caullery & Mesnil, 1856 | 2 | - | - | - | 5 | 2 | 5 | 2 | - | - | - | 2 | 4 |
| <i>Filograna</i> sp. cf. <i>implexa</i> Berkeley, 1827 | - | - | - | - | - | - | 3 | 6 | - | - | - | 2 | 2 |
| Spirorbinae | | | | | | | | | | | | | |
| <i>Pileolaria militaris</i> Claparède, 1870 | - | 2 | - | 6 | - | 2 | - | - | - | - | - | - | 2 |
| <i>Simplaria pseudomilitaris</i> (Thiriot-Quiévreux, 1965) | 3 | - | - | - | - | 1 | 5 | - | - | - | - | 1 | 2 |
| <i>Janua (Dexiospira) pagenstecheri</i> (Quatrefages, 1866) | 90 | 1 | 45 (10) | 321 (95) | 8(3) | 5 | 20 | 10 | 40 | 900 (600) | 40(5) | 5 | 10 |
| <i>Neodexiospira pseudocorrugata</i> (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 | | | | | | | | | | | | | |
| <i>Afrocardium richardi</i> (Audouin, 1826) | 1 | 1 | - | - | - | 2 | - | 8 | - | - | - | 1 | 3 |
| <i>Anomia ephippium</i> Linnaeus, 1758 | - | - | - | - | 1 | 1 | - | - | - | - | - | - | 1 |
| <i>Arca noae</i> Linnaeus, 1758 | 2 | 1 | 1 | 2 | 1 | 5 | 1 | 6 | 1 | 3 | - | 4 | 9 |
| <i>Barbatia barbata</i> (Linnaeus, 1758) | - | - | - | - | 1 | 1 | - | - | - | - | - | - | 1 |
| <i>Cardita calyculata</i> (Linnaeus, 1758) | 1 | - | - | - | - | 1 | 2 | 5 | - | - | 1 | 1 | 2 |
| <i>Chama gryphoides</i> Linnaeus, 1758 | - | 1 | 1 | - | - | 2 | - | - | - | - | - | - | 2 |
| <i>Flexopecten hyalinus</i> (Poli, 1795) | 1 | - | - | - | - | 1 | - | - | - | - | - | - | 1 |
| <i>Hiattella arctica</i> (Linnaeus, 1767) | 1 | 2 | - | 1 | - | 3 | - | 1 | - | 11 | 1 | 3 | 6 |
| <i>Irus irus</i> (Linnaeus, 1758) | - | - | - | - | - | - | - | - | - | 1 | - | 1 | 1 |
| <i>Lasaea rubra</i> (Montagu, 1803) | - | - | - | - | - | - | - | 1 | - | - | - | 1 | 1 |
| <i>Limaria loscombi</i> (G. B. Sowerby I, 1823) | - | 1 | - | - | - | 1 | - | 4 | - | 2 | 1 | 3 | 4 |
| <i>Modiolus barbatus</i> (Linnaeus, 1758) | - | - | - | - | - | - | - | 2 | - | - | 1 | 2 | 2 |
| <i>Modiolus</i> sp. | 2 | - | 2 | - | - | 2 | 1 | 6 | - | - | - | 2 | 4 |
| <i>Musculus costulatus</i> (Risso, 1826) | 1 | 2 | - | 5 | - | 3 | - | 6 | 2 | 8 | 4 | 4 | 7 |
| Ostreidae sp. | - | 1 | - | - | - | 1 | - | - | - | - | - | - | 1 |
| <i>Pinctada imbricata radiata</i> (Leach, 1814) | - | - | 1 | - | - | 1 | - | - | - | - | 1 | 1 | 2 |
| <i>Pseudochama gryphina</i> (Lamarck, 1819) | 1 | - | - | - | - | 1 | - | - | - | 2 | - | 1 | 2 |
| <i>Rocellaria dubia</i> (Pennant, 1777) | - | - | - | - | - | - | - | 1 | - | - | - | 1 | 1 |
| <i>Striarca lactea</i> (Linnaeus, 1758) | - | - | 2 | - | 2 | 1 | 1 | - | - | - | 2 | 2 | 3 |
| Gastropoda | | | | | | | | | | | | | |
| <i>Alvania</i> cf. <i>clathrella</i> L. Seguenza, 1903 | - | - | - | - | - | - | - | 1 | - | - | - | 1 | 1 |
| <i>Alvania dictyophora</i> (Philippi, 1844) | - | 1 | 1 | - | - | 2 | - | 1 | - | 1 | - | 2 | 4 |

continued

Table 3 continued

| | CPA | | | | | CPA | | SM | | | SM | | Total |
|--|-----------|-----------|-----------|-----------|-----------|-----|----------|----|-----------|-----------|-----------|----|-------|
| Surveys | 1 | 2 | 3 | 4 | 5 | Fr | 1 | 2 | 3 | 4 | 5 | Fr | Fr |
| <i>Alvania dorbignyi</i> (Audouin, 1826) | - | - | - | - | - | - | - | 1 | - | - | - | 1 | 1 |
| <i>Aplysiidae</i> sp. | - | - | 1 | 1 | - | 2 | - | 3 | 1 | - | - | 2 | 4 |
| <i>Barleeia unifasciata</i> (Montagu, 1803) | - | 2 | - | - | 1 | 2 | 1 | 5 | 4 | - | 3 | 4 | 6 |
| <i>Bittium latreillii</i> (Payraudeau, 1826) | 5 | 36 | 4 | 1 | 3 | 5 | - | 20 | | - | 8 | 2 | 7 |
| <i>Bittium reticulatum</i> (da Costa, 1778) | - | 7 | - | 1 | - | 2 | - | 3 | 1 | - | - | 2 | 4 |
| <i>Bulla striata</i> Bruguière, 1792 | - | - | - | - | - | - | - | 1 | - | - | - | 1 | 1 |
| <i>Cerithium renovatum</i> Monterosato, 1884 | 1 | 1 | - | - | 1 | 3 | 1 | 2 | - | 1 | - | 3 | 6 |
| <i>Columbella rustica</i> (Linnaeus, 1758) | - | - | - | 2 | - | 1 | - | | 1 | - | - | 2 | 3 |
| <i>Conus ventricosus</i> Gmelin, 1791 | - | - | - | - | - | - | - | | - | - | - | 1 | 1 |
| <i>Crepidula fornicata</i> (Linnaeus, 1758) | - | - | - | - | - | - | - | | - | - | - | 1 | 1 |
| <i>Crisilla semistriata</i> (Montagu, 1808) | - | - | - | 1 | - | 1 | - | | - | - | - | - | 1 |
| <i>Euthria cornea</i> (Linnaeus, 1758) | - | - | - | - | - | - | 1 | | - | - | - | 1 | 1 |
| <i>Fusinus</i> sp. | - | - | - | - | - | - | - | | - | - | - | 1 | 1 |
| <i>Haminoea</i> sp. | - | - | - | 4 | - | 1 | - | | 1 | - | - | 2 | 3 |
| <i>Mangelia taeniata</i> (Deshayes, 1835) | - | - | - | - | - | - | - | | - | - | - | 1 | 1 |
| <i>Mitrella gervillii</i> (Payraudeau, 1826) | - | - | - | 3 | - | 1 | - | | 1 | - | - | 2 | 3 |
| <i>Philine catena</i> (Montagu, 1803) | 1 | - | - | 1 | - | 2 | - | | - | - | - | 1 | 3 |
| <i>Pisinna glabrata</i> (Megerle von Mühlfeld, 1824) | - | 1 | - | - | - | 1 | - | | - | - | - | - | 1 |
| <i>Pusia savignyi</i> (Payraudeau, 1826) | - | - | - | 1 | - | 1 | - | | - | - | - | - | 1 |
| <i>Pusia tricolor</i> (Gmelin, 1791) | - | - | - | - | - | - | - | | - | 1 | 1 | 2 | 2 |
| <i>Scissurella costata</i> d'Orbigny, 1824 | 1 | - | - | - | 1 | 2 | - | | - | - | - | - | 2 |
| <i>Sinezona cingulata</i> (O. G. Costa, 1861) | 2 | - | - | - | - | 1 | - | | - | - | - | 1 | 2 |
| <i>Thylacodes arenarius</i> (Linnaeus, 1758) | - | 1 | - | - | - | 1 | - | | - | - | - | - | 1 |
| <i>Tritia cuvierii</i> (Payraudeau, 1826) | - | - | - | 1 | - | 1 | - | | - | - | - | 1 | 2 |
| <i>Trophonopsis</i> ? sp. | - | - | - | - | - | - | - | | - | 1 | - | 1 | 1 |
| <i>Vitreolina incurva</i> (Bucquoy <i>et al.</i> , 1883) | - | - | - | 1 | - | 1 | - | | - | 1 | - | 1 | 2 |
| <i>Williamia gussoni</i> (Costa O. G., 1829) | - | - | 1 | - | - | 1 | - | | 2 | 1 | 1 | 3 | 4 |
| Polyplacophora | | | | | | | | | | | | | |
| ? <i>Acanthochitona crinita</i> (Pennant, 1777) | - | - | - | - | - | - | - | | - | - | - | 1 | 1 |
| Polyplacophora sp. | - | - | - | - | 1 | 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 | | | | | | | | | | | | | |
| ? <i>Annectocyma mayor</i> (Johnston, 1847) | - | 1 | - | - | - | 1 | - | | - | - | - | - | 1 |
| <i>Crisia fistulosa</i> Heller, 1867 | - | - | - | 6 | - | 1 | - | | - | - | - | - | 1 |
| ? <i>Crisia pyrula</i> Harmelin, 1990 | - | - | 3 | 1 | - | 2 | 40 | | 21 | 3 | 5 | 5 | 7 |
| <i>Crisia ramosa</i> Harmer, 1891 | 4 | - | - | - | - | 1 | 4 | | - | 2 | - | 3 | 4 |
| <i>Filicrisia geniculata</i> (Milne-Edwards, 1838) | 19 | 1 | 1 | 5 | | 4 | 60 | | 9 | 41 | - | 4 | 8 |
| <i>Patinella radiata</i> (Audouin, 1826) | 4 | 1 | 7 | 5 | 2 | 5 | 154 | | 54 | 49 | 22 | 5 | 10 |
| Ctenostomatida | | | | | | | | | | | | | |
| <i>Pherusella tubulosa</i> (Ellis & Solander, 1786) | - | - | - | - | - | - | - | | 4 | 1 | - | 2 | 2 |
| <i>Amathia delicatula</i> Souto <i>et al.</i> , 2010 | - | 5 | 6 | 16 | 3 | 4 | 6 | | 8 | 8 | 18 | 5 | 9 |
| <i>Walkeria tuberosa</i> (Heller, 1867) | - | - | - | 2 | - | 1 | - | | - | - | - | - | 1 |
| Cheilostomatida | | | | | | | | | | | | | |
| <i>Aetea anguina</i> (Linnaeus, 1758) | - | - | - | - | - | - | 6 | | 1 | - | - | 2 | 2 |
| <i>Aetea truncata</i> (Landsborough, 1852) | 1 | 1 | 1 | - | - | 3 | - | | - | - | - | - | 3 |
| Bugulidae sp. | - | - | - | - | - | - | - | | - | - | - | 1 | 1 |
| <i>Beania hirtissima</i> (Heller, 1867) | 4 | 2 | 19 | 3 | 1 | 5 | - | | 1 | - | - | 1 | 6 |
| <i>Beania mirabilis</i> Johnston, 1840 | 2 | - | - | - | - | 1 | - | | - | - | - | - | 1 |
| <i>Collarina</i> sp.1 | - | - | - | - | - | - | 4 | | - | - | - | 2 | 2 |

continued

Table 3 continued

| Surveys | CPA | | | | | CPA | | | | | SM | | | | | SM | | Total |
|---|-----------|-----------|-----------|-----------|-----------|-----|------------|---|------------|------------|-----------|----|----|----|----|----|----|-------|
| | 1 | 2 | 3 | 4 | 5 | Fr | 1 | 2 | 3 | 4 | 5 | Fr | Fr | Fr | Fr | Fr | Fr | |
| <i>Catenicella paradoxa</i> Rosso, 2009 | - | - | - | - | - | - | 1 | - | - | - | - | 2 | 2 | - | - | - | - | 2 |
| <i>Haplopoma</i> cf. <i>bimucronatum</i> (Moll, 1803) | - | - | - | - | - | - | - | - | 2 | - | - | 2 | 2 | - | - | - | - | 2 |
| <i>Reptadeonella violacea</i> (Johnston, 1847) | - | - | - | 1 | - | 1 | - | - | - | - | - | - | 1 | - | - | - | - | 1 |
| <i>Schizobrachiella sanguinea</i> (Norman, 1868) | - | - | - | - | 1 | 1 | - | - | - | - | - | - | 1 | - | - | - | - | 1 |
| <i>Schizoporella dunkeri</i> (Reuss, 1848) | - | - | - | - | 1 | 1 | - | - | - | - | - | - | 1 | - | - | - | - | 1 |
| <i>Cellepora posidoniae</i> (Hayward, 1975) | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | 1 |
| <i>Turbicellepora robusta</i> (Barroso, 1921) | - | 1 | 2 | - | - | 2 | 6 | - | 8 | 2 | - | 4 | 6 | - | - | - | - | 6 |
| Total specimens | 34 | 12 | 39 | 39 | 8 | | 281 | | 108 | 106 | 45 | | | | | | | |
| Total species | 6 | 7 | 7 | 8 | 5 | | 9 | | 9 | 7 | 3 | | | | | | | |
| Ostracoda | | | | | | | | | | | | | | | | | | |
| <i>Aurila convexa</i> (Baird, 1850) | 10 | 3 | 21 | 3 | - | 4 | - | - | - | - | - | - | 4 | - | - | - | - | 4 |
| <i>Aurila</i> gr. <i>punctata</i> (Muenster, 1830) | 5 | - | - | - | 8 | 2 | - | - | - | 4 | 6 | 2 | 4 | - | - | - | - | 4 |
| <i>Aurila prasina</i> Barbeito-Gonzalez, 1971 | - | - | - | 4 | 15 | 2 | - | - | - | 5 | - | 1 | 3 | - | - | - | - | 3 |
| <i>Bairdia longevaginata</i> (Müller, 1894) | - | - | 3 | - | - | 1 | - | - | - | - | - | - | 1 | - | - | - | - | 1 |
| <i>Bairdia mediterranea</i> (Müller, 1894) | 10 | 6 | 4 | - | 18 | 4 | 9 | - | 21 | 8 | 8 | 5 | 9 | - | - | - | - | 9 |
| <i>Callistocythere</i> sp. | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | - | - | - | - | 1 |
| <i>Loxoconcha bairdi</i> Müller, 1912 | 10 | - | 25 | 3 | 14 | 4 | - | - | 14 | 6 | 4 | 3 | 7 | - | - | - | - | 7 |
| <i>Loxoconcha stellifera</i> (Müller, 1894) | - | - | - | 18 | 8 | 2 | - | - | - | - | - | - | 2 | - | - | - | - | 2 |
| <i>Paradoxostoma atrum</i> (Müller, 1894) | 5 | - | - | 11 | - | 2 | 5 | - | 9 | - | - | 2 | 4 | - | - | - | - | 4 |
| <i>Paradoxostoma simile</i> (Müller, 1894) | 5 | - | - | 17 | - | 2 | - | - | 12 | 3 | 9 | 3 | 5 | - | - | - | - | 5 |
| <i>Propontocypris pirifera</i> (Müller, 1894) | 10 | 14 | - | - | 10 | 3 | - | - | 16 | 15 | 14 | 4 | 7 | - | - | - | - | 7 |
| <i>Xestoleberis dispar</i> (Müller, 1894) | 20 | 8 | 11 | 13 | 16 | 5 | 14 | - | 5 | 28 | 9 | 4 | 9 | - | - | - | - | 9 |
| Total specimens | 75 | 31 | 64 | 69 | 89 | | 28 | | 77 | 69 | 50 | | | | | | | |
| Total species | 8 | 4 | 5 | 7 | 7 | | 3 | | 6 | 7 | 6 | | | | | | | |

in at least one sample (Table 3, Fig. 5). Gastropods (29 spp.) prevailed over bivalves (20 spp.) and polyplacophorans (2 spp.). The bivalve family Mytilidae (3 spp.), and the gastropod families Rissoidae (4 spp.) and Cerithiidae (3 spp.) were the richest in species number.

CPA station included a slightly lower number of species (35 spp.) than the SM one (39 spp.); 23 species were shared by both stations. The mean number of species per sample was 13, but CPA samples exhibited a great variability, ranging from 7 to 30 species. Shannon-Weaver diversity showed comparable values among all samples (1.9-2.4) with the only exceptions of the oligotypic CPA2 sample (1.6) and the relatively more diverse SM2 (3.0).

Both CPA and SM mollusc communities were dominated by the cerithiid *Bittium latreillii* and the mytilid *Musculus costulatus*, though they differed for accompanying taxa (Table 3).

Mollusc fauna was clearly related to hard substrates. Most bivalves were bissally attached (either infaunal/semifunal or epifaunal) or cemented. *Hiattella arctica* was common in the sediment-rich upper layer of the algal mat, when present. Gastropods were almost exclusively epifaunal (except for a couple of epizoic/parasitic taxa) and were nearly equally distributed between detritivores and carnivores.

No significative trend between sampling surveys was noted but CPA and SM showed comparable fluctuations in both number of species and specimens during time,

with a maximum in October 2015 and a minimum in June 2016.

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 lichenoporiid *Patinella radiata* and the crisiids *Filicrisia 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-

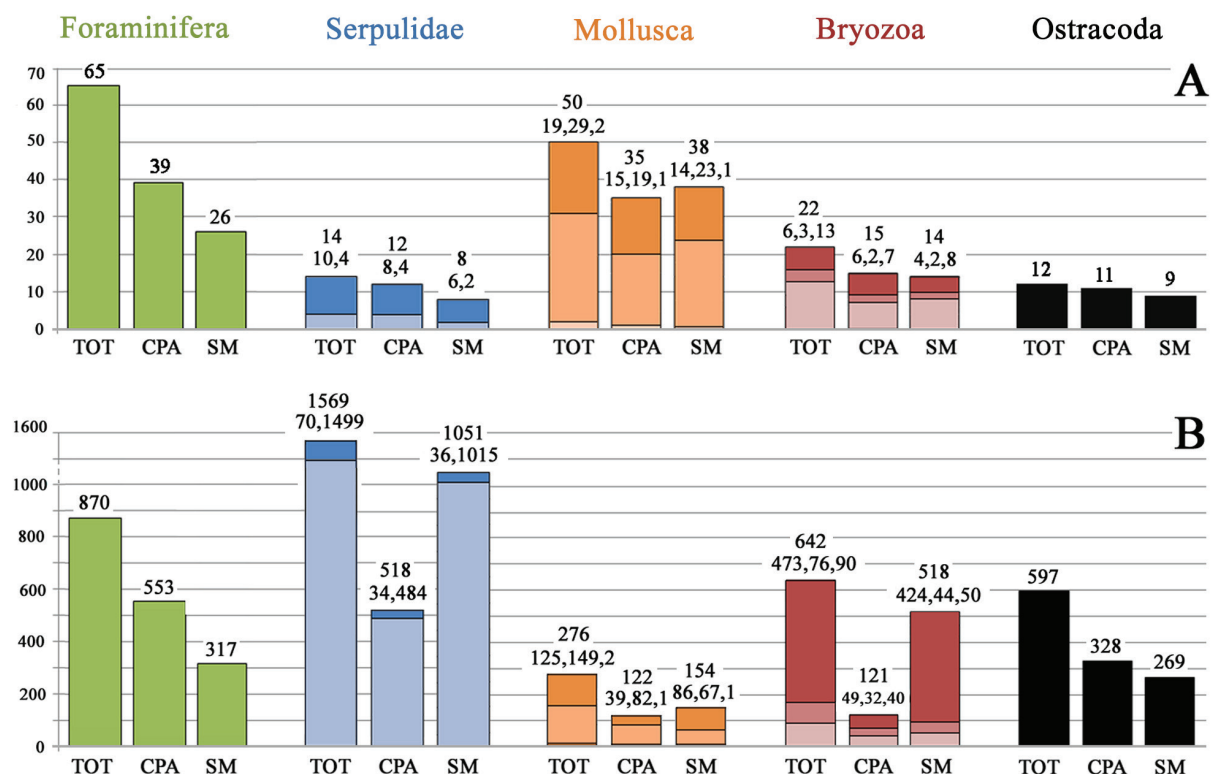


Fig. 5: Histograms illustrating species richness (A) and specimen abundance (B) for all investigated taxonomic groups from the examined algal community in the whole area (TOT) and in individual sampling stations (CPA, SM). Relationships between low-rank taxonomic groups are shown for some taxa. For serpulids: dark and light nuances refer to Serpulinae and Spirorbinae, 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 comas).

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.

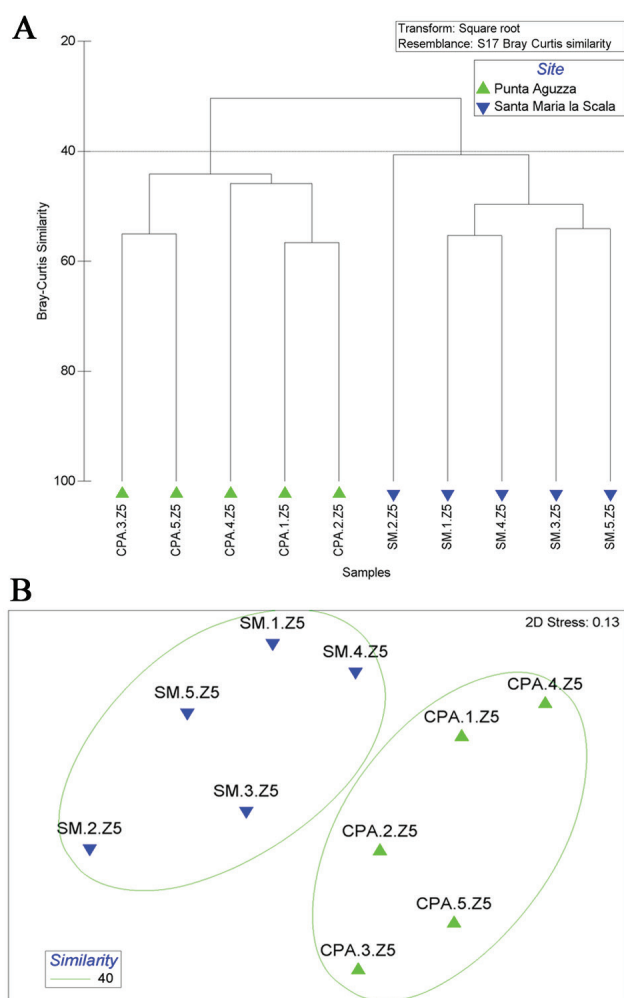


Fig. 6: Dendrogram (A) and MDS ordination (B) obtained from a data matrix of live specimens abundance (cf. Tables 1-3) of macrofauna samples (Z5) collected in the examined community. The horizontal line in the dendrogram and the MDS grouping (40% BC similarity) separate CPA (Punta Aguzza) and SM (Santa Matia La Scala) sites. 1, 2, 3, 4, and 5 refer to subsequent sampling surveys.

Discussion

Field observations and sample analysis proved that during 2015-2016 *Cystoseira brachycarpa* was absent in the investigated area, both inside and outside CIMPA, 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 CIMPA, 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 richest 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 *Ellisolandia 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*

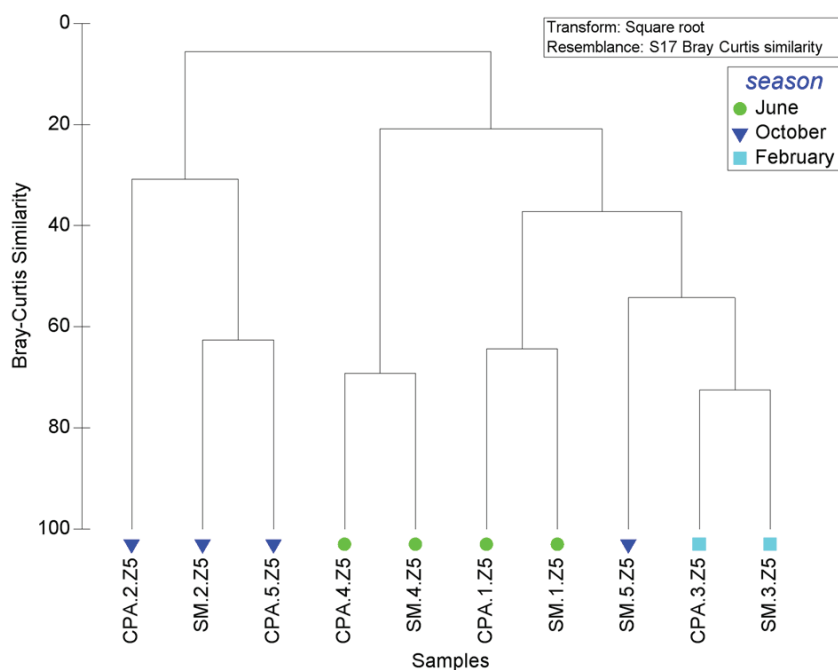


Fig. 7: Dendrogram restricted to serpulid fauna, showing an almost complete seasonal matching of samples at 60-70% BC similarity. Acronyms as in Figure 6.

(*Dexiospira*) *pagenstecheri*, mostly in June, probably results from its life cycle. Bianchi (1979, 1983) and Kupriyanova *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; Piazzzi *et al.*, 2018). Indeed, Piazzzi *et al.* (2018) found decidedly more diversified mollusc, and especially gastropod, 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; Piazzzi *et al.*, 2018). Piazzzi *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*, *Haplopoma bimucronatum*, *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 biocoenosis 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 overgrazing 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 & Beninato, 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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