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First data on ostracods and foraminifera living in *Cystoseira* communities in western Ionian Sea (southern Italy, Mediterranean Sea)

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Abstract

Ostracod and foraminifera associations living on infralittoral algae in three different localities inside and outside the Ciclopi Islands Marine Protected Area (CIMPA), along the Ionian coast of Sicily, a few km N of Catania were analysed for the first time. A total of 19 samples were collected in three different *Cystoseira* communities, at 5, 10, and 26 m depth in areas where the Biocoenosis of the Infralittoral Algae develops. Ostracod associations include 22 living species but only 7 make up the bulk of associations, which consist of shallow water phytal taxa and infralittoral sediment-dwelling taxa. The family Xestoleberididae dominates, especially in the shallowest samples, followed by representatives of Paradoxostomatidae, Hemicytheridae, and Bairdidae. Loxoconchidae, Pontocyprididae and Cytheruridae are subordinate. Foraminifera include 55 taxa, but only 14 species are frequent and abundant, accounting for the majority of specimens in individual samples. Associations are almost exclusively represented by benthic phytal taxa. The family Miliolidae prevails, followed by Elphidiidae, Rotaliidae, Rosalinidae, and Discorbidae. Cibicididae and Planorbulinidae are subordinate. Both ostracod and foraminifer associations include species already known from the Mediterranean Sea. Ecological analysis, based on phytal- to sediment-dweller ratios for ostracods, and on trophic requirements and mobility behaviour for foraminifera, clearly indicates a vegetate bottom characterised by stress conditions, especially related to environmental high energy, leading to the selection of a few particularly adapted species. The removal of skeletons contributes bioclasts for carbonate production in deeper areas. Differences between investigated localities and communities at different depths, are hardly evident, especially with foraminifera.

Keywords: Ostracoda, Foraminifera, Living associations, *Cystoseira* communities, Infralittoral Zone, East Sicily, Ionian Sea.

Introduction

The Biocoenosis of the Infralittoral Algae (IA), largely corresponding to the Biocoenosis of the Photophilic Algae of Pérès & Picard (1964), is widespread in Mediterranean shallow-water rocky bottoms and includes, among others, the *Cystoseira brachycarpa* J. Agardh *emend*. Giaccone, *C. sauvageauana* Hamel, and *C. spinosa* Sauvageau communities, which are distributed at different depths. Along the eastern coasts of Sicily, *Cystoseira* communities were considered to be in a good state until at least the '80s-'90s (Pizzuto, 1999), but later began to exhibit evidence of deterioration, as observed throughout the Mediterranean (Thibaut *et al.,* 2015; Serio *et al.*, 2016). *Cystoseira* communities are among the most important habitat-forming algal species in shallow waters (Bellissimo *et al.*, 2014) and provide substrate and a considerable food source for associated biota including molluscs, ostracods, foraminifera, bryozoans, brachiopods, amphipods, and polychaetes (Athersuch, 1979; Poursanidis *et al.*, 2016; Rosso *et al.*, in press; Sanfilippo *et al.*, in press). According to Pérès & Picard (1964), *Cystoseira* communities represent the climax for the infralittoral zone. They have therefore been listed in the Barcelona Convention among priority habitats to be protected (Panayotidis *et al.*, 2007).

Few reports exist on the faunas associated with the *Cystoseira* community from the Mediterranean as a whole and especially for the studied area in the western Ionian Sea. Available lists of species, dating back to the early '70s, exclusively record bryozoans and molluscs (Campisi, 1973; Campisi *et al.*, 1973). Bryozoans have been reviewed (Rosso *et al.*, in press) and serpulids first reported (Sanfilippo *et al.*, 2016, in press) in the frame of an ongoing project on the biodiversity associated to these algal communities. Nevertheless, nothing is known about living ostracods and foraminifera associated with the *Cystoseira* communities of the area. This paper represents a first contribution to the knowledge of these taxonomic groups and aims to analyse the composition and structure of these associations in relation to biotic and abiotic environmental parameters. By doing so, it also contributes information for a more reliable employment of ostracods and foraminifera in palaeoecological interpretations.

Materials and Methods

This study is part of a project on selected *Cystoseira* communities located in the northern sector of the Gulf of Catania, along the Ionian coasts of Sicily (Fig. 1).

This area, which represents the Etna eastern slopes, is geologically constituted by: 1) a complex of subvolcanic rocks, mainly consisting of columnar basalts, resulting from magmas injected into the Upper Calabrian so-called “blue clays”, which were deposited within the “pre-Etnean Gulf”, and 2) effusive submarine products forming extensive fields of pillow lavas (Cristofolini, 1975; Corsaro & Cristofolini, 1997). Rocky outcrops are dissected by fault systems and partly dismantled, causing a belt of blocks, up to a few m in size, accumulated along the coast and at the base of local shallow cliffs. From the

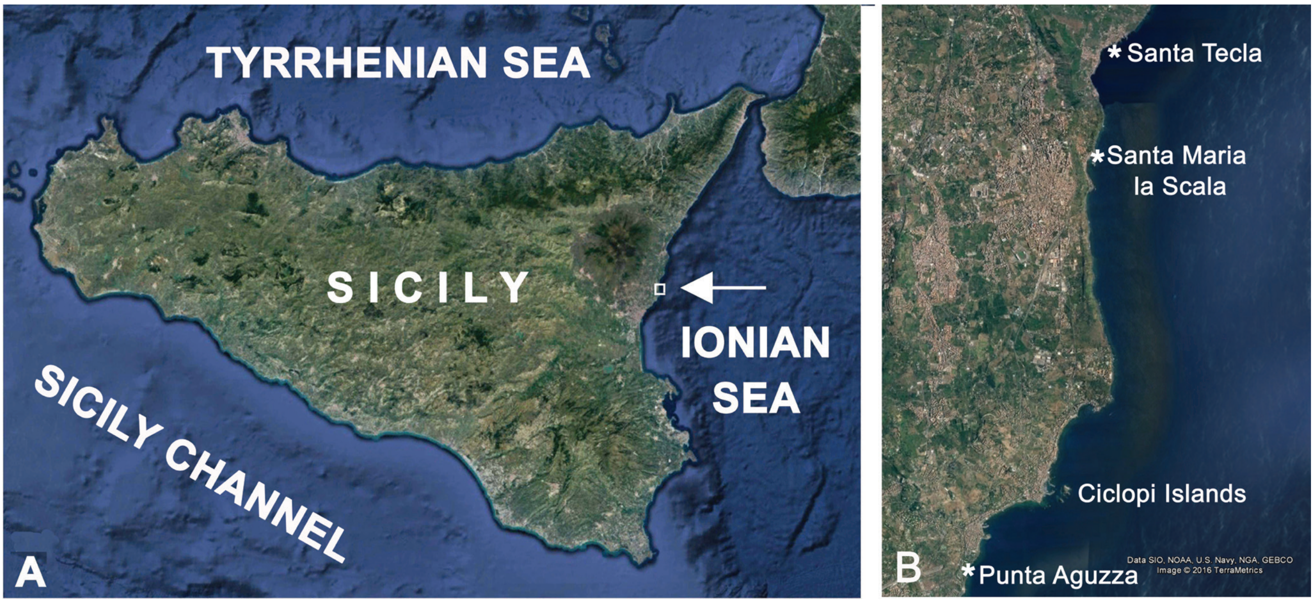

Fig. 1: A) Geographical location of the study area (arrowed) along the eastern coast of Sicily in the Ionian Sea. B) Detail of the study area with the three sampling stations: Punta Aguzza (inside the Ciclopi Islands Marine Protected Area), Santa Maria la Scala, and Santa Tecla (outside the CIMPA).

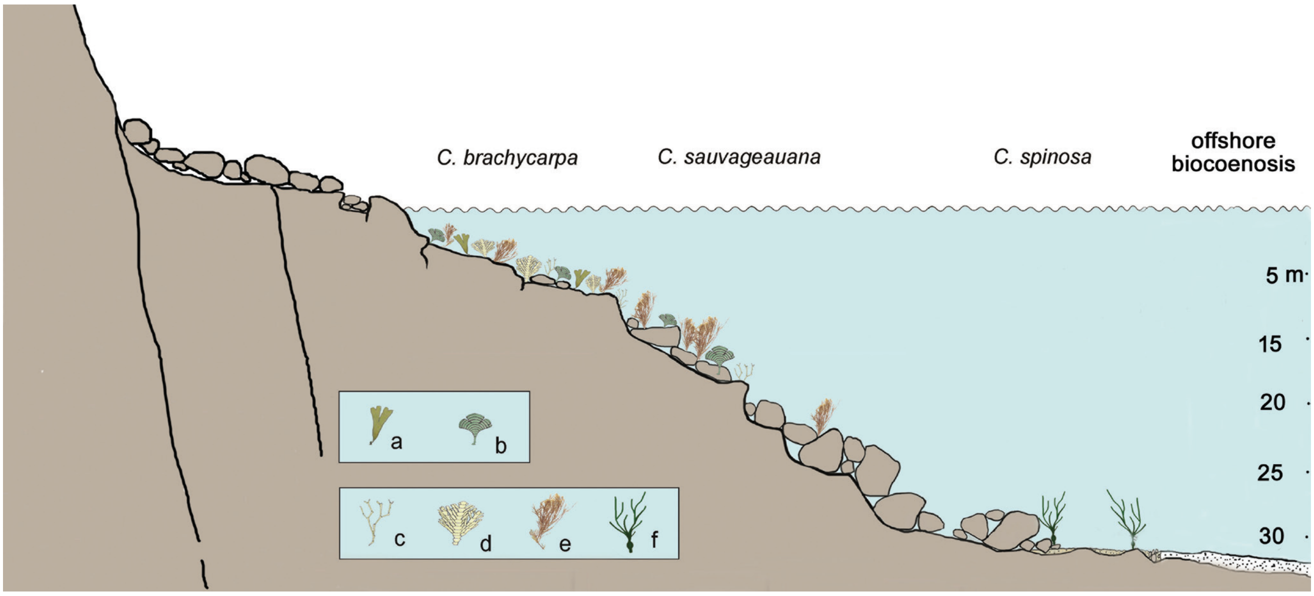

Fig. 2: Shallow water schematic profile of the Ciclopi Islands area, which hosts the investigated *Cystoseira brachycarpa*, *C. sauvageauana* and *C. spinosa* communities (after Rosso et al. in press, modified). a: *Dictyota dichotoma*; b: *Padina pavonica*; c: *Jania rubens*, d: *Ellisolandia elongata*; e: *Halopteris* spp.; f: *Cystoseira zosteroides*.

coastline down to 10-15 m depth, and locally to about 40 m, the bottom has a steeply sloping topography (Fig. 2) and largely consists of the *in situ* basaltic bedrock locally covered with large volcanic blocks. These hard substrates host the Biocoenosis of the Infralittoral Algae (IA). Pockets of coarse (sandy to gravely) sediment commonly occur between blocks. Offshore, the bottom gently slopes to 130-145 m, beyond the outer limit of the Ciclopi Islands Marine Protected Area (CIMPA), largely consisting of sediments becoming progressively muddier at major depths; rocky outcrops are locally exposed (Rosso, 2001). All sediments are largely bioclastic, but volcanic ashes can account for large percentages especially after Etna paroxysmal explosive activity. These sediments host several biocoenoses typical of differently textured soft bottoms, as reported by Di Geronimo (1975), Rosso (2001), Rosso *et al.* (2014) and Sciuto *et al.* (2015).

Sampling stations were chosen on the basis of historical information about the presence and the state of the target communities and after preliminary surveys along the coast, at convenient depths. Three sites were selected, one of which is located within the CIMPA and two outside it, in areas where the *C. brachycarpa, C. sauvageauana,* and *C. spinosa* communities were identified, at 5, 10, and 26 m water depth, respectively (Figs 1, 2; Table 1). The CIMPA samples come from its southern sector, immediately off Cape Punta Aguzza (CPA samples) whereas the sampling stations outside the CIMPA area, are located directly north of its limit at Santa Maria La Scala (samples SM) and Santa Tecla (samples ST). Samples were collected in 2015 and 2016 by scuba divers. Foraminifers and ostracods were aspirated through a siphon from a standard surface of 40x40 cm, selected within physionomically homogeneous surfaces (Fig. 3).

For the present study nineteen samples were analysed (Table. 1). Collected samples, including sediments and algal fronds, were first preserved in alcohol, than rinsed in fresh-water using a sieve with a 63 micron mesh. Residues were dried, weighed and examined for their texture and composition. The material was split into subsamples when organisms were too numerous. Ostracods and foraminifera were picked up under a stereomicroscope. All specimens were identified and counted. In order to distinguish living specimens from dead ones, the following characteristics were taken into account: 1) the presence of the soft parts

Table 1: List of the collected samples with indication of locality and date of collection, latitude, longitude and depth.

Algal community	*C. brachycarpa*								*C. sauvageauana*						*C. spinosa*				
location	37° 32' 52" N, 15° 08' 44" E				37° 37' 10" N, 15° 10' 31" E				37° 32' 52" N, 15° 08' 45" E		37° 38' 17" N, 15° 10' 53" E				32' 52" N, 15° 08' 47" E			37° 37' 10" N, 15° 10' 33" E	
Station name	CPA				SM				CPA		ST				CPA			SM	
date	2015 June	2016 February	2016 June	2016 October	2015 June	2015 October	2016 February	2016 October	2015 June	2015 October	2015 June	2015 October	2016 February	2016 June	2015 June	2016 February	2016 October	2015 June	2016 October
Sample	1	3	4	5	1	2	3	5	1	2	1	2	3	4	1	3	5	1	5
Depth (m)	5	5	5	5	5	5	5	5	10	10	9	9	9	9	26	26	26	25	25

Fig. 3: Example of microfaunas sampling using the sorbona on basaltic blocks hosting the studied algal community in the Ciclopi Islands area. ST1/9, collected at Santa Tecla, -9 m, on May 2015.

for ostracods and, 2) the pristine test colour for foraminifera, following Mateu-Vicens *et al.* (2010).

Identification of Foraminifera species was carried out using main monographs on the Mediterranean Sea and especially Cimerman & Langer (1991), Sgarrella & Moncharmont Zei (1993), Fiorini & Vaiani (2001), Casieri & Carboni (2007) and Milker & Schmiedl (2012). Generic attribution followed the criteria of Loeblich & Tappan (1987). Systematics of Ostracoda was based on Horne *et al.* (2001) and species identification profited from key papers on the Mediterranean area, among which Müller (1894), Puri *et al.* (1969) and Bonaduce *et al.* (1975).

Photographs were acquired using a LMU Tescan Vega II Scanning Electron Microscope at the Department of Biological, Geological and Environmental Sciences of the University of Catania. The material is housed in the Museo di Paleontologia of the University of Catania under the collective code CIMPA 2015-2016 Sciuto micro bio.

Results

Sediments

Dry residues of the analysed samples weigh from 4 to 15 grams. They include occasional algal fronds and a sediment fraction mainly consisting of sandy-silt and silty-sand. Sediments are mixed and constituted by terrigenous and biogenic clasts. The former component exclusively consists of volcanic ashes (fine sands and silts) ejected by the Etna volcano and carried to the sea largely by the wind. Biogenic clastic component is composed by carbonate skeletons and fragments of individuals once living in the algal habitat, largely belonging to foraminifers, ostracods, bryozoans, serpulids, and molluscs. Remains of brachiopods, crustaceans other than ostracods, echinoderms and geniculate coralline algae were occasionally found.

Foraminifera

A total of 55 living benthic taxa were identified, 44 of which at species level (Table 2). Some of these species are illustrated in Fig. 4. No clear trend is obvious for both species richness and specimen abundance, although these values are generally positively correlated in individual samples (Fig. 5). The samples ST2/9 and CPA5/26 are the richest in species and specimens, whereas the samples SM2/5 and ST3/9 are the poorest. A group of eight taxa (15%) including all *Elphidiidae* and part of Hauerinidae, are very frequent (*i.e.* present in most to several of the collected samples: 13-18 out of 19) and particularly abundant (*i.e.* represented by numerous specimens). In contrast, the majority of taxa (36, accounting for 67% of the association) are unfrequent and rare. The most frequent species are *Quinqueloculina auberiana, Planorbulina mediterranensis, Vertebralina striata* (Fig. 4A), as well as *Elphidium crispum*, *E. advenum* and *E. aculeatum* (Fig. 4H). All these species, except for *E. aculeatum,* are abundant in almost all samples. *Pseudotriloculina rotunda*, *Peneroplis planatus* (Fig. 4E), *Quinqueloculina seminula, Lachlanella carinata* (Fig. 4D), *Miliolinella subrotunda,* and *Cibicidoides lobatulum* follow, being present in 9-11 samples. Further taxa are less frequent than the previous ones, although sometimes abundant.

The total number of species per sample ranges from 4 to 33. The species richness is slightly higher for the CPA localities (52 species) than for the SM-ST ones (46 species) paralleling the trend in mean specimen abundance, which is again higher in the CPA samples (a mean of 37 specimens per sample) than in the SM-ST ones (a mean of 30 specimens per sample). The species richness, with values of 45, 42 and 48 species, shows no special trend for the three investigated *Cystoseira* communities, whereas the mean specimen abundance (with 30, 32 and 39 specimens) slightly increases from the shallowest to the deepest community.

Following Langer (1993) and Mateu-Vicens *et al.* (2014), foraminifera have been grouped according to their autoecology. Besides a few unplaced taxa (UN in Table 2 and Figs 6, 7), five morphotypes of epiphytic species have been identified, based on life behaviour including trophic requirements and motility. The morphotype A *sensu* Langer (1993) or A* *sensu* Mateu-Vicens *et al.* (2014) groups encrusting species permanently attached to the substratum, such as *P. mediterranensis*. The morphotype SB *sensu* Mateu-Vicens *et al.* (2014), includes all sessile symbiont-bearing taxa and large benthic foraminifera, such as *Peneroplis* species. The morphotype B *sensu* Langer (1993) or B* *sensu* Mateu-Vicens *et al.* (2014) includes taxa, such as *Rosalina* species, and *Asterigerinata mamilla*, which live temporarily attached to the substrate with their specially adapted umbilical surfaces but can move using a pseudopodial network. The morphotype C *sensu* Langer (1993) or C* *sensu* Mateu-Vicens *et al.* (2014), includes suspension feeding motile foraminifera which extrude pseudopods from a canal-system and multiple apertural openings, suspending the test in a mucous network attached to the framework of algal fronds. This group is represented by Elphidiidae (Fig. 4G, H, I). The morphotype D *sensu* Langer (1993) or D* *sensu* Mateu-Vicens *et al.* (2014) includes permanently motile grazing epiphyte foraminifera, which actively move by extending their pseudopods. This group is represented by species of the genera *Quinqueloculina, Triloculina, Adelosina, Lachlanella, Miliolinella, Pseudotriloculina*, and *Vertebralina*.

In the analysed samples the D morphotype consists of 34 taxa (47%) dominated by foraminifera with porcellaneous tests, such as *Quinqueloculina* species, *V. striata*, *Triloculina trigonula*, *P. rotunda, Miliolinella subrotunda*, and *L. carinata.* The morphotype B is represented by 7 taxa (12%) accounting for 10% of specimens; *Asterigerinata* spp. (4%) and *Rosalina* sp. are the most representative taxa, followed by *Cibicidoides lobatulus,*

Table 2: List of living Foraminifera associated with the *Cystoseira* communities found in the collected samples from the Ciclopi Islands area. CPA: Punta Aguzza samples; SM: Santa Maria La Scala samples; ST: Santa Tecla samples. The relative percentage (%) for each taxon and for each examined sample is reported. A: encrusting or permanently attached taxa; B: temporarily attached taxa with flat umbilical surface; C suspension feeder motile foraminifers which can extrude pseudopods to suspend themselves to the algae; D: permanently motile grazing epiphyte foraminifers; SB: sessile symbiont-bearing taxa; UN: unplaced species. See text for further information.

	Taxa **Samples**	**CPA1/5**	**CPA3/5**	**CPA4/5**	**CPA5/5**	**SM1/5**	**SM2/5**	**SM3/5**	**SM5/5**	**CPA1/10**	**CPA2/10**	**ST1/9**	**ST2/9**	**ST3/9**	**ST4/9**	**CPA1/26**	**CPA3/26**	**CPA5/26**	**SM1/25**	**SM5/26**
A	*Planorbulina mediterranensis* d’Orbigny, 1826	7,0	7,1	2,6	11,1	2,0	23,08	5,3	6,7	2,9	14,3		1,7		2,5	8,3	16,67	11,3	5,7	5,4
A	*Cibicidoides variabilis* (d’Orbigny, 1826)	2,3				2,0					3,6					4,2	4,17		5,7	
B	*Asterigerinata* spp. (Williamson, 1858)	9,3	7,1			8,2		10,5		11,8	7,1	4,2	1,7	50	2,5	4,2			5,7	8,1
B	*Cibicides refulgens* (de Montfort,1808)		3,6	5,1			7,69	5,3					1,7	12,5	5			3,8		2,7
B	*Biasterigerina planorbis* (d’Orbigny, 1846)	2,3															12,50			5,4
B	*Discorbis bulbosus* Parker, 1954			2,6									1,7		2,5			1,9		
B	*Eponides concameratus* (Williamson, 1858)							5,3				4,2								
B	*Rosalina* sp.	4,7		2,6		8,2		5,3		2,9		4,2			2,5	2,1		1,9		2,7
B	*Tretomphalus bulloides* (d’Orbigny, 1839)												1,7					5,7		
C	*Elphidium aculeatum* (d’Orbigny, 1846)	9,3	3,6	2,6	2,8	8,2				11,8	3,6	16,7	6,7		10	8,3		1,9	11,4	10,8
C	*Elphidium advenum* (Cushman,1922)	2,3	7,1	2,6	2,8	8,2	7,69	15,8		5,9	3,6	12,5	6,7		7,5	2,1	4,17	3,8	11,4	10,8
C	*Elphidium complanatum* (d’Orbigny, 1839)	2,3	0,0								3,6					2,1				
C	*Elphidium crispum* (Linnaeus, 1758)	4,7	7,1	2,6	2,8	4,1	7,69	10,5		5,9	3,6	16,7	6,7		15	4,2		5,7	11,4	10,8
C	*Elphidium depressulum* Cushman, 1933		3,6	2,6													8,33			2,7
C	*Elphidium macellum* (Fichtel and Moll, 1798)		7,1					15,8								2,1				
C	*Elphidium* sp.	7,0		7,7	2,8	8,2			6,7		3,6	16,7	6,7		12,5	8,3	8,33	3,8	11,4	8,1
D	*Adelosina dubia* (d’Orbigny, 1826)			2,6											2,50	2,1				
D	*Adelosina elegans* (Williamson, 1858)															2,1	4,17			
D	*Adelosina* sp.															2,1				2,7
D	*Lachlanella variolata* (d’Orbigny, 1826)	2,3	3,6	2,6	8,3					5,9	7,1		1,7		2,5	2,1		1,9		
D	*Triloculinella dilatata* (d’Orbigny, 1839)								6,7						2,5			3,8		
D	*Flintinoides labiosa* (d’Orbigny, 1839)		3,6		2,8			5,3	6,7				3,3							2,7
D	*Miliolinella* sp.					6,1				2,9	10,7				2,5			1,9		
D	*Miliolinella subrotunda* (Montagu, 1803)				2,8	4,1	7,69		13,3				6,7		2,5		4,17	3,8		2,7
D	*Pseudotriloculina cuneata* (Karrer, 1867)									2,9			3,3							
D	*Triloculina oblonga* (Montagu, 1803)			2,6											2,5			1,9		
D	*Pseudotriloculina rotunda* (Schlumberger, 1893)	9,3		5,1	2,8	8,2		5,3		11,8	3,6		6,7			4,2		3,8	2,9	
D	*Pseudotriloculina* sp.			2,6	2,8				6,7						2,5					
D	*Pyrgo mutabilis* (Martinotti, 1921)	2,3																		
D	*Pyrgo* sp.				2,8			5,3									4,17	1,9		
D	*Quinqueloculina annectens* (Schlumberger, 1893)	2,3	3,6	2,6	2,8										2,5			1,9		
D	*Quinqueloculina auberiana* d’Orbigny, 1839	2,3	7,1	7,7	8,3	4,1	7,69	5,3	6,7	5,9	3,6	4,2	6,7		5	4,2	4,17	1,9	5,7	10,8
D	*Quinqueloculina bradyana* Cushman, 1917					2,0					3,6					2,1			2,9	
D	*Quinqueloculina disparilis* d’Orbigny, 1826															2,1		1,9		2,7

(continued)

Table 2 *(continued)*

	Taxa Samples	CPA1/5	CPA3/5	CPA4/5	CPA5/5	SM1/5	SM2/5	SM3/5	SM5/5	CPA1/10	CPA2/10	ST1/9	ST2/9	ST3/9	ST4/9	CPA1/26	CPA3/26	CPA5/26	SM1/25	SM5/26
D	*Quinqueloculina laevigata* d'Orbigny, 1839		7,1	2,6																
D	*Quinqueloculina lamarckiana* d'Orbigny, 1839	4,7		5,1		8,2			6,7	2,9	10,7							3,8	5,7	
D	*Quinqueloculina lata* Terquem, 1876				2,8	8,2							6,7			2,1		1,9		
D	*Pseudotriloculina limbata* d'Orbigny, 1826		3,6	2,6				5,3					6,7				4,17		2,9	2,7
D	*Quinqueloculina parvula* Schlumberger, 1894		3,6	2,6	2,8					2,9			3,3		2,5			1,9		2,7
D	*Quinqueloculina seminula* (Linnaeus, 1758)	4,7	3,6	2,6		4,1				5,9	3,6					4,2	4,17	1,9	2,9	
D	*Quinqueloculina* spp.			2,6	5,6				6,7						2,5	2,1		3,8	5,7	
D	*Quinqueloculina vulgaris* d'Orbigny, 1826	2,3		7,7	5,6										2,5			1,9		
D	*Spiroloculina angulosa* Terquem, 1878															2,1		1,9		
D	*Spiroloculina ornata* d'Orbigny, 1839		3,6		2,8						3,6					2,1	4,17	3,8		
D	*Textularia bocki* Höglund, 1947						7,69							12,5	2,5	2,1			2,9	2,7
D	*Triloculina oblonga* (Montagu, 1803)				2,8												4,17			
D	*Triloculina* sp.																	1,9		
D	*Triloculina tricarinata* d'Orbigny, 1826		3,6										6,7			2,1		1,9		
D	*Triloculina trigonula* (Lamarck, 1804)	7,0		2,6		6,1				11,8		16,7				6,3		1,9	2,9	
D	*Vertebralina striata* Cushman, 1917	2,3	3,6	2,56	8,3		30,77		33,33		10,7		1,7	25	2,5	2,1	4,17	3,8	2,86	2,7
SB	*Laevipeneroplis karreri* Wiesner, 1923			2,6													4,17			
SB	*Peneroplis planatus* (Fichtel and Moll, 1798)	9,3	7,1	10,3	13,9				0,0	5,9			6,7		2,5	8,3		5,7		
UN	*Globocassidulina crassa* (d'Orbigny)												1,7				4,17			
UN	*Fissurina marginata* (Montagu, 1803)												1,7							
UN	*Polymorphina* sp.											4,2	1,7							

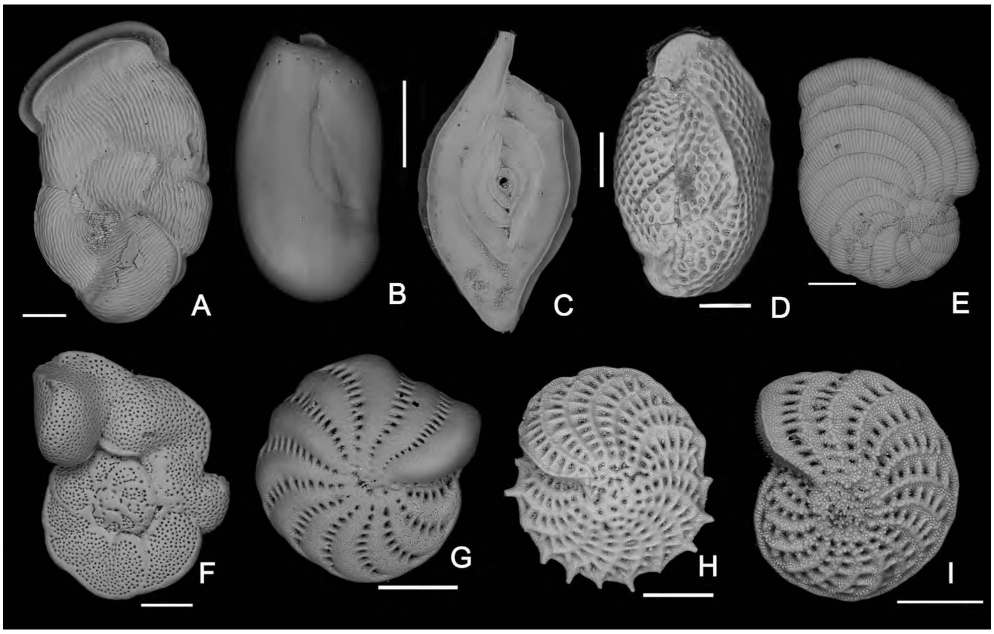

Fig. 4: Selected Foraminifera found associated to *Cystoseira* communities from the Ciclopi Islands area. A) *Vertebralina striata* d'Orbigny, side view. B) *Quinqueloculina lata* Terquem, side view. C) *Spiroluculina ornata* d'Orbigny, side view. D) *Lachlanella carinata* (d'Orbigny) side view. E) *Peneroplis planatus* (Fichtel & Moll), side view. F) *Cibicidoides lobatulus* (Walker & Jacob, 1878) spiral view. G) *Elphidium depressulum* Cushman, side view. H) *Elphidium aculeatum* (d'Orbigny), side view. I) *Elphidium jenseni* Cushman, side view (Scale bar = 200 µm for all species).

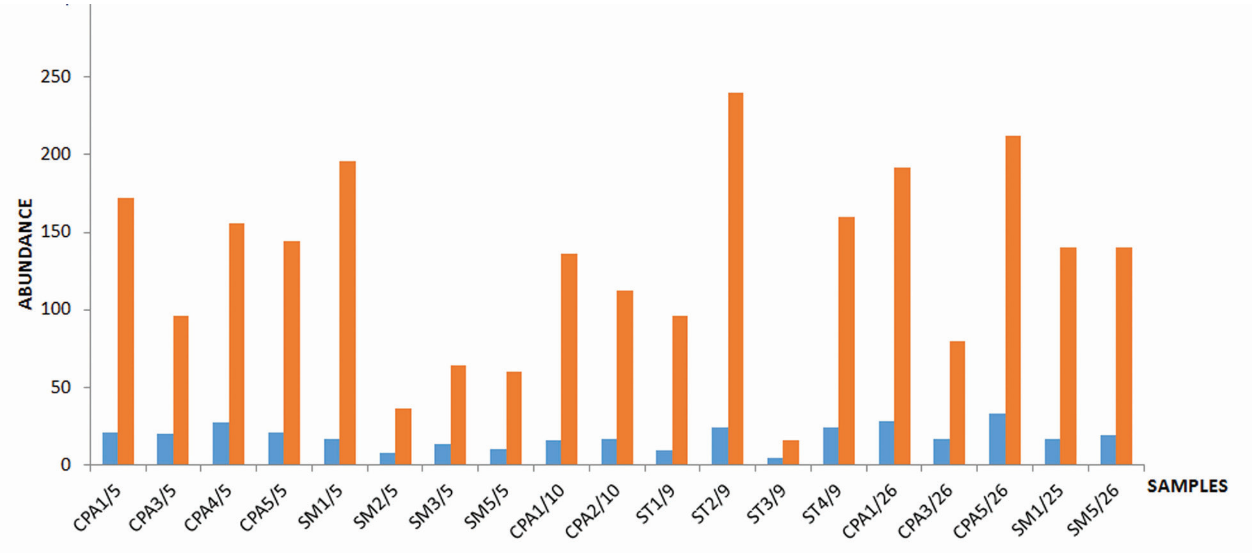

Fig. 5: Distribution of taxa and specimens of living foraminifera associated to *Cystoseira* communities from the Ciclopi Islands area. CPA: Punta Aguzza samples; SM: Santa Maria La Scala samples; ST: Santa Tecla samples. The first column in each group (blue- and dark grey-coloured in the colour and printed versions, respectively) indicates the number of species. The second column (red- and light grey-coloured in the colour and printed versions, respectively) indicates the number of specimens.

Tretomphalus bulloides, Discorbis bulbosus, Discorbina planorbis, and *Eponides concameratus.* The morphotype C is represented again by 7 taxa (29%), all belonging to Elphidiidae. Morphotypes A (7%) and SB (4%) are subordinate. The former is represented by *P. mediterranensis*, which is frequent but always represented by few specimens, followed by *Planorbulina variabilis.* The latter morphotype is represented by *P. planatus* and by rare specimens of *Laevipeneroplis karreri*. Nevertheless, some of these species can be locally abundant.

The distribution of ecological morphotypes in the three investigated *Cystoseira* communities shows no particular trend, except for a slight increase of representatives of the D morphotype and a counteracting increase of the C morphotype in the shallowest *C. brachycharpa* community.

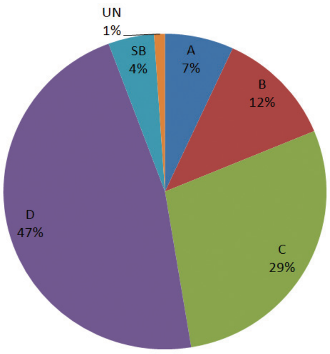

Fig. 6: General distribution of foraminifer morphotypes in the examined *Cystoseira* communities. A: encrusting or permanently attached taxa; B: temporarily attached taxa with flat umbilical surface; C: suspension feeder motile foraminifers which can extrude pseudopods to suspend themselves to the algae; D: permanently motile grazing epiphyte foraminifers; SB: sessile symbiont-bearing taxa; UN: unplaced species. See text for further information.

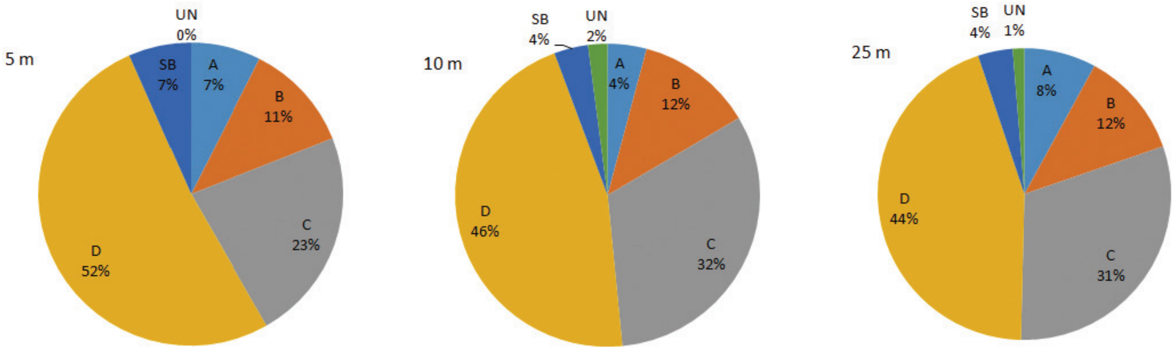

Fig. 7: Foraminifera morphotype distribution in relation to *Cystoseira* communities and water depth. A: encrusting or permanently attached taxa; B: temporarily attached taxa with flat umbilical surface; C: suspension feeder motile foraminifers which can extrude pseudopods to suspend themselves to the algae; D: permanently motile grazing epiphyte foraminifers; SB: sessile symbiont-bearing taxa; UN: unplaced species. See text for further information.

Ostracoda

A total of 27 taxa were identified (Table 3) but 22 of them are represented by living specimens (some illustrated in Fig. 8). In contrast, 5 taxa, namely *Carinocythereis whitei* (Baird, 1850), *Cytherella thrakiensis* Stambolidis, 1980, *Cushmanidea turbida* (Müller,1894) , *Urocythereis* sp., and *Triebelina raripila*) (Mueller, 1894), which only occur with disjointed valves of dead specimens, have been omitted in the species list. Juveniles of the living specimens are present and abundant in all samples.

Ostracods are irregularly distributed in the samples (Fig. 9) and sometimes a rather high abundance in specimens corresponds to low species richness, whereas in other cases both species richness and specimen abundance are extremely low. The total number of taxa per sample is generally low, ranging from 0 to 8 and only occasionally reaching higher values, as in samples ST2/9 (12 species) and CPA5/26 (15 species). The number of specimens is more variable, ranging from 4 (sample CPA2/10) to 80, and reaching 140 in sample ST2/9. Specimens were completely missing in sample SM1/5.

The number of species in the CPA and SM-ST areas is quite comparable (18 *vs* 16 taxa, respectively). In contrast, the mean number of specimens for the SM-ST area (47 specimens) is almost double that of the CPA area (25 specimens). A slightly increasing trend in both species

Table 3: List of living Ostracoda associated with the *Cystoseira* communities found in the collected samples from the Ciclopi Islands area. CPA: Punta Aguzza samples; SM: Santa Maria La Scala samples; ST: Santa Tecla samples. The relative percentage (%) for each taxon and for each examined sample is reported. V: epyphitic taxa, F: sediment-dweller taxa.

	TAXA SAMPLES	**CPA1/5**	**CPA3/5**	**CPA4/5**	**CPA5/5**	**SM2/5**	**SM3/5**	**SM4/5**	**CPA5/10**	**CPA2/10**	**CPA4/10**	**ST1/9**	**ST2/9**	**ST3/9**	**ST4/9**	**ST5/9**	**CPA3/26**	**CPA5/26**	**SM5/25**	**SM 3/25**
V	*Aurila convexa* (Baird, 1850)	13,3	17,2	9,4							18,8	10	12,5	16,3		10	13,3	4,9	7,4	
V	*Aurila* gr. *punctata* (Münster, 1830)	6,7			9,1										5,3					
V	*Aurila prasina* Barbeito-Gonzalez, 1971			12,5	13,6						6,25									
V	*Neonesidea corpulenta* (Müller,1894)																6,7	7,3	11,1	
V	*Neonesidea longevaginata* (Müller,1894)		17,2															2,4		
V	*Neonesidea mediterranea* (Müller,1894)	13,3			18,2	57,1	31,3				12,5		14,0	18,4			40	2,4		16,9
F	*Callistocythere* sp.															6,7				20,0
V	*Loxoconcha bairdi* Müller, 1912	13,3	27,6	6,3	13,6		18,8			100	18,8	33,3	11,8	16,3	34,2	23,3	20	17,1	22,2	21,5
V	*Loxoconcha stellifera* Müller,1894			9,4	9,1															
F	*Paradoxostoma angustum* Müller,1894																	4,9		
F	*Paradoxostoma atrum* Müller,1894	6,7		9,4			12,5				6,25		11,0	14,3		10,0		2,4	11,1	13,8
F	*Paradoxostoma caecum* Müller,1894												1,5					2,4		
F	*Paradoxostoma intermedium* Müller,1894																	2,4		
F	*Paradoxostoma parallelum* Müller,1894												0,7					2,4		
F	*Paradoxostoma simile* Müller,1894	6,7		12,5			12,5						14,7	18,4	7,9			4,9	7,4	
V	*Pontocypris pirifera* Müller, 1894																	9,8		
V	*Propontocypris mediterranea* Müller, 1894)								100			13,3						7,3		
F	*Propontocypris pirifer*a Müller,1894	13,3			13,6	42,9	18,8				12,5		12,5		36,8	26,7		12,2	40,7	13,8
V	*Semicytherura* spp.												0,7							
V	*Triebelina raripila* (Müller, 1894)												0,7							
F	*Xestoleberis dispar* Müller,1894	26,7	37,9	40,6	22,7		6,3				25	43,3	10,3		15,8	23,3	20	17,1		7,7
F	*Xestoleberis communis* Müller,1894												9,6	16,3						6,2

richness and specimen abundances can be traced when the three *Cystoseira* communities are compared, with values of 11, 16, and 17 and of 20, 45, and 49 registered at 5, 10, and 25 m, respectively.

The most frequent and abundant species are *Loxoconcha bairdi* (Table 3) and *Xestoleberis dispar* (Fig. 8I), followed by *Aurila convexa* and *Propontocypris pirifera* (Fig. 8C). *Neonesidea mediterranea, Paradoxostoma atrum* (Fig. 8G) and *P. simile* (Fig. 8F) are also frequent

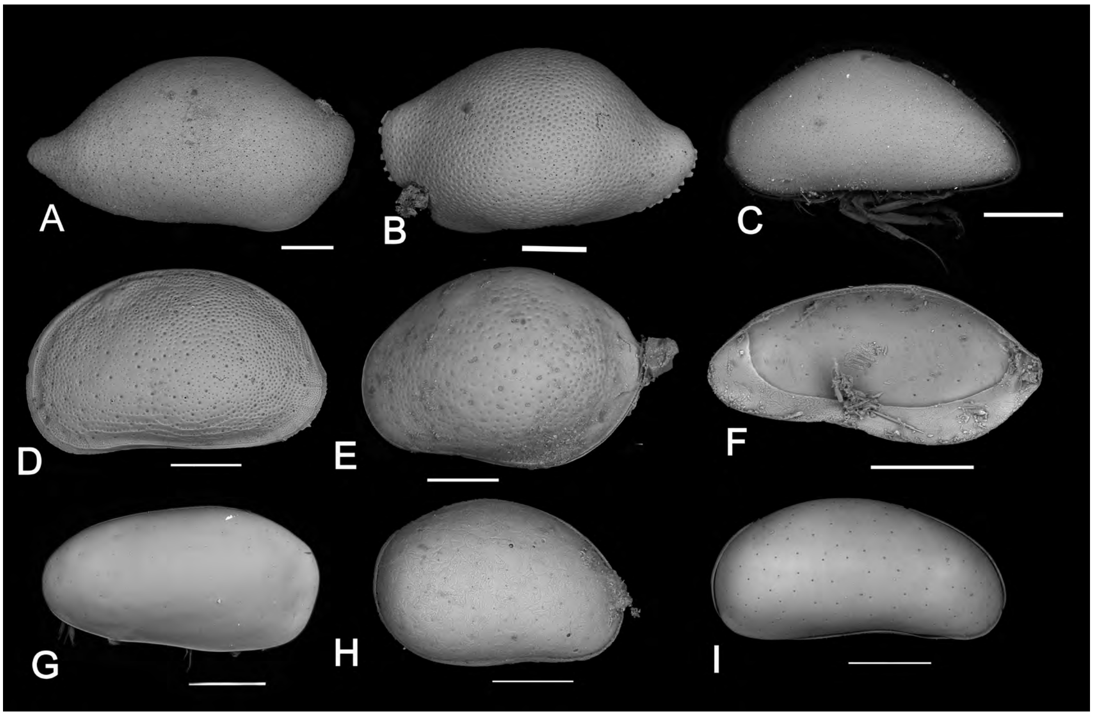

Fig. 8: Selected Ostracoda found associated to *Cystoseira* communities from the Ciclopi Islands area. A) *Neonesidea longevaginata* (Müller). B) *Neonesidea corpulenta* (Müller). C) *Propontocypris pirifera* Müller. D) *Aurila prasina* Barbeito-Gonzalez. E) *Loxoconcha stellifera* (Müller). F) *Paradoxostoma simile* Müller. G) *Paradoxostoma atrum* Müller. H) *Xestoleberis communis* Müller. I) *Xestoleberis dispar* Müller (Scale bar 200 µm).

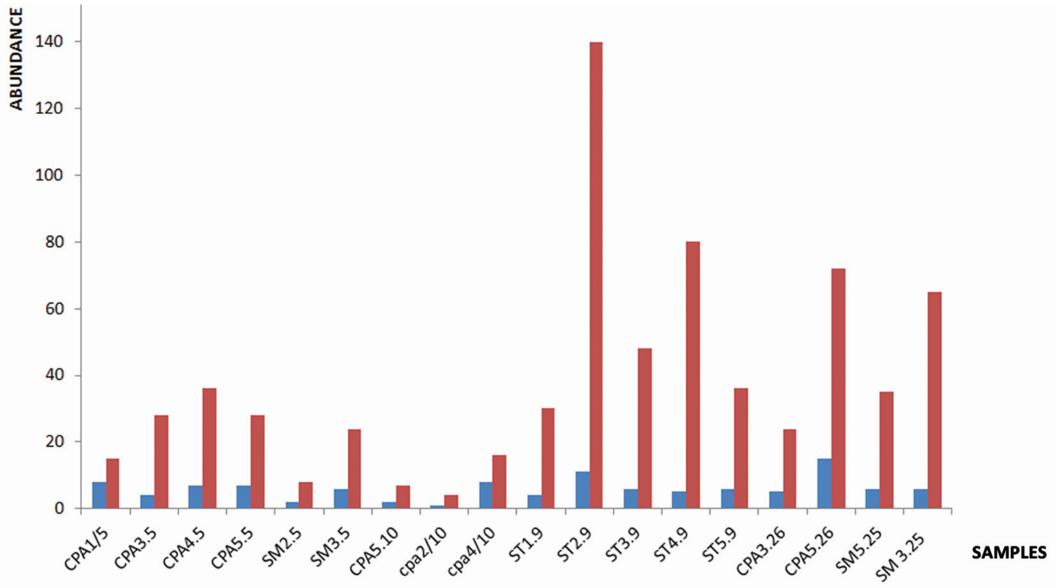

Fig. 9: Distribution of taxa and specimens of living ostracods associated to *Cystoseira* communities from the Ciclopi Islands area. CPA: Punta Aguzza samples; SM: Santa Maria La Scala samples; ST: Santa Tecla samples. The first column in each group (blue- and dark grey-coloured in the colour and printed versions, respectively) indicates the number of species. The second column (red- and light grey- coloured in the colour and printed versions, respectively) indicates the number of specimens.

but less abundant, whereas all other taxa are infrequent (only present in 1-3 samples out of 19) although some of them are abundant in certain samples or even represent the only ostracoda found (as for *Propontocypris mediterranea* in the sample CPA5/10).

Taxa especially adapted to live in vegetate bottoms and known as phytal indicators (such as *Paradoxostoma* spp. and *Xestoleberis* spp. in the present samples) are relatively subordinate when the number of species is considered (10 out of 22) but become largely dominant at specimen level, representing more than 75% of the entire association (Fig. 10). Sediment-dweller taxa (*Aurila* spp., *Loxoconcha* spp. and *Neonesidea* spp.) show an opposite trend with more than half of the number of species but low specimen percentages. When the three investigated *Cystoseira* communities are considered, phytal taxa show their lowest values in the *C. brachycharpa* community at 5 m but increase at major depth (Fig. 11).

by plants (Müller, 1894; Puri *et al.*, 1964, 1969; Rome, 1964; Athersuch, 1979; Langer, 1988; 1993; Casieri *et al.*, 2008; Mateu-Vicens *et al.*, 2010, 2014; Frezza *et al.*, 2011; Benedetti & Frezza 2016; inter alias). However, comparisons can hardly be carried out due to the absence of papers dealing with strictly comparable environments. Indeed, papers on living ostracods and foraminifera associated to *Cystoseira* communities, or even to the IA Biocoenosis, are almost absent and some information can only be extracted from papers dealing with other shallow-water vegetate bottoms such as those belonging to the Biocenosis of the *Posidonia* meadow or to particular algal species/genera (Triantaphyllou *et al.*, 2005; Mateu-Vicens *et al.*, 2014). It is noteworthy that all the identified foraminifera, as well as many of the recognized ostracod species, are known as typical epiphyte taxa.

The low values in species richness and specimen abundances registered for ostracod associations in the investigated *Cystoseira* communities, together with the low relative percentage of species belonging to *Xestoleberis,* could be considered as indicative of low algal abundance and density in the area (see Triantaphyllou *et al.*, 2005).

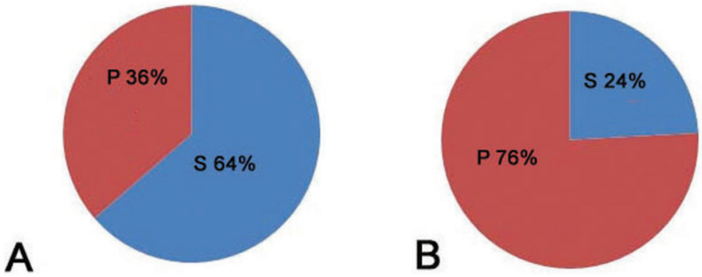

Fig. 10: Trophic structure of the whole ostracod fauna taking into consideration the number of taxa (A) and specimens (B). P: Phytal taxa; S: sediment-dwelling taxa.

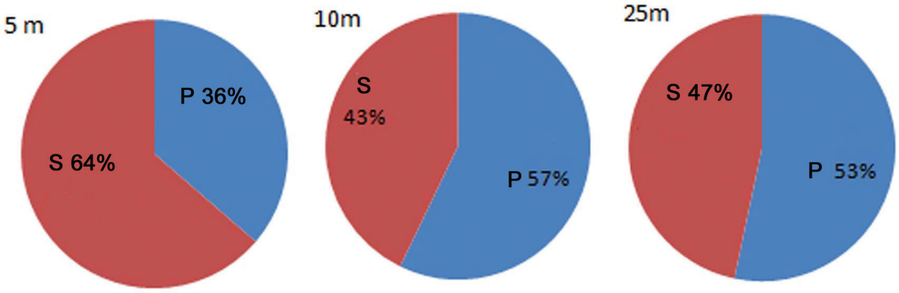

Fig. 11: Trophic structure of the ostracod fauna in the investigated *Cystoseira* communities, at 5, 10, and 25 m depth. P: Phytal taxa; S: sediment-dwelling taxa.

Discussion

Ostracods and foraminifera species found in the analysed samples, thrive in the present-day Mediterranean Sea (Cimerman & Langer, 1991; Sgarrella & Moncharmont Zei, 1993; Montenegro *et al.*, 1996; Horne *et al.*, 2001; Aiello & Barra, 2010; Mateu-Vicens *et al.*, 2010; Sciuto *et al.*, 2015, inter alias). Furthermore, the composition of the associations found in the investigated *Cystoseira* communities includes species known in other Mediterranean shallow-water bottoms dominated

In agreement with observations by Athersuch *et al.* (1989), ostracod associations consist of a mixture of species exhibiting different autoecological behaviours, including dominant infralittoral sediment-dwelling taxa (64%), that adapt to different sediment textures depending also on food availability, and typical shallow water phytal taxa (36%). Although only represented by nearly one half of the species found, phytal taxa (*sensu* Athersuch *et al.*, 1989) show high specimen abundances (76%) in the sampled stations. In contrast, the infralittoral sediment-dwelling species, although more numerous, are decidedly less abundant (24%). This structure fits well with direct observation of a vegetate bottom favouring the phytal taxa, and co-occurring sediment pockets and possible local sediment veneers trapped within the algal canopy, allowing the settlement of a certain number of sediment-dweller species, whose populations remain however scant. When associations from the CPA area are compared to those of SM and ST sites, the relative dominance of phytal taxa changes from a percentage of about 43 to a percentage of about 55, pointing to a major sediment input in the CPA area. It is noteworthy that, although the total number of species found in the two areas is roughly comparable (18 *vs.* 16 species, in CPA and SM+ST areas respectively) samples from the CPA sites show a mean specimen number per sample of 25, decidedly lower than that (nearly 47) found in the SM and ST sites. This suggests that environmental conditions are not particularly suitable for ostracods in the Punta Aguzza area.

Similarly to ostracods, foraminifera associations – which are characterised by the absence of *Amphistegina* species, the scantiness of symbiont-bearing species, and the high diversity and numerical relevance of small-sized herbivorous to detritivorous miliolids – point to a general unsuitability of the environment (see Triantaphyllou *et al.*, 2005). However, differences between the two investigated areas are not clearly supported by foraminifera associations. As expected for habitats hardly colonisable because of their high hydrodynamic energy, the analysed associations show a dominance of permanently motile foraminifera species exhibiting the D morphotype (Figs 6, 7). These species are considered by Mateu-Vicens *et al.* (2014) as opportunistic and stress-tolerant taxa, particularly adapted for nutrient-rich environments. The D morphotype also attains high dominances at specimen level (32-64% and occasionally even lower and higher percentages of 21% and 87%, respectively) in individual samples. When the D morphotype and the B morphotype – also considered as constituted by species able to live in stressful environments by Mateu-Vicens *et al.* (2014) – are treated together, values further rise ranging from 43 to 87% (and even lower and higher percentages of 33% and 100%, respectively). The dominance of temporarily to permanently motile species could be forced by the high energy of the environment which selects morphotypes able to move or rapidly re-attach after possible displacement. Nevertheless, no trend can be recognised either between the CPA and the SM/ST stations, or between stations from the three investigated *Cystoseira* communities, respectively at 5, 10, and 26 m depth (Fig. 11). However, it could be observed that a group of 7 species restricted to the CPA station includes 6 species expressing the D morphotype.

Some species were found only in the shallowest 5 m deep (*E. concameratus*, *F. marginata*) or in the 5 and 10 m deep (*P. mutabilis, Q. laevigata*) *Cystoseira* communities, whereas others were restricted to the 25 m (*A. elegans* and *Spiroloculina angulosa*) or to the 10 and 25 m (*Tretomphalus bulloides* and *Globocassidulina crassa*) *Cystoseira* communities. However, all these species are known to have larger distributions.

The sediment veneer occurring in some samples allowed a few species of ostracods to thrive inside, but was probably not enough for the settlement of typical sediment-dwelling ostracods *sensu* Athersuch *et al.* (1989). Agglutinated foraminifera are scarce or absent with only few specimens of *Textularia* species.

Dead specimens are extremely rare. This suggests a *post mortem* rapid displacement of the skeletons of dead specimens by the strong energy of longshore currents and storm waves, especially in autumn-winter seasons. The removal of epiphytic foraminifer skeletons from shallow water vegetate bottoms has already been reported for the Tunisian coast by Davaud & Septfontaine (1995). Displacement of biogenic (micro- and macrofaunas) as well as terrigenous components, can be very intense in shallow waters. In the Ciclopi Islands area biogenic and terrigenous particles removed from the *Cystoseira* habitat are partly entrapped in fissures between blocks but are often displaced along the shelf, where they add to autochthonous biogenic sediments. Valves and carapaces of epiphytic ostracods were largely reported from intermediate to deep shelf environments added to representatives of local biocoenoses (Sciuto *et al.*, 2015). This and further additions of biogenic material including bryozoans (Rosso *et al.*, 2014) and remains of other organisms such as serpulids, molluscs, brachiopods, and echinoderms to mid to deep shelf environments (e. g. Poursanidis *et al.*, 2016) points to the important role of the *Cystoseira* community in bioclastic sediment production.

Present results represent a first contribution to the knowledge of both ostracods and foraminifera thriving in the *Cystoseira* communities and a possible reference datum for future investigation of these associations in the Ionian Sea, as well as in other Mediterranean localities.

Acknowledgements

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