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Ocean Acidification alters the composition of decapod crustacean communities associated to *Posidonia oceanica* beds

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Abstract

Ocean Acidification (OA) produces manifest changes in the species assemblages of stable marine ecosystems, although the general levels of biodiversity may be partially conserved. In the case of decapod crustaceans, that represent an interesting taxon because it reacts both to direct and indirect effects of OA, a lowering of pH induces clear changes in the structure of species assemblages. In this study we collected decapod crustaceans at two sites at low pH located at Castello d'Ischia, two control sites at normal pH located at Castello d'Ischia and one external control site. The results confirm that a lower biodiversity characterizes the acidified zones over the year and indicate that key species, normally very abundant in normal conditions all over the year, exhibit impoverished populations associated to the *Posidonia oceanica* beds off the island of Ischia.

Keyword - *Posidonia oceanica,* Ocean Acidification, decapod crustaceans

Riassunto

L'acidificazione degli oceani altera la composizione delle comunità di crostacei decapodi associate ai letti di *Posidonia oceanica*

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Introduction

Everyday anthropogenic pressures trigger clear and deep degradation of marine ecosystems and of the services they should provide (Zunino et al., 2019), causing alterations of planktonic and benthic communities all over the world (Harfoot et al., 2014). Ocean Acidification (OA) is one of the most important and recent effects of anthropogenic activities and it is influencing all marine ecosystems, at any latitude and in every continent. Due to CO2 emissions produced in the last century (Campbell & Fourqurean 2013) and of those still influencing our atmosphere, the pH of oceans is likely to drop 0.3–0.4 units over the next century (Caldeira & Wickett 2005; Pachauri et al., 2014). Some ecosystems are more resistant to OA than others; however, besides the direct effects on individual species (e.g., on calcareous algae or calcified organisms, as corals), several indirect effects of OA are impacting marine ecosystems and changing their structure and functioning, including the biodiversity trends, both locally and at larger scales (Munday et al., 2009; Zupo et al., 2015; Zupo et al., 2016). Consequently, the species assemblages of "stable" ecosystems may be dramatically modified due to direct effects of OA on the physiology of organisms and to the drastic modification of interspecific relationships, as the plant-animal relationships and the chemical communications among organisms. In fact, although some organisms may adapt to O.A. (Tynyakov et al., 2015; Porzio et al., 2017) (e.g., by tuning the expression of genes involved in the calcification process), they might not survive to changed trends of chemical signal communications (Dixson et al., 2010; Zupo et al., 2014).

Decapod crustaceans are quite stimulating organisms to investigate the changes of biodiversity triggered by O.A., because they have an external exoskeleton partially or totally calcified (according to the species) that is directly impacted by the pH of the medium, and they also demonstrated prompt responsiveness to chemical signals produced by various plant items, that may be interrupted or disturbed by the acidification processes (Mutalipassi et al., 2020). In this study we compare the species assemblages of decapod crustaceans in various sites in the island of Ischia taking into account both stations at normal pH (about 8.1) and stations located in a special area influenced by volcanic emissions that trigger a drastic drop of the pH.

Material and Methods

Study area

Various sites in the island of Ischia have been considered for collections of decapods. In particular, we sampled in two acidified stations, S2 and N3 (Fig. 1) located at the Castello d'Ischia and characterized by pH of 7.83 and 7.09, respectively (Fig. 1). We compared the species assemblages with

Figure 1. Study area. LA, Lacco Ameno Lacco d'Ischia.

those of sites at normal pH named S1 and N1, both at pH of 8.14, located in the area of Castello d'Ischia (Fig. 1). In addition, we set a control area in a zone far from the CO^2 vents, located in Lacco Ameno d'Ischia (LA in Fig.1)

Collection of specimens

Specimens of decapod crustaceans were collected in three periods of the year (*i.e.*, March, July and November, corresponding to winter, summer and fall, in the considered areas) using an airlift sampler operated in a surface area of 1 square meter by divers, at depths of 5 meter, over the leaves of *Posidonia oceanica*. In particular, 4 replicate samples (indicated as a, b, c, d) were collected in each site, at each season. Samples collected were immediately fixed in 70% alcohol and conserved for taxonomic identification under the optical microscope.

Statistical treatment of the data

All the collected specimens were identified, where possible, at the species level, and their numerical abundance was recorded for each site and each season. Some graphical representations were obtained to show the trends of abundance according to seasons and sites, with special attention to the differences observed at the two pH levels considered. We performed a t-test analysis to establish the significance of differences between samples at different pH.

Results

The species assemblages characterizing the acidified site are reported in table 1. The species assemblages characterizing the normal pH sites are reported in table 2. Both tables are offered integrally, to allow further computations and hypothesis testing by other authors. In total, 25 species were collected all over the year in the acidified

Table 1: Number of individuals of each species of decapods collected in the acidified sites (S2, N3) in four replicates (a, b, c, d) in three months

	Acidified sites																							
	March								July								November							
	S2				N3				S2				N3				S2				N3			
	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d
Acanthonyx lunulatus											2			1			1							
Achaeus gracilis															1								1	
Alpheus dentipes		1			1	5	1				1		4	8	1	1	1	8	2		9	1	16	19
Athanas nitescens	3	1	4	7	5	8	6	3	7		4	2	2	12	4		26	17	26	20	28	9	67	75
Brachynotus sexdentatus										2	2		4	4		1	3							
Calcinus tubularis																								
Cestopagurus timidus	5	5	3	4	1	16	7	4	3	1	2	4	7	21				6	5	11	7	2	6	8
Dromia personata	1																							
Ebalia edwardsi																								
Ebalia nux																								
Eriphia verrucosa														1										
Eualus pusiolus														1										
Galathea bolivari							1	2															1	
Hippolyte inermis		1				1								1		7	12	12	4	5	7	8	13	11
Hippolyte leptocerus							1	1		1	1		1		1	1	17	16	20	12	9	7	13	12
Ilia nucleus																								
Inachus phalangium																								
Liocarcinus arcuatus																								
Lysmata seticaudata																	1	2						
Microcassiope minor																								
Munida curvimana																								
Munida sp														2										
Pagurus anachoretus																								
Palaemon serratus																			1					
Parthenope massena																								
Pasiphaea multidentata																								
Philocheras fasciatus														1										
Pilumnus hirtellus	1								1	1	2							3		1			1	5
Pisa carinimana												1												
Pisa nodipes														1										
Pisa tetradon																								
Pisidia bluteli			1	1						1		1					2	1	1					
Processa canaliculata																								
Scyllarus sp.							1																	
Sicyonia carinata																			1					
Sirpus zariquieyi																								
Thoralus chranchii	2	1	1		1		2				1		1				2	2	1	1	1	1		3
Upogedia deltaura																								
Xantho pilipes														5										1
Xantho poressa						3	1	1	1						1			1	1	1	1	1		4

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Table 2: Number of individuals of each species of decapods collected in the control sites (S1, N1 and Lacco Ameno) in four replicates (a, b, c, d) in three months

	Control sites																																			
	Marzo												Luglio												Novembre											
	S1				N1				LA				S1				N1				LA				S1				N1				LA			
	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	c	a	b	c	d
Acanthonyx lunulatus																																				
Achaeus gracilis			1					1								1					1			1	1		2	1		1			1	2	2	3
Alpheus dentipes			4	2		2	3			1	1	2		1			3	3	2	1	2			1	1			9	6	6	8	1	7	5	4	11
Athanas nitescens		5	4	2	4	3	7	15	16	13	4	2	5	32	1	6	3	4	8	10	9	4		13	17	26	2	24	11	20	27	9	45	29	28	58
Brachynotus sexdentatus					1								1	1	3	1			1	1																
Calcinus tubularis									3	1				7	1		1	2	2							1		1	1	1					1	1
Cestopagurus timidus	26	9	41	11	8	10	26	36		31	32	45	55	118	16	18	16	17	18	87	12	4	8	19	18	11	14	39	41	27	27	18	54	58	89	102
Dromia personata																															1					
Ebalia edwardsi										2		1											1	1											2	1
Ebalia nux																					1															
Eriphia verrucosa																																				
Eualus pusiolus																							1													
Galathea bolivari						1	3	6			2	2		2			1	5	6	4	2	1	1	2	1			3	4	3	10	2	1	2	5	7
Hippolyte inermis						1				1			2		1	2					3	2	2	1	8	6	3	1	13	3	1	11	4	2	9	4
Hippolyte leptocerus		1									1	1	10						4		1	2			5	3	1	4	5	4	3	2	12	4	4	22
Ilia nucleus			1										1																							
Inachus phalangium																																			1	
Liocarcinus arcuatus																										1										
Lysmata seticaudata	1															1																				
Microcassiope minor													1																							
Munida curvimana													1																							
Munida sp																																				
Pagurus anachoretus	1																																			
Palaemon serratus																																				
Parthenope massena																															1					
Pasiphaea multidentata													1																							
Philocheras fasciatus												1	1											1			1									
Pilumnus hirtellus	2		2				1	1	1	1		1	5	3	1	6										6	4	7			1	1	5		3	2
Pisa carinimana																																				
Pisa nodipes			1																																	
Pisa tetradon																1																	2			
Pisidia bluteli							2	2		1	1			7		1		2		1	1				1			1		1	5	1	1		2	
Processa canaliculata																		2		1									1	1		1				
Scyllarus sp.			1																																	
Sicyonia carinata																																				
Sirpus zariquieyi																																		1		
Thoralus chranchii		2	1		1	1	3	4		3	2	1	4	1		4		6		3						3	2	2	4	7	10	6	7		7	11
Upogedia deltaura													1																							
Xantho pilipes													2	2					1	1							1									2
Xantho poressa							2	3				1						1								1	1		1		2		1		1	1

sites, while 34 species of decapods were collected in the sites at normal pH (Fig. 2). In the acidified sites we recorded 12, 19 and 17 species in March, July and November, respectively. Alternatively, the "normal pH" site exhibited 20, 18 and 20 species in March, July and November, respectively. The differences in alpha diversity measured in sites at different pH were significant. The species assemblages also significantly differed between the different acidified stations but not among the normal pH sites.

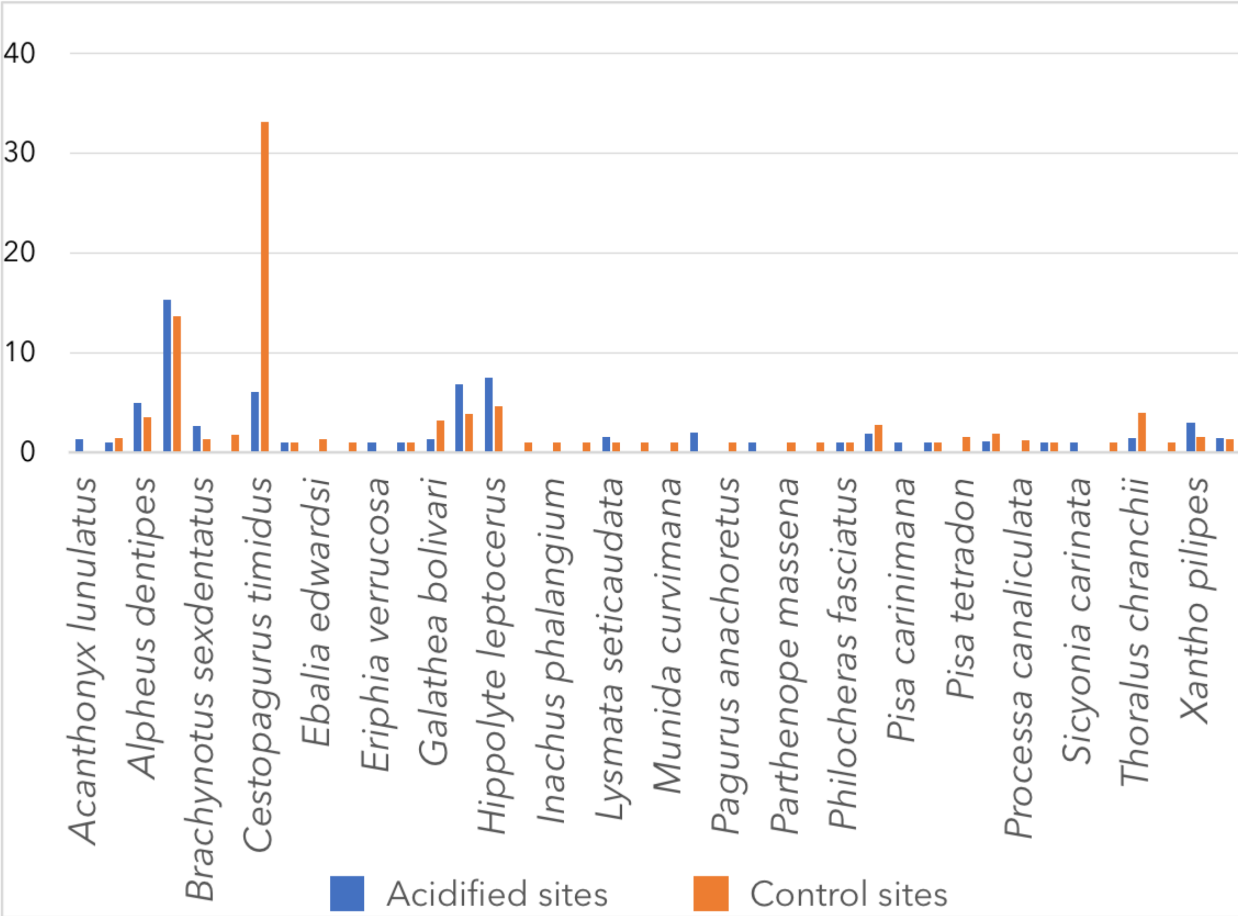

Figure 2: Averages of numerical abundances of decapod species in sites at normal pH and acidified ones.

Discussion

Ocean acidification produces clear shifts in the assemblages of decapod crustaceans and a general lowering of biodiversity, in the stations affected by low pH. Key species characterizing *P. oceanica* meadows in normal conditions (Mazzella et al., 1989), as *Cestopagurus timidus* (averaging at 33 individuals per square meter in each month of the year) and *Athanas nitescens* (averaging at 14 individuals per square meter in each month) (Tab.3) are replaced by other species more tolerant to O.A. in the acidified sites, and a general flattening of the abundances of species is observed at lower pH. Further analyses will be possible using the tables contained in this article, to test various hypotheses on the effects of O.A. on the species assemblages of future oceans in the world.

Table 3: Distribution of species in acidified and control areas and their preferences for low or normal pH.

Acid-preferring species	**Average acidified sites**	**Average control sites**	**Average control-acid**
Munida sp	2,00	0,00	-100,00
Acanthonyx lunulatus	1,33	0,00	-100,00
Eriphia verrucosa	1,00	0,00	-100,00
Palaemon serratus	1,00	0,00	-100,00
Pisa carinimana	1,00	0,00	-100,00
Sicyonia carinata	1,00	0,00	-100,00
Neutral species			
Brachynotus sexdentatus	2,67	1,29	-34,94
Xantho pilipes	3,00	1,50	-33,33
Hippolyte inermis	6,83	3,81	-28,41
Hippolyte leptocerus	7,53	4,68	-23,32
Lysmata seticaudata	1,50	1,00	-20,00
Alpheus dentipes	4,94	3,58	-15,89
Athanas nitescens	15,27	13,71	-5,41
Xantho poressa	1,45	1,36	-3,23
Dromia personata	1,00	1,00	0,00
Eualus pusiolus	1,00	1,00	0,00
Philocheras fasciatus	1,00	1,00	0,00
Pisa nodipes	1,00	1,00	0,00
Scyllarus sp.	1,00	1,00	0,00
Achaeus gracilis	1,00	1,38	16,13
Pilumnus hirtellus	1,88	2,79	19,61
Pisidia bluteli	1,14	1,88	24,26
Galathea bolivari	1,33	3,17	40,74
Thoralus chranchii	1,43	3,96	46,96
Basic preferring species			
Cestopagurus timidus	6,10	33,17	68,95
Ebalia nux	0,00	1,00	100,00
Ilia nucleus	0,00	1,00	100,00
Inachus phalangium	0,00	1,00	100,00
Liocarcinus arcuatus	0,00	1,00	100,00
Microcassiope minor	0,00	1,00	100,00
Munida curvimana	0,00	1,00	100,00
Pagurus anachoretus	0,00	1,00	100,00
Parthenope massena	0,00	1,00	100,00
Pasiphaea multidentata	0,00	1,00	100,00
Sirpus zariquieyi	0,00	1,00	100,00
Upogedia deltaura	0,00	1,00	100,00
Processa canaliculata	0,00	1,20	100,00
Ebalia edwardsi	0,00	1,33	100,00
Pisa tetradon	0,00	1,50	100,00
Calcinus tubularis	0,00	1,77	100,00

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