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ORIGINAL ARTICLE

Distribution patterns of the peracarid crustaceans associated with the alga *Corallina elongata* along the intertidal rocky shores of the Iberian Peninsula

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Abstract Spatial patterns of intertidal peracarids, associated with the alga *Corallina elongata*, were studied along the whole Iberian Peninsula. A total of 28,215 specimens were collected, comprising 78 different species (57 amphipods, 16 isopods, 4 tanaids and 1 cumacean), most of them with Atlantic-Mediterranean distribution (60%) and only 9% of Mediterranean endemics. Gammarids were dominant in abundance and number of species, representing more than 70% of the total peracarids. The most common species collected during the present study were the caprellid *Caprella penantis*, the gammarids *Hyale schmidti*, *Hyale stebbingi*, *Jassa* cf. *falcata* and *Stenothoe monoculoides*, the isopod *Ischyromene lacazei* and the tanaid *Tanais dulongii*. Caprellids and tanaidaceans presented their highest populations in the stations of the Strait of Gibraltar, whereas isopods were more abundant in Atlantic stations. Univariate analyses did not reflected differences in number of species, abundance and Shannon-Weaver diversity between Mediterranean and Atlantic. However, cluster analyses and Whittaker index, as measure of ß-diversity, showed a different species composition between Mediterranean and Atlantic and a replacement of species along the coast, especially at the Strait of Gibraltar. The turnover mainly affected species of the same genera, probably related with sympatric speciation. CCA and BIO-ENV analyses showed high correlations between environmental measures (especially conductivity) and peracarid distribution. Mediterranean species tolerated higher values of conductivity and temperature, while Atlantic species were associated with stations characterized by higher oxygen concentrations.

Keywords Peracarida · Iberian Peninsula · Intertidal · *Corallina elongata* · Biogeography

Introduction

Understanding assemblages of organisms is based on the quantitative description of patterns of distribution and abundance of species (Andrew and Mapstone 1987; Underwood et al. 2000), which has become one of the main challenges that studies on biogeography have to face nowadays (Pereira et al. 2006). The borders in an ecological level are often attributed to climatic conditions (Repasky 1991; Wardell-Johnson and Roberts 1993) or antagonistic relationships of competition and predation (Hersteinsson and McDonald 1992). Likewise, food selection and habitat complexity may also play an important role in distribution and abundance of marine organisms (Duffy and Hay 1991; Edgar and Robertson 1992).

Crustaceans exhibit one of the highest ranges of morphological diversity. Of these, it is believed that approximately 40% of all belongs to the group Peracarida (Kaestner 1980). Most peracarids are bottom-dwelling animals, either infaunal or epifaunal; they have a wide variety of feeding habits, i.e. surface deposit feeding, filter feeding, carnivory, omnivory and even foraminiferivory (Gudmundsson et al. 2000; De Broyer et al. 2003; Riisgard and Schotge 2007; Krapp et al. 2008; Guerra-García and Tierno de Figueroa 2009), and changes in food supply may influence the distribution of the species and the diversity

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patterns in the benthic environment. Furthermore, peracarids are being studied as bioindicators, since they have shown to be good indicators of environmental changes (Conradi and López-González 2001; Guerra-García and García-Gómez 2001; Ohji et al. 2002; Guerra-García and García-Gómez 2004; Dauvin and Ruellet 2007; Guerra-García et al. 2009a).

Given that this group lacks pelagic larvae and their capacities for long-distance movement are limited in adults, the studies on biogeography focused on this group have been numerous in recent years (e.g. Chavanich and Wilson 2000; Thiel 2002; Castellanos et al. 2003; De Broyer et al. 2003; Chiesa et al. 2005; Winfield et al. 2006; Myers and Lowry 2009). Nevertheless, research has not been so intensive in the Iberian Peninsula, and the knowledge in this field is still fragmentary (Bellan-Santini and Ruffo 1998; Guerra-García et al. 2009b, c, d) and mainly focused on the Strait of Gibraltar (Conradi et al. 1997; Castelló and Carballo 2001; Guerra-García and Takeuchi 2002). However, there has been a slight increase in the interest of this region during the last decade (e.g. Ballesteros 1988; Cruz et al. 2003; Pereira et al. 2006; Guerra-García et al. 2010). The Iberian Peninsula is located in the southwest of Europe and is the westernmost of the three major southern European peninsulas. Its coasts are washed by the Mediterranean on the eastern side and Atlantic on the northern and western side, converging at the Strait of Gibraltar.

Corallina elongata (hereafter *C. elongata*) is a macroalga belonging to the family Corallinaceae (Rhodophyta). This species is widely distributed, occurring not only all along Mediterranean (Flores-Moya et al. 1989; Conde et al. 1996; Bárbara and Cremades 1996; Babbini and Bressan 1997) and Atlantic (Guiry 1977; Neto 1994; Araujo et al. 2009), where it has been extensively reported, but also in the Pacific (Abbott 1999; Lee 2008). It is a whitish-pink to reddish-lilac calcified algae, with articulated fronds and fish-bone-like arrangement. Its axis is compressed and repeatedly pinnate from discoid base. Coralline algae can be considered as ecosystem engineers, since they can modify the environment by providing shelter from desiccation stress, wave action and predation, enriching biodiversity within its structure (Jones et al. 1994; Daleo et al. 2006). In extreme environments, intertidal coralline algal turfs ameliorate hard physical conditions, allowing the presence of many fauna that otherwise would not dwell at this level (Bertness et al. 2006). *Corallina elongata* was selected in this study, since it is one of the dominant macroalgae along the intertidal ecosystems of the whole Iberian Peninsula (Pérez-Cirera and Maldonado 1982; Guerra-García et al. 2006), and it was present in all sampling stations selected for the present work. Studies on biogeography of macrofauna associated with *Corallina* worldwide are scarce (Dommasnes 1969; Fernández and Niell 1987; Bitar 1984; Ballesteros 1988; Kelaher et al. 2001; Kelaher 2002; Kelaher and Castilla 2002; Kelaher et al. 2003; Bertness et al. 2006; Bussell et al. 2007; Liuzzi and López-Gappa 2008; Guerra-García et al. 2009b), especially in the Iberian Peninsula.

The main aim of this study was to demarcate the distribution and abundance patterns of benthic peracarids associated with the alga *C. elongata* in the intertidal zone along the whole coast of the Iberian Peninsula, and explore the relationship with some environmental variables such as oxygen concentration, turbidity, temperature, pH and conductivity

Materials and methods

The present study encompassed the whole coasts of the Iberian Peninsula (Spain and Portugal) (Fig. 1). Nineteen stations were selected in order to cover the greatest range of natural environmental conditions (Fig. 1). We chose relatively undisturbed enclaves with low human pressure to avoid the effect of anthropogenic influence on the natural biogeographical and ecological patterns of species.

Sampling was conducted in summer 2008 (June, July and August). The following environmental parameters were measured "in situ" at each sampling site: water temperature, pH, conductivity, dissolved oxygen and turbidity. Temperature and oxygen concentration were measured with an oxymeter CRISON OXI 45; pH and conductivity were measured using a conductivimeter-pHmeter CRISON MM40, and finally turbidity was measured in nephelometric turbidity units (ntu) using a turbidimeter WTW 335 IR. The seaweed *C. elongata* was

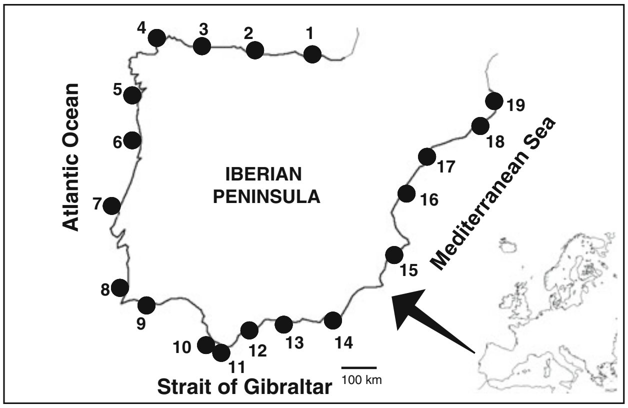


Fig. 1 Study area showing the sampling station. Ogella (*1*), Oyambre (*2*), Cetarea (*3*), Baleo (*4*), Cabo Silleiro (*5*), Labruge (*6*), Playa Azul (*7*), Vale dos Homens (*8*), Castelo (*9*), Bolonia (*10*), Isla de Tarifa (*11*), Torreguadiaro (*12*), Cerro Gordo-Herradura (*13*), Cabo de Gata (*14*), Cala del tío Ximo (*15*), Benicassim-Oropesa (*16*), Torrent del Pi (*17*), Cala de Sant Françesc (*18*), L'Estartit (*19*)

selected as substrate, and three replicates (quadrats 20 × 20cm) were sampled in each station. *Corallina elongata* was distributed along the low intertidal level and sublittoral in most of stations, and the intertidal belt was selected for this study. The surface was scrapped, and the seaweed and associated fauna were collected. The samples were fixed in ethanol 80%, brought to laboratory and sieved using a mesh size of 0.5 mm. Peracarid crustaceans were sorted and identified to species level. Volume of *C. elongata* of each replicate was estimated as the difference between the initial and final volume when placed into a graduated cylinder with a fixed amount of water (see Pereira et al. 2006). Dry weight was also measured (after 24 h at 70°C). To estimate the cover of *C. elongata* in each locality, we used five random quadrats of 50 × 50 cm subdivided with thick fishing line into 25 square units of 10 × 10 cm. The presence/absence of the species was recorded for each unit, and data were expressed as cover percentage (mean ± SD of the 5 replicates).

Species richness (*S*), abundance (*N*), Shannon-Weaver diversity (*H*') and Pielou's evenness (*J*) were measured for each station. Possible differences in these parameters between Mediterranean and Atlantic stations were tested by one-way ANOVA, after verifying normality using the Kolmogorov–Smirnov test and the homogeneity of variances using the Levene test. To explore the species replacement along the Atlantic and Mediterranean gradients, the Whittaker index (Whittaker 1972) was calculated as measure of ß-diversity. The affinities among stations based on peracarid data were measured through cluster analysis using UPGMA method, based on the Bray-Curtis similarity index. The relationships between environmental measures and peracarid assemblages were studied by Canonical Correspondence Analysis (CCA) and BIO-ENV. Multivariate analyses were carried out using the PRIMER package (Clarke and Gorley 2001) and the PC-ORD programme (McCune and Mefford 1997), whereas for univariate analyses the SPSS programme was used.

Species were classified in geographical distribution groups (see also López de la Cuadra and García-Gómez 1994; Conradi and López-González 1999; Guerra-García et al. 2009b). For the present study, five groups were considered: I (Endemic Mediterranean), II (Atlantic and Mediterranean), III (Atlantic, absent in Mediterranean) IV (Atlantic, Mediterranean and Indo-Pacific) and V (Cosmopolitan)

Results

Abiotic data and abundance patterns of *C. elongata*

Regarding the measures taken for the environmental parameters, it was observed that the Mediterranean stations showed higher values of temperature and conductivity, as well as lower values of oxygen concentration and turbidity than the stations along the Atlantic coast (Fig. 2). Oppositely, pH remained rather unalterable among the surveyed sites, with an average of 8.16, ranging from 8 (station 6) to 8.33 (station 10). Furthermore, it was also seen that temperature was negatively correlated with oxygen ($r = -0.69$, $P < 0.01$) and turbidity ($r = -0.54$, $P < 0.05$) and positively with conductivity ($r = 0.73$, $P < 0.01$). Station 6 showed abnormal characteristics when compared with the rest of the stations, with the maximum value of turbidity and minimum value of conductivity and temperature.

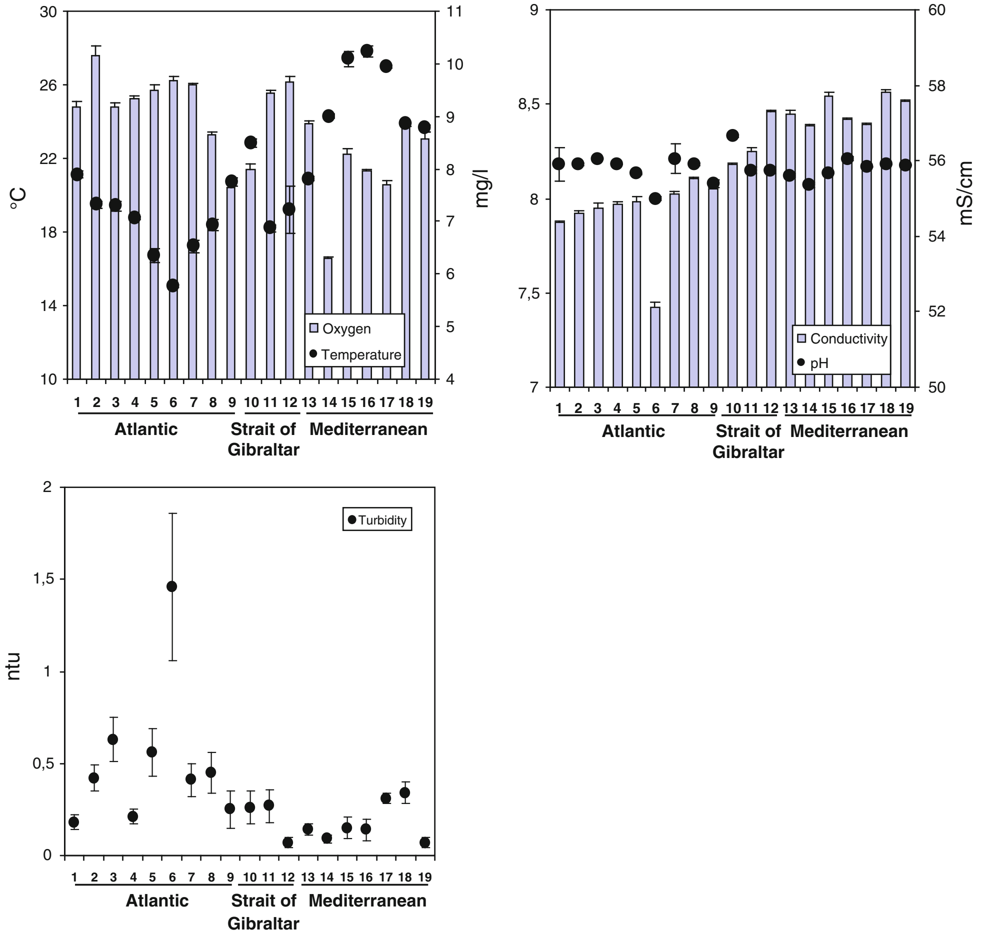
When focusing on the abundance patterns of *C. elongata*, the data obtained showed a negative correlation between cover of the seaweed and seawater temperature ($r = -0.491$, $P < 0.05$); thus, cover of *C. elongata* on Mediterranean stations was in general below 30%, while cover on the Atlantic stations was closer to 50% (Fig. 3). Biomass, however, did not show significant difference between the Mediterranean and Atlantic, ranging approximately from 500 to 1,500 g/m^2. Therefore, although Mediterranean intertidal was characterized by lower cover percentages of *C. elongata*, the patches in which the alga was present showed a similar biomass to Atlantic stations. Furthermore, values of volume of *C. elongata* were significantly correlated with dry weight ($r = 0.95$, $P < 0.001$, $n = 19$).

Peracarid assemblages

A total of 28,215 specimens were sorted and examined, out of which more than 87% were crustaceans of the superorder Peracarida, followed in importance by molluscs and annelids. In this study, 78 different species of peracarids were identified: 57 species of amphipods, 16 isopods, 4 tanaids and 1 cumacean (Table 1). Gammarids were the dominant group in the majority of stations, representing more than 70% of the total peracarids and 61% of the total macrofauna on average, except on stations 7 (Playa Azul) and 11 (Tarifa) where isopods and caprellids were, respectively, the dominant groups. The most common species collected during the present study were the caprellid *Caprella penantis*, the gammarids *Hyale schmidti*, *Hyale stebbingi*, *Jassa* cf. *falcata, Parajassa pelagica* and *Stenothoe monoculoides*, the isopod *Ischyromene lacazei* and the tanaid *Tanais dulongii*. Gammarids did not show any particular preference for either Atlantic or Mediterranean, being equally distributed along the whole Peninsula, whereas caprellids and tanaidaceans presented their highest populations in the stations of the Strait of Gibraltar, and isopods were more abundant in Atlantic stations (Fig. 4).

In connection with the descriptive parameters, the number of species per station ranged from 15 (station 9) to

Fig. 2 Abiotic variables measured in each station (Mean ± SD)



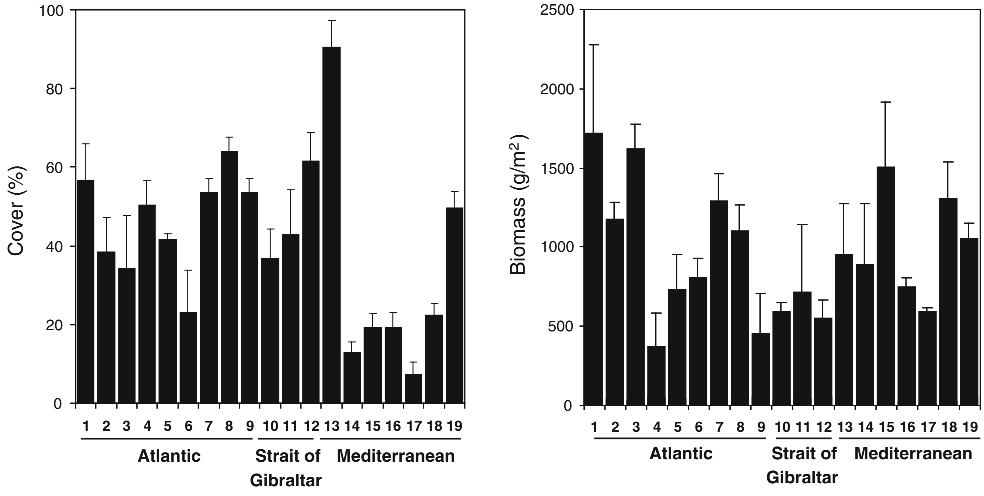


Fig. 3 Cover percentage and biomass of *C. elongata* (Mean ± SD) in each station

38 (station 8) (Fig. 5). The highest abundances were measured in the Atlantic stations 2, 6 and 8. Anyway, no significant differences of species richness, abundance and Shannon diversity were found between Mediterranean and Atlantic. Only the Pielou index was significantly higher in the Mediterranean ($F = 5.3$, $P < 0.05$). The Whittaker index, measured between contiguous stations, showed higher values around the Strait of Gibraltar, indicating that the highest replacement of species corresponded to this area (Fig. 6)

Table 1 Abundance (ind/m^2) of the peracaridean species associated with *Corallina elongata* in the Iberian Peninsula

	BG	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
AMPHIPODA:																				
Caprellidea:																				
Caprella acanthifera Leach, 1814	II						101-500		1-10		11-50	51-100								
Caprella danilevskii Czerniavskii, 1868	IV			11-50																
Caprella grandimana Mayer, 1882	II										1001-5000	>5000	1001-5000	1-10	101-500					
Caprella hirsuta Mayer, 1890	II													1001-5000	11-50	101-500	51-100	501-1000	101-500	101-500
Caprella liparotensis Haller, 1879	II													51-100	11-50	51-100	101-500	1-10	101-500	51-100
Caprella penantis Leach, 1814	V	1001-5000	1001-5000	51-100	101-500	11-50	>5000	1-10	51-100		11-50	1-10	1001-5000	51-100						
Pseudoprotella phasma Montagu, 1804	II			1-10								1-10								
Gammaridea:																				
Ampelisca serraticauda Chevreus, 1888	II										101-500									
Ampelisca sp	-				1-10															
Ampelisca unidentata Schellenberg, 1936	II									11-50										
Amphilochus neapolitanus Della Valle, 1893	IV			101-500					51-100			51-100							51-100	
Ampithoe ferox (Chevreux, 1902)	II								51-100				11-50	11-50						
Ampithoe gammaroides (Bate, 1856)	II								101-500			11-50								
Ampithoe helleri G. Karaman, 1975	II	11-50			11-50	101-500		101-500	101-500	11-50	1-10									
Ampithoe ramondi Audouin, 1826	V									51-100	11-50		101-500	51-100					51-100	
Ampithoe riedli Krapp-Shickel, 1968	I						1-10				101-500	51-100	101-500	51-100	101-500	101-500	51-100	101-500	51-100	51-100
Ampithoe spp	-					11-50	11-50	1-10	101-500	101-500	101-500	51-100	101-500	101-500	101-500	51-100	11-50	1-10	51-100	11-50
Apherusa mediterranea Chevreux, 1911	II										11-50	101-500	1-10							1-10
Apherusa jurinei (Milne-Edwards, 1830)	II		501-1000	501-1000	101-500	101-500	501-1000		501-1000	101-500	11-50									
Apocorophium acutum (Chevreux, 1908)	V										1-10						51-100			
Dexamine spiniventris (Costa, 1853)	IV								1-10	11-50										
Dexamine spinosa (Montagu, 1813)	IV			101-500	1-10	11-50	11-50		1-10											
Elasmopus cf. Pectenicrus (Bate, 1862)	IV			11-50																
Elasmopus pocillimanus (Bate, 1862)	IV	1-10					11-50						51-100	51-100	1-10	101-500	101-500	11-50	11-50	11-50
Elasmopus rapax Costa, 1853	V														11-50					
Elasmopus vachoni Mateus & Mateus, 1966	II	1-10			11-50	11-50		11-50	51-100	51-100	51-100	101-500	101-500	101-500	51-100	101-500	101-500	51-100	51-100	101-500
Elasmopus spp	-	11-50		11-50	51-100		11-50	11-50	101-500		11-50		101-500	1001-5000	501-1000	501-1000	101-500	101-500	101-500	51-100
Gammaropsis maculata (Johnston, 1828)	II				11-50															
Gammarellus homari (Fabricius, 1779)	III			11-50																
Guernea coalita (Norman, 1868)	II							1-10	51-100		11-50									
Hyale camptonyx (Heller, 1866)	IV		11-50																	
Hyale perieri (Lucas, 1849)	II	51-100	1-10					101-500				11-50			101-500	101-500	11-50			
Hyale pontica Rathke, 1837	II	501-1000	501-1000	101-500		101-500	1001-5000	501-1000	1-10			11-50			101-500				11-50	
Hyale schmidti (Heller, 1866)	II	1001-5000	1001-5000	1001-5000	101-500	1001-5000	501-1000		101-500	1-10			501-1000	1001-5000	51-100	101-500	51-100	51-100	>5000	501-1000
Hyale stebbingi Chevreux, 1888	II	101-500	11-50	1-10			11-50	1001-5000	501-1000	1001-5000	1001-5000	1001-5000	101-500	1-10	1001-5000	1001-5000	1001-5000	1001-5000	101-500	501-1000
Jassa cadetta Krapp, Rampin & Libertini, 2008	I														101-500	101-500	1001-5000	101-500	501-1000	501-1000
Jassa dentex Chevreux & Fage, 1925	II	11-50	51-100	1-10	1-10								11-50							
Jassa cf. falcata (Montagu, 1808)	II	1001-5000	>5000	>5000	1001-5000	11-50	1001-5000		501-1000		11-50		501-1000							
Jassa marmorata Holmes, 1903	V															101-500				1-10
Jassa ocia (Bate, 1862)	II										11-50				1-10	11-50				
Lembos cf. spiniventris (Della Valle, 1893)	I																			1-10
Lembos sp	-					51-100	11-50						1-10	11-50				11-50		
Lembos websteri Bate, 1857	II		1-10		11-50						101-500		1-10	1-10						
Lysianassa costae (Milne-Edwards, 1830)	II										1-10									
Maera inaequipes (Costa, 1857)	IV													1-10						
Melita hergensis Reid, 1939	II								501-1000											
Microdeutopus chelifer (Bate, 1862)	II				101-500	11-50			101-500	101-500	51-100									
Microdeutopus sp	-																	101-500		
Microprotopus maculatus Norman, 1867	II	1-10							1-10											
Parajassa pelagica Leach, 1814	II	51-100	>5000	1001-5000	101-500	101-500	>5000	501-1000	101-500		1-10									
Peltocoxa damnoniensis (Stebbing, 1885)	III						1-10		1-10											
Pereionotus testudo (Montagu, 1808)	II															1-10				
Podocerus variegatus Leach, 1814	II		501-1000	101-500	51-100	51-100	101-500		101-500				51-100	11-50	11-50	101-500	1-10	51-100	11-50	11-50
Stenothoe dollfusi Chevreux, 1887	I															1-10				
Stenothoe gallensis Walker, 1904	IV												1-10							
Stenothoe monoculoides (Montagu, 1813)	IV	51-100	51-100	101-500	101-500	101-500	101-500		>5000	101-500	501-1000	1001-5000	501-1000	11-50					11-50	
Stenothoe tergestina Nebeski, 1881	II	11-50	101-500	501-1000			11-50		1-10		1-10	1-10	501-1000	501-1000	101-500	501-1000	101-500	101-500	101-500	1001-5000
CUMACEA:																				
Cumella limicola Sars, 1879	I										1-10									
ISOPODA:																				
Cymodoce truncata Leach, 1814	II		101-500	11-50				11-50	101-500											
Dynamene edwardsii (Lucas, 1849)	II								101-500	11-50		101-500							1-10	
Dynamene torelliae Holdich, 1968	I								11-50											
Dynamene sp	-		101-500	101-500	101-500	1-10	101-500		1001-5000	11-50	11-50		1-10							11-50
Gnathia sp	-								1-10		11-50		1-10		11-50	1-10		11-50		
Idotea baltica (Pallas, 1772)	V						1001-5000	501-1000	101-500											
Idotea granulosa Rathke, 1843	III		501-1000	51-100		101-500	101-500	1-10	101-500											
Idotea pelagica Leach, 1815	II	51-100	1-10		101-500			101-500	51-100											
Ischyromene lacazei Racovitza, 1908	II	501-1000	1001-5000	101-500		51-100	1001-5000	>5000	1001-5000		101-500	51-100	1001-5000	501-1000	101-500	101-500	501-1000	501-1000	101-500	101-500
Jaeropsis brevicornis Koehler, 1885	II		51-100	11-50				1-10			101-500		51-100	101-500	51-100	11-50	101-500	11-50		101-500
Janiropsis breviremis (Sars, 1883)	II								51-100					11-50				11-50		
Munna cf. limicola Sars, 1866	II		51-100						11-50	101-500	1-10	1-10								
Munna sp	-																			1-10
Paranthura costana Bate & Westwood, 1868	II	1-10	11-50	51-100	11-50				1-10					1-10						11-50
Synisoma lancifer (Miers, 1881)	II		11-50	1-10			1-10													
Synisoma sp	-				1-10															
TANAIDACEA:																				
Leptochelia dubia (Krøyer, 1842)	V		1-10								1-10			1-10		1-10				
Synapseudes shiinoi Riggio, 1973	II														1-10	11-50				
Tanais dulongii (Audouin, 1826)	IV		11-50		11-50	51-100	1-10	11-50	51-100	1001-5000	1001-5000	1-10	101-500	51-100	501-1000	51-100	101-500	101-500		11-50
Zeuxo normani (H. Richardson, 1905)	IV													1-10						

●	1-10
●	11-50
●	51-100
●	101-500
●	501-1000
●	1001-5000
●	>5000

BG Biogeographical group (see Fig. 9)

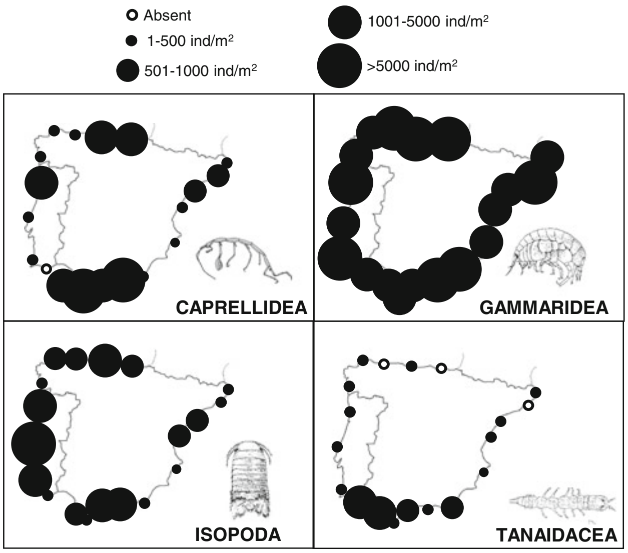
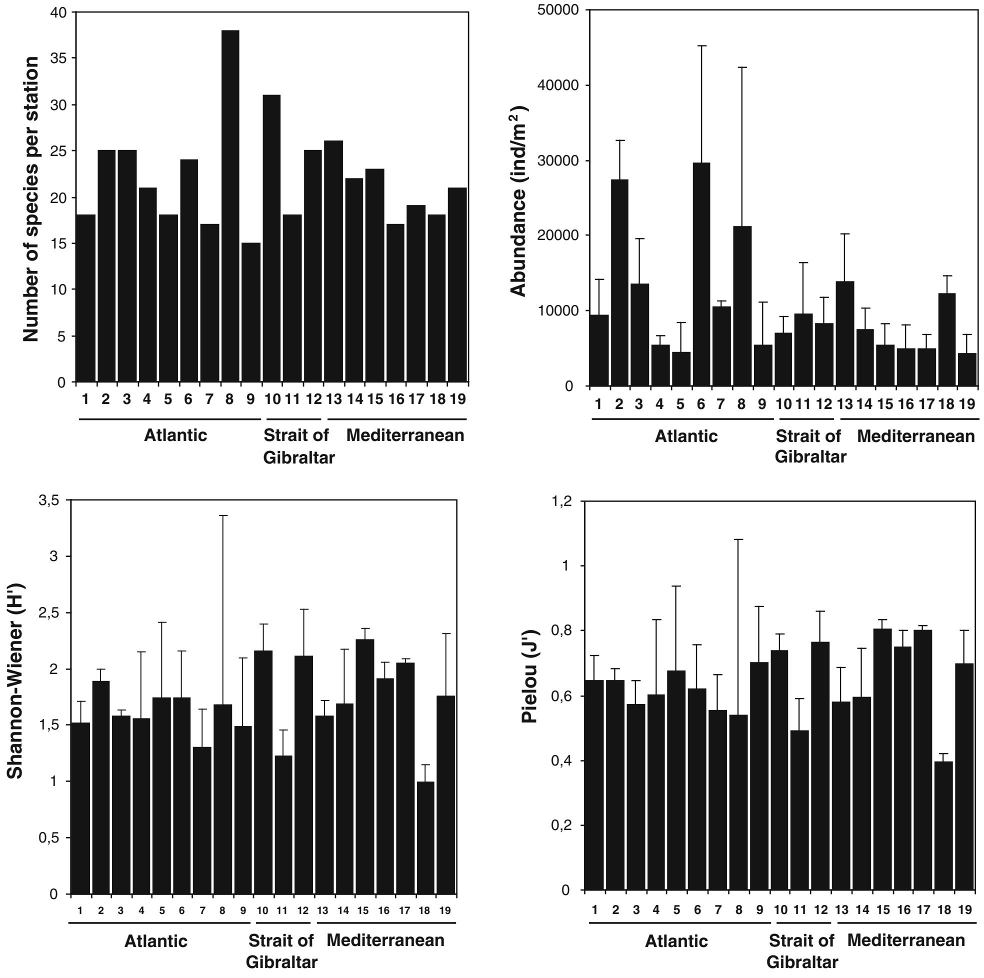


Fig. 4 Abundance patterns of the peracarids associated with *C. elongata*

When examining the cluster based on Bray-Curtis similarity, two main groups can be differentiated. One group included stations 1–8 (Atlantic) and the other one clustered stations 9–19 (Mediterranean and Strait of Gibraltar together) (Fig. 7). Figure 8 and Table 2 show the results of the Canonical Correspondence Analysis (CCA). First axis, which absorbed 17.9% of total variance, was significantly correlated with temperature, conductivity, turbidity and oxygen, whereas the second axis mainly correlated with the algal cover. Species such as the gammarids *Ampelisca unidentata*, *Elasmopus vachoni*, *Ampithoe riedli*, *Jassa ocia* or *Elasmopus rapax*, isopods such *Gnathia* sp., or tanaids such as *Synapseudes shinoi* were associated with stations characterized by higher temperature and conductivity. *Caprella penantis*, *Idotea* species, *Gammaropsis maculata*, *Gammarellus homari*, *Hyale pontica* among others were found in oxygenate waters with high levels of turbidity. The highest correlation in the BIO-ENV was measured for conductivity ($r = 0.55$, $P < 0.05$) as unique

Fig. 5 Descriptive parameters of the peracarid community measured in each station. Number of species is measured per station (considering the three replicates). Abundance, Shannon diversity and Pielou evenness are mean ± SD of the three replicates



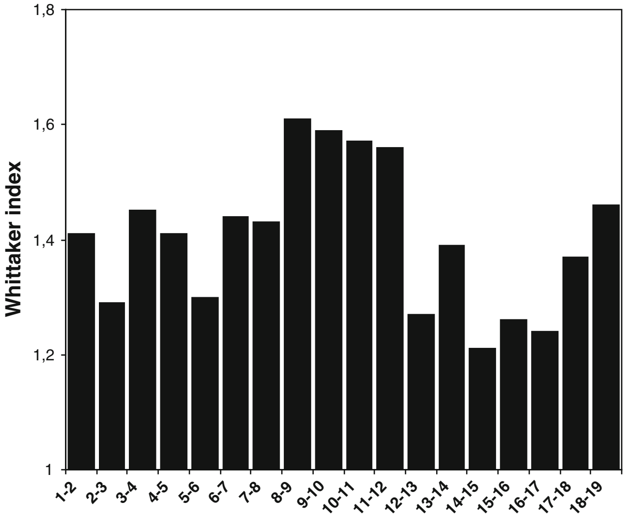


Fig. 6 Whittaker index measured between pairs of contiguous stations

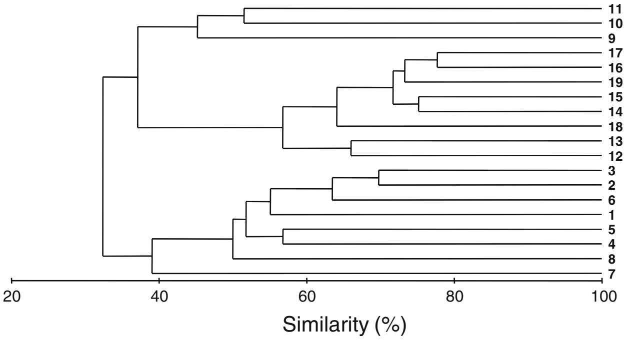


Fig. 7 Cluster analysis based on the peracarid composition of each station

variable, which was the best to explain peracarid distribution. All the remaining combinations of variables showed lower correlation values.

The classification of species in geographical distribution groups (Fig. 9; Table 1) shows that most species have an Atlantic-Mediterranean distribution (60%). Only the gammarids *Gammarellus homari* and *Peltocoxa damnoniensis*, and the isopod *Idotea granulosa* are restricted to the Atlantic. In connection with the endemic species, only these species *Ampithoe riedli*, *Jassa cadetta*, *Lembos spiniventris*, *Stenothoe dollfusi*, *Cumella limicola*, and *Dynamene torelliae* were Mediterranean endemisms.

Discussion

The peracarid crustaceans constitute the dominant group of epiphytic macrofauna in the intertidal region (Guerra-García et al. 2010) and are useful as bioindicators (e.g. Conradi et al. 1997; Sánchez-Moyano and García-Gómez 1998; Guerra-García and García-Gómez 2001; Ohji et al. 2002; Dauvin and Ruellet 2007). On the other hand, *C. elongata* is one of the most important algae in the intertidal ecosystems (Pérez-Cirera and Maldonado 1982; Guerra-García et al. 2006). Consequently, the study of the peracarids associated with *C. elongata* in the Iberian Peninsula is especially relevant.

The most relevant aspect of this study lies on the faunistic contribution: seventy-eight species of peracarids have been identified during the present study, most of them widely distributed along the Atlantic and Mediterranean, and patterns of abundance along the whole Iberian Peninsula are also included (see Table 1). The percentage of Mediterranean endemics was very low (9%). These results agree with Guerra-García et al. (2009b), who studied the peracarids associated with *C. elongata* in the Strait of Gibraltar and found 40 species in the 25 selected stations. In the present study, we found 42 species in the 3 stations located in the Strait of Gibraltar (see stations 10, 11 y 12 in Fig. 1) with similar biogeographical distribution. The percentage of Mediterranean endemics is very low (3–5% for the Strait and 9% if we consider the whole Iberian Peninsula) when compared to other studies (see Bellan-Santini and Ruffo 1998; Conradi and López-González 1999; Guerra-García and Takeuchi 2002). The low number of Mediterranean endemics found for peracarids associated with *C. elongata* (see also Guerra-García et al. 2009b) contrast with the 37% of endemic amphipods reported by Bellan-Santini and Ruffo (1998), even higher than the 26.6% calculated by Fredj et al. (1992) for all the Mediterranean fauna as a whole. Conradi and López-González (1999) also reported a high endemic benthic Gammaridea fauna (18.3% endemics) from Algeciras Bay (Iberian side of the Strait of Gibraltar). Guerra-García et al. (2009b) explained this low endemicity on the basis of the distribution of *C. elongata*, which is an unspecific substrate widely distributed along the Atlantic and Mediterranean intertidal ecosystems. The peracarid fauna associated with this alga seems to have a low endemic component, but a high percentage of lessepsian species (group IV) due to colonization in progress by Indo-Pacific elements via the Suez Canal.

Multivariate analyses based on peracarid abundance clearly showed two groups of stations (Mediterranean vs. Atlantic) with stations of the Strait of Gibraltar clustered together with Mediterranean stations. This pattern was also obtained for the caprellid community associated with the seaweed *Stypocaulon scoparium* (see Guerra-García et al. 2009d), so the present study also reflects that the fauna of the Strait of Gibraltar seems to be more similar to the Mediterranean than to the Atlantic. In any case, along the Iberian Peninsula, the Strait is the area with higher rates of

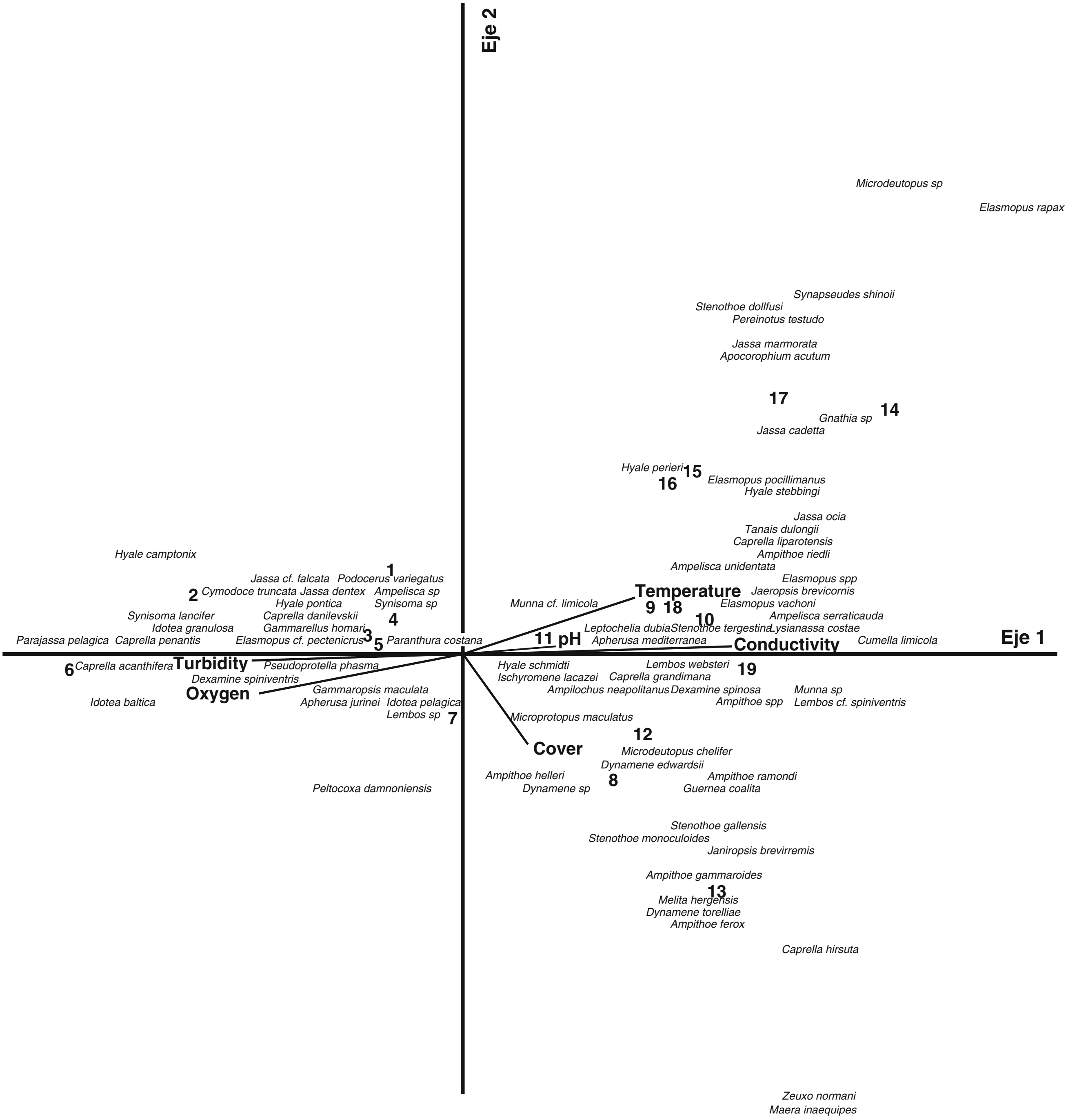


Fig. 8 Graph representation of the stations and caprellid species with respect to the first two axes of the Canonical Correspondence Analysis (CCA)

species replacement or turnover, as measured by the Whittaker index in the present study.

Among the physicochemical parameters, hydrodinamism and sedimentation rate are reported in literature as two of the most relevant factors to structure marine communities (Moore 1972; Dodds 1991; Gibbons 1988), together with temperature, conductivity, availability of food, predation and habitat structure (Duffy and Hay 1991; Dauby et al. 2001). In the present study, according to the CCA and BIO-ENV, conductivity was the variable which better explained peracarid distribution along the Iberian Peninsula. Mediterranean is characterized by higher conductivity and temperature and lower values of dissolved oxygen and turbidity. Tanaids showed preferences for Mediterranean stations, while isopods were more abundant in Atlantic stations. Amphipods did not show a clear

Table 2 Summary of the results of the CCA analysis

	Axis 1	Axis 2	Axis 3
Eigenvalue	0.63	0.41	0.29
Percentage of species variance	17.9	11.5	8.1
Correlation with environmental variables			
Temperature (°C)	−0.71***	−0.66**	0.55*
pH	–	–	–
Oxygen (mg/l)	−0.79***	−0.56**	–
Conductivity (mS/cm)	0.86***	–	0.6**
Turbidity (ntu)	−0.70***	–	–
C. elongata cover (%)	–	−0.87***	–

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$. See also Fig. 8

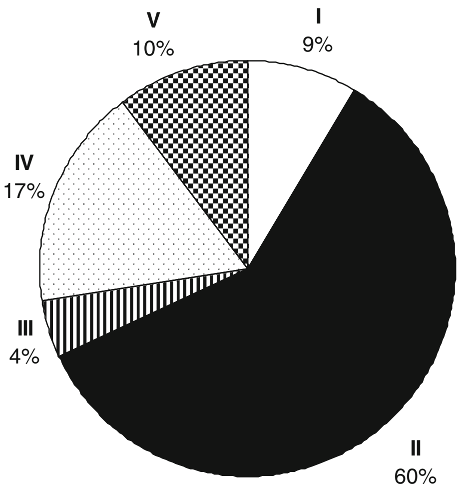


Fig. 9 Percentage of species in the zoogeographical groups considered. *I* (Endemic Mediterranean), *II* (Atlantic and Mediterranean), *III* (Atlantic, absent in Mediterranean) *IV* (Atlantic, Mediterranean and Indo-Pacific) and *V* (Cosmopolitan)

general pattern as a group, since different species showed distinct distribution pattern. The unusual conditions measured in station 6 (low conductivity and oxygen and high turbidity) could be related to rivers influence discharging fresh water. These conditions seem to be excellent for some species, such as *Parajassa pelagica*. On the other hand, species of the genus *Hyale* were the most abundant in the present study. In fact, the genus *Hyale* is well adapted to life among algae of the higher littoral levels (Tararam et al. 1986; Baldinger and Gable 1995).

In the present study, although there were no significant differences in the number of species and Shannon diversity between Atlantic and Mediterranean stations, some species are substituted by others along the Atlantic-Mediterranean axis. Most of the substitution events affect species of the same genera, probably related to sympatric speciation. Some examples are the substitution of the species *Jassa falcata* (Atlantic) by *J. cadetta* (Mediterranean), *Apherusa jurinei* (Atlantic) by *A. mediterranea* (Mediterranean), *Ampithoe helleri* (Atlantic) by *A. riedli* (Mediterranean) or *Stenothoe monoculoides* (Atlantic) by *S. tergestina* (Mediterranean). Nevertheless, there are other factors that could also affect, such as competition or facilitation among species. For example, Viejo and Arrontes (1992) showed that the feeding activity of the isopod *Dynamene bidentata* was beneficial for the amphipod *Hyale nilsonii*, by providing suitable feeding surface on *Fucus vesiculosus*. A similar interaction seems to occur also in Tarifa Island between *H. perieri*, *D. bidentata* and the alga *F. spiralis* (Guerra-García et al. unpublished data). On the other hand, the higher Pielou index measured in the Mediterranean is probably due to high abundance values of some species in Atlantic stations such as *Caprella penantis*, *Jassa falcata* and *Parajassa pelagica*.

During the last decade, changes in the species distribution in marine ecosystems due to the climatic change are increasing (Francour et al. 1994; Walther et al. 2002; Macdonald et al. 2005; Harley et al. 2006; Barber et al. 2008). Further studies are necessary to explore whether observed patterns of the peracarid species are strictly consequence of natural factors or are already affected by the climatic change.

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