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Vertical distribution and seasonality of peracarid crustaceans associated with intertidal macroalgae

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A B S T R A C T

Spatial patterns and seasonal fluctuations of intertidal peracarids from Tarifa Island, Strait of Gibraltar, were studied over a two-year period (December 2005–December 2007). A total of 25,749 individuals were collected, comprising 46 species. Amphipods were best represented in the total number of species (32) and individuals (89% of numerical abundance) followed by isopods (12 species and 11% abundance) and tanaids (2 species and 1%). The highest number of species was registered in intermediate levels (1–1.5 m) dominated by *Corallina elongata*, although the highest abundances of peracarids were associated to seaweeds of lower levels (0–1 m) such as *Gelidium corneum*, *Osmundea pinnatifida*, *Valonia utricularis* and a turf of *Caulacanthus ustulatus*. The most abundant peracarids, *Hyale stebbingi*, *H. schmidti*, *H. perieri*, *Stenothoe monoculoides*, *Caprella penantis*, *C. grandimana*, *Dynamene edwardsii* and *Ischyromene lacazei*, were present throughout the whole year during 2006 and 2007. The highest peracarid densities were measured in April–August coinciding with the highest development of seaweeds, just before the maximum values of water temperature measured at the end of summer. Multivariate analyses confirmed a clear zonation of algae and associated peracarids in a vertical gradient, which was maintained stable during the two-year study. Several physical and biological factors may regulate such patterns of peracarid abundance and future experimental studies are necessary to explore the importance of factors such as competition, predation or weather conditions.

1. Introduction

Seasonal variation is a major feature of the dynamics of rocky intertidal communities (Underwood, 1981; Arrontes and Anadón, 1990). Rocky intertidal zonation of marine animals and plants has been described classically by Lewis (1964) and Stephenson and Stephenson (1972) and many studies have shown that physical and biological factors have effects on such a pattern of abundance (see Chavanich and Wilson, 2000 for details). Zonation patterns of marine algae and marine invertebrates, especially mussels, barnacles, snails, and limpets, have been intensively studied (Chavanich and Wilson, 2000); however, only a few researchers have studied the zonation patterns of rocky intertidal peracarids (Tararam et al., 1986; Buschmann, 1990; Krapp-Schickel, 1993; Baldinger and Gable, 1995) and there is a lack of studies dealing with seasonal fluctuations of peracarids based on temporal series of data (Arrontes and Anadón, 1990; Chavanich and Wilson, 2000).

Peracarid crustaceans are among the most diverse and numerically dominant organisms of benthic faunas (e.g. Cunha et al., 1997; Dauby et al., 2001; Lourido et al., 2008; Moreira et al., 2008a, b) and play an important role in the structuring of benthic assemblages (Duffy and Hay, 2000). They are also important source of food for other benthic animals and fishes of commercial importance (McDermott, 1987; Beare and Moore, 1996; Woods, 2009) and are important contributors to benthic production (Mancinelli and Rossi, 2002). Many peracarid species are also good indicators of environmental conditions (Bonsdorff, 1984; Corbera and Cardell, 1995; Conradi et al., 1997; Sánchez-Moyano and García-Gómez, 1998; Gómez-Gesteira and Dauvin, 2000; Conradi and López-González, 2001; Ohji et al., 2002; Guerra-García and García-Gómez, 2001, 2004). In spite of their interest, the knowledge of peracarid crustaceans associated to algae along the coasts of the Iberian Peninsula is still scarce, and most of the research has been focused in the Strait of Gibraltar. Sánchez-Moyano and García-Gómez (1998) and Sánchez-Moyano et al. (2007) studied the whole crustacean community associated to *Stypocaulon scoparium* and *Caulerpa prolifera* respectively, from Algeciras Bay. Guerra-García et al. (2009) used the intertidal peracarids associated to the seaweed *Corallina elongata* to show that the north side of the Strait of Gibraltar is more diverse than the south side. Castelló and Carballo (2001) revised the isopod species inhabiting the Strait of Gibraltar, Sanz et al. (1994) studied the tanaids from Algeciras Bay, and Alfonso et al. (1998) used the cumacean community associated with *S. scoparium* as a bioindicator of environmental conditions. Several amphipod (gammarids and caprellids) studies have been also undertaken during the last decade in the Strait of Gibraltar (e.g. Conradi et al., 1997; Guerra-García, 2001; Guerra-García and Takeuchi, 2002; Guerra-García et al., 2000, 2001). Jimeno and Turón (1995) studied the

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ecological distribution of Gammaridea and Caprellidea from the northeast coast of Spain, and Pereira et al. (2006) studied the biogeographical patterns of intertidal peracarids, including isopods, tanaids and cumaceans, and their associations with macroalgal distribution along the Portuguese coast. However, information dealing with seasonal fluctuations and vertical distribution patterns of peracarids along the intertidal is extremely scarce in the Iberian Peninsula in general and the Strait of Gibraltar in particular. The Strait of Gibraltar is an important biogeographic zone in which faunas of the Mediterranean and the Atlantic, along one axis, and of Europe and Africa along the other, overlap (Guerra-García et al., 2009). It is a very important geographical–geological region formed in the final phases of the Pliocene period, being the boundary for the Mediterranean region (to the east), the Lusitanian region (to the northwest) and the Mauretanian region (to the southwest). The Spanish side of the strait is protected under the Straits Natural Park (Parque Natural del Estrecho) (Fig. 1) which was declared a protected area last 2003. It is a maritime–terrestrial park along 54 km of coastline in Southern Spain and includes highly diverse and structured marine communities (García-Gómez et al., 2003). Inside the Park, Tarifa Island is considered a marine reserve, and constitutes the most interesting enclave of the park regarding to the marine habitats. Tarifa Island is the southernmost point of Europe, just between the Mediterranean and Atlantic, with 21 ha and 2 km of coastline. Its unique biogeographical position, together with the substrate heterogeneity and the long-term military access restrictions has contributed to maintain the richest rocky shore intertidal ecosystems of Southern Spain (Guerra-García and García-Gómez, 2000).

Given that the main algae of the intertidal zone of the Strait of Gibraltar is perennial (see Guerra-García et al., in press), the present study deals with the following hypothesis: Are also the peracaridean species present during the whole year in the intertidal zone? Consequently, the main objectives of the present study were to characterize the composition, vertical distribution along the intertidal, and seasonal fluctuations of the peracarid fauna associated to seaweeds of a relatively pristine environment (Tarifa Island). We expect that the temporal and zonation patterns of peracarids would either reflect those of the macroalgae (i.e., substrate dominates) or not (other biotic or environmental factors are important). Furthermore, the data provided in this study may be used as a baseline for further, comparative studies.

2. Materials and methods

The study was conducted at the most southern point of Tarifa Island (Punta Marroquí, 36º00′00.7″N, 5º36′37.5″W) (Fig. 1). For this study, we selected a single site since a previous spatial study showed little variation in the peracarid fauna associated to algae along different sites of the whole Island (LBM, Laboratorio de Biología Marina, 2010). The width of the intertidal range in this location is 250 cm approximately and we considered 5 levels to establish the zonation of the intertidal algae and associated peracarids (level 1: from zero tidal level to 0.5 m; level 2: 0.5–1 m; level 3: 1–1.5 m; level 4: 1.5–2 m and level 5: 2–2.5 m) (Fig. 1). A ruler, a set square and a rope were used to establish the different heights. The first height was the zero tidal level and the process was continued until the vertical height of 2.5 m had been achieved, coinciding with the upper limit of the intertidal community (see also Fa et al., 2002; Guerra-García et al., 2006). In each height, three replicates (quadrats 20×20 cm) were sampled. The surface was scrapped and all macroalgae and associated fauna were collected. Samples were taken randomly every two months from the different intertidal levels (December 2005 to December 2007). The samples were fixed in 80% ethanol, brought to laboratory and sieved using a mesh size of 0.5 mm. Peracarids were sorted and identified to species level. The main seaweeds were also identified to species level and the volume of each species 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; Guerra-García et al., 2009). Dry weight of each seaweed was also measured (after 24 h at 70 °C). The abundance of crustaceans was expressed in number of individuals per m^2. In each sampling, water temperature and salinity were measured using a conductivimeter WTW LF-323.

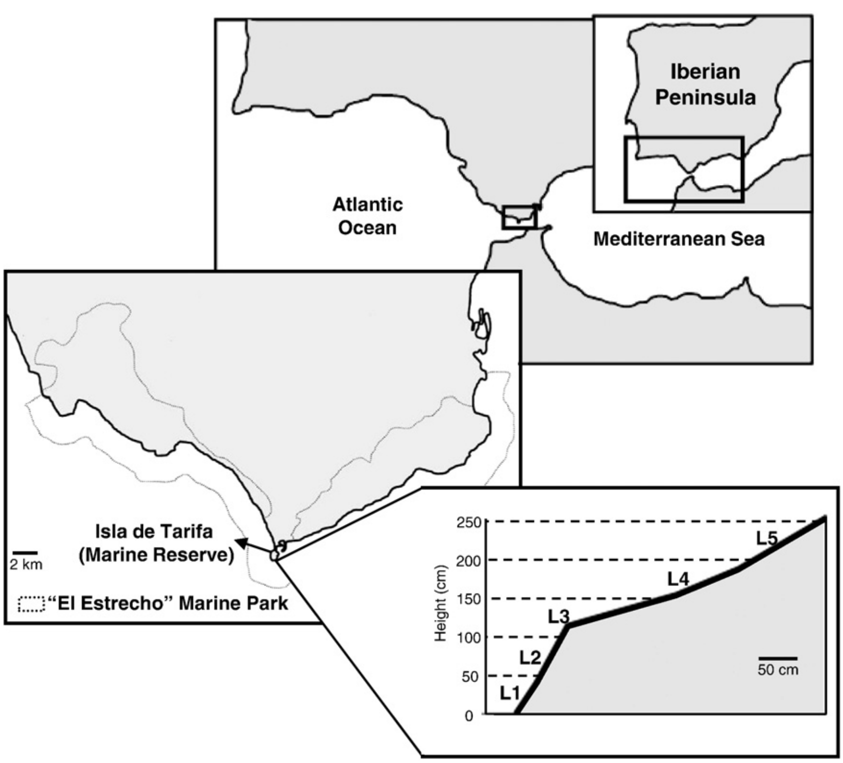

Fig. 1. Location of Tarifa Island in the Strait of Gibraltar and schematic diagram of the intertidal selected for the study.

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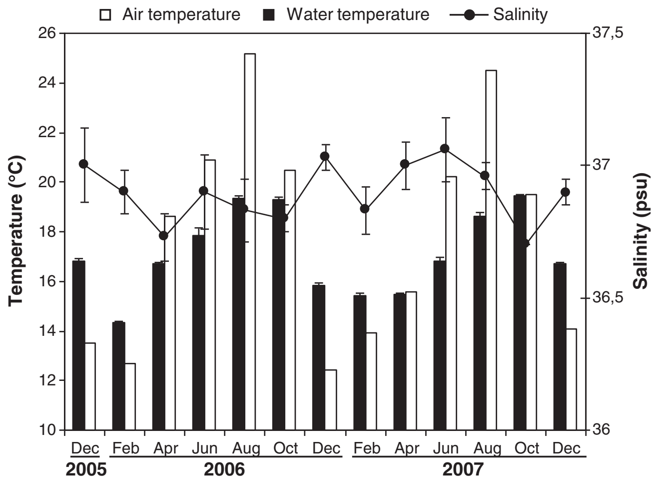

Fig. 2. Data (mean ± SD) of salinity and temperature in the study area.

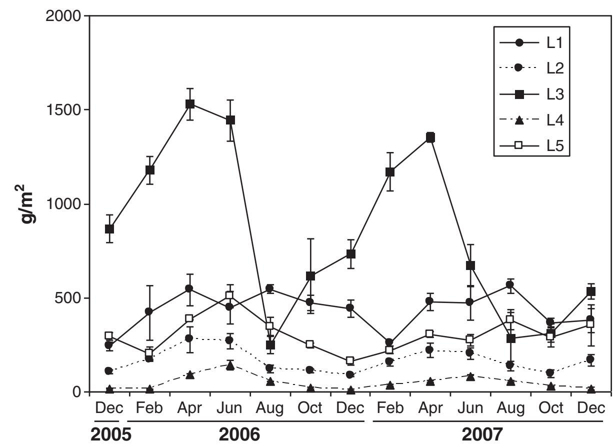

Fig. 4. Seasonal fluctuations of total algal biomass (g/m^2) in each intertidal level. Values are mean ± SD.

The affinities among samples based on the peracarid abundance were established through MDS analysis using the UPGMA (unweighted pair group method using arithmetic averages) and the Bray–Curtis similarity index. The relationships between peracarids and macroalgal composition were studied by Canonical Correspondence Analysis (CCA). Multivariate analyses were carried out using the PRIMER package (Clarke and Gorley, 2001) and the PC-ORD programme (McCune and Mefford, 1997).

3. Results

3.1. Salinity and temperature

Salinity values were rather constant (around 37 psu) along the two years of study, while water temperature ranged from 14.4 °C (February) to 19.4 °C (August and October) (Fig. 2). Maximum air temperatures were registered in August, while the maximum of water temperature was slightly delayed towards October. Both studied years showed a similar behaviour regarding with air and water temperature.

3.2. Spatial and seasonal patterns of seaweeds

Level 1 (0–0.5 m) was dominated by *Gelidium corneum* (Hudson) J. V. Lamouroux (= *G. sesquipedale*) and *Gymnogongrus patens* (Goodenough and Woodward) J. Agardh (Fig. 3). Level 2 (0.5–1 m) was mainly constituted by *Valonia utricularis* (Roth) C. Agardh, *Osmundea pinnatifida* (Hudson) Stackhouse (= *Laurencia pinnatifida*) and a turf of *Caulacanthus ustulatus* (Mertens ex Turner) Kützing and several species of *Gelidium*. Corallinacea algae (*C. elongata* J. Ellis and Solander and *Jania rubens* (Linnaeus) J.V. Lamouroux) were dominant in level 3 (1–1.5 m). *Ulva rigida* C. Agardh and *Chaetomorpha aerea* (Dillwyn) Kützing were collected from level 4, while *Fucus spiralis* Linnaeus was the only species found in level 5 (Fig. 3). More details of macroalgal assemblages can be found in Guerra-García *et al.* (in press). Maximum values of seaweeds' biomass were measured from April to August in the five levels considered (Fig. 4). Intermediate levels (2 and 3) showed the maximum biomass in spring, while belts 1, 4 and 5 showed maximum values in summer. Level 3, dominated by *C. elongata*, was the belt with higher values of biomass throughout the whole year except for August, when biomass of level 1 and 5 were higher (Fig. 4).

3.3. Vertical distribution and seasonal fluctuations of peracarid fauna

A total of 25,749 individuals were collected, comprising 46 species of peracarids belonging to three orders: Amphipoda, Isopoda and Tanaidacea. Amphipods were best represented in the total number of species (32) and individuals (89% of numerical abundance) followed by isopods (12 species and 11% abundance) and tanaids (2 species and 1%). Among amphipods, gammarids were represented by 27 species

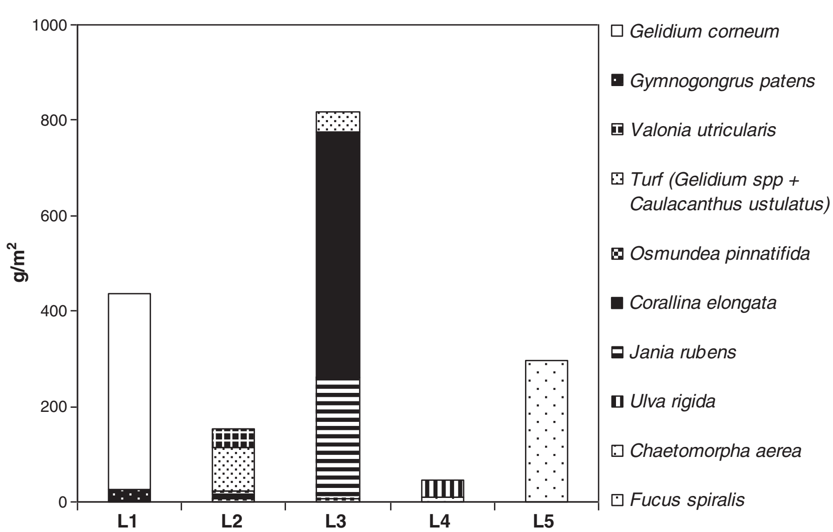

Fig. 3. Main seaweed species in each intertidal level and their mean biomass (g/m^2).

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and 15,688 specimens, while 5 species of caprellids with 7227 specimens were collected (Table 1).

The highest number of species (31) were found in level 3, followed by level 1 (27 species), level 2 (25 species), level 4 (23 species) and finally level 5 with only 9 peracarid species (Table 1). *Hyale* and *Caprella* were the most represented genera in the number of individuals during the whole study. Level 1 was dominated by the caprellid *Caprella penantis* and the gammarid *Hyale schmidti*, level 2 by the gammarid *Hyale stebbingi* and the isopod *Ischyromene lacazei*, level 3 by the caprellid *Caprella grandimana* and the gammarid *H. stebbingi*, level 4 again by *H. stebbingi*, and level 5 by *Hyale perieri*.

The most abundant species, such as *Hyale stebbingi*, *H. schmidti*, *H. perieri*, *Stenothoe monoculoides*, *C. penantis*, *C. grandimana*, *Dynamene edwardsii* and *I. lacazei*, were present throughout the whole year during 2006 and 2007 (Table 1). The higher abundances of peracarids were measured in April–August (Fig. 5) coinciding with the highest development of seaweeds by the end of spring (Fig. 4). Level 1 showed the maximum values from April to June, level 2 from June to August, levels 3 and 4 in June and level 5 in August. The abundance pattern was very similar with the two years of study, 2006 and 2007. The seasonal fluctuations, clearly evident in terms of abundance, were not so clear for the number of species (Fig. 5). The highest number of

Table 1
Abundance (ind/m^2) of the peracaridean species along the year and in each level of the intertidal.

	Seasonal fluctuations													Intertidal levels				
	2005	2006						2007										
	Dec	Feb	Apr	Jun	Aug	Oct	Dec	Feb	Apr	Jun	Aug	Oct	Dec	L1	L2	L3	L4	L5
Amphipoda																		
Gammaridea																		
Amphilochus neapolitanus Della Valle, 1893	1–50	1–50	1–50	51–500	1–50	1–50	1–50	1–50	1–50	1–50	1–50	1–50	1–50		1–50	51–500		
Ampithoe ferox (Chevreux, 1902)	1–50	1–50	1–50	51–500	51–500	51–500	1–50	1–50	1–50	51–500	51–500	1–50	1–50	1–50	51–500	1–50	1–50	1–50
Ampithoe ramondi Audouin, 1826	1–50		1–50	1–50									1–50	1–50				
Apherusa mediterranea Chevreux, 1911			51–500	1–50	1–50	1–50		1–50		1–50	1–50		1–50	1–50	1–50	1–50		
Atylus massiliensis Bellan-Santini, 1975												1–50					1–50	
Elasmopus pocillimanus (Bate, 1862)		1–50		1–50	1–50	1–50	1–50	1–50		1–50	1–50		1–50	1–50	1–50	1–50		
Elasmopus vachoni Mateus & Mateus, 1966		1–50	1–50	1–50	1–50				1–50	1–50	1–50			1–50	1–50	1–50		
Elasmopus spp	1–50	1–50	1–50	51–500	1–50	1–50		1–50	1–50	1–50	1–50	1–50	1–50	1–50	1–50	51–500		
Guernea coalita (Norman, 1868)					1–50				1–50							1–50	1–50	
Hyale camptonyx (Heller, 1866)			1–50	1–50						1–50					1–50	1–50		
Hyale cf. youngi Serejo, 2001			1–50	501–1000	1–50				1–50	51–500	1–50			1–50	1–50	51–500	1–50	
Hyale perieri (Lucas, 1849)	51–500	51–500	51–500	51–500	501–1000	501–1000	51–500	51–500	51–500	51–500	501–1000	51–500	51–500	1–50	1–50	51–500	51–500	501–1000
Hyale pontica Rathke, 1837	1–50	51–500	1–50	1–50		1–50	1–50	1–50	1–50	1–50	1–50		51–500	51–500	1–50	1–50	1–50	
Hyale schmidti (Heller, 1866)	1–50	1–50	51–500	501–1000	51–500	51–500	1–50	1–50	1–50	51–500	51–500	1–50	1–50	501–1000	51–500	1–50	1–50	
Hyale spinidactyla Chevreux, 1926		1–50	1–50			51–500	1–50	1–50	1–50	51–500	51–500	51–500	51–500	1–50	1–50	51–500	51–500	
Hyale stebbingi Chevreux, 1888	1001–5000	51–500	1001–5000	1001–5000	1001–5000	1001–5000	501–1000	51–500	501–1000	1001–5000	501–1000	501–1000	501–1000	1–50	1001–5000	501–1000	501–1000	1–50
Hyale sp	1–50	1–50			51–500								1–50		1–50	51–500	1–50	
Jassa cadetta Krapp, Rampin & Libertini, 2008	1–50	1–50	51–500	51–500	51–500	1–50	1–50	1–50	51–500	51–500	1–50	1–50	1–50	51–500	1–50	1–50		
Jassa dentex Chevreux & Fage, 1925			1–50	1–50	1–50		1–50		1–50	1–50				1–50				
Jassa ocia (Bate, 1862)						1–50	1–50			1–50					1–50			
Lysianassa costae (Milne-Edwards, 1830)	1–50		1–50													1–50		
Melita palmata (Montagu, 1804)	1–50	1–50		51–500	51–500	1–50	1–50	1–50	1–50	1–50	51–500	51–500	1–50		1–50	51–500	51–500	1–50
Microdeutopus chelifer (Bate, 1862)			1–50									1–50				1–50	1–50	
Microdeutopus sp					1–50	1–50				1–50						1–50	1–50	
Stenothoe dollfusi Chevreux, 1887					1–50									1–50				
Stenothoe monoculoides (Montagu, 1813)	51–500	51–500	51–500	51–500	1–50	1–50	1–50	51–500	1–50	51–500	51–500	51–500	51–500	1–50	1–50	51–500	1–50	
Stenothoe tergestina Nebeski, 1881	1–50	1–50	1–50			1–50		1–50	1–50	1–50			1–50	1–50	1–50			
Caprellidea																		
Caprella acanthifera Leach, 1814		1–50		1–50	1–50			1–50	1–50	1–50	1–50	1–50	1–50			1–50	1–50	
Caprella equilibra Say, 1818		1–50							1–50					1–50				
Caprella grandimana Mayer, 1882	501–1000	51–500	501–1000	501–1000	51–500	501–1000	51–500	51–500	501–1000	501–1000	51–500	51–500	501–1000		51–500	1001–5000	51–500	
Caprella liparotensis Haller, 1879			1–50	1–50										1–50				
Caprella penantis Leach, 1814	51–500	51–500	1001–5000	501–1000	501–1000	501–1000	1–50	1–50	51–500	1001–5000	501–1000	51–500	51–500	1001–5000				
Isopoda																		
Cirolana sp			1–50													1–50		
Cyathura carinata (Krøyer, 1847)				1–50												1–50		
Dynamene bidentata (Adams, 1800)			1–50	1–50	51–500	1–50	1–50	1–50	1–50		1–50	1–50	1–50			1–50	1–50	51–500
Dynamene edwardsii (Lucas, 1849)	51–500	51–500	1–50	51–500	1–50	51–500	51–500	51–500	1–50	51–500	1–50	1–50	51–500		1–50	51–500	51–500	1–50
Dynamene magnitorata Holdich, 1968	1–50				1–50										1–50		1–50	
Dynamene torelliae Holdich, 1968											1–50			1–50				
Gnathia sp	1–50			1–50				1–50								1–50	1–50	
Ischyromene lacazei Racovitza, 1908	51–500	51–500	51–500	51–500	51–500	51–500	51–500	51–500	51–500	51–500	51–500	51–500	51–500	51–500	501–1000	51–500	1–50	1–50
Jaeropsis brevicornis Koehler, 1885							1–50		1–50	1–50			1–50	1–50	1–50			
Janira maculosa Leach, 1814					1–50									1–50				
Paranthura nigropunctata (Lucas, 1849)		1–50	1–50	1–50			1–50	1–50		1–50		1–50		1–50		1–50	1–50	
Synisoma capito (Risso, 1826)				1–50										1–50				
Tanaidacae																		
Tanais dulongii (Audouin, 1826)	1–50	1–50	1–50	1–50	1–50	1–50	1–50	1–50	1–50	1–50	1–50	1–50	1–50	1–50	1–50	1–50	1–50	1–50
Zeuxo normani (H. Richardson, 1905)													1–50					1–50

Absent.
1–50 ind/m^2.
51–500 ind/m^2.
501–1000 ind/m^2.
1001–5000 ind/m^2.

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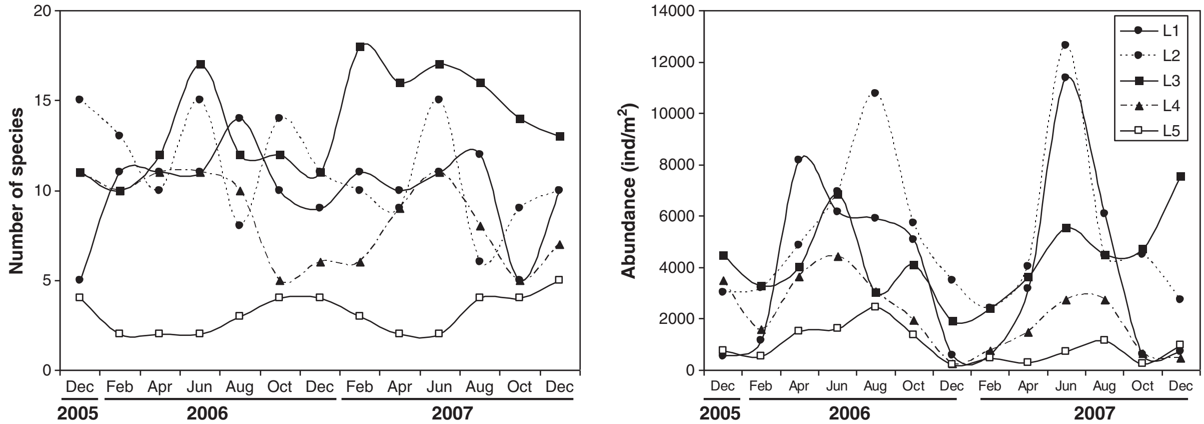

Fig. 5. Seasonal fluctuations of number of species and abundance of peracarids (ind/m^2) in each intertidal level. Values are mean ± SD.

species in level 1 was measured in August, in levels 2, 3 and 4 around June, but in level 5 the highest number of species was registered in December. The seasonal fluctuations for each level of the most common species are represented in Fig. 6. *H. perieri*, dominant in the level 5, but also frequent in level 4 and 3, showed the maximum densities in August in 2006 and 2007, while *H. schmidti,* especially abundant in levels 1 and 2, showed the highest abundances in June for 2006 and August for 2007. *Hyale stebbingi* showed a different pattern depending on the level; at level 2 maximum values were registered in summer (June–August) whereas at level 3 the maximum values were measured in winter (December–February). *C. penantis*, the dominant species of level 1, showed higher densities from April to August, while *C. grandimana*, the most common species of level 3, was more abundant in December. The abundance of *D. edwardsii* and *I. lacazei* did not show consistent seasonal patterns, showing maximal values either in summer or winter months (Fig. 6).

3.4. Multivariate analyses

The MDS analysis (Fig. 7) revealed that samples were grouped according to the different levels regardless of the period of the year, indicating a rather constant composition along the vertical gradient from level 1 (close to the subtidal zone) to level 5 (close to the supralittoral zone). Levels 1 and 5 presented the most different peracarid fauna, while levels 2, 3 and 4 presented more species in common, being closer in the MDS output. The axis 1 of the CCA analysis absorbed 20.2% of the total variance and negatively correlated mainly with *G. corneum* and *G. patens* (Fig. 8 and Table 2). Axis 1 separated level 1 from the remaining levels. Species such as *Caprella penantis*, *C. equilibra*, *C. liparotensis*, *Ampithoe ramondi*, *Stenothoe dollfusi*, *Dynamene torelliae*, *Janira maculosa* and *Synisoma capito* were strictly associated to the algae of level 1, revealing that they cannot tolerate a long emersion period. The second axis accumulated the 12.9% of the total variance and mainly correlated with *C. elongata* and *J. rubens*, separating the fauna associated to these algae in level 3 from the other levels.

4. Discussion

The results of the present study revealed that rocky intertidal peracarids were distributed along different levels, associated with several species of algae, and that the upper area of *F. spiralis* had fewer species and lower peracarid abundance than lower zones. A similar pattern has also been reported for rocky intertidal from Long Island Sound, Connecticut (Chavanich and Wilson, 2000). The intertidal seaweeds were present along the whole year in Tarifa Island, although maximum values of biomass were registered during late spring and the beginning of summer for most of the species. This fact probably determined that the associated peracarids were also present throughout the whole year with maximum densities from April to August. This seasonality is reported to be related to cyclic variations in environmental factors such as seawater temperature, day-length and wave action (Neto, 2000). Chavanich and Wilson (2000) also reported greater number of peracarid individuals from April to June; however, Delgado et al. (2009) reported the highest abundances in autumn–winter for a Mediterranean coastal lagoon, probably due to high environmental stress caused by the alternating inputs of marine water and fresh water, in addition to the eutrophication caused by human activities. The present study reflects that in Tarifa Island, Strait of Gibraltar, although higher water temperatures are measured by the end of summer, the peaks of algal biomass are reached earlier (from April to June) and many of the dominant seaweeds suffer an important decrease of biomass in August. This is probably due to extremely high air temperatures (occasionally over 40 °C) measured during some days of July and August (pers. observ.), which are surely critical for most of the macroalgae and consequently, also for peracarids. However, in spite of the important biomass decrease of level 3 algae (mainly *C. elongata*) in summer due to high temperatures, the density of peracarids (mainly represented by the caprellid *C. grandimana*) maintained high abundance values around 1000 ind/m^2. On the other hand, *G. corneum* (the main seaweed of level 1) showed similar biomass values throughout all the year round and peracarids associated, such as *C. penantis* showed important fluctuations with more than 5000 ind/m^2 in April and less than 200 ind/m^2 in December–February. These patterns indicate that peracarid density in the intertidal is not only influenced by the distribution of algae as substrate. Causes underlying the distribution patterns of organisms in intertidal rocky systems not only include the frond morphology (Tararam et al., 1986) but also the role of competition, herbivory and predation, settlement and recruitment, height above chart datum and gradient of wave exposure (see Araújo et al., 2005). Probably, the level 1, very close to the subtidal, is more exposed to wave action, and is therefore more affected by winter storms; this will have, in turn, a negative effect on the population of *C. penantis*, as reflected in the decrease of its biomass during the winter period. Oppositely, *C. grandimana* from level 3 was able to maintain high densities in the platforms of *C. elongata* since level 3 is not so affected by waves during winter storms. Furthermore, *C. penantis* is especially sensible to environmental stress (Guerra-García and García-Gómez, 2001), while *C. grandimana* seems to be more resistant (Baeza-Rojano et al., unpublished data).

In the present study, the gammarid *H. perieri* and the isopod *Dynamene bidentata*, although distributed also in intermediate levels, were more abundant in level 5, associated to *F. spiralis*. Both species are probably very resistant to desiccation during the low tide, and avoid competence or predation inhabiting this area. Furthermore,

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curiously, Viejo and Arrontes (1992) showed that the feeding activity of the isopod *D. bidentata* was beneficial for the amphipod *H. nilssoni*, 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*. According to McBane and Croker (1983) certain species used to live among algae of the superior levels to avoid predation, especially from fish and crabs. In fact, the genus *Hyale* is well adapted to life among algae of the higher littoral levels

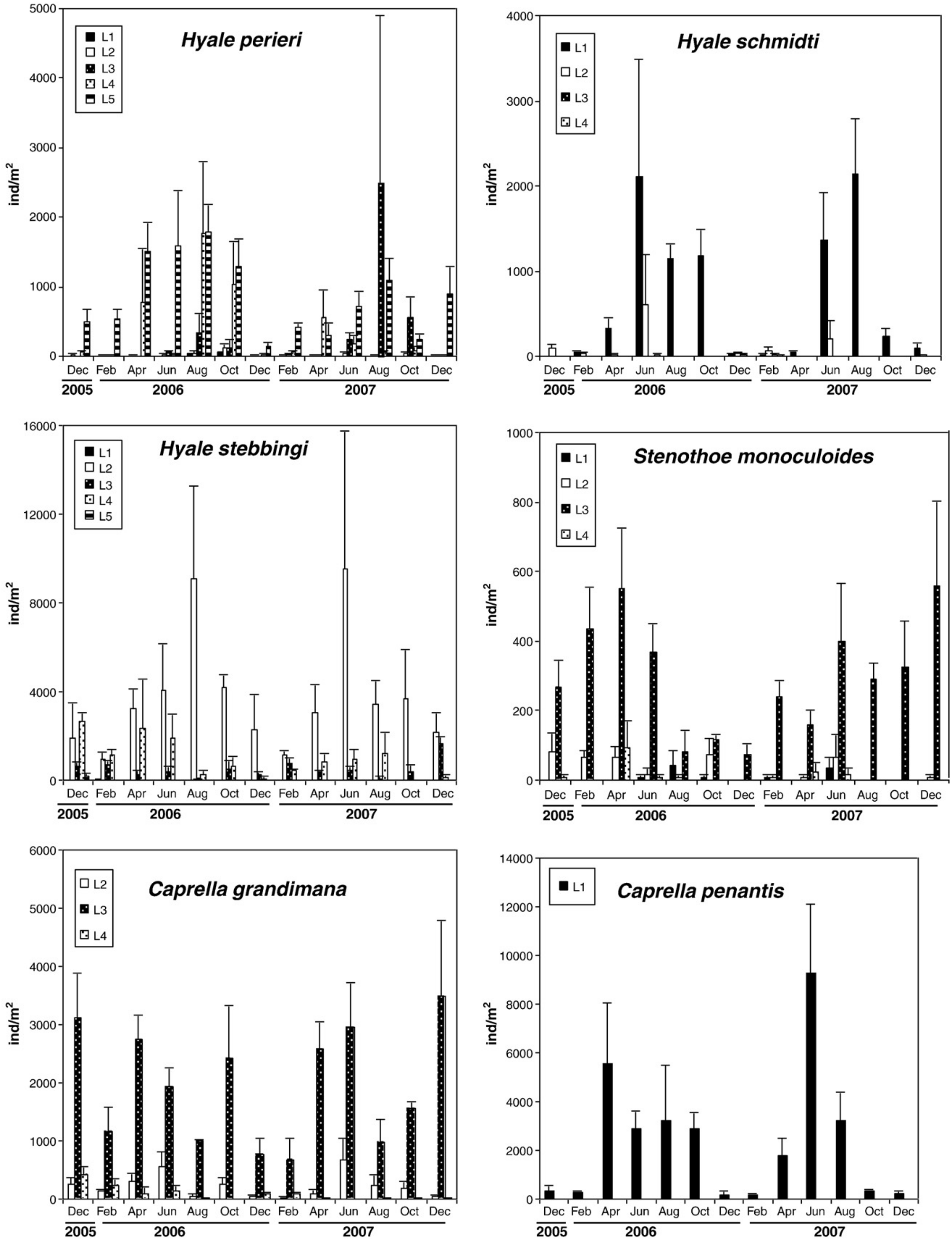

Fig. 6. Seasonal fluctuations of abundance (ind/m^2) of the dominant peracarids in the different levels in which each species was found. Values are mean ± SD.

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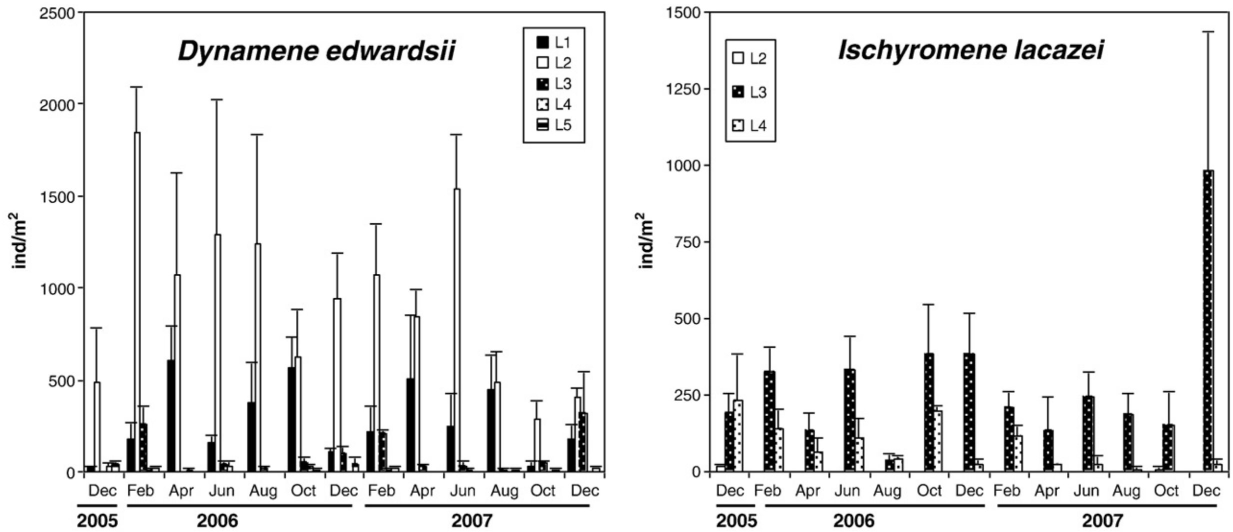

Fig. 6 (*continued*).

(Tararam et al., 1986; Baldinger and Gable, 1995). Chavanich and Wilson (2000) suggested that *H. nilssoni* could remain in the upper zone by using its ability to tolerate desiccation and thus avoiding competition for spaces or food sources in the lower zone.

At Tarifa Island, as reported above, most of the species showed their highest densities from April to August. In connection with the number of species per level, the highest value in level 1 was measured in August, in levels 2, 3 and 4 around June, but in level 5 the highest number of species was registered in December. Probably, this could be explained by the arrival in winter of some species from the adjacent level 4, where seaweeds almost disappear in winter; therefore, species might migrate from level 4 to level 5 where they would find more favourable conditions for survival. On the other hand, *H. stebbingi* showed a different behaviour depending on the level; at level 2 maximum values of abundance were registered in summer (June–August) whereas at level 3 the maximum values were measured in winter (December–February). Algae of level 3 (mainly *C. elongata*) suffer a strong decrease of biomass in August, while in winter the biomass is still relatively high. Oppositely, level 2 still maintain considerably biomass in August and probably *H. stebbingi* spread significantly at this level in detriment of level 3 during the summer season, affected directly by the seasonality of algal substrate. In fact, Ingólfsson and Agnarsson (2003) reported that many peracarid species moved away from their respective zones occupied at low tide, and that some species, such as the amphipod *Anonyx sarsi*, can be common at all levels during high tide, but absent from the intertidal at low tide. Mobile amphipods can combine the use of algal resources as a refuge with the use of food, because they can separate their use in space and time (Buschmann, 1990). In the present study conducted at Tarifa Island during low tides, we got a very stable composition in each level during the two years of study. In spite of the fact that some species showed marked seasonality in terms of abundance, the vertical zonation was maintained throughout the whole year. The stability of the peracaridean assemblages composition through the year had been shown previously for soft bottom communities (Moreira et al., 2008a, b) but little had been explored for rocky shores.

Regarding the biogeographical patterns of intertidal peracarids occurring with dominant macroalgal species, Guerra-García et al.

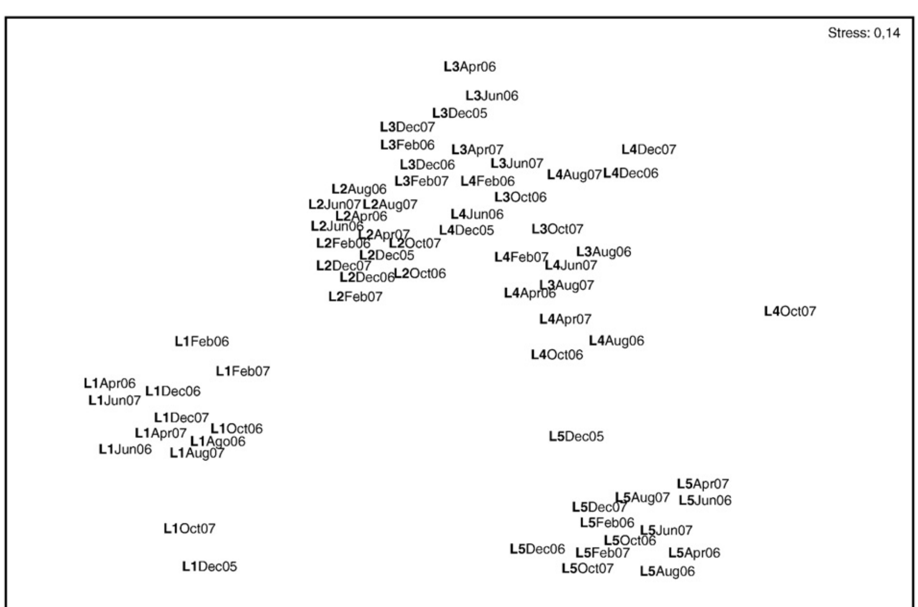

Fig. 7. MDS ordination based on the matrix of peracarid abundances.

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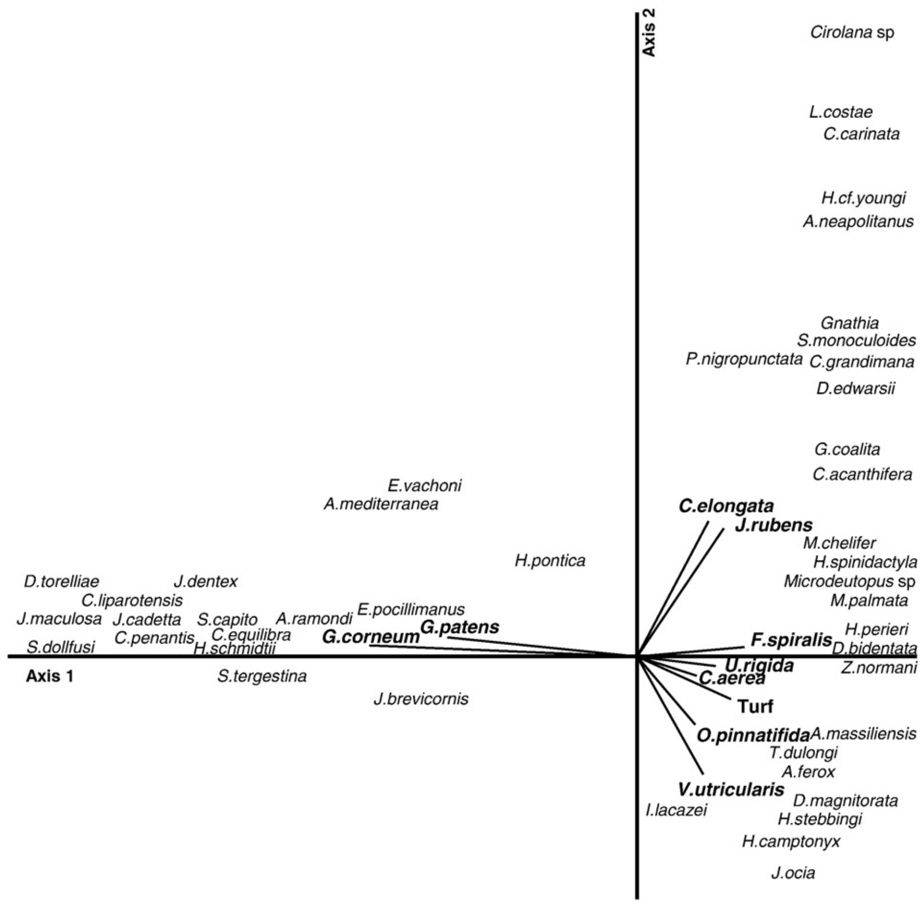

Fig. 8. Graph representation of the species of peracarids and seaweeds with respect to the first two axes of the Canonical Correspondence Analysis (CCA).

(2009) conducted the study of the intertidal peracarids associated to the seaweed *C. elongata* in the north and south sides of the Strait of Gibraltar and reported 40 species, most of them shared with the present study at Tarifa Island. Pereira et al. (2006) studied the intertidal peracarid fauna along the Portuguese coast (Atlantic coast of the Iberian Peninsula) and reported 57 taxa. Although some species are abundant in both, Portugal and Tarifa Island, such as the amphipods *C. penantis*, *S. monoculoides*, *H. stebbingi*, *H. schmidti*, *H. perieri*, the isopod *D. bidentata* and the tanaid *Tanais dulongii*, some other species were different. The amphipods *Amphitholina cuniculus*, *Ampithoe gammaroides*, *Microprotopus longimanus* and the isopods *Dynamene magnitorata* and *Cymodoce truncata*, were abundant along the Atlantic coast of the Iberian Peninsula, but absent or less abundant in the Strait of Gibraltar. Oppositely, the amphipods *Apherusa mediterranea*, *Melita palmata*, *Stenothoe tergestina*, *C. grandimana*, and the isopod *D. edwardsii*, were dominant species in the Strait of Gibraltar, but absent or rare along the Atlantic coast. These faunistic studies are basic to properly conduct future biogeographical studies. A previous and accurate knowledge of the species inhabiting the area is essential to carry out ecological and experimental studies with rigor.

Table 2
Summary of the results of the CCA analysis.

	Axis 1	Axis 2	Axis 3
Eigenvalue	0.86	0.55	0.48
Species–environment correlation	0.99	0.89	0.94
Percentage of species variance	20.2	12.9	11.5
Correlation with environmental variables			
Gelidium corneum	−0.99***	–	–
Gymnogongrus patens	−0.65**	–	–
Valonia utricularis	–	−0.56**	–
Turf	–	−0.48*	–
Osmundea pinnatifida	–	−0.3*	–
Corallina elongata	–	0.79***	−0.32*
Jania rubens	–	0.76***	−0.32*
Ulva rigida	0.24*	–	–
Chaetomorpha aerea	–	–	0.95***
Fucus spiralis	0.32*	–	–

*** $p<0.001$.
** $p<0.01$.
* $p<0.05$.

Collecting data over a series of years is rare in ecological literature because it is time-consuming, costly and often not possible (Simkanin et al., 2005). However, the knowledge of seasonal fluctuations of seaweeds and associated macrofauna is essential for future monitoring, conservation and for making reliable management decisions, especially in protected areas such as Tarifa Island in the Strait of Gibraltar. The present study constitutes the first baseline approach to the seasonal fluctuations of rocky shore intertidal peracarids at the Strait of Gibraltar, a most interesting biogeographic area between the Mediterranean and the Atlantic. The results of this study indicate that the distribution of the intertidal peracarids from the Strait of Gibraltar shows a clear tidal zonation. Most of the species reproduce continuously during the whole year and their seasonal fluctuations (with peaks of abundance in April–August) are directly related to the seasonality of the main seaweed in which they are associated to. Further experimental studies are still needed to understand other factors (such as competition, predation and weather conditions) causing zonation of peracarids and seasonal changes in their abundance.

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