Spatial patterns and seasonal fluctuations of the intertidal Caprellidae (Crustacea: Amphipoda) from Tarifa Island, Southern Spain

Distribución espacial y fluctuaciones estacionales de los caprélidos intermareales (Crustacea: Amphipoda) de la Isla de Tarifa, sur de España

J.M. Guerra-García, E. Baeza-Rojano, M.P. Cabezas, I. Pacios, J.J. Díaz-Pavón & J.C. García-Gómez

Laboratorio de Biología Marina, Departamento de Fisiología y Zoología, Facultad de Biología, Universidad de Sevilla, Avda Reina Mercedes 6, 41012, Sevilla (Spain) Fax: 0034 954233480; E-mail: jmguerra@us.es

Recibido el 24 de junio de 2009. Aceptado el 6 de julio de 2009.

ISSN: 1130-4251 (2009), vol. 20, 59-72

Key words: Caprellids, seaweeds, intertidal, ecology, spatio-temporal distribution.
Palabras clave: Caprélidos, algas, intermareal, ecología, distribución espacio-temporal.

ABSTRACT

Tarifa Island is located in the Strait of Gibraltar, between the Mediterranean and Atlantic. The unique biogeographical position, together with the substrate heterogeneity and the protection degree resulting from its condition of marine reserve, has contributed to maintain very diverse intertidal ecosystems at their rocky shores. Under absence of anthropogenic influence, we have studied the fluctuations of macroalgae and associated caprellids during two years (December 2005 to December 2007). Samples were taken every two months from the different intertidal levels. *Caprella penantis*, *C. liparotensis* and *C. equilibra* were exclusively distributed in the low intertidal levels dominated by *Gelidium corneum*; *Caprella grandimana* and *C. acanthifera* were found in the intermediate levels of *Corallina elongata*, *Jania rubens* and *Gelidium* spp. and the caprellids were absent in the upper intertidal levels dominated by *Fucus spiralis*. The caprellid species and the main seaweeds were present during the whole year. The peaks of seaweed biomass were observed from April to June, and were coincident with the peaks in caprellid abundances. The highest caprellid fluctuations were registered in the low levels: although *G. corneum* maintained high biomass during the whole year, the associated *C. penantis* had very low densities in winter (<50 ind/m^2) and high densities (around 5,000 ind/m^2) in early summer. On the other hand, the population of *C. grandimana* associated to intermediate levels, showed similar densities all the year round. These seasonal patterns could be related to winter storms, which mainly affect to the low intertidal levels, near the subtidal area.

RESUMEN

La Isla de Tarifa se localiza en el Estrecho de Gibraltar, entre el Mediterráneo y el Atlántico. Su posición biogeográfica singular, junto con la heterogeneidad del sustrato y el grado de protección como zona de reserva, ha contribuido a mantener ecosistemas intermareales rocosos muy biodiversos. Teniendo en cuenta la ausencia de influencia antrópica en el área de estudio, se estudiaron las fluctuaciones de las algas y caprélidos asociados durante dos años (diciembre 2005 a diciembre de 2007). Las muestras se recolectaron cada dos meses en los distintos niveles del intermareal. *Caprella penantis*, C. *liparotensis* y *C. equilibra* se distribuyeron exclusivamente en los niveles más bajos dominados por *Gelidium corneum*; *Caprella grandimana* y *C. acanthifera* se encontraron en los niveles intermedios de *Corallina elongata*, *Jania rubens* y *Gelidium* spp., y no se encontraron caprélidos en los niveles superiores dominados por *Fucus spiralis*. Las especies de caprélidos y las algas principales estuvieron presentes durante todo el año. Los picos de biomasa de algas se registraron de abril a junio, coincidiendo con los picos en las abundancias de los caprélidos. Las mayores fluctuaciones estacionales en los caprélidos se midieron en los niveles inferiores: aunque *G. corneum* mantuvo una biomasa elevada durante todo el año, el caprélido asociado *C. penantis* mostró bajas densidades en invierno (<50 ind/m^2) y altas densidades (en torno a 5.000 ind/m^2) a comienzos del verano. Por otra parte, la población de *C. grandimana* asociada a los niveles intermedios mostró densidades similares durante todo el año. Estos patrones estacionales podrían estar relacionados con los temporales de invierno, que afectan fundamentalmente a los niveles más bajos del intermareal, próximos a la zona infralitoral.

INTRODUCTION

The Straits Natural Park (Parque Natural del Estrecho) (Fig. 1) was declared a protected area in 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 as marine reserve, and constitutes the most interesting enclave of the park regarding to the marine habitat. Tarifa Island is the most southern point of Europe, just between the Mediterranean and Atlantic, with 21 hectares and 2 km of coastline. The unique biogeographical position, together with the substrate heterogeneity and the access restrictions to the

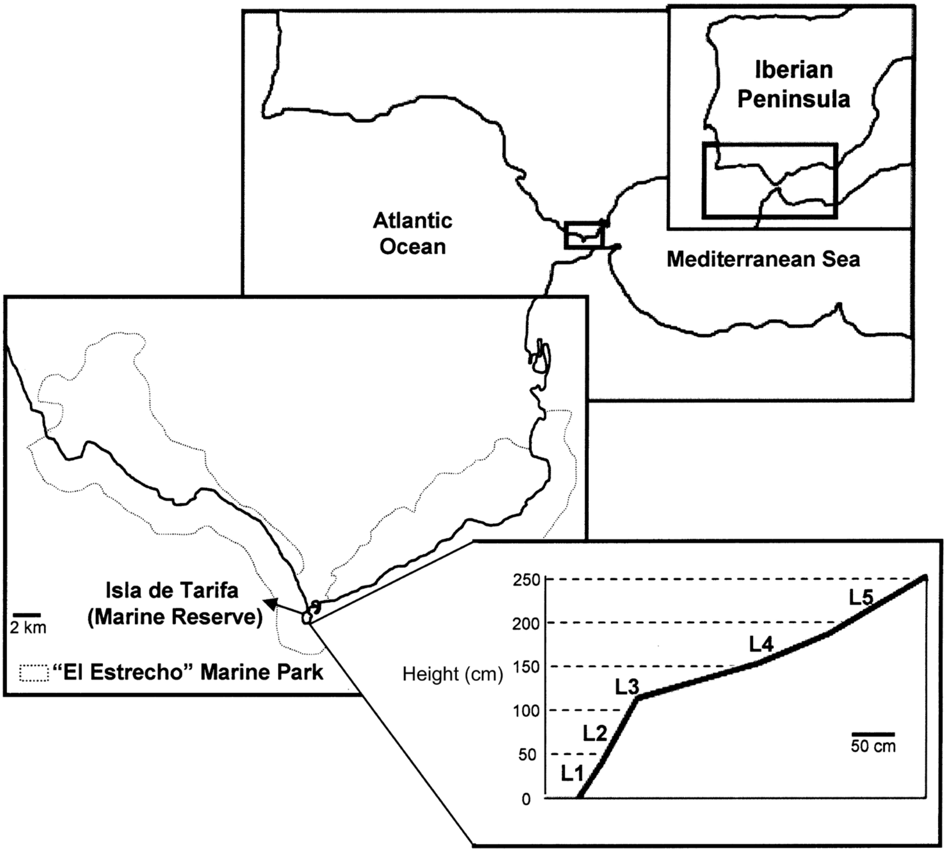

Fig. 1.—Study area showing the location of "El Estrecho" Marine Park in the Strait of Gibraltar. A schematic diagram of the intertidal selected for the study in Tarifa Island is also included.

Fig. 1.—Área de estudio mostrando la localización del Parque Natural del Estrecho de Gibraltar. Se incluye un esquema del intermareal seleccionado para el estudio en la Isla de Tarifa.

area by the military for a long time, has contributed to maintain very diverse intertidal ecosystems at their rocky shores. Guerra-García & García-Gómez (2000) reviewed the marine fauna of Tarifa Island, compiling all the literature dealing with marine communities of the area.

Zonation patterns of marine algae and invertebrates, especially mussels, barnacles, snails, and limpets, have been intensively studied, while only a few researches have studied the zonation patterns of rocky intertidal amphipods (but see Chavanich & Wilson, 2000). In Europe, research on caprellids' life cycles based on field studies is limited to a few species. For example, *Pseudoprotella phasma* from the southwest coast of England showed a life span of 6 to 9 months with three generations per year (Hughes, 1978). Ovigerous females of *Caprella acanthifera* from Ireland were collected from April to June and October to November by Costello & Myers (1989), suggesting that *C. acanthifera* produces two generations per year or reproduces twice each year (Takeuchi & Hirano, 1991). The breeding activity of *Caprella equilibra* from a lagoon estuary of the Northern Adriatic Sea showed peaks in April and September, breeding stopped in winter and females produced more than one brood per year (Sconfietty & Luparia, 1995). The density of *Phtisica marina* from an estuarine zone of southwest Spain was higher in winter and spring than in summer and autumn; in fact, there was a complete cessation in the reproduction of this species from August to November (Guerra-García *et al*., 2000).

Recently, it has been an increasing interest in the study of growth and reproduction of caprellids reared under laboratory conditions (see Takeuchi & Hirano, 1991, 1992a,b; Cook *et al*., 2007). Takeuchi & Hirano (1991) pointed out the difficulty of estimating generation structure for caprellid amphipods based on size-frequency distribution data from monthly field samples due to the important fluctuations in the number of individuals during short periods of time. According to this, moulting cycle, growth, and maturation should be better examined under laboratory conditions. However, for management and conservation purposes, especially in protected areas, it is also essential to know and understand the spatial distribution and seasonal fluctuations of species in the field, since many factors such as habitat complexity, competition and predation among species, winter storms, etc, can severely influence life cycles; those factors can not be properly evaluated in the laboratory when rearing specimens under controlled conditions. Consequently, the purpose of this study was to examine the zonation pattern and seasonal abundance of caprellids associated to intertidal algae from Tarifa Island.

MATERIAL AND METHODS

All the samples were collected from the most southern point of Tarifa Island (Punta Marroquí, 36º00'00.7''N, 5º36'37.5''W). The width of the intertidal range in this location is 250 cm approximately (Fig. 1) and we considered 5 levels to establish the zonation of the intertidal algae (level 1: from zero tidal level to 0.5 m; level 2: 0.5-1 m; level 3: 1-1.5 m; level 4: 1.5-2m and level 5: 2-2.5 m). A ruler, set square and 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 meters had been achieved, coinciding with upper limit of the intertidal community (see Fa *et al*., 2002; Guerra-García *et al*., 2006). At each height, three replicates (quadrats 20 x 20 cm) were sampled. The surface was scrapped and all specimens of algae and associate fauna were collected. Samples were taken every two months from the different intertidal levels (December 2005 to December 2007). The samples were fixed in ethanol 70-80% and brought to laboratory. Samples were sieved using a mesh size of 0.5 mm and caprellids were sorted, identified to species level and counted; abundance of caprellid species was expressed in number of individuals per m^2. The most abundant seaweeds were identified to species level and biomass of algae was expressed in grams of dry weight per m^2. In each sampling, water temperature and salinity were measured using a conductivimeter WTW LF-323.

The relationships between seaweeds and caprellids in the different intertidal levels along the studied period, were explored by Canonical Correspondence Analysis (CCA). Multivariate analyses were carried out using the PC-ORD programme (McCune & Mefford, 1997).

RESULTS

Salinity values were more or less constant (around 37 psu) along the two years of study, while water temperature ranged from 14.4ºC (February) and 19.4ºC (August and October) (Fig. 2).

Level 1 (0-0.5 m) was dominated by *Gelidium corneum* (=*sesquipedale*) and *Gymnogongrus patens* (Fig. 3). Level 2 (0.5-1 m) was mainly constituted by a turf of several species of *Gelidium* and *Caulacanthus ustulatus*, *Valonia utricularis* and *Osmundea* (=*Laurencia*) *pinnatifida*. Corallinacea algae (*Corallina elongata* and *Jania rubens*) were located in level 3 (1-1.5 m), level 4 was dominated by the green algae *Ulva rigida* and *Chaetomorpha aerea*, while *Fucus spiralis* was the only species found in level 5 (Fig. 3). The highest values of seaweed biomass were registered in level 3, followed by level 1 and 4 (Fig. 4). The intermediate levels (2-4) showed the maximum biomass values in April-June, while level 1 and 5 showed the highest values along April-August. Anyway, both studied years showed a similar pattern, with higher values of seaweed biomass during spring and beginning of summer, and lower values from late summer to winter.

A total of 7,227 caprellids of five species were collected during the present study from the intertidal of Tarifa Island: *Caprella penantis*, *C. liparotensis* and *C. equilibra*, distributed exclusively in level 1, *Caprella grandimana*, especially abundant in level 3 but also present in level 2 and 4, and *Caprella acanthifera*, distributed in levels 3 and 4 (Table 1). Caprellids were absent in level 5. The highest abundances were registered in level 1,

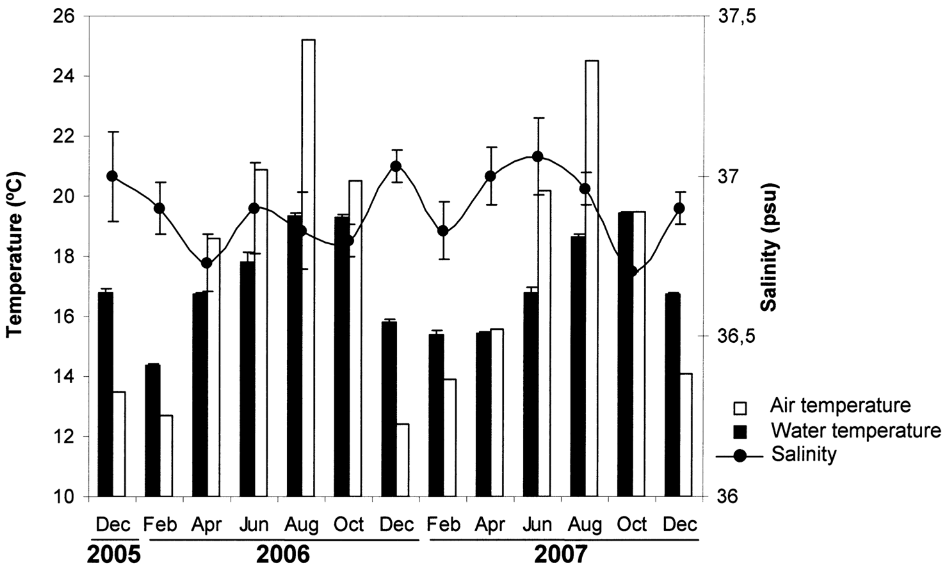

Fig. 2.—Data (Mean ± SD) of temperature and salinity in the study area.
Fig. 2.—Datos (Media ± DE) de temperatura y salinidad en el área de estudio.

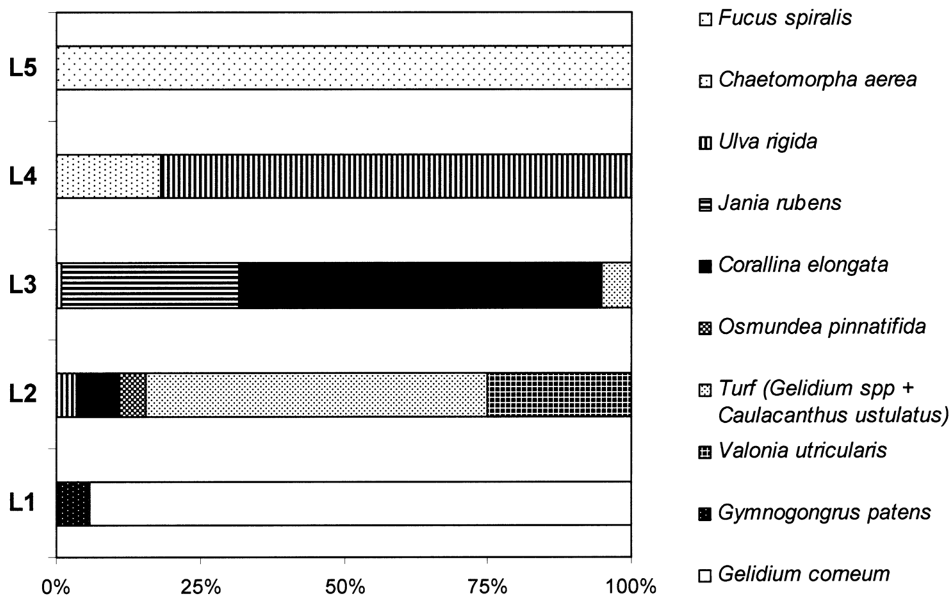

Fig. 3.—Macroalgal species in each intertidal level (L1-L5) and their relative abundance.
Fig. 3.—Especies de macroalgas en cada nivel intermareal (L1-L5) y su abundancia relativa.

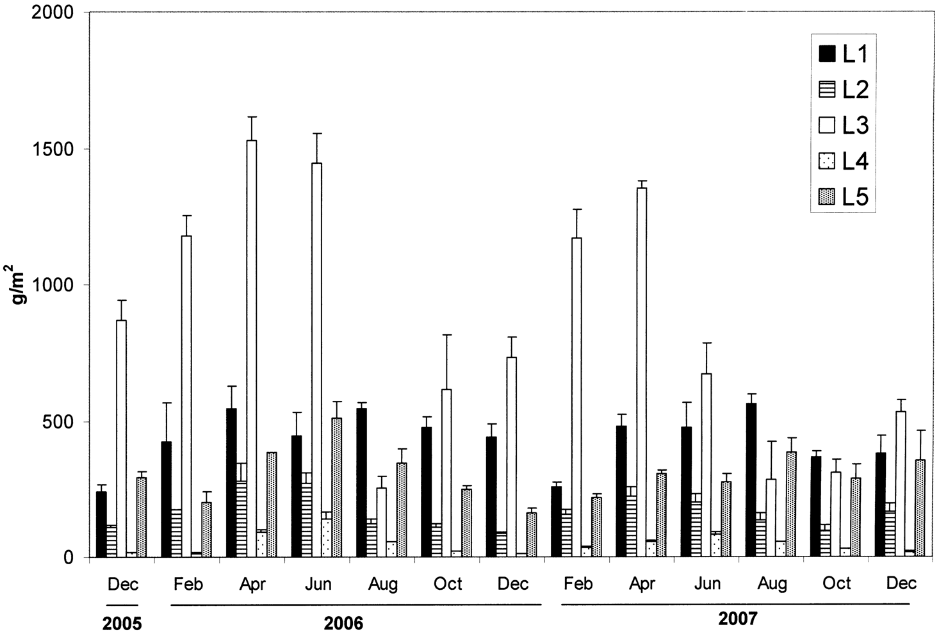

Fig. 4.—Seasonal fluctuations of seaweed biomass (g/m^2) in each intertidal level (L1-L5). Values are mean ± SD.
Fig. 4.—Fluctuaciones estacionales de la biomasa algal (g/m^2) en cada nivel intermareal (L1-L5). Los valores son media ± DE.

with maximum values in April-June and very low values in December-February (Fig. 5). In general, caprellids also showed higher abundances in spring and beginning of summer, similarly to seaweeds. However, patterns of abundance of caprellids associated to level 3 were not so clear as in level 1. *Caprella penantis* and *C. grandimana* were the dominant caprellids; *Caprella penantis* showed clearly the seasonal pattern of abundance peaks in April and June and very low densities in December and February, while *Caprella grandimana* showed abundances ranging from 100-1,000 ind/m^2 along the whole year. Figure 6 and table 2 show the results of the CCA analysis. The first axis absorbed almost all the variance explained by the data, and correlated positively with *Gelidium corneum* and *G. patens* and negatively with *Corallina elongata*, *Jania rubens*, *Valonia utricularis*, *Osmundea pinnatifida* and the algal turf. This axis 1 separated clearly samples of level 1 (L1) dominated by *C. penantis* from the other levels (L2, L3 and L4). Axis 2 mainly correlated with green algae (*Chaetomorpha aerea* and *Ulva rigida*), separating level 4 dominated by *C. acanthifera* from levels 2 and 3 dominated by *C. grandimana*.

Table 1.—Caprellid species found during the study and their abundance along the year (seasonal fluctuations) and zonation in the different intertidal levels (L1-L5).
Tabla 1.—Especies de caprélidos encontrados durante el estudio y su abundancia a lo largo del año (fluctuaciones estacionales) y zonación en los diferentes niveles del intermareal (L1-L5).

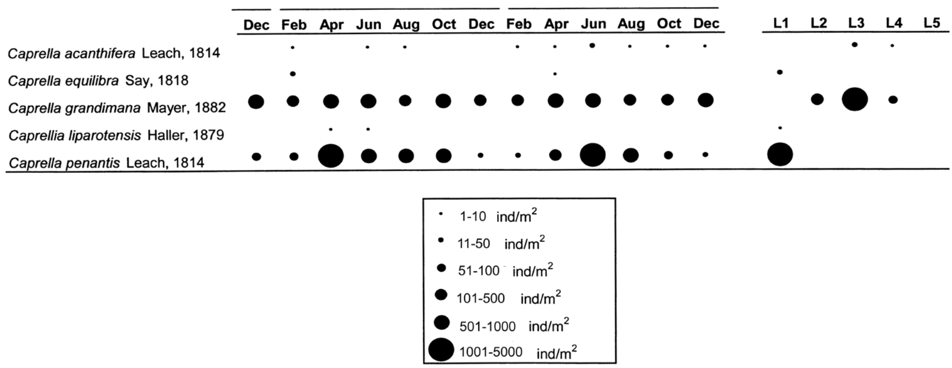

Table 2.—Summary of the results of the CCA analysis. *p<0.05, **p<0.01, ***p<0.001
Tabla 2.—Resumen de los resultados del análisis ACC. *p<0.05, **p<0.01, ***p<0.001

		Axis 1	Axis 2
Eigenvalue		0.98	0.04
Caprellid-seaweed correlation		0.99	0.29
Percentage of species variance		54.5	2.2
Correlation with seaweeds			
	Gelidium corneum	0.99***	—
	Gymnogongrus patens	0.63**	—
	Valonia utricularis	–0.3*	—
	Turf	–0.4*	–0.4*
	Osmundea pinnatifida	–0.3*	–0.3*
	Corallina elongata	–0.3*	—
	Jania rubens	–0.3*	—
	Ulva rigida	—	0.83***
	Chaetomorpha aerea	—	0.85***

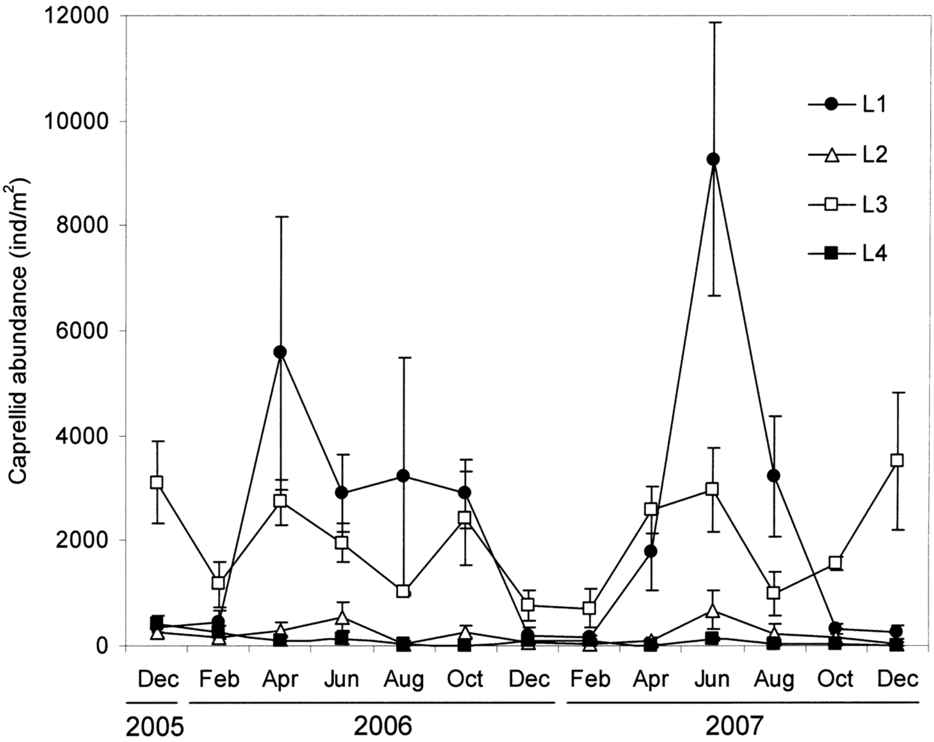

Fig. 5.—Seasonal fluctuations of caprellid abundances (ind/m^2) in each intertidal level (L1-L4). Caprellids were absent in L5. Values are mean ± SD.
Fig. 5.—Fluctuaciones estacionales de la abundancia de caprélidos (ind/m^2) en cada nivel intermareal (L1-L4). No se encontraron caprélidos en L5. Los valores son media ± DE.

DISCUSSION

The main intertidal seaweeds of Tarifa Island showed a perennial behaviour. The species were present along the whole year, although maximum values of biomass were registered during spring and beginning of summer for most of the algae. This fact probably determined that the main caprellid species, i.e. *Caprella penantis* and *C. grandimana* were also present throughout the year. Seasonal fluctuations of caprellids were, in general terms, coincident with seasonality of the seaweeds, having higher biomass from April to June. However, in spite of the important biomass decrease of level 3 algae (*Corallina elongata* and *Jania rubens*) in summer due to high temperatures, density of caprellids (mainly that of *C. grandimana*) maintained values above 1000 ind/m^2. On the other hand, *Gelidium corneum* showed similar biomass values throughout all the year round and caprellids

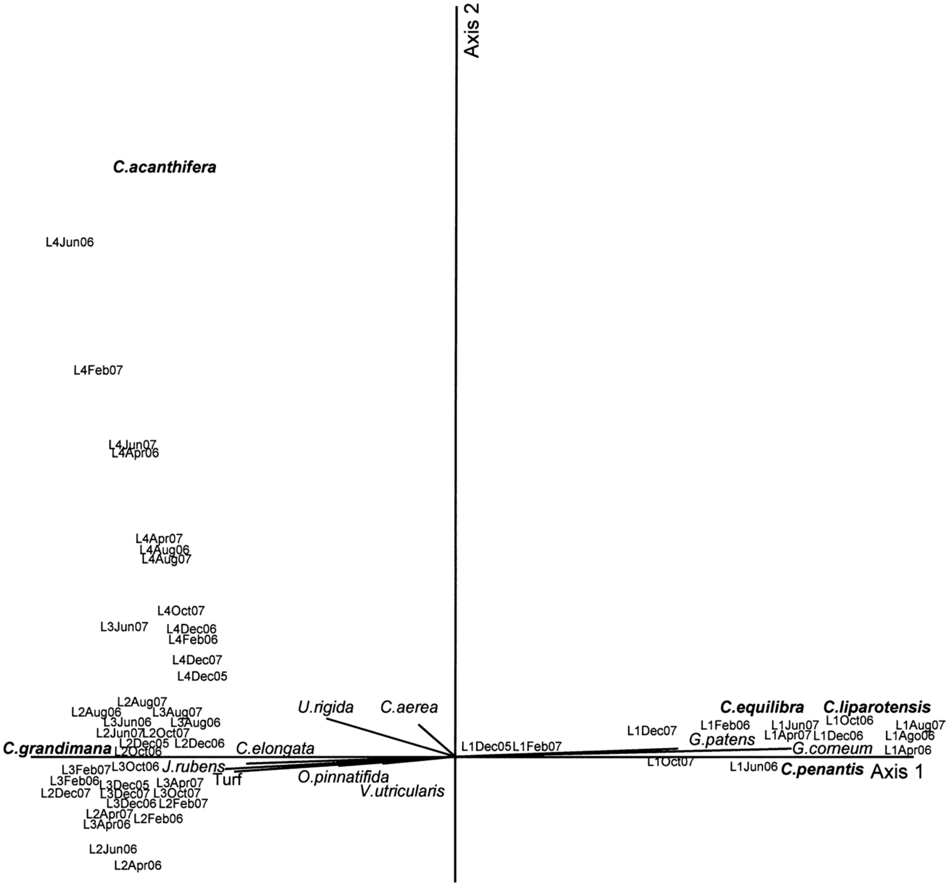

Fig. 6.—Graphic representation of the samplings, caprellids and seaweeds with respect to the first two axes of the Canonical Correspondence Analysis (CCA).
Fig. 6.—Representación gráfica de los muestreos, caprélidos y algas con respecto a los dos primeros ejes del Análisis Canónico de Correspondencias (ACC).

associated (mainly *C. penantis*) showed important fluctuations with more than 5,000 ind/m^2 in April-June and less than 200 ind/m^2 in December-February. These patterns indicate that caprellid density in the intertidal is not only influenced by distribution of algae as substrate, but also by external factors, such as hydrodinamics, oxygen, weather conditions, competition or predation. Probably, the level 1, very close to the subtidal, is more exposed to wave action, and is more sensitive to winter storms, which are likely to negatively affect to the population of *C. penantis*, according to 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 *Corallina elongata*. Level 3 is not so affected by waves during winter storms. Furthermore, *C. penantis* is especially sensible to environmental stress (Guerra-García & García-Gómez, 2001; Guerra-García *et al*., 2009a), while *C. grandimana* seems to be more resistant (Baeza-Rojano *et al*., unpublished data).

Under favourable conditions, according to the literature, populations of some caprellid species can reach high densities, even higher than 300,000 ind/m^2, although there may be considerable temporal and spatial variation depending upon a range of biophysical factors, such as temperature and food supply (Woods, 2009). In the present study *Caprella penantis* showed densities of more than 10,000 ind/m^2 in June, and this species, together with *C. grandimana*, were present all the year round; in fact, caprellid reproduction may be continuous throughout the year (Woods, 2009). Some temperate species exhibit peak abundances in spring/summer and marked declines in winter (Keith, 1971; Thom *et al*., 1995; Ashton, 2006), as those registered in the present study, whilst others such as *Phtisica marina* exhibit peak abundances in winter and spring (Guerra-García *et al*., 2000). On the other hand, temporal patterns of caprellid populations have also been shown to be positively correlated with the seasonal cycles of the biomass of the host that they inhabit (see Woods, 2009 for details). The present study confirms this trend but also shows that other factors are also involved, probably related with winter storms. Some authors have also pointed predation pressure as an important factor (Duffy & Hay, 2000). *Caprella penantis* and *C. grandimana*, the most abundant species found in the intertidal of Tarifa Island, are also the most common species in other areas of the Strait of Gibraltar (Guerra-García *et al*., 2009b), being *C. penantis* also common in intertidal ecosystems of the Atlantic coasts of the Iberian Peninsula (Pereira *et al*., 2006). Although in the present study *C. penantis* has been restricted to level 1 associated to *Gelidium corneum*, in other localities *C. penantis* can reach high densities also on *Corallina elongata*.

Summarising, the results of this study indicate that the distribution of the intertidal caprellids from the Strait of Gibraltar shows a clear tidal zonation, with some species living near the subtidal and others in intermediate tidal levels. The dominant caprellid species reproduce continuously during the whole year and their seasonal fluctuations (with peaks of abundance in April-June) are directly related to 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 caprellids and seasonal changes in their abundance.

ACKNOWLEDGEMENTS

Financial support of this work was provided by the *Ministerio de Educación y Ciencia* (Project CGL2007-60044/BOS) co-financed by FEDER funds, and by the *Consejería de Innovación, Ciencia y Empresa, Junta de Andalucía* (Project P07-RNM-02524).

REFERENCES

Ashton, G.V. 2006. Distribution and dispersal of the non-native caprellid Amphipoda, *Caprella mutica* Schurin 1935. PhD thesis, University of Aberdeen, Scotland, 180 pp.

Chavanich, S. & Wilson, K.A. 2000. Rocky intertidal zonation of gammaridean amphipods in Long Island Sound, Connecticut. *Crustaceana*, 73: 853-846

Cook, E.J.; Willis, K.J. & Lozano-Fernández, M. 2007. Survivorship, growth and reproduction of the non-native *Caprella mutica* Schurin, 1935 (Crustacea: Amphipoda). *Hydrobiologia*, 590: 55-64.

Costello, M.J. & Myers, A.A. 1989. Breeding periodicity and sex ratios in epifaunal marine Amphipoda in Lough Hine, Ireland. *Estuarine, Coastal and Shelf Science*, 29: 409-419.

Duffy, J.E. & Hay, M.E. 2000. Strong impacts of grazing amphipods on the organization of a benthic community. *Ecological Monographs*, 70: 237-263.

Fa, D.A.; Finlayson, C.; García-Adiego, E.; Sánchez-Moyano, J.E. & García-Gómez, J.C. 2002. Influence of some environmental factors on the structure and distribution of the rocky shore macrobenthic communities in the Bay of Gibraltar: preliminary results. *Almoraima*, 28: 73-88.

García-Gómez, J.C.; Corzo, J.R.; López-Fé, C.M.; Sánchez-Moyano, J.E.; Corzo, M.; Rey, J.; Guerra-García, J.M. & García-Asencio, I.M. 2003. Metodología cartográfica submarina orientada a la gestión y conservación del medio litoral: mapa de las comunidades bentónicas del frente litoral norte del Estrecho de Gibraltar. *Boletín del Instituto Español de Oceanografía*, 19: 149-163.

Guerra-García, J.M.; Baeza-Rojano, E.; Cabezas, M.P.; Díaz-Pavón, J.J.; Pacios, I. & García-Gómez, J.C. 2009a. The amphipods *Caprella penantis* and *Hyale schmidtii* as biomonitors of trace metal contamination in intertidal ecosystems of Algeciras Bay, Southern Spain. *Marine Pollution Bulletin*, 58: 783-786

Guerra-García, J.M.; Cabezas, P.; Baeza-Rojano, E.; Espinosa, F. & García-Gómez, J.C. 2009b. Is the north side of the Strait of Gibraltar more diverse than the south side? A case study using the intertidal peracarids (Crustacea: Malacostraca) associated to the seaweed *Corallina elongata*. *Journal of the Marine Biological Association of the United Kingdom*, 89: 387-397.

Guerra-García, J.M.; Corzo, J., García-Asencio, I. & García-Gómez, J.C. 2000. Seasonal fluctuations of *Phtisica marina* Slabber (Crustacea: Amphipoda: Caprellidea) in estuarine zone of Southwest Spain. *Polskie Archiwum Hydrobiologii*, 47: 527-531.

Guerra-García, J.M. & García-Gómez, J.C. 2000. La fauna submarina de la Isla de las Palomas (Tarifa, Cádiz). Temas de Flora, Fauna y Ecología del Campo de Gibraltar. Cuadernos del Instituto II, Campo de Gibraltar, pp 7-17.

— 2001. Spatial distribution of Caprellidea (Crustacea: Amphipoda): a stress bioindicator in Ceuta (North Africa, Gibraltar area). *P.S.Z.N. Marine Ecology*, 22: 357-367.

Guerra-García, J.M.; Maestre, M.J.; González, A.R. & García-Gómez, J.C. 2006. Assessing a quick monitoring method using rocky intertidal communities as a bioindicador: a multivariate approach in Algeciras Bay. *Environmental Monitoring and Assessment*, 116: 345-361.

Hughes, R.G. 1978. Life-histories and abundance of epizoites of the hydroid *Nemertesia antennina* (L.). *Journal of the Marine Biological Association of the United Kingdom*, 58: 313-332.

Keith, D.E. 1971. Substrate selection in caprellid amphipods of southern California, with emphasis on *Caprella californica* Stimpson and *Caprella equilibra* Say (Amphipoda). *Pacific Science*, 25: 387-394.

McCune, B. & Mefford, M.J. 1997. PC-ORD. Multivariate Analysis of Ecological Data. MJM Software Design, Gleneden Beach, 77 pp.

Pereira, S.G.; Lima, F.P.; Queiroz, N.C.; Ribeiro, P.A. & Santos, A.M. 2006. Biogeographic patterns of intertidal macroinvertebrates and their association with macroalgae distribution along the Portuguese coast. *Hydrobiologia*, 555: 185-192.

Sconfietti, R. & Luparia, P. 1995. Population ecology of the amphipod *Caprella equilibra* Say in a lagoon estuary (Northern Adriatic Sea, Italy). *P.S.Z.N.I: Marine Ecology*, 16: 1-11.

Takeuchi, I. & Hirano, R. 1991. Growth and reproduction of *Caprella danilevskii* (Crustacea: Amphipoda) reared in the laboratory. *Marine Biology*, 110: 391-397.

— 1992a. Growth and reproduction of the epifaunal amphipod *Caprella okadai* Arimoto (Crustacea: Amphipoda: Caprellidea). *Journal of Experimental Marine Biology and Ecology*, 161: 201-212.

— 1992b. Duration and size of embryos in epifaunal amphipods *Caprella danilevskii* Czerniavskii and *C. okadai* Arimoto (Crustacea: Amphipoda: Caprellidea). *Journal of Experimental Marine Biology and Ecology*, 164: 161-169.

Thom, R.; Miller, B. & Kennedy, M. 1995. Temporal patterns of grazers and vegetation in a temperate seagrass system. *Aquatic Botany*, 50: 201-205.

Woods, C.M.C. 2009. Caprellid amphipods: an overlooked marine finfish aquaculture resource? *Aquaculture*, 289: 199-211.