Bol. Inst. Esp. Oceanogr. 19 (1-4). 2003: 7-15

BOLETÍN. INSTITUTO ESPAÑOL DE OCEANOGRAFÍA
ISSN: 0074-0195

Suprabenthos distribution in a shallow temperate estuary (Mondego estuary, western Portugal)

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Received January 2003. Accepted December 2003.

ABSTRACT

For this paper we studied the suprabenthos distribution in the Mondego estuary's southern arm. Samples were taken monthly at two stations from October 1999 to May 2000. The collections were made during high spring tides, using a suprabenthic net mounted on a sledge (40 cm diameter, 500 mm mesh) in suprabenthic tows. Mollusca and Crustacea, especially Mysidacea, dominated the suprabenthos. Other important groups were the Copepoda, Isopoda, eggs and post larvae of Pisces, and larval stages of Decapoda. The high densities of *Hydrobia ulvae* (Pennant, 1777) post-larvae caught in the downstream station, which decreased species evenness due to the dominance of this species, led to a spatial diversity pattern with higher diversities in the upstream area. The mysid species *Mesopodopsis slabberi* (Van Beneden, 1861), together with the calanoid copepod *Acartia tonsa* (Dana, 1848), dominated in the upstream area. Significant differences were found in community structure between the two selected areas of the estuary, with a dominance of the spatial structure in the cluster analysis.

Keywords: Suprabenthos, estuaries, Mondego.

RESUMEN

Suprabentos en el estuario del río Mondego

Para este artículo, estudiamos la distribución del suprabentos en el brazo sur del estuario del río Mondego. Las muestras se tomaron mensualmente entre octubre de 1999 y mayo de 2000 en dos áreas: una de mayor flujo, río arriba, y otra en la zona de encuentro con el mar. Las recolecciones se hicieron durante las mareas vivas, utilizando una red suprabentónica de 40 cm de diámetro y 500 mm de luz de malla. Los moluscos y los crustáceos, especialmente los misidáceos, fueron los grupos que dominaron el suprabentos. Otros grupos importantes fueron los copépodos, los isópodos, los huevos y poslarvas de peces y las larvas de decápodos. La captura de altas densidades de poslarvas de Hydrobia ulvae *(Pennant, 1777) en el área de encuentro desvela que su predominio es el causante de la disminución en la uniformidad de las especies en esta zona y, como consecuencia, se ha desarrollado para ella un patrón mayor de diversidad espacial. La especie* Mesopodopsis slabberi *(Van Beneden, 1861), junto con el copépodo calanoide* Acartia tonsa *(Dana, 1848), dominaron el área de mayor flujo, río arriba. Se encontraron diferencias significativas entre las estructuras de la comunidad de las dos áreas del estuario seleccionadas, dominando la estructura espacial en el análisis por agrupación (efectuado mediante cluster).*

Palabras clave: *Suprabentos, estuarios, río Mondego.*

INTRODUCTION

The suprabenthos plays an important role in estuarine trophodynamics (Sorbe, 1981; Hamerlynck, Van de Vyver and Janssen, 1990). A clear understanding of the energy and material fluxes in estuaries should always take into consideration the suprabentho's well-established importance in these ecosystems (Buhl-Jensen and Fossa, 1991; Hamerlynck and Mees, 1991; Mees and Hamerlynck, 1992; Mees, Cattrijsse and Hamerlynck, 1993; Mees, Dewcke and Hamerlynck, 1993; Mees, Fockedey and Hamerlynck 1995; Azeiteiro and Marques, 1999; Azeiteiro, Ré and Marques, 2002).

Suprabenthic organisms are important components of the biomass of estuarine and coastal regions (Sorbe, 1981; Williams and Collins, 1984; Hamerlynck, Van de Vyver and Janssen, 1990; Cunha, Sorbe and Bernardes, 1997; Azeiteiro and Marques, 1999, Marquiegui and Sorbe, 1999; Azeiteiro, Ré and Marques, 2002), structuring zooplankton communities by predation (Dodson, 1974; Fulton, 1982), contributing to the diet of demersal fishes (Mauchline, 1980; Sorbe, 1981) and shrimps (Sitts and Knight, 1979), and also as important grazers of organic matter. They represent a key link in the marine and estuarine food webs (detritus-based food chains).

A first study on the suprabenthos of the Mondego estuary was performed in 1998 by Azeiteiro and Marques (1999), and the main results were: 1) diversity was highest in the mouth of the estuary, where density and biomass were lowest; 2) diversity decreased upstream and was lowest in the middle and inner estuary, where density and biomass reached maximal values; 3) suprabenthic animals, mainly the mysid *Mesopodopsis slabberi* (Van Beneden, 1861), reached high densities in inner and upstream stations, whereas the more seaward stations had lower densities but a higher number of species; and 4) spatial patterns dominated over temporal patterns.

The main objective of the present paper is, besides the distribution study and community parameters description (from October 1999 to May 2000), to analyse these results, comparing them to those obtained by Azeiteiro and Marques (1999) in 1998.

MATERIALS AND METHODS

Study site

The Mondego River estuary, located on the west coast of Portugal (40° 08' N, 8° 50' W), has an area of 3.3 km^2 and a volume of 0.0075 km^3 (figure 1). The hydrological basin of the Mondego, with an area of 6 670 km^2, provides an average run-off rate of 8.5×10^9 m^3 s^{-1}. At about 5.5 km from the sea, the river branches into two arms (north and south), which then converge again near the mouth. In this area, the tidal range is 0.35-3.3 m, and the average residence time is 2 days for the north arm and 9 days for the south arm. This fact denotes the sheer

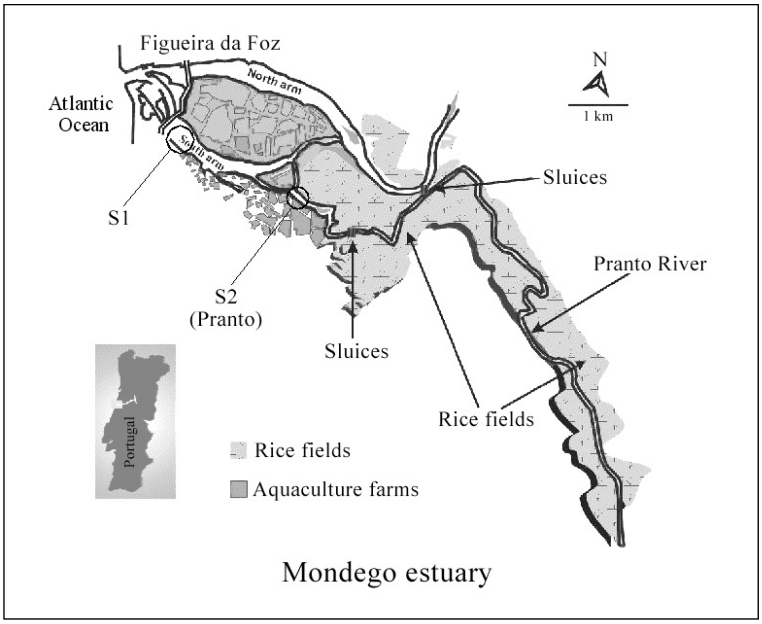


Figure 1. Map of the Mondego estuary showing the locations of the two sampling stations in the south arm

contrasting characteristics of the two arms. During high tide, the north arm is 5-10 m deep, while the south is only 2-4 m, being almost totally silted in its upstream areas. As a consequence, the circulation in the south arm depends largely on the tides and, to a lesser extent, on the freshwater discharge from a tributary –the Pranto River, which is controlled by a sluice located 3 km from its confluence with the Mondego. Sampling station 1 was the closest to the mouth of the estuary (figure 1). The average depth was 2-4 m, and bottom substrata consisted of coarse to medium sand, with low organic matter and carbonate contents. The influence of both the north arm and neritic waters is stronger in station 1. Sampling station 2, in the vicinity of the sluice (figure 1), is very shallow and characterised by fine sediments, with large fractions ranging from fine sand to clay, and one of the highest organic matter and carbonate contents recorded within the estuary (Azeiteiro and Marques, 1999).

Sampling programme

Samples were taken monthly at the two stations from October 1999 to May 2000. The collections were taken in the suprabenthal, during high spring tides, using a suprabenthic net mounted on a sledge (40-cm diameter, 500 µm mesh) in suprabenthic tows for 5 min (Azeiteiro and Marques, 1999).

Laboratory procedures

In the laboratory, animals were identified, when possible to species level, and counted; all densities data are presented as number of individuals per cubic meter (indiv m^{-3}).

Communities data analysis

The biological data were analysed by cluster analysis of taxa, performed using the UPGMA method and Pearson's correlation coefficient (Legendre and Legendre, 1984). Prior to analysis, data were subjected to a logarithmic transformation, in order to achieve parametric analysis requirements (Zar, 1984).

Physico-chemical parameters, chlorophyll *a* and phytoplankton

All samples were analysed in situ for salinity, temperature, dissolved oxygen and pH. Samples were also analysed in the laboratory (in triplicate) for their content in dissolved nitrate, nitrite, ammonia, phosphate, and chlorophyll *a* (Strickland and Parsons, 1972; Bacelar-Nicolau *et al.*, 2002, 2003; Vieira *et al.*, 2002).

A detailed description and analysis of the physico-chemical data has been published by Bacelar-Nicolau *et al.* (2002, 2003) and Vieira *et al.* (2002) were the composition and distribution of the bacterioplankton (Bacelar-Nicolau *et al.*, 2002, 2003) and phytoplankton (Vieira *et al.*, 2002) is also available.

RESULTS

Physicochemical parameters and Chlorophyll *a*

The analysis of the physico-chemical data (table I) revealed a clear difference between the two sam-

Table I. Environmental data (temperature, salinity, pH, oxygen dissolved – saturation %, NO$_2^-$, NO$_3^-$, NH$_3$, PO$_4^{3-}$ and chlorophyll-*a* values) from monthly sampling cycle in the south arm of the Mondego estuary, in both sampling stations, between September 1999 and May 2000

	October		November		December		January		February		March		April		May	
	S$_1$	S$_2$	S$_1$	S$_2$	S$_1$	S$_2$	S$_1$	S$_2$	S$_1$	S$_2$	S$_1$	S$_2$	S$_1$	S$_2$	S$_1$	S$_2$
Temperature (°C)	16.9	19.6	16.8	16.6	11.8	13.2	11.9	11.0	14.1	14.1	14	13.9	14.2	14.0	15.8	18.3
Salinity	27.0	22.0	31.1	19.5	17.9	29.3	23.2	23.2	29.7	29.4	31.7	19.5	31.7	19.5	21.1	12.0
pH	7.6	8.3	7.9	7.5	7.8	8.4	7.8	7.9	7.9	7.6	7.5	7.6	7.5	7.6	7.7	7.6
DO$_2$ (%)	80.5	60.0	68.4	48.0	69.5	79.0	89.5	91.0	99.4	72.4	85	79	85.0	74.0	97.4	75.2
NO$_2$ (mg l^{-1})	0.009	0.036	0.007	0.048	0.005	0.060	0.005	0.006	0.008	0.055	0.051	0.231	0.008	0.042	0.007	0.028
NO$_3$ (mg l^{-1})	0.085	0.076	0.073	0.106	0.061	0.135	0.129	0.193	0.164	0.163	0.817	0.817	0.171	0.274	0.178	0.384
NH$_3$ (mg l^{-1})	0.003	0.181	0.007	0.172	0.010	0.163	0.032	0.034	0.045	0.188	0.220	0.410	0.040	0.189	0.034	0.191
PO$_4$ (mg l^{-1})	0.003	0.007	0.003	0.007	0.003	0.007	0.003	0.009	0.004	0.007	0.085	0.111	0.003	0.008	0.003	0.008
Chlorophyll *a*	1.080	1.620	0.670	1.390	0.260	1.160	0.190	0.810	0.340	2.040	0.81	1.3	0.810	1.300	0.740	2.730

pling stations, therefore defining a clear spatial differentiation: samples characterised by a higher levels of total nitrogen, ammonia, nitrite, chlorophyll *a*, and temperature largely corresponded to those from S2, while samples characterised by higher salinity corresponded to those from S1. Secondarily, the data defined temporal gradients (Bacelar-Nicolau *et al.*, 2002, 2003; Vieira *et al.*, 2002).

Composition and spatio-temporal distribution of the suprabenthos

The overall monthly densities of the suprabenthic fauna ranged from 12.7 indiv m^{-3} (May, 2000), at station 2, to 385 indiv m^{-3} (March, 2000), at station 1 (figure 2). The suprabenthos abundance during the period of study showed peaks, at station 1, in December (368 indiv m^{-3}), January (306 indiv m^{-3}), March (385 indiv m^{-3}) and April (142 indiv m^{-3}); and at station 2, in October (180 indiv m^{-3}), March (75 indiv m^{-3}) and February (54 indiv m^{-3}) (figure 2).

The suprabenthos was dominated by Mollusca (74 %) and Crustacea, especially Mysidacea (15 %). Other important groups were Copepoda (2.6 %), Isopoda (1.6 %), eggs and post-larvae of Pisces (1.9 %), and larval stages of Decapoda (0.5 %). At station 1, on most occasions, the suprabenthos was dominated by post-larvae of Mollusca (always higher than 60 %), Peracarida (excluding mysids), (11.6. % in October), Copepoda (4 % in October), and Decapoda larvae (3 % in March); Polychaeta larvae and Mysidacea (respectively, 3 % and 2 %, in March) were also frequently observed (figure 3A). At station 2 the suprabenthos was dominated by Mysidacea (always higher than 40 %), although Copepoda (21 % in December, 42 % in January, 20 % in February, and 27 % in April), Mollusca larvae and eggs (24 % in January and 6 % in December and April), Pisces larvae and eggs (32 % in March and 10 % in May), and Isopoda (64 % in May and 10 % in March) were frequently observed (figure 3B). At station 1 the dominant species were the post-veligers of *Hydrobia ulvae* (Pennant, 1777) and *Gastrosaccus spinifer* (Goes, 1864). At station 2 *M. slabberi* and *Acartia tonsa* (Dana, 1848) were by far the most abundant species, followed by *Pomatoschistus* larvae and *Paragnathia formica* (Hesse, 1864).

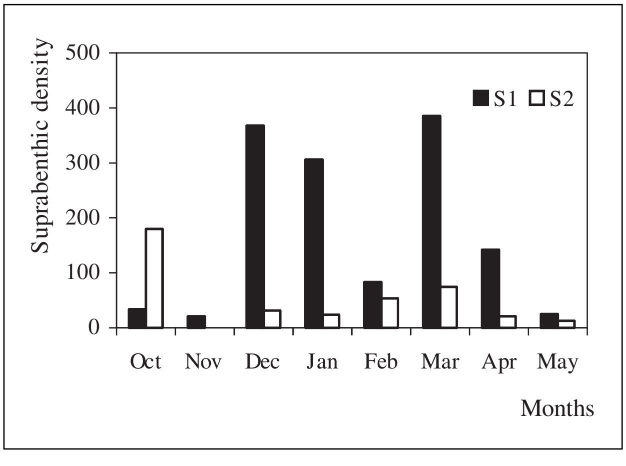


Figure 2. Seasonal variation in the density of the suprabenthos, at sampling stations 1 and 2, during the study period

The monthly patterns of abundance of the *H. ulvae* post-veligers at station 1, almost paralleled that of the total suprabenthos. At station 2 *M. slabberi* dominated the suprabenthos, with higher densities in October (160 indiv m^{-3}), February (37 indiv m^{-3}) and March (29 indiv m^{-3}). Besides this species, others showing important densities were the *Pomatoschistus* larvae, in March (24 indiv m^{-3}); *A. tonsa*, in October (12 indiv m^{-3}), February (10 indiv m^{-3}) and December (5 indiv m^{-3}); and *P. formica*, in May (8 indiv m^{-3}), March (5 indiv m^{-3}) and January (3 indiv m^{-3}).

Diversity values

Diversity values were lower at station 1, and showed no evident seasonal distribution pattern (figure 4A). At station 2, diversity values decreased till January, where they reached a minimum and increased till May (figure 4B).

Cluster analysis

Significant differences were found in community structure between the two selected areas of the estuary, with a dominance of the spatial structure in the cluster analysis (figure 5). A first split divided the main cluster into two groups: a first cluster with the species that occurred with higher densities in the outer station, including post-veligers of *H. ulvae, Schistomysis* spp., *G. spinifer, Paramysis* spp., zoeae of *C. maenas,* and Pisces eggs and larvae; and a second cluster including species that occurred with high abundance in the inner station, such as

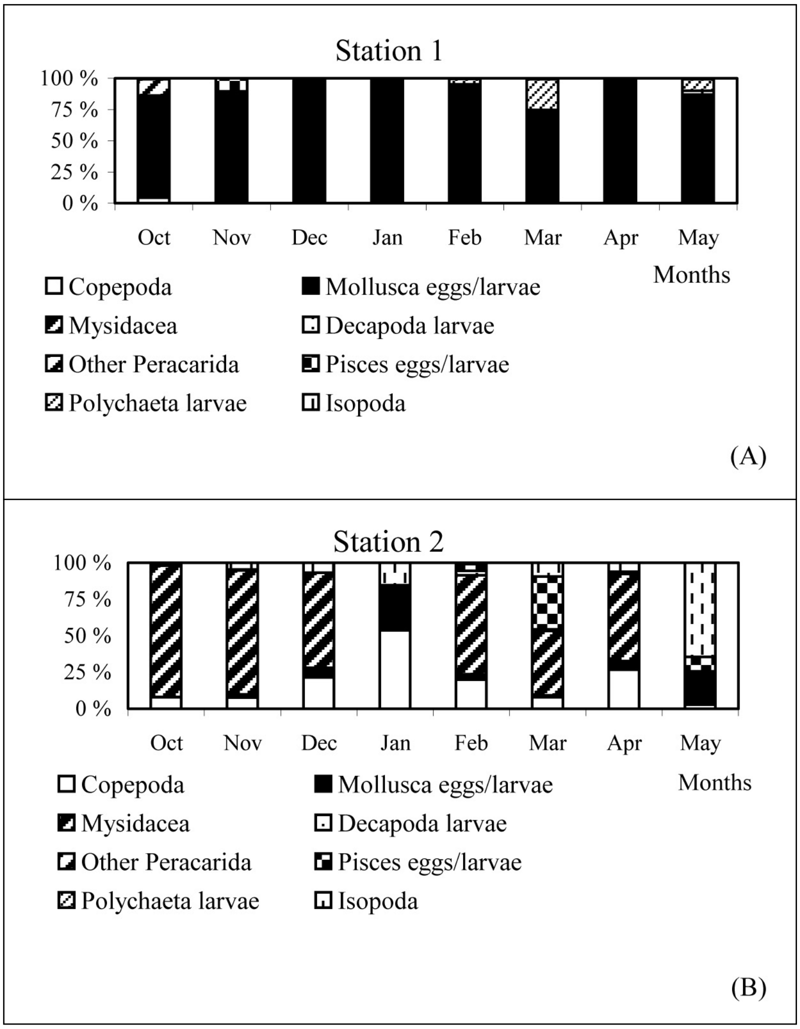


Figure 3. Percentage of the main suprabenthic groups at sampling station 1 (A) and sampling station 2 (B), during the study period

Harpacticoida copepod species, *A. tonsa, M. slabberi*, *P. formica* praniza and adults, *Palaemon elegans* (Rathke, 1837) zoeae*, Pomatoschistus* larvae, and *Crangon crangon* (Linnaeus, 1758). This group can also be divided into two sub-groups according to monthly occurrence: one sub-group included species occurring throughout the year, including Harpacticoida copepod species, *A. tonsa*, and *M. slabberi*; a second sub-group comprised species occurring mainly in Spring such as *P. formica* praniza and adults, *P. elegans* zoeae*,* and *Pomatoschistus* larvae.

DISCUSSION

The south arm of the Mondego estuary exhibits a clear spatial differentiation (Azeiteiro and Marques, 2000; Azeiteiro, Bacelar-Nicolau and Marques, 2002; Vieira *et al.*, 2002), which led to distinctive suprabenthic spatial structure patterns for the two sampling stations. The spatial segregation in species composition in estuaries is very steep: the communities of the marine and brackish parts are mostly composed of different species (Hamerlynck and Mees, 1991; Mees and Hamerlynck, 1992; Mees, Cattrijsse and Hamerlynck, 1993; Mees, Dewcke and Hamerlynck, 1993; Azeiteiro and Marques, 1999; Azeiteiro, Marques and Ré, 2000; Azeiteiro, Ré and Marques, 2002). Furthermore, most temporary (merosuprabenthos: Hamerlynck and Mees, 1991) and migratory suprabenthic species are not able to penetrate far into the estuary (Azeiteiro and Marques, 1999; Azeiteiro, Ré and Marques, 2002), resulting in a species-poor community upstream, which is always dominated by the same few species (Azeiteiro and Marques, 1999; Azeiteiro, Ré and Marques, 2002). One of the main conclusions of Azeiteiro and Marques (1999) was that the estuary under study contained distinct

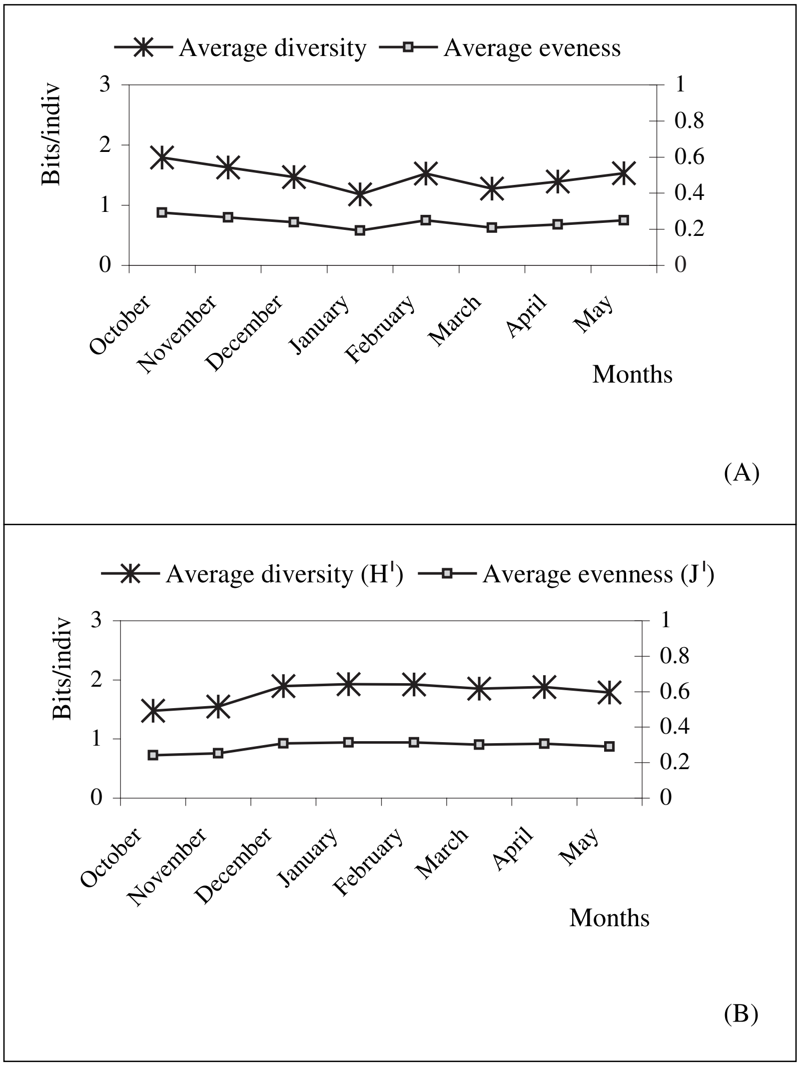


Figure 4. Diversity values at sampling station 1 (A) and sampling station 2 (B), during the study period

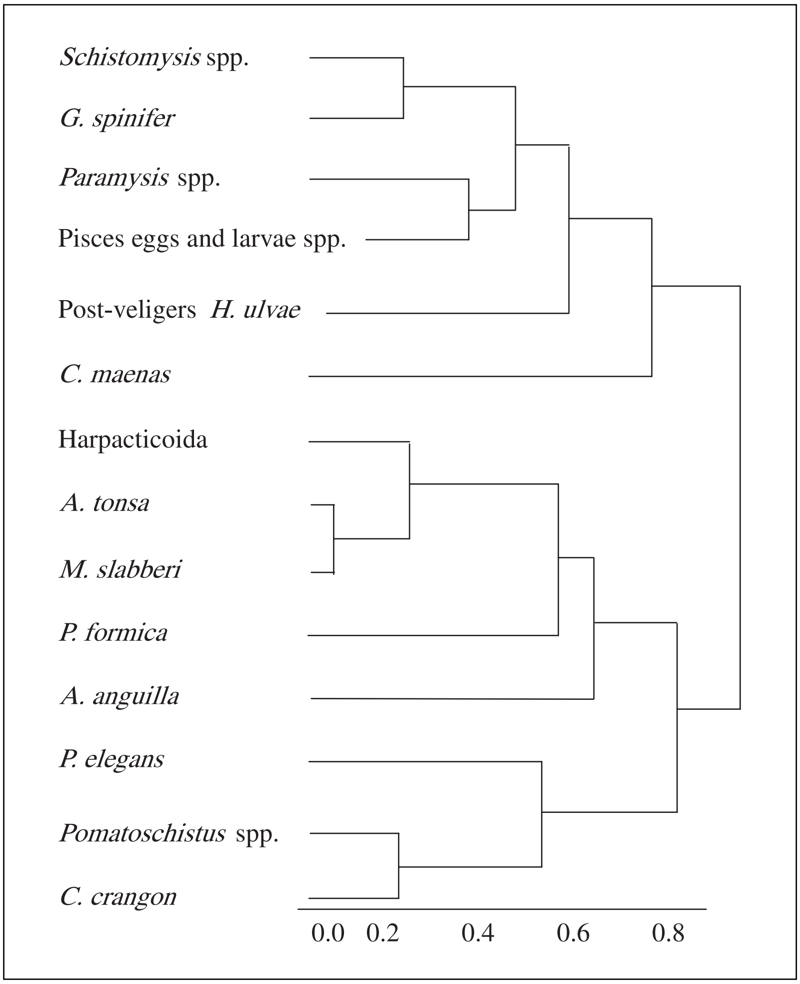
communities along the unidirectional salinity-transparency gradient (spatial segregation) and temperature-chlorophyll *a*-oxygen gradient (temporal evolution).

The diversity values found in the present study are not in accordance with the following within-estuary patterns: diversity is highest in the marine zone, where density is lowest, and diversity decreased in an upstream direction, where density reached maximum values. The explanation for this may be found in the high densities of *H. ulvae* post-larvae caught in the downstream station (which decreased species evenness due to the dominance of the species), and thus, the species diversity values are underestimated in the downstream area (not corresponding to a reduction in species richness, but to a dominance situation).

The gastropod *H. ulvae* is usually found in the intertidal areas of the northwest European estuaries and lagoons (Fish and Fish, 1974; Bachelet and Yacine-Kassab, 1987; Lillebø, Pardal and Marques, 1999). In the Mondego River estuary, as described in other northwest European estuarine lagoon environments (Fish and Fish, 1974; Bachelet and Yacine-Kassab, 1987), this species releases planktonic larvae, with high densities of post-larvae being registered, mainly between January and April (Azeiteiro, Marques and Ré, 1999). Its occurrence is associated with the presence or absence of food supply and related to light intensity and gravity (Barnes, 1981).

In the work of Azeiteiro and Marques (1999), a total of 74 species were identified. The suprabenthos was dominated by crustaceans, especially mysids. Other important groups were amphipods, isopods, caridean shrimps, larval stages of brachyuran crabs, and post-larval fish (Azeiteiro and Marques, 1999; Azeiteiro, Ré and Marques, 2002).

Figure 5. Classification of the most abundant species at both stations during the study period



In the present work, we identified fewer species. One of the explanations is the fact that our study left out the late spring and summer months. In these months the merosuprabenthos (caridean shrimps, larval stages of brachyuran crabs and other merosuprabenthic groups) (Hamerlynck and Mees, 1991) is very important in the estuary (Azeiteiro and Marques, 1999; Azeiteiro, Ré and Marques, 2002). Also in the winter, lower diversity values are affected by the combined effect of tides and freshwater discharge, causing strong daily variations in physico-chemical factors. From winter to summer, the decrease in freshwater discharge, and consequently easier tidal penetration, favour the incursion of suprabenthic marine species inside the estuary (Azeiteiro and Marques, 1999; Azeiteiro, Ré and Marques, 2002). On the other hand, any threats to the estuarine system will consequently endanger this sediment dependent fauna structure, as demonstrated by Martins *et al.* (1997), Pardal *et al.* (2000, 2002), and Cardoso *et al.*(2002) with key Mondego benthic estuarine species facing eutrophication.

Mysids dominated the suprabenthos. Mysids and decapods are well represented in coastal communities (Wang and Dauvin, 1984; Fossa, 1985; Webb and Wooldridge, 1990; Buhl-Jensen and Fossa, 1991; Elizalde, Dauvin and Sorbe, 1991; Hamerlynck and Mees, 1991; Dauvin, Iglesias and Lorgeré, 1994; Azeiteiro and Marques, 1999; Azeiteiro, Jesus and Marques, 1999; Azeiteiro, Ré and Marques, 2002) and our results followed a distribution pattern already observed in the estuary (Azeiteiro and Marques, 1999) and that of other European estuaries (Mees, Fockedey and Hamerlynck, 1995). The species *M. slabberi* is known to be very abundant in the estuary (Azeiteiro and Marques, 1999; Azeiteiro, Jesus and Marques, 1999; Azeiteiro *et al.*, 2000; Azeiteiro, Fonseca and Marques, 2001, 2002; Azeiteiro *et al.*, 2001; Azeiteiro, Ré and Marques, 2002; Pastorinho *et al.*, 2003a) and together with the calanoid copepod *Acartia tonsa* dominated in the upstream area (Azeiteiro, Marques and Ré, 1999, 2000; Antunes *et al.*, 2002; Pastorinho *et al.*, 2003b; Vieira *et al.*, 2003).

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