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Spatial distribution and seasonal variation of subtidal polychaete populations in the Mondego estuary (western Portugal)

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Résumé : L'estuaire du Mondego est divisé en deux bras, nord et sud. Le bras sud est fortement envasé tandis que le bras nord, plus profond, permet l'évacuation de la plus grande partie des eaux du fleuve. La pression anthropique est très forte : activités portuaires, salines, aquaculture, rejets d'usines chimiques et délavage des terres agricoles de la vallée du Mondego. Une étude des communautés macrobenthiques subtidales a été effectuée de décembre 1989 à septembre 1990. Les Polychètes, avec 35,6 % des espèces et 63 % des individus forment le groupe le plus abondant. Les données biologiques et physico-chimiques ont été soumises à une analyse en composantes principales (ACP). Globalement, l'estuaire du Mondego apparaît comme une zone qualitativement appauvrie. Néanmoins, des populations denses de quelques espèces de Polychètes sont présentes dans le bras sud. Le secteur le plus en amont de ce bras est caractérisé par la large dominance d'*Amage adspersa*, et la présence, en moindre abondance de *Capitella capitata, Heteromastus filiformis, Polydora ciliata* et *Streblospio shrubsolii.* Plus en aval du bras sud et près de l'embouchure de l'estuaire, la faune des Polychètes est caractérisée par la présence d'espèces des sables fins subtidaux, indicatrices d'une forte influence marine : *Eulalia sp., Eteone picta, Glycera convoluta, Lagis koreni, Nephthys spp.* et *Spio decoratus.* À l'opposé, le bras nord est caractérisé par les espèces indicatrices de milieux saumâtres *Hedistes diversicolor* et *Streblospio shrubsolii,* plutôt limitées au secteur amont et par la présence sporadique de quelques autres espèces. La répartition de la faune des Polychètes semble bien conditionnée par des facteurs physico-chimiques, le plus important apparaissant la nature du sédiment, suivi de la salinité. Les deux bras de l'estuaire constituent deux sous-systèmes dissemblables. Par ailleurs, les opérations de dragage le long du bras nord sont trop fréquentes pour autoriser une restauration de l'endofaune tandis qu'un processus d'eutrophisation semble être en cours dans le bras sud.

Abstract : The Mondego estuary consists of two arms, north and south. The north arm is deeper, while the south arm is largely silted up, causing freshwater to flow primarily by the north arm. Environmental stress is severe, essentially due to harbour activities, salt-works, aquaculture farms, and nutrients and chemicals discharged from agricultural areas of the lower Mondego river valley. From December 1989 to September 1990 a study of the subtidal macrofaunal community was carried out. Polychaetes were found to be the most abundant macrofaunal group of the Mondego estuary subtidal community, representing about 34.5 % of the species and 63 % of the individuals sampled. Both biological and physicochemical data were analysed by principal components analysis (PCA), and data on the Polychaete fauna was also analysed with regard to spatial and temporal variations of total abundance. The Mondego estuary seems to present an impoverished subtidal Polychaete fauna with regard to the number of species, although the south arm presents enhanced populations. In the inner areas of the south arm, the Polychaete fauna is characterized by abundant populations of *Amage adspersa,* followed by more sparse populations of *Capitella capitata, Heteromastus filiformis, Polydora ciliata,* and *Streblospio shrubsolii.* Moreover, the number of species was roughly stable through the year, and Polychaetes exhibited by far the most elevated abundances found in the estuary. In the north arm, the Polychaete fauna was characterized by *Hediste diversicolor* and *Streblospio shrubsolii,* almost restricted to the upstream section, followed by the sporadic occurrence of other species. The north arm exhibited an extremely impoverished Polychaete fauna, both in number of species and total abundance, as compared to the south arm. In the downstream area of the south arm and near the mouth of the estuary the Polychaete fauna was characterized by the occurrence of a mixture of uncommon species e.g. *Eulalia sp., Eteone picta, Glycera convoluta, Lagis koreni, Nephthys* spp., and *Spio decoratus,* reflecting a stronger marine influence. The subtidal Polychaete fauna appears to be controlled primarily by physicochemical factors, especially sediments type and salinity. Biologically, the two arms of the estuary constitute distinct sub-systems, with dissimilar physicochemical characteristics. Furthermore, time intervals between dredging operations along the north arm are apparently inadequate to allow infaunal recovery in the north arm, and extensive eutrophication seems to be taking place in the south arm.

INTRODUCTION

The Mondego river drains a hydrological basin of about 6 670 Km^2 and its estuary (Fig. 1) is the location of Figueira da Foz harbour, which has considerable regional importance. Besides dredging activities related to harbour facilities, which cause physical disturbance, the estuary supports several industries, many salt-works, and aquaculture farms. Finally, it receives nutrients and chemical discharges from the agricultural areas of the lower Mondego river valley, which can be especially significant in the rainy period.

Despite the increasing pressure, there was no data on the Mondego estuarine system available until 1985. A study of the intertidal macrobenthic community was concluded in 1988 (Marques *et al*, in press) ; from December 1989 to September 1990 a study of the subtidal macrobenthic community was also carried out. The purpose of both studies was to provide data to which future studies of the impact of human activities could be compared.

The aims of this study were to characterize the macrofaunal community in relation to physicochemical environmental factors, to identify the species which may have a key role in the ecosystem functioning, and to assess the impact of dredgings and water circulation.

Polychaetes are especially important components in estuarine ecosystems, because of their limited mobility and response to environmental stress (Byliard, 1987). Although using only the most abundant species to characterize communities, or as indicators of physicochemical conditions, may be unreliable because of their variation in both time and space (Jones, 1990), it seems appropriate to look at Polychaetes as good indicators of environmental conditions in the Mondego estuary. Actually, the available data showed that Polychaetes are the most abundant macrofaunal group of the Mondego estuary, representing about 34.5 % of the species and 63 % of the individuals sampled. Therefore, in order to allow further comparisons with the present situation, a particular study on the distributional ecology and seasonal variation of the Polychaete fauna was accomplished.

MATERIAL AND METHODS

Study site

The Mondego estuary is warm-temperate in a region with a basic mediterranean temperate climate. It consists of two arms, north and south (Fig. 1), with very different hydrographic characteristics. The north arm, where the harbour is located, is deeper than the south arm, which is almost silted up in the upstream areas, causing the freshwater to flow essentially by the north arm. Consequently, the circulation in the south arm is mostly due to the tides and to the usually small freshwater input of the Pranto river (Fig. 1). Due to diffe-

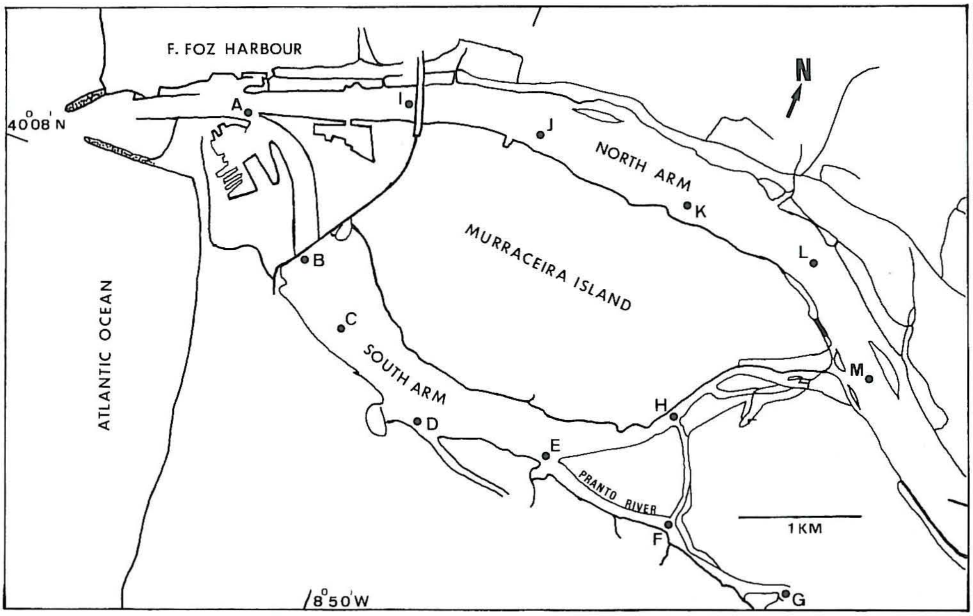

Fig. 1 : The Mondego estuary : Localization of the subtidal sampling stations.

rences in depth, the penetration of the tide is faster in the north arm, causing daily changes in salinity to be much stronger in the north arm, whereas daily temperature changes are higher in the south arm (Marques, 1989).

Dredging activities related to the harbour facilities take place regularly in the north arm, causing sediment resuspension in the water column and physical disturbance of the bottom. In addition, uncommon blooms of the macroalgae *Enteromorpha spp.* have been observed in the south arm, probably due to excessive nutrient release. Actually, since circulation in the south arm depends mainly on tides, the persistence of nutrients (inorganic nitrogen and phosphorus) in the water column is usually longer than in the north arm (Marques *et al*, in press).

Sampling program

In December 1989 and March, June, and September 1990 quantitative samples were carried out at 13 sampling stations (A to M) (Fig. 1), to provide a seasonal characterization of the subtidal macrobenthic community. On each occasion samples were taken over a two day period, during high water of spring tides. At each station six replicates were randomly sampled using a small Van Veen grab operated from a boat. The sampled area was approximately constant (496 cm^2) but, although the maximum capacity of the grab was 5 L, the amount of sediment collected was not always the same, depending primarily on bottom compactness. Therefore, some bias might have been introduced into the sampling strategy for burrowing Polychaetes.

All biological samples were sieved *in situ* on a 1 mm mesh size sieve, then fixed in 4 % neutralized formalin. Due to the expected sediment composition along the estuary (preliminary sampling data was available), this mesh size was considered suitable for the study.

Each time at each station, water salinity, temperature, pH, and oxygen dissolved in the water were measured *in situ*, close to the bottom, while nitrite, nitrate and phosphate concentrations were determined in the laboratory from analysis of water samples, following Strickland and Parsons (1968). Sediment samples were collected and analysed for the granulometry (only once during the period of study), using the Udden-Wentworth scale (McManus, 1988), and organic matter content (each season). The organic matter was determined by loss on ignitions (24 hours at 500 ° C).

In the laboratory, the organisms were separated, and Polychaetes identified to the species level and counted.

Data analysis

It was assumed that data from each season should correspond to different ecological conditions, and were therefore analysed separately. With regard to Polychaetes, seasonal matrices of species X stations were analysed, considering data combined from each series of six replicates. Since the goal of the analysis was to study the distributional ecology of species along the estuarine gradient, and to reveal probable differences in the Polychaete fauna composition between the two arms of the estuary, Principal Component Analysis (PCA), using the sampling stations as operational units in the space of biological variables, was employed. Eigenvalues and eigenvectors of correlation matrices between variables were computed after centering and reduction to unit variance. The correlation matrices were computed using the Parametric Correlation coefficient (Pearson's r) (Legendre & Legendre, 1984).

Physicochemical data of water and sediments (matrices of factors X stations) also underwent PCA, following the same procedure as for biological data. Data on sediment granulometric fractions and carbonate content (expressed in percentages) were nevertheless submitted to angular transformation.

The analysis were performed using the NTSYS-PC 1.60 software system (Rohlf, 1990).

RESULTS

A total of 52 samples, corresponding to 306 replicates, provided 4761 individual Polychaetes of 20 species, respectively *Amage adspersa, Capitella capitata, Chaetozone setosa, Chone collaris, Eteone picta, Eulalia sp., Glycera convoluta, Hediste diversicolor, Heteromastus filiformis, Lagis koreni, Nephthys hombergii, Nephthys longosetosa, Nephthys paradoxa, Nereis succinea, Perinereis cultrifera, Polydora ciliata, Oriopsis sp., Spio decoratus, and Streblospio shrubsolii.* The most frequent and abundant species were *Amage adspersa* and *Streblospio shrubsolii*, followed by *Hediste diversicolor* and *Polydora*

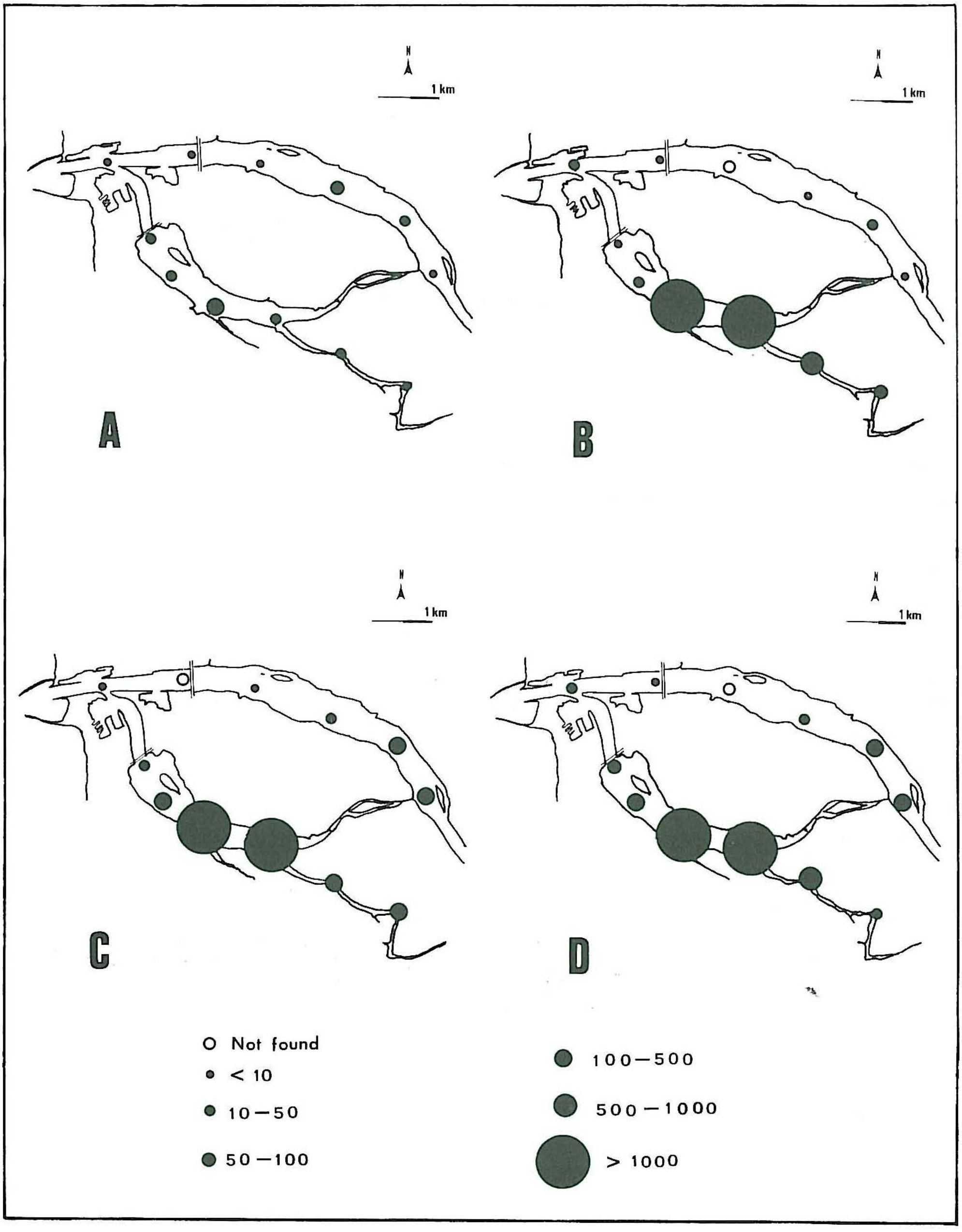

Fig. 2 : Spatial and temporal variation of Polychaete total abundance (individuals.m^{-2}) in the Mondego estuary : **A** - December ; **B** - March ; **C** - June ; **D** - September.

ciliata. A. adspersa appeared to be clearly dominant, while all the other species either presented more sparse populations or occurred only occasionally.

Distribution and abundance of subtidal Polychaete fauna

A seasonal variation of the Polychaete fauna abundance was observed. The lowest values were found in December (166 individuals of 13 species). Until March, although total abundance of the Polychaete fauna increased (895 individuals were collected), the number of species found was lower (only 8 species), probably as a repercussion of the winter effects. From March to June the spring influence was clearly reflected in the increase of total abundance and number of Polychaete species found (2581 individuals of 12 species). Finally, from June to September, total abundance decreased (1119 individuals were collected), although the number of species found (14) was slightly higher.

Total abundance of Polychaete fauna (individuals.m^{-2}), despite seasonal variations and possible sampling bias, corresponded to a consistent spatial pattern through the year (Fig. 2). Polychaete populations were much more abundant in the inner areas of the south arm, although becoming less dense in the Pranto river (Fig. 2). A significant Polychaete abundance was also observed in downstream areas of the south arm and in the upstream section of the north arm, while in the rest of the north arm Polychaete populations appeared clearly impoverished, which was particularly evident in the middle section.

PCA of matrices of species X stations reveals differences between the two arms of the estuary with regard to Polychaetes. This is particularly clear from projection of stations against the first and second axes of variability based on data from December (Fig. 3), June (Fig. 5), and September (Fig. 6), although differences are not apparent in March (Fig. 4). Despite seasonal variations, we found a constant pattern of discontinuity between stations located in inner areas of the south arm (D, E, F, G, and H) and stations located along the north arm (I, J, K, L, and M). Station A, located near the mouth, and stations B and C, located in the downstream area of the south arm, appeared to be distinct from the other stations, which is especially evident from PCA of data from December and September (figures 3 and 6). These three stations exhibit a stronger seasonal variation of the Polychaete fauna composition, probably due to marine influence, which may explain their irregular pattern of assemblage through the year. On the other hand, stations L and M, located in the upstream section of the north arm, appear to be relatively different when compared to other stations from the north arm. This is particularly visible in June (Fig. 5), when these two stations appeared assembled, and separated from other stations.

Stations from inner areas of the south arm (D, E, F, G, and H) were mainly characterized by abundant populations of *Amage adspersa*, followed by more sparse populations of *Capitella capitata, Heteromastus filiformis, Polydora ciliata* and *Streblospio shrubsolii,* and depending on the season, by the occasional occurrence of other species like *Chaetozone setosa, Chone collaris, Oriopsis* sp., and *Spio decoratus* (Figs 3 to 6).

In stations located along the north arm (I, J, K, L, and M) the Polychaete fauna appeared clearly impoverished, being mainly characterized by sparse populations of *Hediste diversi-*

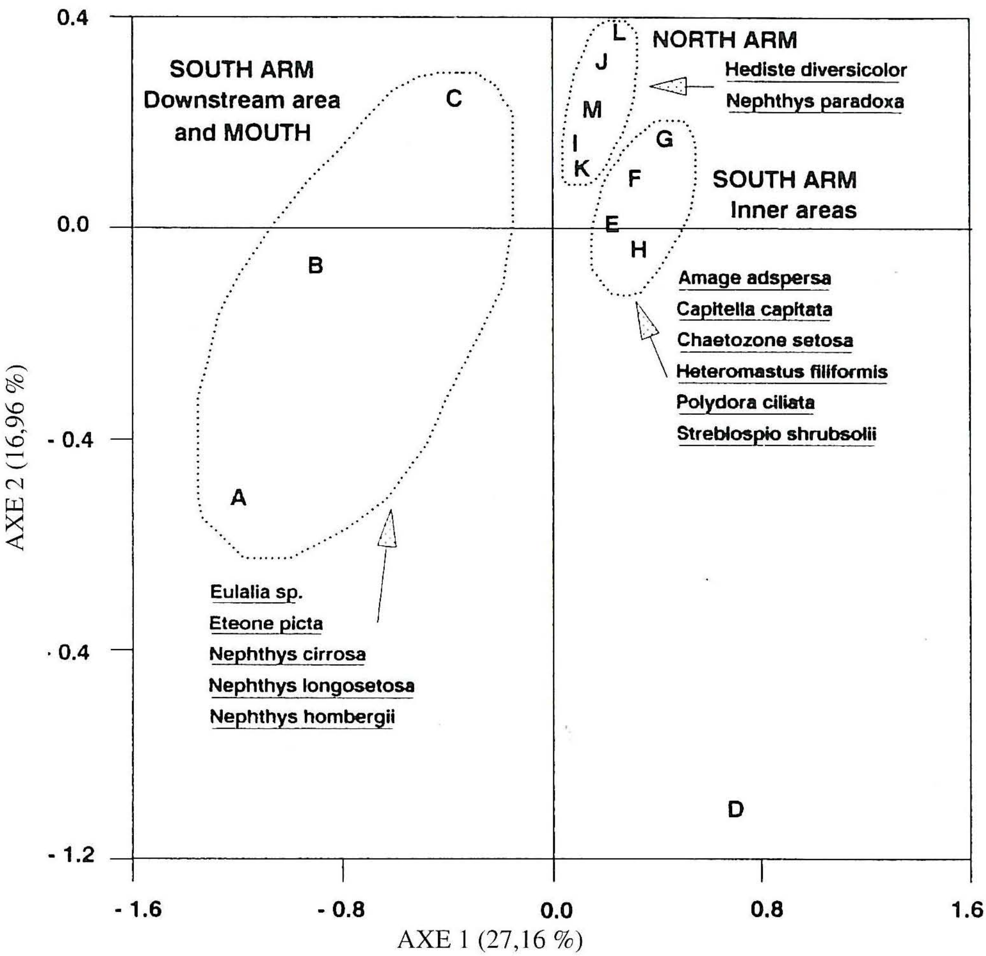

Fig. 3 : December situation : Results from Principal Components Analysis of matrices of Polychaete species X stations. Projection of stations (A to M) against the first and second axes of variability. Species characterizing each group of stations are indicated.

color and *Streblospio shrubsolii*, although other species like *Nephthys paradoxa, Nereis succinea*, and *Perinereis cultrifera* could be found more or less sporadically in these stations. The occurrence of *H. diversicolor* and *S. shrubsolii* was nevertheless almost limited to stations L and M, located in the upstream section (Figs 3 to 6).

Station A, located near the mouth, and stations B and C, located in downstream areas of the south arm, despite important seasonal variations in the Polychaete fauna composition, could be primarily characterized by irregular or sporadic occurrence of several species e. g. *Eteone picta, Eulalia sp., Glycera convoluta, Lagis koreni, Nephthys hombergii, N. longo-*

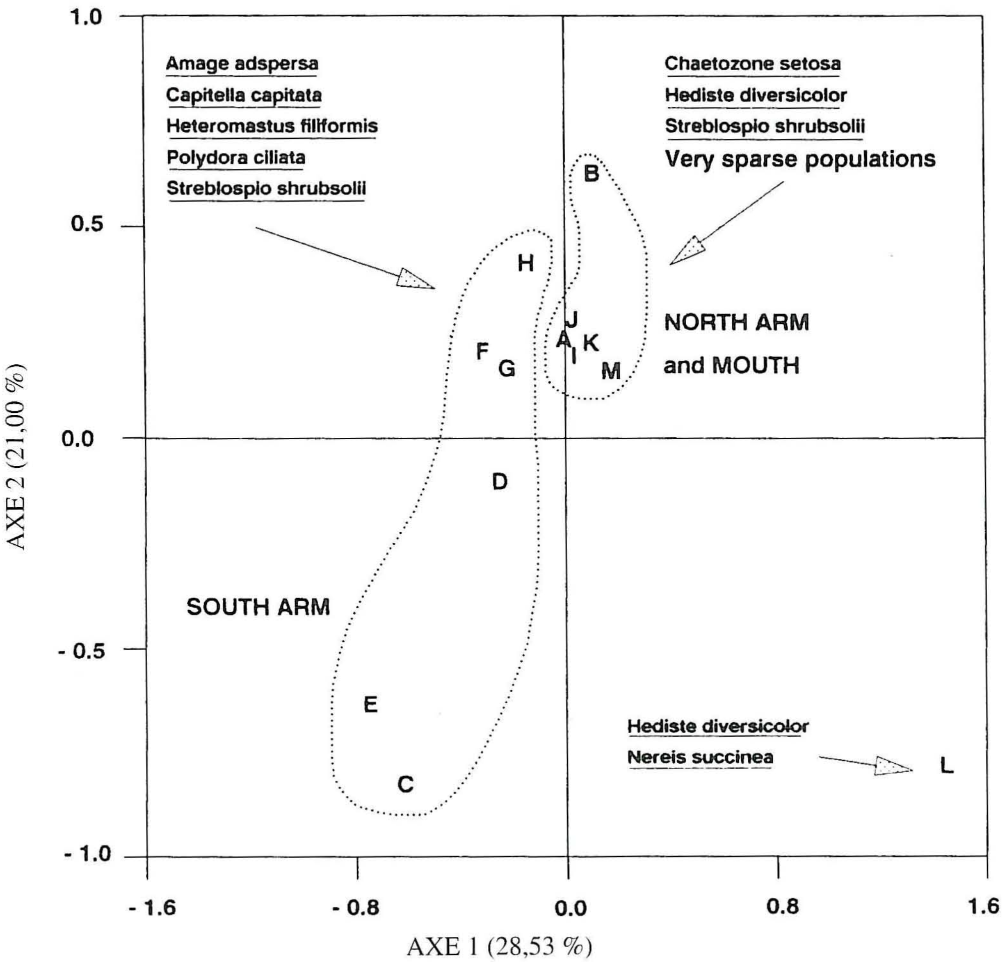

Fig. 4 : March situation : Results from Principal Components Analysis of matrices of Polychaete species X stations. Projection of stations (A to M) against the first and second axes of variability. Species characterizing each group of stations are indicated.

setosa, N. paradoxa, N. cirrosa, Spio decoratus, which might reflect stronger marine influence.

Influence of environmental factors on Polychaetes distribution and abundance

To understand the influence of physicochemical factors on Polychaetes distribution and abundance, the first step was to characterize the estuary with regard to these factors.

PCA of matrices of physicochemical factors X sampling stations (Fig. 7, A to D) show a consistent pattern through the year, and apparently seasonality does not have significant

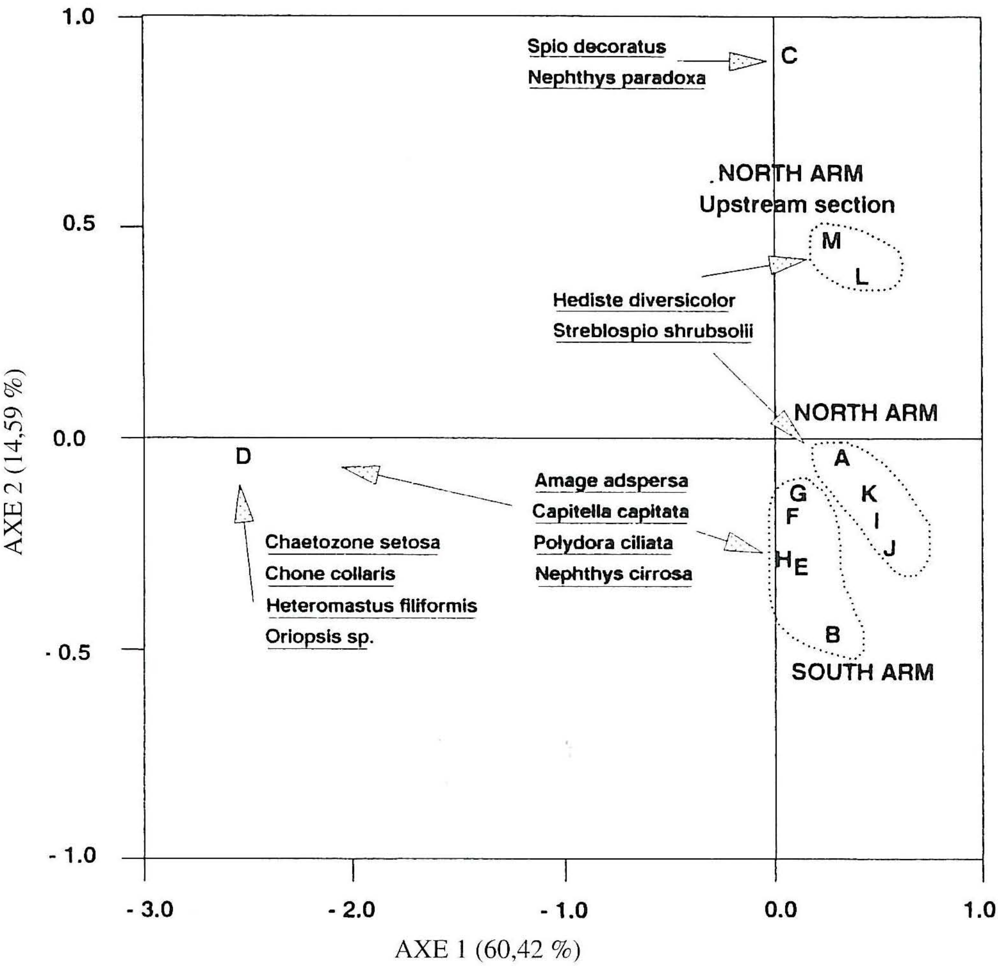

Fig. 5 : June situation bienn: Results from Principal Components Analysis of matrices of Polychaete species X stations. Projection of stations (A to M) against the first and second axes of variability. Species characterizing each group of stations are indicated.

influence in the observed structure. Actually, each time the projection of stations against the first two axes of variability clearly discriminates stations located in the north arm from stations located in the south arm (including the Pranto river) along the first axe. On the other hand, stations A, B, and C, respectively located near the mouth and in downstream areas of the south arm, are only discriminated along the second axe of variability. Stations B and C appear always assembled and in opposition to station A.

The major factors explaining variability along the first axe are differences in granulometry and organic mater contents of sediments between stations located in the south arm (D,

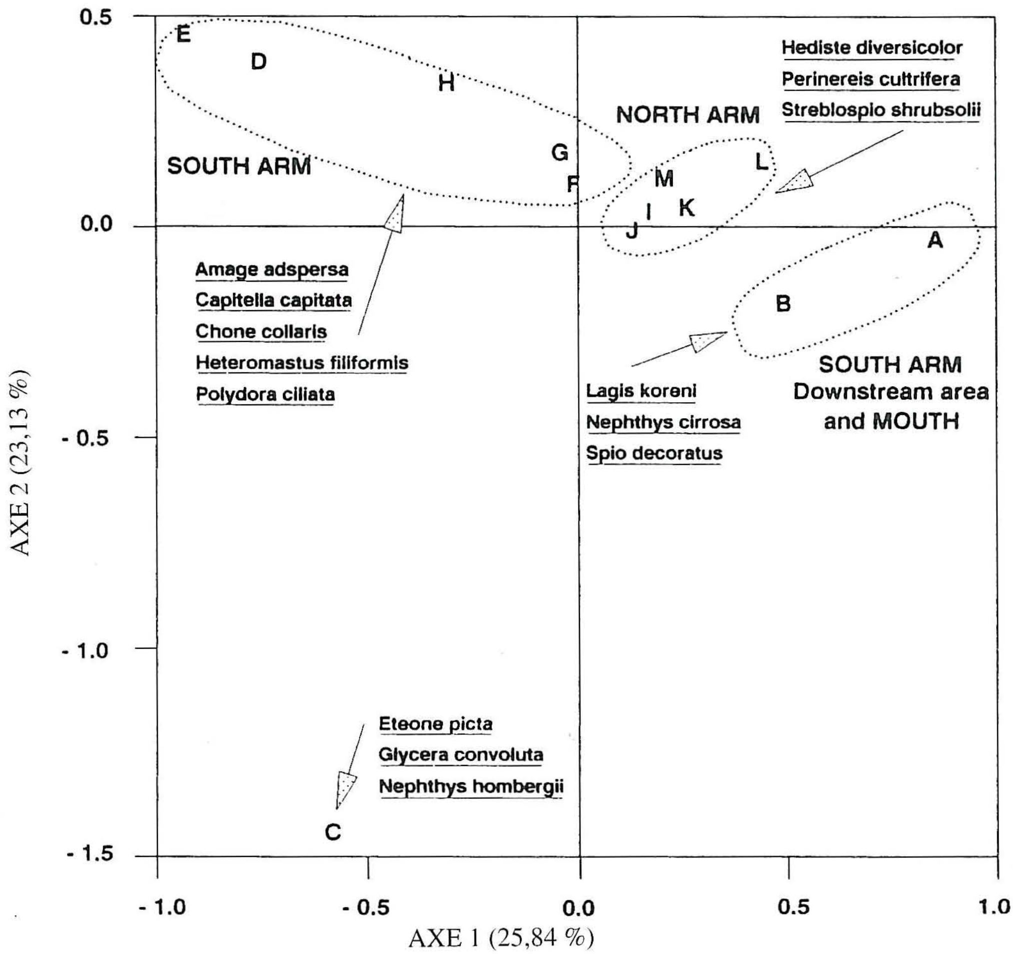

Fig. 6 : September situation : Results from Principal Components Analysis of matrices of Polychaete species X stations. Projection of stations (A to M) against the first and second axes of variability. Species characterizing each group of stations are indicated.

E, F, G and H) and stations located in the north arm (I, J, K, L, M). Actually, stations located in the south arm were mainly characterized by sediments with larger fractions of fine sand to clay, and higher organic matter and carbonate contents, while stations located in the north arm were mainly characterized by sediments with larger fractions of gravel and coarse to medium sand. In addition, stations from the north arm also presented higher values of salinity and oxygen dissolved in the water column. In December, stations located in the south arm exhibited higher nitrite concentration in the water column, while stations in the north arm presented lower nitrite concentrations but higher pH values.

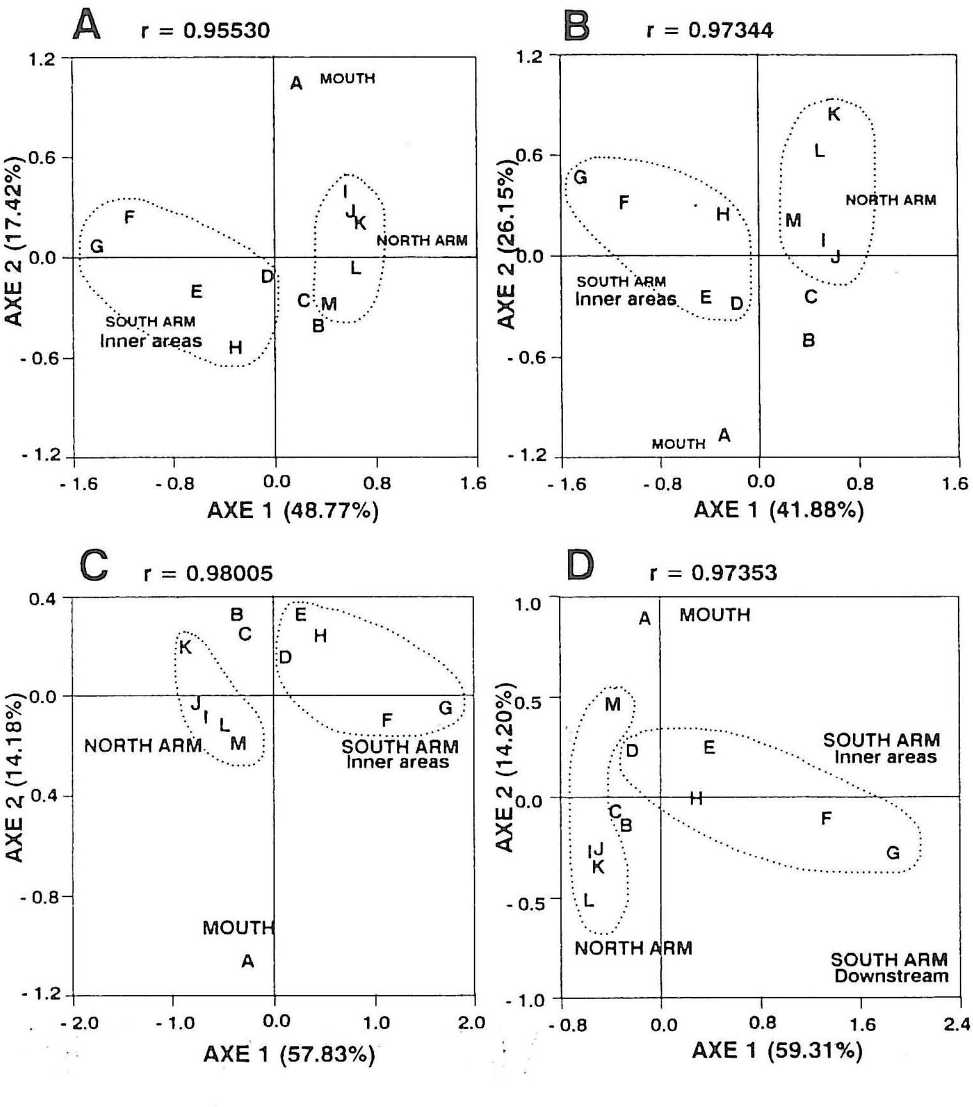

Fig. 7 : Results from PCA of matrices of physicochemical factors of water and sediments X stations. Projection of stations (A to M) against the first and second axes of variability : **A** - December ; **B** - March ; **C** - June ; **D** - September.

The major factor explaining the opposition of stations B and C to station A along the second axe of variability is indubitably salinity, although nitrate concentration in the water column also play a significant role as discriminating factor in December and March. In station A, located near the mouth, salinities were normally higher, while nitrate concentration tended to be more elevated inside the estuary.

With regard to physicochemical factors, it was therefore possible to characterize different estuarine areas, which was also clearly reflected in Polychaetes distribution and abundance. Stations located in the south arm, especially in inner areas (D, E, F, G, and H), characterized by fine sediments, richer in organic matter and carbonate contents, and often by higher concentration of nitrogen in the water column (Table I), presented a roughly stable number of species and, by far, the highest abundance of Polychaetes. Comparatively, stations from downstream areas of the south arm (B and C), characterized by sediments with more significant fractions of coarse to medium sand and smaller organic matter and carbonate contents, and also by higher salinities and dissolved oxygen levels, presented larger number of species but lower Polychaetes abundance.

Stations located along the north arm (I, J, K, L and M) were characterized by sandy bottoms, poor in organic matter and carbonate contents (Table I). Nevertheless, the fine sand fraction in sediments was more important closer to the mouth and in the upstream section of the north arm, while gravel to medium sand fractions were predominant in the middle section. Total abundance of polychaetes was very low along the north arm through the year, with the exception of its upstream section. In addition, the number of species found in the north arm was clearly lower than in the south arm, particularly in the middle section, which was found to be the poorest area in the estuary with regard to Polychaete fauna.

Station A, located near the mouth, presenting a fine sand bottom, was mainly characterized by higher salinities as compared to other stations, which obviously reflected stronger marine influence. In this station, both total abundance of Polychaetes and number of species found were lower than in stations from the south arm and upstream section of the north arm.

DISCUSSION

We could not found in the literature an appropriate data set for comparison with our present results on the Mondego estuary. Nevertheless, within certain limits, it was possible to establish a comparison with another portuguese estuary, the Mira, located in the southwestern coast of Portugal. Actually, the Mira is approximately identical to the Mondego in size, and has been considered more or less unaffected by human activities, providing therefore a reasonable basis for comparison. In addition, data on the Mira estuary macrobenthic communities (Andrade, 1986), although limited to June, was collected according to a similar sampling strategy and using identical grabs. With regard to subtidal Polychaetes, 34 species were identified for the Mira, while only 20 (approximately 59 %) were identified for the Mondego. Only seven species were found in both estuaries, which also revealed a significant contrast in the species composition. With regard to Polychaetes total abundance, based on June data, an average of 234 individuals.m^{-2} per sample was found in the Mira, while in the Mondego estuary, taking into consideration the two arms separately, we found respectively 1204 individuals.m^{-2} per sample in the south arm and only 43 individuals.m^{-2} per

TABLE I

Physicochemical characteristics of water and sediments. For each station (A to M), average annual values (A) and standard deviations (SD) are given (based on data from December, March, June, and September), with the exception of data on sediment granulometric fractions and carbonate content, which were determined only once during the period of study.

FACTORS		A		B		C		D		E		F		G		H		I		J		K		L		M	
		Av	SD	Av	SD	Av	SD	Av	SD	Av	SD	Av	SD	Av	SD	Av	SD	Av	SD	Av	SD	Av	SD	Av	SD	Av	SD
Water column	Temperature	15.9	1.0	17.1	3.0	16.6	3.0	17.1	2.4	17.0	2.8	17.6	3.1	18.4	3.9	18	2.9	16.5	1.7	16.5	1.3	16.4	1.4	16.4	1.7	16.3	1.9
	Salinity	35.5	4.0	27	7.3	27.1	7.0	26.9	3.7	26.6	5.9	26.6	5.3	22.6	4.2	20.8	9.4	30.0	3.7	28.6	8.0	25.6	13.8	24.9	11.4	19.6	16.3
	Oxygen	8.7	0.2	8.6	0.4	8.8	0.6	8.4	0.9	8.7	0.9	7.8	0.5	7.7	0.6	8.5	0.6	8.6	0.6	8.6	0.3	9.3	0.60	8.7	0.7	8.8	0.7
	pH	7.2	1.0	7.4	0.8	7.4	0.8	7.4	0.7	7.3	1.0	7.2	0.9	6.8	1.1	7.7	0.5	7.3	1.2	7.6	0.8	7.7	0.60	7.5	0.9	7.7	0.9
	Nitrites	0.73	0.43	0.86	0.55	1.10	0.51	0.81	0.35	1.02	0.69	1.31	0.60	1.55	0.49	1.05	0.54	0.75	0.36	0.75	0.25	1.06	0.64	1.01	0.45	0.93	0.47
	Nitrates	4.1	1.68	12.2	11.0	13.3	10.9	9.00	4.99	12.4	7.71	13.5	12.2	12.4	11.0	14.7	14.1	10.1	9.62	8.54	6.38	15.9	12.0	21.4	14.5	19.6	18.0
	Phosphates	0.61	0.21	0.62	0.36	0.86	0.45	0.71	0.27	0.74	0.26	0.88	0.38	1.26	0.32	0.70	0.36	0.70	0.51	0.67	0.34	0.79	0.66	0.67	0.57	0.68	0.31
Sediments	Organic mater	1.54	0.1	0.76	0.03	0.97	0.12	3.18	1.91	5.85	2.77	7.52	1.38	9.01	0.83	4.43	0.91	0.85	0.33	0.67	0.19	0.50	0.05	0.61	0.01	1.16	0.45
	> 2 mm	0.01	-	6.05	-	4.18	-	3.03	-	1.84	-	0.39	-	0.0	-	2.67	-	6.91	-	8.37	-	12.5	-	29.3	-	4.99	-
	1 - 2 mm	1.57	-	17.2	-	32.8	-	17.3	-	8.26	-	1.89	-	0.26	-	14.8	-	53.7	-	54.2	-	55.1	-	31.7	-	10.6	-
	0.5 - 1 mm	9.8	-	53.6	-	32.1	-	22.3	-	20.8	-	7.16	-	2.94	-	15.4	-	31.9	-	30.2	-	24.3	-	10.8	-	35.3	-
	0.250 - 0.5 mm	87.8	-	23.0	-	30.6	-	45.6	-	45.3	-	41.1	-	43.6	-	45.3	-	7.50	-	7.21	-	6.85	-	28.3	-	46.5	-
	0.125 - 0.250 mm	0.7	-	0.09	-	0.27	-	4.73	-	12.3	-	19.7	-	19.0	-	8.95	-	0.04	-	0.04	-	0.45	-	0.12	-	1.24	-
	0.063 - 0.125 mm	0.05	-	0.0	-	0.0	-	2.95	-	5.88	-	11.7	-	14.1	-	5.63	-	0.00	-	0.00	-	0.26	-	0.00	-	0.65	-
	0.002 - 0.063 mm	0.02	-	0.0	-	0.0	-	2.46	-	4.78	-	10.0	-	11.7	-	4.04	-	0.00	-	0.00	-	0.19	-	0.00	-	0.52	-
	< 0.002 mm	0.01	-	0.0	-	0.0	-	1.88	-	3.37	-	7.51	-	9.23	-	2.96	-	0.00	-	0.00	-	0.15	-	0.00	-	0.42	-
	Carbonates	4.44	-	3.52	-	1.9	-	3.27	-	5.22	-	7.41	-	8.65	-	4.2	-	1.56	-	1.27	-	1.29	-	2.18	-	2.62	--

sample in the north arm. Despite any conceivable bias in sampling, these differences must be considered significant. The subtidal Polychaete fauna of the Mondego estuary seems to be impoverished in number of species. On the other hand, as compared to the Mira, the south arm of the Mondego estuary exhibits an abundant Polychaete fauna, while in the north arm Polychaete populations appear to be very sparse.

The analysis of Polychaetes distributional ecology and of physicochemical factors through the year fit well, both allowing to recognize consistent differences between the two arms of the Mondego estuary, which actually constitute distinct sub-systems. In the south arm, where water circulation depends primarily on tides, conditions appear to be favourable to the deposition of fine particles and organic matter (McLusky, 1989). This determined a biological improvement, since subtidal infauna depends on sediments stability and organic matter content (Gould *et al*, 1987). In the north arm, bottom characteristics may be primarily controlled by the combined effects of river discharge and tidal penetration, which could explain the differences observed between the two arms.

Although the species-sediments relationship is not always a simple linear function of grain size and organic matter contents (Jones *et al*, 1986), in the present case bottom characteristics appear certainly as a major factor controlling the Polychaete fauna distribution and abundance. In addition, due to river discharge and tidal currents, daily salinity fluctuations in the north arm are normally stronger than in the south arm (Marques, 1989), which may contribute to explain the observed faunal impoverishment (Barr *et al*, 1990). This agrees with the direct relationship between faunal type and tidal stress observed by other authors (Warwick & Uncles, 1980). Therefore, granulometry and salinity fluctuations appear to be the most important factors controlling the distributional ecology of subtidal Polychaete populations in the Mondego estuary.

In the north arm, the observed impoverishment of Polychaete fauna was surely related with instable sediments and tidal stress, which tend to prevent the colonization and long-term establishment of a permanent infauna (Barr *et al*, 1990). Nevertheless, in the upstream section of the north arm, where dredging operations do not take place, *Hediste diversicolor* and *Streblospio shrubsolii* could be found through the year. It seems therefore that the extreme impoverishment of Polychaete fauna in the middle section of the north arm, was also a function of regular dredgings. Therefore, time intervals between dredging operations in the north arm of the Mondego estuary (approximately twice a year) seem to be to short, which might not allow infaunal recovery.

The south arm, due to the weak water circulation, may be more exposed to eutrophication as a function of nutrient enrichment. Macroalgae blooms of *Enteromorpha* spp. (green algae) have actually been observed, but *Capitella capitata, Polydora ciliata* and *Streblospio shrubsolii*, species which have frequently been associated with organic enrichment, present relatively sparse populations. On the other hand, *Amage adspersa* presents high abundances in sediments rich in organic matter, and therefore this species might be also an indicator of organic enrichment.

It is known that estuarine benthic communities are normally characterized by wide fluctuations in the abundance of many constituent species, although presenting a more persistent qualitative composition (Boesch *et al*, 1976). Therefore, it seems necessary to monitor the Mondego estuary benthic communities, and Polychaetes, like in other coastal systems, may be used as a good indicators for the interpretation of environmental conditions (Sordino *et al*, 1989).

CONCLUSIONS

The Mondego estuary presented an impoverished subtidal Polychaete fauna.

In the south arm, Polychaetes presented higher number of species, and by far the largest abundance, while in the north arm, with the exception of the upstream section, an extreme faunal impoverishment was observed. The two arms of the estuary constitute therefore distinct subsystems, which is a consequence of their dissimilar physicochemical characteristics.

Polychaetes distributional ecology appeared to be primarily controlled primarily by physicochemical factors, with emphasis on sediment type, salinity and currents.

Time intervals between dredgings along the north arm appear to be inadequate for infaunal recovery, contrary to other case studies, demonstrating that this kind of operations must be carefully undertaken, taking into consideration the characteristics of each particular system.

New environmental changes have been observed recently in the Mondego estuary, and therefore it seems essential to monitor the biological communities, in order to assess potential modifications in the ecosystem structure and functioning. Polychaetes may be used as good indicators of environmental conditions.

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