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ABSTRACT

The present work is part of an environmental assessment undertaken in the Sado estuary (Southern Channel and Mitrena Peninsula), western coast of Portugal, on February 1999 prior to maintenance dredging works. The macrofauna communities in the study area are generally rich and abundant. A single exception was found: a sampling site in the Mitrena area, with extreme impoverishment, probably related to sediment characteristics, i.e., fluid mud, unfavourable to the establishment of individuals. A comparative analysis of these macrofauna results to previous data from 1986 showed that this biological component had suffered no significant changes, especially as far as the most characteristic species. Although the Southern Channel had been dredged in 1995, no clear signs of such operation were apparent in the present survey.

The main differences between both periods (1986-1999) was an increase in the abundance and presence of some common species of organic enriched areas, such as *Tharyx* sp., *Corbula gibba*, *Spiochaetopterus costarum* and *Ampelisca* spp., which might be related to organic enrichment in the Southern Channel. The joint consideration of our results on benthic macrofauna and those regarding sediment contamination and sediment bioassays, performed at the same time by other researchers, does not indicate the necessity of any particular constraints on the dredging operations.

Key words: Benthic communities, dredging operations, Sado estuary, organic enrichment.

RESUMEN

Caracterización de la comunidad macrobentónica de un estuario de la costa oeste de Portugal (estuario del Sado) previa a la realización de operaciones de dragados

El presente trabajo forma parte de un estudio de impacto ambiental que fue llevado a cabo en el estuario del río Sado (canal sur y península de Mitrena), costa oeste de Portugal, en febrero de 1999, previa a la realización de operaciones de dragados.

Los resultados de las comunidades macrobentónicas obtenidos muestran que, en general, el área estudiada es rica en especies y abundante en individuos excepto una estación de la zona del Mitrena, cuya pobreza biológica puede estar asociada con las características del sedimento, fango fluido, que no posibilita el establecimiento de los individuos. La comparación entre los datos biológicos recolectados en 1986 y 1999 ha revelado la semejanza entre las comunidades de macrofauna bentónica de los dos periodos, especialmente en relación con las especies características, y que el canal sur (dragado en 1995) no presenta señales del efecto de dragado.

Las principales diferencias entre los dos periodos son un incremento en la abundancia y presencia de determinadas especies asociadas con áreas orgánicamente enriquecidas, como Tharyx *sp.,* Corbula gibba *(prácticamente ausentes del canal sur en 1986),* Spiochaetopterus costarum *y* Ampelisca *spp., que pueden estar relacionados con el incremento de la materia orgánica en el área estudiada.*

El conjunto de la información obtenida en el presente trabajo (comunidades macrobentónicas) y en otros estudios -contaminación de zona y bioensayos- hechos al mismo tiempo por otros investigadores, no evidencian inconveniente para el dragado del área seleccionada.

Palabras clave: *Comunidades bentónicas, dragados, estuario del Sado, enriquecimiento orgánico.*

INTRODUCTION

Dredging activities are usually essential to the management of aquatic systems. In addition to ensuring the navigability of harbours and channels, they can also be used to obtain construction materials (Kenny and Rees, 1994; Morton, 1994) and to clean up contaminated areas (Degetto *et al.*, 1997; Silva *et al.*, 1997). Nevertheless, they represent an environmental risk in each part of the process (extraction, transport and dumping), that must be carefully considered.

Essentially, the impacts associated with dredging depend not only on the methods used, but also on the amount and characteristics of the sediments to be dredged (e.g., the presence of contaminants), local hydrology and the seasonal effects (Newell, Seiderer and Hitchcock, 1998). In the target area, benthic communities are directly affected by dredging. However, its impact varies widely and depends, among other factors, on the intensity of dredging in a particular area, the degree of sediment disturbance and recolonization (by passive transport of adult organisms and the intrinsic rate of reproduction) and growth of the damaged communities (Newell, Seiderer and Hitchcock, 1998).

Although dredging has obviously become an economic necessity, sustainable management requires information on the functioning of the ecosystems, specially an understanding of how vulnerable particular habitats, communities and species are to different activities being undertaken in a certain area (Hiscok, 1997). The study of macrofaunal communities thus becomes relevant, not only because they are directly affected by dredging, but also because they play an important role in the structure and functioning of ecosystems, supporting several human activities directly or indirectly (Rhoads, McCall and Yingst, 1978; Chapman, Dexter and Long, 1987; Rees *et al.*, 1990).

Despite the fact that information provided by benthic communities may avoid negative impacts of dredging operations on estuary resources, they are not mentioned in the Portuguese legislation concerning dredging or sediment dumping (Anonymous, 1995). Portuguese legislation regarding dredging activities is mainly concerned with the chemical analysis (metals and organic compounds) of the material to be dredged and, under some circumstances, bioassays are also used. However, these assays are conducted in the laboratory, under controlled conditions, whereas the use of a resident biological component seems to be essential in the assessment of in situ alterations in a certain area (Chapman, Dexter and Long, 1987).

The Sado estuary is one of the major estuaries in Portugal. It is a multiple-use system, with a strong industrial component. This estuary has been submitted to several maintenance dredging operations, in order to satisfy the expanding necessities of its harbour.

The present study was undertaken in the Southern Channel and in the Mitrena Peninsula with the following objectives: (1) to provide update data on the composition and structure of the macrozoobenthic communities for future monitoring studies; (2) to evaluate the importance for the entire estuary of the macrofaunal communities from the area to be dredged; (3) to analyse whether there should be any constraints placed on dredging operations, drawing conclusion not only from our macrofaunal data, but also from the sediment contamination (Gil *et al.*, 1999) and the sediment toxicity studies (Rodrigues, Quintino and Carvalho, 1999) performed at the same time; (4) to identify potential impacts of dredging operations (the study area was dredged in 1995), by comparing the present study's results with those observed in 1986 for the same area (Rodrigues, 1992; Rodrigues and Quintino, 1993).

Study area

The Sado estuary (figure 1) is located in the western coast of Portugal on the Setúbal Peninsula (50 km south of Lisbon) and can be classified as a bar estuary due to its physical structure and topography (Pritchard, 1955).

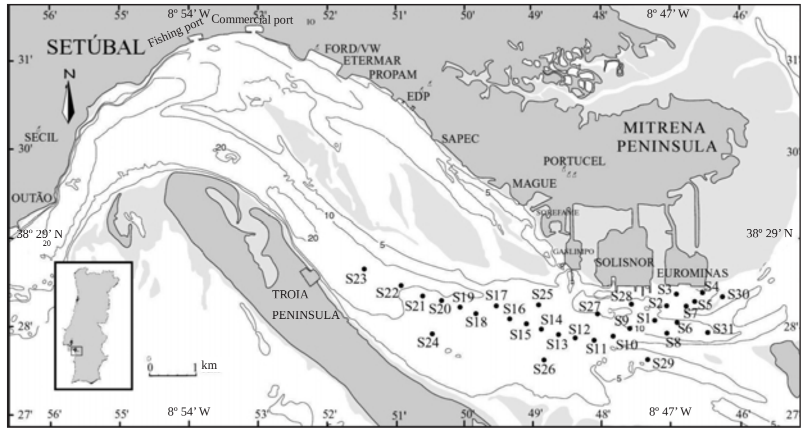

Figure 1. Location of sampling sites. Depth in metres. Intertidal areas are shown in light grey

The estuary comprises the Northern and the Southern Channels, partially separated by intertidal sandbanks. Most of the water exchange is made through the Southern Channel, which reaches a depth of 25 m, whereas the Northern Channel's maximal depth is generally 10 m (Neves, 1985). In the inner part of the estuary there is another channel (Alcácer Channel), 20 km long and with a mean depth of 1 m. The estuary is linked to the ocean by a narrow and deep channel (maximal depth of 50 m), which makes a major contribution to the general pattern of the estuarine circulation (Neves, 1985).

The present work was undertaken on February 1999, in the Southern Channel and the Mitrena Peninsula (figure1).

METHODS

Sampling

This study featured 31 sampling sites, 22 located within the dredging area (S1 to S22) and nine in neighbouring areas (S23 to S31) (figure 1). At each site, two replicates were collected with a Smith-McIntyre grab (0.1 m^2), one for the benthic macrofaunal analysis, another for sediment characterisation.

Sediment characterisation

The sediment sample from each site was homogenised, and two sub-samples were collected for granulometric and total volatile solids (TVS) analysis, the latter frozen on board.

The particle-size analysis was performed by dry sieving. For a detailed description of the method used, see Quintino, Rodrigues and Gentil (1989).

The total volatile solids analysis was determined by weight loss on ignition of approximately 1 g of dried sediment, at 450 ºC, for 5 h (Kristensen and Anderson, 1987). Kristensen and Anderson (1987) consider this method one of the most reliable, as no pre-treatment is involved, and at this temperature there is a minimum risk of volatilising the inorganic carbon.

Benthic macrofauna

The sediment samples collected for the study of benthic macrofaunal were sieved on board through a 1mm-mesh sieve, and the retained material was preserved in 10 % buffered formalin stained with Rose Bengal. In the laboratory, the samples were washed again through a 1mm-mesh sieve and the organisms were sorted, identified whenever possible to the species level, and counted. The identifications were performed mainly according to Campoy (1982), Chambers (1985), Chambers and Garwood (1992), Chambers and Muir (1997), Fauchald (1977), Fauvel (1923, 1927), George and Hartmann-Schröder (1985), Giordanella (1969), Holthe (1986), Katzman, Laubier and Ramos (1974), Kirtley (1994), Laborda (1987), Laubier (1962), Laubier and Ramos (1973), O' Connor (1987), Pleijel and Dales (1991), Rainer (1989), Ramberg and Schram (1983) and Sigvaldadóttir and Mackie (1993), concerning polychaete worms; Bellan-Santini *et al.* (1982), Lincoln (1979), Jones (1976), Naylor (1972) and Kensley (1978) for crustaceans; Nobre

(1936), Graham (1971), Tebble (1976) and Macedo (1999) regarding molluscs; and Nobre (1938) and Tortonese (1965) for echinoderms.

Data analysis

Sediment was classified according to the Wentworth scale (Doeglas, 1968) and Larsonneur (1977). Sediments were characterised by their percentage of silt (< 63 µm), sand (63 - 2 000 µm) and gravel (> 2 000 µm) and by the median value.

Biological data analysis was performed with PRIMER v 4.0 (Clarke and Warwick, 1994). In order to characterise the macrobenthic communities of the study area, species richness (S) and abundance (A) values were determined for each site and expressed per 0.1 m^2. Abundance data was analysed by cluster and ordination techniques with log (y + 1) transformed values. Cluster analysis applied the unweighted pair group average algorithm to a similarity matrix between sites calculated with the Bray-Curtis coefficient. Non-metric multidimensional scaling (MDS) was the technique chosen for the ordination analysis (Ludwig and Reynolds, 1988; Clarke, 1993). Characteristic species of each affinity assemblage were determined according to the mean abundance and frequency in a certain group

F = (species abundance/total species abundance) × 100.

Oligochaetes, Nematodes and Nemertineans were not considered to the groups' characterisation because they were not identified, but were used to define affinity assemblages. Macrofaunal comparison between 1986 and 1999 data was carried out using a matrix analysis considering both periods' values, following the method described above.

RESULTS

Sediment characterisation

The results obtained show that the Southern Channel and Mitrena Peninsula are characterised by different sediments. The Mitrena Peninsula is dominated by silty sediments, with a percentage of fine particles ranging from 22.3 to 93.5 % (at site 2), while the Southern Channel is mainly constituted by medium (median: 250 - 500 µm) and coarse sand (median: 500 - 1 000 µm). The mean organic matter content of each region emphasises this individualisation. In fact, the mean value at the Mitrena Peninsula sampling sites was high (7.4 %) compared with the Southern Channel stations (2.6 %).

Benthic macrofauna

In the present study, a total of 151 species, comprising 13 179 specimens, have been collected. The species are distributed among three major groups: polychaetes, amphipods and bivalves. The class Polychaeta is dominant in terms of species number, number of individuals and presence throughout the entire study area. The most abundant species are also the most frequent, and include the polychaetes *Spiochaetopterus costarum*, *Aonides oxycephala*, *Tharyx* sp., *Melinna palmata*, *Scoloplos armiger*, *Caulleriella alata*, *Caulleriella bioculata* and *Lumbrinereis gracilis*, the amphipods *Ampelisca* spp., the bivalves *Corbula gibba* and *Modiolus* cf. *adriaticus* and the gastropod *Nassarius incrassatus*.

The spatial distribution of species richness (figure 2) and abundance (figure 3) shows no clear patterns. However, concerning species richness, it

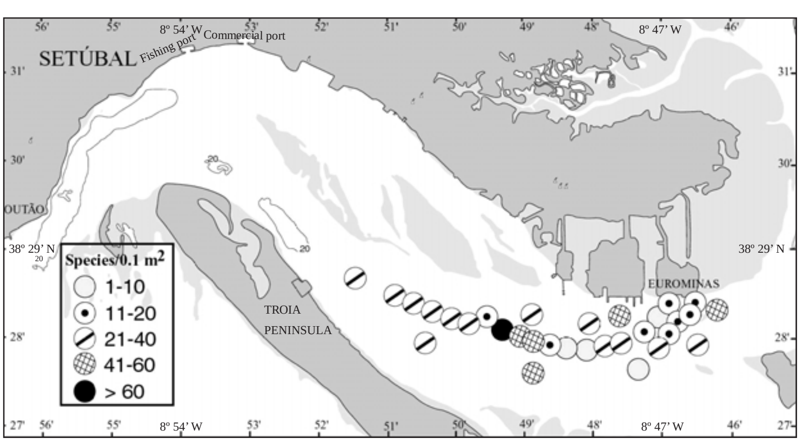

Figure 2. Spatial distribution of species richness

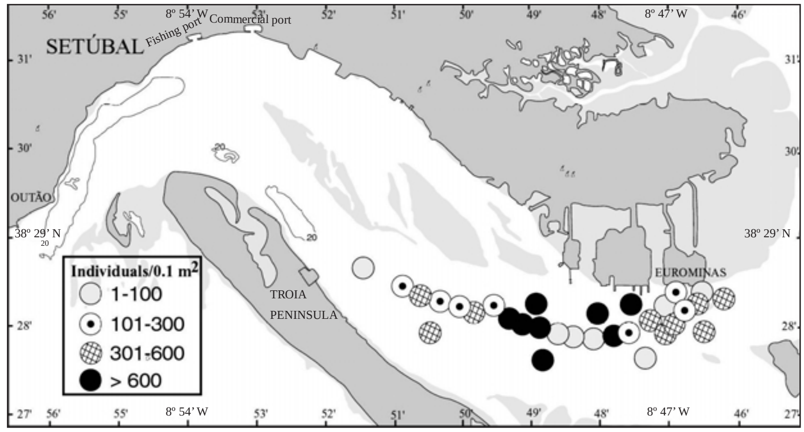

Figure 3. Spatial distribution of abundance

is possible to detect two different regions, one in front of Eurominas (Mitrena Peninsula), characterised by low values, and another one, in the central part of the channel, with high species richness values.

Cluster and ordination analysis identified three major assemblages, A, B1 and B2 (figure 4), from which site S2 appears isolated. The observation of the most abundant and frequent species of each group, presented in table I, and their characterisation, given in table II, suggests that site S2 corresponds to an impoverishment of sub-group B1. This is in agreement with its positioning in the estuary (figure 1). In figure 5, representing the spatial distribution of the three main assemblages, site S2 has been included in Group B1.

Group A comprises sandy sediments sites (medium and coarse sand) with a low percentage of fines and total volatile solids (table II). This group includes both species usually associated with such sediments (*Nephtys cirrosa*, *Goniada galaica*, *Protodorvilea kefersteini*, *Urothoe* cf. *intermedia* Bellan-Santini & Ruffo, 1986, *Urothoe grimaldii* Chevreux, 1895 and *Tellina tenuis*) and species characteristic from organically enriched areas, such as *Scoloplos armiger*, *Tharyx* sp., *Caulleriella allata, Caulleriella bioculata*, *Aonides oxycephala*, *Spiochaetopterus costarum* and *Corbula gibba*. However, excepting *Scoloplos armiger*, these species are preferentially distributed in other groups. *S. armiger* and *N. cirrosa* are the most characteristic species for the Group A (tables I and II).

Group B1, located in front of Eurominas, presents the highest content in fines and total volatile solids (table II). This group comprises seven exclusive species of which only *Abra alba* and *Barnea candida* are represented by more than a single individual.

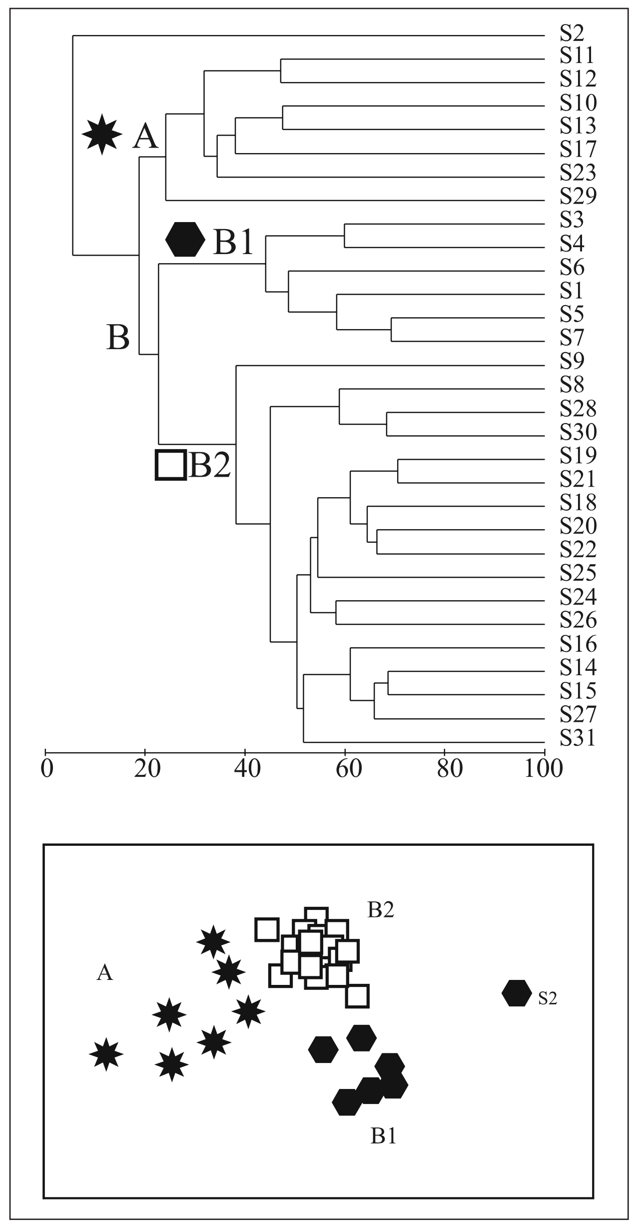

Figure 4. Classification and ordination diagrams concerning 1999 biological data

Table I. Mean abundance (A/0.1 m^2) and abundance frequency (%) (F: Abundance of sp. A in group x/total abundance of group x) of the most abundant species in each of the affinity groups identified from the cluster analysis performed with 1999 data

Group A (7 sites)		
Species	F	A
Nematodes	54.0	80.9
Scoloplos armiger (O. F. Müller, 1776)	14.0	21.9
Tharyx sp.	10.0	15.6
Corbula gibba (Olivi, 1792)	3.0	4.7
Nephtys cirrosa Ehlers, 1868	2.0	3.4
Aonides oxycephala (Sars, 1862)	2.0	2.4
Spiochaetopterus costarum (Claparède, 1870)	1.0	2.1
Alcyonium sp.	1.0	1.9
Caulleriella alata (Southern, 1914)	1.0	1.7
Parapionosylis gestans (Pierantoni, 1903)	1.0	1.6
Caulleriella bioculata (Keferstein, 1862)	1.0	1.3
Ascidea ind.	1.0	1.1
Parapionosylis sp.	1.0	0.9
Typosyllis sp.	1.0	0.9
Protodorvillea kefersteini (McIntosh, 1869)	0.5	0.7
Sub-group B1 (6 sites)		
Species	F	A
Ampelisca spp.	56.0	130.7
Melinna palmata Grube, 1870	17.0	39.3
Corbula gibba	8.0	18.3
Tharyx sp.	4.0	9.2
Nassarius incrassatus (Ström, 1768)	4.0	8.3
Nephtys hombergii Savigny, 1818	3.0	8.0
Parvicardium exiguum (Gmelin, 1791)	2.0	3.5
Ampharetidae ind.	1.0	2.8
Corophium runcicorne Della Valle, 1893	1.0	2.2
Capitella sp.	0.3	0.7
Cyathura carinata (Kroyer, 1847)	0.3	0.7
Pagurus spp.	0.3	0.7
Pandora albida (Röding, 1789)	0.3	0.7
Abra alba (Wood, 1802)	0.2	0.5
Barnea candida (Linné, 1758)	0.2	0.5
Subgroup B2 (17 sites)		
Species	F	A
Spiochaetopterus costarum (Claparède, 1870)	25.0	157.8
Aonides oxycephala	13.0	79.8
Corbula gibba	12.0	74.2
Modiolus cf. *adriaticus* (Lamarck, 1819)	10.0	65.6
Tharyx sp.	9.0	55.5
Nematodes	5.0	31.5
Nassarius incrassatus	2.0	10.8
Oligochaetes	2.0	10.6
Caulleriella bioculata	2.0	10.5
Lumbrineris gracilis (Schmarda, 1868)	2.0	10.2
Ampelisca spp.	2.0	9.6
Nucula sp.	1.0	9.2
Ascidea ind.	1.0	8.4
Paradoneis lyra (Southern, 1914)	1.0	7.4
Parvicardium exiguum	1.0	6.6
Site S2		
Species	F	A
Nephtys hombergii	60.0	3.0
Nassarius incrassatus	20.0	1.0
Caulleriella bioculata	20.0	1.0

The most important species identified in this group reflect its sedimentary characteristics (tables I and II).

The sites included in Group B2 present intermediate content of fines and TVS, in relation to Groups A and B1. This assemblage has the highest species richness, abundance and number of exclusive species (table II). The most abundant species (table I) reflect a certain degree of organic enrichment (e.g., *S. costarum*, *A. oxycephala*, *C. gibba*, *Tharyx* sp., *C. bioculata*), although some of the less abundant species in the group are also usually associated with sandy sediments (e.g., *Lygdamis muratus* (Allen, 1904), *Gammaropsis maculata* Johnston, 1928, *Typossylis* sp., *Upogebia* sp., *Calyptraea chinensis* (Linné, 1778), *Sphaerosyllis hystrix* Claparède, 1863, *Poecilochaetus serpens* Allen, 1904, *N. cirrosa*).

Comparison of 1986 *versus* 1999 macrofauna data

In order to analyse the temporal and spatial relationships between both sampling periods, macrofaunal data obtained in 1986 at the same estuarine area (Rodrigues and Quintino, 1993) was also submitted to cluster and ordination analysis (figure 6). The results obtained revealed the existence of two major affinity assemblages, A' and B', which are characterised in tables II and III. According to the cluster and ordination diagrams (figure 6), sites S117 and S126 appear isolated from groups A' and B'. Both these sites (as was the case of site S2 from 1999 data) are located near the northern margin, in the vicinity of industrial complexes, and present an impoverished fauna, emphasised by the lowest mean abundance (36 indiv/0.1 m^2) and species richness (12 species/0.1 m^2) (table II). This may be related not only to their having the highest content of fines and TVS (39.6 % and 5.4 %, respectively), but also to potential contamination of the area, due to the proximity of industry. The fauna identified reflects these sedimentary features, with species characteristic of silty sediments, such as *Abra nitida* and the polychaete *Nephtys hombergii* (Pearson, 1975; Tebble, 1976; Hily, Le Bris and Glémarec, 1986).

Group A' comprises seven stations. The sediment and biological characteristics of this group are remarkably similar to Group A, identified in 1999 (table II). *Scoloplos armiger* is the most abundant and frequent species, comprising almost 50 % of total abundance (table III).

Table II. Biological and environmental characterisation of the affinity groups defined from the cluster analysis in 1986 and 1999. (TVS): total volatile solids; (S): species richness; (A): abundance

1999 1986	Group A Group A'	Group B1	Group B2 Group B'	Site S2 	 Sites S117 and S126
Nº of sampling sites	7	6	17		
	7		13		2
Fines (mean %)	7.1	58.0	16.6	93.5	
	7.1		20.1		39.6
Gravel (mean %)	3.0	1.0	7.8	0.5	
	2.7		2.0		1.8
TVS (mean %)	1.5	7.1	3.0	9.0	
	1.0		2.3		5.4
S (total)	48	44	134	3	
	46		79		32
S (mean, 0.1 m²)	13.1	15.0	36.9	3.0	
	12.7		28.8		8.0
A (total)	1 057	1 395	10 722	5	
	443		6 146		36
A (mean, 0.1 m²)	151.0	232.5	630.7	5.0	
	63.3		473.0		18.0
Exclusive species	9	7	73		
	9		38		3
Characteristic species 1999	*S. armiger* *N. cirrosa*	*Ampelisca* spp. *M. palmata* *N. hombergii*	*S. costarum* *A. oxycephala* *C. gibba* *M.* cf. *adriaticus* *Tharyx* sp.	*N. hombergii*	
1986	*S. armiger* *P. elegans* *N. cirrosa*		*S. costarum* *Cirriformia* sp. *A. oxycephala* *Tharyx* sp. *L. nitidum* *S. inflatum*		*A. nitida* *E. punctatus* *N. hombergii*

Finally, all the stations of the Group B' are characterised by an intermediate percentage of fines and TVS in relation to the other groups (table II). This group presents the richest and most abundant faunal assemblage, with the annelid polychaetes *Spiochaetopterus costarum*, *Cirriformia* sp., *Aonides oxycephala*, *Tharyx* sp. and the bivalve *Lepton nitidum* as dominant species (table III). Group B' closely resembles Group B2, identified in 1999 (table II).

The comparison of the macrofauna data from both periods made it possible to recognise, in 1999 set, the main faunal assemblages observed in 1986,

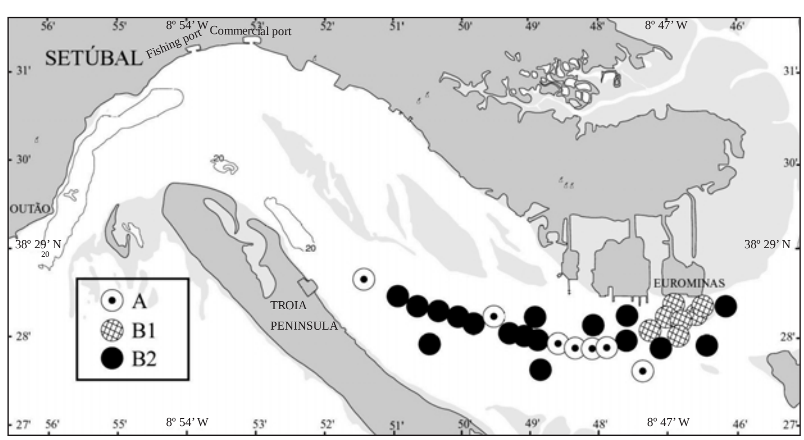

Figure 5. Spatial distribution of the main affinity groups emphasised by cluster analysis (1999 data)

Table III. Mean abundance (A/0.1 m^2) and abundance frequency (%) (F: Abundance of sp. A in group x/total abundance of group x) of the most abundant species in each of the affinity groups identified from the cluster analysis performed with 1986 data

Species	F	A
Group A' (7 sites)		
Scoloplos armiger	46.5	29.4
Cirriformia sp.	19.4	12.3
Caulleriella sp.	4.3	2.7
Parapionosyllis elegans (Pierantoni, 1903)	4.1	2.6
Nephtys cirrosa	2.7	1.7
Tharyx sp.	2.5	1.6
Goniada galaica (Rioja, 1923)	1.8	1.1
Glycera tridactyla Schamarda, 1861	1.4	0.9
Spiochaetopterus costarum	1.4	0.9
Crangon crangon (Linnaeus, 1758)	1.1	0.7
Notomastus latericeus Sars, 1851	1.1	0.7
Saccocirrus papillocercus Bobretzky, 1872	0.9	0.6
Aonides oxycephala	0.7	0.4
Heteromastus filiformis (Clapadère, 1864)	0.7	0.4
Polycirrus sp.	0.7	0.4
Pygospio elegans Clapadère, 1863	0.7	0.4
Tellina tenuis Costa, 1778	0.7	0.4
Group B' (13 sites)		
Spiochaetopterus costarum	39.0	184.2
Cirriformia sp.	10.5	49.5
Aonides oxycephala	6.9	32.5
Tharyx sp.	6.6	31.0
Lepton nitidum Turton, 1822	6.0	28.3
Scalibregma inflatum Kathke, 1843	5.5	25.9
Caulleriella sp.	3.0	14.3
Scoloplos armiger	2.1	9.7
Mediomastus capensis Day, 1961	2.0	9.5
Notomastus latericeus Sars, 1851	2.0	9.4
Apseudes talpa (Montagu, 1808)	1.3	6.0
Oligochaeta ind.	1.1	5.0
Polydora caeca (Orsted, 1843)	0.8	4.0
Cyathura carinata	0.7	3.2
Cerastoderma edule (Linnaeus, 1758)	0.7	3.2
Corophium annulatum Chevreux, 1908)	0.7	3.1
Sites 117 and 126		
Abra nitida (Müller, 1776)	22.2	4.0
Ericthonius punctatus (Bate, 1857)	16.7	3.0
Cirriformia sp.	11.1	2.0
Corophium sextonae Crawford, 1937	11.1	2.0
Nephtys hombergii	8.3	1.5
Virgularia mirabilis (Muller, 1776)	8.3	1.5
Caulleriella sp.	5.6	1.0
Spiochaetopterus costarum	5.6	1.0
Aoridae ind.	2.8	0.5
Melita gladiosa Bate, 1862	2.8	0.5
Pandora albida	2.8	0.5
Phtisica marina	2.8	0.5

especially concerning the most characteristic species. In fact, some of the characteristic species identified in 1986 remained as the most important in 1999, such as *Scoloplos armiger* and *Nephtys cirrosa* (Groups A' and A), *Spiochaetopterus costarum*, *Aonides oxycephala* and *Tharyx* sp. (Group B' and B2).

Although the sampling methodology and sample treatment were the same in both occasions, the sites analysed in 1986 and 1999 did not coincide completely. The absence in 1986 of an assemblage equivalent to the sub-group B1 identified in 1999 (figure 6; table II) is due to a lower number of sampling sites in front of Eurominas in 1986, compared to 1999. Nevertheless, it is possible to recognise in the sampling sites S117 and S126 (1986) some of the characteristics that occurred in the affinity Group B1, namely the dominance of species usually associated with organically enriched

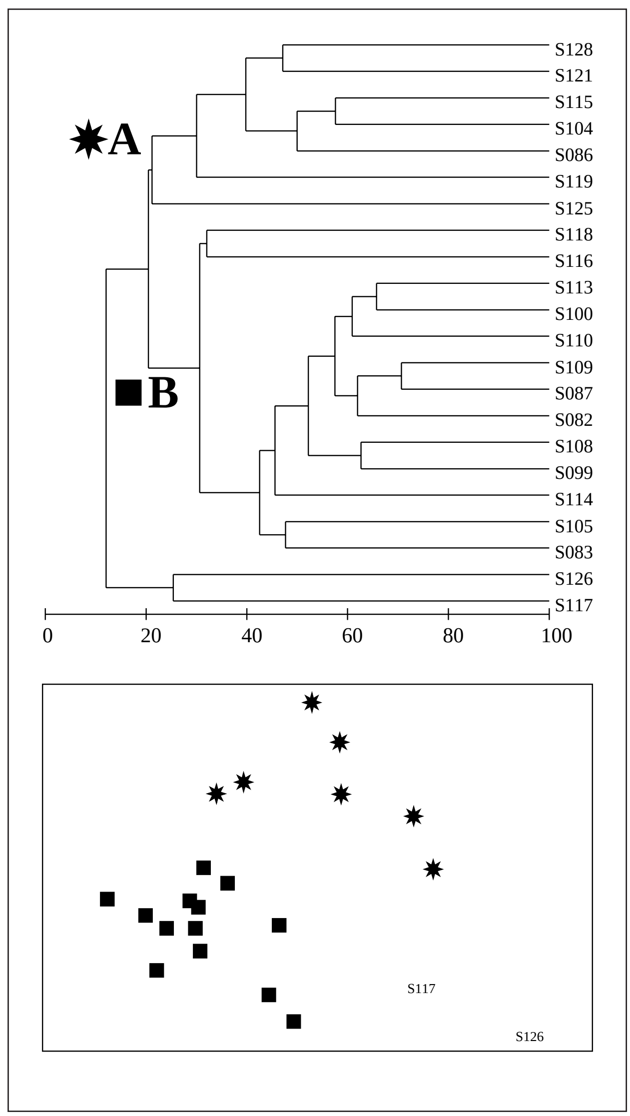

Figure 6. Classification an ordination diagrams concerning 1986 biological data

sediments (Pearson, 1975; Tebble, 1976; Pearson and Rosenberg, 1978; Hily, Le Bris and Glémarec, 1986; Newel, Seiderer and Hitchcock, 1998), such as *Ampelisca* spp., *Melinna palmata*, *Nephtys hombergii*, *Abra nitida* and *Cirriformia* sp. (tables II and III).

Despite the similarities observed between the two data sets, a more detailed analysis suggests some changes in the sediment and faunal characteristics of the study area. Concerning the sediments, the main difference is due to the mean percentage of total volatile solids, which rose between 1986 and 1999 (table II, namely Groups A/A' and B2/B'). In relation to the faunal assemblages, we found a richer and more abundant macrobenthic community in 1999, compared with 1986 (table II). It was also possible to recognise some changes regarding the characteristic species identified in the affinity groups of 1999, namely *Tharyx* sp., *Modiolus* cf. *adriaticus* and *C. gibba* (Group B2 - 1999; Group B' - 1986). Those species appeared in 1999 at Group A sampling sites, but in the corresponding area in 1986 (Group A') they were either absent or present low abundance (tables I and III). Moreover, the marked increase in abundance and frequency of the two latter species bring them to a high rank in Group B2, in 1999 (Group B' - 1986) (tables I and II).

As an example of this change, figures 7 and 8 illustrate the abundance and distribution pattern of *C. gibba* for both sampling periods.

DISCUSSION

The present study's results regarding macrofaunal characterisation agree with previous benthic descriptions pertaining this particular area of the Sado estuary (Rodrigues and Quintino, 1993). Such resemblance, namely concerning the affinity assemblages and their characteristic species, was confirmed through comparative data analysis of both 1999 and 1986 data sets.

The study area's macrofaunal communities are rich and abundant, excluding site S2, a local impoverishment of Group B1. Such impoverishment is most probably related with the particular sedi-

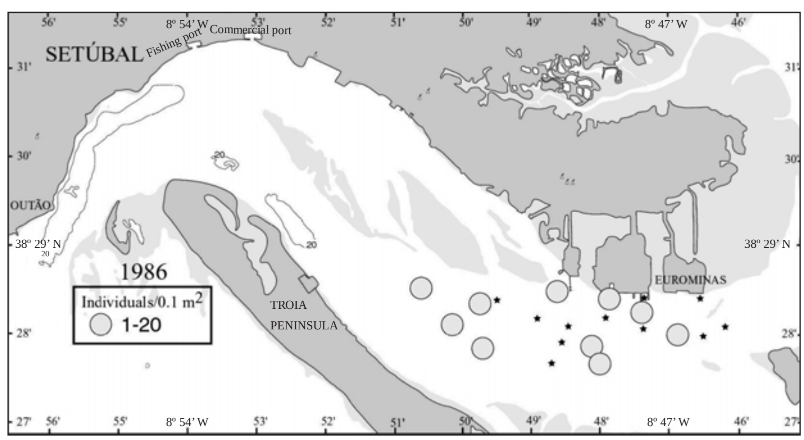

Figure 7. Abundance of *Corbula gibba* in 1996. ★: site where the species was absent

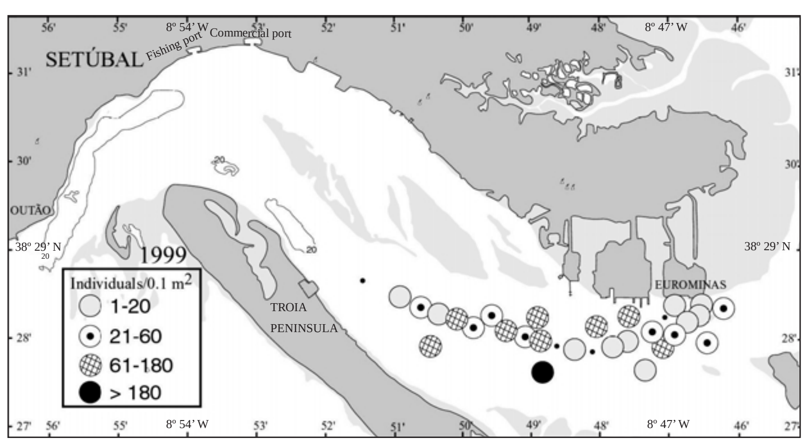

Figure 8. Abundance of *Corbula gibba* in 1999. •: site where the species was absent

ment characteristics of this site, i.e., fluid mud, unfavourable to the establishment of individuals.

The joint consideration of the present study's macrofaunal results and data involving sediment contamination (Gil *et al.*, 1999) and toxicological bioassays (Rodrigues, Quintino and Carvalho, 1999), also analysed before the dredging operations, does not indicate the necessity of placing any particular constraints on them. In fact, the area to be dredged presents sediments with minor contamination (Gil *et al.*, 1999) and the toxicological bioassays revealed no significant differences between control and tested sediments (Rodrigues, Quintino and Carvalho, 1999). Moreover, currently available data on the Sado estuary' macrofaunal communities indicate that the area to be dredged, although rich and abundant in species, is not included in the richest part of the estuary (Rodrigues and Quintino, 1993). In addition, the macrozoobenthic communities identified presented no unique features, as they are part of widespread areas within the Southern Channel (Rodrigues and Quintino, 1993).

The Southern Channel was dredged in 1995, but the present study found no evident signs of such operations. In contrast, dredging effects have occurred in other areas of the estuary, closer to the entrance, where the typical fauna was replaced by marine species, which spread their distribution to inner parts of the estuary (Rodrigues and Quintino, submitted). In fact, even though there were some differences in mean abundance, in 1999 most species retain their relative abundance and presence in the different areas identified in this channel. The changes observed compared with 1986, mainly involve an increase in abundance and species richness in the study area. These changes are especially apparent regarding some species known to be common in organic enriched areas (Pearson and Rosenberg, 1978; Hily, Le Bris and Glémarec, 1986; Rodrigues and Quintino, 1993; Newel, Seiderer and Hitchcock, 1998), such as *Tharyx* sp., *C. gibba* (almost absent of Southern Channel in 1986), *S. costarum* and *Ampelisca* spp., the latter considered an opportunistic genus, very common in mobile mud (Newel, Seiderer and Hitchcock, 1998). Moreover, *Corbula gibba* is considered by some authors to be indifferent to organic pollution and hypoxia (Pearson, 1971; Rosenberg, 1980) and characteristic of the transitory zone along a gradient of organic enrichment (Pearson and Rosenberg, 1978). Therefore, these results suggest that the study area might be evolving to a higher degree of organic enrichment than the one noted in 1986, as also shown by the increase of the total volatile solids, found between 1986 to 1999, in sediments of comparable fines content. This hypothesis must be confirmed with further studies, since the two sampling periods were in different seasons (summer in 1986; winter in 1999) and information regarding these species' life cycles is unavailable.

The use of benthic communities in impact assessment studies enjoys widespread support within the scientific community (e.g., Long and Chapman, 1985; Quintino, 1996; Radenac, Miramand and Tardy, 1997; Van den Hurk, Eertman and Stronkhorst, 1997). In the particular case of dredging, it is clear that a careful evaluation of the potential impacts resulting from the handling of dredged sediments is essential to a proper management of aquatic systems, since sediments have long been recognised as a sink for many contaminants. Nevertheless, those communities directly affected by dredging operations are often disregarded in the management of aquatic systems exposed to this activity. In spite of this, in most jurisdictions, including Portugal, legislation regarding dredging operations is essentially concerned with chemical analysis. Indeed, such chemistry data is needed to provide a measure of local contamination, and bioassays have proved to be useful in the assessment of the bioavailability of contaminants (Chapman, 1990). However, as bioassays are usually performed under controlled laboratory conditions, confirmation of the effects on the biota is also necessary, and only a resident biological component can provide such information (Chapman, Dexter and Long, 1987). When used alone, such measures of resident community structure may however provide confusing conclusions, because these communities also respond to natural fluctuations in biotic and abiotic factors. Nevertheless, together with the other two components, they proved to be an essential tool in the proper management of dredging activities, providing unique information, namely, on the exploitable resources potentially affected by those activities.

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