

## Assessment of macrozoobenthic communities in the lagoon of Obidos, western coast of Portugal

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**SUMMARY:** A benthic and sedimentological survey undertaken in the lagoon of Obidos, western coast of Portugal, based on 57 faunal samples and 61 grain-size analysis provided initial data for the assessment of the bio-sedimentological gradients in that system. Five sediment types were characterized and charted, ranging from clean coarse sand, in the vicinity of the lagoon mouth, to fine mud in the inner areas with a mean silt percentage of 98 %. The 68157 individuals collected were distributed among 119 species characteristic of both Atlantic and Mediterranean lagoons. Species richness was higher at those intermediate sampling stations, where more diverse surface sediments occur. Faunal abundance was higher in the center of the lagoon, on fine muds, and on the intertidal sand-banks. The correspondence analysis shows that both surface sediments and benthic communities were distributed along a gradient normal to the longitudinal axis of the lagoon, evolving from an outer marine community, occupying 4 % of the lagoon bottom and settled on clean coarse unstable sand, to an inner lagoon community, corresponding to 85 % of the lagoon bottom and located on fine muds. Transition occurred within a central ecotone area, where species richness was higher, which occupied the remaining 11 % of the bottom surface and was located on slightly silty medium sand. A cenotic model proposed for this lagoon is discussed in relation to hydrological and sedimentological data, and compared with both the faunistically similar lagoon of Albufeira located 140 km south of Obidos, and the general model proposed for Mediterranean lagoon systems.

*Key words:* benthic macrofauna, surface sediments, bio-sedimentological gradients, coastal lagoons.

### INTRODUCTION

The lagoon of Obidos is located on the western coast of Portugal, 100 km north of Lisbon (39° 26' N to 39° 23' N; 9° 11' W to 9° 14' W). It is a shallow semi-enclosed body of water with northwest-southeast orientation, and its longitudinal axis perpendicular to the coast line. It has an area of  $\approx 7.0$  km<sup>2</sup> and a maximal depth of 5 m, located in an inner area, the Bom Sucesso (Fig. 1). The lagoon communicates with the ocean by a shallow and narrow channel which may be obstructed by sand deposition following storms. Intertidal sand-banks extend from the lagoon mouth inwards, for up to one third of maximal lagoon length. Besides the delta channels, there is only a single northern navigation channel crossing the sand-banks (Fig. 1).

On a topographical basis, three regions will be distinguished and referred in the text as the outer area, comprising the delta channels near the entrance of the lagoon, the intermediate region, comprising the navigation channel and the sand-banks, and the inner basin, located inward of the sand-banks (Fig. 1).

Physico-chemical data taken monthly from May 1985 to May 1986 (CÁLDEIRA *et al.*, 1986) have shown that surface and bottom temperatures increase inwards in summer (18 °C near the entrance to 25 °C in the inner basin) but are more uniform in winter, when they average 13 °C throughout. Salinity is always higher near the bottom. It increases inwards in summer (from 35.8 to 36.2) and decreases in winter, due to fluvial inputs (mean surface value near the entrance of 33.6, and 24.9 in the inner



FIG. 1. — The lagoon of Obidos showing positions of the sampling stations. Depth in meters shown by isobaths (continuous line and numbers 1 to 4; the interrupted line is the 0m contour).

basin). Dissolved oxygen is always higher at the surface. From the outer to the inner regions, mean annual values increase at the surface (from  $6.31 \text{ ml l}^{-1}$  to  $7.80 \text{ ml l}^{-1}$ ) and decrease at the bottom (from  $6.31 \text{ ml l}^{-1}$  to  $4.58 \text{ ml l}^{-1}$ ). Temporary oxygen depletion has only been found near the bottom in the inner deeper regions (Bom Sucesso). Particulate suspended matter is always higher in the inner basin than near the entrance, with greater differences at the bottom (mean annual value of  $20.2 \text{ mg l}^{-1}$  in the navigation channel and  $34.5 \text{ mg l}^{-1}$  near Bom Sucesso).

These four parameters showed higher annual amplitudes in the inner areas than around the lagoon mouth.

In order to characterize the general ecology of this system, a survey was undertaken between February 1984 and December 1986. In this contribution we present the results concerning the sedimentological and macrozoobenthic baseline data.

## MATERIAL AND METHODS

### Sampling

Surface sediment description was based on grain-size analysis from 61 samples: Stations 1 to 21 and 23 to 62 (Fig. 1).

Macrozoobenthic communities composition and distribution were assessed from 57 faunal samples taken during two weeks in February-March 1984: Stations 1 to 8 and 10 to 58 (Fig. 1). Subtidal

sampling (Stations 1 to 13, 17, 18 and 20 to 51) was performed with a Rallier du Baty dredge, a semi-quantitative anchor sampler. It is a small scale model adapted from those used by CABIOCH (1968), LARSONNEUR (1971) and RETIÈRE (1979) in sedimentological and benthic studies in the English Channel. It has a circular mouth of 0.30 m diameter, maximal capacity of 50 l and collecting bag with a mesh size  $< 1 \text{ mm}$ . Intertidal samples were collected on foot, from a surface of  $0.5 \text{ m}^2$  to a depth of 0.15 m.

Samples for faunal studies were sieved through a 1 mm mesh screen and the material fixed in 10 % buffered formalin (stained by Rose Bengal). In the laboratory macrofauna was enumerated and identified to species level whenever possible.

### Analysis

Grain-size analysis consisted of three major steps: i) Chemical destruction of organic matter with  $\text{H}_2\text{O}_2$ ; ii) Measurement of the total dry weight ( $P_1$ ), followed by chemical dispersion of the sediment in tetra-sodium pyrophosphate (30 g/l) and wet sieving through a  $63 \mu\text{m}$  mesh screen. Measurement of a second dry weight of the material left on the mesh ( $P_2$ ) and calculation of the weight of the fraction  $< 63 \mu\text{m}$  by difference ( $P_1 - P_2$ ); iii) Dry mechanical sieving of the remaining sediment with mesh screens ranging from  $63 \mu\text{m}$  ( $4\phi$ ) to  $8000 \mu\text{m}$  ( $-3\phi$ ), at 1  $\phi$  intervals.

Final total dry weight of a sample,  $P_t$ , is given by  $P_1$  exclusive of its biogenic fraction (mostly molluscs shells) retained by a mesh screen  $\geq 1 \text{ mm}$ . This fraction was removed manually under microscope. For a given sample, the values of each of the 9 grain-size classes thus obtained is a percentage of  $P_t$ .

### Data treatment

Surface sediments and faunal data were both treated by correspondence analysis (BENZECRI *et al.*, 1973), with interpretation aided by ascendent hierarchical classification (LEBART *et al.*, 1977; JAMBU, 1978; JAMBU & LEBEAUX, 1978). This methodology for the analysis of numerical data concerning grain-size classes and benthic ecology has been used and discussed by CHARDY *et al.* (1976a and b), MALMGREN *et al.* (1978), CREVEL (1983), PLANTE *et al.* (1983) and QUINTINO *et al.* (1987).

Affinity groups obtained from sediment data were further characterized by some classical grain-size parameters, the median ( $P_{50}$ ) (TRASK, 1930), mean ( $M_2$ ) (FOLK & WARD, 1957), sorting coefficient ( $\Gamma_1$ ) (FOLK & WARD, 1957) and mean percentages of silt ( $< 63 \mu\text{m}$ ), sand ( $< 2000 \mu\text{m}$ ;  $\geq 63 \mu\text{m}$ ) and gravel ( $\geq 2000 \mu\text{m}$ ). Given the fact that the silt + clay content was not analysed, the sorting coefficient was not

calculated in those samples where this content was above 5 %.

## RESULTS

### Sediments

The raw data consisted of a 9 grain-size classes  $\times$  61 samples matrix. The final analysis considered a  $7 \times 60$  matrix, by the omission of the coarser grain-size classes, almost absent in the samples (4000 to 8000  $\mu\text{m}$ ) and the omission of sampling station 27, due to its heterogeneous sediment (pebbles and silt).

Axes 1 and 2 of the correspondence analysis explains 87 % of the total inertia. The distribution of affinity groups among the sampling stations and the grain-size classes in Plane 1-2 is shown in figure 2. Due to the large number of points simultaneous representation has been avoided. Both figures are, however, drawn to the same scale.

Among samples, four major affinity groups were obtained: Aa, Ab, Ba and Bb, the latter being split into subgroups Bb<sub>1</sub> and Bb<sub>2</sub>. They correspond to

groups Ia, Ib, IIa and IIb, obtained among the grain-size classes. The succession from group Aa (quadrant 1<sup>-</sup> 2<sup>-</sup>) to group Bb (centred in quadrant 1<sup>+</sup> 2<sup>-</sup>) is made by the groups Ab (1<sup>-</sup> 2<sup>+</sup>) and Ba (1<sup>+</sup> 2<sup>+</sup>). The transition represented by Aa  $\rightarrow$  Ab  $\rightarrow$  Ba  $\rightarrow$  Bb corresponds to a spatial succession of sampling stations located from the vicinity of the lagoon mouth (Aa), to the intertidal sand-bank and navigation channel (Ab), to the inner northern margin (Ba) and to the center and innermost regions of the lagoon (Bb). Within this group, the sampling stations belonging to subgroup Bb<sub>1</sub> are located between the intertidal sand-bank and subgroup Bb<sub>2</sub>, which comprises the majority of the sampling stations in the inner parts of the lagoon.

The grain-size classes affinity groups show a similar transition. Ia  $\rightarrow$  Ib  $\rightarrow$  IIa  $\rightarrow$  IIb, corresponding to a gradually increasing silt content of the surface sediments. Thus, axis 1 opposes the coarser fractions predominating at the outer stations (groups Ia and Aa) to the finer fractions of the innermost stations (groups IIb and Bb). Axis 2 isolates a few intermediate stations (group Ba) with a grain-size class corresponding to fine sand (IIa).

The increasing silt content towards the inner

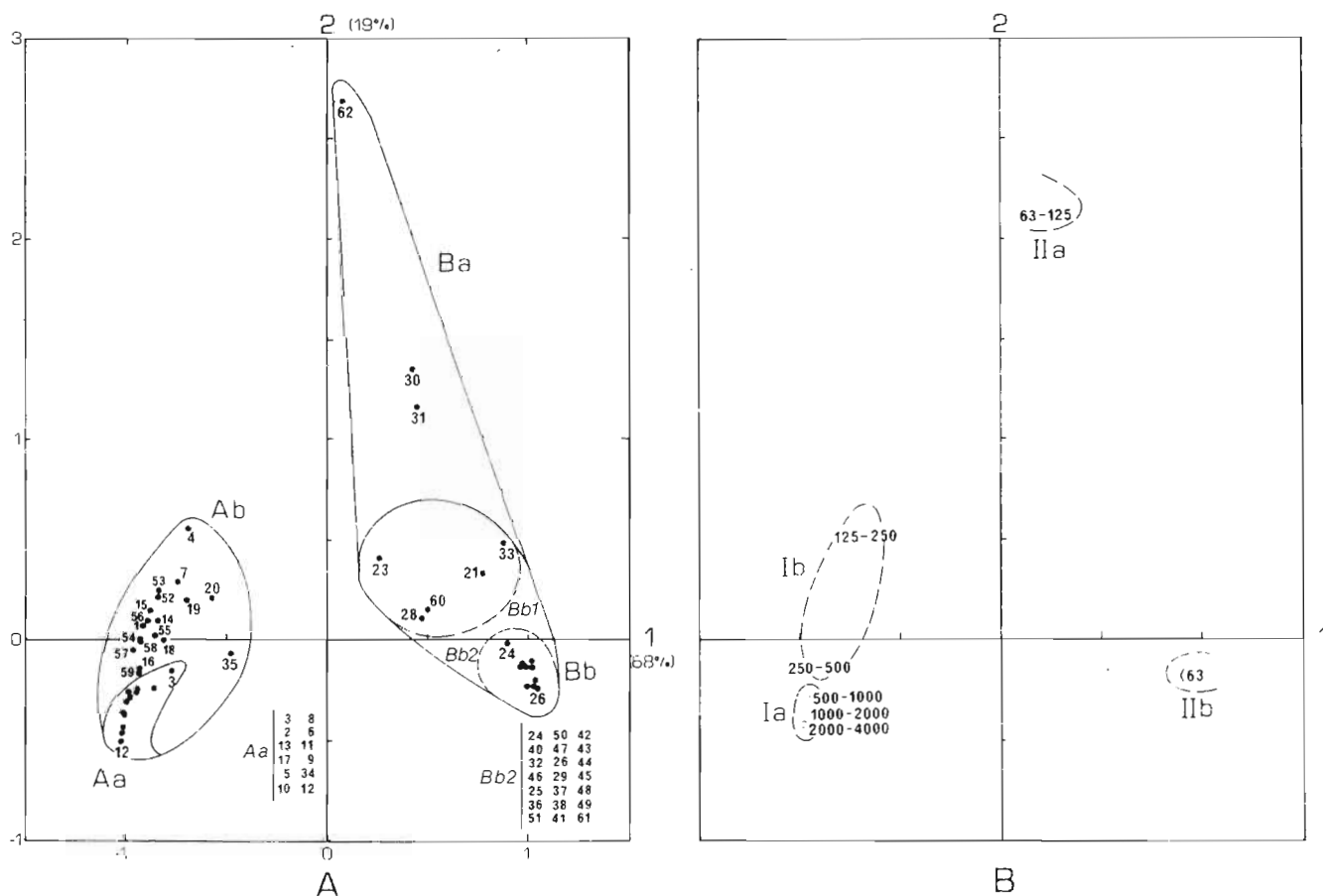


FIG. 2. — Affinity assemblages among sampling stations (A) and grain-size classes (B), according to the partition obtained in plane 1-2 of the correspondence analysis. Grain-size classes in  $\mu\text{m}$ .

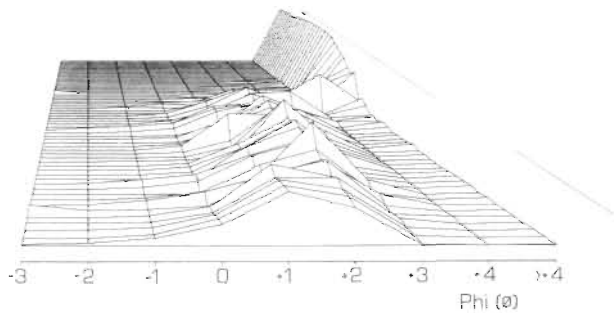


FIG. 3. — Succession of the sampling stations according to their projection on axis 1 of the correspondence analysis. Direction of silting up is given by arrow.

areas, expressed by axis 1, is represented on figure 3, obtained by projecting both the sampling stations and the grain-size classes on that axis. This shows the marked distinction of sandy sediments (foreground) from muddy sediments (background). Table I summarizes the results for each of the affinity groups established among the sampling stations.

According to Wentworth's system (MORGANS, 1956; DOEGLAS, 1968), LARSONNEUR (1977) and to the FOLK & WARD (1957) sorting coefficient scale, the stations of group Aa comprise moderately sorted coarse sands, group Ab corresponds to moderately sorted slightly silty medium sands, group Ba comprises silty very fine sands and group Bb corresponds to muds. Within this latter group, stations of assemblage Bb<sub>1</sub> correspond to slightly sandy muds and Bb<sub>2</sub> to fine muds.

The spatial distribution of these five sediment types is charted in figure 4, where it is shown that muddy sediments predominate. Muds with a silt percentage > 95 % correspond to 80 % of the subtidal bottom of this lagoon.

### Macrofauna

#### FAUNAL ANALYSIS

The 68157 individuals collected were distributed among 119 species. Annelids, Molluscs and Arthro-

TABLE I. — Grain-size parameters for each of the affinity groups established by the correspondence analysis. Mean percentage of silt+clay (Si), sand (Sa) and gravel (G) and mean values for percentile 5 (P5), median (Md), mean (Mz) and sorting coefficient ( $\Gamma_1$ ).

| Affinity groups | No. of stations | Si   | Sa % | G   | P5   | Md   | Mz   | $\Gamma_1$ |
|-----------------|-----------------|------|------|-----|------|------|------|------------|
| Aa              | 12              | 2.5  | 92.7 | 4.8 | 0.98 | 0.95 | 0.89 | 0.96       |
| Ab              | 18              | 6.1  | 93.5 | 0.4 | 0.23 | 1.57 | 1.60 | 0.99       |
| Ba              | 3               | 40.9 | 58.4 | 0.7 | 1.57 | 3.75 | -    | -          |
| Bb              | 27              | 92.8 | 7.0  | 0.2 | 3.20 | >4.0 | -    | -          |
| Bb1             | 5               | 70.6 | 29.3 | 0.1 | 1.68 | >4.0 | -    | -          |
| Bb2             | 22              | 97.9 | 1.9  | 0.2 | >4.0 | >4.0 | -    | -          |

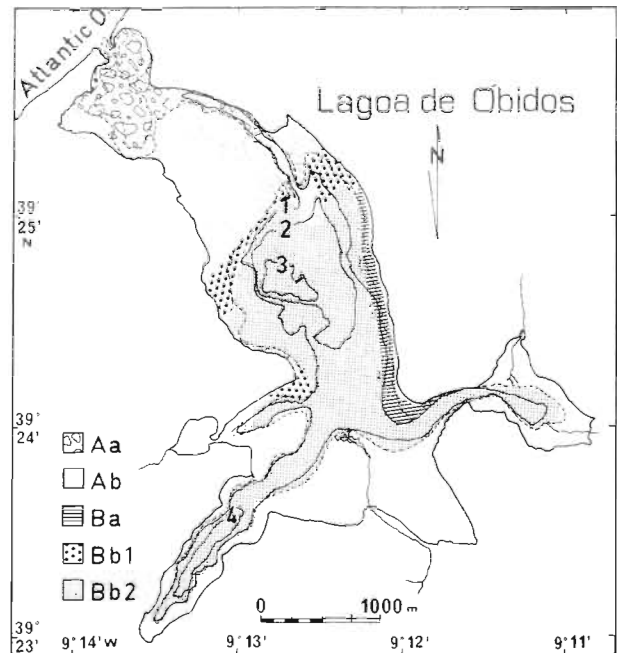


FIG. 4. — The lagoon of Obidos showing the spatial distribution of surface sediments. Aa, clean coarse sand; Ab, slightly silty medium sand; Ba, silty very fine sand; Bb<sub>1</sub>, slightly sandy mud; Bb<sub>2</sub>, fine mud.

pods together comprise more than 95 % of the individuals and more than 85 % of the species. Table II shows the distribution of species and specimens among the major taxa.

Of the 119 species, 21 (17 %) were collected once comprising 31 individuals (0.05 %), and 61 (51 %) had a frequency  $\leq 10$  % (sampled in less than 6 stations) and comprising only 489 individuals (0.72 %); 39 species (33 %) were sampled in 12 or more stations (frequency  $\geq 20$  %) and were represented by 66782 individuals (98 %), showing the strong disproportion of the distribution of individuals among

TABLE II. — Distribution of species and individuals among the major taxa.

| Taxa            | No. of species | No. of individuals |
|-----------------|----------------|--------------------|
| Bivalves        | 22             | 8170               |
| Gastropods      | 16             | 9753               |
| Polyplacophores | 2              | 28                 |
| Polychaetes     | 38             | 13525              |
| Oligochaetes    | 2              | 2817               |
| Amphipods       | 7              | 24725              |
| Peracarids*     | 7              | 1722               |
| Decapods        | 7              | 35                 |
| Chironomids**   | 1              | 4345               |
| Echinoderms     | 2              | 32                 |
| Phoronids       | 1              | 1617               |
| Chordates       | 6              | 44                 |
| Other groups*** | 8              | 1344               |
| Total           | 119            | 68157              |

\* Mysidaceans and Isopods

\*\* larval stage

\*\*\* Nemerteans, Platyhelminthes and Anthozoans

TABLE III. — Macrozoobenthic fauna list. The code number given to each species is used in figure 7.

| ANNELIDA      |  |
|---------------|--|
| 9             | <i>Aonides oxycephala</i> (Sars, 1862)                     |
| 12            | <i>Cirriiformia tentaculata</i> (Montagu, 1808)            |
| 16            | <i>Capitella capitata</i> (Fabricius, 1780)                |
| 25            | <i>Diopatra neapolitana</i> delle Chiaje, 1841             |
| 33            | <i>Eteone foliosa</i> Quatrefages, 1865                    |
| 34            | <i>Mysta picta</i> (Quatrefages, 1865)                     |
| 35            | <i>Eulalia viridis</i> (Linnaeus, 1767)                    |
| 36            | <i>Eumida sanguinea</i> (Oersted, 1843)                    |
| 41            | <i>Glycera convoluta</i> Keferstein, 1862                  |
| 43            | <i>Heteromastus filiformis</i> (Claparède, 1864)           |
| 48            | <i>Lagis koreni</i> Malmgren, 1866                         |
| 54            | <i>Malacoceros ciliata</i> (Keferstein, 1862)              |
| 55            | <i>Malacoceros fuliginosa</i> (Claparède, 1870)            |
| 56            | <i>Mediomastus capensis</i> Day, 1961                      |
| 66            | <i>Nephtys cirrosa</i> Ehlers, 1868                        |
| 67            | <i>Nephtys hombergii</i> Savigny, 1818                     |
| 68            | <i>Nereis diversicolor</i> Müller, 1776                    |
| 69            | <i>Ophelia bicornis</i> Savigny, 1818                      |
| 70            | <i>Ophelina modesta</i> Stop-Bowitz, 1958                  |
| 71            | <i>Owenia fusiformis</i> delle Chiaje, 1841                |
| 82            | <i>Pholoe</i> sp.  |
| 84            | <i>Phylo foetida</i> (Claparède, 1870)                     |
| 85            | <i>Anatides groenlandica</i> (Oersted, 1843)               |
| 86            | <i>Platynereis dumerilii</i> (Audouin & M.-Edwards, 1833)  |
| 87            | <i>Pseudopolydora antennata</i> (Claparède, 1870)          |
| 88            | <i>Polydora ciliata</i> (Johnston, 1838)                   |
| 90            | <i>Pomatoceros lamarkii</i> (Quatrefages, 1865)            |
| 91            | <i>Prionospio malmgreni</i> Claparède, 1878                |
| 93            | <i>Pygospio elegans</i> Claparède, 1863                    |
| 96            | <i>Saccocirrus papillocercus</i> Bobretzky, 1872           |
| 97            | <i>Scoloplos armiger</i> (Müller, 1776)                    |
| 101           | <i>Spiophanes bombyx</i> (Claparède, 1870)                 |
| 102           | <i>Spio martinensis</i> Mesnil, 1896                       |
| 103           | <i>Spio</i> sp.  |
| 104           | <i>Spiomidae</i> sp.                                       |
| 107           | <i>Sthenelais boa</i> (Johnston, 1839)                     |
| 108           | <i>Streblospio shrubsolii</i> (Buchanan, 1890)             |
| 109           | <i>Syllidia armata</i> Quatrefages, 1865                   |
| 113           | <i>Tubificoides benedeni</i> (Udekem)                      |
| 114           | <i>Tubificidae</i> sp.                                     |
| MOLLUSCA      |  |
| 1             | <i>Abra alba</i> (Wood, 1801)                              |
| 2             | <i>Abra ovata</i> (Philippi, 1836)                         |
| 3             | <i>Acantochitona fascicularis</i> (Linnaeus, 1767)         |
| 4             | <i>Akera bullata</i> Müller, 1776                          |
| 13            | <i>Bitium reticulatum</i> (da Costa, 1778)                 |
| 15            | <i>Calyptrea chinensis</i> (Linnaeus, 1758)                |
| 19            | <i>Cerastoderma edule</i> (Linnaeus, 1758)                 |
| 22            | <i>Corbula gibba</i> (Olivi, 1792)                         |
| 26            | <i>Donax trunculus</i> Linnaeus, 1758                      |
| 27            | <i>Dosinia exoleta</i> (Linnaeus, 1758)                    |
| 29            | <i>Ensis siliqua</i> (Linnaeus, 1758)                      |
| 30            | <i>Epitonium clathratulum</i> (Kamacher, 1797)             |
| 32            | <i>Ervilia castanea</i> (Montagu, 1859)                    |
| 38            | <i>Gibbula cineraria</i> (Linnaeus, 1758)                  |
| 39            | <i>Gibbula pennanti</i> (Philippi, 1836)                   |
| 40            | <i>Gibbula umbilicalis</i> (da Costa, 1778)                |
| 42            | <i>Hamnea navicula</i> (da Costa, 1778)                    |
| 44            | <i>Hiattella arcuata</i> (Linnaeus, 1758)                  |
| 45            | <i>Hydrobia ulvae</i> (Pennant, 1777)                      |
| 46            | <i>Hydrobia ventrosa</i> (Montagu, 1803)                   |
| 49            | <i>Lepidochitona cinereus</i> (Linnaeus, 1769)             |
| 50            | <i>Liitorina litorea</i> (Linnaeus, 1758)                  |
| 51            | <i>Loripes lacteus</i> (Linnaeus, 1758)                    |
| 59            | <i>Mytilus galloprovincialis</i> Lamarck, 1819             |
| 60            | <i>Nassarius reticulatus</i> (Linnaeus, 1758)              |
| 78            | <i>Parvicardium exiguum</i> (Gmelin, 1790)                 |
| 79            | <i>Parvicardium</i> sp.                                    |
| 80            | <i>Pharus legumen</i> (Linnaeus, 1758)                     |
| 81            | <i>Philine aperta</i> (Linnaeus, 1758)                     |
| 94            | <i>Rissoa labiosa</i> (Montagu, 1803)                      |
| 95            | <i>Rissoa parva</i> (da Costa, 1778)                       |
| 98            | <i>Scrobicularia plana</i> (da Costa, 1778)                |
| 105           | <i>Spisula solida</i> (Linnaeus, 1758)                     |
| 106           | <i>Spisula subtruncata</i> (da Costa, 1778)                |
| 111           | <i>Tellina donacina</i> Linnaeus, 1758                     |
| 112           | <i>Tellina tenuis</i> da Costa, 1778                       |
| 115           | <i>Chrysallida terebelum</i> (Philippi, 1844)              |
| 117           | <i>Venerupis decussata</i> (Linnaeus, 1758)                |
| 118           | <i>Venerupis pullastra</i> (Montagu, 1803)                 |
| 119           | <i>Venus striatula</i> (da Costa, 1778)                    |
| ARTHROPODA    |  |
| 10            | <i>Atelecyclus</i> sp.                                     |
| 11            | <i>Atylus swammerdami</i> (Milne-Edwards, 1830)            |
| 17            | <i>Caprella acanthifera</i> Leach, 1814                    |
| 18            | <i>Carcinus maenas</i> (Linnaeus, 1758)                    |
| 20            | <i>Chironomidae</i> sp.                                    |
| 23            | <i>Corophium insidiosum</i> Crawford, 1937                 |
| 24            | <i>Cyathura carinata</i> (Krøyer, 1847)                    |
| 28            | <i>Dynamene bidentata</i> Adams, 1800                      |
| 31            | <i>Ericthonius difformis</i> Milne-Edwards, 1830           |
| 37            | <i>Gammarus insensibilis</i> Stock, 1966                   |
| 47            | <i>Idotea chelipes</i> (= <i>viridis</i> ) (Slabber, 1778) |
| 52            | <i>Macropodia rostrata</i> Linnaeus, 1761                  |
| 53            | <i>Macropipus</i> sp.                                      |
| 57            | <i>Melita palmata</i> (Montagu, 1804)                      |
| 58            | <i>Microdeutopus gryllotalpa</i> Costa, 1853               |
| 72            | <i>Palaemon elegans</i> Rathke, 1837                       |
| 73            | <i>Palaemon serratus</i> (Pennant, 1777)                   |
| 74            | <i>Palaemonetes varians</i> (Leach, 1814)                  |
| 75            | <i>Paramysis hancescoi</i> Labat, 1953                     |
| 77            | <i>Paramysis nouveli</i> Labat, 1953                       |
| 99            | <i>Sphaeroma hookeri</i> Leach, 1814                       |
| 100           | <i>Sphaeroma monodi</i> Bocquet, Hoestland Lévi, 1954      |
| ECHINODERMATA |  |
| 76            | <i>Paracentrotus lividus</i> (Lamarck, 1816)               |
| 92            | <i>Psammechinus miliaris</i> (Gmelin, 1807)                |
| VARIA         |  |
| 5             | <i>Ammodytes tobianus</i> Linnaeus, 1758)                  |
| 6             | <i>Anguilla anguilla</i> (Linnaeus, 1758)                  |
| 7             | <i>Anemonia</i> sp.  |
| 8             | Anthozoan sp. indet.                                       |
| 14            | <i>Branchiostoma lanceolatum</i> (Pallas, 1778)            |
| 21            | <i>Ciona intestinalis</i> (Linnaeus, 1767)                 |
| 61            | Nemertea sp. A   |
| 62            | Nemertea sp. B   |
| 63            | Nemertea sp. C   |
| 64            | Nemertea sp. D   |
| 65            | Nemertea sp. E   |
| 83            | <i>Phoronis psammophila</i> Cori, 1889                     |
| 89            | <i>Pomatosthis microps</i> (Krøyer, 1838)                  |
| 110           | <i>Syngnathus acus</i> (Linnaeus, 1758)                    |
| 116           | Platyhelminthes sp. indet.                                 |

species. A species list with taxonomic authorities is given in table III.

The distribution of species per sampling station shows an enrichment gradient, directed from the outer and inner stations towards intermediate ones, located along the navigation channel and bordering the intertidal sand-bank (Fig. 5). The distribution of the abundance of individuals (Fig. 5) also shows that the poorest regions comprise the outermost and innermost sampling stations. However, the sampling stations with the highest total abundances are located further from the channel sand-bank area than those with the highest species richness.

Thus along the axis of the lagoon from the entrance to the inner basin, the species enrichment reaches a maximum before the highest densities are found. Similar results are known from the Lagoon of Albufeira (QUINTINO & RODRIGUES, 1985) and the Ria of Alvor (RODRIGUES & QUINTINO, 1986), western and southern coast of Portugal. Perimediterranean lagoon systems show similar gradients. (AMANIEU *et al.*, 1977; 1979; GUELORGET & PERTHUISOT, 1983), the major difference being the absence of an initial inwards enrichment. This could be caused by the stronger tidal currents along the entrance channel in Atlantic lagoons which induces a coarse and moving sedimentation, thus inhibiting the settlement of species in the vicinity of the lagoon mouth.

#### BENTHIC COMMUNITIES

The raw data consisted of a binary matrix (presence-absence) of station  $\times$  species. The final

treatment considered a 57 stations  $\times$  98 species matrix, by the omission of species sampled once.

The first ten eigenvalues of the correspondence analysis explained 57.1 % of the total inertia, with axes 1 and 2 comprising 24.5 %. The results showed three major affinity groups among both stations and species, distributed in plane 1-2 according to figures 6 (stations) and 7 (species). Again, the simultaneous representation of samples and species has been avoided; figures 6 and 7 are, however, drawn to the same scale.

Among the sampling stations the groups Aa, Ab and B, with Ba and Bb, were obtained. Subgroup Bb comprised three further divisions represented in figure 6 by assemblages Bb<sub>1</sub>, Bb<sub>2</sub> and Bb<sub>3</sub>. Axis 1 opposes assemblage Aa (quadrant 1<sup>+</sup> 2<sup>-</sup>) to assemblage Bb (1<sup>-</sup> 2<sup>-</sup>). The transition from Aa to Bb is made by groups Ab (1<sup>+</sup> 2<sup>+</sup>) and Ba (mainly 1<sup>-</sup> 2<sup>+</sup>), by the positive pole of axis 2. The succession Aa  $\rightarrow$  Ab  $\rightarrow$  B (Ba  $\rightarrow$  Bb) shows a clear spatial correspondence represented by the outermost sampling stations located in the vicinity of the lagoon mouth (Aa) to the stations of the navigation channel (Ab) and to the stations comprising the intertidal sand-bank (Ba) and the remaining stations located inwards of any of the previous groups (Bb).

The subgroups Bb<sub>1</sub>, Bb<sub>2</sub> and Bb<sub>3</sub> maintain this geographical coherence; Bb<sub>1</sub> comprises 4 stations located inwards to the intertidal sand-bank; Bb<sub>2</sub> is a group of 17 stations inward to Bb<sub>1</sub> and located in the shallow regions of the center of the lagoon, and Bb<sub>3</sub> concerns 10 stations occupying both the deeper regions of the center of the lagoon and the innermost

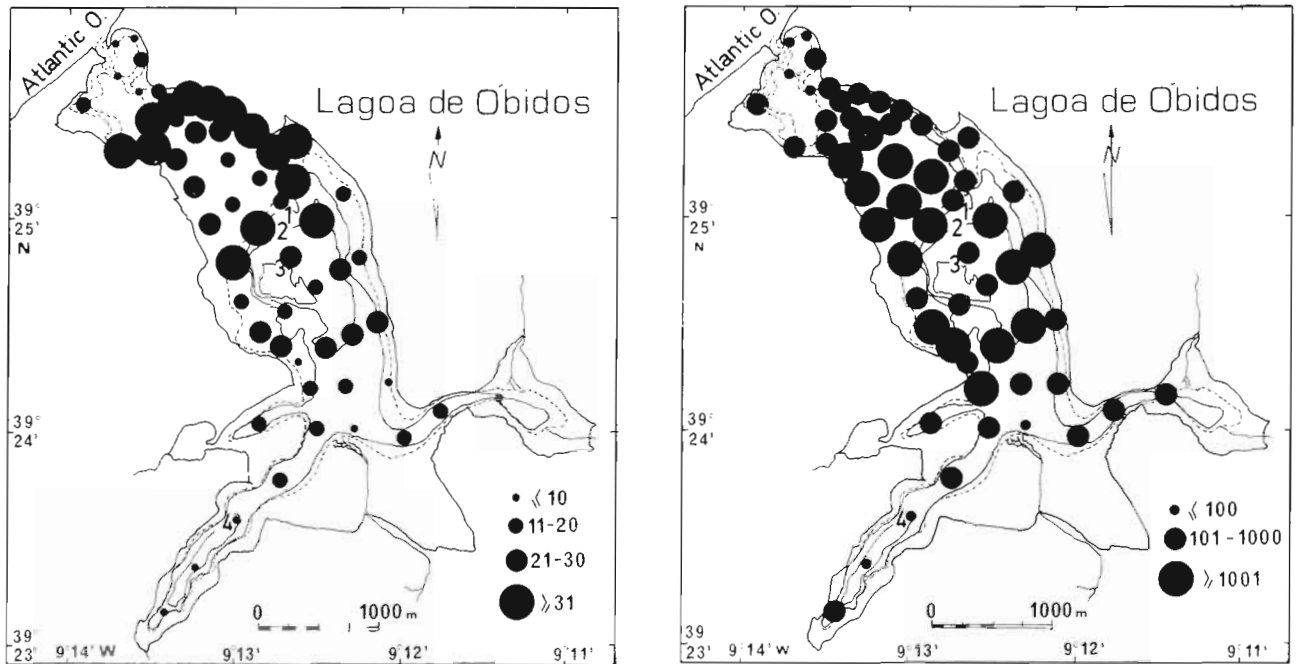


FIG. 5. — Number of species (left) and number of individuals (right) per sample in the Obidos lagoon.

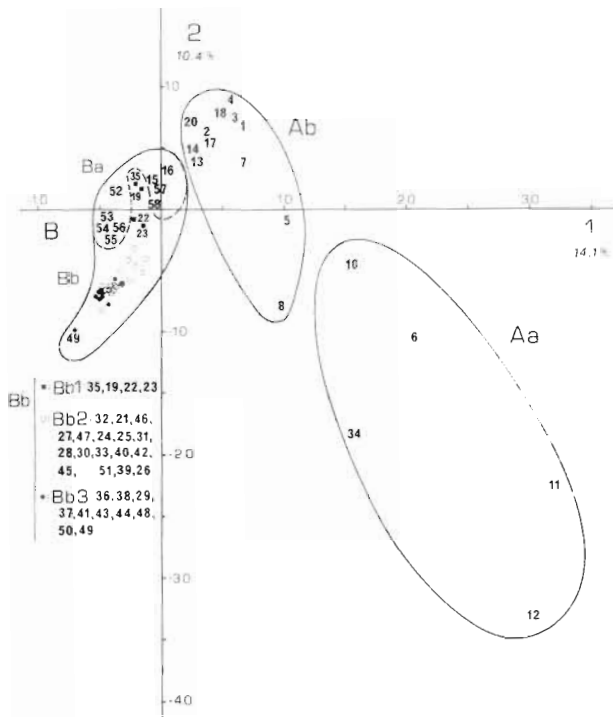


FIG. 6. — Affinity assemblages among sampling stations according to the partition obtained in plane 1-2 of the correspondence analysis.

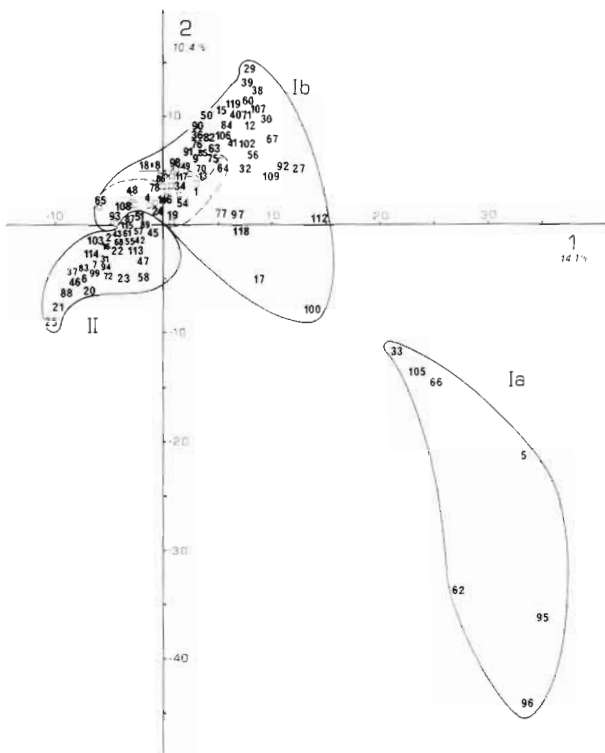


FIG. 7. — Affinity assemblages among species according to the partition obtained in plane 1-2 of the correspondence analysis. For correspondence of code numbers with species names refer to Table III.

sampling stations located in Barrosa and Bom Sucesso.

Among the species the affinity groups Ia ( $1^+ 2^-$ ), Ib ( $1^+ 2^+$ ) and II ( $1^- 2^-$ ) were obtained (Fig. 7). Axis 1 opposes the group Ia, comprising 7 species, to the group II, of 33 species. The transition is made by the group Ib, of 58 species, by the positive pole of axis 2.

Assemblages Ia, Ib and II agree with the former partition into groups Aa, Ab and B.

Group Ia consists of a few characteristic marine species (*Spisula solida*, *Nephtys cirrosa*, *Anmodytes tobianus*, *Saccocirrus papillocercus*, etc.) and group II contains several characteristic lagoon and estuarine species (*Abra ovata*, *Loripes lacteus*, *Rissoa labiosa*, *Hydrobia ventrosa*, *Heteromastus filiformis*, *Nereis diversicolor*, *Capitella capitata*, *Polydora ciliata*, *Tubificoides benedeni*, *Corophium insidiosum*, *Gammarus insensibilis*, *Microdeutopus gryllotalpa*, *Sphaeroma hookeri*, *Idotea chelipes*, *Phoronis psammophila*, etc.).

Thus, axis 1 opposes the outermost stations together with a group of marine species, to the innermost stations and a group of characteristic lagoonal species. Axis 2 isolates a group of intermediate stations together with the richest affinity group of species.

These results suggest the presence of two distinct benthic communities, one located near the lagoon mouth and the other in inner areas, connected by a transition area characterized by high species richness.

The macrozoobenthic community structure of the lagoon of Obidos, illustrated in figure 8, is described as follows:

OI: marine community located on clean coarse unstable sand (mean =  $0.78\phi$ ; median =  $0.83\phi$ ; sorting coefficient =  $0.82\phi$ ; mean silt percentage = 1.1 %). Geographically identified with the lagoon mouth, this community was defined by sampling stations 6, 10 to 12 and 34. It corresponds to 4 % of the bottom surface, and it is characterized by *S. solida*, *N. cirrosa*, *S. papillocercus* and *A. tobianus*. Species richness and individual abundance are both low in this community due to coarse and moving sand sedimentation.

OII: intermediate assemblage, geographically inward of OI, located on slightly silty medium sand (mean =  $1.32\phi$ ; median =  $1.37\phi$ ; sorting coefficient =  $0.99\phi$ ; mean silt percentage = 5.9 %). This assemblage comprises 11 % of the bottom surface and corresponds to the navigation channel, crossing the intertidal sand-bank along the northern margin of the lagoon. It was defined by sampling stations 1 to 5, 7, 8, 13, 14, 17, 18 and 20. Containing some species from both the marine and lagoon communities, this assemblage is also characterized by several species sampled only in this region, namely the polychaetes

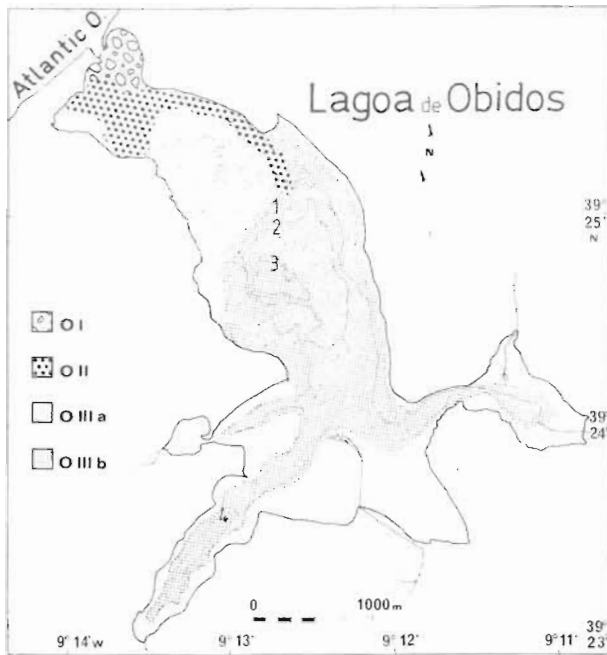


FIG. 8. — Spatial distribution of the macrozoobenthic communities in the lagoon of Obidos. O I = marine community of *Spisula solidissima-Nephtys cirrosa*; O II = ecotone area; O III = lagoon community of *Abra ovata-Heteromastus filiformis* with O IIIa = sand-bank of *Pygospio elegans* and O IIIb = type lagoon community.

*Cirriiformia tentaculata*, *Sihenelais boa*, *Owenia fusiformis* and *Phylo foetida*, and the molluscs *Nassarius reticulatus*, *Gibbula pennanti*, *G. umbilicalis* and *Venus striatula*.

This assemblage shows the highest values for species richness and intermediate values for total abundance. It may be considered an ecotone area in the sense described by ODUM (1971).

O III: lagoon community, inward of O I and O II, mainly located on fine muds. This community corresponds to 85 % of the bottom surface and comprises both the intertidal sand-bank (sampling stations 15.

TABLE IV. — Distribution of the number of species and individuals in each of the communities. N, number of sampling stations; S, number of species; FI, number of species sampled once; s, mean number of species per sampling station; T, number of individuals per sampling station; t, mean number of individuals per sampling station; A, bottom percentage area.

| Communities | N  | S   | FI | s  | T     | t    | A     |
|-------------|----|-----|----|----|-------|------|-------|
| Marine      | 5  | 26  | 12 | 10 | 261   | 52   | 4 %   |
| Lagoon      | 40 | 84  | 23 | 19 | 62067 | 1552 | 85 %  |
| sand-bank   | 9  | 54  | 15 | 21 | 18629 | 2070 |       |
| mud-bottom  | 31 | 72  | 17 | 18 | 43438 | 1401 |       |
| Bb1         | 4  | 59  | 24 | 34 | 22780 | 5695 |       |
| Bb2         | 17 | 51  | 16 | 17 | 15446 | 909  |       |
| Bb3         | 10 | 37  | 10 | 14 | 5212  | 521  |       |
| Ecotone     | 12 | 97  | 23 | 37 | 5829  | 486  | 11 %  |
| Total       | 57 | 119 | 21 | 22 | 68157 | 1196 | 100 % |

16 and 52 to 58, with mean = 1.54 $\phi$ , median = 1.53 $\phi$ , sorting coefficient = 0.77 $\phi$  and mean silt content = 3.0 %), and the whole group of stations located in the center and innermost regions of the lagoon (sampling stations 19, 22 to 33 and 35 to 51, with mean and median > 4 $\phi$  and mean silt content = 80 %).

The lagoon community is characterized by a large number of species frequently reported from lagoon systems, namely the molluscs *A. ovata* and *H. venirosa*, the annelids *H. filiformis*, *C. capitata*, *N. diversicolor*, *P. ciliata*, *P. antennata*, *M. fuliginosa* and *T. benedeni*, the arthropods *C. insidiosum*, *G. insensibilis*, *M. gryllotalpa*, *S. hookeri* and Chironomids, and the phoronid *P. psammophila*.

The lagoon community has no particular subdivisions. However, the intertidal sand-bank is characterized by the polychaete *Pygospio elegans*, collected only in this region. The assemblages Bb<sub>1</sub>, Bb<sub>2</sub> and Bb<sub>3</sub> established within the group Bb show only different species richness and individual abundance with an impoverishment gradient from Bb<sub>1</sub> to Bb<sub>2</sub> and to Bb<sub>3</sub>. This gradient is established from outwards (Bb<sub>1</sub>) to inwards (Bb<sub>3</sub>) and corresponds to an increasing silt content of the surface sediments. The mean silt content of subgroups, Bb<sub>1</sub>, Bb<sub>2</sub> and Bb<sub>3</sub> is respectively 30 %, 83 % and 99 %.

Table IV presents the total number of individuals and species of each of the assemblages, together with species sampled only once in each of the regions.

This coenotic model for the lagoon of Obidos suggests that the major factor determining the composition and distribution pattern of macrozoobenthos is related to a hydrosedimentological gradient acting along the longitudinal axis of the lagoon. This gradient could be expressed as a decreasing hydrodynamic energy level as distance from the lagoon entrance increases, resulting in an increase in the sedimentary silt content in the inner areas and in higher annual amplitudes of physico-chemical parameters in the innermost regions.

## DISCUSSION

According to the NICHOLS & ALLEN (1978) classification of lagoon systems, based on the relative importance of wave action, tidal currents and fluvial inputs, the lagoon of Obidos may be considered a semi-enclosed system, comparable namely to the lagoon of Albufeira, western coast of Portugal (QUINTINO & RODRIGUES, 1986) and the lagoon of Moulay-bou-Salham, atlantic coast of Morocco (BIDET *et al.*, 1977). In this type of lagoon system the major hydrodynamic agents are the waves and tidal currents, tending to establish a shallow and narrow

entrance channel subject to episodic sand obstructions. Muds predominate in the inner areas and sandy sediments are distributed only near the entrance area.

The bio-sedimentological gradients identified suggest a coenotic model consisting of successive inward zones related to the incursion of coastal waters through the entrance channel. Thus, surface sediments and benthic communities are both distributed along the longitudinal axis of the lagoon, without showing particular transverse components. This distribution is represented by an outer marine community settled on clean coarse unstable sand, in contrast to an inner lagoon community settled on fine muds, connected by an ecotone area settled on more diverse surface sediments.

The faunal composition of the lagoon of Obidos can be related to the Atlantic and Mediterranean fauna of coastal or lagoon systems (MUUS, 1967; RASMUSSEN, 1973; GUELORGET & PERTHUISOT, 1983). In this analysis, the outer marine community corresponds to a similar community described by RETIERE (1979) in Rance Maritime and by GENTIL (1982) in the outer part of Aber Wrac'k, both settled on unstable medium to coarse sands due to strong hydrodynamic action. The inner lagoon community is typical of coastal Atlantic and Mediterranean lagoons and is related to the *biocenose lagunaire euryhaline et eurytherme* (LEE) (PÉRÈS & PICARD, 1964; BELLAN, 1964) and to the *Cardium edule - Scrobicularia plana* variety of the *Macoma balthica* community in THORSON'S (1957) system.

This scheme for the distribution and composition of soft bottoms and benthic communities in the lagoon of Obidos is similar to the one described in the lagoon of Albufeira, Portugal (QUINTINO *et al.*, 1987) and to the general model proposed by GUELORGET & PERTHUISOT (1983) for the perimediterranean lagoon systems. The major difference may be considered to be the initial inwards species enrichment. This may reflect the stronger wave action and tidal currents in the entrance channels of Atlantic lagoons.

The inner lagoon community, occupying 85 % of the total bottom surface, has a species composition which also reflects an organic enrichment of sediments (*M. fuliginosa*, *H. filiformis*, *P. ciliata*, *T. benedeni*, *P. psammophila*, *C. gibba*, etc.) (PEARSON & ROSENBERG, 1978). Recorded densities higher than 10,000 ind. m<sup>-2</sup> (unpubl. data), could, in a situation of temporary oxygen depletion, induce mass mortality in this community, as observed in the lagoon of Albufeira, during a period when the communication with the ocean was obstructed (QUINTINO & RODRIGUES, 1985). In order to study the dynamics of these benthic populations a quantitative survey was held from October 1984 to December 1986.

## ACKNOWLEDGMENTS

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