PHYSICAL CHARACTERIZATION OF ODECEIXE, ALJEZUR AND CARRAPATEIRA LAGUNARY SYSTEMS (SW PORTUGAL)

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ABSTRACT

Odeceixe, Aljezur and Carrapateira are small rivers draining the occidental part of SW Portugal. Their discharges are frequently prevented by sand barriers enclosing small lagoons. The average rainfall is higher from November to March and the dry months are July and August. As a consequence of a low hydraulic inertia, rainfall directly reflects on the fluvial discharge. The main observed phenomena are the sand accumulation at the river mouths and its upstream progression. Its origin is essentially marine and sources may be sandy beaches along the coast and/or dunes.

INTRODUCTION

The Portuguese SW coast is one of the best preserved littoral systems of Europe. Landscape beauty and natural richness make this coast one of the most interesting areas in Portugal. At an international level, its particular uniqueness is conferred by endemic plant species and rare animals, as well as ecological peculiarities (Palma *et* al., 1984).

In the last twenty years, the pressure upon the littoral zone has increased in many important aspects endangering estuaries, lanscape, geological peculiarities, historical and archaelogical sites and species (Tavares & Sacarrão, 1960; Silva e Costa et al., 1983).

Yet the Portuguese SW coast remains one of the least disturbed coastlines of southern Europe. A high species richness is in some way related to its estuaries. In fact they play a very important role in the life cycle of severa1 species of its fauna (Cancela da Fonseca et al., 1983).

Those estuaries within Pleistocene - Holocene basins are surrounded by dominant schist formations of the Maritime Carboniferous Period. These catchment basins include Paleozoic, Mesozoic and Cenozoic land (Teixeira & Gonçalves, 1980; Teixeira, 1981).

According to Begg (1978 *in* Day 1981a) and from their physiography these can be considered not true estuaries but lagunary systems or lagoons even with regard to its physical properties (Stewart, 1972, Colombo, 1978).

At the river mouth, because of its dynamic nature, water movement processes and sediment transport are closely interrelated. If that equilibrium is disturbed, severe erosion problems and/ or sediment deposition can occur. They are not separate entities but form a continuum with the other coastal components, having an important regulatory effect upon the sands (Heydom & Tinley, 1980).

With catchment areas of 250 Km^2, 200 km^2 and 111 km^2, respectively, Odeceixe (ODX), Aljezur (ALZ) and Carrapateira (CAR) are small rivers draining the occidental part of SW Portugal and not previously studied. Their discharges are frequently prevented by sandy barners enclosing small lagoons.

During 1984-1985 a study conceming water, sediment, macrobenthos and fish was undertaken. In this period Odeceixe and Aljezur were open to the sea. Carrapateira was generally isolated, except in winter after some rainy days. Physical characterization (water and sediments) is here discussed, considering precipitation.

METHODS

Covenng the terminal part of the three lagoons, several stations were established. From March 1984 to December 1985 seasonal lowtide sediment samples were collected. Surface and bottom data of salinity (S‰), dissolved oxygen (DO), temperature (T) and pH were measured *in sifu* with sensors. For this study only bottom values were considered.

Subtidal sediment samples collected with a hand corer (0,02m^2 section) were separated in two sub-samples: 1) a 20 cm vertical section for granulometric purposes, and 2) an upper layer (1 cm), for loss on ignition determinations, which was frozen as soon as possible.

1) After samples were treated with H_2O_2, gravel (< -1 o fraction), sand (from -1 to 4 ø) and mud (>4 o) were separated by wet sieving. Sand grain-size distribution was determined by sedimentation tube balance. Silt (from 4 to 8 ø) and clay (>8 o) percentages were obtained by pipette analysis after samples dispersion and sedimentations procedure (Buller & McManus, 1979). Wentworth scale was used.

2) Organic matter content of sediments (OM) were obtained by loss on ignition, 24 hr at 450" C (Perthuisot, pers. comm.). Loss on ignition, 24hr. at 650° C, was also undertaken, according to Medhioub (1979).

Symetric correlation matrices were calculated (Bravais-Pearson corr. coef.) for sedirnent and water parameters.

A cluster analysis (Programs by F. Andrade at L. M. G. – Teltronix 6130) was performed on loss on ignition and grain-size distribution values. Weight percentages data were plotted on Shepard diagrams and frequency and cumulative frequency curves were used for sediment data (Buchanan & Kain, 1971; Day, 1981b).

RESULTS

From the study of grain-size distribution we can separate four sedimentary zones: i) sands at all the sampling points of Carrapateira and near the mouth of Odeceixe and Aljezur streams, followed in the last ones by ii) sandy-muds and iii) muds at Aljezur (ALZ 18) or iv) sandy-gravelly muds at Odeceixe (ODX 10). The main types of sediments are represented by its average cumulative frequency curves (Fig. 1) during the study period.

Water temperature had a normal seasonal variation following athmospheric values. Its extreme values were 9.7 and 30.0" C at CAR, 12.2 and 28.9" C at ALZ and 11.2 and 26.0 C at ODX. pH ranged from 7.1 to 9.4 at ALZ, 5.4 to 8.9 at ODX (with values from 6.0 to 7.0 in March 1984 and March 1985, after rainfall) and 6.5 to 9.2 at CAR, with values from 6 to 7 at March 1984. Only once (ODX 10, September 1985) a low pH (5.4) was associated to a DO saturation of 51.2%.

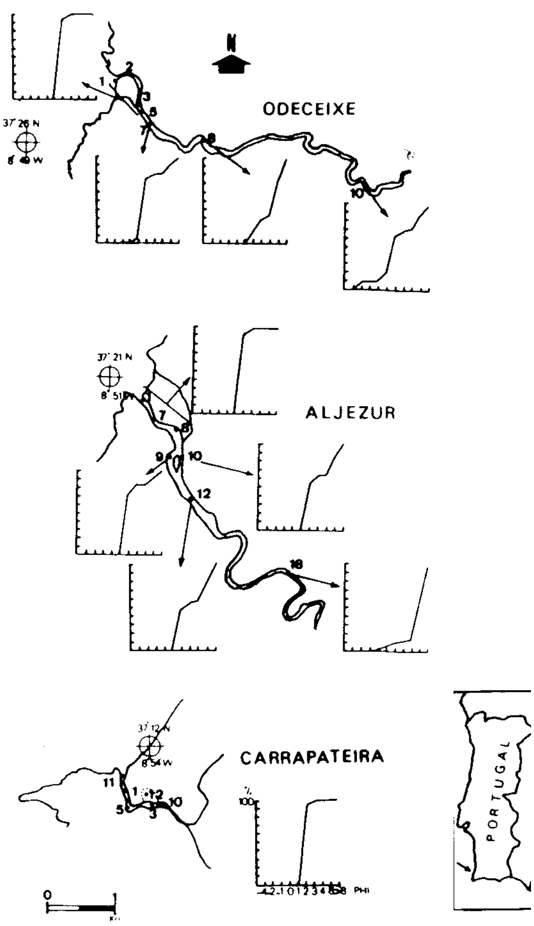


Figure 1.- Odeceixe (ODX), Aljezur (ALZ) and Carrapateira (CAR) streams: location of the sampling points and average grain-size distribution (cumulative curves).

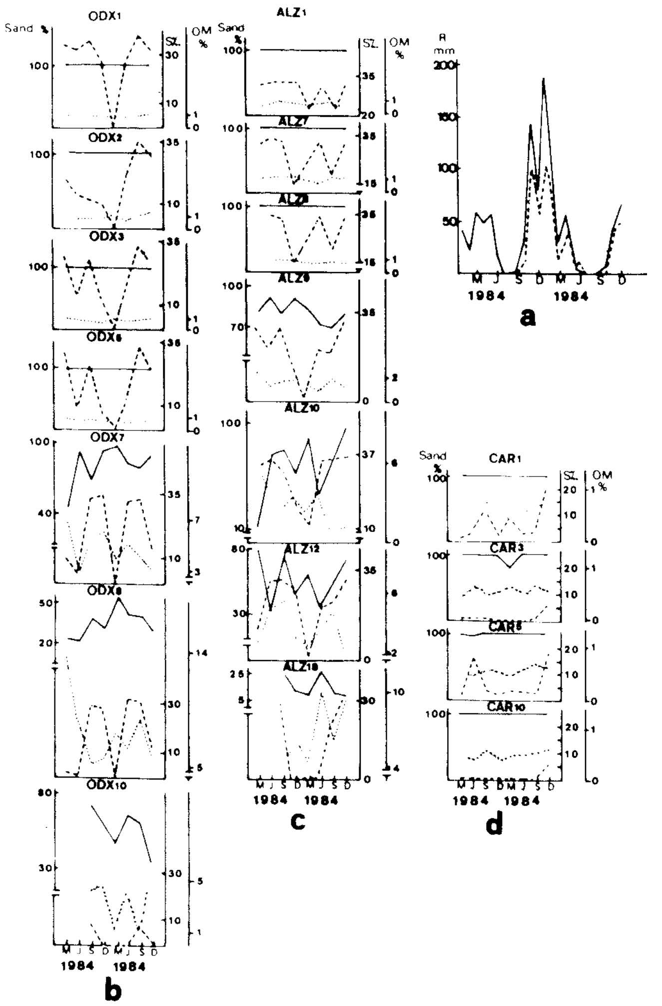


Figure 2.- 1984 and 1985 survey period. Precipitation at SAGRES (----) and ZAMBUJEIRA DO MAR (——) - INMG data (a). Variation of salinity (----) and percentages of sand (——) and organic matter (......) at Odeceixe (b), Aljezur (c) and Carrapateira (d) stations.

No critical values of DO were noticed with the exception of those at CAR 10, whereby in June and Septembre 1985, values of 10 and 0.6 ppm were recorded respectively. This was due to very dense populations of *Myriophyllum spicatum* and *Ceratophyllum demersum.*

Salinities between 0‰ and 37‰ were observed. Odeceixe has a maximum of 37‰ (ODX 1, September 1985) and a minimum of 0‰ (ODX 10, December 1984, June 1985 and ODX 1, ODX 2, ODX 3, ODX 7, ODX 8 and ODX 10 at March 1985, after an important rainfall period – Fig. 2a and 2b). At Aljezur, 37‰ was found at ALZ 10, (December 1985) and 0‰ at ALZ 18 (June 1985) – Fig. 2c. Concerning Carrapateira (Fig. 2d) a maximum of 20.5‰ was noticed at Car 1 (December 1985) and a minimum of 0‰ was obtained for CAR 3 and CAR 10 (March and June 1985).

Precipitation during 1984 and 1985 at Sagres and Zambujeira do Mar, sand percentage in sediments, percentage of organic matter (OM) and salinities were presented (Fig. 2) for the different stations at all the sampling periods.

No correlation at the 0.05 level was found among the considered water parameters.

Concerning sediment data analysis:

– No correlation exists between loss on ignition at 450° C and 650" C. The values at 659° C obtained for clean sands at the inlets are higher than in muds with rich organic layers, although an interference of compounds other than organic matter was found (e.g. carbonates –Buchanan & Kain, 1971; Dowgiallo, 1975). Thus, loss on ignition at 450° C was assumed as the best approach to obtaining OM, according to Perthuisot (pers. comm.).

– OM correlates with silt and clay ($p<0.05$ for CAR and $p<0.001$ at ALZ and ODX). From cluster analysis (Fig. 3) an opposition exists between loss on ignition at 650° C, 20 class of grain size and all the other parameters, at ODX. An opposition was also found in ALZ, between loss on ignition at 650° C, 20 and 3ø classes of grain size and the other parameters.

Carrapateira presents, all along the surveillance period, low contents of OM (less than 1% – Fig. 2d). Values of the same order (but slightly higher – ca. 1%) were found in the sandy areas of ALZ and ODX. CAR presents a quite constant sand sediment. Regarding the **37** samples of its sediment that were analysed, average standard deviations for all the categories of grain-size were within the 0.01 - 2.96 range. Muddy sediments were absent, but in the other two systems their presence increased upstream, where greater OM contents were observed (Fig. 2b and 2c).

After the plots of sediment grain-size distributions on Shepard diagrams, one may say that the behaviour of the stations is almost constant with respect to the sands, or they suffer cyclic variations. The main differences were found at ODX 7 and ALZ 19, where a sand accumulation was detected.

Fig. 4 shows ODX 7 and ALZ 10 migration across the different types of sediment. Differences between the grain-size frequency curves of those stations are shown in Fig. 5.

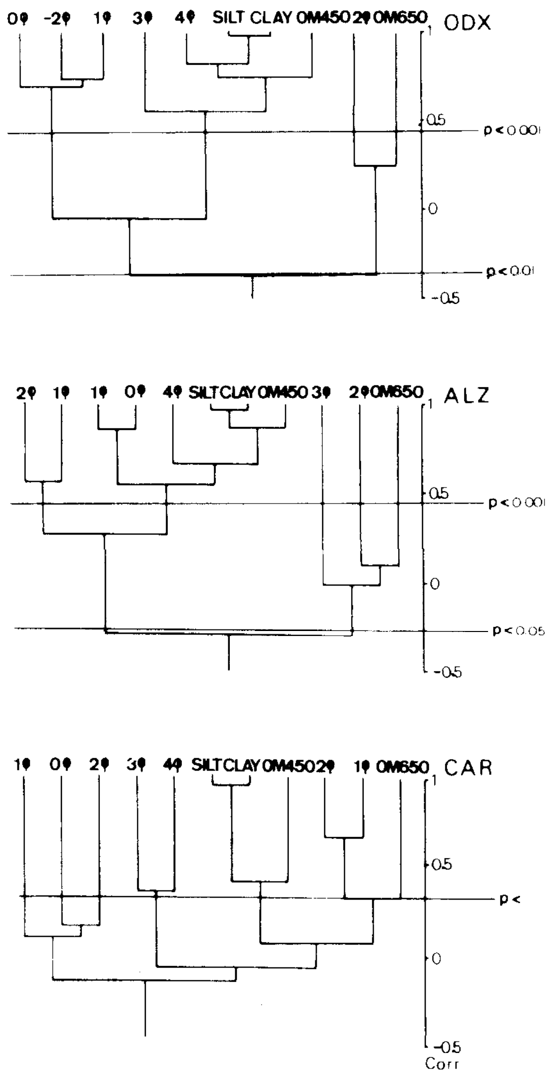


Figure **3**.- Sediment parameters of ODX, ALZ and CAR – Cluster Analysis.

DISCUSSION

On the Portuguese SW coast, the great interannual variations of rainfall (Fig. 2a) common to mediterranean climatic regions, have important consequences on river flows (Silva, *in litt.*). Large salinity variations in ODX (maximum values), ALZ and CAR waters, could be explained by rainfall regime.

The typical torrential character of Portuguese rivers (Teixeira & Gonçalves, 1980) is clearly shown here, by the strong salinity fluctuations (Fig. 2). This is rather evident at ODX where in March 1985, salinity reached zero even at the exterior station (ODX1 – Fig. 1).

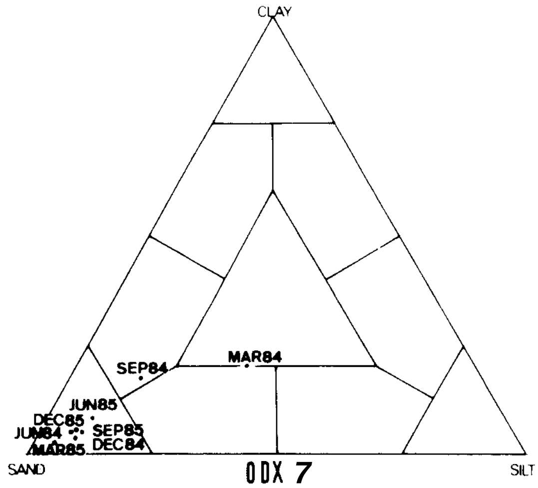
Odeceixe and Aljezur had greater variations in salinity and smaller thermal amplitudes compared to Carrapateira because of their higher oceanic influence. Throughout the study Carrapateira had, usually, been isolated from the sea by a sand barrier. After the rainy winter periods, it opened in March 1984 and March 1985. As a consequence, its salinity had lower values and thermal range was much wider than in the other two systems (Fig. 2). The high salinities at Carrapateira in March and December 1985 were, respectively, a consequence of run-off, which opened the bar, and of sea water incoming into the closed lagoon over the sand barrier.

The inexistence of a correlation between loss on ignition at 450° C and 650" C, in spite of our observations made at Stº André lagoon (Fonseca et al. 198), leads to a non-uniform distribution of the interfering compounds (e.g. carbonates) in these systems. From loss on ignition at 650° C opposition with muds (Fig. 3), one can suppose that carbonates have a sea origin.

At Odexeixe and Aljezur grain-size distribution and organic matter percentage are influenced by run-off. With the strong decrease in salinity (March 85), organic matter also decreases, except al ODX 8, probably a deposition zone of carried material. This is shown by an increase of fine sands with probable fluvial origin.

Circulation pattern is dominated by tidal currents, except CAR and flood situations at ODX and ALZ. This can be seen by salinity values (Fig. 2). So they are well mixed estuaries (Dyer, 1979). According to Barnes (1974), in those estuaries where sea water is the dominant water mass, the bulk of deposited material is manne. Odeceixe and Aljezur sediments certainly have both, marine and fluvial, origins.

The sand of their inlets and terminal zones, like that of Carrapateira, contains more than 90%



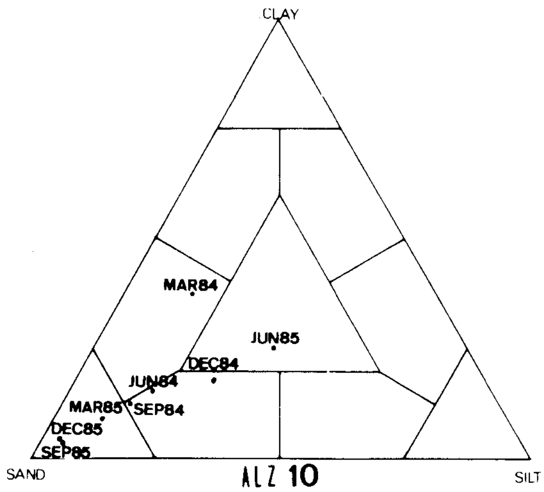


Figure 4.- ODX 7 and ALZ 10: Plots on Shepard Diagrams showing the fluctuations of sedimentcomposition.

20 fraction (Fig. 1). According to Buller & McManus (1979), this sand has a marine origin.

Differences in settled sediments can be related to flood regime, since, in these periods, river discharge tends to flush sediment through and out of the lagoons. At these, only in ODX does the freshwater reach the sea. The sediment-type range is greater in ALZ (from sand to silty clay or clayey silt) than in ODX (from sand to muddy sand or sandy gravelly mud).

The plots on Shepard diagrams emphasize an usptream sand accumulation. This is evident at ODX 7 and ALZ 10, where incoming sand arnves at first (Fig.4 and 5). Their sand contents increases during the sampling period with positive balances of 20 and 57%, respectively (Fig. 2b and 2c). This sand accumulation is also due to a well sorted medium marine sand mostly of 20 fraction. A similar one can also be found at the mouth of Sado (Andrade & Cancela da Fonseca, 1982) and Mira (Andrade, 1986) estuanes.

As a consequence of fluvial transport of allochthonous material and estuanne tidal processes (Dyer, 1979; Day, 1981c), silt and clay are closely related to organic matter. This clearly appears in ODX and ALZ and, in a lower level, at CAR (Fig. 3).

Some of the remaining stations, present a regular (ODX8 – always sand-silt-clay) or almost regular behaviour (ALZ 9 – sand or clayey sand). Other ones, like ALZ 12 and 18, have a fluvial – tidal influence with significative fluctuations in silt, clay and organic matter contents. Day (1981c) states that deposition and re-suspension of those components are closely related to salinity variations. ODX 10 is a fluvial regulated station with coarse sediments. According to Day (1981c) coarse sand and gravels are only transported into the tidal reaches during floods, and medium to fine sand usually by normal flow. ODX 10 changes from a muddy sand to a gravelly sand with the 1985 flood period, afterwards turning into a sandy gravelly mud.

Disturbance of unconsolidated sediments and their natural plant cover frequently leads to erosion problems (Kemp, 1976) such as sandblows and sediment deposition in lagoons (Heydorn & Tinley, 1980).

The degradation of dune vegetation was initiated with the storms of February 1979 (P. Simões, pers. comm.). Trampling increment (motor vehicles, horses, pedestrians and cattle), grazing –two factors of considerable impact on the dunes (Boorman, 1978)–and water retention for irrigation purposes intensified that situation.

In ALZ and CAR the summer dominant NW wind against the dunes promotes accretion at the bars. This is slower at ODX because of the lack of a dune system.

CAR is an extreme case especially elucidating the vulnerability of small rivers with torrential regime. Recently discovered as an area of marginal tourism, it faces a considerable human impact dunnga period of irregular precipitation. Having a small watershed it dries at severa1 places during the summer. To find its way across a large sandy

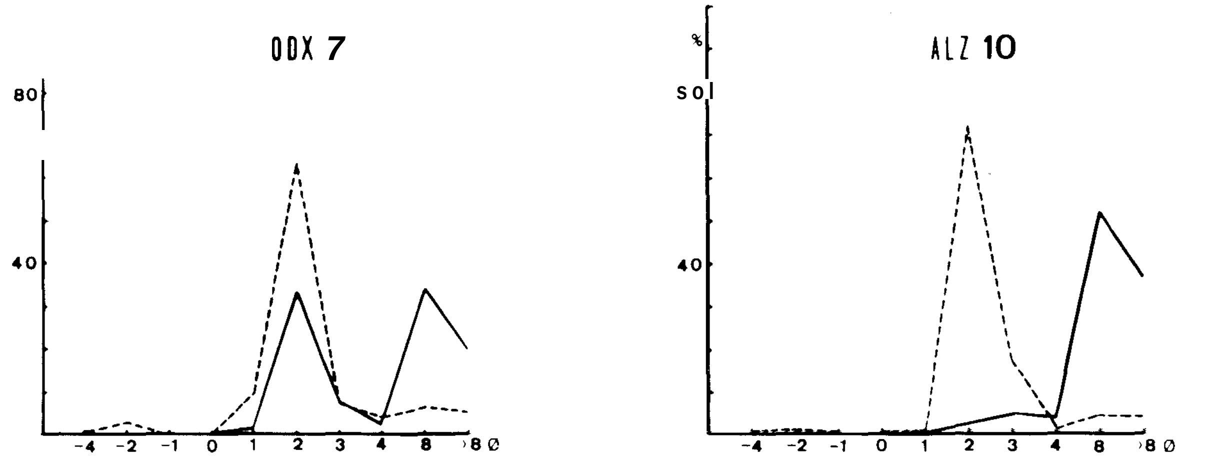


Figure 5.- ODX 7 and ALZ 10: Frequency Curves of grain-size distribution on March 1984 (——) and December 1985 (------)

beach, strong fluvial discharge is needed to remove the accumulated sand and to reach the sea.

On the other hand, human impact on the watershed and at a local level, is responsible for the actual degradated circumstances and prevents its solution. As a consequence the regulatory effect of the river over the sand disappears. The dune is moving over the river bed towards the agricultura1 lands of the valley and the estuary is bccoming progressively (but rapidly) limnetic and less productive.

The sand deposition and storage seems to be a general proccss on the estuaries of the Portuguese occidental coast to the south of Sado river. Mira river, also suffering disturbances in its watershed, is facing a somewhat similar sedimentary evolution (Andrade, 1986).

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RESUMEN

Odeceixe, Aljezur y Carrapateira son pequeños rios que drenan la parte occidental del Sur de Portugal. Sus desembocaduras están frecuentemente semicerradas por barras arenosas originando pequeñas lagunas. La pluviosidad es alta desde noviembre a marzo, siendo julio y agosto meses secos. Como consecuencia de una inercia hidráulica baja, las precipitaciones determinan directamente en la descarga fluvial. Los fenómenos principales observados son la aculación de arena en las desembocaduras de los rios y su progresión aguas arriba. Su origen es fundamentalmente marino proveniendo de las playas arenosas a lo largo de la costa y/o de las dunas.

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