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### Abstract

The beach sediment of the Ebro Delta shows significant temporal grain size changes unrelated with seasonal processes. The evolution of the grain size during the 1988–1991 period shows coarsening and fining variations, with a general coarsening trend which ranges from 2.10 to 1.96 phi (about  $8 \cdot 10^{-3}$  mm/year). This low-magnitude grain size change is considered significant because it is indicated by both mean values from the data set (textural zones) and individualized sampling points. The coarsening trend of the beach sediment in the Ebro Delta is mainly caused by the sedimentary deficit affecting the Ebro coast. The finer sand fractions of the sediment are progressively winnowed from the initial beach deposit without being replaced by new river sediment supplies. Superimposed on the general coarsening trend there exist grain size variations that may be related with processes of a shorter period such as changes in the sediment supplied from the river into the nearshore zone, variations in the wave energy affecting the beach, and man-induced actions, such as beach nourishment. The mean grain size of beach sediment sampled 20 years ago indicates that the coarsening gradient measured during the study period cannot be extrapolated to longer periods of time (decades). This work shows that processes of a different temporal scale but a similar magnitude must be integrated in order to explain the evolution of sediment grain size in deltaic beaches.

### 1. Introduction

The grain size of beach sediment shows spatial (longshore and cross-shore) and temporal changes. The longshore changes are mainly related to variations in the incident wave energy along the beach, the selective sorting of sediment during transport or changes in the amount and size of sediment supplied to the beach (McCave, 1978; Bryant, 1982; McLaren and Bowles, 1985; Stone et al., 1992). The sediment grain size distribution in the cross-shore profile is usually related to the “equilibrium profile” concept, which indicates that a particular grain size tends “to move

across the profile to a position in which it is in equilibrium with the wave and flows acting on that sediment grain” (Horn, 1992). Temporal changes of grain size in beach sediment have received comparatively less attention than longshore and cross-shore changes, probably because temporal variations have a lower magnitude and are more difficult to recognize (Stubblefield et al., 1977; Davis, 1985; Liu and Zarillo, 1989).

Studies of the temporal evolution of beach sediment grain size have focused on seasonal variations in the beach sediment textural parameters related to the seasonal wave climate affecting the beach (Prakash and Prithviraj, 1988; Dubois,

1989; Stone et al., 1992). However, if the seasonal wave climate were the single controlling factor of temporal grain size evolution, the beach sediment would show a steady grain size trend over time. Inter-annual grain size variations in deltaic beaches must be caused by other factors, such as the variations in the amount and texture of sediment supplied to the beach. The sediment can be supplied from rivers, from offshore, from eroded areas of the coast or from anthropogenic beach nourishment. An increase in sediment supply leads to a net deposition of sediment, whereas a decrease produces an erosional trend in the beach and the eroded sediment is transported to accretional areas. An accretional trend in the beach is generally associated with the fining of sediment, whereas an erosional trend produces a coarser sediment (McLaren, 1981; Prakash and Prithviraj, 1988; Dubois, 1989). Thus, besides the seasonal components associated with annual wave climate changes, the temporal evolution of beach sediment grain size over several years can be expected to include longer period oscillations caused by variations in the sediment supply and other random events.

The temporal evolution of the sediment grain size on the Ebro Delta coast was studied during the period 1988–1991. The Ebro Delta shoreline is 50 km long; it is a microtidal, storm-dominated coast that has developed from the sand sediment supplied through the Ebro River (Fig. 1). The mean wave climate affecting the Ebro coast is of low energy ( $H = 1$  m and  $T = 3.5$  s), though during storms wave heights can be up to 6 m (Flos, 1985; Gracia et al., 1989). Strong storms usually occur during the October–February period, whereas for the remaining months they are unusual. The sand sediment extends in the Ebro Delta from the backshore to about 11 m depth. The low amounts of sediment supplied from the Ebro River cause a sediment deficit in the nearshore zone and an erosional trend along the shoreline (Guillén and Palanques, 1992; Guillén, 1992).

The main objectives of this paper are: (1) to study the grain size evolution of beach sediment in an erosion-dominated deltaic coast, (2) to determine the control factors of this evolution, and

(3) to evaluate the possibility of using the temporal changes in beach sediment size as one measure of erosion and accretion processes in the coast.

## 2. Methods

Eight sampling surveys were carried out during the period 1988–1991 on the Ebro Delta coast (June and October 1988, March and July 1989, March and July 1990, March and July 1991). On each survey 31 pre-fixed profiles spaced 1–2 km apart along the Ebro Delta shoreline were sampled, and on each profile a sample was taken of the dune, swash, trough and bar crest (Fig. 1). Profiles located in the Ebro River mouth (P-26 to P-29) are not considered. The total number of samples analyzed in this study was about 1,100. Location of sampling profiles was indicated by permanent poles situated along the beach. In each profile, standard topographic procedures were used in order to determine the exact position of samples. Sediment was collected by dragging on the bottom a plastic bag inserted in an oval metallic frame. The mouth of this frame is

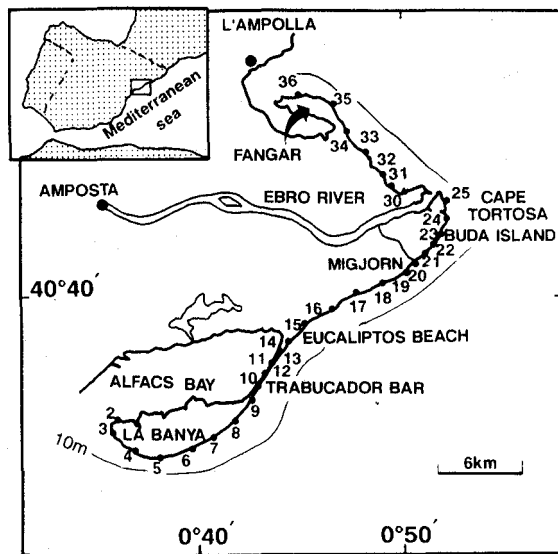


Fig. 1. Study area and locations of sampled profiles along the Ebro Delta coast.

10 cm wide and the vertical penetration in the sediment is about 2–4 cm. The weight of samples ranges from 100 to 200 g. Each sample can be considered the result of all the processes acting in the beach during a certain period of time before the sampling. It is assumed that samples are

representative of daily or weekly sedimentary processes, and that the effect of processes operating on scales of hours immediately before the sampling have a subordinate influence in the grain size. This assumption is achieved because the sampling was carried out during non-storm

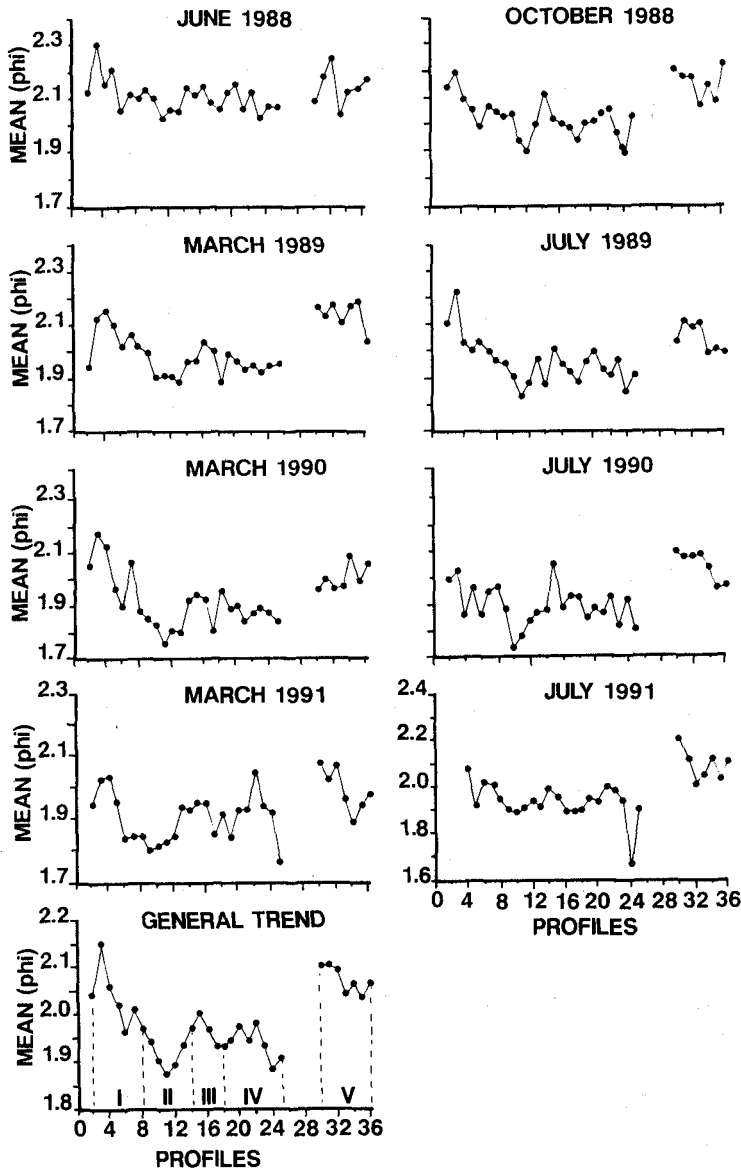


Fig. 2. Longshore variation in the sediment grain size in each sampling survey and the resulting general trend, indicating the differentiated textural zones (I = Fangar, II = Trabucador Bar, III = Eucaliptos Beach, IV = Buda Island, V = Fangar) (locations of profiles in Fig. 1).

conditions, the volume of sediment sampled is relatively high and at least 4 samples are used in the characterization of the sediment grain size at each point of the profile.

The grain size distribution of sediment was determined by settling tube, according to the techniques explained in Giró and Maldonado (1985), and textural parameters were computed

by the moments method (Friedman, 1967). Furthermore, 21 beach samples taken in 1970 along the Ebro Delta beachface were re-analyzed in order to obtain a medium-term approach to the grain size evolution.

The changes in sediment grain size were found to be of low magnitude along beaches of the Ebro Delta during the study period. The magnitude of

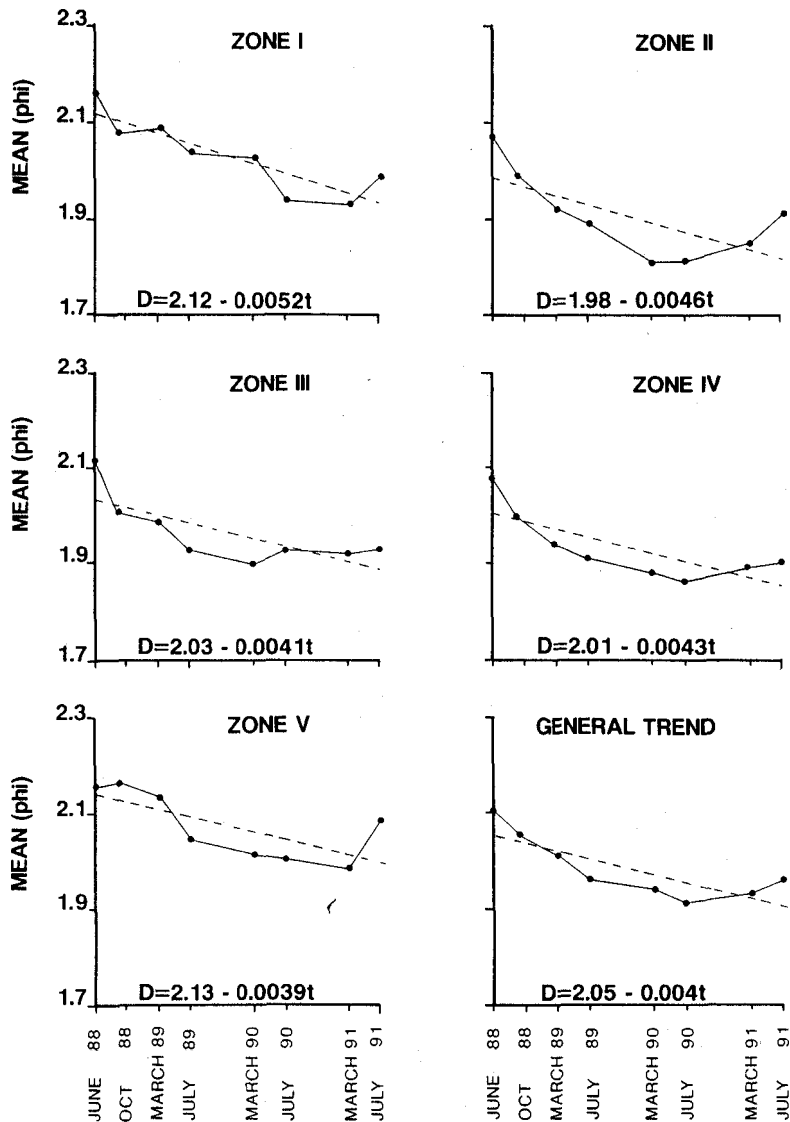


Fig. 3. Temporal evolution from June 1988 to July 1991 of the beachface sediment grain size in the Ebro Delta, showing the resulting coarsening gradient in the five textural zones and the general gradient ( $D$  = grain diameter in phi units,  $t$  = time in months).

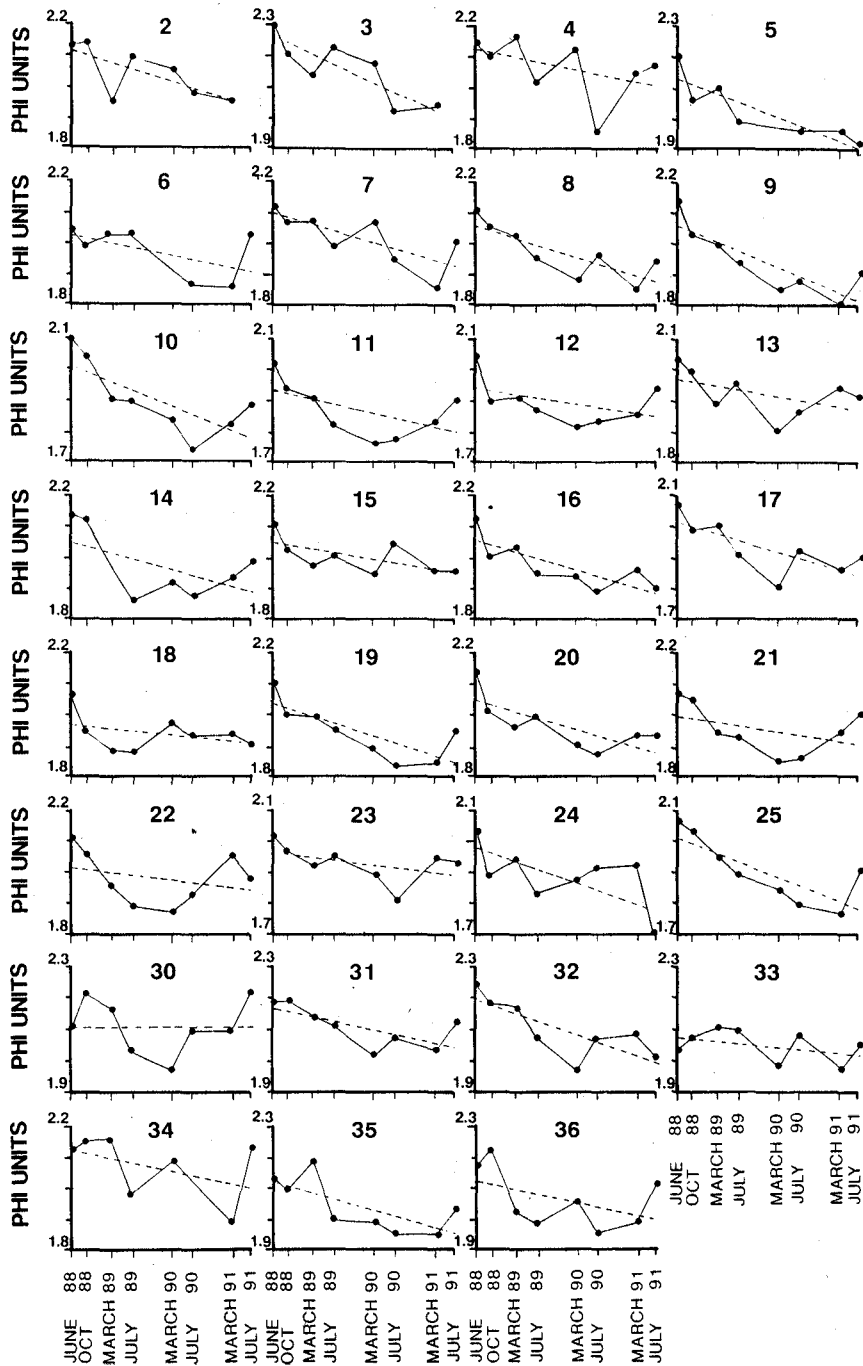


Fig. 4. Temporal evolution from June 1988 to July 1991 of the beachface sediment grain size in the sampling profiles of the Ebro Delta, showing the coarsening trend in all of them (locations of profiles in Fig. 1).

the grain size variation in individual samples was similar to the expected variability caused by sampling methods and grain size determination techniques. Therefore, highly reliable data are obtained by using the mean values of samples. It was necessary to consider the mean value of groups of samples (profiles or surveys) for the interpretation of the results. The average mean-size of the four samples taken at each profile ( $M$ , the "mean sediment-size profile") is used here as the characteristic sediment size at each site of the beach. The longshore distribution of sediment was computed as the mean value of all the samples corresponding to the textural zone and to the survey.

### 3. Sediment-size changes

The spatial distribution of the sediment grain size along the Ebro Delta beaches maintained the same general patterns and trends during the 1988–1991 survey period (Fig. 2): (1) the finer sediment is located in the La Banya, Eucaliptos Beach and Fangar zones, and (2) the coarser sediment is found in the Trabucador Bar and Buda Island. The alongshore grain size sediment distribution allows us to define five textural zones along the Ebro coast: La Banya (zone I), Trabucador Bar (zone II), Eucaliptos Beach (zone III), Buda Island (zone IV) and Fangar (zone V) (Fig. 2). Longshore gradients of the mean grain size range from  $1 \cdot 10^{-3}$  to  $10 \cdot 10^{-3}$  mm/km, being

Table 2

Temporal evolution of mean grain size of the sediment in dune, swash, trough and bar zones (values in phi units)

	Dune	Swash	Trough	Bar
June 1988	2.07	2.02	2.14	2.17
October 1988	2.07	2.00	2.09	2.01
March 1989	1.93	1.99	2.12	2.03
July 1989	1.93	1.91	2.06	1.96
March 1990	1.89	1.88	2.01	1.95
July 1990	1.82	1.83	1.99	1.97
March 1991	1.86	1.93	2.02	1.97
July 1991	1.88	1.86	2.03	2.07

minimum from the river mouth towards the Fangar and maximum from Cape Tortosa towards the south.

The mean sediment grain size was 1.99 phi during this period of time. However, the temporal variation of the grain size shows a general coarsening trend from a mean size of 2.10 phi in June 1988 to 1.96 phi in July 1991. The coarsening evolution is accompanied by a better sorting (from 0.44 to 0.34 phi) and a less negative skewness (from  $-2.31$  to  $-0.41$ ) of the beach sediment (Table 1). This temporal coarsening trend

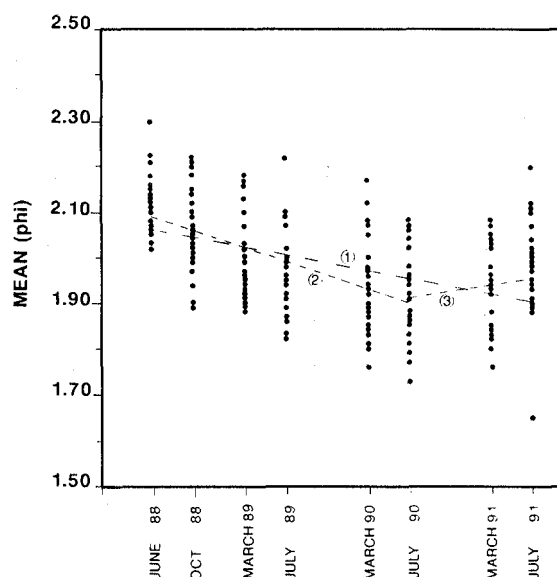


Fig. 5. Temporal evolution from June 1988 to July 1991 of the beachface sediment grain size in all the profiles showing the spatial variability of the sediment and the resulting temporal trends (1:  $r^2 = 0.23$ ; 2:  $r^2 = 0.36$ ; 3:  $r^2 = 0.03$ )

Table 1

Changes in textural parameters of beach sediment on the Ebro Delta coast

	Mean	Deviation	Skewness
June 1988	2.10	0.44	$-2.31$
October 1988	2.05	0.31	$-2.55$
March 1989	2.01	0.37	$-1.78$
July 1989	1.96	0.34	$-1.61$
March 1990	1.94	0.38	$-1.00$
July 1990	1.91	0.34	$-0.68$
March 1991	1.93	0.34	$-0.66$
July 1991	1.96	0.34	$-0.41$

Mean values from all the samples taken in each survey (mean and standard deviation in phi units).

of sediment grain size is observed in the five textural zones, although some different textural gradients may occur (Fig. 3). The Banya (zone I) shows a strong coarsening gradient, except between March and July 1991, when the sediment size was considerably finer. The Trabucador, Eucaliptos Beach and Buda Island textural zones (zones II, III and IV) show a progressive coarsen-

ing trend from June 1988 to March 1990 and a fining trend between July 1990 and 1991. The coarsening trend has a low gradient in the Fangar (zone V), where the sediment is finer between March and July 1991 (Fig. 3). These gradients represent a rate of grain size change that ranges from  $7 \cdot 10^{-3}$  mm/year in the Fangar to  $11 \cdot 10^{-3}$  mm/year in the Banya. The coarsening pattern

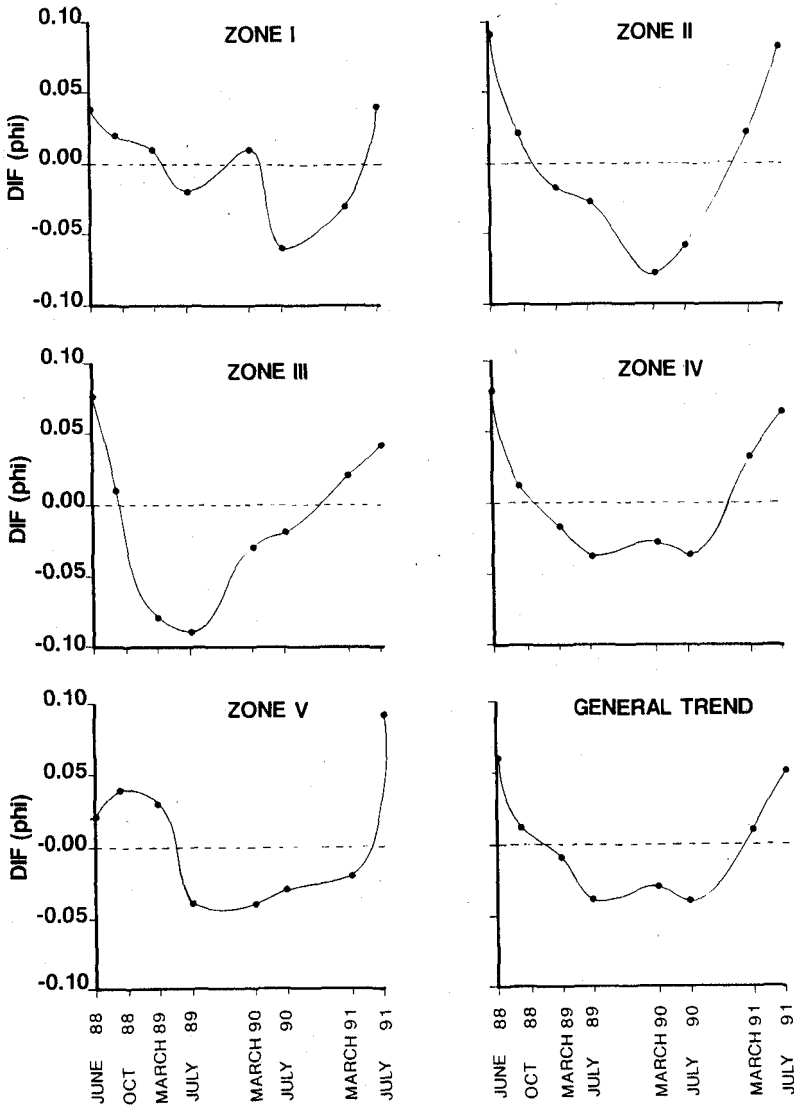


Fig. 6. Temporal evolution from June 1988 to July 1991 of the sediment grain size difference (*Dif*) between the sediment size of the profile and the estimated size from the grain size variation gradient. Although the general coarsening trend is suppressed, seasonal oscillations are unobserved (location textural zones in Fig. 2).



can also be observed in the temporal grain size evolution of the individualized sampling profiles (Fig. 4) and in each of the different morphological areas of these profiles that were sampled (Table 2): dune, swash, trough and bar. The general coarsening trend of beach sediment grain size along the Ebro Delta beaches during the 1988–1991 period estimated from the mean value of each survey can be obtained from the resulting linear relationship

$$D = 2.05 - 0.004t$$

where  $D$  is the mean diameter of the sediment in phi units and  $t$  is the time in months. This relation implies that the sediment shows a coarsening gradient of about  $8.5 \cdot 10^{-3}$  mm/year during the study period. The coefficient of determination ( $r^2$ ) of this relation is 0.65. Better correlation is obtained if two phases are differentiated in the general coarsening trend of sediment: (1) from June 1988 to July 1990 ( $r^2 = 0.95$ ), when the sediment is progressively coarser ( $17 \cdot 10^{-3}$  mm/year), and (2) from July 1990 to July 1991 ( $r^2 = 0.94$ ), when the sediment is gradually finer ( $-7 \cdot 10^{-3}$  mm/year) (Fig. 3). These two phases of sediment evolution can also be identified in most of the individual sampling profiles (Fig. 4).

The coefficients of determination have also been calculated for the individualized profile data in order to determine the significance level of the general gradient (Fig. 5). The value of  $r^2$  is 0.23 when the general coarsening trend is considered. This value increases if the June 1988–July 1990 period is considered separately ( $r^2 = 0.36$ ), but during the July 1990–July 1991 period the statistical significance of the fining gradient is null ( $r^2 = 0.03$ ). These moderate correlations between the general trend and individualized profiles are due to the fact that the spatial variability of the sediment grain size along the Ebro coast is more important than the temporal one (Fig. 5). The correlation with the general coarsening trend improves considerably if the textural zones are analyzed independently and the spatial variability of the sediment is reduced ( $r^2 = 0.32$  to  $0.39$ , except in the Fangar zone where  $r^2 = 0.23$ ).

These data clearly show the existence of a general coarsening trend in the Ebro coast during

the study period and indicates that the detected grain size changes have periods longer than 1 year (Fig. 3). In order to check the existence of seasonal or shorter-term variations in the beach sediment grain size, the sediment size difference ( $Dif$ ) between the mean sediment size of the profile ( $M$ ) and the sediment size ( $D$ ) estimated from the equation of the temporal sediment size variation in each textural zone ( $Dif = D - M$ ) was evaluated (Fig. 6). Thus, the general coarsening gradient of the sediment is suppressed and a residual grain size value is obtained: a  $Dif$  positive value implies a deviation to finer sediment and a  $Dif$  negative value indicates a deviation to coarser sediment. Fig. 6 shows the sediment size deviation of the five textural zones and the mean grain size. Deviation to finer sediment, or a negative value of  $Dif$ , occurred during the June–October 1988 and July 1991 surveys and deviation to coarser sediment (positive  $Dif$ ) occurred the remainder of the time (Fig. 6). The analysis of the residual grain size values shows more clearly the existence of a coarsening and a fining trend during the study period, with some disturbances in textural zones I and V (Fig. 6). However, a seasonal change in the grain size of sediment was not observed.

## 4. Discussion

On the Ebro Delta coast the sediment grain size is affected by changes of a different temporal scale: (1) a general medium-term coarsening trend related to processes with a temporal scale higher than the study period (3 years), and (2) modifications superimposed on the general coarsening trend caused by processes of a lower temporal scale.

### 4.1. General medium-term coarsening trend

The textural variations observed in the sediment of the Ebro Delta (coarser, better sorted and more positively skewed) are characteristic of lag deposits (McLaren and Bowles, 1985), which indicates that the present beach sediment is a lag deposit of the pre-existing beach sediment. The

coarsening trend of the beach sediment occurred during a period of time when erosional processes had dominated on the coast (Fig. 7). The erosion has been produced by the shortage of river sediment and the winnowing of the finer sediment fractions on the beachface. The sediment discharge of the river has been drastically reduced by the trapping effect of the dams constructed during the last few decades (Palanques et al., 1990; Guillén and Palanques, 1992). The amount of sand sediment supplied from the Ebro River to the Ebro Delta coast during the 1988–1991 period was lower than  $1 \cdot 10^5$  tons/year (Guillén, 1992). The shortage of sand sediment caused a negative sediment budget in the external coast of the delta and a dominant erosional trend in the shoreline (Guillén, 1992; Jiménez and Sánchez-Arcilla, 1993), which favoured the selective winnowing of the finer fractions.

The relationship observed between the coarsening evolution of the grain size and the negative sediment budget in the external nearshore zone of the Ebro Delta suggests that the gradient of the grain size change may have some proportionality with the intensity of the accretional or erosive processes in the beach. In this situation, the stronger coarsening gradients would occur during maximum erosion periods and fining or weaker coarsening gradients during accretion or equilibrium periods. However, the use of the temporal grain size variation rates as a measure of erosion

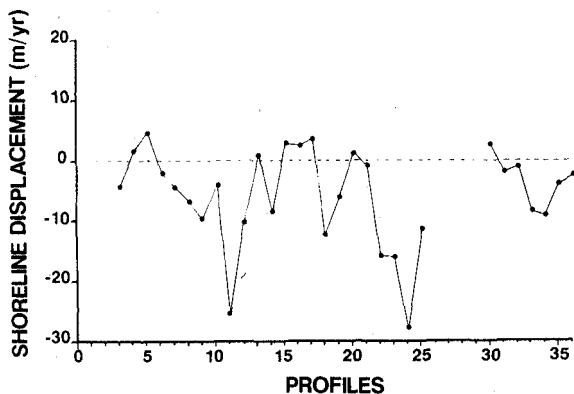


Fig. 7. Shoreline displacement trends along the Ebro Delta coast during the study period. The river mouth is located between profiles 26 and 30 (location profiles in Fig. 1).

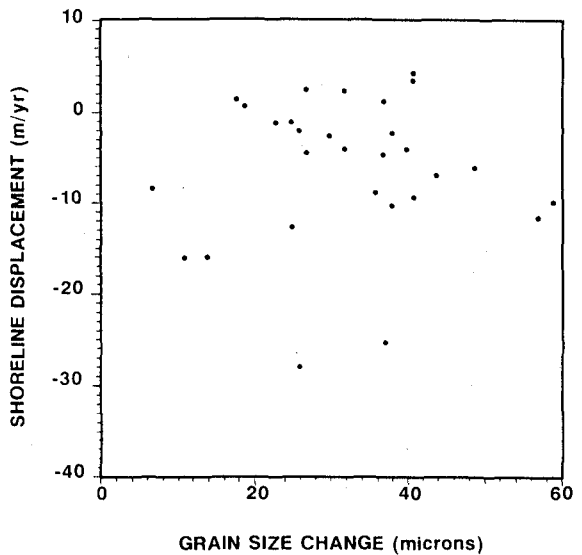


Fig. 8. Comparison between the shoreline displacement and the sediment grain size variation at each profile from June 1988 to March 1991. The plot shows that the erosion and accretion processes are not proportional to the grain size variation when individual profiles are considered.

or accretion processes in the coast is limited to a general qualitative trend. The comparison between the sediment grain size variation at each profile during the 1988–1991 period and the shoreline displacement rate in the profile during the same period of time shows a bad correlation (Fig. 8). The coarsening of the beach sediment was of 28, 28, 32, 32 and  $11 \cdot 10^{-3}$  mm from textural zones I to V, respectively, during the 1988–1991 survey period (Fig. 4). These temporal grain size variations show that the coarsening trend of sediment in the Ebro Delta beaches is a general process affecting the entire delta coast: the coarsening trend occurs both in erosional (i.e. Trabucador Bar) and in accretional (i.e. La Banya) zones (Fig. 7). On sandy deltaic coasts such as the Ebro Delta where the longshore transport of sediment is dominant (Jiménez and Sánchez-Arcilla, 1993), the gradual winnowing of finer grain sizes in erosional zones produces the coarsening trend of sediment in these areas, but it also produces a coarsening trend in the sediment grain size of accretional zones located downdrift, because the sediment supplied from erosion zones

is progressively coarser (Guillén and Jiménez, 1995).

The erosional trend along the Ebro Delta coast has occurred during the last decades (Maldonado, 1972; Callís et al., 1988). However, a medium-term coarsening rate of the beachface sediment has not been estimated. If the coarsening rate had been a constant, the rate estimated by the 1988–1991 survey period ( $8 \cdot 10^{-3}$  mm/year) could be extrapolated and the grain size of the beach sediment two decades ago would be 3.5 phi. However, some samples taken in 1970 along the Ebro beachface indicate that the mean grain size sediment was about 2.15 phi. Although the number of 1970 samples is comparatively low, it is obvious that the coarsening rate during the last two decades estimated from the 1970 samples (about  $1 \cdot 10^{-3}$  mm/year) is lower than the gradient determined for the 1988–1991 period (Fig. 9). This change in the coarsening gradient can be partially explained by the different intensity of the erosive processes affecting the coast during the two periods considered. Mean erosion rates were about 7 m/year during the 1988/1991 period and 4 m/year during the 1970–1988 period (Callís et al., 1988; Guillén, 1992).

#### 4.2. Shorter-term grain size modifications

The shorter-term grain size variations can mainly be associated with shorter-term variations in the intensity of erosive or accretional processes affecting the coast. Three main factors can modify the intensity of these processes: (1) changes in the amount of the river sand supply, (2) variations in the wave energy reaching the beach, and (3)

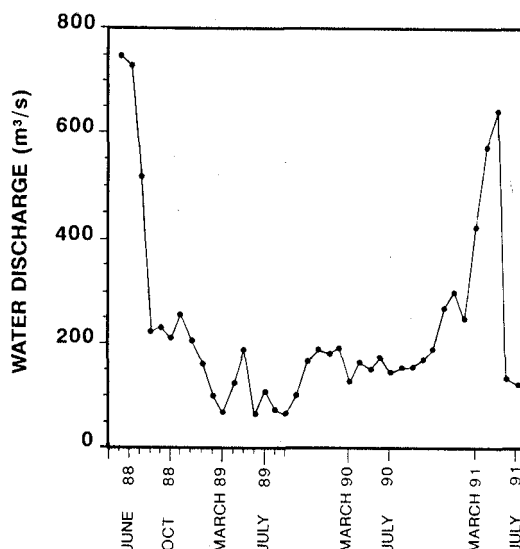


Fig. 10. Monthly data of water discharge of the Ebro River between May 1988 and July 1991 showing the low water discharges during most of the study period.

man-induced action on the beach. Changes in the grain size of the sand sediment supplied to the coast are not expected because the only sediment source (the Ebro River) supplies homogeneous sand (Guillén and Jiménez, 1995).

(1) Short-term changes in the amount of sand sediment supplied from the Ebro River are related to water discharge variations (Fig. 10). Sand transport in the lower Ebro River only occurs when the water discharge is higher than  $400 \text{ m}^3/\text{s}$  (Guillén et al., 1992). Thus, during the study period the Ebro River could only supply significant amounts of sand in June 1988, and in the period April to May 1991. These periods of high water discharge correspond with periods of comparatively finer sediment on the beachface (Fig. 6): the mixing of the new sand river inputs and the former (strongly winnowed) coarser sediment results in a finer sediment on the beachface. The higher water discharge of the Ebro River in April–May 1991 allowed sand sediment supplied from the river to reach the coast. As a consequence, finer sediments were detected in July 1991 in the Fangar area and in some profiles of the Buda Island located close to the river mouth (Figs. 3 and 5).

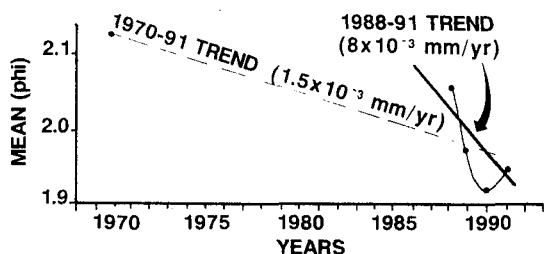


Fig. 9. Measured sediment grain size in 1970 and during the 1988–1991 period, and resulting coarsening trend.

(2) The wave climate affecting the Ebro Delta shows seasonal variations characteristic of intermediate latitude areas (Jiménez, 1995) (Fig. 11). The summer corresponds with the low-energy period, and during the autumn and the winter high-energy conditions occur. However, the observed grain size changes do not show any relation to this seasonal regime. The wave-induced grain size changes in the Ebro Delta are probably more related to the action of sporadic storm waves than to mean wave conditions. The relation between storm waves and grain size changes during the study is not completely clear because the period between the sampling campaigns is too long. The major storms occurred in the Ebro Delta coast during the study period are shown in Table 3. The significant wave height is only higher than 4 m in October 1990 and February 1991. The comparison between the sediment grain size before and after these storms (July 1990 and March 1991) shows that the resulting deposit along the coast displayed a mean grain size similar to, or finer than, the pre-existing one (Fig. 3). In the Eucaliptos Beach and Fangar the sediment size was scarcely modified by the storms. A fining trend of the sediment grain size was observed in the Trabucador Bar and Buda Island, whereas in La Banya the sediment was still coarser after the storms. In spite of these variable responses, it is

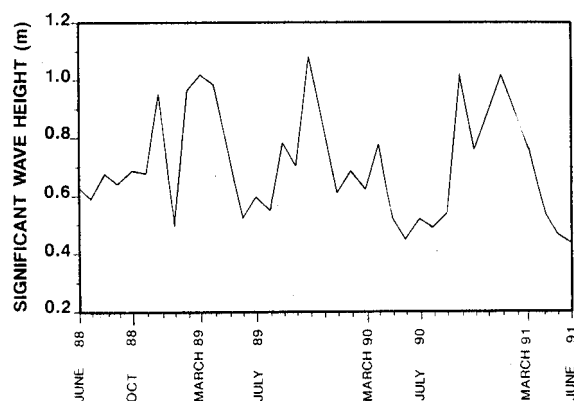


Fig. 11. Monthly data of significant wave height in the Ebro Delta during the study period showing the seasonal components of the wave climate (data from Jiménez, 1994).

Table 3

Major storms occurred in the Ebro Delta area during the study period

Date	Hs (m)
01-09-1988	3.0
03-12-1988	3.0
25-02-1989	3.6
13-04-1989	3.6
08-10-1990	4.5
02-02-1991	4.3
19-02-1991	3.4
24-03-1991	3.0

Hs = significant wave height (data from Jiménez, 1994).

evident that the general coarsening trend of sediment was interrupted by these storms. Although it is usually considered that storm waves produce a coarsening of the beach sediment, examples of sediment fining caused by severe storms have also been reported (Winkelmolen and Veenstra, 1980). The sediment fining related to the strongest storm waves is caused by the remobilization of all the fractions of previous sediment during the storm. The new sediment would reflect the characteristics of the previously underlying sedimentary body (Dubois, 1989), or it is a poorly sorted deposit composed of all the grain size fractions available on the coast (Winkelmolen and Veenstra, 1980).

(3) Human action related to beach nourishment also alters the general grain size trend. An artificial dune was constructed on the area of the Trabucador Bar affected by overwashing during the storm in October 1990 (profile 11). The dune was built up with sand slightly finer than the beach sediment mined from the Alfacs Bay during the November 1990–February 1991 period. The fining of the beach sediment was detected in March 1991 in profiles 10 and 11, where the dune was constructed, and finer sediments were also detected towards the south in July 1991 (profiles 6, 7, 8 and 9) (Fig. 4). The distribution of these finer sediments was caused by the progressive erosion of the dune and the transport of sediment towards the southwest by littoral drift.

The 1988–1991 grain size evolution shows an initial coarsening phase and a second fining phase (Fig. 5). The coarsening phase (June 1988–July

1990) can be explained by the selective winnowing of the finer fractions of the beach sediment. The selective winnowing produces a better sorting and a less negative skewness in the sediment. The coarsening of sediment has been significant from La Banya to Buda Island since October 1988. In Fangar the sediment became coarser later, in July 1989 (Fig. 3). The action of the three factors analyzed was different along the textural zones. The Fangar zone was especially sensitive to the sediment inputs from the Ebro River because most of them accumulate in this zone. The dune construction affected first the Trabucador Bar and later the Banya zones, whereas storm action had an irregular impact along the coast. These factors produced a sediment fining and their action was mainly concentrated at the end of the study period (Fig. 6).

## 5. Summary and conclusions

The temporal evolution of the beachface sediment grain size is difficult to investigate because temporal variations have a lower magnitude than spatial grain size changes. Observations about the temporal evolution can also be influenced by the noise produced from sampling techniques. One way to reduce these problems is to work with a high number of samples and to consider textural zones with a homogeneous sand content. The main factors causing temporal grain size variations on deltaic beaches are the sediment discharge and the wave regime. These factors have different temporal scales of action, from a single storm or a river flood to a medium-term (decades) erosional trend in the shoreline. The observed textural changes result from the combined action of all the processes.

The beach sediment of the Ebro Delta is affected by temporal grain size changes unrelated to seasonal variation. This sediment was progressively coarser, better sorted and less negatively skewed during the study period (1988–1991). The coarsening in the beach sediment is mainly caused by the negative sediment budget in the nearshore zone and the resulting erosion processes on the beach. The erosional processes produce a pro-

gressive winnowing of the finer fractions and a coarsening trend of the beachface sediment.

The coarsening gradient of this period ( $8 \cdot 10^{-3}$  mm/year) cannot be extrapolated to a medium-term temporal scale because it is higher than that which occurred during recent decades. Erosional processes and the resulting coarsening trend were especially intense during the 1988–1991 period because of the low amounts of sand supplied from the Ebro River. The sediment coarsening is general, affecting both erosional and accretional areas due to the longshore transport pattern of the Ebro Delta. It can be observed that two different shorter-term oscillations (coarsening and fining periods) are superimposed on the general coarsening trend. These shorter-term oscillations may be related to changes in the amount of sediment supplied from the Ebro River, modifications induced by storms and anthropogenic actions. All these processes cause grain size variations of a similar magnitude and their identification is complex.

The study of beach sediments from the Ebro Delta shows that the temporal evolution of the sediment size on deltaic beaches may be controlled by processes not related to a seasonal temporal scale. Furthermore, the inter-annual evolution of the beach sediment grain size can be used to understand the dominant controlling processes of the sediment dynamics on the coast.

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