Sandbar morphology on the Epiguette spit, Mediterranean Sea, France

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Abstract

We have analysed sandbar morphology of the accretional Espiguette spit, using 10 meters depth bathymetric profiles for the time period 1985-1996. These profiles provide the morphological parameters of three sandbars. Our results show that the evolution of the bars according to distance from the shoreline might be linked with wave action. Moreover, the evolution of the bars according to time evidences that the shoreface general movement is offshore. In this preliminary study, the lack of data does not permit predictions of the shoreline and bar movement in relation with wave action.

Introduction

Sandbar morphologies and processes have been thoroughly investigated in the last few years. Some of these studies, based on wave tank and in-situ current measurement, show the importance of the breaking wave, incident wave stresses and the infra-gravity wave on these patterns (Holman and Bowen, 1982; Osborne and Greenwood, 1992; Hsu and Wang, 1998; Lee *et al*., 1999). The behaviour of multiple bars system in the nearshore zone has also been investigated by bathymetric profile. Generally, bar morphology and displacement are in relation with wave breaking and climate (Larson and Krauss, 1993; Ruessink and Kroon, 1994 and Pruszak et al. 1997). In the laboratory as in the field, the case studies appear as straight beach in sedimentary equilibrium budget (sometimes in negative budget), and with long steep waves.

In the Mediterranean Sea, bar morphology is a relatively new coastal processes approach. Barusseau et al. (1994), by using bathymetric profile analysis of a beach barrier of Thau Lagoon (France), have shown that the sand bar morphology changes in relation with storm wave. Similarly, precise descriptions of bar behaviour and morphology have been given using bathymetric profiles from the Ebro delta (Spain) (Guillen and Palanques, 1993). Offshore or on-shore bar migrations are very rapid during storm periods and bathymetric profile modifications may reach a new equilibrium profile in calm condition.

The purpose of this work is to present a first bar analysis on a microtidal sea (North Mediterranean) in an accretional area (sandy spit) based on 10 years bathymetric survey.

1. Site presentation

Espiguette spit is a sandy beach on the west part of the Rhone delta, which displays an accretional sedimentation type since several decades (figure 1). The maximum shoreline movement deduced from aerial photographs (1944-1987), ranges between +3 and +30 m/year (Sabatier, 1997). The sand coming from the littoral of Petite Camargue on the east side of the spit induces a east to west dominant longshore transport trend (Blanc, 1977). Since 1969, following the construction of the big touristic harbour of *Port Camargue*, this accretional area increases. Despite groin protection, the medium term evolution of the harbour is to silt up. Thus, a good knowledge of nearshore bathymetric change and bar morphology is necessary before any management decision.

The wave climate is recorded by the Sete buoy (figure 1), which provides data for the period 1988-1992 (STNMTE, 1993). Modal significant wave height (Hsig) is 0.5 m with a period (Tsig) of 4 s. Storm waves are much stronger with Hsig ranging from 3.3 m to 4.6 m, with annual and decennial recurrence. In relation with the wind force and duration, the storm dominant directions are NW and SE. Tide amplitude, which is of +/- 30 cm, can be considered as negligible in our study.

The nearshore zone is characterised by the presence of 2 or 3 bars. Beaches of the surf zone are (very) dissipative, according to the classification of Wright and Short (1984) and the parameter of Guza and Inman (1975).

The mean grain size (D_{50}) of the beachface is 0.215-0.263 mm. It decreases in the seaward direction, with values of 0.196-0.275 mm on the first bar and 0.153-0.216 mm on the second one. At –10 m depth, the mean grain size is comprised between 0.88-0.120 mm and at about –15 m depth the limit of sand/mud is reached.

2. Method

2.1. Bathymetric data

The nearshore profile data used in this study were collected by the *Service Maritime de la Navigation du Languedoc-Roussillon* (SMNLR) along the profile lines PR31 and PR32 (Fig. 1 and Tab. 1). Elevation data are referenced on the basis of the French Geodesic Level (IGN 69). Each bathymetric measurement was performed with an echosounder system which accuracy has been estimated at +/- 5 cm. According to weather conditions, the precision may be enhanced up to +/- 20 cm. The equidistance between each point has been chosen at 10 m, in order to provide a clear description of the bathymetry. The X, Y positions (Lambert III South) were calculated using a laser theodolite with the uncertainty of 5 m. Five repetitive profiles have been measured for PR31 and PR32 lines, during 1985 to 1996. However, some of them are not complete (table 1) and cannot be used to calculate bar morphology.

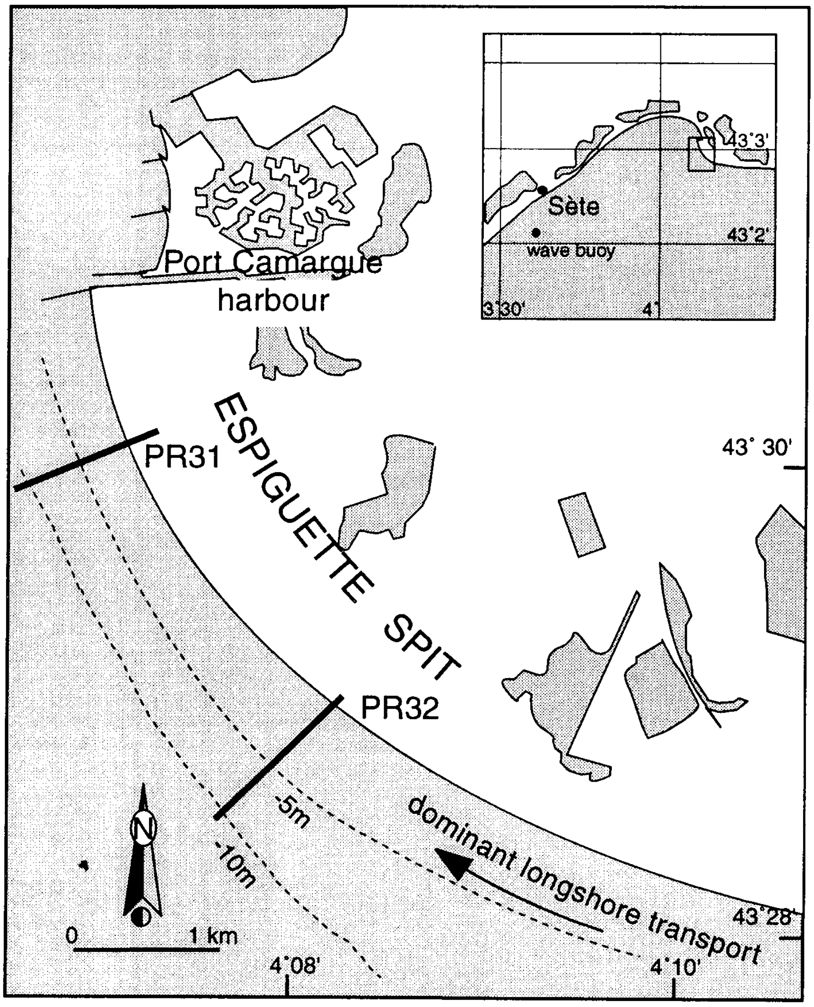


figure 1 Location of the study area

2.2. Calculation of the bar parameters and bathymetric profiles

The calculation of six bar parameters has been performed using BMAP software (Fig. 2).

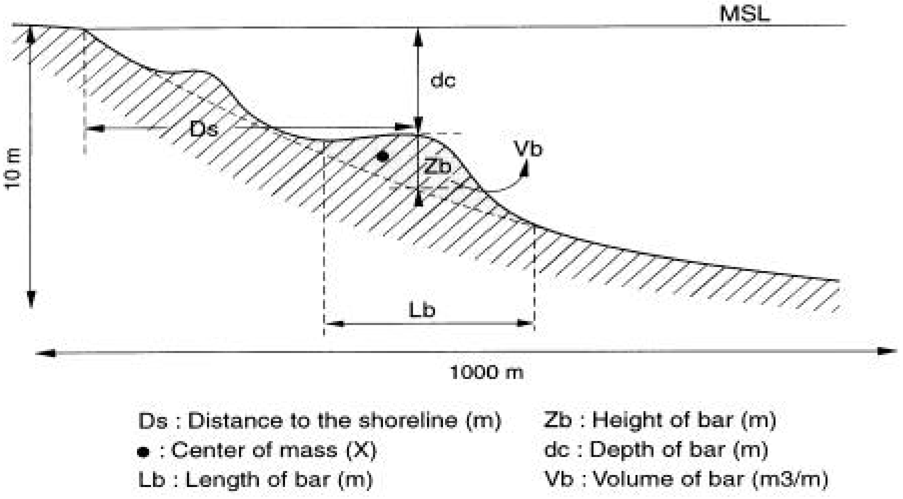


figure 2 bar parameters definition

The presence of the bars had been determined visually with the software. This empirical, and so arbitrary method, has been preferred to the determination of the bar by using a beach equilibrium reference, in that it does not give enough reliable results (Larson and Kraus, 1993; Ruessink and Kroon, 1994 and Pruszak et al. 1997).

For a complete definition of the bar parameters, we have also calculated 1) the shoreline evolution (in m/year), 2) the speed and direction of X movement (Sb, in m/year), which positive (negative) values indicate on-shore (off-shore) migration of the bars, and 3) the steepness of the bars (St, i.e the ratio Zb/Lb).

The PR31 and PR32 bathymetric profiles are plotted in figures 3 and 4. On both profiles, the first bars are at a mean distance of the shoreline of about 80 m, the second at about 260 m and the third at about 900 m.

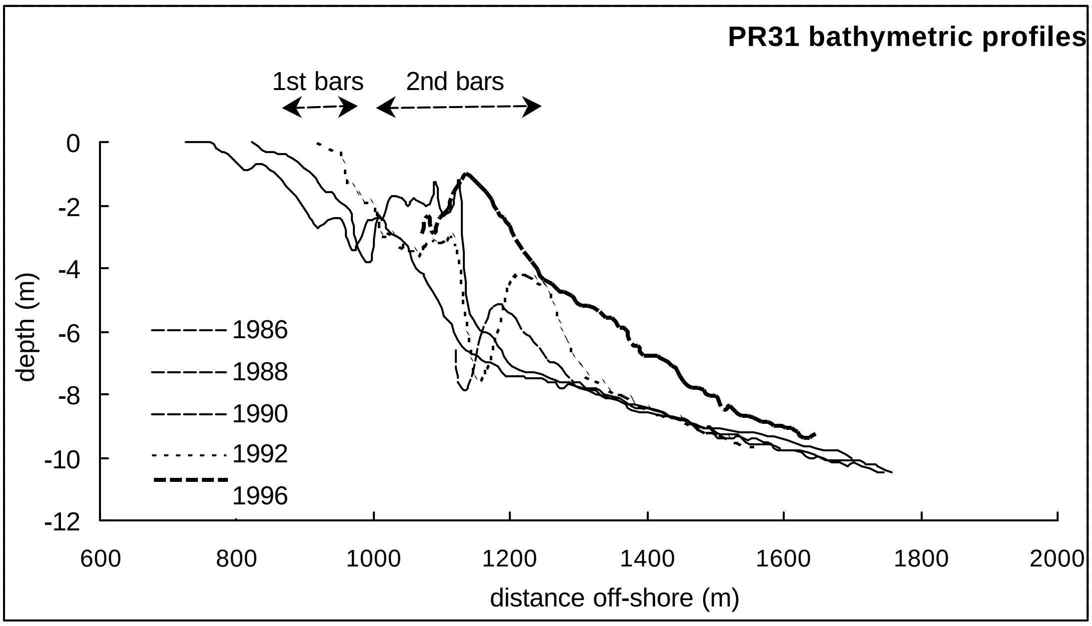


figure 3 bathymetric profiles on PR31 line

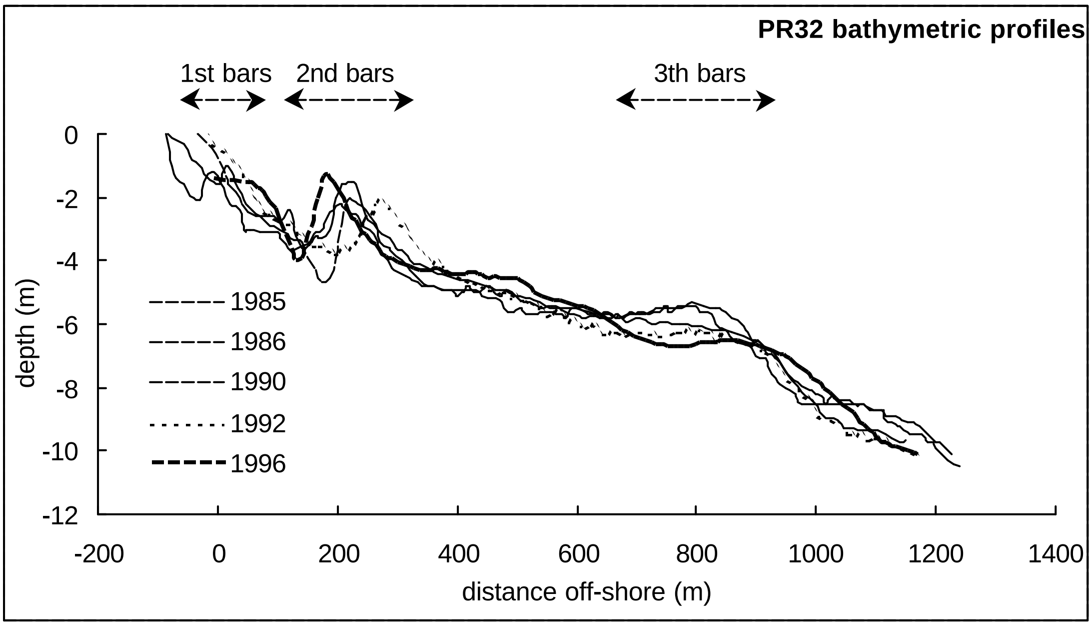


figure 4 bathymetric profiles on PR32 line

3. Results

3.1. Bar morphology and distance from the shoreline.

On figure 5, we have plotted the bar parameters as a function of the distance from the shoreline. For the three bars, depth, length and volume increase with the distance from the shoreline. The height and speed movements are the greatest for the second bar. Bar steepness decreases as distance from the shoreline increases. This is in agreement with previous studies by Guillen and Palanques (1993), Larson and Kraus (1993), and Pruszak et al. (1997), who interpreted such pattern as a result of wave action. The negative speed movement of the three bars indicates an offshore displacement of the shoreface.

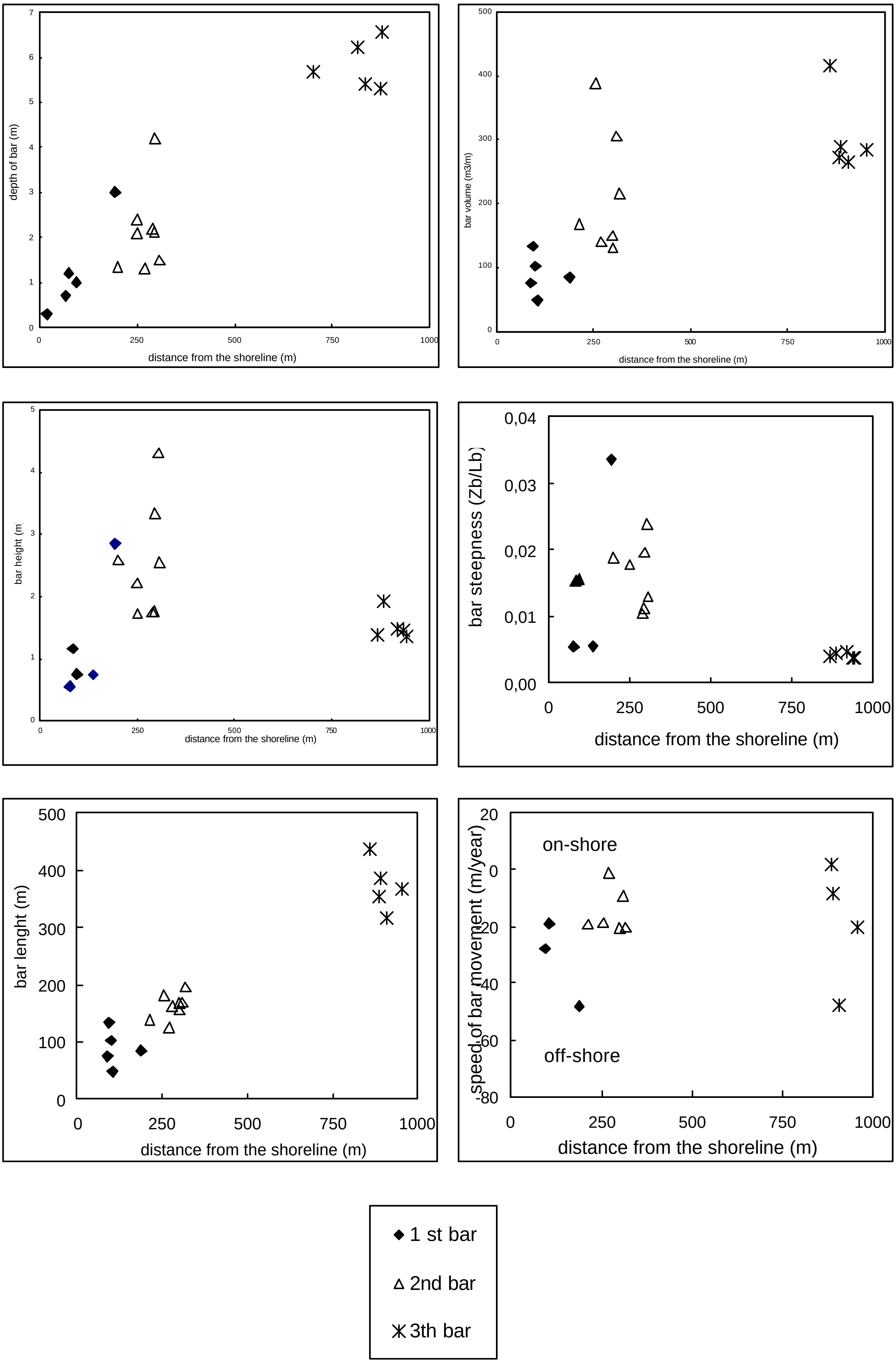
3.2. Relations within bar parameters

Relations within bar parameters are investigated using a bivaried analysis. A good correlation between bar length and depth ($R^2 = 0.60$) and between steepness and height ($R^2 = 0.50$) have been obtained. Low correlation between volume and height ($R^2 = 0.37$) and between length and volume ($R^2 = 0.33$) have been obtained. So, we have focussed on the relationships between the shoreline evolution (Tab. 2) and the speed of bar movement (Tab. 3) for bars 2 and 3. We do not present the results of the first bars because of a lack of data.

For each bar, there is a good correlation ($R^2 = 0.72$ and $R^2 = 0.35$) between shoreline evolution and bar volume (Tab. 2). These patterns may be explain by the fact that sand moves cross-shore from the shoreline to the bars, and/or because an intense long-shore sediment transport is localised along the entire nearshore zone. This second interpretation seems more realistic in the context of the spit sedimentation thanks to the longshore sediment transport.

No significant correlation exists between speed of bar movement and bars parameters except for the third bars, which present high correlation factor of 0.66 and 0.52 for the steepness (St) and length (Lb). It is most likely due to the fact that bathymetric survey, which varies from 1 to 4 years, mixes short and medium term bar evolution.

figure 5 bar parameters and distance from the shoreline



3.3. Bar morphology and time evolution

On figure 6, we have plotted the bar parameters as a function of time for the period 1985-1996. These scatter plots evidence that depth, height, volume and steepness of the first and second bars are characterised by a large interannual variability but no time. However, no significant trend in the evolution of the bar morphology is evidenced. Through time, length, volume, height of the third bars decreases while depth increases and steepness remains constant. Such pattern may indicate the degeneration of the third bar. The evolution of speed and direction of the three bars indicates that the shoreface of the spit is going seaward although the general morphology remains the same.

3.4. Bar movements and prediction of the shoreline displacement

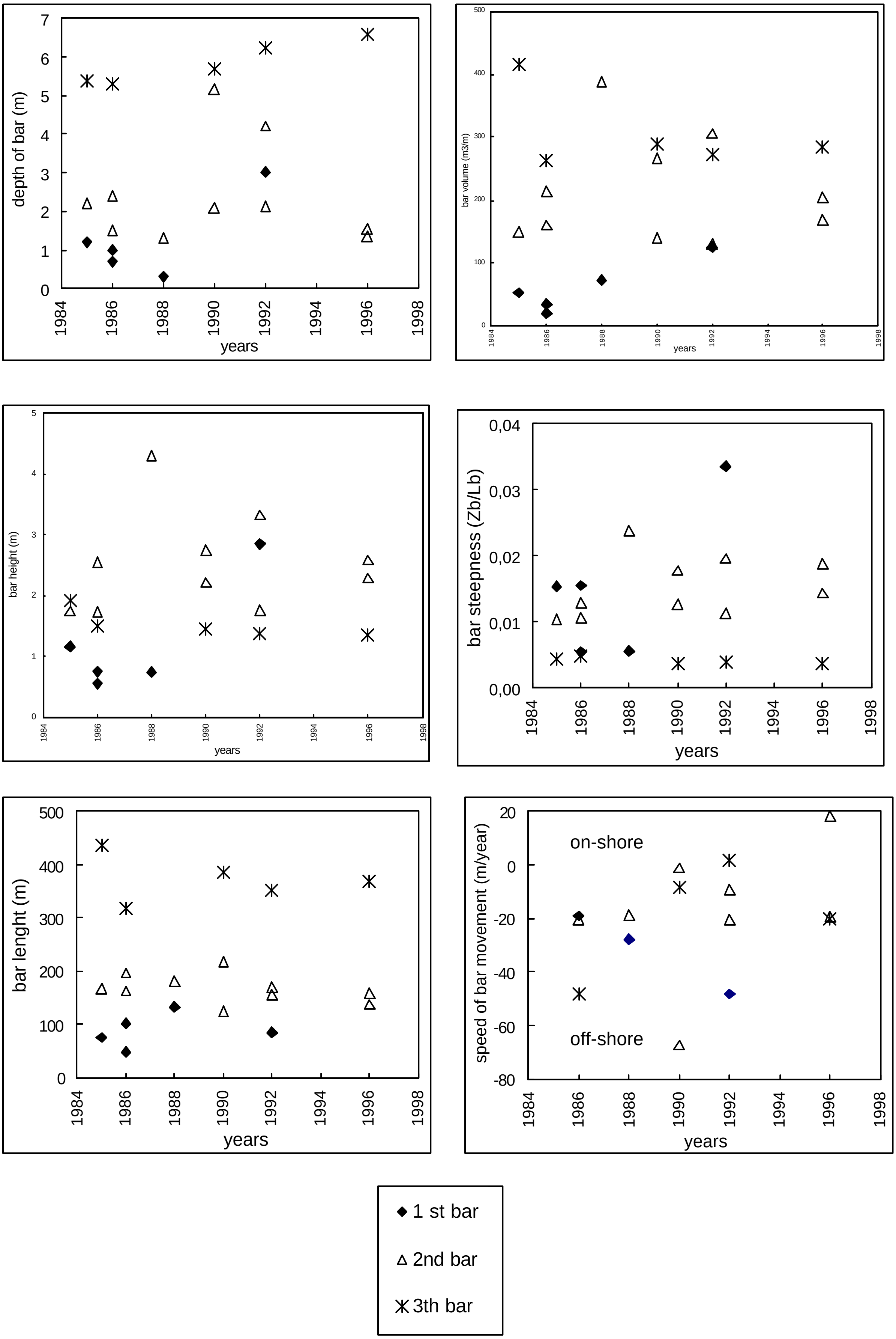
We have tested several empirical equations, based on bathymetric survey and bar changes, to predict the shoreline movement with wave climate and grain size, as suggested by Sunamura and Horikawa (1974), Sunamura (1988), Kraus et al. (1991). The tests show that such predictive models are not appropriate for the study of the curved Espiguette accretional spit for which we possess only data scattered over 1 to 4 years. Indeed, these models are better adapted for straight beaches in equilibrium budget with episodic event.

Conclusion

There are two or three bars on the nearshore zone of Espiguette spit. Their mobility is proportional to the distance from the shoreline and therefore with the depth. Despite a high interannual variability, bar morphological parameters (depth, height, volume, length, speed and steeples) are the same with time for the first and second bars. The third bars seem to decrease. The general movement of bars is off-shore. This movement is in relation to shoreline positive evolution, and the better correlation is given with bar volume. The role of the longshore sediment transport is suspected in this relationship.

The actual predictive models of shoreline and bar migration are not adapted for sedimentation area as Espiguet spit. The understanding and the predicative evolution of sandbars will be possible by more long bathymetric profile survey compilation and analysis.

figure 6 bar parameters and time evolution



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				Bars		
Profile	Date	Maximum elevation (m)	Maximum depth (m)	1st	2nd	3th
PR31	16/06/86	0,80	-10,00	+	+	0
PR31	17/11/88	0,50	-10,50	+	+	0
PR31	13/07/90	-6,61	-10,46	-	+	0
PR31	16/11/92	0,00	-9,62	+	+	0
PR31	26/03/96	-3,40	-9,80	-	+	0
PR32	31/01/85	0,00	-21,00	+	+	+
PR32	19/06/86	1,40	-10,10	+	+	+
PR32	13/07/90	0,63	-9,64	0	+	+
PR32	16/11/92	0,00	-10,18	-	+	+
PR32	26/03/96	0,00	-10,10	-	+	+

Table 1: Bathymetric profile references, as given by the Service Maritime de la Navigation du Languedoc-Roussillon (SMNLR). Existing data are marked with +, no existing data are marked with 0 and - indicates the absence of bar at a given date.

	dc	Zb	Vb	Lb	Sb	St
2nd bar	0,13	0,69	0,72	0,05	0,05	0,08
3rd bar	0,04	0,04	0,35	0,49	0,31	0,17

Table 2: Correlation factors (R²) obtained between the bar parameters and shoreline movement for the second and third bars.

	dc	Zb	Vb	Lb	St
2nd bar	0,7	0,01	0,04	0,45	0,05
3rd bar	0,32	0,38	0,24	0,52	0,66

Table 3: Correlation factors (R²) obtained between some bar parameters and the speed of bar movement, for the second and third bars.