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ORIGINAL ARTICLE

An approximation to short-term evolution and sediment transport pathways along the littoral of Cadiz Bay (SW Spain)

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Abstract This work presents the results of a beach-monitoring program carried out in the Bay of Cadiz (SW Spain), which consists of urban, natural and nourished beaches. In the present study, 24 topographic profiles have been monthly monitored during the 1996–1998 period, in order to draw the morphodynamic behavior of this coast and the general characterization of short-term coastal trends. This way, total volumetric budgets have been calculated for each beach profile in order to group beaches in different erosive/accreting sectors. Studied beaches recorded both erosion and accretion: the greatest accretionary trends have been observed at Aguadulce, La Costilla and Rota beaches, with values ranging from 30 to 70 m^3/m. The largest erosion episodes have been recorded in the southernmost end of Valdelagrana spit, with values over 50 m^3/m, and in Rota and Vistahermosa, after nourishment works. Main erosion and accretion pathways have been related to the existence of natural and human structures, which blocked the longshore drift suggesting the existence of littoral cells.

Keywords Beach profiling · Sediment transport · Littoral cell · Erosion management · Cádiz

Introduction

During the last decades, the necessity of protecting human structures from coastal erosion and the growing demand for recreational beach uses have raised interest in coastal morphodynamic processes. The knowledge of coastal processes and evolution is the basis for determining erosion/accretion areas, sediment transport pathways, littoral cell distribution, as well as elaborating land use and vulnerability plans, and properly designing coastal defense structures (Berlanga and Ruiz 2002; Cooper and Pethick 2005; Domínguez et al. 2005).

Such kinds of studies have important management implications, particularly where sediment transport boundaries are adjacent to administrative boundaries. Furthermore, an identification of sediment cells and its budgets will become increasingly important in assessing the regional and local impacts of sea-level rise and in appraising the implications of possible mitigation strategies, including managed retreat and widespread artificial beach nourishment (Bray et al. 1995; Pilkey and Dixon 1996).

The establishment of coastal trends is sometimes very difficult as shoreline position fluctuates in a variety of time scales because of seasonal and storm-induced changes (Crowell et al. 1993). Consequently, coastal changes are surveyed using a variety of methods and data sets according to the studied time spans (Smith and Zarillo 1990; Dolan et al. 1991; Jiménez and Sánchez-Arcilla 1993).

Short-term shoreline dynamics are usually studied at small spatial scales and time spans of less than 10 years (Crowell et al. 1993). Despite recent development of airborne laser surveys (LIDAR), the main techniques used in short-term coastal studies are beach profiling and 3D surveying, repeated at regular intervals, in order to measure daily to annual variations in shoreline position and beach volume (Morton 1991; Short 1999).

This work presents the results of a beach monitoring program carried out in SW Spain during the 1996–1998

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period, with a monthly periodicity. The obtained results allowed the characterization of the seasonal changes and morphodynamic behavior of this coast and enabled to address the evolutionary trends as well as the distribution of littoral cells recorded during the investigated period.

Study area

The studied coast includes about 22 km of quartz sandy beaches, both natural and nourished, located between Chipiona and Puerto Real villages (SW Spain, Fig. 1).

The Chipiona-Punta Candor sector belongs to an open, NNW–SSE oriented coast (Fig. 1), rectilinear and apparently homogeneous. In this sector, beaches are backed by cliffs and, secondarily, by dune ridges. Cliff retreat and the scarcity of sediments in this sector give rise to the outcropping of well-developed rocky shore platforms in the nearshore and, at places, foreshore zones. The coast between Punta Candor and Punta Santa Catalina is NW–SE oriented and includes both open and pocket beaches (Vistahermosa being the most important), limited by human and natural structures and backed by cliffs (Fig. 1). The southernmost part of the study area is constituted by Valdelagrana spit barrier, a 7-km long, N–S oriented, sandy body backed by salt marshes.

The irregular distribution of rocky shore platforms gives rise to small headlands like Punta Camarón, Punta Candor and Punta Santa Catalina (Fig. 1). Concerning human structures, the most important ones are the harbors of Rota, Puerto Sherry (East of Punta Santa Catalina) and the NATO Naval Base (Fig. 1); besides, three short groins exist at Regla, La Costilla and in the northern limit of Vistahermosa beach, and two jetties channelize the Guadalete river mouth (Fig. 1). Contributions from the main rivers in SW Spain have been blocked in dams constructed from the 1960s to the present, while minor streams reaching the coast present very small catchments and do not supply significant amounts of sediment. Furthermore, the rocky shore platform between Chipiona and Rota prevents the arrival of sediments from the nearshore, and sediments deriving from cliff retreat are very fine and easily winnowed by waves and currents (Muñoz et al. 1999; Anfuso et al. 2003).

Concerning tidal range, the studied zone can be classified as a mesotidal coast with spring and neap tidal ranges of 3.2, 1.1 m, respectively. Prevailing winds blow from the Atlantic Ocean, mainly from WNW, with a 12.8% of annual frequency and 19.3 m/s of mean annual velocity, and from the inland, especially ESE, with 19.6% of annual frequency and 27.8 m/s of mean annual velocity (Muñoz and Sánchez 1994).

Wave height is usually lower than 1 m during fair weather conditions and about 2 m during storms (Reyes et al. 1999), which classifies the area as a low-energy coast (Benavente et al. 2000). According to Rodríguez et al. (2003), storm generation in Cadiz Gulf is related to the NAO (North Atlantic Oscillation), which represents the difference in atmospheric pressures at sea level between the Azores Islands and Iceland. In Southern Europe, positive values of the NAO index are associated with low cyclonic activity and vice versa (Rodwell et al. 1999).

Methods

Beach morphological changes were studied through a topographic monitoring program carried out with monthly periodicity from March 1996 to May 1998. During the studied period, 24 shore-normal transepts distributed along the study area were surveyed, resulting in a total amount of 472 profiles. An electronic theodolite was used for measuring the topographic profiles, from the dry beach to a depth equivalent to the mean spring low water level. Beach width, beach face slope and erosion/accretion volumes of sand per unit of beach length were then calculated. The high (i.e. monthly) sampling density provided a reliable measure of beach short-term variability (Smith and Zarillo 1990). Following Jiménez and Sánchez-Arcilla (1993), widely-used least-squares linear regression has been chosen to analyze profile evolution. This method employs the entire sample of surveyed volumes and, due to the similar time span between the surveys, there is no data clustering. Furthermore, an advantage of linear regression with respect to the end point rate method is that all the data points are used, thus reducing the impact of potential outliers (e.g. impact of important storms or accretion periods). In the linear regression analysis, the slope of the fitted line can be considered as an estimate of the rate of volumetric change during the investigated period, while the value of the correlation coefficient shows the "quality" of the linear relationship between volume changes and time, which essentially depends on beach variability.

In order to have an approximation to coastal evolution trend during the studied period, the total volumetric budget has been calculated for each profile by considering the initial and final beach volumes calculated on the regression line (Anfuso and Gracia 2005). In a further step, the results obtained were grouped on several erosion/accretion classes for the studied period; here variations between ± 5 m^3/m were not considered, as they correspond to profiles which did not show a clear trend.

As for beach sediment characteristics, surface samples were gathered in the foreshore and dry sieved in laboratory through seven sieves with 1 phi intervals, obtaining the statistical parameters described by Folk and Ward (1957). Carbonate concentrations were also analyzed.

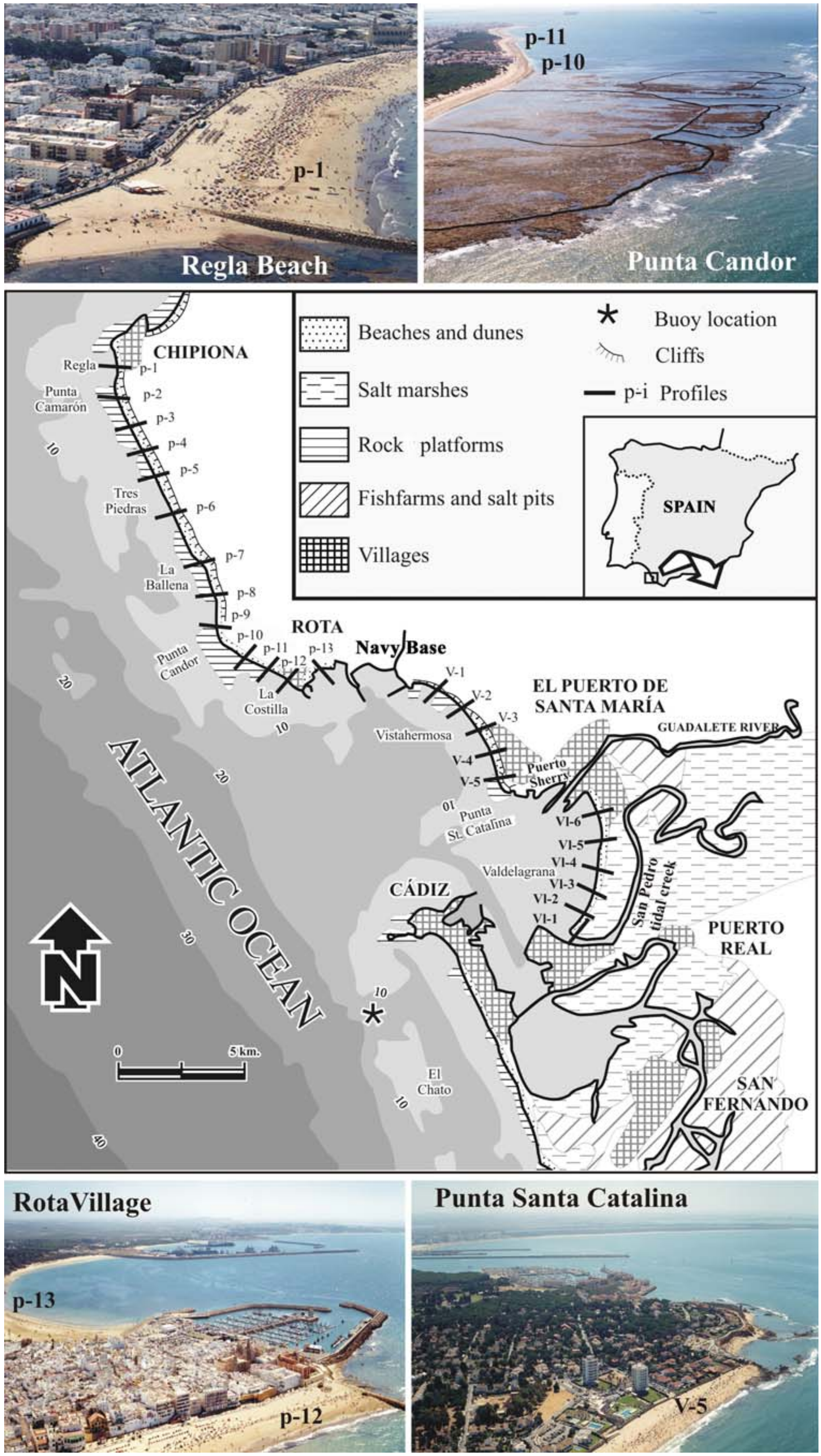

Fig. 1 Location map. Aerial photographs, from North to South, of the beaches of Regla and Rota, both limited by small groins, and Punta Candor and Punta Santa Catalina promontories. Location of beach profiles is also indicated. Images obtained from the "Dirección General de Costas", Spanish Ministry of Environment

Wave height and period during the 1996–1998 interval were obtained from the offshore "Cádiz" waverider buoy (Fig. 1), which belongs to the EMOD network (Spanish Wave Climate Service, Ministry of Environment). Additional observations on wave approaching directions were carried out several times during the studied period. Lastly, littoral cells have been identified according to volumetric changes and cell limits defined by morphological features and discontinuities in sediment transport directions (Carter 1988; Bray et al. 1995).

Results

Wave climate

Wave height presented important seasonal variations (Fig. 2a): higher values characterized winter months (November–January) and springtime (April–May), while lower values prevailed during summer and February–March. These data match regional wave conditions prevailing in the western Cadiz Gulf, which were compiled by Rodríguez et al. (2003): high-energy events concentrate in December–January, although isolated storms can also take place in springtime. Wave steepness did not show a clear seasonal behavior (Fig. 2b), as recorded period variations were quite small.

As for wave approaching direction, sea and swell waves approached mainly from the third and fourth quadrants (Fig. 3, data recorded from June 1997 to June 1998). Low waves approached the coast from the West, while most powerful waves approached from the SW and WSW. By one side, taking the previous observations in mind, for the open sectors of the studied littoral, i.e. Chipiona-Rota sector and Vistahermosa beach, coastline orientation determines dominant longshore drift, associated with waves from the West, to flow south-eastward. An opposite transport, northwestward directed, can be recorded at some points, associated with most important storms (Fig. 3). By the other side, Valdelagrana spit is located in the inner bay, this making more complex the wave refraction/diffraction patterns. Approaching waves record important refraction processes because the low bathymetry of the nearshore in front of Valdelagrana spit and, probably, minor diffraction at Cadiz point and at the Guadalete jetties. As a result, waves approach the shoreline with low or no angles, depending on the original approaching direction in open sea, and in general resulting in a low-associated longshore drift.

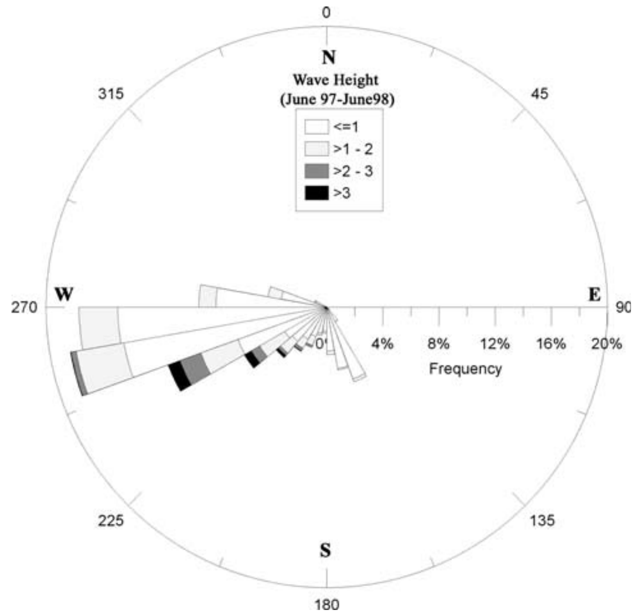

Fig. 3 Distribution of waves approach directions for the period June 1997–June 1998, obtained from the offshore buoy "Cádiz" (EMOD)

Morphological characteristics and behavior

In the Chipiona-Rota sector, beach profile morphology was visually close to the "intermediate" and "dissipative" states of the Wright and Short (1984) classification (Fig. 4a, b), and to the "barred intermediate" and "barred

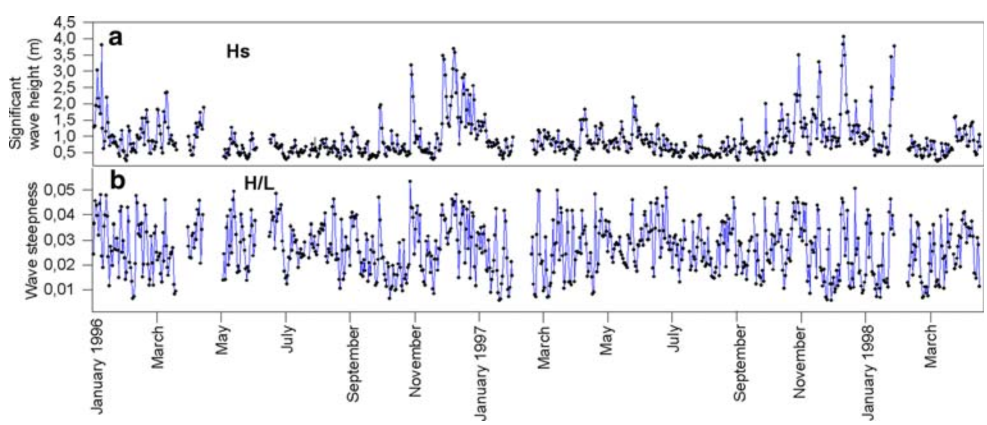

Fig. 2 Wave height and wave steepness distribution from January 1996 to March 1998. Data obtained from the offshore buoy "Cádiz" (EMOD network, Wave Climate Service, Spanish Ministry of Environment), located south of the study zone, over a water depth of about 20 m (see Fig. 1 for location)

dissipative" beach states of the Masselink and Short (1993) classification (Anfuso et al. 2006).

Vistahermosa beach presented dissipative profiles, especially in the northernmost part (namely V1 and V2), their state being related to the lack of sediment supply (Benavente et al. 2000). In the southern part, intermediate beach slopes prevailed, with important morphological seasonal changes (Fig. 4c). According to the Masselink and Short (1993) classification, most profiles in Vistahermosa belonged to the "barred" and "non-barred" dissipative states.

In Valdelagrana spit, very smooth profiles were recorded, especially in the southernmost area (Fig. 4d). Northern profiles were closer to the intermediate states, with intertidal bars appearing during spring and summer. Almost all the beach profiles in Valdelagrana spit belonged to "the barred" and "non-barred" dissipative states of the Masselink and Short (1993) classification, the southernmost end of the spit showing "ultradissipative" states.

Concerning beach morphodynamic behavior, cross-shore morphological changes were generally quite evident in the Chipiona-Rota sector and Vistahermosa beach, with Valdelagrana spit presenting less important cross-shore variability. The reason for this is that most transepts from Chipiona-Rota sector and Vistahermosa beach showed important monthly and seasonal volumetric and morphological changes (Figs. 4, 5) because of beach pivoting processes [terminology according to Thom and Hall (1991) and Nordstrom and Jackson (1992)]. A smooth, sediment-starved, dissipative beach gradient was associated with storm conditions; a well-developed, sediment-rich, intermediate profile with berm was associated with fair weather conditions. On the contrary, transepts surveyed at Valdelagrana spit, and also at few places along the Chipiona-Rota sector and at the northernmost part of Vistahermosa, recorded small morphological and volumetric variations, the modalities of change being close to the parallel retreat [Hughes and Cowell (1987); Nordstrom and Jackson (1992); Shih and Komar (1994)].

Dealing with granulometric characteristics, most beaches were composed of fine-to-medium quartz sands, with fine and very fine sediments being observed at Valdelagrana beach. Seasonal sediment size variability was generally very small (about 0.06 mm), with coarser sediments observed after storm conditions. Low percentages of carbonates were recorded, essentially related to shell fragments.

Beach volumetric variations and coastal compartmentalization

Volumetric changes (m^3/m) along the studied littoral were calculated by considering the differences in sediment

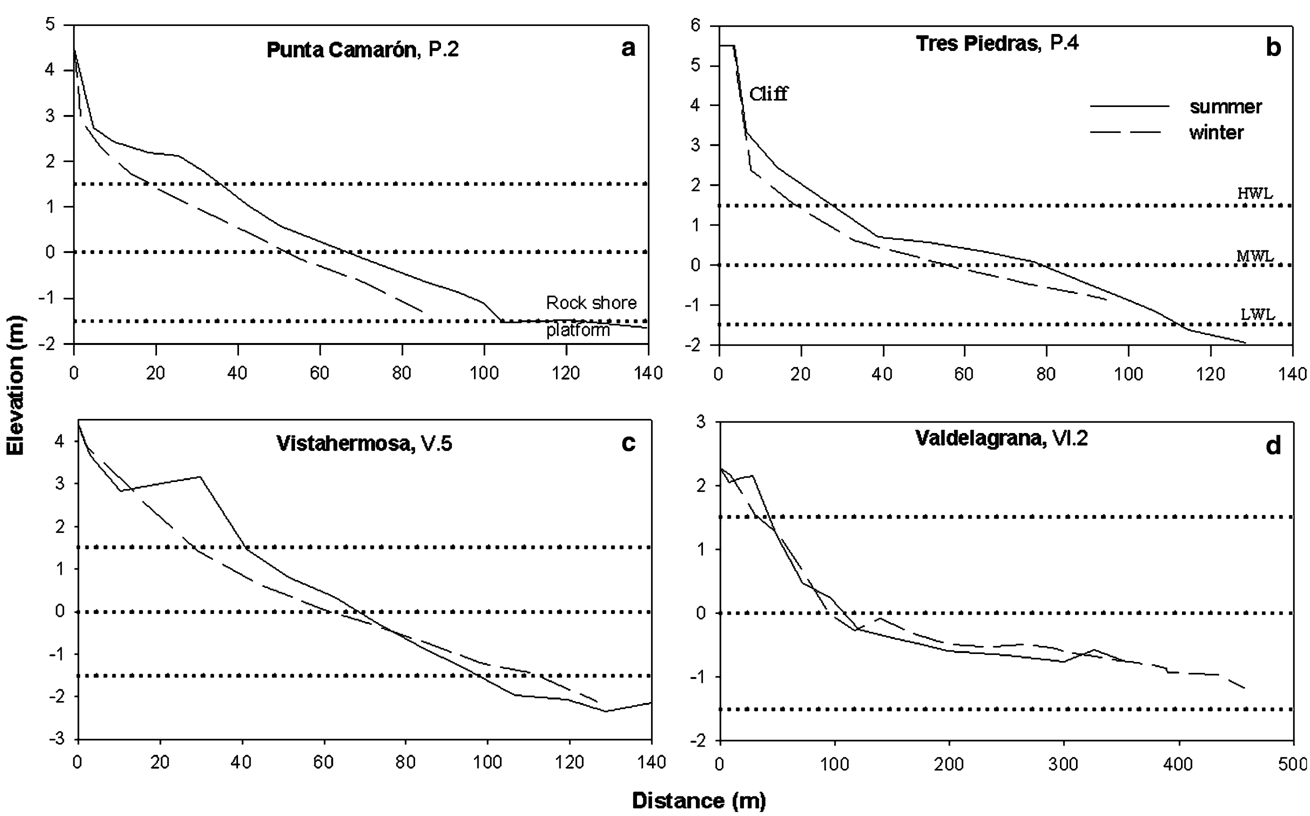

Fig. 4 Summer and winter beach profiles at Punta Camarón, Tres Piedras, Vistahermosa and Valdelagrana beaches

volume recorded at each profile between two consecutive field surveys. Figure 5 shows examples of evolution of beach transepts during the monitoring period. Alongshore homogeneous variations (erosion–accretion trends), as well as opposite behavior between adjacent transepts or groups of them, have been identified. The former was related to the seasonal variability of the studied beaches: accretion was usually recorded during summer months (from June to September) and, secondarily, in February and March (Fig. 5). Erosion started in October and continued during November, December and January, the last 2 months being the ones with maximum erosion rates. Less important sediment loss was observed in April and May (Fig. 5).

The latter behavior was recorded several times, and was related to the prevalence of longshore over cross-shore transport. Longshore transport interacts with natural and human coastal structures, and the opposite trends between adjacent profiles suggest the existence of morphological cells in the sense defined by Carter (1988).

According to wave observations, volumetric variations recorded in October 1997 were related to waves approaching from the SW and reflected a northward transport (Anfuso and Gracia 2005). In fact, in Chipiona-Rota sector, erosion was observed at profile P12 and deposition at P11 (Fig. 5d, e), where the rocky shore platform worked as a submerged groin (Fig. 1). Also, erosion was recorded in P2 and deposition in P1 (Fig. 5a, b), where longshore drift was blocked by a groin (Fig. 1). In May 1998, after a long-lasting situation of waves approaching from the NW, a southward transport prevailed: erosion was observed at profiles P1 and P11, with related accretion areas, respectively, in P2 and P12, and also at V5 and Vl 2. Important accumulative conditions observed in September 1996 at transepts P12 and V1 (Fig. 5e, f) were linked to the artificial nourishment of La Costilla and Vistahermosa beaches, with the pouring of 200,000 and 134,000 m^3 of sand, respectively.

The total volumetric budget for the 1996/98 period was calculated for each transept by considering the initial and final volumes on the regression lines of Fig. 5. As previously observed, all data points are used in the linear regression, thus reducing the influence of possible anomalous values. The correlation coefficients for all the studied beaches (Table 1) recorded different values because affected by the degree of volumetric seasonal variability of each studied beach and the impact of single storms or unusual accretion periods. This way, extremely low correlation coefficients were observed at profiles like P1, due to the great accretion recorded in April and October 1997, P2, where strong erosion was recorded in December 1996, or V5, because of the great seasonal variability of this beach profile. For the nourished beaches of La Costilla (P12) and Vistahermosa (V1; Fig. 5e, f), regression lines were obtained for the period September 1996–May 1998, hence not considering the data previous to the nourishment works. It is interesting to point out that the behavior of these nourished profiles is better described by an exponential decay relationship according to Benavente et al. (2004). In fact, nourished beaches usually record important initial erosion and then they tend to achieve a minimum equilibrium volume. Nevertheless, in order to use a single method for the whole study area, in this paper linear regression was used for the aforementioned beaches too.

The slope of the regression line estimates the volumetric rate of change during the surveyed period, the "b" values in Fig. 5 expressing m^3/m of erosion/accretion per month. The higher the slope of the fitted line, the clearer is the profile trend. This way, P12 and Vl 2 presented high values of "b", e.g. clear tendencies, but low R-squared values because of seasonal variability and great erosion and accretion episodes.

In a further step, volumetric results have been classified into different intervals of erosion/accretion rates (Fig. 6). In spite of the occurrence of some erosive episodes, most profiles in the Chipiona-Rota sector experienced accretion or remained stable (Fig. 6), while Vistahermosa beach and Valdelagrana recorded a prevalence of erosion processes.

In detail, in the Chipiona-Rota sector (Fig. 6) the greatest accretion trends were observed at Aguadulce (P6), La Costilla (P11) and Rota (P13). Concerning Vistahermosa and Valdelagrana beaches, most important accretions were recorded at V5 and Vl 6. Important erosive trends were observed at La Castile (P12) and Vistahermosa (V1) after the aforementioned nourishment works, and in the southern end of Valdelagrana spit, with a sediment loss of about 66 m^3/m.

Discussion

Many geomorphologists have underlain the importance of a budgetary approach to study coastal systems (Carter 1988; Bray and Hooke 1995; Short 1999). This process involves the study of coastal changes and the identification, in a qualitative or quantitative term, of sediment inputs, transport pathways and sediment outputs. The complex interaction between environmental parameters (mainly wave characteristics and approaching directions) and coastal morphology (essentially the location of natural and human structures which constitute littoral cell limits) controls the distribution of erosion and accretion areas along the littoral, as previously observed by several authors (Domínguez et al. 1992; McLean and Woodroffe 1994; Bray et al. 1995; Masselink and Pattiaratchi 2001; Cooper and Pethick 2005). It is important to stress out that, in the studied littoral, coastal configuration does not amplify tidal

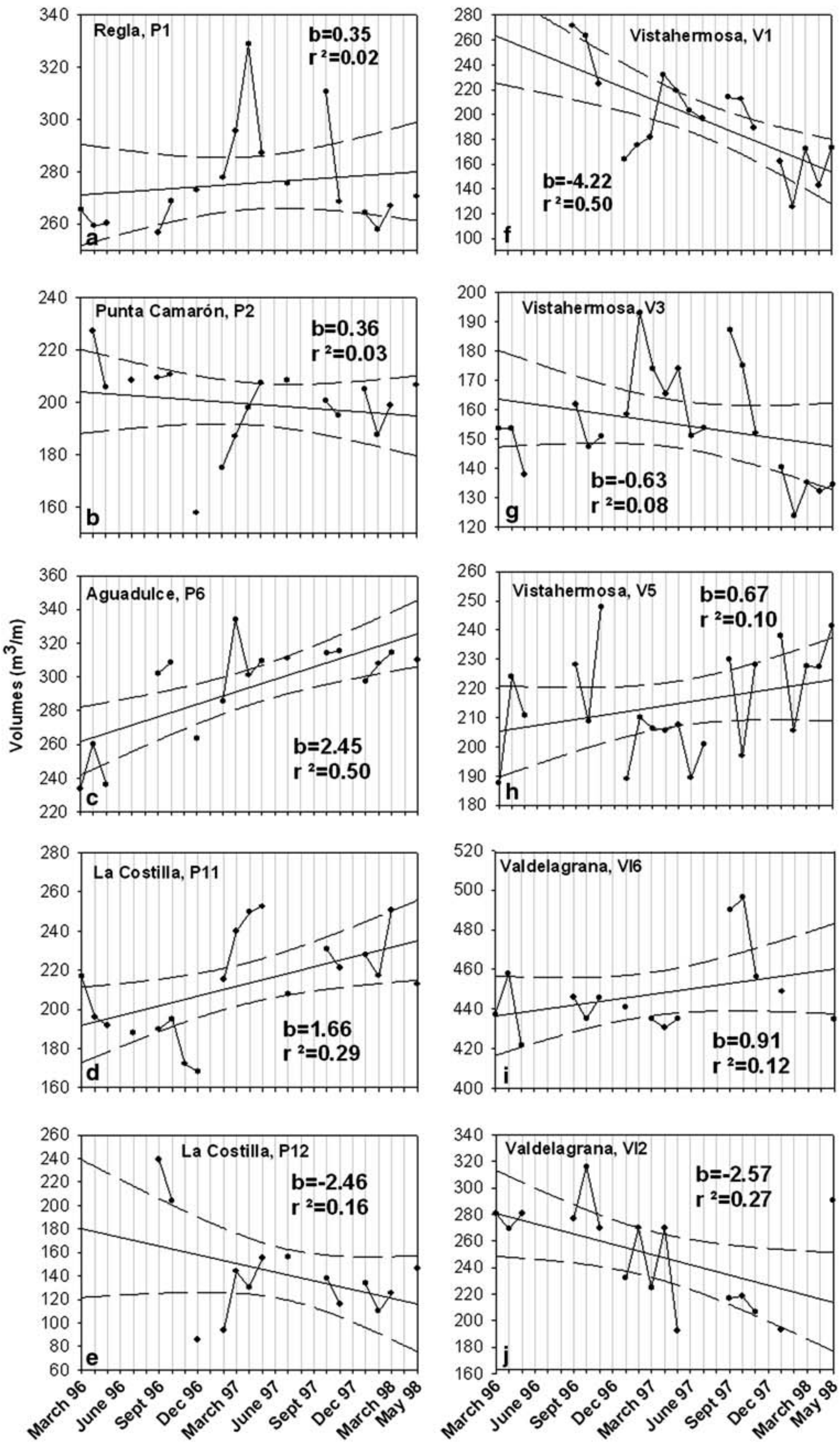

Fig. 5 Evolution of several studied beaches during the March 1996–May 1998 period. The 95% confidence intervals (CI95%) are also shown

Table 1 Slope ("*b*") and *R*-squared values ("r^2") for the regression lines of all the studied beaches

Chipiona-Rota Sector	"*b*" and "r^2" values	Vistahermosa	"*b*" and "r^2" values
P1	0.35/0.02	V1	−4.22/0.50
P2	0.36/0.03	V2	0.14/0.01
P3	−0.23/0.02	V3	−0.63/0.08
P4	0.85/0.25	V4	−0.25/0.01
P5	−0.32/0.03	V5	0.67/0.10
P6	2.45/0.50	Valdelagrana	
P7	0.01/0.01	Vl 1	−5.9/0.42
P8	0.26/0.01	Vl 2	−2.57/0.27
P9	−1.04/0.36	Vl 3	−1.34/0.20
P10	0.16/0.01	Vl 4	−0.04/0.01
P11	1.66/0.29	Vl 5	0.21/0.01
P12	−2.46/0.16	Vl 6	0.91/0.12

currents hence they not acquire any influence on sediment transport.

Littoral cells are limited by free and fixed limits, which are typically longshore drift convergences, divides or places marked by discernible changes in transport rate (convergent, divergent and transit limits, respectively). Free boundaries are generally of more diffuse character and limited stability, and they are not associated with particular structures or morphological features, while fixed limits are constituted by both natural and human structures. Lastly, limits are divided into absolute and partial boundaries according to their permeability to sediment (Carter 1988; Bray and Hooke 1995).

In this paper, approximate sediment transport pathways and location of main cell limits for the study area have been represented in Fig. 7, by considering the results of coastal evolution during the 1996/98 period (Fig. 6) and following Bray et al. (1995) and Cooper and Pethick (2005). Each beach profile was considered as broadly representative of a coastal sector according to detailed field observations (Anfuso et al. 2000; Benavente et al. 2000; Anfuso and Gracia 2005). Obviously, the definition of cells proposed in this work for the study area is strongly dependent on profile spacing and hence it represents a simple scheme.

Cell limits were located between adjacent transepts characterized by opposite volumetric trends (Carter 1988).

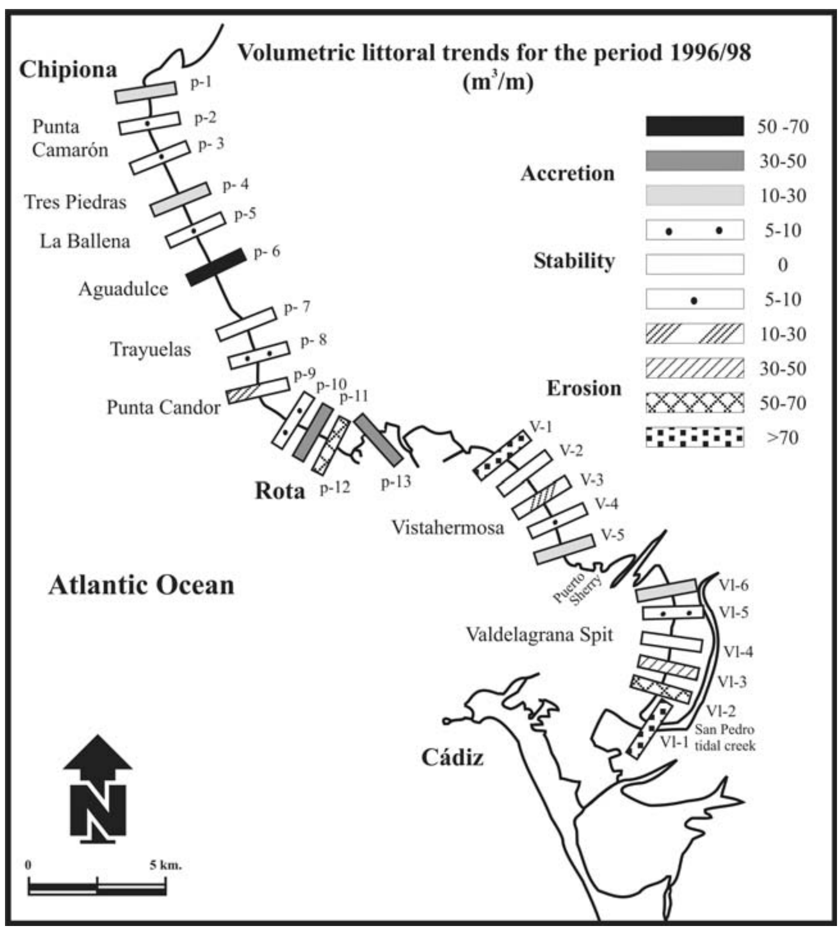

Fig. 6 Volumetric littoral trends of the studied beaches for the period March 1996–May 1998

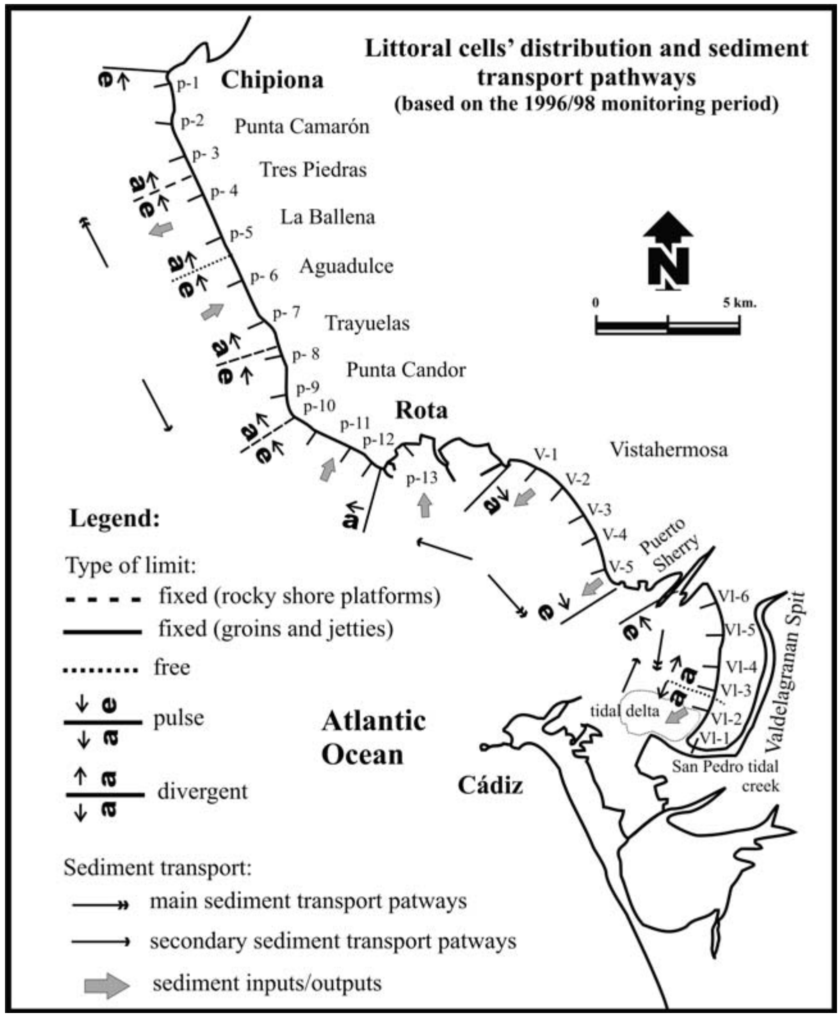

Fig. 7 Approximation to littoral cells' distribution and sediment transport pathways along the studied littoral

In this study, fixed limits coincided with both natural structures, i.e. the rocky shore platform which outcrops at several places, and human structures, essentially the groins located at Chipiona, Rota and northern Vistahermosa and the jetties at the Guadalete river mouth. These structures presented different degrees of permeability according to sea level fluctuation due to tides. This way, a particular characteristic of these boundaries is the intermittent nature of bypassing transport, which at places is storm-related. On large structures, the transfer of suspended matter is possibly dominant. Where boundaries are permeable in one way, downdrift coasts are highly dependent upon those areas located updrift. Free limits have also been mapped at Tres Piedras and Valdelagrana.

Sediments moved mainly northwestward in the Chipiona-Rota sector, more exposed to S and SW winds and associated storm waves that prevailed during the survey period (Fig. 3). The result of the aforementioned transport produced accretion at P1, northward limited by a groin, and at P10 and P11, limited by rocky shore platforms; erosion was recorded at P9 and P12, located downdrift of a rocky platform and a groin respectively (Figs. 1, 6, 7). Similar results were observed by Masselink and Pattiaratchi (2001), which stressed out the importance of longshore drift obstacles in affecting beach width. In fact, beach width increased with proximity to an obstacle and also with the dimensions of the obstacle, which represented a cell limit.

At Vistahermosa beach, the northwestward transport is impeded by its location as the beach is relatively protected from SSW approaching waves, and SW approaching waves are almost shore-normal. Further, according to results of wave propagations carried out by Benavente et al. (2000), W, WSW and WNW approaching waves give rise to a prevailing transport southward-directed with certain accretion resulting at V5.

At Valdelagrana beach, according to the results obtained during the monitoring program, a northward-directed drift was observed, which was responsible for beach accretion at Vl 5 and Vl 6 (Figs. 6, 7). The aforementioned drift was associated with wind-driven waves generated by strong winds blowing from the S and SE, which achieve a great importance in the Cadiz area (Muñoz and Sánchez 1994). An opposite southward-directed transport in this area was also recorded by Benavente et al. (2000). The coexistence of a southward-directed transport (related to west approaching waves) with a northward-directed one, associated with sea waves because strong S and SE winds, suggested the existence of a divergent limit.

All studied beaches recorded the existence of an opposite transport. A similar situation was observed by Domínguez et al. (1992), which demonstrated that the seasonal reversal in the longshore drift direction caused changes in beach morphology with widening and narrowing beaches occurring simultaneously, but at opposite ends of an embayment. McLean and Woodroffe (1994), over larger time scales, observed as beach width changes can occur as a result of beach rotation due to a shift in the prevailing wave direction causing an alongshore redistribution of sediment within an embayment.

Potential sediment sources for the area are cliff and rocky shore platform erosion, fluvial and marine inputs, longshore transport and beach replenishment. According to Anfuso et al. (2003), no significant inputs are associated with cliff retreat and rocky shore platform abrasion or fluvial supplies. Offshore marine sediment supply probably takes place at very local areas, such as Rota (P13) and Aguadulce (P6; Fig. 7), and longshore transport supplies sediments at P10 and P11 by eroding the artificial nourishment at P12. At all these places, aeolian transport accumulated large quantities of sand in the backshore forming foredunes, which migrated landward.

Important sediment losses occur at several locations in correspondence with rocky shore platforms and at the southern end of Valdelagrana spit. At the former places, i.e. P4, V1 and partially at V5 (Fig. 7), offshore-directed sediment transfer prevails, and sediment is lost due to the presence of a morphological step at the seaward edge of the platform (Muñoz et al. 1999).

As noted by Bray et al. (1995) in the southern coast of England, most of the sediment transport pathways observed within this study are roughly confirmed by historical and present coastal changes. In fact, dune accretion at P10 and P11 was confirmed through the analysis of aerial photographs by Dominguez et al. (2005), who recorded a seaward migration of dune foot of about 35 m in the period 1956–2001. Beach accretion at P13 still occurs nowadays, as shown by the periodic sand bypass performed by trucks from this transept to P12.

The erosive trend recorded at V1 is also still present, and has led to the artificial pouring of 150,000 m^3 of sediments during the 1999–2005 period. Part of the eroded sand is transported offshore and part moved longshore, feeding V3 and V5.

At Valdelagrana spit, erosion processes were also observed at the medium-term scale by Martínez et al. (2001). The authors attributed the serious coastal retreat to the construction of the jetties at Guadalete river mouth, which produced a pivoting in beach planform; eroded sediments at the southernmost end of the spit are transported offshore, constituting the ebb tidal delta shown in Fig. 7. This feature has recorded huge accretion over the recent years, because of the artificial land fill carried out in the opposite bank of the tidal creek located at the southern limit of the spit. According to Martinez et al. (2001), the ebb flow of the tidal creek is channelized and intensified by the landfill, hence blocking longshore drift.

Conclusions

The monitoring program allowed for the characterization of short-term beach trends, littoral cell distribution and broad sediment circulation pathways. The total volumetric budget of each beach profile was calculated and beaches were grouped into several erosive/accretionary sectors. The main erosion and accretion areas were related to the interaction between longshore transport and the existence of natural and human structures dividing the coast in littoral cells. Thus, a northwestward transport in the Chipiona-Rota sector, and an apposite one in Vistahermosa beach, determined beach accretion updrift of rocky shore platforms or human structures and consequent downdrift erosion. Valdelagrana spit presented a complex situation with erosion processes prevailing in its free end and accretion in the northern part, close to the Guadalete jetties. Additionally, zones of sediment sinks have been observed at different places and related to the presence of a rocky shore platform. Information obtained in the present study may be easily used to address local erosion problems, by means of small sand bypass works from accreting to eroding beaches. The amount of sand needed and the periodicity of the works should be adapted to the volumetric trend and seasonal behavior of every beach, which may also be used as a natural reference for estimating average lifetime and design profile of nourished beaches.

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