COASTAL DYNAMICS 2005

PROCEEDINGS OF THE 5TH INTERNATIONAL CONFERENCE

April 4–8, 2005
Barcelona, Spain

SPONSORED BY
Laboratori d'Enginyeria Marítima
Universitat Politècnica de Catalunya

WITH THE SUPPORT OF
International Centre for Coastal Resources Research (CIIRC)
E.T.S. d'Enginyers de Camins, Canals i Ports de Barcelona
D.G. de Investigación, Ministerio de Educación y Ciencia
D.G. de Costas, Ministerio de Medio Ambiente
Dursi, Generalitat de Catalunya
Universitat Politècnica de Catalunya

WITH THE COOPERATION OF
The Coasts, Oceans, Ports, and Rivers Institute (COPRI)
of the American Society of Civil Engineers

EDITED BY
Agustín Sánchez-Arcilla

ASCE

Published by the American Society of Civil Engineers

Notices

ISBN 0-7844-0855-6

ISBN 0-7844-0855-6
Manufactured in the United States of America.

American Society of Civil Engineers
ASCE International Headquarters
1801 Alexander Bell Drive
Reston, VA 20191-4400 USA

Call Toll-Free in the U.S.: 1-800-548-2723 (ASCE)
Call from anywhere in the world: 1-703-295-6300
Internet: http://www/pubs.asce.org

Sponsors

ORGANIZED BY

Laboratori d'Enginyeria Marítima
UNIVERSITAT POLITÈCNICA DE CATALUNYA

WITH THE SUPPORT OF

International Centre for Coastal Resources Research

CIIRC
International Centre
for Coastal Resources
Research

E.T.S. d'Enginyers de Camins, Canals i Ports de Barcelona

Escola Tècnica Superior d'Enginyers
de Camins, Canals i Ports de Barcelona
UNIVERSITAT POLITÈCNICA DE CATALUNYA

D.G. De Investigación, Ministerio De Educación Y Ciencia
(Ref. Ctm2004-21603-E)

D.G. de Costas, Ministerio de Medio Ambiente

Dursi, Generalitat de Catalunya (Ref. 2005 Arcs1 00243)

Universitat Politècnica De Catalunya

WITH THE COOPERATION OF

The Coasts, Oceans, Ports, and Rivers Institute (COPRI)
of the American Society of Civil Engineers

SEDIMENT TRANSPORT PATTERN AND COASTAL EVOLUTION AT LIDO DI DANTE BEACH, ADRIATIC SEA

Yann Balouin[1], Paolo Ciavola[2], Clara Armaroli[3]

[1] BRGM, Service Géologique Régional, Languedoc-Roussillon (SGR/LRO), 1039, rue de Pinville, 34000 Montpellier, France. y.balouin@brgm.fr.
[2] Dipartimento di Scienze della Terra, Università di Ferrara, via Saragat, 1, 44100 Ferrara, Italy. cvp@unife.it
[3] Dipartimento di Scienze della Terra, Università di Ferrara, via Saragat, 1, 44100 Ferrara, Italy. clara.armaroli@unife.it.

Abstract: Inter-disciplinary medium term monitoring of a small coastal cell of the Northern Adriatic, Lido di Dante Beach, was undertaken starting from 2001. In association with the EU-CoastView Project, coastal state indicators were developed and surveyed. This paper presents the observations done during 3 years of surveys: beach morphodynamics, intertidal bars, dune morphology and vegetation, overwash observation and risk. Results evidence two areas with different dynamics: the Southern part of the beach is dependent on the Bevano River by-pass processes and all indicators are positive (stable vegetation, large beach) while the Northern part is very narrow, eroding (10m/year) and the dune is easily overwashed. This atypical behavior is though to be due to the groin that disturbs the protective function of the nearshore bar system.

INTRODUCTION

In some places of the NE coast of Italy, more than 70% of shore retreat is due to a reduction in littoral transport of sediment. Causes are multiple: most commonly it is the construction of coastal defences and a reduction of bedload in rivers, mainly due to dredging. Lido di Dante is a 2 km coastal cell limited by coastal structures and a river mouth. During the last years, a significant effort was undertaken at this site to develop and monitor beach state indicators. This effort was supported by the EU-CoastView project, and the installation of a video monitoring system at the site. This study presents the analysis of the medium term survey of these indicators, and proposes a conceptual model explaining the dynamics of this very particular coastal environment.

FIELD SITE

The Lido di Dante beach is a 2 km stretch of coast, almost aligned in the N-S direction, limited by the protected area in front of the Lido di Dante village (a breakwater and three groins) and by the Bevano river mouth southwards (Figure 1). The beach, composed of fine to medium sands, is completely natural with dunes and a pine forest behind them. The dune system is very irregular, partially vegetated, and its elevation ranges from 2 m above MSL on the northern part of the beach to 4.5-5 m in the southern one. It is divided in two parts: dynamic foredunes and stable dunes at their back.

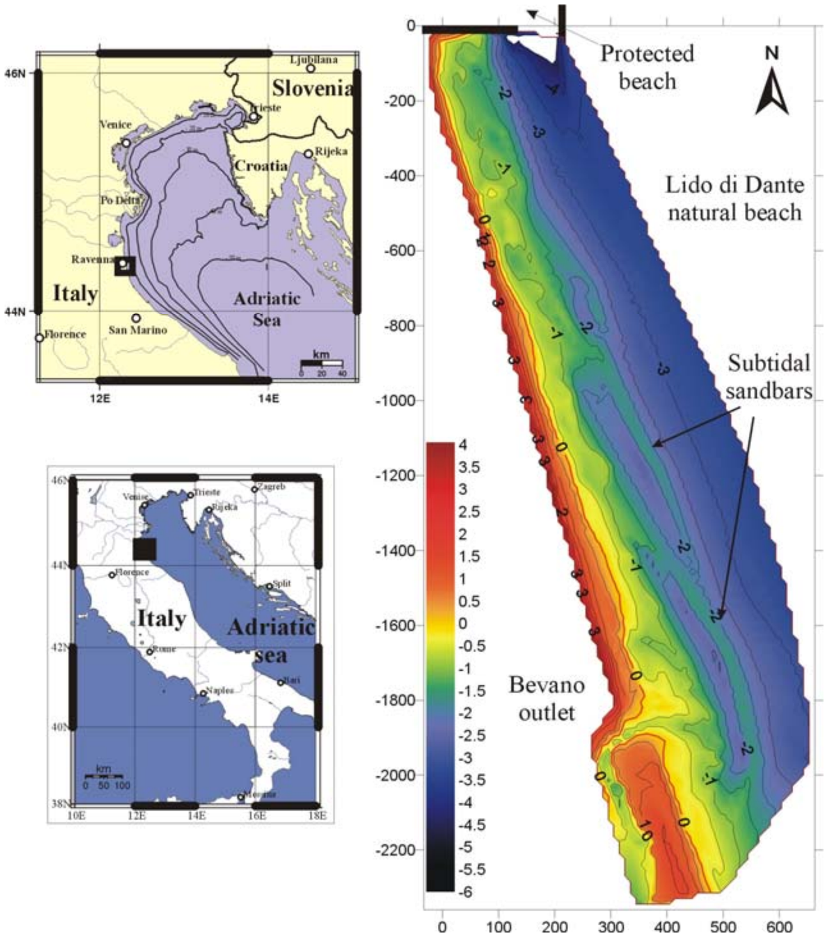

Figure 1. Location of the Lido di Dante field site (left) and topobathymetry realised in April 2003 (right).

The tidal regime here, and in the whole Northern Adriatic, is strongly asymmetric, showing both diurnal and semi-diurnal components. The maximum tidal range is about 1.2 m during spring tides. The wave climate is usually of low energy, with significant wave heights less than 0.5 m, mainly from the East (65% of occurrences) (Gambolati et al. 1998). Two different storm directions prevail in the Adriatic Sea: the Scirocco from

SE, and the Bora from NE. Storms with one-year return period have wave heights around 3 m and periods of 7.5 s (IDROSER 1996).

METHODS

In this study, an interdisciplinary approach was used to characterise the beach state of Lido di Dante. Several indicators were used to define and characterise beach state (Table 1), such as: vegetation associations, shoreline evolution (measured continuously using ARGUS video techniques within the EU Coastview Project, Albertazzi et al. 2003), topography and bathymetry surveys, hydrodynamic measurements. Nine surveys were done using a Total Station and an RTK DGPS, starting in December 2001 till February 2005. The beach and the dunes were monitored along cross-shore profiles regularly spaced (almost 150 m), starting from the dune crest down to a depth of -1/-1.5 m below MSL. Moreover, two sets of beach samples were analysed to perform grain size trend analysis, and sediment transport was quantified using sand tracers during intensive campaigns involving the deployment of hydrodynamic devices and experiments on the swash processes over the bars.

On February 2003 an Argus system was installed at the site within the European Project CoastView. The System consists of four cameras: three looking at the Lido di Dante protected beach, and one looking at the natural part of the beach. It is possible to extract information from video images such as shoreline position (Aarninkhof et al. 2003), bar position and shape (Holman and Lippmann 1987; Lippmann and Holman 1989; Lippmann and Holman 1990), beach width, dune vegetation cover, beach use (Jimenez et al. 2005). In this study, the intertidal bars were studied using a specific tool of Argus (Argus Stack Tool, AST), by sampling pixel luminosity intensity along cross-shore profiles regularly spaced (50 m).

Table 1. Different field investigations undertaken and main indicators analyzed

Field Technique	Indicators
Topography, bathymetry	Long term evolution Beach width River mouth migration
RTK GPS	Erosion hot spots – overwash areas Dune front steepness
Video system	Beach width Beach occupation Impact of storm events Bar location and shape
Hydrodynamics	Energetical context
Vegetation	Dune state

The dune vegetation was studied using one aerial photograph (2002 flight over the whole area) at very high on-the-ground resolution (less than 1 m) and using direct measurements to characterize different species present on the area. An estimation of the percentage of coverage of each species was evaluated coupling the aerial photo with direct observations. The dune crest elevation was obtained from direct surveys by walking on the foredune ridge with an RTK DGPS. Particular attention was put on measuring the extension of overwash areas and on measuring the presence and elevation of trampling-induced paths (“corridors” that cut the dune ridge in several parts).

RESULTS

Geomorphology of the Lido di Dante beach

The beach at the Lido di Dante field site forms a small coastal cell limited in its northern part by a permanent boundary corresponding to the rock groin in front of the village, and in its southern part by the very dynamic Bevano river mouth. The morphodynamics of this area can be defined as natural, except near the groin.

The Bevano is a small river draining a basin of 92.5 km². The river discharge (Q_{355}=0.064 m^3/s) is very low compared to the tidal prism ($3x10^5$ m^3) and was negligible during the studied period, which was particularly dry (Balouin et al. 2004). Consequently, most of the river mouth dynamics resulted from longshore processes that induced a rapid lateral migration, progressively decreasing the extent of the coastal cell. The beach can be subdivided into two main areas: the northern part, close to the groin, which shows evident coastline retreat (more than 10 m/year), and the southern part that seems to be relatively stable (Table 2). In the northern part, the beach is quite reflective (beach slope of 11%), very narrow (around 10-20m), while it has a low tide terrace morphology in the southern part, yielding a larger beach width (40-50 m). In the subtidal domain, two bars can be observed (Figure 1): an intertidal bar system, irregular and non-continuous, and a nearshore bar system, almost non-existent in the northern part, that forms well-developed crescentic features southwards (see also Armaroli et al., this volume).

Hydrodynamics

During the survey period the oceanographic regime was in line with long-term observations available for the area (IDROSER 1996): predominance of ESE low energy waves, and occurrence of the main storm from the Scirocco and Bora directions (Figure 2). The wave energy shows a strong seasonal pattern with more energetic events occurring between November and March, and lower energy during spring and summer. The years 2003 and 2004 have shown a very similar hydrodynamic setting with a comparable number of energetic events (7 events with wave height around 3 m), same directions of main storms (NE and SE), comparable duration of each event (between 2 and 18 hours). However, in December 2003 there was a significant event that was not particularly strong (Hs=3 m, direction from NE) but it lasted for a long time (almost 72 hours, between 23 and 26 December), and had a significant impact on the dynamics of the beach.

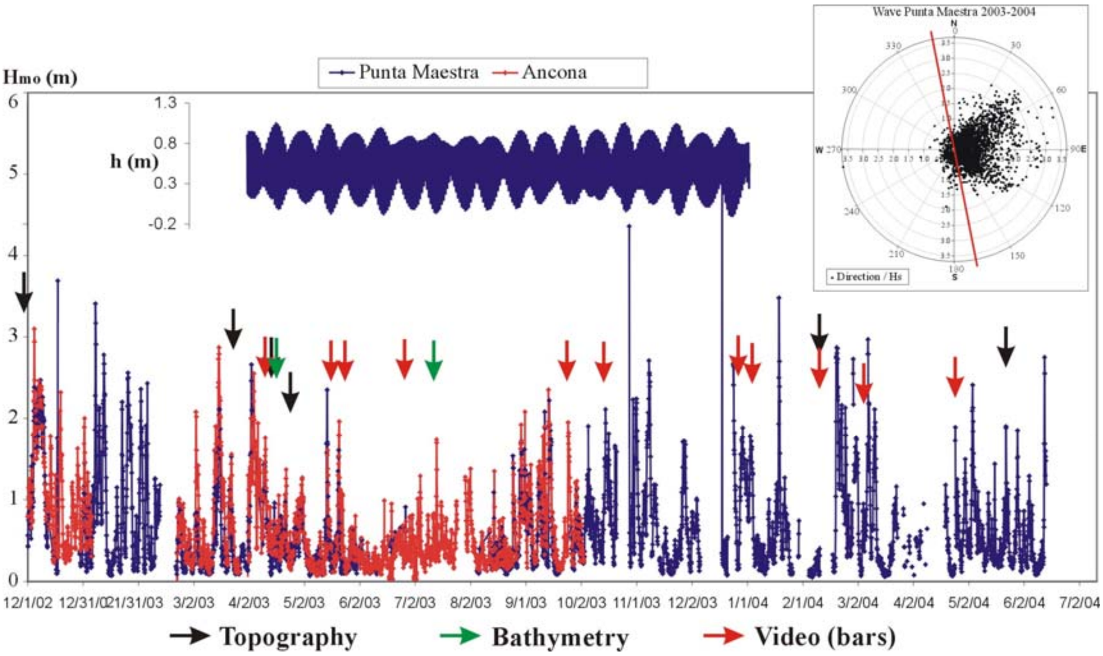

Figure 2. Hydrodynamics during the survey period. Wave conditions from December 2002 to July 2004, tidal curve and wave direction at the offshore buoy of Punta Maestra (in front of the Po river delta).

Morphology evolution

The Bevano mouth is a small river outlet that shows a very dynamic evolution (Balouin et al. 2004a; Ciavola et al. 2005). Longshore processes are dominant over the tidal exchange, and the river discharge is very low. This induces a rapid lateral migration of the river mouth (more than 80 m / year, Figure 3). As described in Balouin et al. (2004), this migration results from two main processes: the dominance of the longshore sediment transport from South to North; the strong meandering of the river mouth, that induces an ebb jet almost parallel to the coastline, thus eroding the dune laterally. Tracer experiments undertaken by the previous authors have shown that the currents flush out sediments eroded from the downdrift flank of the channel, accumulate on the downdrift swash platform, and progressively reach the beach downdrift. The resulting enlargement of the channel is compensated by an accumulation at the extremity of the updrift spit, thus keeping the tidal prism almost constant.

The sediment budget of the river mouth is almost equilibrated, and dynamics at a medium term timescale are roughly producing a simple translation of the system. There are evidences of an offshore bar-by-pass process that contributes to the total amount of sand to the considered coastal cell. However, this sediment by-pass was not quantified in this study.

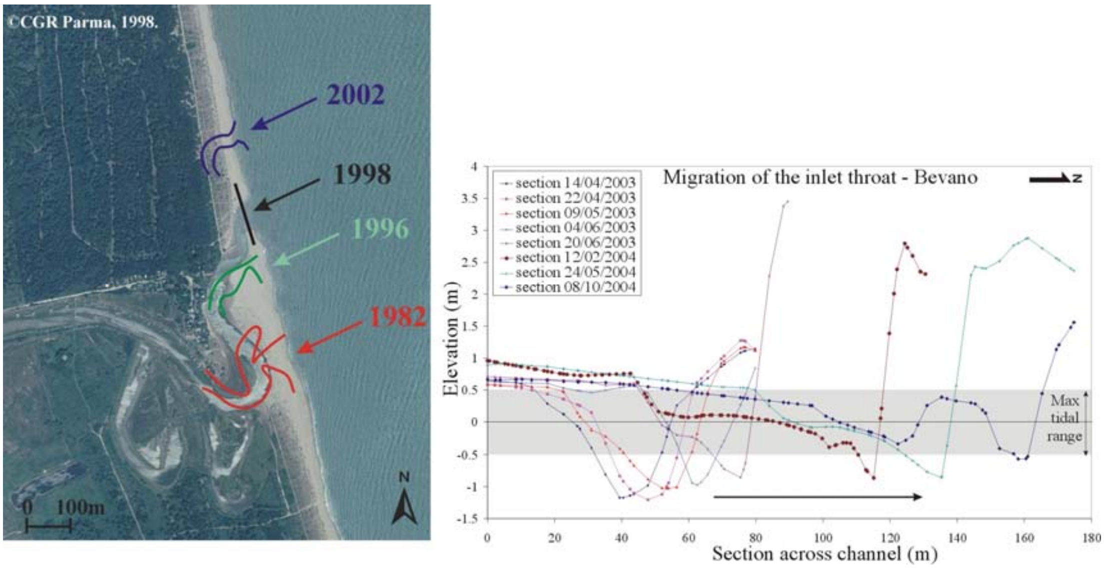

Figure 3. Lateral migration of the Bevano river mouth. Left: position of the river outlet since 1982; right: cross section of the river channel from April 14th 2003 to October 08th 2004.

Beach evolution

Long-term monitoring of beach profiles reveals that the central and southern parts are oscillating or stable (Figure 4). Here the beach shows a dynamic equilibrium around its mean profile. There is a strong shoreline retreat in the northern area, the one close to the structures, while the southern part shows a longshore oscillation, associated with the dynamics of the intertidal sand bars (Kroon et al. 2005). This area should benefit from a South to North longshore transport trapped by the groin. However, the 10 m/year retreat of the coast and the very steep profile testify strong erosive processes.

Table 2: Beach state indicators results in both unprotected (North) and bar-protected (South) areas

Indicators	Southern part	Northern part
Beach width	40-50 m	10-20 m
Dune retreat	0.2 m/month	0.85 m/month
Dune height	3.5-4.5 m/M.S.L.	1.6-3.5 m /M.S.L.
Dune front steepness	16%	66%
Dune vegetation	Stable associations	Sparse *Ammophila*
Bar location	100-200 m/shoreline	No external bars
Storm breakers	Bar breakers	Shore breakers
Overwash areas	1 localized area	3 large areas
River mouth migration	80 m /year	

Intertidal sand bars are well developed in the southern part of the beach. Long-term monitoring has evidenced the longshore mobility of these features. Under the prevailing

ESE wave climate, bars are migrating northwards, in close relationship with the sediment released from the Bevano delta.

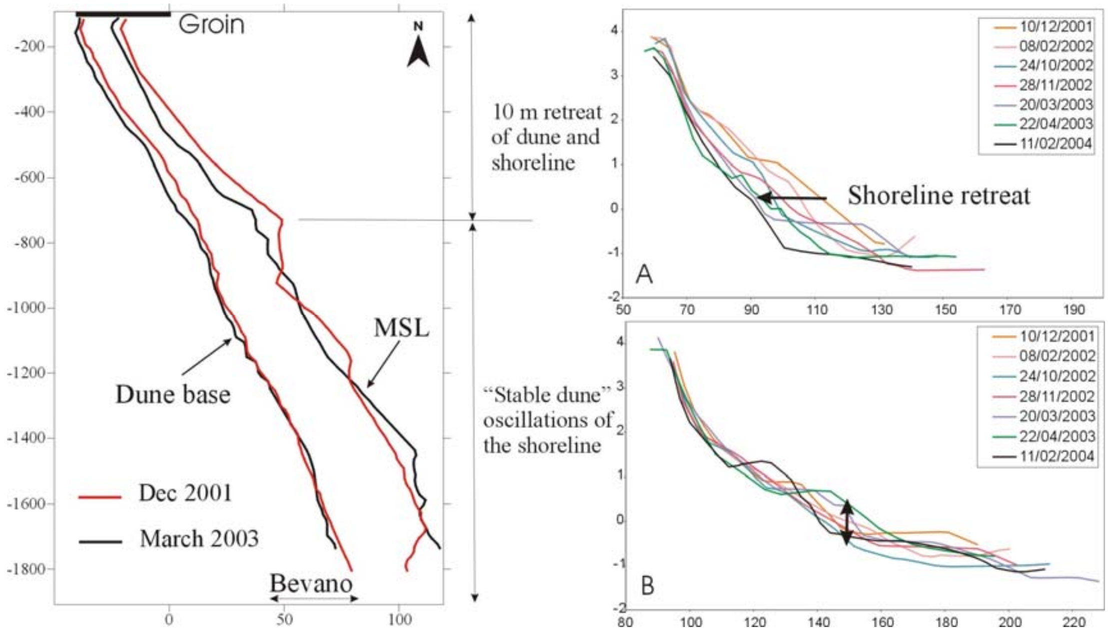

Figure 4. Retreat of dune foot and shoreline between December 2001 and March 2003. Dune foot defined as the +2 m above MSL contour line, shoreline as MSL contour line.

In the middle part of the beach, a small intertidal bar was previously studied in detail (Balouin et al. 2004b). Morphological surveys, as well as tracer experiments, permitted to characterize a very rapid attachment to the beach. An analysis of this particular feature was also done using video images. The position of the bar crest was identified along cross-shore profiles 50 m spaced alongshore. This particular point of the beach corresponds to the attachment point of the nearshore bar that bypasses offshore the Bevano delta (Figure 5). Figure 5 shows the evolution from April to October 2003. The nearshore bar connected to the Bevano by-pass bar, progressively migrates northwards. At approximately 1200 m from the video tower, this oblique bar is attached to the beach. This indicates that the attachment point of the river by-pass bar is located at almost 1 km from the river mouth, thus furnishing a significant amount of sediment in the middle part of the coastal cell.

This alongshore movement of sand bars is confirmed by the analysis of grain size trends (McLaren and Bowles 1985; Gao and Collins 1992). Transport vectors obtained with this method indicate a northward longshore transport of sediment in the southern part of the beach, while offshore transport seems to be widely dominant on the northern part. This is in total agreement with the long-term evolution of the beach that shows strong erosion near the southernmost groin in front of the Lido di Dante village.

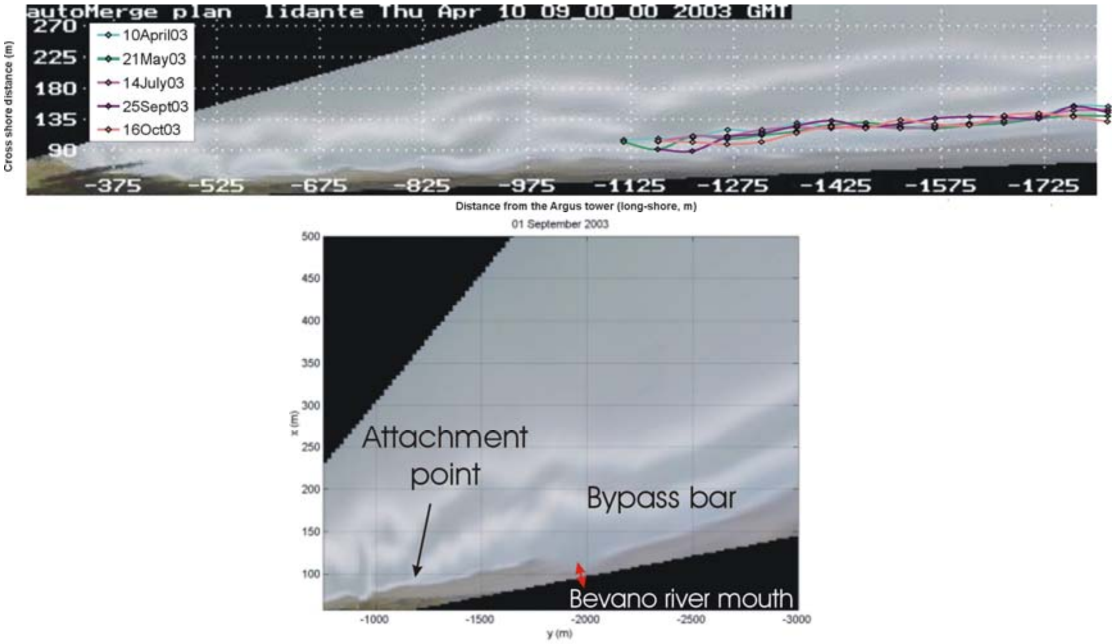

Figure 5. Dynamics of the nearshore bar. Upper: position of the bar crest from 10 April to 16 October 2003; lower: bypass bar offshore the Bevano river mouth, and location of the attachment point at approximately 1200 m from the tower.

The dune system and overwash processes

The dune system height is changing moving southwards. The dune height is around 2 m close to the structures while it is of 4-5 m in the area close to the Bevano river mouth. Dune vegetation cover is an indicator of where the dunes are healthy and where there is a constant influence of destabilizing factors on the vegetation growing on the crest and at its foot. The vegetation distribution identifies three areas: the one in the southern part is characterized by the presence of wide areas covered by *Ammophila*, that is an indicator of dune stability. The area presents a vegetation association sequence (from the beach to the back dunes) composed by *Cakile maritimum*/ *Ammophila arenaria*/ *Tortula ruralis*. Moving northwards the density of *Ammophila* decreases constantly and dramatically, with a prevalence of shrubs, and *Cakile maritimum* and *Tortula ruralis* disappear. The northern area has almost no *Ammophila*. These changes in vegetation testify the stability of the southern part of the coastal cell, where the dune is high and the front steepness is low. The northern part is affected by the presence of defense structures and is constantly eroding. Between December 2001 and March 2003 the retreat was of 10 m (more than 0.6 m/month, Figure 4).

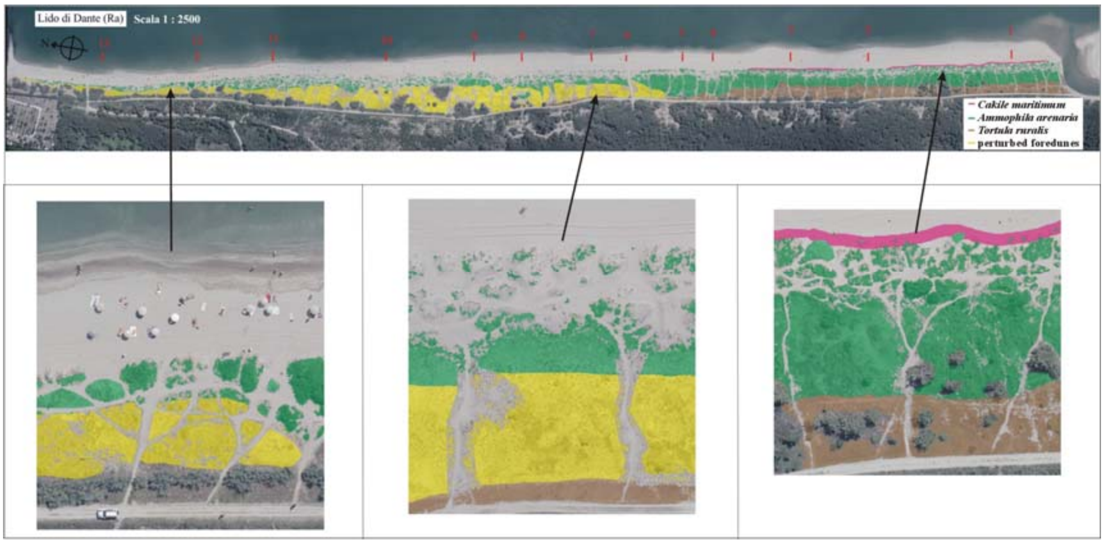

Fig. 6. Vegetation distribution over the dune system.

The dune crest elevation ranges between 1.5 m and 5 m. As it is clearly visible in Figures 6 and 7, the dune crest is not continuous and trampling-induced paths in several parts cut it. These "corridors" are affected by wind scouring, because the vegetation has been destroyed, and by salt-water intrusion, because they become preferential paths for the sea when it reaches the dune foot during storms, generating wide overwash areas. According to the classification of Short and Hesp (1982), the foredunes could be divided in two parts: the northern one is classified as percentage of vegetation cover between 20% and 45%, small blowouts and lee side avalanching. Here the vegetation has almost disappeared due to the effect of storms occurred in winter 2004/2005. In this area the sea reaches the stable dune at the back during strong events. The southernmost foredune ridge could be classified as percentage of vegetation cover between 75% and 90%, incipient blowouts, discontinuous ridge and lee side accumulation. The southern area is characterized by a fragmented topography but the elevation of the dune crest and of trampling-induced paths is higher. The stable dune at the back is characterized by a dense vegetation cover and is never reached by uprush, even during bad weather conditions.

It is possible to calculate the maximum water elevation (including storm surge, wave set-up, run-up, tide) for the study area, considering the worst scenario, to create a dune risk map. The mean beach slope was calculated as 5% (mean slope along four reference profiles along the whole area). The highest tidal level during spring tides used here is of 0.5 m above MSL. The maximum run-up was computed using the formula of Holman (1986), in Kroon and Masselink (2002), for the wave with return period of 1, 10, 100 years. Storm surge and wave set up effects, calculated for the study area by Yu et al. (1998), were added to the highest tidal level. The results are shown in Figure 7, in which the foredune elevation is represented together with the maximum elevation reached by the water during storm events at the three considered return periods. It is evident that the northern area is at risk even from overwash for a wave with a return period of 1 year, while the southern one is not at risk even for the wave with a return period of 100 years. Using the results presented here a dune risk map was created, dividing the risk in overwash-risk and overtopping-risk (Figure 8).

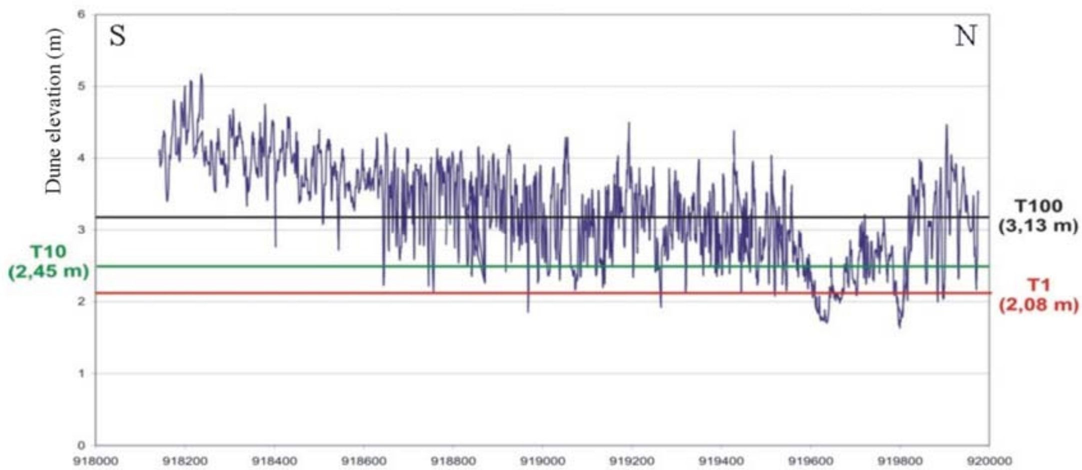

Fig. 7. Dune crest elevation and maximum wave run-up for waves with return periods of 1, 10 and 100 years, considering the worst scenario (high tide + storm surge +wave set up). The dune crest was surveyed on February 2004.

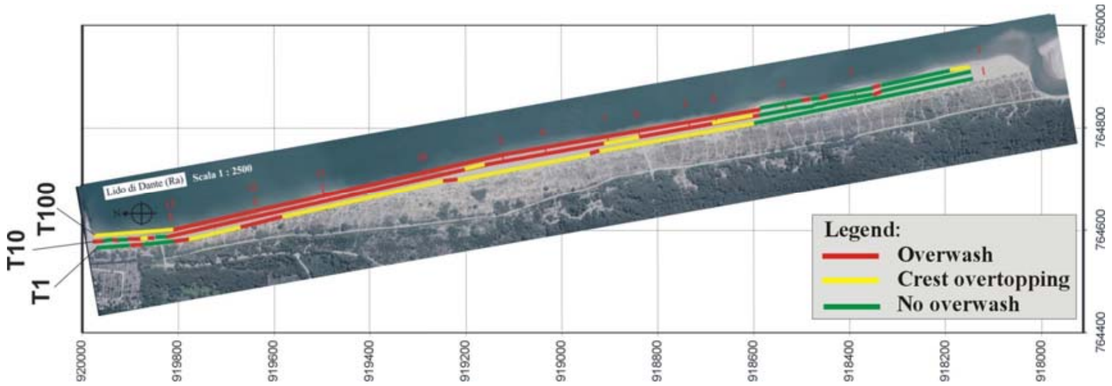

Fig. 8. Dune risk map considering the worst scenario, for waves with return periods of 1, 10 and 100 years.

SEDIMENT TRANSPORT PATTERN

Monitoring activities of the Lido di Dante beach from 2001, and survey of different beach state indicators (beach width, dune retreat, dune height, vegetation, bar location, overwash hot-spots and river mouth migration) have evidenced a very particular behavior of this small coastal cell. Sediment input into the system results from a south to north longshore transport. As seen from video image analysis and characterization of by-pass processes at the river outlet (Balouin et al. 2004a), there are two main processes that can bring sediment to the Lido di Dante beach: i) by-pass processes associated with the channel lateral migration. In this case, sediment is eroded on the dune, flushed out by currents, and bypassed through swash bars attachment on the updrift coast under wave action; ii) direct offshore by-pass of sediments along the delta with an attachment to the coast in the middle part of the beach (i.e. at approximately 1 km from the river outlet). This sediment is then transported northwards with the longshore migration of the intertidal bars. These processes are of course dependent on the Bevano river dynamics, and the consequent release of sediments.

A consistent accumulation of sediment should then be expected near the groin at the northern limit of the coastal cell. However, in this area the beach is very narrow, and eroded even during small energetic events. This is probably related to perturbations generated by the groin structure, with consistent edge effects. However, even if the subtidal dynamics are not presented here, a close relationship with the nearshore bars can be inferred. As shown by Armaroli et al. (this volume), subtidal bars have a particular shape, probably resulting from the presence of hard coastal protections. A well-developed crescentic system can be observed at approximately 100 m from the shoreline. This system disappears near the groin, and the resulting shoreface is very steep. Armaroli et al. (this volume) have shown that the shape of this bar system can be strongly modified during extreme storm events, but its position remains quite stable in time. Even if no quantitative energetic analysis has been performed at the moment, these bars are expected to have a protective role during storm events, which could explain the particular dynamics of the coastal cell. In the southern part of the beach, the nearshore area is protected and exhibits indeed a low slope. A littoral circulation is established and maintained by a significant amount of sediment from the river mouth. In the northern part, sediment supply is expected to be important. However, the beach is narrow, the shoreface here is very steep (Figure 9), and offshore sediment transport could be predominant even during fair weather conditions. Moreover, this area suffers from direct attack of storm waves during energetic events, generating consistent shore and dune retreat.

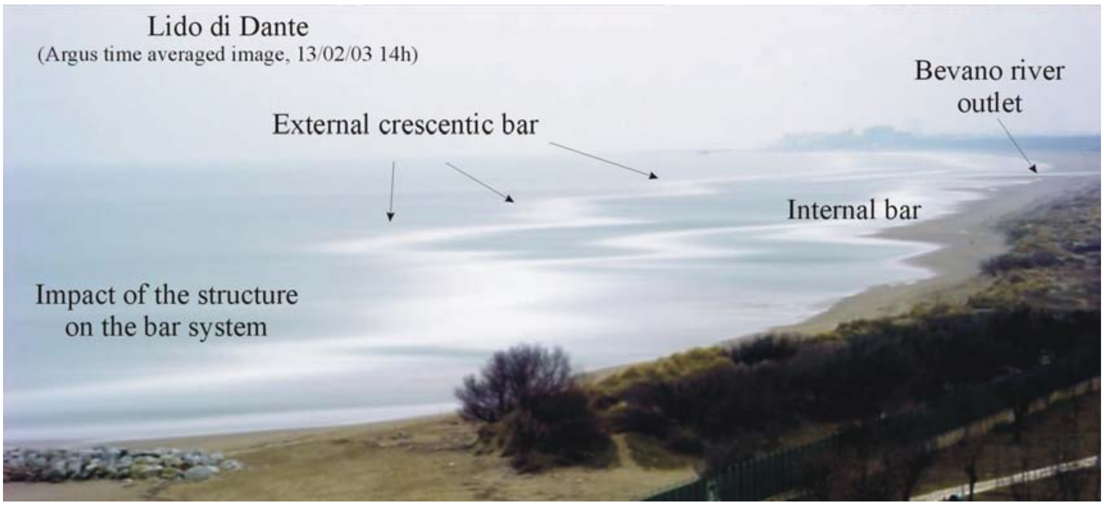

Figure 9. A 10 min averaged Argus oblique video image (looking southward) showing the location of the inner and outer bar systems. White areas indicate the wave breaking zones, and thus the location of subtidal morphologies. Note the relationship between bar presence and beach width.

CONCLUSIONS

All indicators point towards a pessimistic scenario for the future evolution of this beach, particularly on the northern part that is already in a critical situation following the overwash events that took place in the winter 2003-2004. This evidence from the medium term monitoring outlines the protective role of the subtidal bars in maintaining a dynamic stability on the southern part of the beach. Despite the quantification of wave energy dissipation by these subtidal bars not being presented here, breaking of waves during energetic events is clearly seen on video images (see Figure 9, and Armaroli et al., this volume). Such a role of the natural bar system should consequently be taken into account in beach management, and nourishment projects should be planned in order to maintain these "natural" forms of wave dissipation.

ACKNOWLEDGEMENTS

This paper is a contribution to the EU project COASTVIEW (contract EVK3-CT-2001-00054). Y. Balouin also acknowledges the financial support of the Commission of the European Communities through a Marie Curie Fellowship (contract EKV3-CT-2002-50014).

REFERENCES

Aarninkhof, S.G.J., Turner, I.L., Dronkers, D.T., Calijouw, M., Nipius, L., 2003. "A video based technique for mapping intertidal beach bathymetry." *Coastal Engineering*, 49, pp. 275-289.

Albertazzi, C., Archetti, R., Armaroli, C., Ceroni, M., Ciavola, C., Lamberti, L., and Medri, S., 2003. "The CoastView Project.". *Proc. of Medcoast Conference*, Ravenna, Italy, p. 235-246.

Armaroli, C., Balouin, Y., Ciavola, P., Gardelli, M. (2005). "Bar changes due to storm events using ARGUS, Lido di Dante, Italy." *5th Int. Conf. Coastal Dynamics*, Barcelona, Spain, this volume.

Balouin, Y., Ciavola, P., Michel, D., (2004a). "Support of subtidal tracer studies to quantify the complex morphodynamics of a river outlet: the Bevano, NE Italy." *Journal of Coastal Research*, SI 39, ICS 2004, in press, 6 pp.

Balouin, Y., Ciavola, P., Anfuso, G., Armaroli, C., Corbau, C. And Tessari, U. (2004b). "Morphodynamics of intertidal sandbars: field studies in the northern Adriatic NE Italy." *Journal of Coastal Research*, SI 39, ICS 2004, in press, 7 pp.

Ciavola, P., Balouin, Y., Armaroli, C. (2005). "River mouth development in the northern Adriatic: the Bevano case study and the dilemma of no intervention." *Proc. of ICCCM '05 Conference*, Algarve, Portugal, in press.

Ferreira, O., Dias, J.A., Taborda, R. (1994). "Wave energy dissipation on a high energy barred nearshore: a natural and effective coastal protection." *Proc. of Littoral 94*, Lisbon, Portugal, vol. 1, pp. 369-379.

Gambolati, G., Giunta, G., Putti, M., Teatini, P., Tomasi, L., Betti, I., Morelli, M., Berlamont, J., De Backer, K., Decouttere, C., Monbaliu, J., Yu, C.S., Broeker, I., Kristenser, E.D, Elfrink, B., Dante, A., Gonella, M. (1998). "Coastal evolution of the Upper Adriatic Sea due to Sea Level Rise, and Natural and Anthropic Land Subsidence." *CENAS*, Kluwer Academic (ed.), Dordrecht, The Netherlands, pp. 1-34.

Gao, S. and Collins, M. (1992). “Net sediment transport patterns inferred from grain-size trend, based upon definitions of “transport vectors”. Sedimentary Geology, 80, pp. 47-60.
Holman, R.A. and Lippmann, T.C. (1987). “Remote sensing of nearshore bar system - making morphology visible”, *Proc. of Coastal Sediments ’87 Conference*, New Orleans, Louisiana, USA, 929-944.
IDROSER (1996). “Progetto di Piano per la riqualificazione ambientale del litorale della Regione Emilia-Romagna. Regione Emilia-Romagna”, Bologna, Italy, 100-122.
Jimenez, J.,A. Osorio, A., Marino-Tapia, I., Kroon, A., Medina, R., Davidson, M., Archetti, R., Ciavola, P., and Aarnikhof, S.G.J. (2005). “Beach recreation planning using video-derived coastal state indicators”, *Coastal Engineering*, Special Issue on CoastView Project, in press.
Kroon, A., Aarninkhof, S.G.J., Armaroli, C., Gonzales, M., Medri, S., Osorio, A., Aagard, T., Holman, R, and Spanhoff, R. (2005). “Application of remote sensing video system for coastline management problems”, *Coastal Engineering*, Special Issue on CoastView Project, in press.
Kroon, A., and Masselink, G. (2002). “Morphodynamics of intertidal bar morphology on a microtidal beach under low energy wave conditions, North Lincolnshire, England.” *Marine Geology*, 190, pp. 591-608.
Lippmann, T.C. and Holman, R.A. (1989). “Quantification of sand bar morphology: a video technique based on wave dissipation.” *Journal of Geophysical Research*, 94, C1, pp. 995-1011.
Lippmann, T.C. and Holman, R.A. (1990). “The spatial and temporal variability of sand bar morphology”, *Journal of Geophysical Research*, 95, C7, 11575-11590.
McLaren, P. and Bowles, D. (1985). “The effects of sediment transport on grain-size distributions”, *Journal of Sedimentary Petrology*, 55 (4), pp. 457-470.
Short, A.D., and Hesp, P.A. (1982). 2Wave, beach and dune interactions in southeastern Australia.” *Marine Geology*, 48, pp. 259-284.
Yu, C.S., Decouttere, C., and Berlamont, J. (1998). “Storm surge simulations in the Adriatic Sea”, *CENAS*, Kluwer Academic (ed.), Dordrecht, The Netherlands, 207-232.