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An integrated approach to beach management in Lido di Dante, Italy

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Abstract

The aim of the paper is to present an integrated approach to coastal zone management and the benefits derived from the synergy of different monitoring methodologies. Lido di Dante, Italy, was selected for this purpose because it suffers from great erosion and is well documented under engineering, socio-economic and ecological aspects (it was one of DELOS Project case studies).

The paper presents the relation among the most relevant results obtained in the site. First, effects of shore protection works and wave climate on beach morphology are examined by analysing field measurements of waves and currents together with hydrodynamic simulations and bathymetry surveys in the area.

Then, socio-economic impact of coastal defence is documented by the statistics derived from face-to-face interviews that provided beach valuation and user preferences.

Finally, abundance and type of organisms on the rocky structures, based on results from ecological surveys, are related to the intensity distribution of wave and current flows around and over the structure.

The complex interaction among the beach, the structures, the hydrodynamics, the eco-system and the society is discussed and the necessity of multi-disciplinary guidelines for constructing beach defences is enhanced.

Keywords: beach; breakwater; hydrodynamics; morphodynamics; ecology; economic value

1. Introduction

Long stretches of the European coastline are threatened by erosion and flooding and, at the same time, their economic importance grows, due to the fact that population concentrate in coastal zones. The consequent proliferation of hard defence structures in several areas has reached a level that might result in relevant environmental implications.

Coastal defence structures are often designed as low-crested, by transposing at a lower scale techniques and results mainly derived for breakwaters, with little attention paid to the fact that wave load parameters and tidal range do not scale down. In particular, these structures result severely overtopped at high tide and frequently submerged, causing currents and relevant beach modifications. As long as hydrodynamic, morphodynamic and ecological problems posed by Low Crested Structures (LCS) are not clarified, unsuccessful design will be frequent (insufficient sand retention, erosion in gaps or at roundheads) or unexpected ecological negative effects could take place (invading species) or positive effects could be not properly accounted for (rocky breeding environment for fishes, water oxygenation).

The DELOS project aimed to promote effective and environmentally compatible design of low crested structures through a multi-disciplinary approach, which integrates research on hydrodynamics, beach morphology,

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engineering design, structure and dynamics of coastal assemblages of animals and plants, cost-benefit analysis as well as assessment of non-economic consequences.

The project provided experimental results on a selected set of cases (Lamberti et al., 2003; Kramer et al., in press), aiming at extending and completing the available information about wave reflection and transmission (van der Meer et al., 2003, in press), breaking wave height and structure stability (Kramer and Burcharth, 2003); these problems are however generally solved in a 2-D context. Structure stability is analysed also in connection with local scour at the laboratory (Sumer et al., in press) and in prototype (Lamberti et al., in press).

Numerical models representing hydrodynamics over and in the structure body (Losada et al., 2003; Johnson et al., in press), currents in complex 3D environmental conditions (Christensen et al., 2003) and morphological evolution – critically checked against prototype observations – were calibrated.

From the ecological point of view, DELOS drew the attention to the quality of habitats in coastal marine areas for deployment of artificial structures such as port installations and coastal defences (Chou, 1997; Connell and Glasby, 1999). So far, the complex interactions between physical and biological processes on and around artificial structures are poorly identified, and the quantification of how the outcomes of such interactions vary in response to environmental changes at a range of spatial and temporal scales (Miller, 1999) is still missing. Few quantitative data are available about colonisation processes, life-histories and food web dynamics of species associated with artificial structures, and even less information is available about linkages with surrounding natural habitats and large scale impacts (either positive or negative) of structures on regional biodiversity and population dynamics (Boshnsack and Sutherland, 1985).

From the socio-economical point of view, DELOS provides an up-to-date inventory of coastal environment valuation methods (Hausman, 1993; Hanemann, 1994), the analysis of the possibility of transferring benefit quantifications from one country to another (Boyle and Bergstrom, 1992) extending significantly the base on which local quantifications can be made; moreover, new specific coastal management projects have been valued.

This present contribution aims at illustrating how to use different tools and their synergy in improving coastal zone management based on the results obtained for the case of Lido di Dante, a small seaside resort in the North Adriatic Sea, 7 km far from the town of Ravenna. The use of the beach for recreational activities, the relevant beach erosion and environmental problems common to the highly defended regional littoral facing a tendentially eutrophic sea made this site an interesting research field for the application of an integrated coastal management approach.

The contribution is composed of five main parts.

The first part presents the construction of the structures at Lido di Dante, identifying necessary measures to preserve beach from erosion.

The second part provides ‘a posteriori’ a societal ‘justification’ of the intervention on the basis of the main results derived from an on-site survey made of 600 face-to-face interviews, that was carried out in the Lido di Dante beach during Summer 2002.

The third part ‘‘justifies’’ the latest intervention from a hydrodynamic point of view by showing results of current monitoring performed in the area. Field data obtained by tracking drifters and by pointwise velocity measurements with an Acoustic Doppler Current Profiler (ADCP) are compared to numerical simulations carried out with MIKE 21 to predict current patterns in the most intensive events. The interaction of the main current system with the LCS and groin system in the area leads to formation of the eddy circulation that is responsible for the relevant changes in the bottom morphology.

The fourth part relates the simulated distribution of current and wave intensities to results of ecological monitoring, providing information on the composition, structure and spatial distribution of intertidal epibiota associated to groins and breakwaters.

Finally, conclusions are drawn on results obtained by field and modelling activities, in order to identify the relevance of such an integrated approach for improving coastal zone management methodologies.

2. Lido di Dante site

2.1. Environmental conditions

Lido di Dante is a small seaside resort in the Northern Adriatic Sea, 7 km from the town of Ravenna, in the area delimited by the outlets of rivers Fiumi Uniti Northwards and Bevano Southwards (see Fig. 1). The two rivers drain basins of very different size and characteristics: Fiumi Uniti basin is much wider and contains an important mountainous part contributing in the past with a significant amount of sediments; Bevano river is essentially a natural drainage channel of the plain with irrelevant sediment transport (IDROSER, 1996).

The Adriatic Sea in this area is characterised by a maximum depth around 50 m and normally eutrophic conditions caused by waters drained by the Po river from the highly inhabited and cultivated Po plain.

Meteorological and wave observations were carried out on the numerous gas platforms just in front of Lido di Dante beach: visual observations from the PCB platform and KNMI ships were done in the period 1971–1983 (IDROSER, 1996), whereas measurement

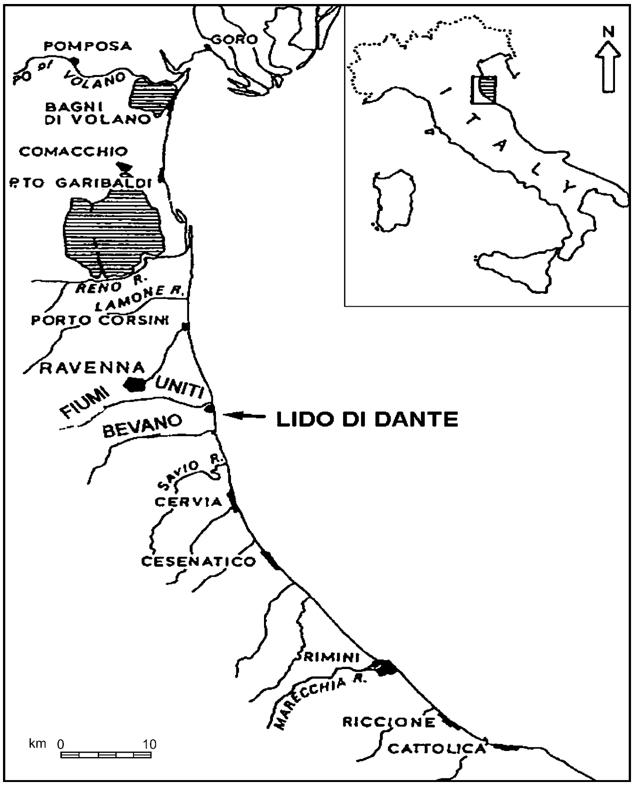

Fig. 1. Location of Lido di Dante site.

from AGIP platforms was performed since 1992 (IDROSER, 1996; Casadei et al., 1998). More recently, two buoys were installed in Ancona (1999) on a 50 m depth and in Punta della Maestra (2002) on a 34 m depth by the Hydro-Marine National Service and data together with statistics are available on-line (http://www.idromare.com).

The tidal excursion in this area is low; the average spring tide range is ± 0.4 m and extreme year values are around ± 0.85 m. Most intense storm events come from Bora and Scirocco with similar intensity; waves may reach 3.5 m every year and rise to 6 m every 100 years. Wind intensity is stronger from the shorter fetch sector of Bora (NE) where it reaches frequently 35 knots intensity, whereas from the long fetch sector of Scirocco it seldom exceeds 30 knots.

The results consist of steep waves breaking far offshore caused by Bora winds and milder slope waves from Scirocco; Bora waves thus dominate in the morphodynamics of the offshore part of the littoral zone and Scirocco waves dominate in the near-shore part. Therefore, in a coast where the Northward directed sediment transport is almost everywhere dominant, the study area is characterised by sand transport diverging from the Fiumi Uniti outlet offshore, whereas Northwards directed sand transport prevails near the shoreline.

The site is part of a sandy flat coastal system, characterised by the presence of sedimentary habitats and by the absence of hard-bottom substrata. The macrofauna of Lido di Dante is represented by a relatively higher number of species (up to 106) belonging to three main phyla: *Mollusca*, *Annelida*, *Arthropoda*, and grouped into 17 major taxa. In particular, the natural benthic assemblages inhabiting the surf zone (from 0 to 4 m depth) can be described as a typical *Lentidium mediterraneum* community. As it is common on the shallow coastal environments of the Northern Adriatic Sea, the living communities of Lido di Dante are relatively 'species poor'; only a few species are quantitatively dominant and characterise the spatial and seasonal variation of the assemblage. In particular, the high dominance of *L. mediterraneum* determines low diversity and marked fluctuations in abundances across the year, with low densities during the winter and spring and a maximum in summer. This is a typical situation of physically-controlled environments, where the main structuring factor is the hydrodynamics.

The sandy beach of Lido di Dante has a concave shape and is more than 2500 m long (Archetti et al., 2000). It can be divided into two parts: the Northern beach (almost 600 m long) was subjected to great erosion and therefore it has been protected by groins, nourishment and semi-submerged breakwater; the Southern beach suffered only slight erosion and is in a very natural state.

Present shoreline recession is mainly caused by the low sediment transport rates of the rivers, by anthropogenic and natural subsidence; prevailing erosion has produced the disruption of beach equilibrium, with major damages when storm surges are coupled with high tides (IDROSER, 1996). Erosion of dunes and land subsidence, together with building of tourism facilities, altered and partially destroyed the sea pinewoods behind the dunes. Littoral retreat will be presumably amplified by the foreseen sea level rise and increased severity of weather conditions due to climate change, requiring a special attention to the problem.

2.2. Shore protection works

Shore protection in Lido di Dante was the result of several successive interventions (Fig. 2) aiming to stop littoral retreat becoming relevant around 1960. The first work was carried out in 1978, when a single northern groin was constructed to retain sediment transport due to shoreline drift. In 1983, two other groins were constructed South of the previous one, forming two cells; a 70 000 m^3 beach nourishment protected by a submerged barrier made of sand bags completed the intervention; many bags were destroyed and found on the beach during the following years.

Despite the intervention, erosion continued reaching in 12 years the highest values North of the defence system (90 m), but remaining significant also in the Northern cell (40 m) and in the Southern one (30 m). A

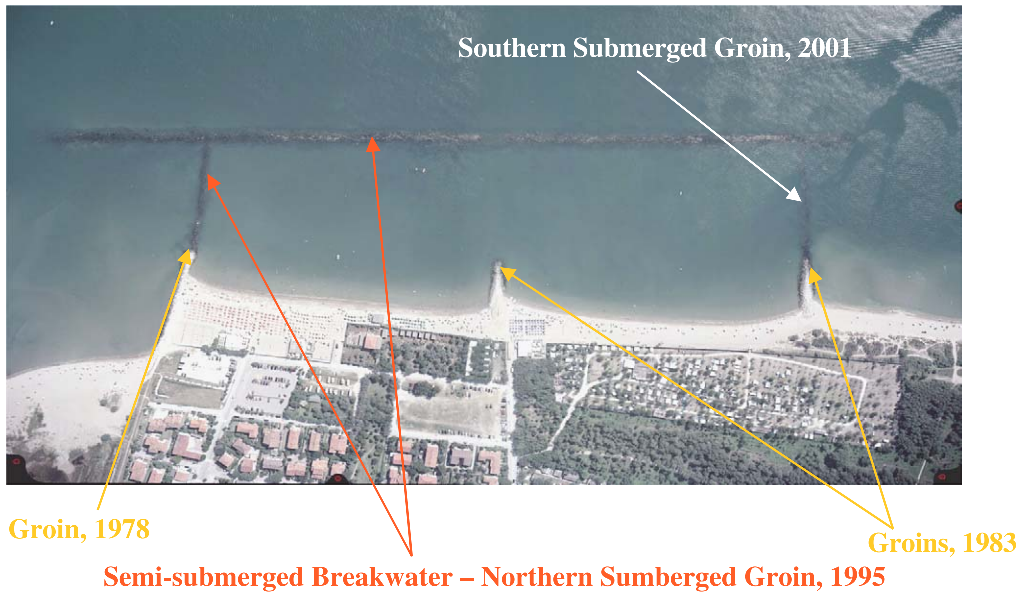

Fig. 2. Shore protection in Lido di Dante.

further intervention was thus required: a new nourishment protected this time by a semi-submerged barrier, placed parallel to the coast 180 m off the shoreline. The barrier was constructed in 1995, whereas the nourishment was performed in different years using sand with $D_{n50} = 0.23$ mm, reaching in 1997 a total volume of 74 400 m^3. The barrier is 770 m long, 600 m in front of the two cells and 170 m to protect the extreme areas, 140 m of which at the North, where most intensive events occur, and 30 m at the South. The design barrier crest width is 12 m and the submergence is 0.5 m. In order to obtain a more effective sand retention capacity, a submerged rocky connector from the Northern groin to the barrier was also built.

In 2001, a 120 m long submerged connector from the Southern groin to the barrier was constructed to reduce the intensity of currents flowing through the gap during Bora events. In order to reduce destabilising phenomena due to erosion offshore the central gap and around and inshore the roundheads, the toe of the structure was reinforced with quarry material. In order to face the structure subsidence due to settlement into the bed and to some armour rock displacements due to wave impacts, the structure was re-charged using 2380 m^3 of natural rocks. Finally, in the northern cell a maintenance renourishment of 2000 m^3 sand was done.

3. Beach valuation

As already introduced in the previous section, Lido di Dante beach is characterised by a significant development of tourism facilities, particularly in the Northern part, where one hotel, around 200 flats to rent and four sun-bathing facilities are present; in the Southern part there are two camping areas. Data collected during the period 1978–1996 from the Tourism Office of Ravenna and reported in Drei (1996) show that the mean presence of tourists in the area is around 100 000 visitors/years (estimated as the sum over one year of the number of daily visitors). Water eutrophication caused severe algal blooms in the years 1988–1990 and eventually a reduction of tourist arrivals until 1995, when the highest beach retreat also took place. Only the two camping in the southern area were not affected by this reduction.

A survey, based on the Contingent Valuation Method (CVM) and made up of 600 face-to-face interviews on the Lido di Dante beach, was carried out in August–September 2002. During the survey design a questionnaire was prepared adapting the site user questionnaire by Penning-Rowsell et al. (1992) to the specific conditions of the Lido di Dante site. The survey was designed to create a hypothetical market in which a contingent value is estimated for the actual beach condition and for two hypothetical scenarios consequent to beach erosion and protection likely to occur in 10 years (see Fig. 3). Interviewed people were requested to provide monetary values representing enjoyment from recreational activities on the beach and its variation when the beach advances or retreats.

More specifically the main aims of the survey were:

(i) to assess the daily value of enjoyment for informal recreational activities on the beach (use value) in its current conditions during summer and winter separately;
(ii) to determine the variation of this value in summer in the case that, due to natural erosion, the beach recedes 10 m landwards or advances seawards 10 m due to maintenance action;

Fig. 3. Status quo (0) and hypothetical scenarios of Lido di Dante beach in 10 years presented in the survey: (1) in case and (2) in absence of renourishment.

(iii) to know the preferences of residents, day-visitors and tourists about different defence techniques and beach materials;
(iv) to collect information on the socio-economic characteristics of visitors, type of beach use and number of visits to Lido di Dante.

The beach was divided into three parts: the Northern beach, characterised by sun-bathing resorts and tourism facilities, the semi-developed Central beach, and the completely free Southern beach. Respondents were divided into residents, national and international visitors.

People were introduced to the questionnaire first asking them to think of a visit or activity (as theatre, swimming pool, nature reserve, cinema and so on) they did and gave them the same enjoyment as they would get from a visit to the seafront. Then, they were asked to think of how much that visit or activity cost them (as admission charges, petrol and parking, bus or train fares and so on) and finally, on the basis of these cost, to value their individual enjoyment of their present visit at sea.

The mean daily use value of the Lido di Dante beach in summer are, respectively:

- 27.67 €/person/day in the status quo,
- 13.26 €/person/day in the hypothetical situation of erosion and
- 28.37 €/person/day in the hypothetical situation of nourishment and Euros/person/day.

The mean daily use value of the beach in winter drops to 4.10 Euros/person/day. Generally the Southern free beach is more valued than the Northern developed beach; for details, see Marzetti and Zanuttigh (2003), Polomé et al. (in press).

It must also be noted that in case the expected erosion of Lido di Dante beach would take place, protection is preferred to the alternative of doing nothing, and the declared value of the eroded beach is much lower than in the status quo. In addition, 16.4% of respondents will never visit the eroded beach and 29.1% will visit it less often than they do in the current state.

Interviewed visitors expressed their preference on the different kinds of coastal defence structures and the main reason for their preference. Amongst the defence techniques:

- 32.5% of respondents prefer composite intervention (submerged breakwaters, groins and nourishment),
- 23.7% choose emerged parallel breakwaters,
- 21.2% prefer groins and
- 19.8% select nourishment.

Aesthetic reasons mainly justify the preference for the composite intervention, while water quality and suitability for children are the main reasons for respondents preferring emerged breakwaters; groins are preferred because of suitability for recreational activities and water quality; finally, the preference for nourishment is motivated by water quality and aesthetic reasons.

In conclusion, the value attributed to the beach in the current state together with the aesthetic preference for the composite type of intervention appear to "justify" completely, based on the societal satisfaction, the works carried out in Lido di Dante (cost 1 M€) and the periodic maintenance necessary to preserve the beach in the current state: the cost of maintenance corresponds to approximately 1/10 of the total declared value of enjoyment.

4. Current effects on beach morphology

After the main intervention in 1996, erosion continued and is documented by periodic detailed bathymetric surveys of the area. Looking at beach morphology evolution and at currents in the protected area we can find the reasons for the construction of the most recent part of the intervention: the Southern submerged prolongation of the groin reaching the offshore submerged breakwater.

Fig. 4 compares two of the most recent bathymetries obtained one month before (Fig. 4(1), June) and three months after (Fig. 4(2), October) the works carried out in July 2001. No significant changes occurred in the Northern part of the defended area, where the erosion inside the barrier stopped and minor sedimentation took place. In the Southern part, from the central gap to the Southern roundhead and around this, significant erosion took place inshore the longitudinal barrier, that resulted, after a couple of years of shoreline progression, in a recession to approximately the original shoreline position.

Fig. 5 compares current patterns simulated using MIKE 21, a 2DH tool developed by the Danish Hydraulic Institute, for the same Bora event, without (Fig. 5(1)) and with (Fig. 5(2)) the Southern submerged connector. The comparison indicates that the submerged groin produces a strong reduction of current intensities inshore the barrier as well as of mass fluxes coming out from the Southern cell; the localized current just inshore the barrier is related to a more submerged part of the groin that was left to allow small boat navigation.

Currents are monitored in Lido di Dante (Archetti et al., 2000, 2003b) using an ADCP, which was placed at a depth of 3.5 m immediately inshore the central barrier gap and once seaward the barrier, close to the Northern groin. Two cableways are placed linking the Northern and Southern groin to signal-poles on the barrier, from which, depending on the climate conditions, drifters are dropped in the sea, between the LCS and the shoreline, during intense wave events. These patterns were used also for calibrating littoral circulation models. For the same aim, ADCP measurements appeared to be essential in order to obtain a reliable representation of velocity fields. Some relevant ADCP data are shown in Fig. 6, which presents wave height and mean sea level acquired during a 23 days campaign, from October 20th to November 13th, 2002 (Archetti et al., 2003b). During these days, three different events were identified, coming from Scirocco, Bora and Levante. The Scirocco's event is characterised by a relatively high mean sea level (0.7 m

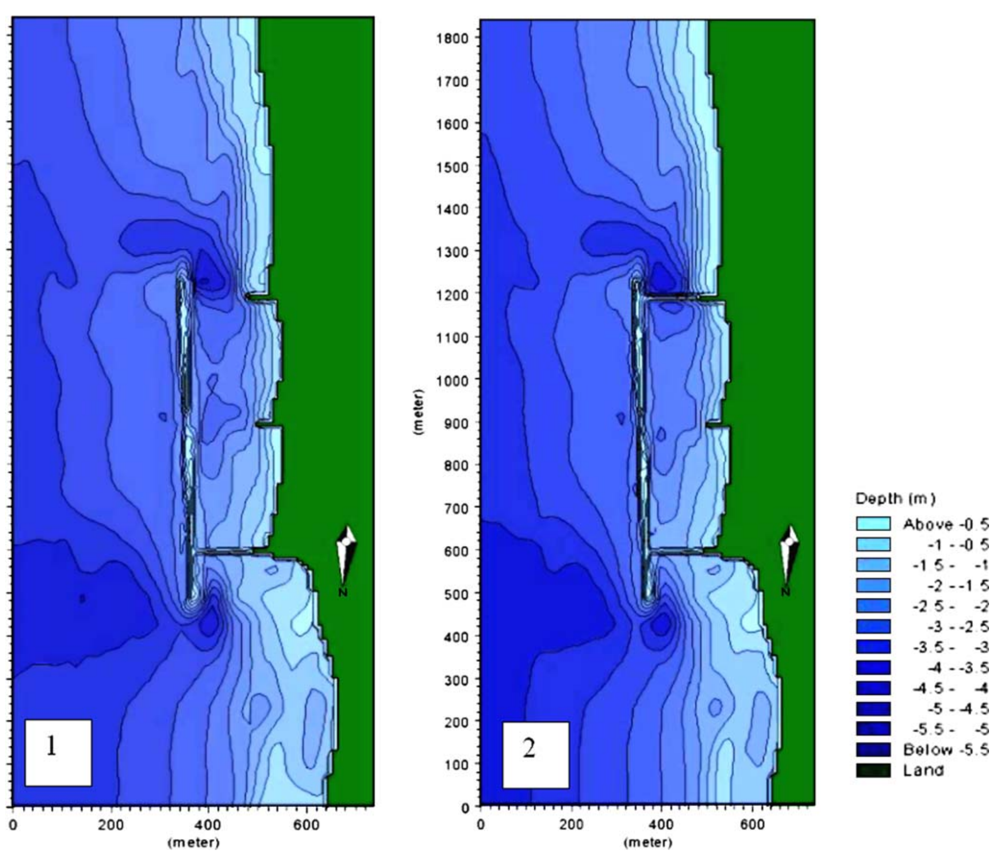

Fig. 4. Bathymetry (1) before (June 2001) and (2) after (October 2001) the construction of the Southern submerged connector.

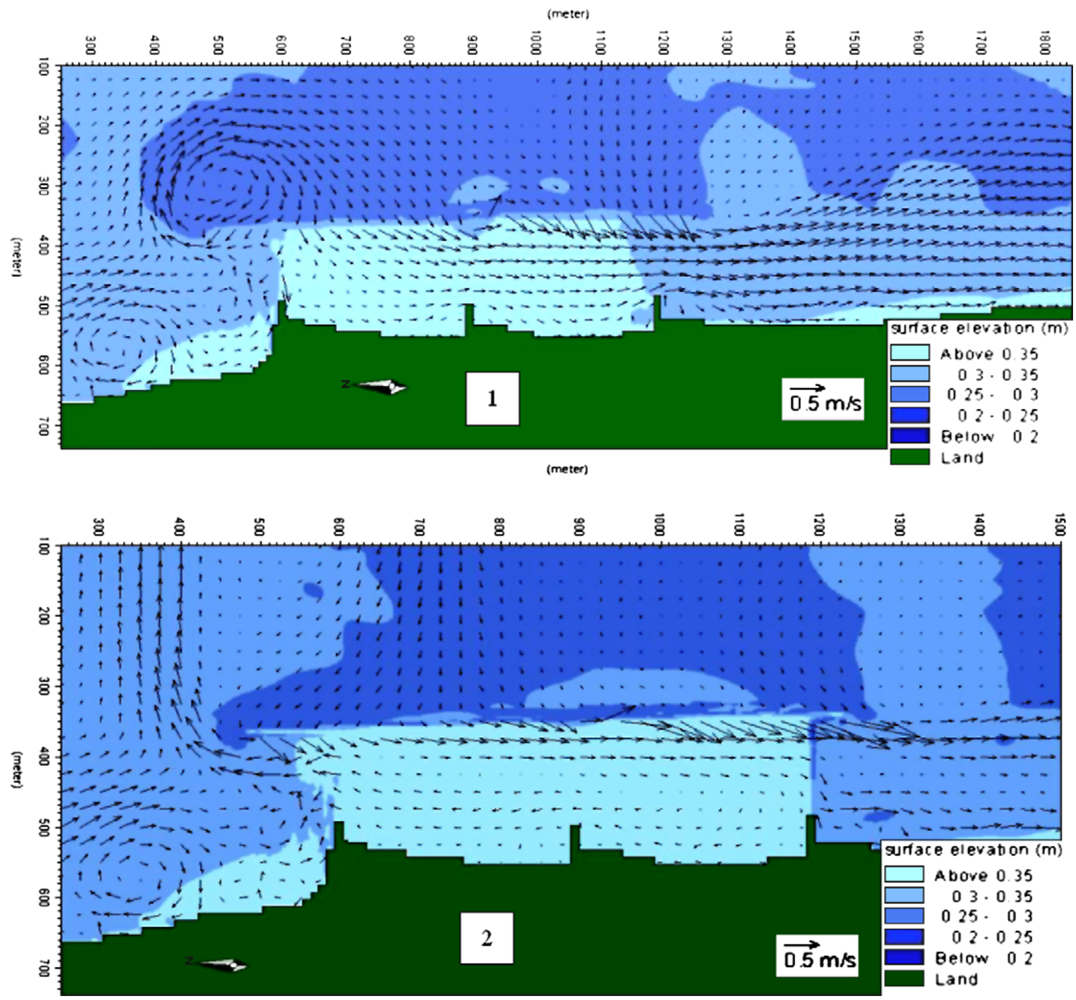

Fig. 5. Currents induced by the same Bora event: (1) in absence and (2) in presence of the Southern connector. Significant wave height $H_s = 2.0$ m, peak period $T_p = 5.6$ s, tide level +0.30 m.

a.s.l.) and moderate wave intensity ($H_s = 1.2$ m), it is followed by a weak Bora event ($H_s = 1.0$ m). The most intense event ($H_s = 1.7$ m) due to easterly winds (Levante) occurred several days later at spring tide.

Data from current monitoring were used both to check numerical simulations with MIKE 21 and to provide boundary conditions regarding waves and currents (Archetti et al., 2003a). The simulations presented in the present contribution were performed with PMS and HD modules, using as input data the detailed bathymetry done after the last works, the wave data obtained by ADCP in the 23 days already presented to calibrate the model with appropriate boundary fluxes, wind data derived by SIMN (Hydrographic and Maritime National Service) registrations (for details, see Archetti et al., 2003a,b). Simulations using wave induced currents at the boundaries resulted in poor agreement with observations because currents induced by other forcing factors as wind and the fresh water flow of the near Fiumi Uniti outlet are relevant. Simulations carried out by imposing long-shore currents at the upstream boundary and wave set-up at the downstream boundary show a good agreement with measurements. Simulations show that the current pattern is very dynamic, changing rapidly and never reaching equilibrium with forcing factors. Currents reach the greatest intensity at the roundheads and in the gaps (the central gap in the barrier and gaps between the submerged groins and the barrier; see Fig. 7).

5. Hydrodynamic effects on barrier colonisation

The analysis of the distribution of wave and current intensities around the structures indicates how hydrodynamics affects the barrier colonisation by biotic assemblages (Bacchiocchi and Airoldi, 2003). Such analysis is performed using the field data in Fig. 6.

Some representative points were identified as the Northern and Southern roundheads, the central gap and two points located leeward and seaward the barrier close to the position of the ADCP (Fig. 7(1)). Current

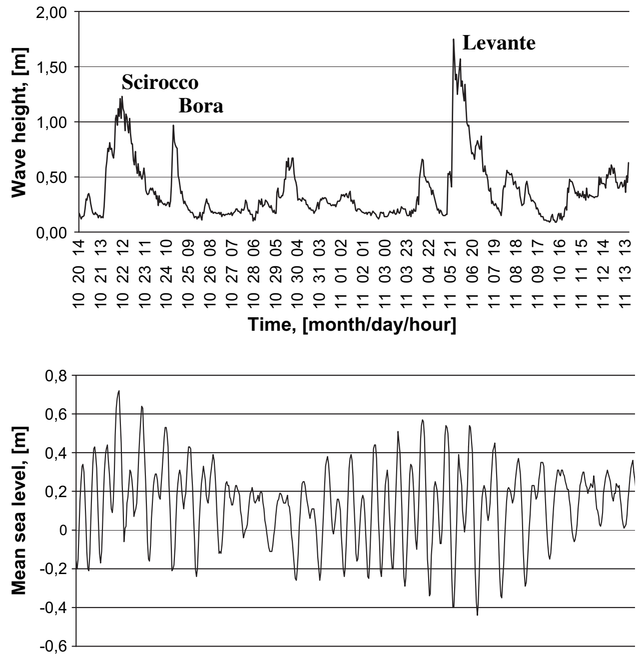

Fig. 6. Recordings of wave height and mean sea level obtained by the ADCP campaign in the period October 20th–November 13th, 2002. Three typical storms occurred: from Scirocco with $H_s = 1.20$ m, from Bora with $H_s = 1.0$ m and from Levante with $H_s = 1.6$ m.

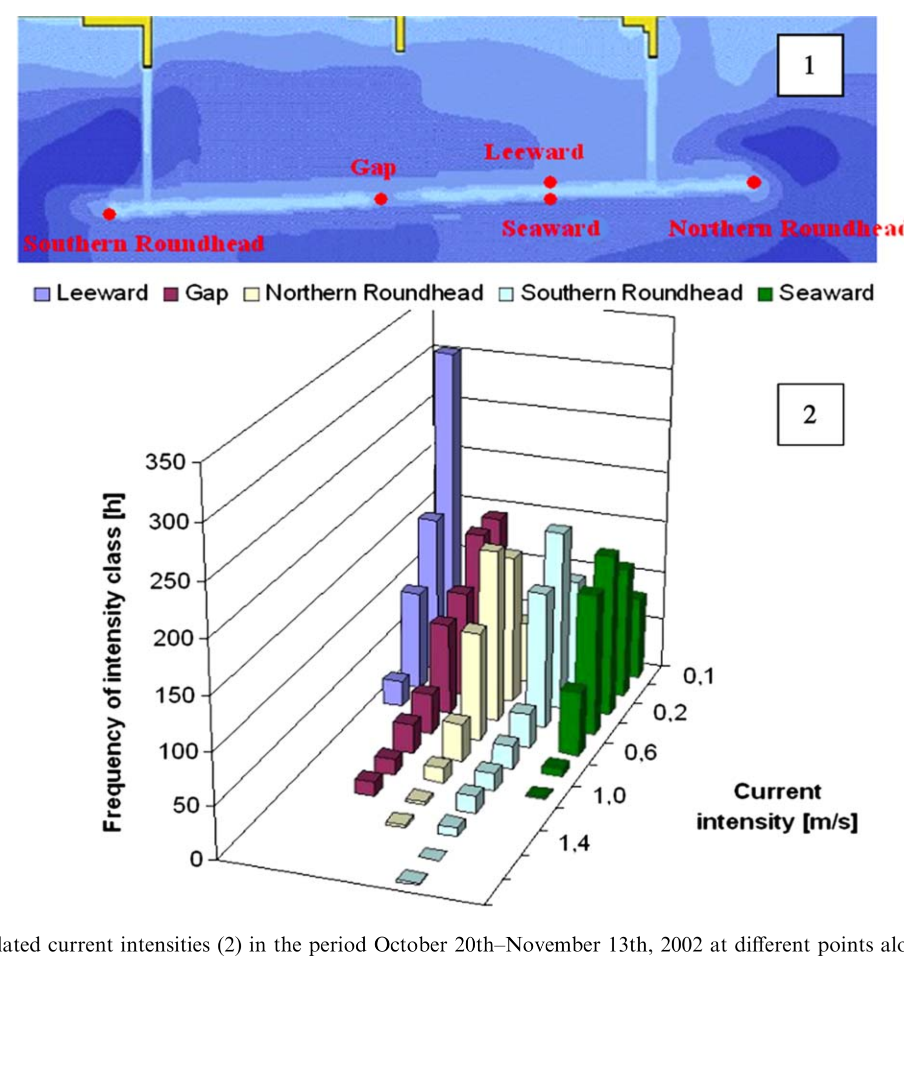

Fig. 7. Mean simulated current intensities (2) in the period October 20th–November 13th, 2002 at different points along the structures (1).

intensity (Fig. 7(2)) reaches the maximum values at the roundheads, where intensities as high as 1.8 m/s were simulated, and at the central gap, whereas is less intense along the barrier where it reached intensity 1.0 m/s offshore but only 0.4 m/s leeward, where it has been demonstrated that the connectors produce a calm area. Wave intensity is obviously higher seaward than leeward the barrier; the average transmission coefficient is 0.5, higher values are associated to high tide.

Waves and currents described so far can be related to barrier colonisation. The periodical ecological surveys in the area and on the structures (Bacchiocchi and Airoldi, 2003) provide the composition of the epibiota and reveal that mussels (*Mytilus galloprovincialis*, Fig. 8(2)) and green algae (*Enteromorpha intestinalis*, Fig. 8(2)) are present both seaward and leeward the structures but are more abundant seawards, whereas oysters (*Ostrea edulis* and *Crassostrea gigas*, Fig. 8(1)) and microfilm are more abundant leeward of the barrier. Oysters in particular are practically absent seawards.

Relating hydrodynamics and ecological data, some preliminary conclusions can be drawn, showing that both mean and extreme values of hydrodynamic fluxes strongly affect the barrier colonisation.

Mean hydrodynamic fluxes influence the position of colonisation areas and also the kind of intertidal epibiota that can survive in the selected areas. If hydrodynamic fluxes are higher than a threshold value, feeding by active filter feeders, as mussels and ascidians, is not possible; on the contrary, if hydrodynamic fluxes are lower than a threshold value, there is an insufficient

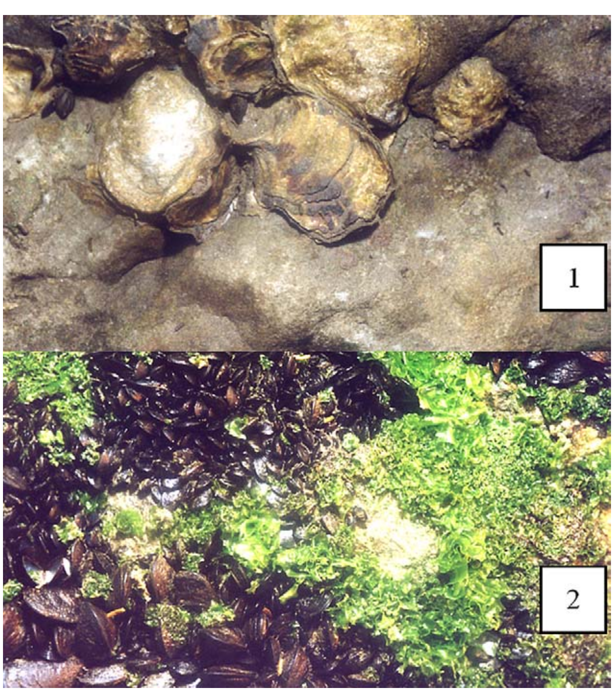

Fig. 8. Epibiota colonising the structures: oysters (1), microfilm and mussels (2).

food flux for passive filter feeders, as polychaets can behave. For both organisms, a very important factor for surviving is obviously the duration of the hydrodynamic threshold exceedance.

Moreover, currents determine sediment transport rates and sediments can affect epibiota patterns through the reduction of light due to turbidity, the deposition on filter and respiratory systems, the processes of abrasion and scouring that inhibit colonisation of rocks.

Finally, extreme hydrodynamic forces can produce the direct removal of organisms from the structures, as it actually happens to green algae stranded during intense storms.

The surveys carried out immediately after the construction of the structures in 1996 showed the presence, after more than 20 years, of the *Hippocampus*, proving that the rocky barrier induces, by improving water oxygenation and quality, a change of assemblages and consequently an increase in biodiversity. A similar case occurred in Ostia, where after the defence intervention and the nourishment (Tomasicchio, 1996) the octopus, another species typical of rocky beds and of good water quality, was found on a naturally sandy beach.

6. Discussion: benefits of an integrated approach

Results presented so far enhance strict relations among hydrodynamics, beach erosion, barrier colonisation and water quality and thus also beach value. These interactions enlighten the importance of an integrated approach to foresee effects of LCS on the littoral environment from a global perspective. Previous sections discussed the main topics but are not exhaustive; others are present and in some cases should be relevant, as, for instance, the risk induced by rip currents on bathers.

In order to achieve an integrated analysis in every day practice, guidelines are necessary that list main problems and tools to solve them, including also some examples.

Under the framework of DELOS, guidelines have been already drafted (Burcharth and Lamberti, 2004) to be appropriate throughout the European Union taking into regard current European Commission policy and directives to promote sustainable development and integrated coastal zone management. The target audience for these guidelines consists of engineers and officials of local authorities promoting coastal protection schemes. It is also of relevance in providing a briefing of current best practice for local and national planning authorities, statutory agencies and other stakeholders in the coastal zone.

The engineering input consists of tools for establishment of design wave climates, selection of types of structures and their lay-out and geometries, structural design with respect to structure stability (armour stability, scour, filter stability), and hydraulic response (wave transmission, internal flow). Further, the local wave field, the currents generated by the structures and the local morphological changes (deposition and erosion around and behind the structures and influence on down-drift coastline developments) are addressed.

Ecological models integrate biological and hydrodynamic data to evaluate different impact scenarios (Martin et al., in press); these scenarios allow to identify characteristics (including breakwater morphology, size, location and distance between the structures) which minimise disruption to coastal assemblages and maximise benefits in terms of production of economically relevant species and/or protection of exploited or endangered species (Airoldi et al., in press; Moschella et al., in press).

The work in the socio-economical field is the final stage of developing criteria to build in and transfer Contingent Valuation monetary values of environmental quality (Polomé et al., in press) into final design guidelines.

Guideline inputs have also been checked through an example application to Lido di Dante as the site appeared in 1994 (Zanuttigh et al., in press) and will be verified in the next future in selected case studies in order to represent a variety of typical cases.

Cross-disciplinary design guidelines are in phase of final revision and will be published in 2005.

7. Conclusions

The presented case of Lido di Dante shows an example of the complex interaction among the beach, the beach defence structures, the biological system and society.

The defence structure built by the local authority was positively valued by beach users, justifying indirectly the investment made.

Current circulation around the structures is active and complicated, causing a strong mixing of water, erosion near the roundheads and apparently a positive effect on water quality.

Currents induced at the Southern gap were underestimated at design phase and caused severe loss of nourishment sand; after closing the Southern gap, the beach condition seems more stable.

Current hydrodynamics is not always easily predictable and hydro-morphodynamic models, which appear to be essential tools both in the design and in the analysis of coast evolution, may require to be verified with field measurements and calibrated in similar conditions to allow the extrapolation of results to other cases.

Hydrodynamics strongly affects barrier colonisation by conditioning feeding process and removing organisms under extreme conditions; in order to quantify these effects, threshold loads for the different components of epibiota have to be evaluated.

The rocky barrier is the support for active and rich biological assemblage, which enhances water filtration, and induces a change of assemblages in the area, increasing biodiversity of the littoral zone.

A strict relation among wave climate, beach erosion, habitat changes and beach value exists, as it is clear from results obtained in Lido di Dante, and suggests the necessity of integrated approaches and thus the relevance of design guidelines for LCS (to be delivered by DELOS staff within 2004), covering: structure stability and construction problems, hydro and morphodynamic effects, environmental effects (colonisation of the structure and water quality), and societal and economic impacts (recreational benefits, swimming safety, beach quality).

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