Foreword

RES MAR "Coastal erosion monitoring - A network of regional observatories" is the natural sequel to previous results on beach erosion monitoring published in 2008 within Project *BEACHMED-e - Strategic management of beach protection measures for the sustainable development of Mediterranean coastal areas* (INTERREG IIIC Regional Framework Operation). Operation BEACHMED-e (October 2005 - June 2008) has been signalled by the European Commission DG Regional Policy as an "example of project covering relevant aspects of risk reduction and adaptation to climate change" (July 2007), within the initiative Regions for Economic Change (Theme 4.1 Coastal zones management).

RES MAR "Network for Environmental Protection in Maritime Space" (June 2010 – June 2013) is a Strategic Project, funded by the "Italy-France Maritime" cross-border co-operation Operational Programme. The programme has been designed to improve monitoring systems, risk prevention, management of environmental issues and emergencies, and mitigation of oil and water pollution in the cross-border space of co-operation between France and Italy. It is composed of seven sub-projects and system actions designed to generate the best cross-border strategies for environmental protection in relation to water and soil.

Coastal erosion and the state of coastlines are treated primarily in system action A and sub-project B, which include activities such as:

- The creation by cross-border regions Corsica, Liguria, Tuscany and Sardinia of a coastal erosion monitoring network with a strategic view,;
- The feasibility of establishing a cross-border centre for the study of coastal morphodynamics.

The publication of this book is contemporary with the official signing ceremony of the latest version of the Bologna Charter (BC 2012) *European Regions Charter for the promotion of a common framework for strategic actions aimed at the protection and sustainable development of the Mediterranean coastal areas*. Drawing from the experience acquired in the framework of the BEACHMED projects and European partnership, one of the main objectives of the Charter consists in establishing a network of existing coastal Observatories - EURIOMCODE proposal initiative (European Interregional Observatory for Mediterranean Coastal Defence). Such observatories will have the purpose of identifying common standards in coastal survey activities harmonised with the INSPIRE Directive; analysing coastal morphodynamics in the Mediterranean; sharing monitoring services; and finding a common structure consistent with the principles of cost-effectiveness and efficiency, to suit the participant Public Administration bodies. In addition, and if needed at local and regional level, the initiative shall promote the establishment of specific structures for coastal monitoring, management of coastal zone risks and erosion phenomena, implementation of defence interventions and management of sediment stocks in coastal areas.

With further relevance to the monitoring and observation mechanisms and networks, Article 16 of *The Protocol on Integrated Coastal Zone Management in the Mediterranean* (effective 24 March, 2011) states that "the Parties shall use and strengthen existing appropriate mechanisms for monitoring and observation, or create new ones if necessary. They shall also prepare and regularly update national inventories of coastal zones which should cover, to the extent possible, information on resources and activities, as well as on institutions, legislation and planning that may influence coastal zones".

One of the key aims of this book is to underline the importance of monitoring and networks aimed at a proactive and adaptive defence strategy for a resilient coastal zone. It urges all of us to understand and work in line with physical processes in order not to do today anything that could hinder future strategies and solutions.

For this reason, and in alignment with the EUROSION and OURCOAST initiatives, we are planning the following steps:

- Joining *The European Dune Network - Sharing experience across borders*, which aims at increasing knowledge and understanding of coastal dunes and promoting the sustainable use and management of coastal dunes in Europe.
- Implementing project-clustering initiatives like FACECOAST - *Face the challenge of climate change in the Mediterranean coastal zones*, launched within the Capitalisation process started by the European MED Programme, in order to strengthen cooperation among Regions, coastal administration bodies, universities and other stakeholders, thus maximising results and favouring potential synergies.

The partners of several European projects and initiative,- including RES MAR - gathered on 26 September 2012 at a joint meeting organised by the PAP RAC in Split, back-to-back with the Mediterranean 2012 Coast Day celebration. The objective of the gathering was to share information and achieve co-ordination of activities and exchange of project outputs so as to create better synergies and alignment among the major ongoing projects for the implementation of the Mediterranean ICZM Protocol, A joint declaration was agreed as follows: "Partners of the projects shall strive to upgrade the level of the existing co-operation and explore fields in which co-operation can be additionally established to facilitate the achievement of the common objectives of sustainable development of coastal zones. In addition, we shall work to enhance the existing networks and search for new possibilities to foster co-operation".

I sincerely hope that this book may present a "good practice" enabling us to share knowledge with the scientific and civil communities and increase our awareness of the actual state of the coastal zone for a better and wiser use of the territory in the future. It has been a great opportunity to edit this book and share experiences with international coastal experts and new partners in the Mediterranean, in particular with cross-border Corsica, in light of the future co-operation opportunities in the field of coastal morphodynamics monitoring arising from the new project RESMARINE “Réseau transfrontalier pour la Stratégie Marine” within the “Italy-France Maritime” cross-border co-operation Operational Programme.

In line with the results presented in this book, future efforts in the implementation of the post-2013 Multiannual Financial Framework should focus chiefly on the promotion of a network of observatories across the Mediterranean and support the creation and maintenance of monitoring strategies in coastal areas with a macro-regional approach.

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The role of coastal evolution monitoring

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Introduction

The coastal zone has long been attractive to men: this area concentrates better economic, social and recreational opportunities than does the hinterland (Goldberg, 1994), in spite of presenting higher risk of subsidence, tsunami, sea storms, flooding and coastal erosion (Nicholls, 2002). This pattern is a reality also in Italy, as shown by the percentage of coastal soil currently in use and the growing occupation of coastal areas in the past years.

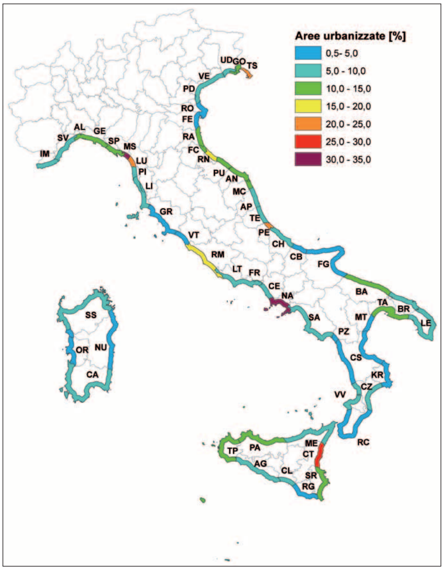


Figure 1 - Percentage of urbanised soil within 10 km from shoreline; representation at Provincia level (2006). Data processing by ISPRA (data from Lacoast Project, CLC 2006 Project and national soil usage monitoring network (ISPRA, 2010).

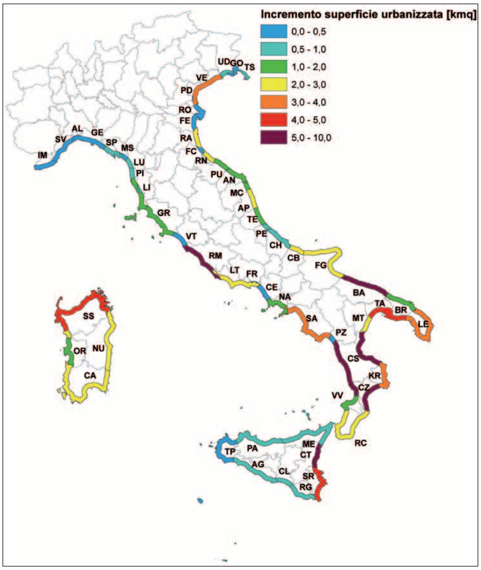


Figure 2 - Increase in urbanised surface between 2000 and 2006 within 10 km from shoreline. Data processing by ISPRA (data from Lacoast Project, CLC 2006 Project and national soil usage monitoring network (ISPRA, 2010).

Migration from the hinterland towards the coast and the development of coastal protection structures (both processes being cause and effect of one another) started in Italy after

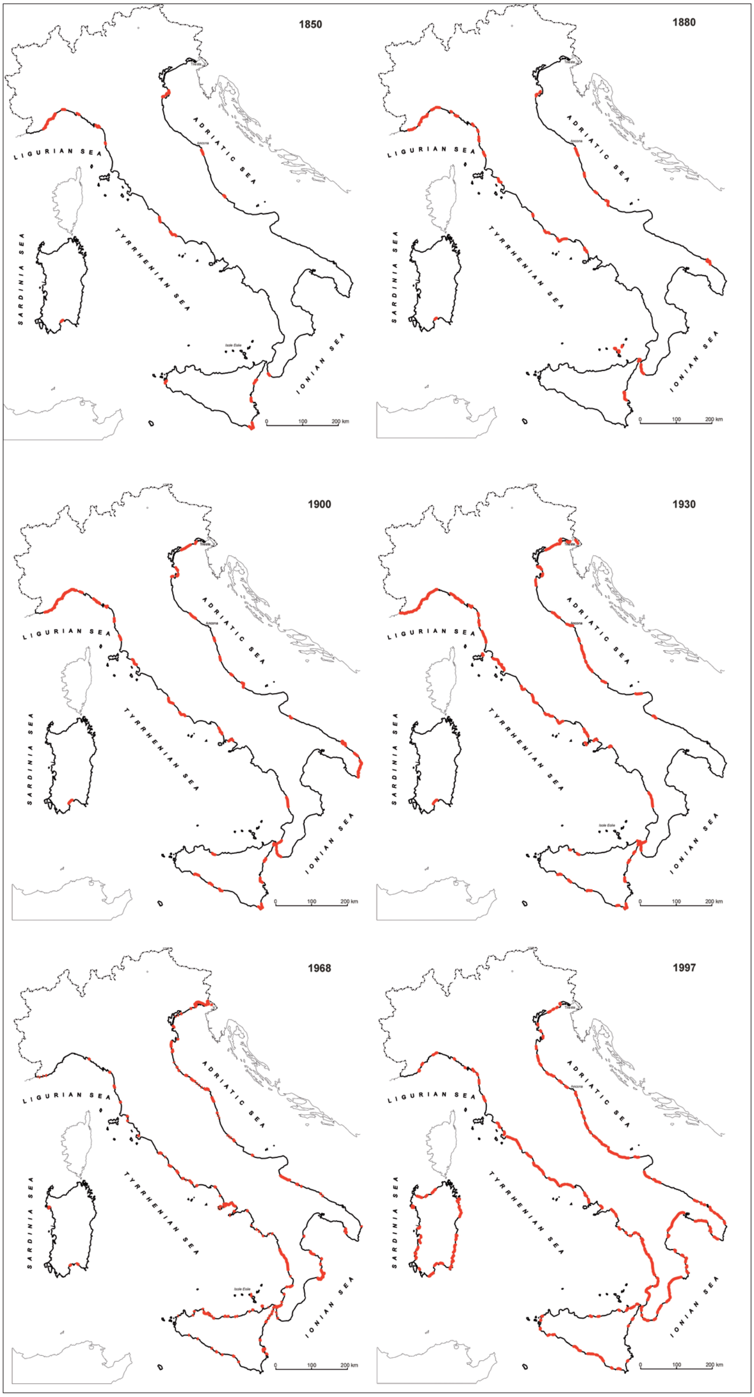


Figure 3 - Coastal erosion in Italy between 1859 and 1997 (Pranzini, 2013; data from Albani, 1933; De Marchi, 1968; CNR, 1997).

the mid 1800's, which coincides with the period when the effects of coastal erosion also began to be felt.
The analysis of Italian coasts shows that erosion started to develop first on the northern shores, then proceeding onto central and southern parts of the coast, following to a certain extent the country's economic and social development (Fig. 3).

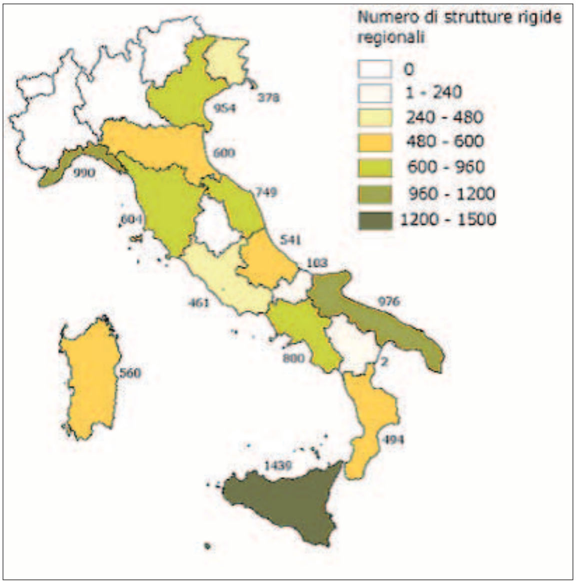


Figure 4 - Distribution of coastal defence and port works, per region (ISPRA, 2009).

Erosion processes progressed onto densely populated parts of the coast, where tourism interests are high, followed by the development of coastal defence structures (Fig. 4) and beach nourishment projects. Knowledge on the current status and evolution trends of the coast became thus became a key issue for public administration, private businesses and users in general.

Coastal monitoring therefore became an important and functional activity, essential to coastal planning and management. In spite of that, monitoring often lacks standardised procedures and is frequently based on a time scale that is not compatible with the processes under act, failing to provide information that can effectively support decision-making.

Need for standardisation

Although each coastal section – and each process responsible for shaping it – requires specific procedures for surveying and for data analysis, minimum requirements for measurement accuracy and operation time scales must be set. This shall lead to a homogeneous level of knowledge, which will make data comparison and transfer/exchange of project and management experiences more effective. Up to date, it has not yet been possible to reach a minimum level of homogeneity in the information obtained, as one can see from data published by many parties involved in data acquisition and the study of coastal evolution trends.

Table 1 presents the percentage of beaches undergoing erosion in each of the Italian regions, according to data published by GNRAC in 2006 and by ISPRA in 2010. The total length of the beaches present in each region differs significantly; in addition, percentages of erosion and accretion seem in some cases to refer to different realities. How could one explain 2% (GNRAC) against 26.6% (ISPRA) erosion in Friuli? In fact, data in these reports originate from different data processing: ISPRA report considered beaches that have retreated at least 25 m in the past 50 years, using a digital database elaborated over shorelines extracted from IGM 1:25.000 scale maps (from different periods) and from 2004 aerial photographs. GNRAC, on the other hand, performed a survey using heterogeneous data, though conducted by a body of 41 expert researches from the different regions involved. Two different scenes emerge from this, and it is evident that the reality described by each of them would imply different policies, strategies and even financing approaches.

Table 1 - Percentage of sandy shores undergoing erosion in each Region, according to GNRAC and ISPRA sources

Region	GNRAC 2006 (% on 3612 km)	ISPRA 2010 (% on 4863 km)
Liguria	84	19.9
Toscana	36	21.3
Lazio	33	23.3
Campania	27	24.7
Calabria	43	32.7
Sicilia	40	28.3
Sardegna	23	13.6
Basilicata	73	38.1
Puglia	48	18.5
Abruzzo	29	28.3
Molise	29	34.7
Marche	35	38.8
Emilia Romagna	10	25.3
Veneto	9	21.0
Friuli	2	26.6
Italia	36	24.1

Most often, the timeframe analysed is rather non-homogeneous: in some situations, historical trends (obtained from older geodetic maps and from confrontation with recent maps at scales that are often different) are compared to variations obtained from shoreline surveys performed in a few years' time interval; in others, information obtained from instant surveys is used - which can be effective in showing certain processes (such as beach dune scarping) but is inappropriate for well-defined evolution dynamics.
If evolution trends are linear, this would not represent a relevant issue, but in most of the cases they are not linear and may even present inversions. Therefore, coastal sections considered to be stable from such data confrontation analyses could now be under erosion after an accretion phase, or vice-versa. One should consider that erosion in Italy began in the second half of the 1800's and had a peak after the end of WWI, after which it started to be counteracted by a series of watershed management measures and the construction of coastal defence structures.
The reduction in the number of coastal sections under erosion in northern Italy, such as in Liguria between 1930 and 1968 (Fig. 3), results from of the construction of coastal structures. That is why evolution trends based on long time period intervals can be highly

misleading; on the other hand, the analysis performed over a short timeframe can be too sensitive to the most recent changes, which could have not yet been consolidated.
Another problem refers to the type of calculations used in the evaluation of shoreline displacement: in some cases, measures from different parallel transects are used, whereas in others changes in beach area divided by shore length at a certain section are considered.
A recent study (Pranzini and Simonetti, 2008) has shown how the analysis of shoreline displacement based on beach area variation at each section (Surface Variation Analysis/SVA) and that based on transects (Transect Based Analysis/TBA) can produce results that differ significantly (Fig. 5).

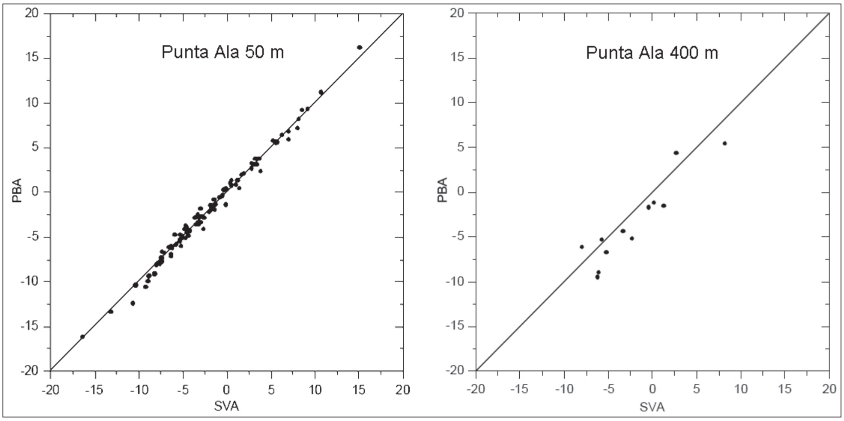


Figure 5 - Comparison between shoreline position displacement using SVA and TBA for sectors 50 m wide (left) and 400 m wide (right). Displacement of median points indicates the magnitude of differences between measurements obtained in different coastal sections.

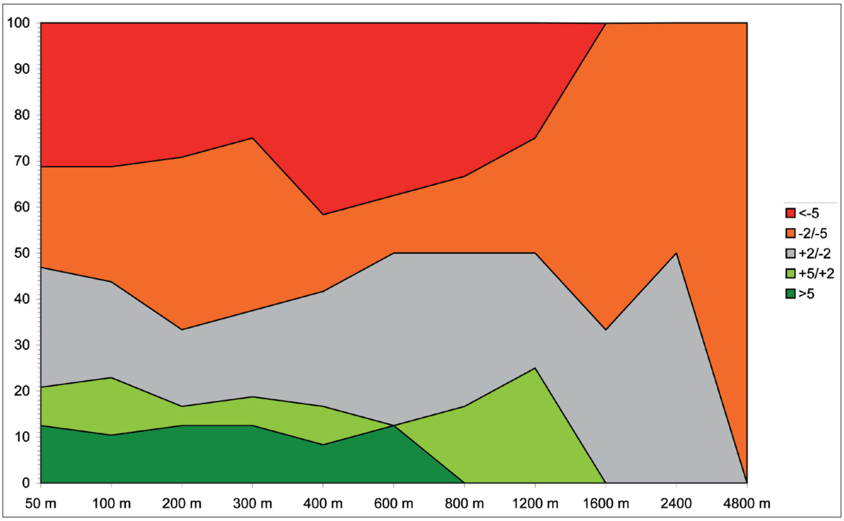


Figure 6 - Follonica coast: frequency of classes of shoreline position displacement between 2000 and 2005 according to different sector lengths (Pranzini and Simonetti, 2008).

Differences become relevant when the shoreline is not straight due to the presence of natural irregularities (rhythmic or non-rhythmic patterns) or coastal morphology induced by coastal defence structures.

In average, SVA and TBA data correlation decreases as section length and distance between transects increase, but there is not a precise trend due to random distribution and the dimensions of the different irregularities.
Different results can be obtained when unequal transect spacing or section lengths are used (Fig. 6). This is particularly evident on coasts that are characterised by the presence of mega-cusps, whose migration can lead to the conclusion that half the littoral is under accretion and half under erosion. Similarly, shoreline rotation in a pocket beach could be read as stability of the whole beach, but could also be read as erosion of 50% of the coast.

Shoreline proxies
One of the main problems in coastal evolution monitoring concerns the indicator chosen for evaluating the process, a subject recently considered by Milli and Surace (2011). A shoreline indicator is a feature used as a proxy to represent the "true position" of the shoreline (Boak and Turner, 2005). A wide variety of indicators, or proxies, can be found in literature, but unfortunately the ones that can be most easily identified are also the ones that are less accurate.

Proxies mostly used are instantaneous water line, high water line, vegetation or debris line, and seaward dune edge (Fig. 7).

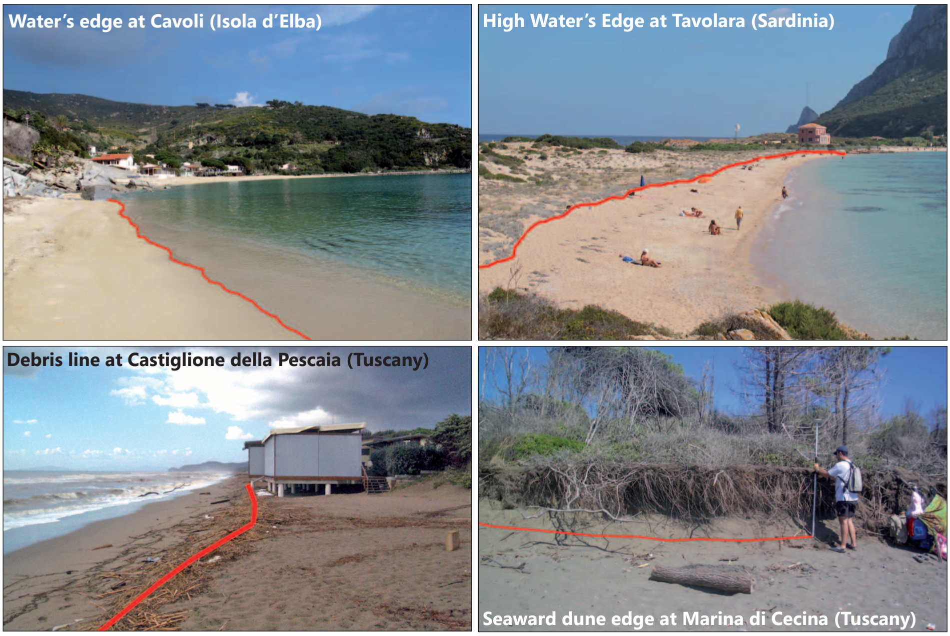


Figure 7 - Different proxis for shoreline position

Shoreline evolution monitoring along the Tuscan coasts has been based on the zero isobath, frequently considering its displacement for the past 10 - 15 years. Isobaths are elements that cannot be easily identified in situ, but which can be defined. In this case determination is not influenced by the instant sea level.
The zero isobath as defined above can be found - and usually is - under or above the instant sea level (Fig. 8). This shoreline position is certainly subject to variability at high, medium and low frequency; this should be taken into account if long term trends are to be described. However, its position does not depend on the conditions under which survey is performed, but relies solely on coastal sediment budget and beach morphology. Even if it is not an absolute reference for the "health status" of the coast, it can be considered to be independent from other variables that are not strictly linked to sediment budget.

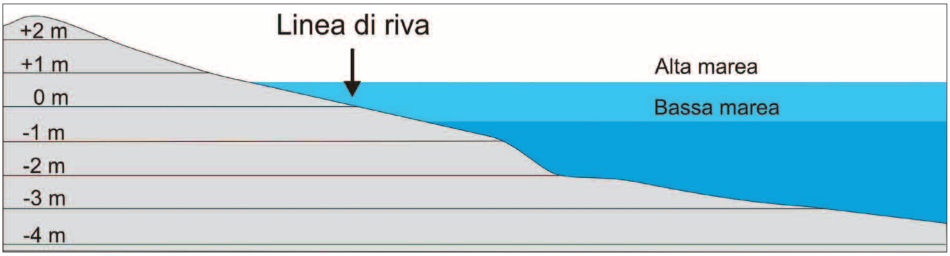


Figure 8 - Identification of shoreline position using zero isobath.

The use of a RTK mode GPS is required for the identification of shoreline position; it is also necessary to obtain the x, y coordinate points (Lat., Long.) at the exact moment when the quote zero is read by the instrument (taking the reference ellipsoid into account).
Whenever traditional instruments are used, points should be acquired in pairs, placed above and below the zero isobath. Shoreline position will then be obtained through linear interpolation of these pairs; this is valid considering the hypothesis of the swash being a sloped plan surface (which is true in a first approach) (Fig. 9).

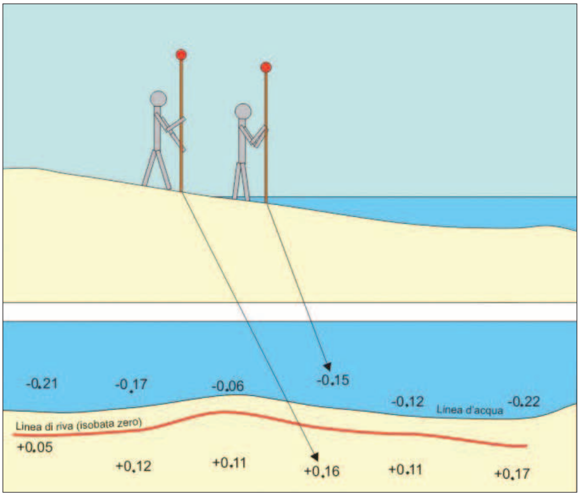


Figure 9 - Shoreline drawn using interpolation of points measured above and below chart datum.

In both cases survey is performed as if the sea did not exist; in theory, one could use any other isobath as an indicator, such as + 1m or – 2m. The zero isobath is chosen only because of its position adjacent the end of the dry beach.
Each proxy gives different assessments of shoreline evolution (Fig. 10) and the rationale of each must be carefully considered.

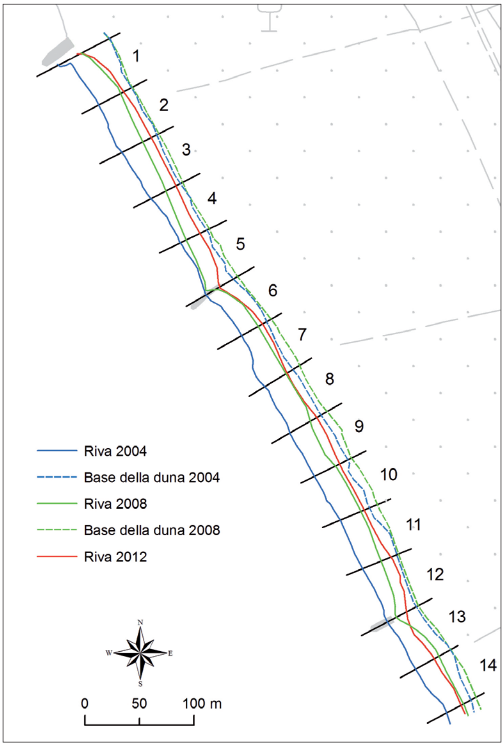


Figure 10 - Displacement of shoreline and dune toe positions south of Marina di Cecina from 1999 to 2008 (Pranzini and Vitale, in progress).

Rationale of beach monitoring

Survey of the dry beach

Acquisition of shoreline position is not the only topographic operation conducted on the dry beach. It is important that other points are acquired in order to reconstruct the surface and calculate the volume of sediments placed above sea level.

Other morphological elements can provide useful information on coastal processes, such as the storm crest elevation, somehow representative of the wave energy reaching each segment of the beach (see Fig. 6.2).

Transects surveyed on the swash line are extended to the upper parts of the beach, up to the dune toe or the first wall, road or other built elements. Extending the profile over the whole dune system is indicated in case of long term monitoring, even if not in every single shoreline position survey. If beach is under erosion, the whole dune system undergoing this process should be surveyed.

If a survey is conducted point by point, the pole should be positioned in each slope break of the profile, being careful not to stick the base in the sand. Minor forms, such as ripple marks, should be filtered, which is possible if the rod has a flat base of about 10 cm diameter; in this case a slight pressure should be made in order to flatten the 2 or 3 sand ripples intercepted.

In cases when survey is extended to the nearshore, using single beam equipment, survey lines will be placed as an extension of those on the berm. This determines transversal oversampling on both parts of the beach when compared to longitudinal sampling, which makes interpolation between points and the creation of a Digital Terrain Model (DTM) a very complex issue. Nevertheless, most morphological features in the dry beach – and, as seen below, also on the nearshore – present transversal development mainly; cross-shore variability is therefore higher than changes that are observed alongshore. The different point densities in these directions are more an issue of theoretical interpolation than substantial problems of form definition.

Whenever high density of points is acquired on the seafloor (by multibeam) reaching a similar detail on the subaerial beach becomes a hard task, unless a different technique is used (such as Laserscan, airborne Lidar or photogrammetric techniques). The use of multibeam alone therefore may not present an optimal cost-benefit ratio, except when the whole coastal monitoring framework is taken into account.

Nearshore survey

The beach is a sedimentary body that extends from the dune toe to the closure depth (beyond which morphological variations are insignificant as the wave energy does not produce substantial sediment transport; Fig. 11). Variations in the volume of this deposit are of most interest to those in charge of coastal monitoring. That is due to the fact that the material that remains in this area may return to shore, and also because bathymetric variations in the nearshore may induce variations in shoaling and thus on the wave energy reaching the shore. This is the reason why the sole analysis of shoreline position displacement is not able to provide an evaluation of the real "health status" of the coast.

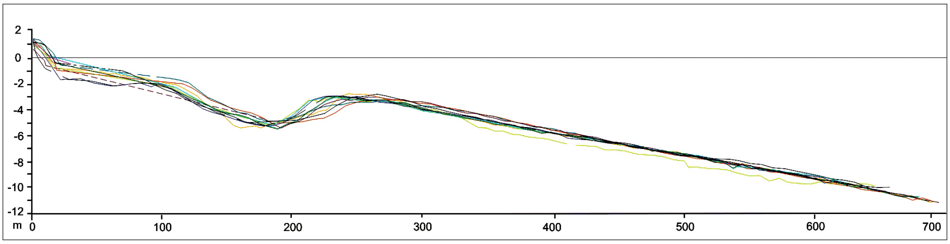


Figure 11 - Bathymetric profiles acquired along the same line over 11 consecutive years (courtesy of ENEL)

However, as will be seen below, the accuracy of bathymetric data is not good enough to allow for the calculation of a reliable sediment budget on short and medium terms – when volumetric variations divided by the surface analysed are smaller than survey accuracy.
We will not detail the varying existing survey instruments and technologies at this point; however, other than the traditional single beam surveys, we can point to other techniques often used today: multibeam, interferometer and Lidar surveys, not to mention the unrivalled beach sled and its own technological evolutions into mobile structures (Fig. 12 and 13).

Figure 12 - Beach profiling sled (Ocean Survey, Inc.)

Figure 13 - Coastal Research Amphibious Buggy (CRAB) used for beach profile measurements at the U.S. Army Corps of Engineers Field Research Facility, Duck, North Carolina

Beach sled is probably the technique with the most adequate accuracy for sediment budget studies, especially under the presence of waves; however, it is not used in Italy and in spite of being an extremely simple instrument, it faces some operational problems.

Defining a monitoring program

The role of coastal evolution monitoring is to forecast the future status of the coast, under natural conditions or following the implementation of coastal protection works. However, it is essential to know the history of the coastal section to be monitored in order to verify if interventions in act have altered past trends – and to what extent.

Data used in this historical analysis are not usually obtained for the scope of monitoring, and should normally be recovered from documents that were produced in different contexts, casual timeframes and often unknown accuracy.

Topographic maps, aerial photographs taken at unknown oceanographic conditions, cadastral maps not aimed at delimiting the coast, and scientific studies developed for a wide myriad of objectives: these are all valuable and irreplaceable sources of information, but they are certainly not structured in the most appropriate form as required for shoreline positioning.

Linking old to new data may show "jumps" in evolution trends, of arguable existence. Today the use of Geographic Information Systems (GIS) has speeded and simplified data recording, sorting and querying.

The definition of a new monitoring plan should therefore be able to extract data from preceding data typologies, preparing them to be imported into a future database.

It is necessary to identify the most appropriate survey and data analysis methodologies; caution should be taken not to oversample (space-wise and time-wise), which would bring unnecessary extra costs to monitoring. This is the most difficult part of the operation: a larger amount of data certainly contributes to a better description of phenomena, but long-term economic sustainability, especially when a project has already reached its final phase, could make it unsuitable.

That is why the cost of procedures becomes a crucial element in defining a monitoring plan. In fact, the high frequency of surveys required for short or medium term monitoring, and the possibility of eventually extending it in time, make it necessary to use a net of low frequency surveys, whereas the analysis of specific structure impacts requires data of high density, both in terms of space (microvariations in seabottom) and time (response to specific oceanographic events).

The system should therefore permit acquisition of data in the timeframe expected or determined by events, without incurring in high mob-demob costs or waiting for specific environmental conditions (e.g., water transparency, as required for Lidar).

Data accuracy, especially in the case of altimetry, is essential for calculating beach sediment budget, its variation along time and, often, for dispersion studies that take into account sediments entering the costal system in an artificial manner. One should note that an error of 10 cm in quote, and thus up to 20 cm when comparing data, implies an error of 200 m3/m in beach volume if the closure depth is located at 1 km offshore. This volume may be comparable to that of a small artificial beach nourishment project.

An issue that should not be overseen refers to the fact that accuracy is a problem of data repeatability. Conformity to international standards such as those from IHO (Internation-

al Hydrographic Organization) should ensure that predetermined limits are followed. The use of Ground Control Points (GCP) can be of immense value in order to obtain accurate topographic positioning when surveys are repeated.
Minor methodological variations regarding instruments or methods of data acquisition and processing, often seen among different companies or operators, have been seen to lead to consistent differences in final data. As a rule-of-thumb, one should favour repetition of surveys under the most homogeneous conditions possible.
Time variability on coastal environments requires surveys to be fast enough to be considered as synoptic, especially if conducted in periods of frequent storms. Should one survey be interrupted and then resumed after a sea storm, data acquisition should start from the very beginning again, to avoid the use of data referring to different oceanographic conditions in the same coastal segment.
Celerity is often also necessary for data elaboration: it may be required for decision-making in the different phases of the project, or when topographic surveys need to be followed by other field activities. Sediment sampling at specific coastal features (such as submerged bars) must be preceded by a topographic survey, but sampling should be carried before oceanographic conditions change.
When monitoring focuses on the evaluation of beach response to defence interventions, both hard and soft, it is opportune to know the initial conditions, which is not an easy task due to inner system variability.
At the "zero moment" of monitoring, beach survey is not able to identify the dynamics that will act on top of processes induced by the intervention and which could jeopardise the correct interpretation of data and evaluation of intervention efficacy. When an intervention is planned for a site where only long-term trends are known (and not short-term trends, such as seasonal) monitoring should begin well before the first works start, allowing the inner system variability to be identified upfront.
Long-term monitoring, aimed at the identification of evolution trends, and thus at the planning of shore protection projects, should consider the whole physiographic unit, so that dynamics under act are well understood and eventual downdrift effects are evaluated ahead.
Whenever monitoring is carried with the scope of evaluating coastal structure impacts (usually commercial ports or recreational marinas), surveys should have as study area a length of coast of at least one magnitude order higher than that of the structure, since the instant structure impact on coastal processes develops for a beach length between 1 and 3 times the largest dimension of the structure.
In fact, the impact of the structure may first affect first the sediment dynamics of the beach segment immediately downdrift (and in cases also updrift, as demonstrated by Cappietti et al., 2003, for the port of Livorno). However it may progressively extend to the whole physiographic unit.
With regard to the positive and eventually negative effects of coastal defence structures, the beach segment to be analysed in detail may be reduced in length, though one should evaluate the impacts on the whole physiographic unit by means of long-term monitoring.

The available planimetric accuracy for surveys today is a few centimetres; lower accuracy

makes it impossible to discriminate morphological features such as shoreline, dune crest, etc). Due to the limited relief energy of the beach, with the exception of dune areas, an error in point position of 1 ÷ 10 cm does not cause relevant deformations or inaccurate estimations of beach sediment volumes.
A more important issue, as seen above, is the problem of altimetric measurement accuracy. If the available accuracy of some centimetres is acceptable for the subaerial beach (below micromorphological beach features as ripple-marks), on the other hand accuracy for seafloor surveys is of 5 – 10 cm.

Extension of area to be monitored
To calculate sediment budget for a certain beach, the observation area should extend from the inner primary dune toe to the depth of closure.
Due to the limited accuracy of bathymetric data and the rather limited value of morphological variations in deeper waters (which could be resolved by using more expensive technologies), the rapport between fictitious and real variations increases as the study area extends onto the offshore. In many cases volumetric variations recorded on areas that extend significantly onto the offshore are much larger than those in the nearshore: an "apparent" negative sediment budget may be recorded after an artificial beach nourishment of modest proportions.
It is evident though that for long–term monitoring plans one must overpass the depth of closure calculated according to the significant wave height exceeded 12 hours per year, and use estimations for longer periods (over a decade; Tab. 2).

Table 2 - Closure depth calculated for 1992-2004 period (De Filippi et al., 2009)

FOCE MAGRA	**dcma [m]**	**3: SUD**	**11,4**	**2: Madonna delle Grazie E**	**6,2**
1: foce Magra	8,3	TOMBOLO DI CECINA		3: Tombolo di C. Regio N	9,8
2: EST foce Magra	9,8	1: NORD	11,7	4: Tombolo di C. Regio Centro	9,8
3: CENTRO	13,5	2: SUD	11,7	5: Tombolo di C. Regio SUD	9,8
4: porto di Carrara NORD	13,5	MARINA DI BIBBONA		6: foce Albegna NORD	9,8
M.CARRARA		1: NORD	11,9	7: foce Albegna SUD	9,8
1: NORD	13,5	2: CENTRO	11,9	8: Tombolo della Giannella	9,8
2: SUD	13,5	3: SUD	11,9	9: S.Liberata NORD	9,5
M. MASSA		TOMBOLO DI BOLGHERI		10: S.Liberata SUD	9,5
1: Marina di Ronchi NORD	13,5	1: NORD	12,0	CALA GALERA	5,5
2: Marina di Ronchi SUD	13,5	2: CENTRO	12,0	TOMBOLO DI FENIGLIA	
M.PIETRASANTA		3: SUD	12,0	1	10,1
1: Cinquale	13,5	DONORATICO		2	10,1
2: Forte dei Marmi	13,5	1: NORD	11,5	3	10,1
3: Marina di Pietrasanta N	13,5	2: SUD	11,5	4	10,1
4: Marina di Pietrasanta SUD	13,5	CASTAGNETO CAR-DUCCI		5	10,1
5: Lido di Camaiore NORD	13,5	1: NORD	11,6	6	10,1

6: Lido di Camaiore SUD	13,7	2: SUD	11,7	TAGLIATA-TORBA	
7: porto di Viareggio NORD	13,7	SAN VINCENZO		1	10,5
M.VECCHIANO		1: NORD	11,7	2	10,5
1: porto di Viareggio SUD	13,5	2: SUD	11,7	3	10,5
2: Torre del Lago NORD	13,5	TORRACCIA		4	10,5
3: Torre del Lago SUD	13,5	1: NORD	11,7	5	10,5
4: M.Vecchiano NORD	13,5	2: CENTRO	11,7	6	10,5
5: M.Vecchiano CENTRO	13,7	3: SUD	11,7	7	10,5
6: M.Vecchiano SUD	14,0	BARATTI		ISOLA D'ELBA	
7: foce Morto NORD	14,0	1: NORD	10,3	Biodola	11,2
F.ARNO		2: SUD	7,6	Scaglieri	11,2
1: foce Morto SUD	13,5	FOLLONICA		Schiopparello	7,9
2: Gombo	13,6	1: Torre del Sale	10,6	Magazzini	7,5
3: CENTRO	13,5	2: foce Cornia OVEST	10,6	Bagnaia	7,5
4: fiume Arno NORD	13,5	3: parco della Sterpaia OVEST	10,6	Nisporto	7,5
TIRRENIA		4: parco della Sterpaia EST	10,6	Nisportino	11,5
1: Marina di Pisa NORD	13,7	5: Torre Mozza	10,8	Cavo NORD	8,5
2: Marina di Pisa SUD	13,7	6: Villaggio Svizzero	10,9	Cavo SUD	8,5
3: Tirrenia NORD	13,5	7: Follonica	10,8	Barbarossa	10,6
4: Tirrenia SUD	13,5	8: Puntone	8,3	Naregno	7,9
5: Calambrone NORD	13,7	9: Cala Violina	10,6	Capoliveri OVEST	9,8
6: Calambrone SUD	13,7	10: Punta Ala NORD	9,8	Capoliveri EST	9,8
7: Scolmatore	13,7	11: Punta Ala CENTRO	9,8	Margidore	10,4
ROSIGNANO		12: Punta Ala SUD	9,3	Lacona	10,4
1: NORD	11,8	ROCCHETTE		Marina di Campo	10,6
2: SUD	11,8	1: Roccamare	9,7	Cavoli ovest	8,3
VADA 1 : NORD	11,9	2: foce Tonfone	9,7	Cavoli est	8,3
VADA 2: SUD	11,9	3: C. Pescaia OVEST	9,7	Seccheto	10,8
MAZZANTA		4: C. Pescaia EST	9,7	Fetovaia	12,1
1: NORD	11,9	5: Le Marze	9,7	Sant'Andrea	7,5
2: CENTRO-SUD	11,9	6: Principina	9,7	Spartaia	7,0
3: CENTRO-NORD	11,9	7: foce Ombrone	9,8	Procchio	8,2
4: SUD	11,9	8: Marina di Alberese	9,8	ISOLA DEL GIGLIO	
MARINA DI CECINA		TALAMONE		Cala delle Cannelle	8,5
1: NORD	11,4	1: Madonna delle Grazie W	6,2	Giglio Campese	9,2

The extension of the coastal area to be surveyed becomes thus an inverse function of beach slope. This means that bathymetric surveys for the scope of monitoring will become much more expensive costlier the smaller the beach slope is (Fig. 14), even if it is a fact that some operations are essential to all surveys, regardless how far the survey extends towards offshore.

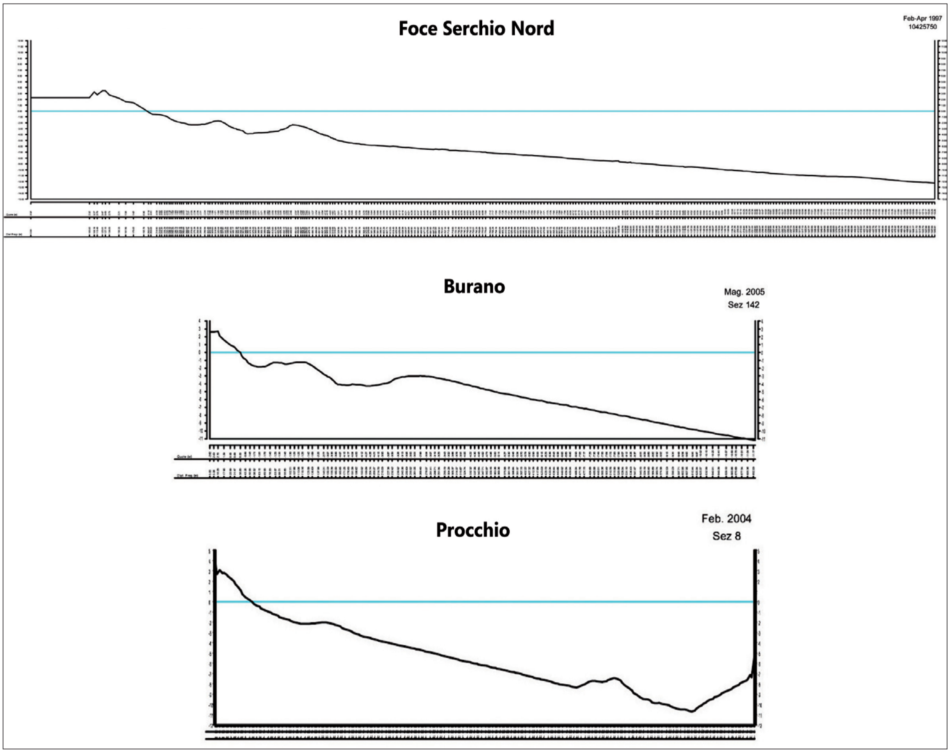


Figure 14 - Profile of three significant sections of the Tuscan coast.

Duration of monitoring

Whereas for long-term monitoring one cannot define a time limit (but only survey frequency), for medium-term monitoring addressing the implementation of a certain defence strategy, or the assessment of efficiency and impact of structures and nourishments, the time involved is relatively short.

In the first case (implementation of defence strategies within the scope of a regional plan rather than urgent interventions) it is understood that data to be collected should be able to represent not only the status at a certain moment, but also the inner beach variability (morphological changes that occur frequently after single storms or periods of extremely variable oceanographic conditions). This is important not only to set an uncertainty value for instant measurements, but also to predict dynamic boundaries within which the shoreline may move in the future (without considering it to be under erosion) so that risk limits for coastal structures may be defined.

In this case, six-monthly measurements along 5 or 10 years would constitute an excellent database for the description of coastal evolution and inner beach variability.

For studies on the efficiency of hard defence structures, one must consider that major variations in beach shape occur after the first sea storms, arriving at structures that are able to modify incident waves (be the works concluded or not). Rather, this is the most delicate phase of the intervention, as the beach is being defended by incomplete structures whose impact (negative or positive) has not been studied during the design phase. If execution of works is not fast enough – and this may happen due to technical, economical or legal problems - littoral response to the first phases of the intervention may be extremely violent and could condition the continuation of works, even imposing technical adaptations to the project (Fig. 15).

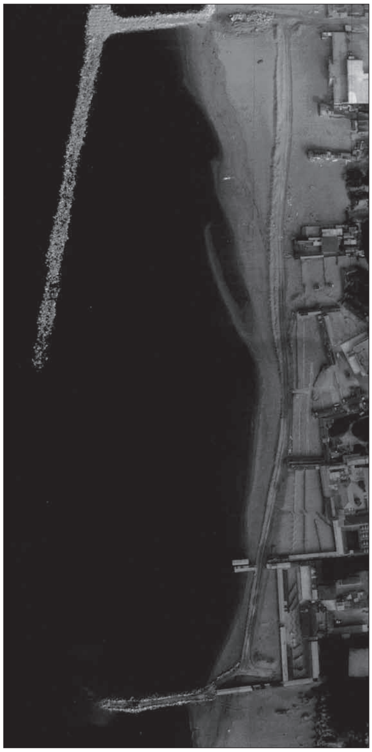


Figure 15 - Above: works executed on 19 05 1999 (Photo: DST-UNIFI archives); Right: structure status on 13 03 2000 (Photo: Corpo delle Capitanerie di Porto, Luni - Sarzana). Although the structure was designed with a submerged crest, it induced changes on beach morphology that had not been predicted by the project.

Although interruptions in the construction of defence structures cannot be foreseen, we can see based on several years' experience that they occur rather frequently, and therefore one should plan intermediate surveys - although hoping never to do them. It may happen that new surveys, not initially planned to be carried within the monitoring plan, become necessary in order to evaluate the effect of extreme storms both over the beach and over the structure itself. It is therefore necessary that resources be allocated for eventual emergency monitoring situations.

5. Shoreline vs. seafloor evolution

Easier access to shoreline and lower survey costs have often led to monitoring being restricted to subaerial beach only, thus covering only a minor part of the coastal system (Fig. 16). In addition, this part of the beach is a visible feature often disputed by stakeholders, and monitoring the shoreline adds a special political interest to this.

Were this feature is a clear indicator of the coastal status, this approach would be reasonable and economically advantageous. However, it would only apply to cases where morphological evolution of the beach meant a parallel displacement of its profile. For that to happen, all events that shape the beach should affect all the section between the dune toe and the depth of closure with the same efficiency for both erosion and deposition processes; in addition, longshore sediment flow should be homogeneous along the whole profile (but different at entrance and exit points of the study area) whereas cross-shore

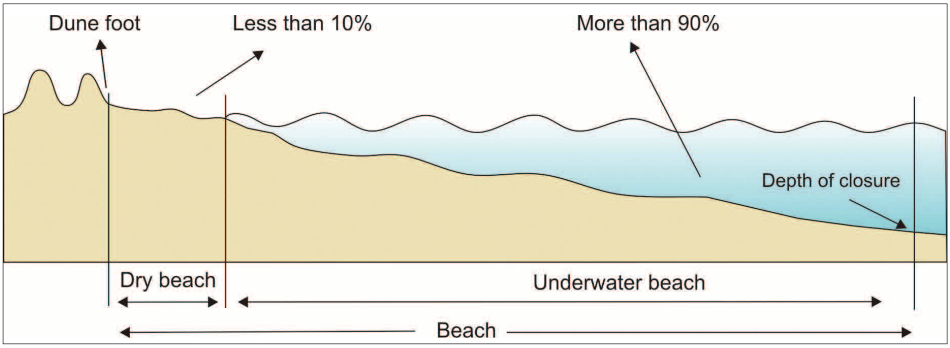


Figure 16 - Sections of the beach subject to monitoring.

sediment flow should be null, to avoid concentrated deposition or erosion at any given point. Sediment texture characteristics should also not change at the different parts of the profile, influencing the slope.

This situation is clearly quite far from reality, especially when monitoring is set to evaluate the stability of artificial nourishments, either distributed along the profile or concentrated on the dry aerial beach (beach nourishment) or on the submerged profile (nearshore nourishment).

Whenever hard structures are later built on the beach, modifying morphology either directly or indirectly, translation of the original profile becomes absolutely impossible.

Therefore, beach evolution monitoring should not be restricted to shoreline position monitoring in all protection projects (both hard and soft strategies). The survey of the whole beach up to closure depth is essential for defining sediment budget and the evolution of coastal defence project efficiency.

When seafloor morphology is under study (with no interest on sediment budget) surveys may be limited to the parts of the profile undergoing morphological changes (such as development, migration or disappearance of bars); this does not refer to the outer parts where evolution implies only minor variations, mostly vertical oscillations.

The coastal response to new defence structures may be indicated by scouring at the toe of structures, increased scouring depth at the head of groins, increased depth in front of detached breakwater gaps, and seaward bar migration. All these elements may be monitored by bathymetric survey methods of moderate accuracy.

Guidelines for coastal monitoring

Based on the theoretical considerations above, and on the experience gained in monitoring natural and structure-induced coastal evolution, a few guidelines can be pointed which could constitute a common ground and thus grant the minimum homogeneity required for comparing results.

Monitoring techniques will not be referred, as data acquired should be independent from the technologies available today. What can maybe be achieved by acoustic multibeam surveys, could in the near future have better quality and be more economic if acquired with Lidar or other techniques still to be developed. Therefore, available methodologies shall not be detailed here but rather introduced in general terms.

Definition of standard techniques could in fact limit research and experimentation of new technologies, as these would be hardly accepted by the public administration if not contemplated in shared protocols.
However, it is necessary to compose a framework of the technologies that are more frequently used in coastal surveys, which makes it possible to understand the criteria proposed and to read example data and images. On the other hand, it is clear that in the future it might be irrelevant to speak of profile spacing should acquisition techniques focus completely on the generation of new points, which would make precision a function of pixel size or resolution cell.
These guidelines will focus on aspects related to data accuracy, their temporal and spatial frequency, modes of processing and comparison, and finally on methods of data interpretation. Due to the issues explained above, "metadata" shall have almost the same value as "data', as different acquisition and analysis procedures may lead to opposite conclusions.
The indications below refer to coastal monitoring focussed on the identification and quantification of morphology and volume variations, to infer the evolution trend and evaluate the efficiency of defence and restoration strategies. Accuracies are suggested according to this understanding.
Higher accuracy in land may be obtained with geodetic instrumentation, which makes survey much slower. Cases of morphology changing during the execution of surveys could then occur, with different parts of the beach profile referring to different oceanographic conditions. In any case a similar accuracy value could be obtained for the submerged part of the beach, which represents the largest beach area as seen.
The scope of this chapter is to present an overview the most problematic aspects of coastal monitoring and indicate major guidelines; readers interested in a more detailed description of instruments and procedures should find it in specific technical literature.
For hydrography, for example, International Hydrographic Organization (IHO) recommendations may be followed (IHO S-44 5th Edition February 2008).

Reference systems

The choice of specific cartographic reference systems for coastal topographic/bathymetric surveys depends usually on each local or regional reality, being determined by the several public administration agencies involved.
Even if different systems are used by countries as their official national datum, GPS technology is leading to a wide use of WGS84 system, in UTM coordinates. This system is based on a network of static points which becomes updated according to Earth surface deformation and has the advantage of having a very precise global datum, free from problems related to local geodetic networks.
A very important aspect of GPS is that many countries today have permanent stations, or rather, a detailed and accurate GPS-based network which provides the necessary corrections in real time and in processing by operators and users of the systems.
The use of permanent stations caused many improvements in GPS system to be developed: through a phone connection, for instance, it is possible to receive corrections in real time and thus work with centimetre accuracy using only one instrument. The continuous increase in the number of cover points makes the creation of local benchmarks along the coast unnecessary and rather superfluous.

In those cases when benchmarks are needed, these should be adequately described and verified.
The above applies to land topography, but not for bathymetry, where reference is usually made to the mean sea level elevation (0.00 m orthometric height). This usually corresponds to a mean value that considers measurements along the years, and is updated by the public agencies concerned.
Conversion between WGS84 coordinates and a specific national or local system (as between ellipsoidal and orthometric heights) may not be performed through the use of a simple mathematical equation. Instead, very complex operations and local parameters are required. Coordinates are obtained searching for the best local correspondence possible between ellipsoid and geoid surfaces, using roto-translation parameters and a scale factor. These parametres can be obtained from calculations that use coordinates of at least three points in both systems. Points should be located at kilometric distance, and on the border of the study area. Parameters however can be easily obtained with the use of specific software, such as "Verto" by Istituto Geografico Militare Italiano.
When WGS84 planimetric coordinates are used to calculate the orthometric height only, it is necessary to know the difference between both heights. This value is often available in the internet today, usually provided by services related to a network of permanent stations.

Accuracy

The accuracy desired in each case is a function of the survey and monitoring scope. Millimetre accuracy is required for geodetic positioning, whereas centimetre accuracy is sufficient for volumetric calculations (as for nourishment monitoring, for example). Lower accuracy, especially in position, could reveal to be sufficient for cartographical description of the beach. Usually precision is defined as a function of the scale of maps to be produced, although this has lost some of its significance after the introduction of digital maps and CAD, which give non-dimensional outputs. This is still a valid praxis for clarifying the different requests: for instance, an error of 10 cm may be accepted for 1:500 maps.
In DEM volume difference calculations, for example, simple equations put into evidence how instrument accuracy which determines the precision of model may have a net weight that is smaller regarding the absolute error in altimetric reference; this will also prove to have a larger weight regarding the difference in calculations that are due to the varying section spacing (Aminti, 1999).
In addition to accuracy limitations resulting from instrumental factors, a series of variables that often reduce the quality of the data should be considered, as human error, reference system error, sensor movements, time-latence and off-set errors, etc. This could however be reduced through the adoption of special procedures or instrument calibrations.

Accuracy of planimetric data

Instruments that are available today provide centimetric accuracy with short, concise surveys that are definitely sufficient when coastal morphological variations are taken into account.
It is considered that slopes rarely exceed 4-5% on subaerial beach profile if fine sediments are present, except at erosion steps that may form at the upper swash zone. Therefore, an error of 10 cm in the position of a certain point produces an error of 1 mm in elevation, a value that is well below ripple-mark dimensions. Important scarps form following nourish-

ment when sediments are placed directly onto the subaerial beach, particularly when the level of the area is consistently raised. For gravel beaches, slopes are quite higher, and often reach the sediment angle of repose (and in certain cases even exceed it if grains are flat and imbricated) and reduced planimetric accuracy could lead to more consistent errors when volumes are calculated.
Swash steps may show a difference in level of a few decimetres, but a position error of 10 cm will not represent more than 0.1 m3 per metre of coastline.
For topographic surveys, accuracy should be higher than 3 cm, and not exceed 5 cm in expeditious ones. Such values should be maintained even in surveys of the nearshore beyond the step, as slopes may still be significant.
For hydrographical surveys beyond and along all the submerged profile, planimetric accuracy should be limited to 1 m, considering that the extremely mild slopes in the seafloor determine errors in elevation that are below-ripple mark dimensions. These considerations are valid only for sandy seabeds and single beam surveys.

Accuracy of altimetric data
The monitoring accuracy required for topographic and bathymetric surveys is usually the maximum accuracy that can be obtained from real time instruments (without further data processing): for both GPS-RTK and professional echosounders, this means a few centimetres. However, accuracy may be reduced due to other errors. Even in such a case, the maximum IHO standard indicates uncertainty should not exceed 25 cm of the bathymetric value, which is often halved in the strictest tender technical specifications. In fact, as seen, an error of 10 cm in quote may lead to wrong beach volume calculations, amounting up to the volume of medium-sized artificial nourishments.
To ensure that standards are maintained and that the desired accuracy is respected, bathymetric surveys may even be certified by specific agencies, such as the Italian Navy Hydrographic Institute. Many data processing software provide this type of control automatically.

Characteristics
Monitoring is constituted by a series of surveys, each being characterised by several phases. The main phases are: activity planning; organisation of the field campaign; execution of the survey itself; control of acquired data; processing, restitution and analysis of data.
A survey project should include the acquisition of all useful and necessary information for its development: available maps at different scales (both topographic and nautical, current and historical); satellite imagery; orthophotographs and other similar materials should therefore be obtained.
Existing studies and surveys should also be analysed, field trips should be conducted and a series of restrictions and bureaucratic requirements should be verified in order to accelerate and improve the development of the survey campaign.
The project should then be able to indicate the survey method that is most appropriate according to the desired accuracy, size and characteristics of the zone to be studied in terms of time and costs.

Extension
The analysis of all material available will also allow determining the correct extension of

monitoring areas, which usually coincide with a physiographic unit or the zone of a certain defence structure or nourishment. In such cases longitudinal extension should extend if possible to the whole unit, or at least to a length equal to both sides of the survey area. The cross-shore extension of the beach should extend from the upper limit of the subaerial beach to the closure depth (in Italian beaches, usually around –10 m). Surveys should be extended at least beyond the last bars present (within the most dynamic band of the seafloor).

Survey line spacing

For single beam surveys, spacing between sections depends on the accuracy desired as well as on morphological variability of the seafloor. For detailed surveys, such as those carried with the purpose of volume calculations, sections could be 10 m distant. In some cases, resolution is increased through the use of a net planned with the same distance between points. Shorter distances become inappropriate and favour the use of multibeam for a complete cover of the area. In such cases the survey becomes a function of the density of the produced DTM grid (which can vary from 0.1 x 0.1 m to 2 x 2 m in coastal water surveys). Longer distances between single beam survey sections are used when monitoring should address the morphological description of the seafloor. In these cases (and also according to the extension of the study area) lines up to 250 m distant can be planned, especially if coastal morphology develops mostly "alongshore" (absence of cusps and in the presence of straight bars). It is good practice to repeat surveys using the same distance as previous surveys, unless the scope of monitoring at a given site has changed. Sections extend from the dune toe (or first construction/building) to the depth of closure.

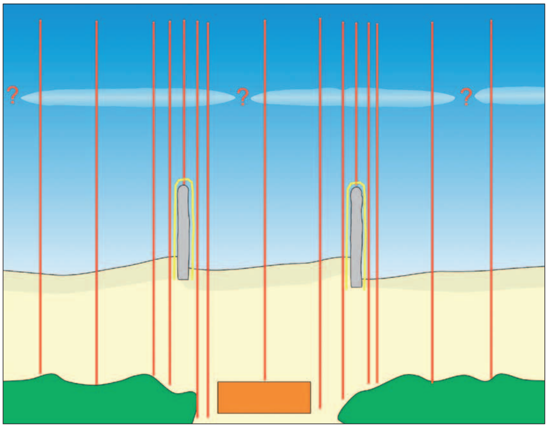


Figure 17 - Number of project survey lines increasing near groins. In this case bar morphology will be continuous.

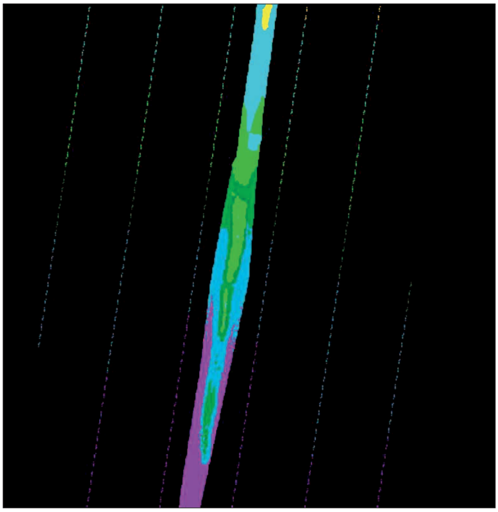
Whenever morphological irregularities or hard defence structures are present, the addition of other sections to monitoring plans is highly recommended to allow for a better description of beach morphology (Fig. 17).

Immediately after the end of the survey planning phase, the following question should be posed: "how will points be interpolated in this zone?" The answer may be difficult, but some aspects that have not yet been exhaustively analysed will then be taken into consideration. In some cases, it might be necessary to include a multibeam survey within the single beam net, so that attention is driven from more homogeneous seafloor sections to an area where structures are able to produce morphological variations at a smaller scale (Fig. 18).

Profile surveys

Figure 18 refers to a section of sandy coast of circa 6 km length, located in Tuscany, Italy. It can be noted how seafloor morphology is well described in the central part of the survey, where sections have been spaced at 25 m, and how it progressively loses detail on the right side (sections at 50 m distance) and even more on the left, where sections are 100 m distant.

On the central part, one can also note more details arising from a multibeam survey of a limited seafloor area, which highlights a submerged groin, built with geocontainers, that is not identifiable by any *discrete* survey.



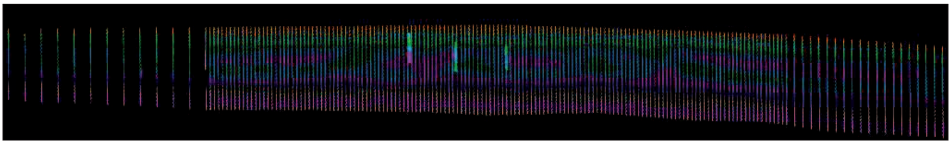


Figure 18 - Multibeam data nested inside a single beam survey in correspondence to a submerged groin.

Survey duration

For single beam surveys, considering the instrument moves at circa 3 knots (circa 5 km/h), for a 1 km long beach with 50 m spaced sections survey will take approximately four hours to be completed.

For multibeam, considering an aperture of 120°, the area of seafloor to be scanned (A) is a function of depth (D) as:

$A= 2(D^* \tan 60°) = D^* 3.46$

This means that the bottom coverage equals circa 3.5 times the depth. We should consider though that in multibeam surveys it is often necessary to obtain an overlap of at least 30%, and thus a good estimate could consider the coverage of the survey area to equal 2.5 times depth.

For example, if a certain coastal monitoring plan establishes that a beach of circa 1 km^2 should be monitored down to 10 m depth, we could simplify the calculations considering an average depth of 5 m, considering that under 2 m it is difficult to operate multibeam instrumentation as it requires the use of boats of a certain minimum tonnage. As surveys are conducted at an average speed of 5 km/h and that in this case spacing of 12.5 m would be acceptable, it can be said that in one hour 62.500 m^2 (5000 m * 12.5 m) of beach can be surveyed. This means that 16 hours (2 working days) will be necessary to survey an area of 1 km^2 (1.000.000 m^2).

As the extension of the scanned area increases with depth when surveys are carried perpendicularly to the shoreline, a few empty spaces will be found near the coast whereas oversampling is expected towards offshore. It is thus more adequate to operate with routes that are parallel to the shoreline, more spaced towards the offshore (for example, 25 m at –10 m) and less spaced near the coast (12.5 m at -5 m, for example).

Frequency

Monitoring campaigns which focus on the study of seafloor morphology should be carried in winter and summer (or, rather, after storm and swell conditions) so that maximum system variations are identified.

It is though not economically possible (and it is scientifically questionable!) to conduct two bathymetric surveys per year in a coastal segment where there are no defence interventions (which could indeed produce fast beach response).

Surveys should be more frequent following the construction of a defence structure or nourishment works. In such cases, monitoring should start before the defence intervention begins to be built. In such manner, the information necessary for the design phase, as well as metric calculations (pre- and post-work) in case of volumetric control, can be acquired. It is often necessary to allocate resources in the plan to cover an eventual repetition of surveys, such as after a severe storm event that can cause significant morphological changes on sandy shores. Shoreline survey can be repeated even more frequently, as they are far cheaper. If pre-existing surveys have been conducted, the new monitoring plan should predict a frequency similar to that of earlier surveys, allowing data to be comparable.

The timeframe of surveys could be defined according to the following:

- 5 years for evaluating the efficiency of a specific defence structure;
- 10 years for executing a coastal defence project;
- 30 years (or longer) for executing a coastal planning project.

Clearly, longer studies need be supported by archive data.

In addition, surveys should consider the wave climate which characterised the study area at the time when survey took place. Data should therefore be obtained from existing wave buoys or inferred from models. In some cases wavemeters can be installed specifically for this purpose.

Once all phases are defined, a schedule should be set for the programmed activities (Tab 3).

Table 3 - Example of monitoring schedule for evaluating the efficiency of a specific coastal defence structure.

	Pre-intervention	End of works	6 months	12 months	18 months	24 months	36 months	60 months
Single beam topographic survey	■	■	■	■	■	■	■	■
Multibeam survey near the structures	■	■				■		■
Laser scanner survey of the structure	■	■				■		■

Methods

A short overview on technologies mostly used in coastal monitoring is given below. Topographic surveys for coastal monitoring usually use GPS (subaerial beach) and single beam echosounder (seafloor). However, new technologies become progressively more used, such as laser scanner or non-conventional photogrammetry (subaerial), satellite imagery and video systems (shoreline), multibeam and interferometres (bathymetric surveys).
Surveys usually focus on the following activities:

- Geodetic positioning and installation of GPS Ground Control Points;
- Installation of vertices of echosounder scanning sections (if required);
- Shoreline position survey;
- Subaerial topographic survey;
- Bathymetric survey.

The major phases of data processing, restitution and graphical presentation are:

- Baseline calculations for static GPS measurements;
- Subaerial GPS relief editing;
- Extraction of digital data and profile restitution;
- Compilation of GPS Ground Control Points identification sheet;
- Elaboration of carthography;
- Illustrated report covering survey modes and processing.

Working procedures

Work methodology for the main activities included in a survey is described below. The final report delivered to the public administration (in Italy, to the Direction of Works/DL) should include indication of instruments used according to the type of survey (positioning system, MRU, data acquisition and navigation system), software used for data acquisition and processing, and tests and calibration procedures applied to the instruments used.
In some cases, before the survey begins, the contractor should present warranty certificates for the instruments used, and must communicate to DL the list of controls followed in laboratory or to be compiled with on board, as well as test and calibration procedures to be followed according to guidelines indicated by the manufacturer and in accordance to the quality procedures of the contractor.
GPS is often used for positioning. Differential double frequency GPS (L1-L2) is used for higher accuracy, with code and phase registration. "On the fly" RTK GPS is also used especially on coastal surveys when differential corrections may be received by GSM or radio. This instrument is able to provide extremely high accuracy values (10 mm + 2 ppm rms in real time and 3 mm + 0.5 ppm rms in static mode).
One GPS instrument is indicated as "Reference" and another as "Rover"; both are linked through a modem radio or GSM. The Reference GPS is left at a benchmark of known coordinates (Fig. 19), described with an accurate datasheet (Fig. 20) while survey is performed using the Rover GPS, which receives coordinate corrections from the first GPS (Fig. 21).
Services provided today by the permanent GPS station networks make it possible to use only one instrument (Rover), as corrections are received via GSM.
In addition to bathymetric and topographic surveys, GPS is often used for positioning known points in static mode, controlled by quotes using Total Station or precision levelling.

This technology has strong advantages: calculation of absolute quotes in real time with centimetre precision; its high acquisition frequency allows automatically correction of all oscillations in sea surface (tide, wave, setup), combining data received from the echo-sounder. There are specific advantages for subaerial surveys as exposed above.
In order to use these functions, it is necessary to perform a coordinate transformation, from WGS84 coordinates (mostly used in satellite technologies) to the desired coordinate system. This requires local transformation parametres to be available. The type of coordinate transformation chosen is important to ensure high precision results are obtained.

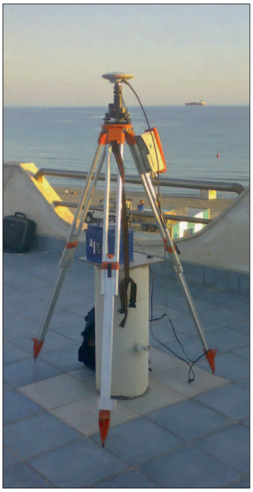
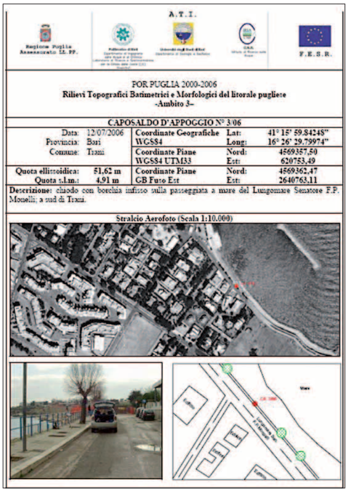


Figure 19 - GPS station on a benchmark.



A.T.I.

Regione Puglia Assessorato LL. PP.

F.E.S.R.

POR PUGLIA 2000-2006
Rilievi Topografici Batimetrici e Morfologici del litorale pugliese
-Ambito 3-

CAPOSALDO D'APPOGGIO N° 3/06

Data:	12/07/2006	Coordinate Geografiche WGS84	Lat:	41° 15' 59.84248"
Provincia:	Bari		Long:	16° 26' 29.79974"
Comune:	Trani	Coordinate Piane WGS84 UTM33	Nord:	4569357,50
			Est:	620753,49
Quota ellissoidica:	51,62 m	Coordinate Piane GB Fuso Est	Nord:	4569362,47
Quota s.l.m.:	4,91 m		Est:	2640763,11

Descrizione: chiodo con borchia infisso sulla passeggiata a mare del Lungomare Senatore F.P. Monelli; a sud di Trani.

Stralcio Aerofoto (Scala 1:10.000)

Figure 20 - GPS benchmark data sheet.

Figure 21 - Operator with a GPS Rover.

Geodetic positioning

To define coordinate transformation in the GPS, a series of points whose coordinates are known in national or regional reference systems are retrieved. Their position is chosen in the way to better delimit the zone under study.
Points that are not marked on the ground are retrieved using GPS static mode after benchmarks from the existing geodetic net.
Geodetic network vertices and support benchmarks should be linked through at least two bases and two points from the network, though it is not necessary to have the exact configuration of a geodetic network.
All measurement sessions shall be performed with double frequency GPS receivers (L1/L2), with sampling interval of usually 10 seconds and a filter over the minimum satellite elevation angle of 15°. This should eliminate satellites that are too low over the horizon and that could reduce precision.
It is a good practice to use at least three receivers, operating simultaneously, to ensure productivity, precision and celerity to operations.
The quote is then corrected from geoid variations, using specific software. Wherever necessary, quotes are also obtained using high precision levelling.

Known points are identified through the insertion of a pin on the ground and are eventually described.
Regarding the implementation of echosounder sections, once coordinates of start point vertices are loaded into the GPS, according to instructions on the palm top, it is possible to retrieve points on the terrain with precision under the centimetre. Once found (using GPS stakeout mode) they can be materialised.

Topographic land survey
Shoreline survey
Shoreline surveys should be performed under calm sea conditions and with a number of points sufficient for their precise configuration. Due to this fact points can be quite distant at straight sectors of the coast, whereas points should be closer at coasts presenting small cusps or salients.
For swash zone surveys, RTK GPS is often used. Here the elevation of the pole base is constantly reported to the operator. The survey is conducted walking along the desired quote, usually the "zero" from the local Datum. In this context, tide levels do not have to be considered.
If RTK mode geodetic GPS instruments are not used (which allow walking along the swash zone, over the correct quote, in real time), the operator should take at least two points, one above and one below the hypothesised shoreline, in order to obtain, with tidal corrections, the effective relative shoreline position, or rather, the ensemble of "zero quote" points.
Alternatively, the shoreline may be surveyed using kinematic GPS. Here two surveys are carried, one during high tide conditions and one during low tide; shoreline position is later identified by interpolation, always hypothesising an intertidal zone of constant slope.

Dry beach survey
All coastal structures and the subaerial beach topography are surveyed along the landward extension of the bathymetric profiles.
Differential GPS is of much help to the operator also in this case. It is possible to download to the palm top the routes of sections to be surveyed. The GPS guides the operator along the route through a graphical interface, indicating also the distance to the off-route. It is thus possible to follow the line and record the (X, Y, Z) coordinates of the points visited. This survey starts at the landward vertex of the section and goes to the first bathymetric quote surveyed by the echosounder, ensuring a complete coverage of the beach. Survey points must be aligned along the project transects corresponding to those at sea, and should be acquired at 5 m spacing maximum (1 m for kinematic survey), with denser coverage at specific points and in case of more berm crests. These should though be surveyed, not only through sections, but also along their contour (Fig. 22). The same should apply to all irregular features whenever these are present.
It is a good practice to give different codes to recorded points that refer to different elements and discontinuities surveyed during the field campaign. Photographs become useful tools for relief reconstruction in the office and visual record of the survey.
Planimetric and altimetric records of storm berm crests are of special interest when surveyed after extreme storm events. They can provide information on extreme run-up values, determined mainly by the existing defence structures rather than by wave characteristics.

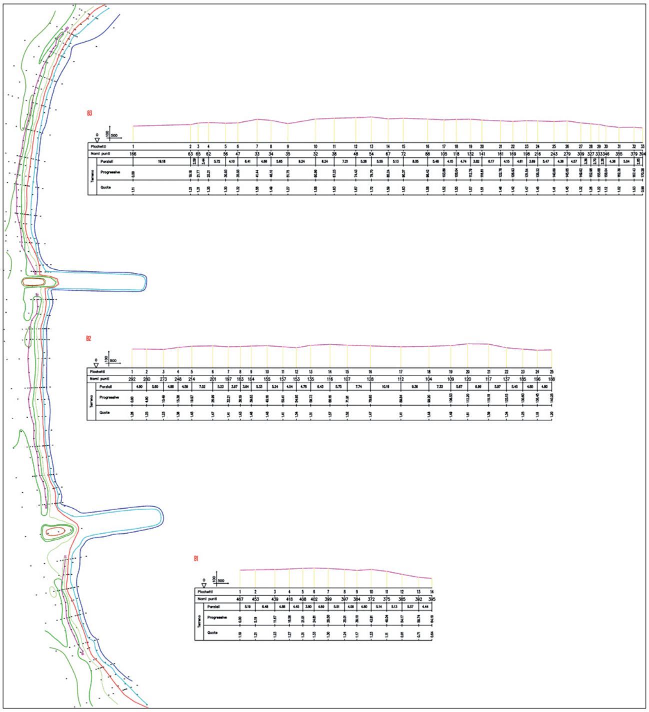


Figure 22 - Cavo (Elba Island - Italy). Survey after a storm event . The berm crest is lower near the groins than in the centre of the beach, where wave energy is higher.

The efficiency of structures can be evaluated from the quote that reaches the berm crest. It is possible to identify points of energy concentration, littoral drift convergence zones, and also overwash fans which may indicate erosion hotspots where coastal areas may be flooded.
For the scope of verifying the congruence of measurements, survey should overlap bathymetric survey for at least 10 m. Wherever this is not planned, it is a good practice to extend the topographic survey to the – 1m quote. This allows identifying the slope and step, where present.
To extend the survey to the wading depth, it is possible to use Total Station and Prism, avoiding risks and water damage to the GPS instrument.

Detailed surveys for structures and beach volume calculation
The presence of artificial structures characterises many shorelines. They may present different typologies, such as groins, submerged breakwaters, protected artificial nourishment, etc. In such cases, a first approach should consider the safety of survey operators and the difficulty in determining stable or reachable positions for land-based topographic operations.
Due to the introduction of measurement systems based on high frequency laser pulses it became possible to take measurements from a distance. In addition to auto-reflective laser total stations, the use of laser scanners has been increasing lately. These instruments allow acquiring thousands of points per second, up to kilometric distances, with precision that equals that of traditional topographic techniques.
In addition to a terrestrial scanner fixed on a tripod, this technology may be transported on board of a plane (Stockdon et al., 2002) or placed on a boat combined, for example, with a multibeam echosounder. This makes it possible to acquire detailed measurements of a structure (both emerged and submerged parts) over large areas and short times (Fig. 23).
Laser scanner has also the advantage of retrieving information on the colour of acquired

points. This method allows high precision monitoring to be performed when traditional topographic techniques cannot be used. Especially when maritime structures are being built, and natural boulders or concrete elements are put into place, only an approximate estimation of the material used can be reached by GPS or total station surveys, since an insufficient number of points is recorded. This is due to intrinsic characteristics of the method and to difficulty in access during the survey.
It has been shown how laser scanner, operating from a distance and potentially measuring millions of points, retrieves the object geometry with high accuracy even for the purpose of precise metric calculations; its combination to a detailed multibeam survey of the near-shore completes reconstruction (Fig. 24).

Figure 23 - Laser scanner survey of a beach (by Geocoste for Politecnico di Bari).

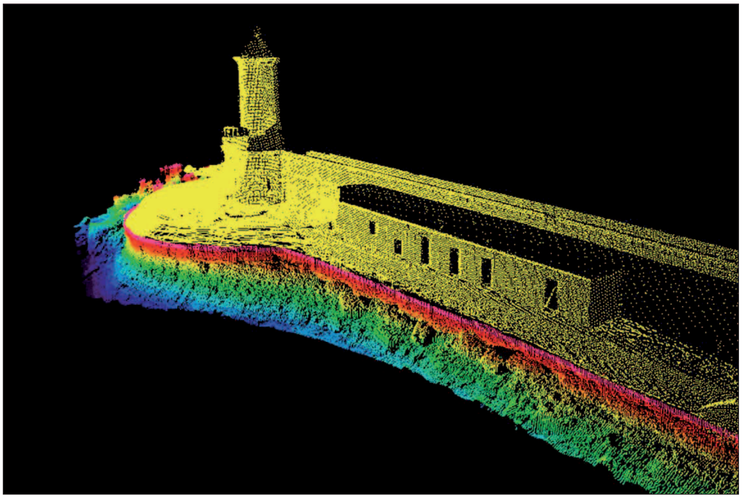


Figure 24 - Laser Scanner and MBES combined surveys.

Results similar to those obtained in laser scanner surveys have been obtained lately with non-conventional photogrammetry. Due to the development of innovative software in the field of digital photogrammetry, it is possible to automatically obtain DTM and DSM models, with the corresponding orthophoto mosaic, at centimetric accuracy. A noticeable advantage is represented by the possibility of using any photo camera, which can be mounted on top of small radio controlled drones, and by the fact it requires very few targets on land (Fig. 25).

Figure 25 - Aerial photographic survey of a port with a small drone (Menci software).

Bathymetric survey

Positioning

In bathymetric surveys, a digital automatic data acquisition system is used, positioning the vessel in real time using GPS technology with coordinate correction by modem radio. This allows the survey to be followed without any need for alignment; neither is it necessary to position at the head of the section which would require instantaneous quote correction.
The “Reference” GPS station is positioned on a benchmark whereas the “Rover” is placed on board with the receiver antenna in axis with the echosounder.
The GPS on board transmits coordinates (East, Nord and elevation) to the navigation software, in real time, and in a wide band of acquisition frequency.
The operator aboard guides the boat according to indications on the computer screen, which indicates the planned line to be surveyed and the instant position of the vessel.
Once the boat is aligned with the section to be surveyed, the operator follows, with maximum precision, the project line that is visualised, and data being to be acquired. Other parameters can be seen, such as off-route, velocity (knots), azimuth, distance from the beginning and end of route; event number and other values that are useful to the survey.
This technology offers significant advantages. In addition to Gauss Boaga coordinates, GPS calculates the absolute quote of the echo transducer in real time and with centimetre precision; it thus becomes possible to, in combination with echosounder data, automatically

correct all oscillations in sea surface (tides, waves, wind set-up) during the bathymetric survey. Tide and atmospheric pressure corrections therefore are not required for data reduction to mean sea level; all vertical oscillations are automatically considered.
Centimetric x-y accuracy is not always necessary for positioning in single beam surveys, especially on sandy floors. Often sub-metric precision DGPS instruments are sufficient for excellent results to be obtained. In this case the value of tide during survey is usually measured using a rod, levelled according to a benchmark of known quota, which is positioned in a calm sea area. Alternatively, tide gauge values can be used.

Single beam
Profile lines for single beam echosounder bathymetric surveys are set according to the project. They are usually positioned orthogonal to the coast, and are further integrated by routes perpendicular to those which act as control.
Surveys are usually carried under completely calm sea conditions, in the absence of winds. The vessel moves along sections at constant low speeds, following a predetermined route (Fig. 26). Usually small vessels of low draught are used for this type of survey, as they need to approach the coast as much as possible.

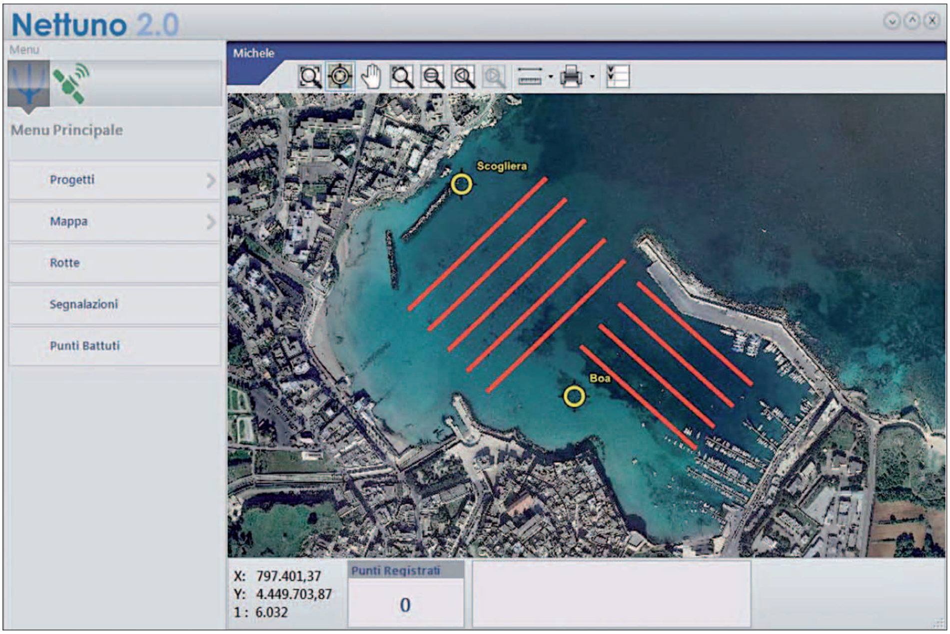


Figure 26 - Example of bathymetric survey software.

Echosounders are hydrographical and have 1-2 cm precision. Frequency used is normally about 200 kHz, which is a good value to ensure an accurate survey of the seafloor, with little interference from the water column. The beam width of the instrument is usually narrow in order to grant high geometric resolution. A frequency of at least one pulse (beam) per second is required. To ensure congruency between planimetric and bathymetric measurement

data, the echosounder is positioned in line to the position receiver or alternatively corresponding offsets are calculated. Echosounders are calibrated before and after the survey.
Water sound velocity on the instrument is set through the "bar check" method (measuring the depth of a bar or metallic disk placed below the transducer and suspended by a threaded rod).
Digital correction of eventual errors is then performed on navigation software. Due to economic factors, motion sensor for roll and pitch correction, are seldom used in this type of survey. The same is true for variations in quota of the transducer. If the survey is carried under calm sea conditions and in the usual low depths (which attenuates the problem from the geometric point of view), error is considered to be acceptable.
If the survey is directly performed in digital format, all data are recorded on the PC on board.

Multibeam
Multibeam "MBES" (MultiBeam EchoSounding) technology is quite sophisticated and is able to provide information of high quantitative and qualitative standards.
The method here changes from single point acquisition (single beam) along the navigation route (traditional echosounder) to continuous acquisition of a high number of concomitant pulses (beams), covering a stripe that equals 2-4 times the survey depth.
Resolution is extremely high and therefore seafloor features, even of small dimensions, can be identified, and their continuity can be followed.
In this case, navigation is also aided by RTK mode precision GPS. To grant the potential instrument accuracy, motion compensator (MRU) and high precision gyro are required for data correction.
In addition to saving time on larger areas, this type of acquisition allows investigating the real morphology of the seafloor with higher precision. Bathymetric quotes can also be detailed, using direct measurements and not (as in single beam products) by means of interpolation of points acquired along the route and during side routes.
Surveys usually plan for a full coverage of the study area, scanning along parallel transects and considering an overlap.

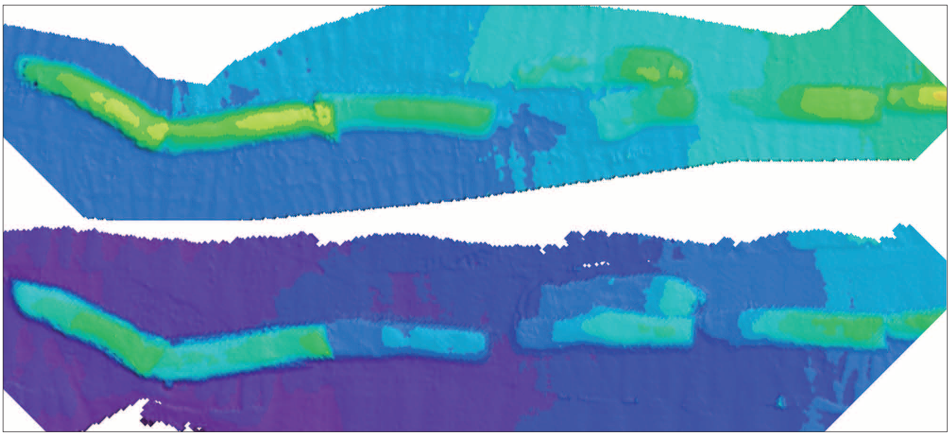


Figure 27 - Submerged groin survey using Multibeam Reson 8125 (top) and Odom ES3 (below).

For specific applications, multibeam transducers can be placed in a laterally inclined mode, in order to cover the relief of defence structure slopes (from their toe to near the water surface), for example.
In spite of higher costs, multibeam surveys are used wherever seafloor features must be detailed, or if a full cover is necessary to calculate volumetric variations of the sediment budget with high precision.
Technology is undergoing constant evolution. Lately, multibeam instruments of smaller dimensions have been appearing on the market, with reduced costs that will extend their use to seafloor morphological surveys, now frequently surveyed by single beam. (Fig. 27)

Data processing and quality control
The major operations regarding survey data processing are listed below, and their general aspects are highlighted.

GPS data processing
As seen, it may be necessary at times to plan one or more benchmarks of known coordinates, departing for instance from points that belong to a national net or, more recently, to permanent GPS station nets.
It has also been shown how the method takes long measurements in static mode. GPS data are then post-processed with specific software.
Once concomitant readings from the stations are uploaded, calculations allow data processing which will resolve eventual ambiguities.
It becomes therefore possible to retrieve coordinates in the desired system, with even millimetre precision. Later it is verified if values for standard deviation and quality factors are appropriate.
RTK (Real Time Kinematic) GPS is used instead for topographic surveys of the dry aerial beach, which do not require post-processing. In addition, it allows searching the terrain and record vertices at the beginning of each route. Having set a coordinate transformation system, data are already recorded by the instrument in the coordinate system chosen, with absolute quotes. Once downloaded from the GPS internal memory, data are exported in CAD format, as 3D coordinate (x, y, z) points.

Single beam
The processing of data acquired during the bathymetric survey leads to the drawing of the profile and isobaths. Such operations can be performed by cartographic modules of the instrument software. They also permit export of data in different ASCII or AutoCAD formats.
Also in this case, recorded data consist of 3 values (x, y, z) of seafloor points, the latter being corrected according to mean sea level and vertical oscillations.
In the first processing operations, corrections are made with a graphical editor for errors (in elevation or plan) which were due to temporary malfunctioning of GPS instruments or, for example, false echo reflections due to external causes.
In addition, all quotes in the points of intersection between transversal sections and longitudinal sections used as control are verified. This control allows verifying if a specific point surveyed at different times gives the same depth value.
Using the due methodology, deviates may be extremely low, even under 5 cm, and mainly

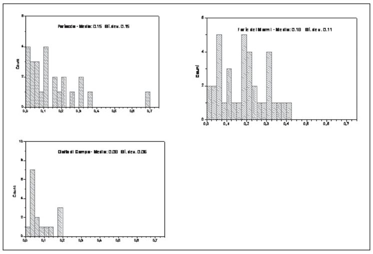


Figure 28 - Histograms of differences in absolute value of depths surveyed in route crossing points, according to 0.025 m classes.

due to echosounder errors and vessel oscillations that were hardly or not compensated at all. (Fig 28)
When verification is over, data are ready in their final version.
Once the right corrections have been made, each section becomes linked to the surveyed parts of the dry beach and the submerged beach (down to the first echosounder data). Data must be verified in the overlapping points.
It is possible to project the points of each section on a straight line using specific algorithms. Graphs may then be obtained for sections of fictitious profiles that are precisely orthogonal (to have real slopes) or which overlap other data acquired on slightly different routes (Fig. 29).
Points are usually resampled to reduce their number, allowing them to be represented on profiles or maps with their actual value (DTM/Digital Terrain Model).

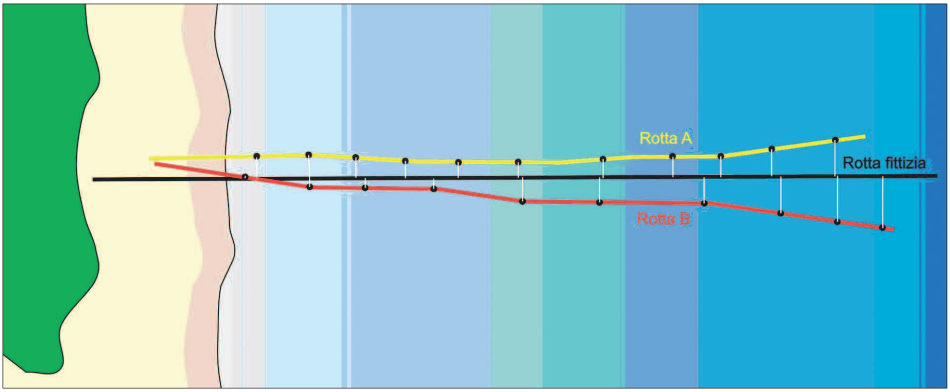


Figure 29 - Projection of two real routes (A and B) over a fictitious route, orthogonal to shore, for comparing purpouses and to obtain the real slope of the varying nearshore sections.

Multibeam

Data acquired by the processor are rather rough and lack corrections, but quality controls are performed once they are transmitted through a serial or LAN cable to the acquisition software.
Processing software are able to calculate total error for every single measurement, based on the errors estimated for every single sensor used (TPE). At the end of such calculations, all measurements not considered to be sufficiently accurate in the IHO Special Order survey class (for hydrographical survey classification) are eliminated.
Finally, the software produces a final report with the full statistics from the whole survey, where survey classes are highlighted for each measurement.
Data are filtered and only those that conform to IHO Special Order class are used in the production of digital models.
Data acquired can also be later compensated according to the variation in sound speed

along the entire water column, through a SVP instrument. Noise filters may also be applied. Bathymetric data are processed according to the following operative phases:

- processing and quality control;
- creation of 3D models for data;
- creation of contour lines;
- preparation of final maps.

In most data processing software, modules are conceived to help operators identify eventual problems, correct and remove errors and correlate in time all associated data records, calculating refraction corrections to determine the effective impact point of each acoustic "beam" on the seafloor.

Data processing follows successive operative phases:

- Phase 1: the user can verify navigation routes, heave-pitch-roll information, tide, draft, and sound velocity information. Different filters can be applied in order to eliminate data that are not statistically valid, or which are of inadequate quality or come from non-established depths. It is also possible to apply a quality control filter, defined by the user. In addition, navigation routes can be modified; whereas tides can be recalculated using adequate modules.
- Phase 2: Editing. The user can examine details of the seafloor using a specific viewer (Fig. 30). In this phase automatic geometric filters can be used to eliminate errors. In addition, errors can be manually corrected and data may be viewed in different modes: tridimensional, longitudinal, or perpendicular to the route followed.

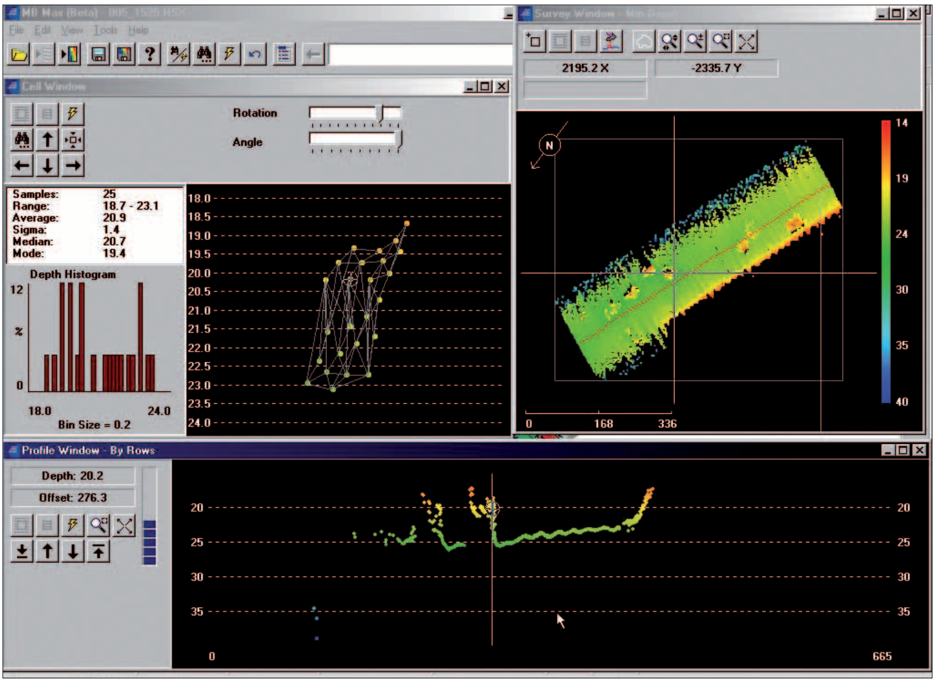


Figure 30 - Example of multibeam data editing.

- Phase 3: Points are regrouped into cells, and statistic filters can be applied according to the distribution of "z" values in each cell. Specific filters can also be applied to eliminate vegetation and take the quote to the real bottom. This phase allows reducing data and creating the DTM according to the chosen cell – this is also function of the density of points. Data are then saved usually as x, y, z.

Calibration

Calibration is essential for the reduction of errors in instrumental data acquisition.
It is necessary to make a proper distinction between calibration of the instrument and methodological calibration: this is able to correct the error caused by external factors, such as inadequate alignment of instrument or delay of data from the instruments. This can be improved due to a particular signal, the PPS (pulse per second) which has the function of aligning time between each single instrument and on-board bathymetric survey instruments.
Instrumental calibration of navigation GPS, for example, compares instrument coordinates to those of benchmarks of known coordinates. Gyrocompass calibration corrects the angle with that from a topographic measure. Calibration of bathymetric instruments compares data to those that can be really measured using traditional techniques.
Methodological calibration, on the other hand, compares bathymetric profiles acquired in opposite directions or at different velocity along the same route, especially where sudden changes in seafloor slope are present. This is essential for multibeam surveys, being often disregarded in single beam surveys (where due to practical and economic reasons MRUs are neither required nor used).

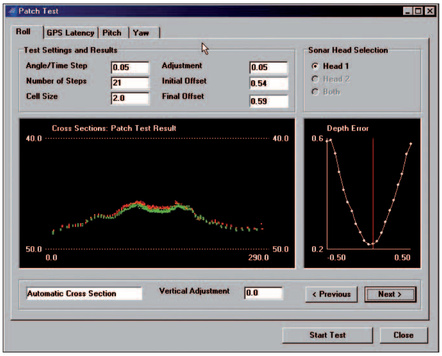


Figure 31 - Multibeam time delay calibration.

Time delay calibration – This calibration refers to time delay, or the delay of position and depth data fusion; such an offset is determined using the same line in the same direction twice (Fig. 31). One of the two acquisitions must be performed at a reasonably higher velocity. Whenever a delay is verified to exist, both profiles should be longitudinally shifted; such shift, and thus the offset to be corrected, would be directly proportional to the difference of velocity between the two profiles acquired.

Pitch calibration – Similar calculations apply to the offset to be used in pitch calibration. In this case the same line should be acquired in different directions, though at the same velocity. Offset is calculated according to the two longitudinal profiles acquired; in the case of offset, they will be longitudinally shifted. For appropriate offset determination it is advisable that those lines be surveyed in zones characterised by high seafloor slope or by evident outcrops.

Roll calibration – For roll calibration the two lines acquired for pitch calibration can be used. However, in this case offset is determined by comparing the two transversal profiles acquired in the same point; offset will be determined from the angle eventually present between them.

Data restitution

Once digital data have been acquired and processed, magnetic and optical support must be given. Data will be made available in different formats according to the instruments used and depending on the type of restitution required, such a Dxf, Txt, Shape, Asc, Seg-Y, XTF, GeoTiff, etc. Lists of benchmark coordinates, section vertices and their identification sheet are also produced.

Cartography

For cartographic restitution of bathymetric data, tables are prepared with the survey key map at different scales, presenting navigation lines, single beam position of bathymetric sections, quoted plan of points, Ground Control Points used, section vertices, isolines and isobaths at (usually) 0.5 m, position of eventual sampling points (Fig. 32).

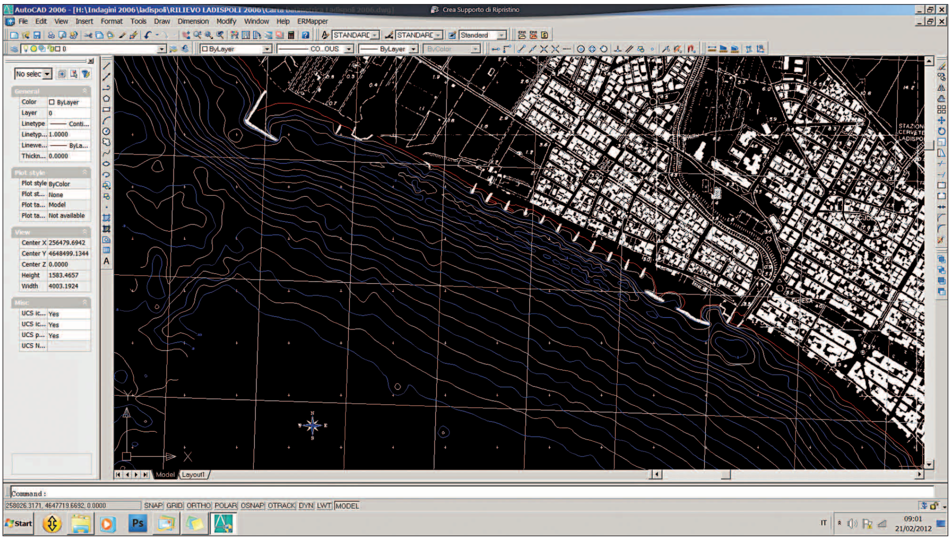


Figure 32 - Example of hydrographic chart in CAD.

Usually automatic processing software are used for drawing bathymetric lines. Due to the particular distribution of data, especially on parallel section surveys, automatic drawing may not prove to be adequate. Level curves are drawn after the DTM is created, which is often produced by triangulation of surveyed points. Due to the linear distribution of data, many software are not able to solve this problem, favouring the creation of triangles along transects instead of between transects parallel to the beach. Level curves are usually affected by this distribution and may have an unrealistic aspect.

In addition to this trend (distribution mainly along transects), model calculations tend to attribute to isobaths the indentations caused by different data weights, as acquired data

are not homogeneous along the survey area. The problem becomes evident on sandy floors, where isobaths should have a smooth shape.
Even if it may be possible to attenuate such characteristic (Fig. 33) by means of smoothing, the problem is often evident and a solution must be achieved by hand drawing.

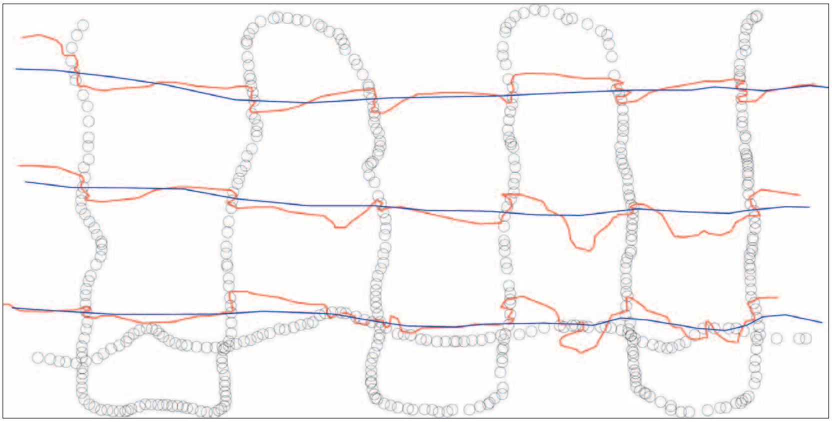


Figure 33 - Automatic and manual (smoothed) interpretation of contour lines for a bathymetric SB survey.

Some software allow setting specific parameters to account for anisotropic distribution of points. This serves to direct choice towards the most adequate options according to the development of the coast. On straight coasts, results may be satisfactory at times - but very seldom when the coast is irregular or continuously variable, such as in small gulfs.
Another problem is verified when there are coastal defence structures. In this case, if the survey is carried with parallel transects, even if closer points have also been surveyed, the lack of a sufficient number of data and the effective discontinuity of the seafloor often prevent correct isobaths from being drawn (Fig. 34).

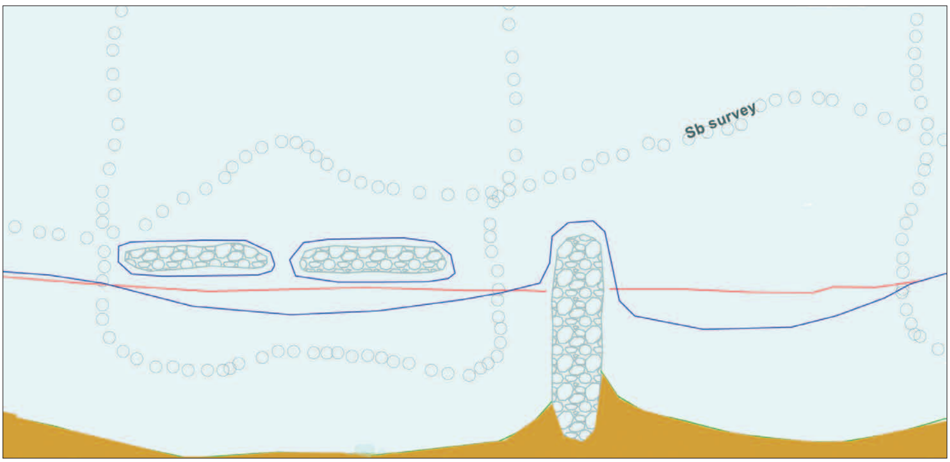


Figure 34 - Example of the difficulty in interpreting contour lines near beach defence structures. Red (interpolated), Blue (possibly correct).

The problem of point interpolation is extremely complex. The manual of many software, such as Surfer® e Origin®, allow choosing the interpolation strategy even if the operator does not know the issue deeply. However, this can lead to grotesque mistakes, which, fortunately, are quite evident in the case of bathymetric data.
Deeper understanding of interpolation techniques will allow choosing the most adequate according to available data (density, homogeneity, anisotropy); it will also lead to better quality maps of the seafloor morphology.
In any case, reconstruction of isobaths must always be corrected by hand and smoothed (Fig. 35).

Figure 35 - Automatic generation of contour line for a SB survey. Normal (top), smoothed (below). Golfo di Campo (Elba Island - Italy).

A professional with high expertise in coastal geomorphology is required for that job - one who has preferably participated of the survey phase, so that eventual blanks generated by automatic processing may be correctly interpreted.
In restitution of section profiles, tables are usually created in 1:1000 (horizontal), and 1:200 (vertical) scales. Vertical variations are put into evidence due to the 1/5 rapport, especially on low slope seafloors, such as sandy seabottoms. Progressive distances and the relative quote of each single point (Fig. 36) are informed.

Even the routes should be reported to the appropriate table.

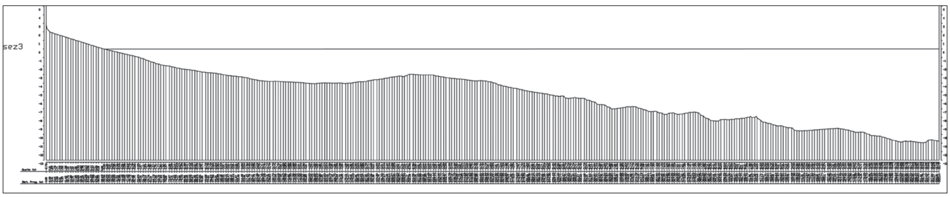


Figure 36 - Example of bathymetric profile.

Profiles are created from the projection of points surveyed along the routes over project lines. Alternatively, these can be derived from the DTM, generating points regularly spaced along the axe of the project profile, but will be associated to interpolated values (rather than original values).
On full coverage surveys such as Lidar or multibeam, a DTM is created (Fig. 37) with a grid that is inversely proportional to the degree of accuracy obtained or required, from which it is possible to obtain 3D views.
In this case distribution of points is rather more homogeneous: interpolation of points does not incur in the same problems as occurs for points surveyed along separate routes.

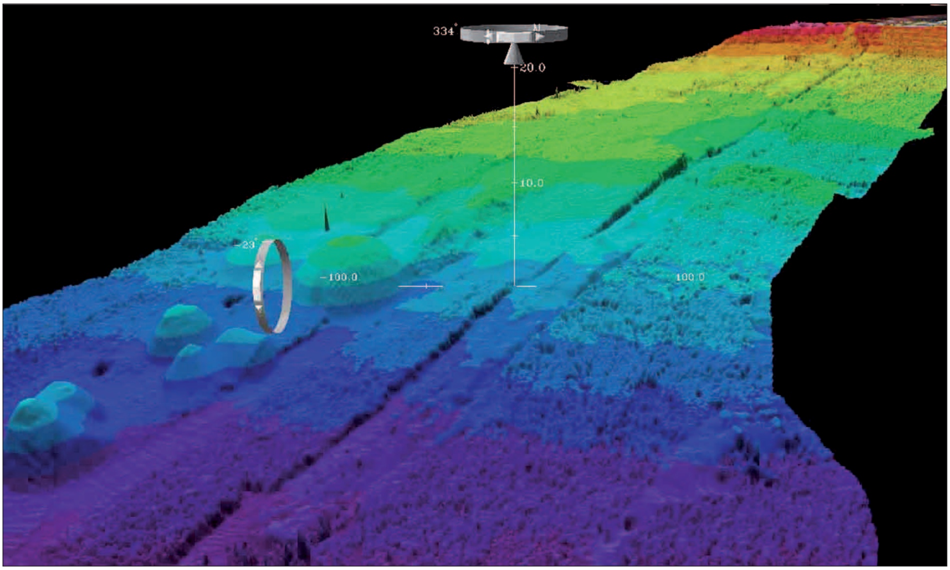


Figure 37 - Multibeam 3D view.

Data analysis
In this chapter we provide an example of data management for the evaluation of coastal erosion trends and the efficiency of defence strategies according to traditional coastal monitoring frameworks. Procedures may vary according to the typology of data acquired and the scope of the study.

Analysis of bathymetric charts
Level curves (isobaths) are reported to bathymetric charts (with 0.25 – 1.0 m interval, according to survey accuracy). Important information on the survey area may be drawn from this chart. Dynamics and energy are deduced, for example, from the presence, number, position and morphology of submerged bars.
Information on the efficiency of defence interventions is obtained according to the accumulation or erosion of nearby sediments. Isobaths may indicate reflection or low energy zones; channelling due to strong current flows at breakwater gaps for the reflow of water masses may also be evident after sea storms (Fig. 38).

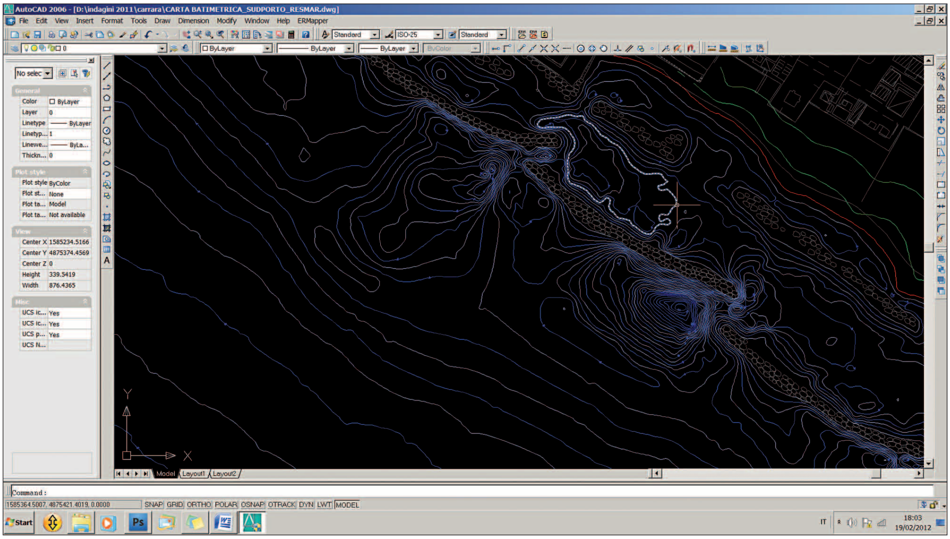
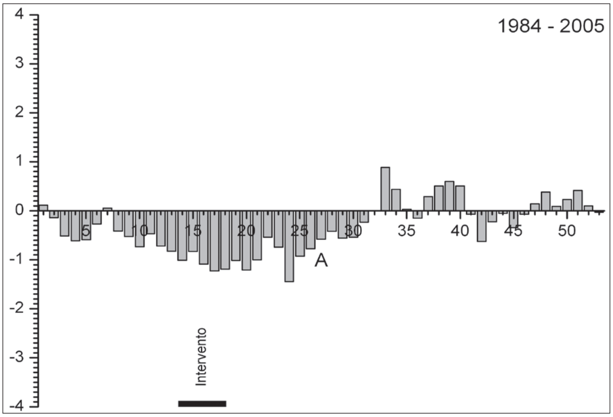


Figure 38 - Greater depth out of the reef channel due to currents induced by piling-up behind the structures.

Analysis of shoreline evolution

For shoreline evolution monitored with the scope of identifying erosion trends, one of the mostly used methods divides the coast into sectors, within which subaerial beach area variation will be measured; mean shoreline displacements are then calculated for the different time intervals.
Data obtained will be time-normalised to calculate the mean shoreline displacement ratio (m/year) in the varying coastal sectors (Fig. 39).



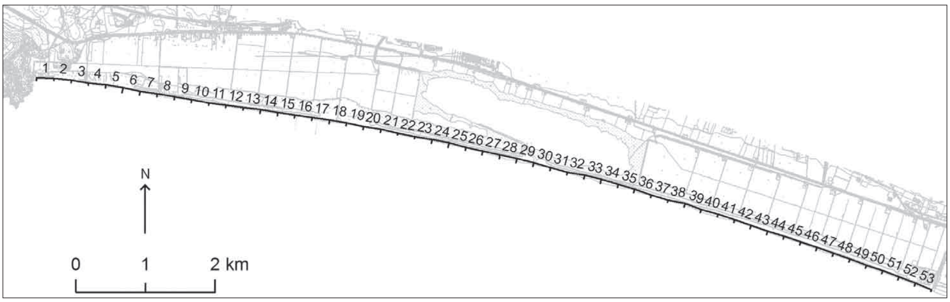


Figure 39 - Example of shoreline segmentation with different displacement rates (m/year).

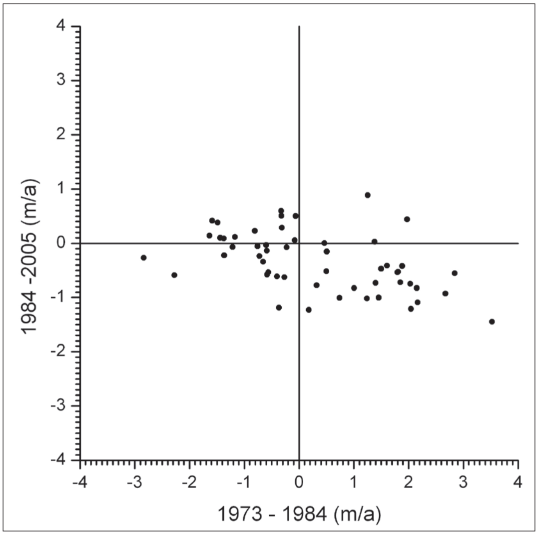


Figure 40 - Example of comparison between evolution trends of varying sectors along the different time intervals analysed. Sectors that maintain their evolution trend are located on the 1° (++) and 3° (--) quadrants; Sectors that have changed from accretion to erosion conditions (+-) are found on the 2° quadrant whereas those that changed from erosion to accretion (-+) are located on the 4° quadrant.

Graphs are then produced for comparing evolution trends in the different periods; persistent accumulation or erosion conditions may then be verified (Fig. 40).

Data from this graph will be summarised in an analysis table for shoreline displacement transition. Alternatively, as stated in the Introduction, a TBA may be performed; this is an extremely fast operation but proves inadequate for coasts characterised by cusps and defence structures.

Generic software for digital vector-based drawing, such as Autocad©, or specific for GIS, such as Arcview©, are able to easily perform these operations. Alternatively, other software are designed ad-hoc, as Digital Shoreline Analysis System (DSAS; Thieler et al., 2009), which is free for download from the United States Geological Survey website.

Variations in beach morphology

For detailed coastal evolution analyses, data from previous surveys are also investigated and adapted to recently acquired data, allowing them to be compared.

The following information must be known for all surveys: data acquisition mode, reference quote, accuracy of each single measurement, and eventual interpolation and extrapolation method applied, especially when only isobaths (and not points) are available. For older data, such as those from Istituto Idrografico della Marina, it is important to obtain the "scanning graphs", much richer in points than the nautical charts that derive from them (Fig. 41).

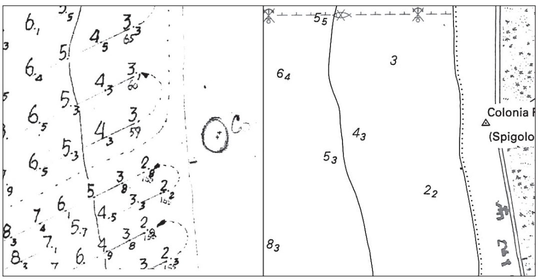


Figure 41 - Part of scan graph no. 8362 from 1976 (Calambrone) in 1:25.000 scale (left) and nautical chart no. 120 from Istituto Idrografico della Marina Militare (Livorno coast) in 1:25.000 scale derived from the same graph. 150% image enlargement.

Accuracy heterogeneity, both bathymetric and planimetric, is usually present on surveys carried out at different times. One of the reasons for that is the evolution of instruments used.

Consistent variations in seafloor morphology offshore from the estimated closure depth may indicate that some documents should not be used.

It is important that the same operators work with the same instruments in all surveys carried out within a monitoring plan.
Volumetric variations of subaerial and submerged beach are calculated for the area under survey; coastal segments that have undergone interventions or that present defence structures are considered separately. In terms of time, monitoring should consider time intervals according to the date when that protection work was built or executed, to avoid mixing periods with different trends caused by different factors.
Profiles from differences periods are compared (Fig. 42), to verify the "closure" of profiles and analyse variations in form, bar position, and slopes along the profile.

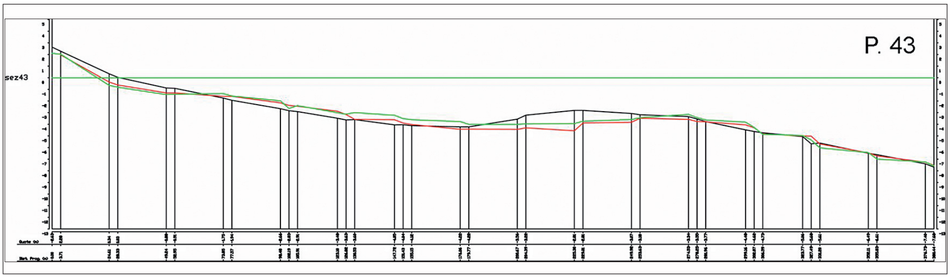


Figure 42 - Comparison of different beach profiles.

Using all profiles surveyed, it is possible to calculate volumes by applying the cross-section method, avoiding interpolation problems between different survey lines.
It is important to note that profiles are most often drawn with a certain vertical exaggeration (often 1:5 or 1:10) and that some calculation procedures may "disregard" such an aspect.
Thanks to specific software, in addition to planimetric and 3D representation of the seafloor, it is also possible to compare "survey pairs" and the corresponding volume calculation for the whole sector or for pre-determined sectors (Fig. 43). This may be represented using colour maps, where the different depth variation intervals are identified.

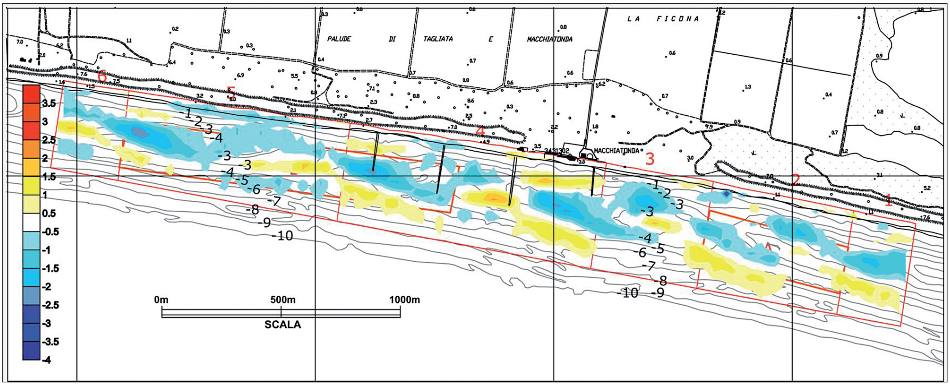


Figure 43 - Bathymetric variation chart.

For accumulated/eroded sediment volumes it is important to note how accuracy of each survey may significantly influence the results. If the accuracy of each survey is estimated in 10 cm, comparison between two surveys may generate a variation of 20 cm in depth for a stable point. Along extensive areas, this thickness may lead to apparent volumetric variations of hundreds of thousands of cubic meters. Along one kilometre of beach length a volume of 200.000 m3 is estimated, which amounts to a small nourishment.
This aspect should be duly considered in graphical representation, where the inaccuracy range should be clearly represented. In Figure 44 areas where depth variation is smaller

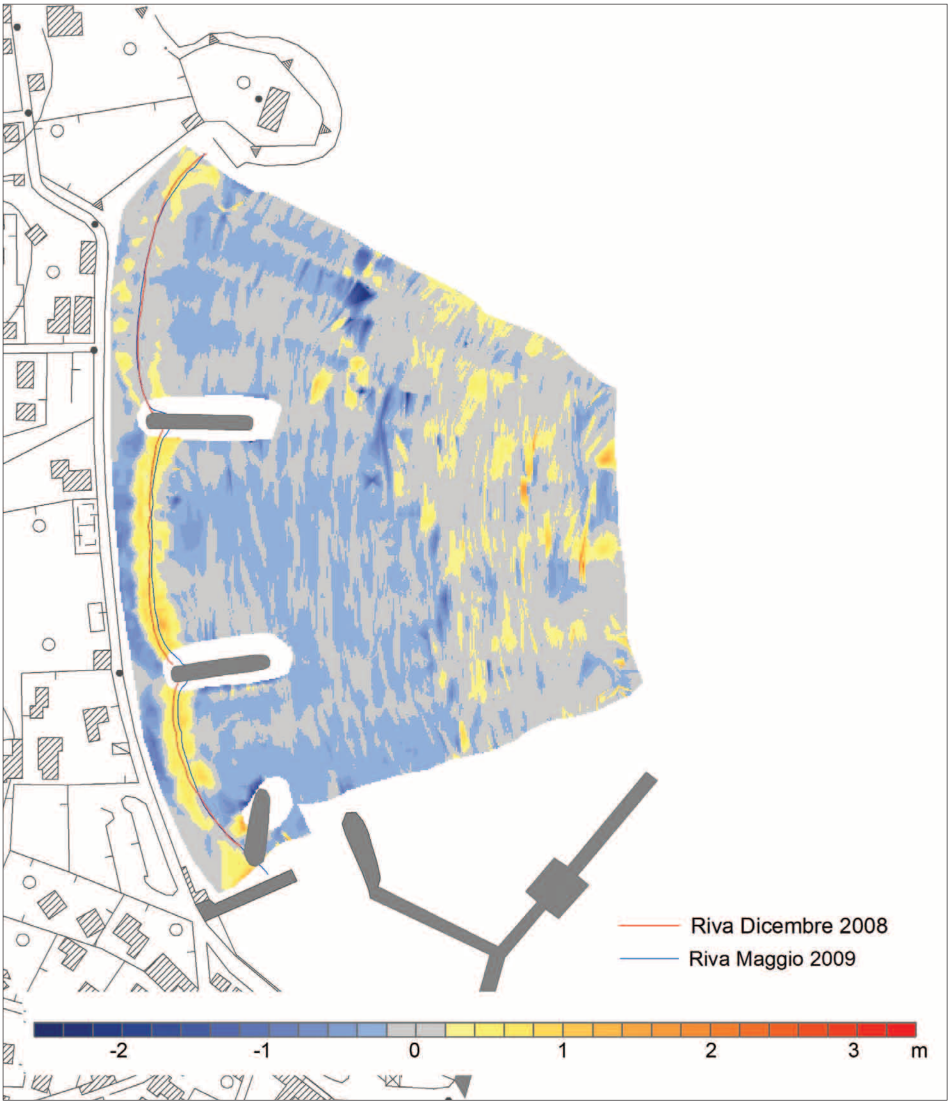


Figure 44 - Comparison of hydrographical surveys for Cavo beach monitoring (Elba Island – Italy). Note the short colour scale range (20 cm).

than comparison accuracy are represented in white; the chromatic scale defines 0.5 m intervals, to indicate the confidence interval used in the comparison. However, calculations of eroded/accumulated volumes cannot take this aspect into account and even small variations will influence the global value.

When data from such a comparison are interpreted, it is important to take into consideration all the procedures adopted during the survey and in the processing phase; this allows conclusions to be compatible to the accuracy of the information available.
Errors from data acquisition or processing may sometimes occur in this phase, such as larger or smaller bathymetric variation along stripes orthogonal to the beach (often due to the effect of "Time delay") or parallel to the shore (at the point of contact with land- and sea-based surveys). Such problems are evident when the interval of variations used equals or overcomes the interval of comparison accuracy.
Usually, the major morphological variations are those associated to cross-shore migration of bars, which determines deepening and accumulation sites that develop almost parallel to the coast. Although such displacements should in theory compensate, they constitute the most important bathymetric variations for surveys that are repeated at a reasonably short time interval; they make the "effective variations" (which are of interest to us) much less significant.

Conclusions
Monitoring the morphological evolution of the coast is an essential phase within the ICZM framework and should be put into practice with strong determination (and allocation of the appropriate resources) by public administration agencies in charge of land planning and protection. It can be set to evaluate its "state of health" or to analyse the beach response to defence strategies such as structures or artificial renourishment.
The cost of monitoring is many times smaller than the value of the beach itself or the cost of defence projects; in spite of that, until recently it had hardly been put into place.
Our coasts are full of defence structures, all built separately and disconnected from an organic project. They have been often modified, removed or enlarged because the expected effect would not materialise. However, at the time there was no availability of data to understand the reason for such malfunctioning and to guide the optimisation of works.
In the past, monitoring meant a single survey of the coast; there was no articulated plan, nor were new and historical data compared and interpreted by experts.
If monitoring is well set and well executed, it may highlight eventual negative responses of the coast, preventing problems from reaching insurmountable levels, from both an economic and technical point of view.
Good quality monitoring may prove to be useful in legal battles between the contracting agency and the contractor responsible for the execution of defence works. Stakeholders also benefit from it, as an updated and objective picture of the "health state" of the coast can be obtained. This can identify the high or low efficiency of the projects developed.
Reliable data, obtained with shared methods, will allow results from different areas to be compared. The need for interventions (and financing) in the different levels (municipal and regional) can also be correctly evaluated, so that resources may be transparently and objectively allocated.

It is important to note that data produced in monitoring allows researchers to deepen knowledge in this field: if the cost of surveys is minimal in the scale of defence structure values, it can very seldom be bore by normal research funds.
In the case of Tuscany, there has always been an important collaboration between universities and public agencies in charge of coastal studies. This illustrates how such a rapport can produce innovative research that is internationally recognised. Many foreign researchers are indeed attracted to our coasts.
The creation of the Regional Centre for the Study of Coastal Dynamics (Centro regionale per lo Studio della Dinamica dei Litorali/CreStDiL), merging research and staff from coastal Tuscan provinces and universities, meets such demand for data acquisition and sharing; Project ResMas allowed the Centre to be consolidated and extended into a wider territory of action.

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The Corsican coastal monitoring network

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Abstract
The littoral of Corsica is composed by rocky shorelines separating sandy beaches in a wide variety of environments: pocket beaches, open beaches, river mouth, lagoon inlets. This sandy coastline is suffering from coastal erosion and a coastal monitoring network was implemented at the end of the 90's to quantify and understand this coastal retreat and provided the coastal managers with an information and prospective tool. Fifteen representative and regional sites are monitored annually to obtain quantitative indicators on coastal retreat and shoreface behaviour. Evolution of two sites, the Tavignano and the Taravo, is presented here to illustrate the evolution observed and the new insight on coastal processes driving this evolution. The entire monitoring network permits to evaluate the state of the littoral zone of Corsica, to provide the scientific community with quantitative datasets on coastal evolution, and to anticipate coastal response and consequent management strategies. All results and gathered datasets are processed and share via a regional web-GIS tool in process that will permit to visualize and obtain metadata and data on the evolution of the Corsican sandy coast.

Introduction
The littoral of Corsica suffers from coastal retreat due to both natural (decreasing sediment budget, storms) and anthropogenic (coastal urbanisation, coastal infrastructures) factors. In this very attractive area, such erosion trend may be responsible for important economic and/or environmental consequences. The development of coastal facilities in the past decades aggravated the vulnerability of the coast to sea storms and their consequences in terms of coastal erosion and flooding.
Within this context, BRGM and OEC (Office de l'Environnement de la Corse, with the support of l'Agence de l'Eau Rhône Méditerranée & Corse AE RM&C), have initiated a pluriannual programme to provide data for improving knowledge on coastal evolution and coastal processes as support to coastal management strategies.
A monitoring programme has been developed in Corsica since 1999 by BRGM, OEC, AERM&C and the Conseil Général de Haute-Corse (CG2B) to evaluate erosion processes on

the sandy beaches of the island. This program, called **Réseau d'Observation du Littoral de la Corse (ROL),** is based on the monitoring of « regional » sites which are representative of natural coastal evolution and "sensitive" sites where critical evolution of the coast currently threatens economic issues.

ROL has three main objectives:

- to promote **coastal evolution monitoring,** in order to provide reliable data for characterising coastal changes and sediment budget;
- to be **an information tool,** able to gather and share the information and knowledge acquired;
- to be a **prospective tool,** to anticipate important coastal evolution events and provide stakeholders with information to facilitate the decision-making process.

Fifteen sandy beaches are currently being monitored in Corsica as part of ROL. This includes pocket beaches, open beaches, coastal barriers, and river outlets presenting a wide range of geological or morphological settings: gravel to fine sand, dissipative to reflective beaches, barred coast, as well as urbanised and natural shorelines. Survey of these areas is carried out once a year (Palvadeau and Nay, 2002, Durand *et al.*, 2003, 2004 ; Balouin *et al.*, 2005a, 2005b, 2006a, 2006b, 2007a, 2008, 2009 ; Stépanian *et al.*, 2010).

The network provides stakeholders with comprehensive, representative monitoring of coastal evolution and allows more sensitive sites to be integrated, if requested by local/public administrations. This was the case of Porticciolo and Tavignano, two sensitive sites that are surveyed by the Conseil Général de Haute-Corse (Balouin *et al.*, 2005a, 2006a, 2007b, 2008; Stépanian *et al.*, 2009, 2010, 2011). In 2012, two additional sites were surveyed by the Communauté d'Agglomération du Pays Ajaccien: the beaches of the Gulf of Ajaccio and Lava.

Data acquisition and processing

The monitoring network of Corsica is mainly focussed on data acquisition at representative and sensitive sites. "Representative" or "regional" sites are beaches which present morphological features common along the coastline of Corsica, allowing the global state of Corsican shores to be analysed. "Sensitive" sites are beaches marked by coastal erosion and where coastal infrastructure or environmental assets are currently exposed. Fifteen sites are presently being surveyed on a yearly basis. That represents approximately a 45 km-long shoreline, and includes approximately 33 topographic/bathymetric profiles (Tab. 1 and Fig. 1).

Table 1 - Sites monitored within ROL. Remarks: local settings and main issue at sensitive sites. PP: number of beach profiles per beach. TC: coastline length. In bold, sites where surveys started after 2002.

Sites	Dept.	Remarks	PP	TC
Regional sites				
TARAVO-TENUTELLA	2A	Sand and pebble	2	3 km
GALERIA	2B	Sand and pebble	2	
AREGNO	2B	High energy coastline (pebble)	2	
BALISTRA	2A	Sand spit	2	1 km
ALISTRO	2B	Sandy coast	2	8 km
PALU POND	2B	Coastal barrier	2	3 km
LIDO OF MARANA	2B	Coastal barrier	2	16 km

Sensitive sites				
CAMPOLORO NORD	2B	Eroding sandy beach (interception of littoral drift by the harbour of Taverna)	2	5 km
CAMPOLORO SUD	2B	Accreting sandy beach (interception of littoral drift by the harbour of Taverna)	2	2 km
CALVI	2B	Eroding sandy beach + breakwaters	2	3 km
SANTA-GIULIA	2A	Eroding coastal barrier with exposed coastal facilities	2	2 km
SAGONE	2A	Eroding sandy beach with facilities	3	1 km
PORTIGLIOLO	2A	Eroding high energy sandy beach	2	3 km
TAVIGNANO	2B	Eroding sandy beach, river mouth	3	4 km
PORTICCIOLO	2B	Eroding sandy beach with exposed coastal road	3	0,4 km
TOTAL	15		33	~ 45 km

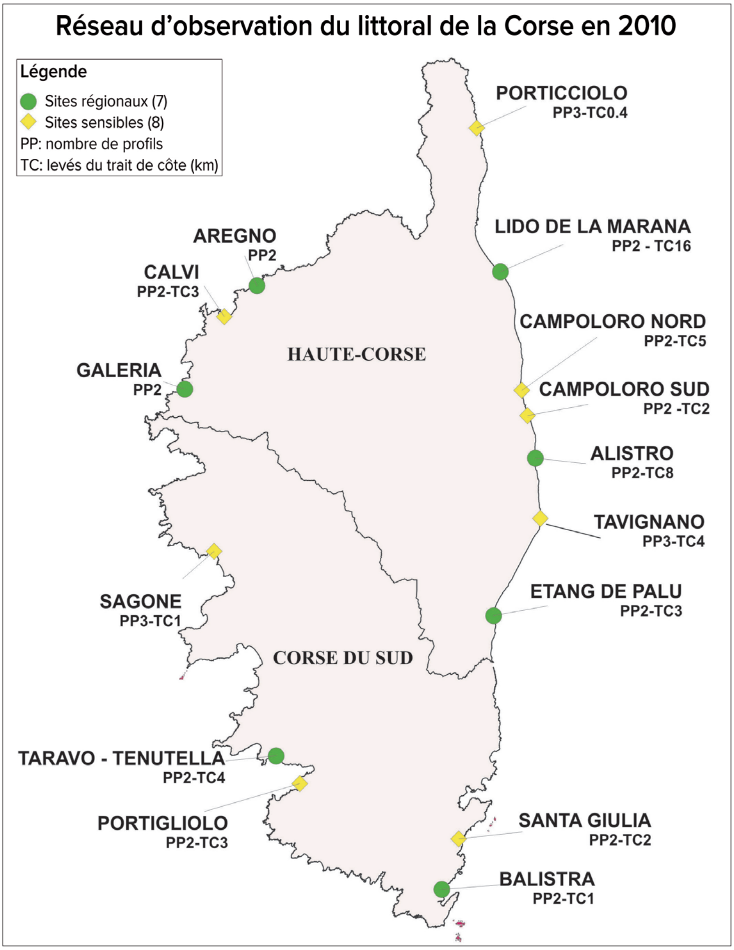

Figure 1 - Sites monitored within ROL in 2010.

Morphological indicators

The complete morphological characterisation of Corsican coastal zone is time-consuming and would require significant budget. In this context, and after an analysis of erosion hazards along the entire Corsican coastline, two main morphological indicators were selected to be used in the analysis of coastal evolution (figure 3):

- Cross-shore topographic and bathymetric profiles;
- Shoreline and dune toe surveys.

Topography surveys are carried out in dry beach areas using a kinematic DGPS TRIMBLE R6 with an accuracy of a few centimetres. Bathymetry surveys of the shoreface are performed with a single-beam echo sounder TRITECH installed on a zodiac whose high frequency acquisition is coupled in real time with kinematic DGPS, using HYPACK software. Accuracy of bathymetry measurements is approximately 10 cm. Simultaneous measurements of topography and bathymetry allow obtaining a complete profile from the dune system (if present) to 10 m water depth.

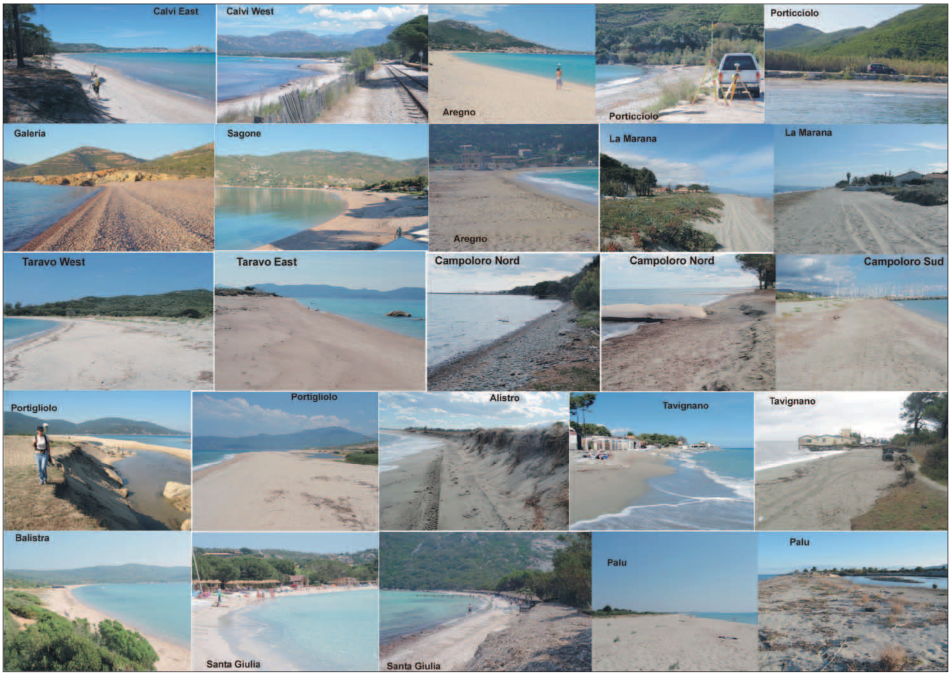

Figure 2 - Sites monitored within ROL

Longshore surveys are undertaken using a RTK GPS deployed on a quad or carried by the operator (depending on local morphology). Two indicators are used:

- Swash zone (or berm of the lower beachface) that corresponds to the mean shoreline (in absence of tidal range) ;
- Dune toe (or the lower limit of vegetation).

These two lines delimit the active area of dry beach under wave action and indicate beach

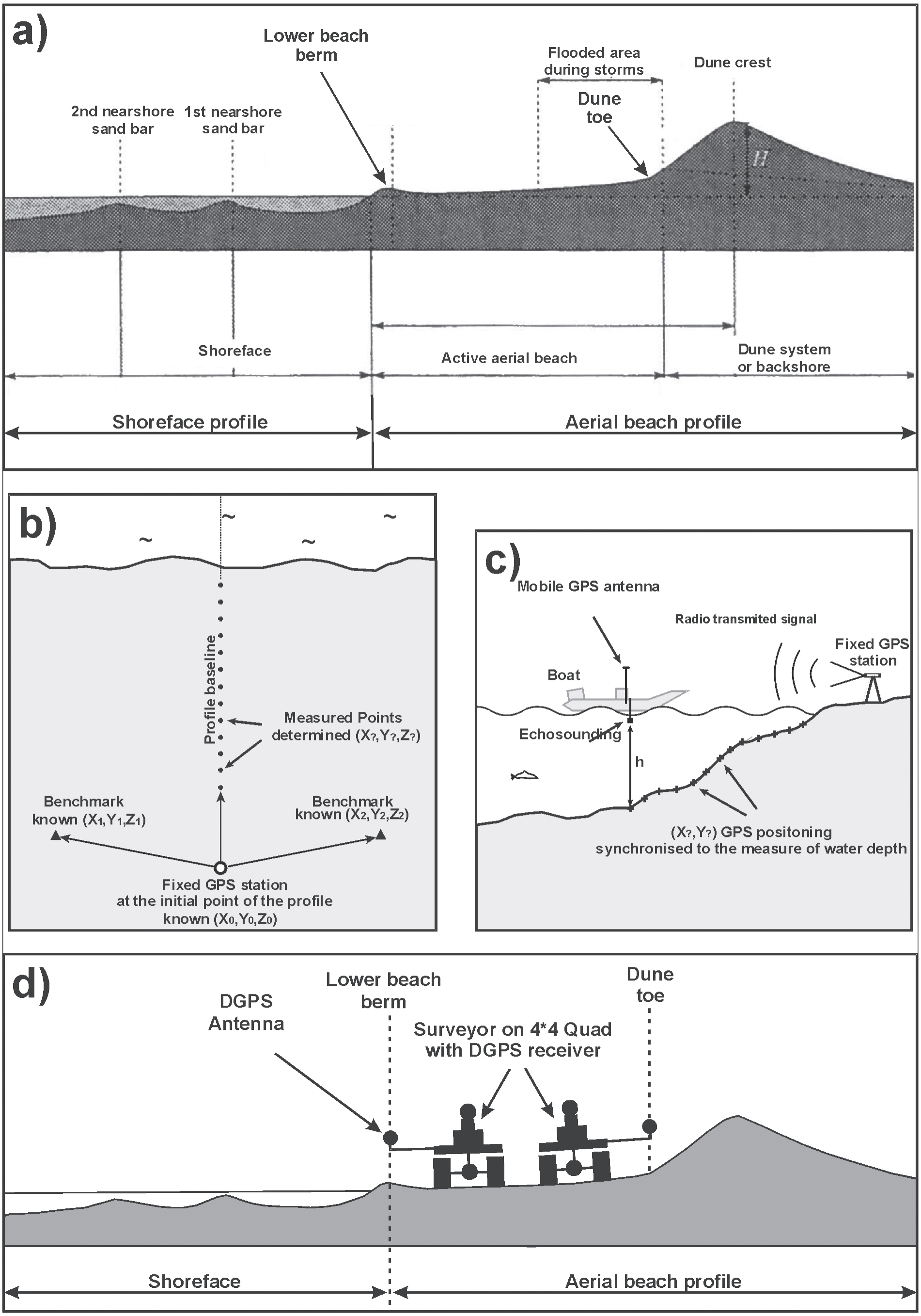

Figure 3 - Methods used within the ROL monitoring program. a: typical Corsican beach profile ; b : Dry beach monitoring ; c: Shoreface monitoring ; d: Shoreline and dune toe monitoring.

width which is also an important parameter to evaluate the sensitivity to both long term erosion trends and storm events. The accuracy of these surveys depends on how the operator interprets beach morphology rather than being linked to GPS accuracy; only changes in shoreline position of 5 m or above are considered to be significant.

From a morphological point of view, the berm of the lower beachface is similar to the mean shoreline detected on past or recent aerial photographs (SHOM and/or IGN). Past shoreline positions from 1948 to 1996 were analysed in the 90's (Oliveros, 1998 ; Oliveros and Delpont *et al.*, 1998, 1999 ; Oliveros *et al.*, 1996 ; 1998) for the entire coastline of Corsica. Their use together with ROL surveys allow long term erosion trends to be assessed.

All datasets correspond to the national coordinate system Lambert 93. The altimetric reference used is the Zero NGF (Nivellement Général de la France, IGN78) that corresponds to the mean sea level measured at the harbour of Ajaccio.

The coastal evolution analysis is performed using several techniques to obtain both volume and spatial variations of erosion/accretion areas.

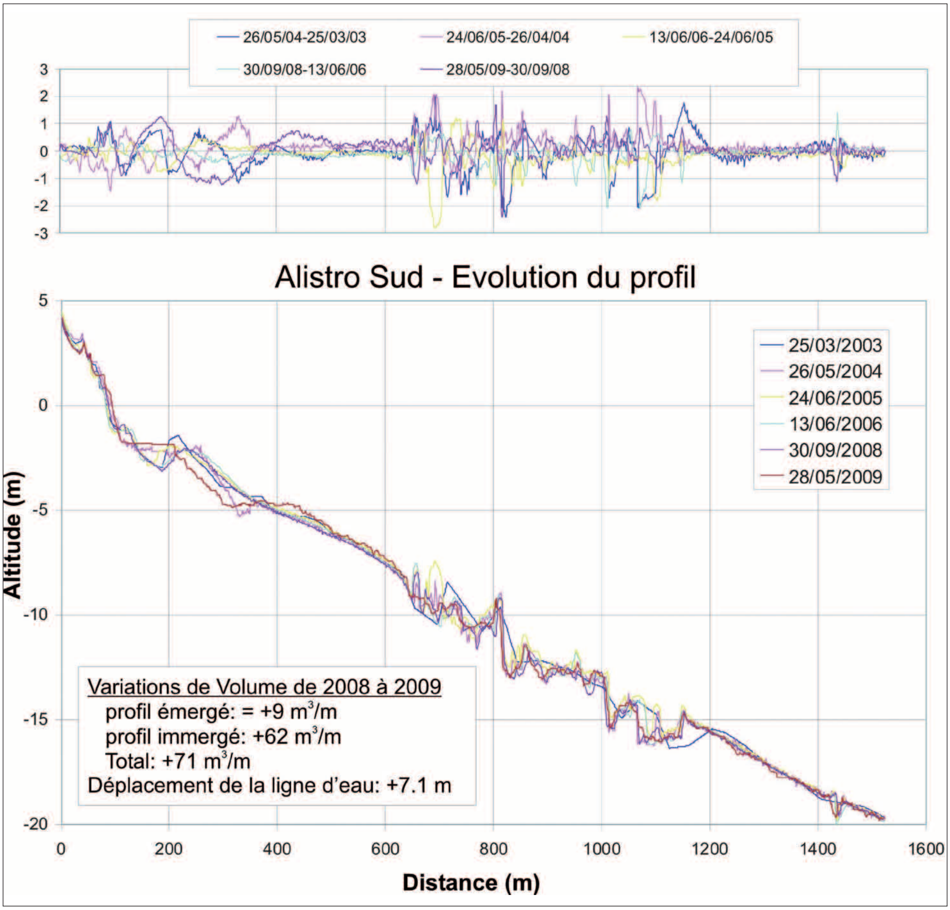

Figure 4 – Example of cross-shore profile analysis at the site of Alistro Sud: Altimetric variations along the cross-shore profile (top) and comparison of successive cross-shore profiles (bottom).

The analysis of morphology evolution (trends, topographic and volume variations) is performed using SURFER© (Golden Software Inc.). The methodology developed allows the following parameters to be obtained and analysed:
Altimetric variations between successive surveys that give the magnitude of evolution and indicate eventual sediment transport from one part of the profile to another, or from one profile to the other;
Volume variations computed for the entire profile, for dry beach and shoreface. The volume is expressed in m^3/m ;
Shoreline displacement derived from the intersection between beach profiles and mean sea level (zero NGF). This information is particularly important to understand the processes involved in shoreline displacement at a larger spatial scale.
An example of cross-shore profile analysis is given in figure 4.

Lidar survey

In addition to these yearly morphological indicators, a complete Digital Terrain Model (DTM) of the eastern Corsican plain was produced in 2010 using Lidar techniques (Light detection and ranging). Recent developments of these techniques have allowed surveying a wide range of coastal environments (Revell *et al.*, 2002 ; Sallenger *et al.*, 2003, White & Wang, 2003) and improved the understanding of coastal morphology evolution (Stockdon *et al.*, 2002 ; Gares *et al.*, 2006, Deronde *et al.*, 2006, Balouin & Heurtefeux, 2007).
Hydrographic Lidar can be used in shallow waters to perform bathymetric surveys (Guenther *et al.*, 2000). In the 90's, the first operational systems were deployed in Australia (LADS) (Setter & Willis, 1994 ; Nairn, 1994), in the USA (SHOALS) (Lillycrop *et al.*, 1994, 1997) and in Sweden (Hawk Eye) (Steinvall *et al.*, 1994). This technique is particularly adequate for surveys of large areas, up to 70 m water depth (more commonly, 3 times Secchi depth).
Survey of the eastern plain was undertaken using the Hawk Eye system (operated by Blom Aerofilms). This system uses two laser wavelengths: one red (532 nm), reflected by the water surface, and one green (1064 nm), which penetrates the water column and is reflected by the seafloor (figure 5).
Even if the technique is known to be highly limited by water turbidity, sea surface agitation and algae blooms, tests operated along the Corsican coastline proved to be very successful, and high detail bathymetric measurements were obtained up to approximately 20 m water depth.

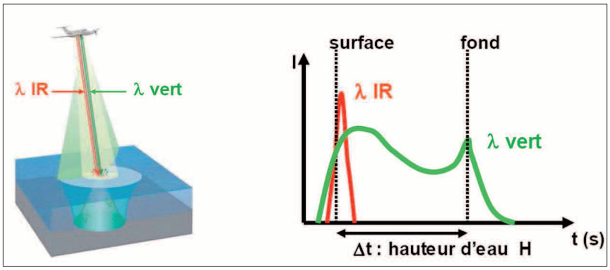

Figure 5 - Principle of hydrographic Lidar.

After a first evaluation in 2006, the survey of the entire coastal plain of Corsica was launched in March 2010. The main objectives were to obtain complete and very accurate altimetric measurements of both coastal topography (including dune systems) and bathymetry up to 10 m water depth.

The density of points obtained was:
- 8 points per 5*5 m^2 in bathymetric surveys;
- 6 points per 1*1 m^2 in topographic surveys.

The validation of this dataset by classical field surveys (using GPS) indicates that the mean standard deviation of the survey is approximately 20 cm.
A DTM and a DEM were produced from these highly accurate datasets (see figure 6).

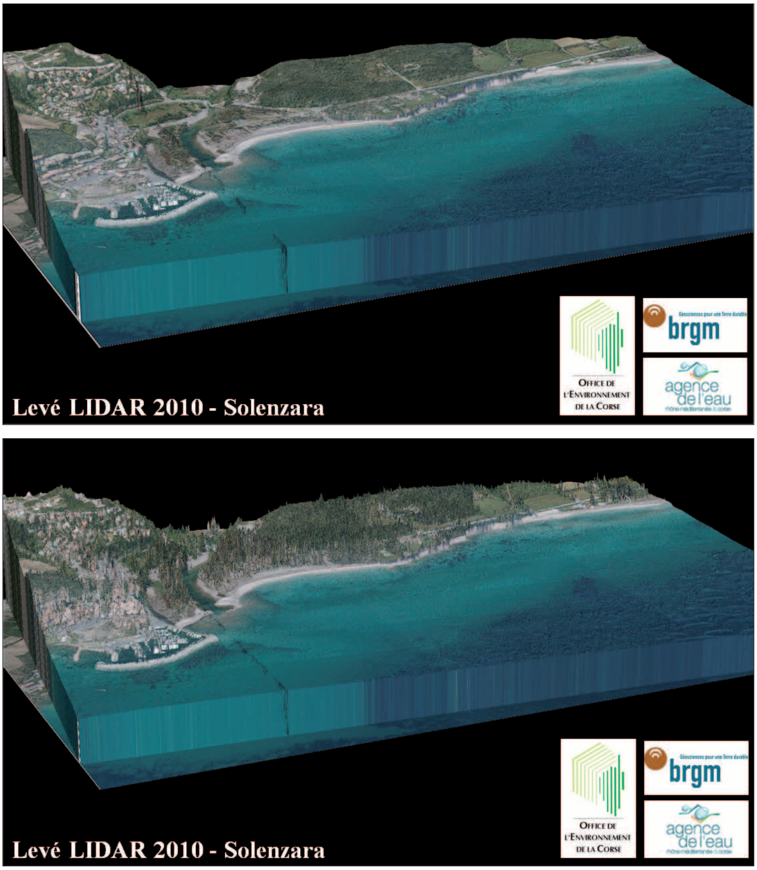

Figure 6 - Example of DTM (left) and DEM (right) obtained in the area of Solenzara. The digital models are covered by the Orthophoto (© IGN 2007).

Figures 7 and 8 illustrate the results obtained during this Lidar survey on several areas of the eastern coastal plain. Coastal infrastructure and nearshore morphology can be clearly observed in these DTMs. One particular point of interest was the characterisation of coastal morphological features. Well-developed nearshore bars were identified, presenting an important longshore variability and a large sediment volume. Nearshore deltas are also well identified, which allows their role in the sediment budget to be assessed (Golo and Tavignano and Solenzara rivers mouths, see figures 7 and 8).

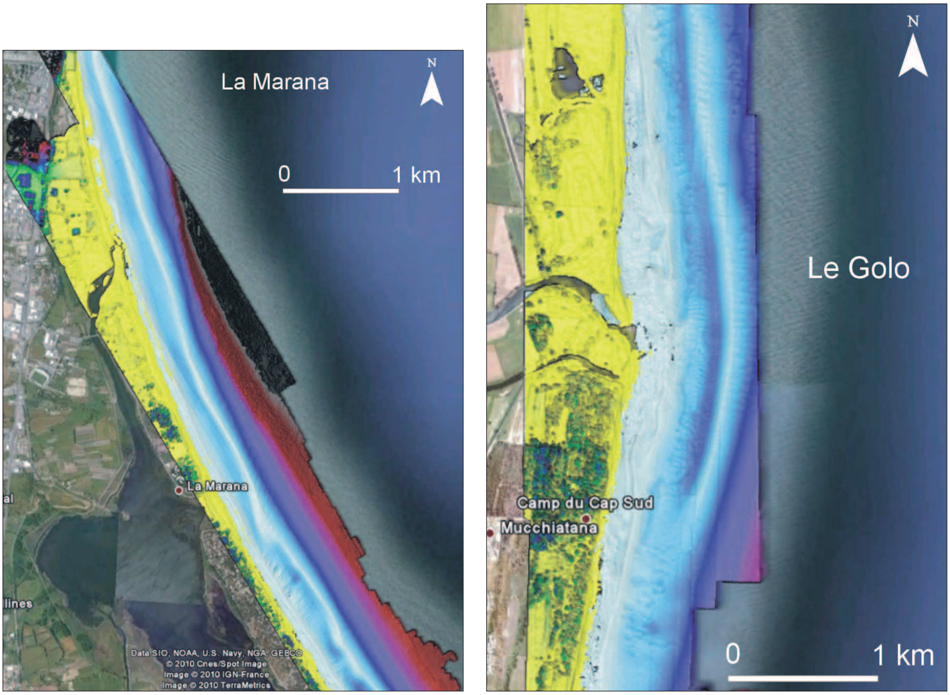

Figure 7 - Examples of Digital Terrain Models in the area of La Marana (left) and at the Golo river mouth (right).

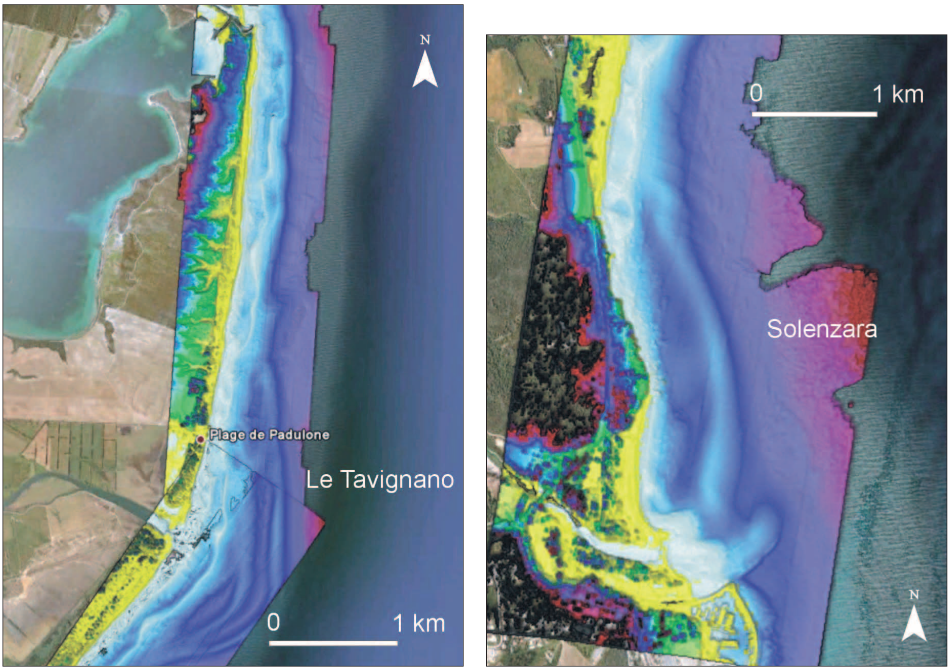

Figure 8 - Examples of Digital Terrain Models in the area from Tavignano river mouth to the inlet of Diane lagoon (left) and at the harbour of Solenzara (right).

Photography database

In order to obtain a more quantitative evaluation of coastal evolution, including changes in both human and environmental assets, a photographic database was implemented. This database contains information on beach surveys (wave and weather conditions), as well as on beach management projects and storm impacts, particularly useful for understanding the evolution factors dominant at each site.

Coastal evolution since the beginning of ROL

ROL was launched in 1999, when beaches were selected for monitoring (Palvadeau and Nay, 2000); for most sites, surveys have been conducted since 2001-2002.
In the following section, evolution of two sites which are particularly representative of coastal dynamics in Corsica will be presented: the beach of Taravo and the beach of Tavignano at Marina d'Aleria. An analysis of evolution trends on the Corsican shoreline will follow.

Evolution of Taravo beach

The beach of Taravo- Tenutella is located at Serra-di-Ferro and Olmeto (figures 9 and 10) in the Gulf of Valinco. This large sandy pocket beach is cut by Taravo river mouth. This area is considered to be a « regional site », sensitive to natural hazards and exposed to hydrodynamic conditions from West and SouthWest. Taravo is a small river with a very steep basin of 331 km^2, and can be characterised by flash floods, such as the one from 1996, able to feed the coast with a significant amount of sediment. The river outlet is highly dynamic and migrates laterally following the littoral drift (figure 10). The river enters the sea with an incised valley; the canyon head is located at a few hundred meters from the shoreline.

Figure 9 - Location of Taravo beach in the Gulf of Valinco.

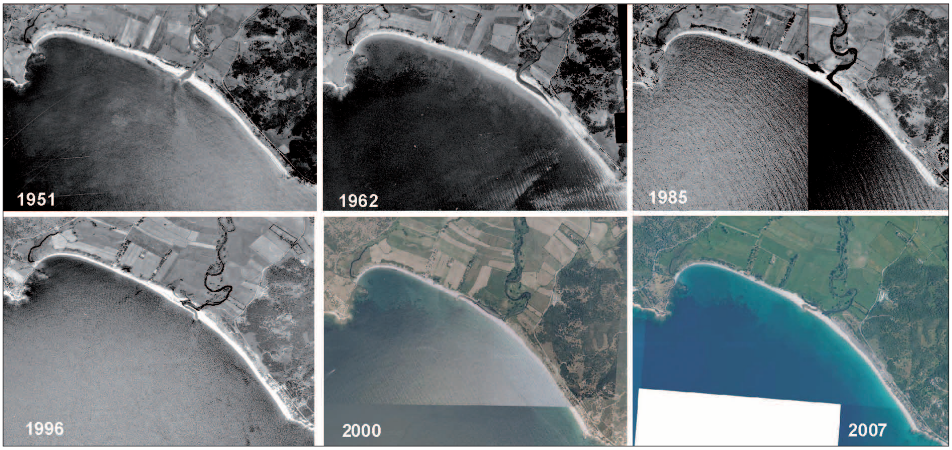

Figure 10 - Historic aerial photographs of Taravo beach illustrating evolution in the past decades (orthophotos © IGN).

The main assets in the area are Natura 2000 wetlands, in the Northwestern part of the beach, and an urbanised area at Olmeto, in the Southeastern part of the bay.
Two cross-shore profiles have been monitored since 2001 (figure 11): one on the northern part of the bay, and one in front of the river mouth. Shoreline position has been monitored since 2009, following a storm event in 2008 that indicated longshore variability of morphological impacts by storms.
The analysis of historical photographs from 1951 to 1996 demonstrated high variability in shoreline position, erosion trend in the northern part of the bay, dynamic equilibrium in the river mouth area and shoreline accretion in the Southeastern area. However, in the past decade, this apparent historical transfer of sediment from NW to SE seemed to decrease, in favour of general retreat between 1996 and 2009 (figure 11). Moreover, in spite of its high variability, migration of the river mouth during the past years suggests a SE to NW longshore transport, thus contrasting to the historical trend.
The beach is very narrow (below 20 m width) with a low-lying dune system (see figure 12). The shoreface slope is very low (around 2%) up to 600 m offshore, where it increases sharply to reach 15%, leading to water depths over 30 m. On profile S, in front of the river mouth, this rupture in shoreface slope is situated 300 m offshore.
In the northern area, the dry beach presents a very concave shape, a slope of about 20% and 20 m width. In the southeast, the beach is wider and the sand volume, associated to the river spit, is much more important.

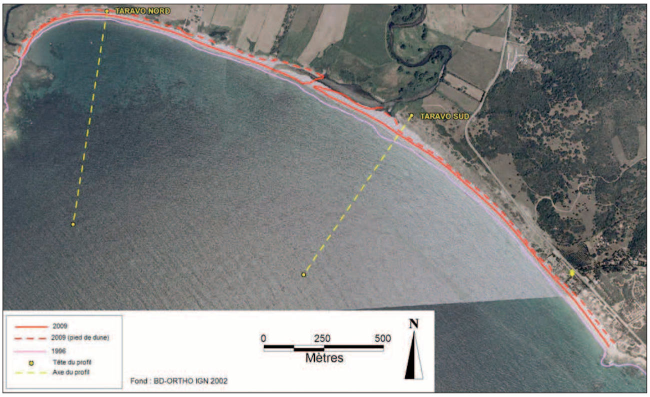

Figure 11 - Location of beach profiles at Taravo, and shoreline evolution from 1996 to 2009.

Evolution in these two areas is not driven by the same processes (figure 12). In the NW part, beach profile evolution indicates the role of storm events in evolution (figure 13). The dune front is retreating, associated with sand deposition in the nearshore. Since 2002, retreat of the dune front has been low but progressive, and no recovery has been observed. Shoreline retreat between 2009 and 2010 was particularly important (8 m, figure 12). In the SE part of the beach, the berm volume is important, and no significant trend has been observed since 2002. Evolution in the South is more balanced; the beach has marked natural rebuilding capacity but presents large retreat at the dune toe, due to winter storm impacts which play an important role in beach evolution.

Evolution of nearshore bathymetry in front of Taravo river mouth (figure 15) indicates loss of sediment in the nearshore (between 0 and -6 m), but also shows the development of an accretionary prism in the old Taravo canyon. A significant amount of sediment was apparently transferred to the canyon and deposited in water depths between -20 and -30 m.

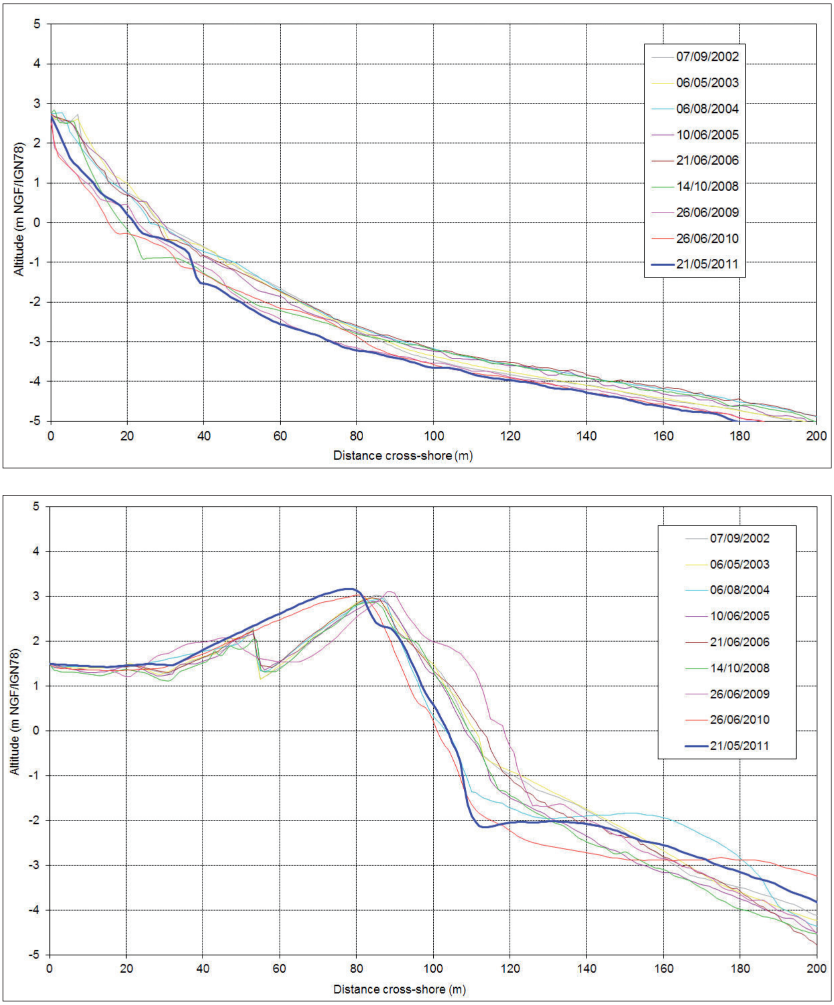

Figure 12 - Evolution of Taravo beach profiles from 2002 to 2010, N (left) and S (right).

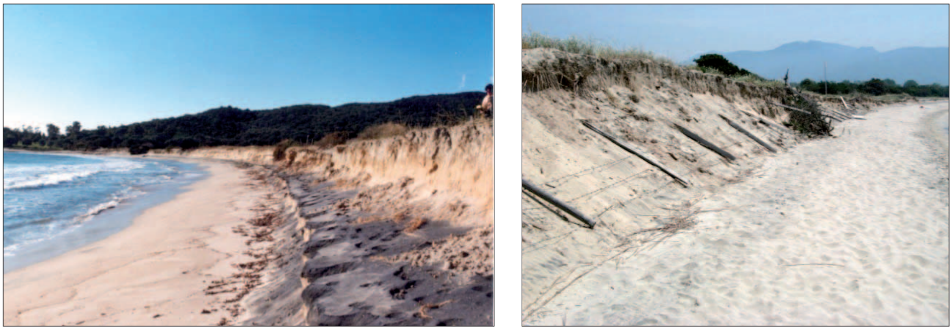

Figure 13 - Storm impacts on Taravo beach. 2000 (left), 2008 (right).

Figure 14 - Erosion in front of the urbanised section (Tenutella beach).

The reason for this accumulation in the canyon is not fully understood yet. However, the main hypothesis is the direct transfer from the Taravo river basin to the nearshore during flash floods. This could lead to absence of sediment supply to the shoreline during such events and to the probable loss of coastal sediment by the breaching of the sand spit that closes the river mouth.

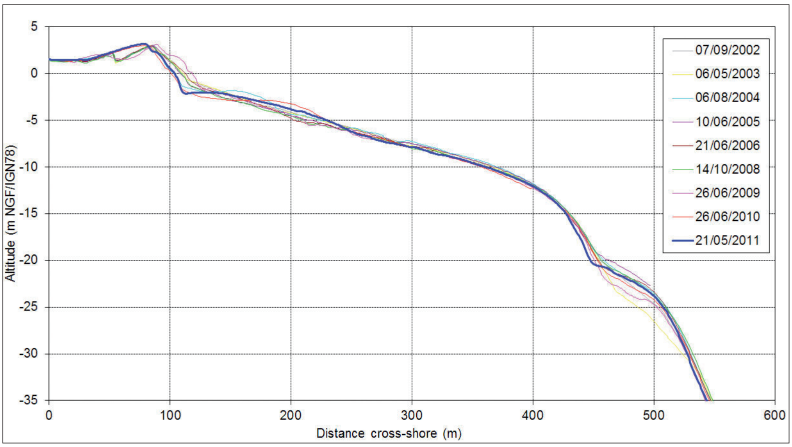

Figure 15 - Evolution of nearshore bathymetry in front of Taravo river mouth.

Tavignano

The Tavigano river mouth and its adjacent shoreline represent an erosion hotspot along the eastern coast of Corsica (Figure 16). This 4 km-long sandy stretch has been affected by chronic shoreline retreat for 50 years. In order to investigate and quantify this phenomenon and prevent it from affecting tourist assets, this site was integrated to the Corsican Coastal Monitoring Network in 2001.

Shoreline retreat between 1948 and 2007 ranges from 60 m to 100 m in this area (Stépanian et al., 2011).

Figure 16 – Coastal erosion trends at Tavignano. a) Beach restaurants endangered by shoreline retreat (October 2007); b) Engineering solutions executed to protect a camping site and economic activities on the backshore (September 2010).

Data

Three topographic/bathymetric profile surveys are conducted on a yearly basis to explore cross-shore altimetric variability of beach morphological features (dune, beachface, berm, submarine bars) (Fig. 17): 1) central profile on Padulone beach (since 2001), 2) Northern profile on the sandy spit between the inlet of Diane lagoon (since 2008) and 3) Southern profile close to Tavigano river mouth (since 2008). Shoreline and dune toe position are also surveyed by RTK DGPS to determine longshore beach dynamics on this timescale.

Figure 17 - Location of topographic/bathymetric profile surveys at Tavignano (©IGN-SCAN25). DGPS monitoring concerns the section between Tavignano river mouth and the inlet of Diane lagoon.

Main cross-shore profile evolution since 2002

The cross-shore profile (figure 18) allows morphological features to be characterised, as well as their evolution. It can be divided in three parts:

- The backshore-dry beach system, with vertical dune front, steep beach-face, and episodic presence of a low berm close to the water-line;
- Inner shoreface, from the shoreline to 5 m water depth, with several nearshore bars. Three bars could be observed in 2011 (figure 18): the inner bar (Zc=-1m), the outer bar (Zc=-5m), and a low-amplitude bar which developed in an intermediate location (Zc=-4 m);
- The outer shoreface, from 850 m to 1500 m seawards, where the seafloor is characterised by chaotic bathymetry corresponding to rocky outcrops and Posidonia seagrasses. Variability of the profiles in this area therefore does not reflect evolution of the seabottom.

During the 2002-2011 period, profile evolution (figure 18) indicates important stability of both outer and inner shoreface areas. The recent evolution (2010-2011) is characterised by the development of a low amplitude intermediate bar, stability of the inner bar and a significant positive evolution of the dry beach concomitant to a +11 m shoreline accretion.

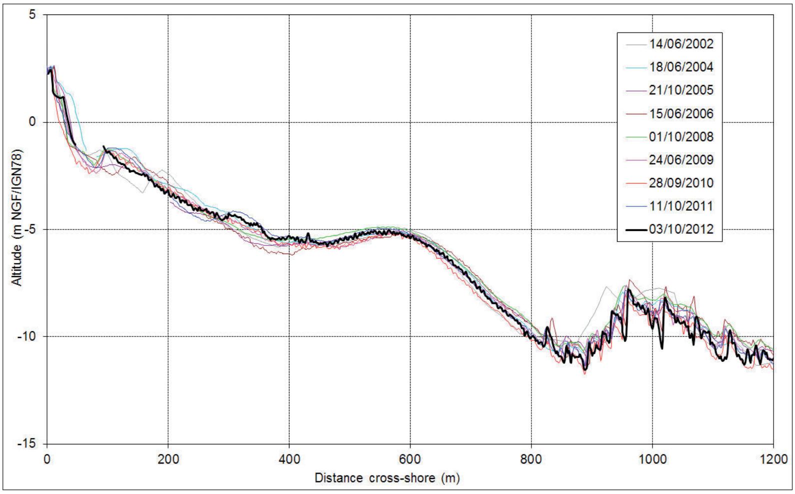

Figure 18 - Main cross-shore profile variability since 2002. Entire profile from dune to Posidonia seagrass and zoom on short profile of beach-shoreface system.

Long-shore morphological variability

Monitoring this area since 2002 allowed the contrasting evolution of northern and southern parts to be characterised.

In the northern part, a clear rhythmic behaviour was observed (Stépanian et al., 2009, 2010). There are "nodes" where evolution is very limited (below 10 m), and intermediate areas where successive erosion/accretion phases are observed with an amplitude reaching 40-50 m (figure 19). The successive erosion/accretion phases have approximately the same amplitude, resulting in a comprehensive medium term «dynamic stability». This behaviour is clearly associated to the presence of rhythmic nearshore bars (figure 8) presenting a cuspate shape. The shoreline is stable in front of the bar horns, while oscillations are observed in front of the bay.

In the southern part of the site, a very different behaviour is observed. Here, the shoreline has been retreating very rapidly, with mean erosion rates near the river mouth reaching 10 m/year. Even if the processes involved in this accelerated retreat are not fully under-

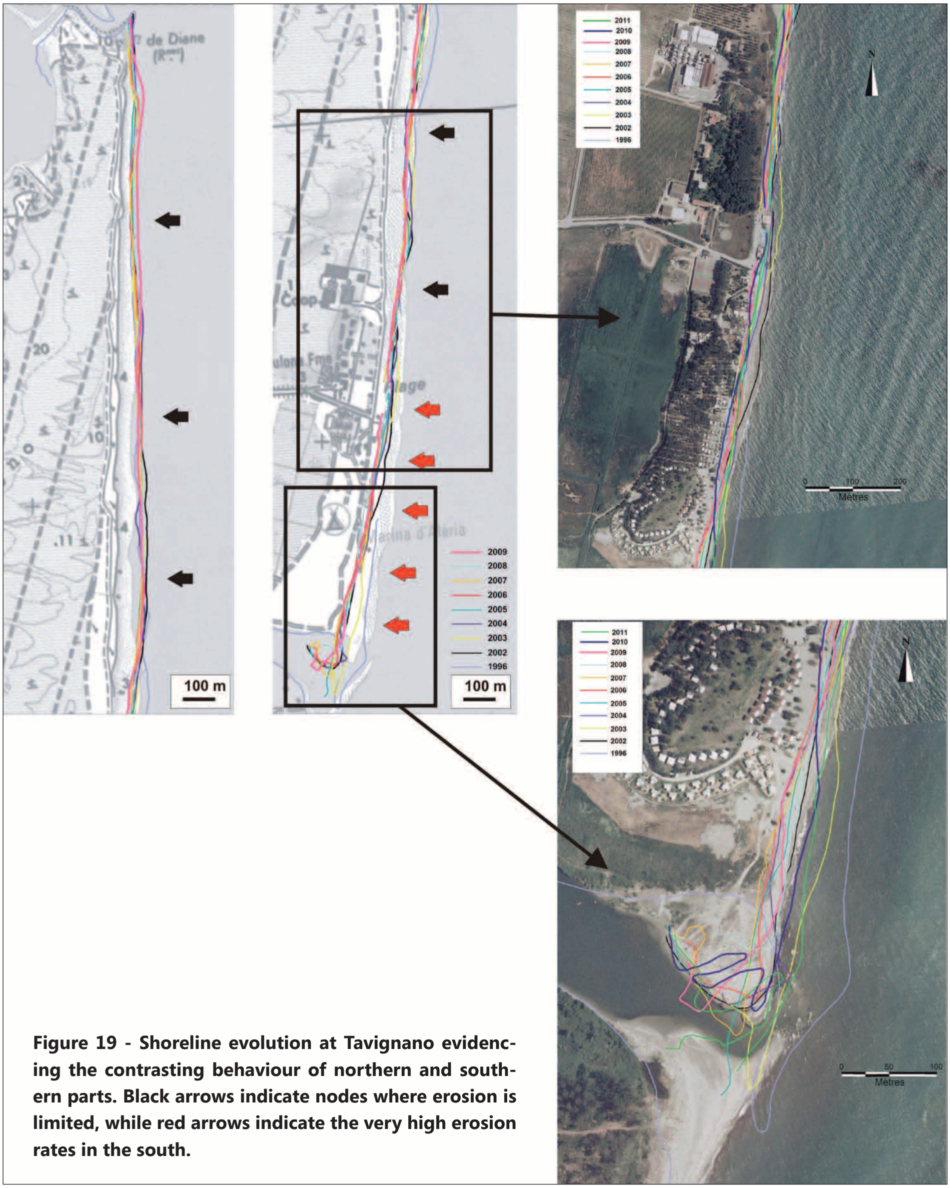

Figure 19 - Shoreline evolution at Tavignano evidencing the contrasting behaviour of northern and southern parts. Black arrows indicate nodes where erosion is limited, while red arrows indicate the very high erosion rates in the south.

stood, the relationship with the river mouth and river delta is obvious. In this area the mean longshore drift is towards N, but wave refraction on the cuspate delta results in a localised southward longshore transport immediately north of the mouth. The subsequent divergence of sand transport directions increases the erosion trend in this particular area of high tourist value.

Synthesis of Coastal Evolution in Corsica

The examples of beach evolution at Taravo and Tavignano illustrate the complexity of coastal dynamics in Corsica. Evolution is driven by oceanographic factors (wave heights, storm events), but may also be caused by local factors including degree of exposure to the dominant wave climate, presence or absence of nearshore morphological features, decrease in sediment supply caused by natural or anthropic interception of longshore drift. This results in different behaviours occurring along the Corsican shoreline (table 2 and figure 20).

Several areas can be considered to be stable. This does not mean that inter-annual dynamics are absent. In several places, oscillation in shoreline position from one year to the other can reach 50 m following a storm event, but at decadal timescale, recovery processes exist and the mean erosion rate remains very low. Monitoring these sites is particularly important to fully understand the inter-annual variability and impacts caused by coastal hazard events. These often have high environmental and/or tourist value that can be affected by the rapid winter erosion, even if the shoreline is reasonably stable at decadal time scale.

Some specific areas present moderate erosion trend. These beaches are usually exposed to dominant storm waves (Balistra, Portigliolo). Here, evolution can be very rapid and lead to significant erosion, followed by recovery periods that limit the medium term trend. This is valid for instance in the case of Porticciolo, where the medium term trend is moderate but the coastal road has already been impacted by storms (in 2003).

Other areas are retreating very rapidly. Their evolution is usually driven by the interception of longshore transport, which can be caused by natural (river mouths, as Tavigano) or anthropic (jetties at Campoloro harbour) factors. In specific places, as Taravo, other processes such as seaward sediment transport might be involved, explaining poor beach recovery, and the increasing risk faced by environmental and human assets.

Table 2 – Evolution of coastal areas monitored within ROL.

Coastal evolution	Short term (annual)	Medium term (decadal)
Stable/Accretion	Taravo-Tenutella N, Galeria, Aregno, Sagone, Campoloro S Balistra, Palu, Porticciolo	Taravo-Tenutella S, Galeria, Aregno, Sagone, Tavignano N, Campoloro S, Alistro, Palu, Santa Giulia
Low erosion	Campoloro N, Alistro, Calvi, Santa Giulia	Calvi, Porticciolo, Campoloro N, Balistra
Moderate erosion		Taravo-Tenutella N, Portigliolo S, Marana
Severe erosion	Taravo-Tenutella S	Tavignano S

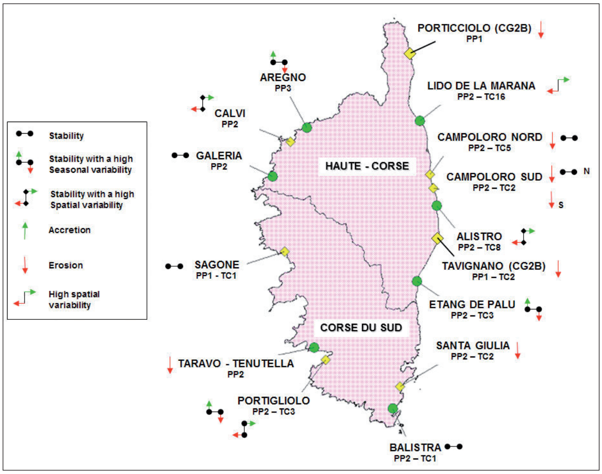

Figure 20 – Synthesis of coastal evolution in Corsica.

A regional Centre for data acquisition, processing and distribution

The coastal monitoring network of Corsica produces an important amount of data including those produced by GPS surveys, Lidar soundings, DTM and DEM, photographs, and hydrodynamic models outputs.

One of the main objectives of ROL is to acquire, gather and share all this information to promote better understanding of coastal processes and the creation of more integrated coastal management strategies. The development of a specific web tool was launched in 2010 within this context.

A feasibility study was undertaken to define the needs and objectives of such tool, the type and format of datasets, and the interoperability of metadata required.

A workshop carried with stakeholders defined the main objective of the web tool. It was set

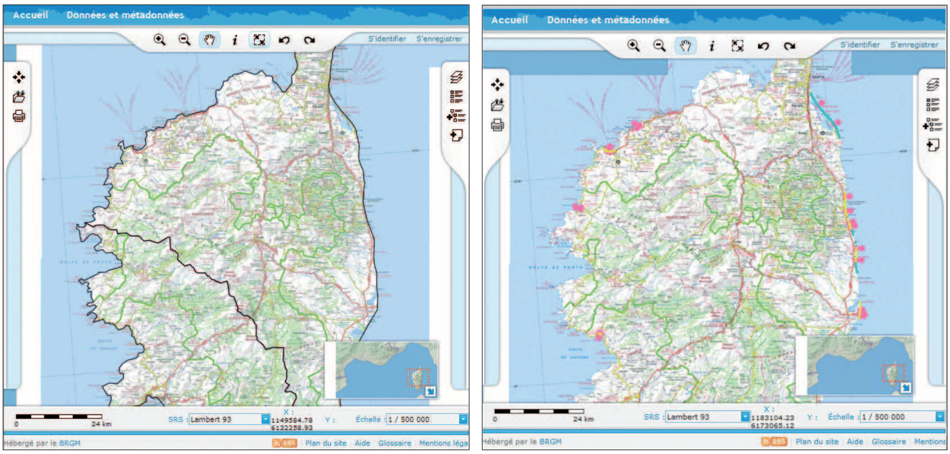

Figure 21 - Example of webGIS that is currently being developed for viewing and sharing data gathered by ROL.

as promoting public information on the actions developed to support management strategies, with special regard to the improvement of knowledge on coastal evolution and risks in Corsica. The web tool, temporary called PROLiCo, will allow the public to access scientific information gathered within ROL. An interactive map will give access to the database and views of coastal evolution. Metadata will be available online, and databases will be available after agreeing on the use of such data.
PROLiCo will contain the following functionalities:

- Management of contents (news, synthesis of actions and results);
- Cataloguing of metadata (interoperable xml according to INSPIRE Directive);
- Online cartography (webGIS, spatial research of metadata).

The development is still in progress; figure 21 indicates the format of the webGIS that will be available online in the next few months.

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The Liguria webcam network and database for coastal management

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Abstract
Littoral erosion has serious repercussions on coastal landscape and socio-economy. The interplay between natural trends and anthropic impact factors complicates its study - and the same is true for planning appropriate solutions. From the point of view of environmentally-aware beach management, it is of primary importance that information concerning littoral morphodynamics should be constantly available.
Action System A of ResMar (Reseau pour l'environnement dans l'espace maritime) Project aims at implementing a monitoring network, i.e. a webcam network for coastal monitoring, based on the processing of images obtained from webcams or digital video cameras already installed, usually for commercial purposes. This rationalises resources employed by reducing management costs of coastal monitoring; moreover, by creating centres for raw data (snapshot image) collection and processing, it supplies information relating to beach morphology with temporal continuity and spatial homogeneity.
If a similar coastal monitoring network is kept active for a long term, it will provide for more accurate and rational planning and design of littoral interventions, and will represent an effective instrument for proper coastal management.
Another useful activity developed in ResMar Project was the enhancement of instruments for littoral data cataloguing, and the improvement of technical and planning procedures for environmental restoration, protection and monitoring of coastal systems.
Standardised catalogues of coastal data, gathered from analyses and tests performed, are currently being produced. They will be hosted by informative systems based on official databases from the public administration (Partner Regions). At the same time, the implications of planning, building, managing and maintaining pre-existing coastal defence works are being assessed. Technical papers and guidelines will be drafted with the purpose of supporting and regulating coastal usage, management and monitoring.

Introduction

Coastal studies involve methods such as physical and morphodynamic modelling and field surveys, which are useful even if somewhat limited in their applicability. Laboratory modelling offers an insight on beach behaviour on a large time scale in a defined environment, but does not provide for an overview of the evolution trend in the coastal zone, since it considers only some of the global aspects that could influence it. Field campaigns are still among the most used coastal monitoring techniques, in spite of being time consuming; in addition, it does not provide for an even coverage of the beach in terms of space and time or for the collection of continuous datasets, due to excessive costs and logistic problems (Aarninkhof et al, 2005).

Only a tool that is equipped for uniform data-recording could provide exhaustive information on beach trends. Video monitoring systems are an alternative method, developed in the last decades. This method allows coastal environments to be studied in continuous and automatic terms, proving to be a very useful tool for the analysis of nearshore processes over a wide temporal range (Aarninkhof and Roelvink, 1999; Davidson et al, 2004; Holland 1998). Many parameters of interest can be acquired in real time with this method, such as longshore and cross-shore evolution of the shoreline and submerged bars, wave direction, storms impacts and beach seasonal changes (Ojeda and Guillén 2008; Kroon et al, 2007; Smith and Pearce, 1997; Turner et al, 2004). In order to evaluate the efficiency of interventions, it is usually necessary to analyse not only shoreline displacement, but also shoreline morphological variations which can provide additional information on beach response to storm events and man-made structures.

All these parameters and information will trace the evolution trend of coastal systems, allowing the efficiency of intervention projects to be evaluated.

In 2007, Coast View project (Van Koningsveld et al, 2007) pointed out the usefulness of a similar tool for coastal monitoring. However, at the same time and in the very same project, problems arose concerning scientific data communication, due to the different goals of researchers and end users.

Video monitoring, as it is presently conceived, lacks data communicability and actual applicability. As Van Koningsveld et al. (2003) suggested, it is necessary to create a compromise and adopt an approach where the different aims can be considered, providing scientific information which end users can also easily read and utilise. Therefore, rather than the method itself, we should change the manner in which it is applied and put to use, and the form in which data are presented.

An innovative and useful method for video systems was presented in ResMar (Reseau pour l'environnement dans l'espace maritime) Project. Video monitoring was applied simultaneously on different sites granting wide spatial coverage and creating a network for the study and management of concomitant beach images, ensuring adequate temporal coverage.

For this purpose, a video monitoring software initially developed in Beachmed-e Project (Brignone et al 2008) and later implemented (Brignone et al, in press) was used. Software *Beachkeeper plus*, differently from others currently in use, allows users to work with any type of images regardless of the corresponding acquisition system. In this study, webcams previously installed for commercial purposes were used without modifying their primary purpose. This rationalisation of resources reduces littoral monitoring management costs; moreover, by creating centres for raw data (snapshot image) collection and processing, it supplies in-

formation related to beach morphology with temporal continuity and spatial homogeneity. The acquired information was also made available for download on certain websites.
A second useful innovation developed in the ResMar Project was the enhancement of instruments for informative cataloguing of data from Ligurian littoral.
Coastal zones are considered difficult to manage because of the several factors to which they are subject: a few examples are weather conditions (as tides and seasons), and local, national and regional government agencies responsible for different sectors (fishing, agriculture, transport) in the same area (Longhorn, 2005). Moreover, at the end of the 19th century, the coast started to be an important source of economic, social and landscape resources, causing its high and vulnerable geological and biological values to be overlooked. For some years, methodologies to deal with the aforementioned factors were developed by different institutions like UNESCO and European Commission (EUROSION, 2004; Coastal Zone Management Program, 2005) to efficiently address the need for sustainable littoral management. Geographic Information Systems (GIS) appeared to be the most appropriate tool, able to integrate and elaborate all coastal factors (Rodriguez et al., 2009) and support national and local decision-making systems.
GIS techniques were preferred to the traditional paper-based reports, due to the larger amount of data involved (coming from different sources, which could be stored and processed with advanced analysis), and because it provided a wider audience with tools for easy access to data and thematic cartography generation (Pan, 2005). While simple software are able to gather, elaborate and display information related to the different disciplines of interest, Geographyc Information Systems (GIS) manage and analyse data with geometric shape (spatial element) and of known position in relation to the Earth surface (georeferenced data).
GIS software describe reality through two types of elements: thematic attributes (statistical data elements) and geographical/spatial data. Attributes represent elements that are not geometrical, such as names, measures and properties, i.e. any alphanumeric element. Geographical and spatial features, instead, are the geometrical elements, and though often employed to describe the same data, reveal some differences. While spatial attributes could consist of any information about multidimensional location, including engineering projects, remote sensing or cartography, geographical data are strictly linked to the information about Earth surface on real-world scale and in real-world space (Frank, 1988). Geographical features are displayed through vector and raster data: whereas the first use basic elements such as points, lines and areas, the later discretise geographical features either in a matrix or in a grid cell. Every element in a vector model is defined by Cartesian coordinates and can include not only the geometry of the point but also the topology or neighbourhood relations. A raster cell is often also referred to as a pixel (picture element) holding data values within the specified range or colour depth of a raster image or raster geodata set. By specifying the raster origin coordinates and the spatial resolution of a raster cell, the spatial position of each cell within the raster grid can be easily calculated (Neuman et al, 2010).

Data acquisition and processing: a coastal video monitoring network

State of the art

Argus Video Monitoring System was the first video monitoring system ever developed. It was created by the Coastal Imaging Lab from Oregon State University at the beginning of the '90s. That system is still the most complete of its kind, managing image acquisition and elaboration. In particular, webcams automatically collect real time beach images at specified intervals. Collected images are then elaborated by software tools to obtain four different types of images (Holman and Stanley, 2007; Alexander and Homan, 2004; Holman et al, 2003): Snapshot, Time Exposure, Variance and Day Timex.

A snapshot photograph is a simple photo of the beach site where webcams are installed. It is used to document site environmental conditions and offers low quantitative information (Zikra, 2007).

Time Exposure (or timex) images are obtained by digitally averaging image intensity over a fixed amount of minutes of image acquisition. It is created by processing and superimposing snapshot images of one acquisition cycle. This process eliminates random momentary sea conditions and removes variability in run-up height. This image processing increases pixel colour intensity, making it possible to distinguish morphological features that would otherwise be difficult to see. The timex image is an excellent tool to underline submerged sand bar topography (Lippmann and Holman, 1989), shoreline (Quartel et al, 2006; Kroon et al, 2007), intertidal beach profile (Plant and Holman, 1997), intertidal beach slope (Madsen and Plant, 2001), and morphology formations in beach face (Holland, 1998; Almar et al, 2008).

Variance images are acquired at the same time as Time Exposure images, but they also enhance the contrast achieved by timex processing. This allows for better recognition of submerged foreshore structures and of regions that are changing during acquisition time (a surf zone is brighter than other parts) as well as of unchanging regions (a dry beach is darker than other parts).

The so-called Day Timex image is obtained through the averaging of all images acquired in one day. This elaboration removes the effects of tidal variation and variation in light intensity due to the changing angle of the sun during the day (Morris et al, 2001).

In addition to these four image types, it is possible to generate Time-Stack images (Zhang and Zhang, 2008; Takewaka and Nakamura, 2000; Kuo et al, 2009; Ojeda et al, 2008), by extracting a line of pixels along a predefined array in a video frame and pasting the lines of pixels side by side. The same set of pixels is extracted from consecutive images and stacked vertically to create an image with time on the vertical axis and cross-shore distance on the horizontal axis. This is used to investigate hydrodynamic characteristics of the beach under study as well as wave orientation and wave length (and their modification approaching the shore), cross-shore variation and run-up.

Due to the evolution in video cameras and video technologies, several systems have been developed in the past years for coastal monitoring purposes and coastal zone management (Lippmann and Holman, 1989). A few examples are Cam-Era[1], Kosta System (Archetti et al, 2008), Coastal Watch[2], Erdman Video System[3], Sirena[4], Horus[5] and many others. The development of these systems was initially based on Argus utilities and software. With such software, a fixed number of webcams, installed on a set elevation above water level,

1 http://www.niwa.co.nz
2 http://www.coastalwatch.com
3 http://www.video-monitoring.com
4 http://imedea.uib-csic.es/tmoos/sirena/
5 http://www.horusvideo.com/

automatically collect real time littoral images at specified intervals. For all these systems, it is necessary to set laboratory accuracy for image acquisition system, in order to perform georeferenciation. The mathematical relation between 3D coordinate systems (xyz) and 2D image coordinates (U,V) involves intrinsic camera parameters, i.e. focal length of lenses, aspect ratio of pixels and pixel location on the optical centre (Holman and Stanley, 2003) as well as extrinsic parameters depending on camera location, i.e. azimuth, tilt and roll angle, camera location coordinates (Aarninkhof et al, 2003) and ground topography.

Material and methods

In this project, nine webcams previously installed for commercial purposes along the Liguria coast were selected to compose the video monitoring network (Fig. 1). Webcams were selected according to specific technical requirements: photo framing to select the most interesting for the study; and the possibility of high image acquisition frequency. To ensure adequate temporal coverage, images were acquired with 5-second frequency for a period of 10 minutes every hour from 9 a.m. to 20 p.m.

Two of those webcams (Moneglia and Ospedaletti) allow raw images from municipal websites to be developed. For the remaining webcams, the management software implemented downloads images directly from the single server belonging to Savona provincial administration.

Images obtained and stored in the central platform were processed with *Beachkeeper plus*

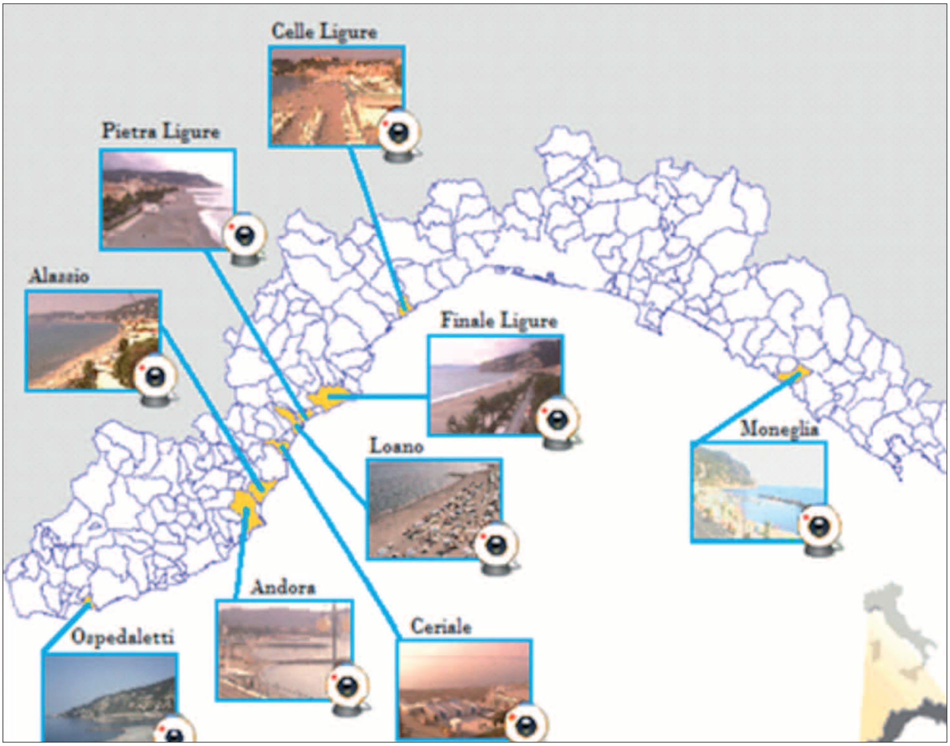

Figure 1 - Study sites.

software (Brignone et al, in press) through photogrammetric techniques, image rectification and digital analysis. This software allows beach morphological traits to be determined and mapped according to the coordinate metric system chosen. In order to georeference webcam images and to ensure the correct functioning of this tool Ground Control Points (GCPs) were surveyed on the beach with a DGPS. GCPs points were spread over the beach so as to cover as many image sectors as possible. Beachkeeper plus georeferenciation tool, differently from others currently in use, bypasses any a-priori laboratory analysis for camera calibration and reduces significant errors caused by camera distortion effects employing the regularisation theory proposed by Landweber (1951).

Results and discussion

The webcam network architecture is formed by nine webcams, and its main operations and procedures are based on a management software linked to host servers and web pages containing raw images, and to the Beachkeeper plus software (Brignone et al, in press). This structure allows all images collected in real time to be downloaded and elaborated, creating an extensive image database consisting of raw data and elaborated images. The primary image elaboration consists of computing Timex, Variance and Day timex images (Fig. 2). Furthermore, detection of Ground Control Points allowed also image rectification and shoreline detection to be carried out (Fig.2).

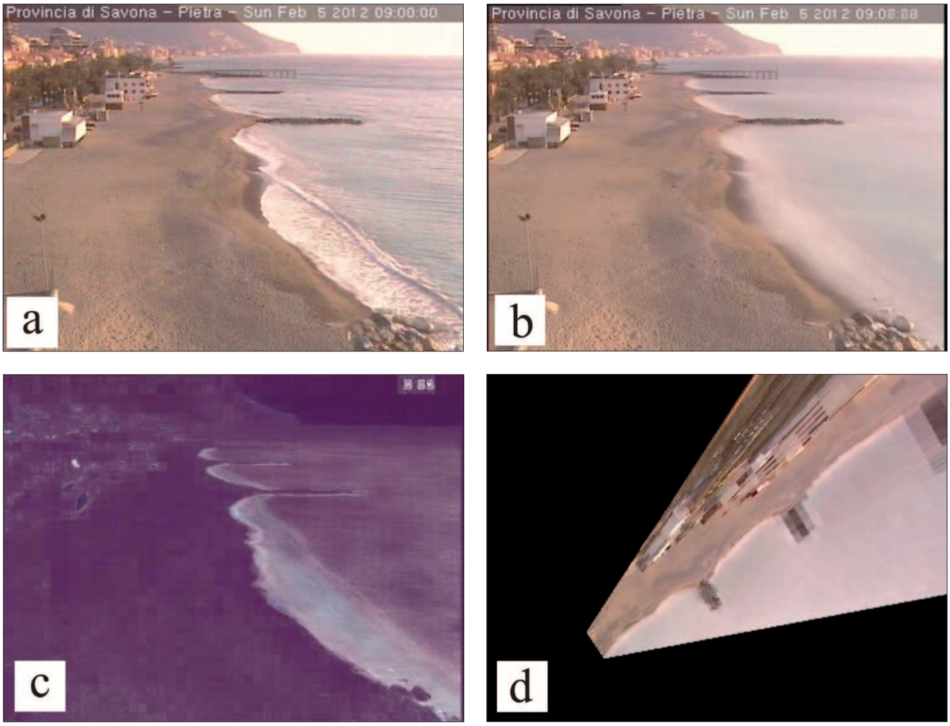

Figure 2 - Example of four types of images obtained through Beachkeeper plus elaboration in Pietra Ligure: a) Snapshot image, February 5, 2012, 9 a.m.; b) Time Exposure image, February 5, 2012, 9 a.m.; c) Variance image, February 5, 2012, 9 a.m.; d) Rectified image February 5, 2012, 9 a.m.

The managing software is also linked to the website http://beachcam.ResMar.eu , especially created for this purpose, where all data obtained are uploaded.
This website is a portal for the ResMar Project - Action A. The portal provides data about the morphological state of beaches, of great use for beach management, and weather conditions in real time, extremely valuable for the tourism industry. The scope of this website is to upload data from the video monitoring network, allowing end users to view and download them.
On the menu located on the left, items link to different articles. A website browser can find information on the main goal of the project and the research group members and activities. Sub-menus can be opened from the main menu, allowing a beach site to be selected and the respective images to be viewed: oblique, rectified or shoreline. In order to select the type of images to be displayed (Snapshot, Timex, Variance and Day Timex) the site also has a “top menu” with a calendar, from where a specific day can be selected (Fig. 3).

Figure 3 - Web page example.

The website structure, and its netsurfing and communication logic, can easily host new users, therefore the network architecture can be expanded if new webcams are installed or used.

Conclusions

The webcam network created in the ResMar Project is the first example of an international monitoring network. It allows information concerning beach morphology to be acquired with temporal continuity and spatial homogeneity, making it possible to use economic resources more rationally. If this coastal monitoring network is maintained active, in the long term littoral interventions may be more accurately and rationally planned and designed, and will represent an effective instrument for proper coastal management. A permanent

monitoring network, available for all interested coastal municipalities, will offer the opportunity to fully frame any phenomenon and underline its temporary features; it will also allow emergency levels to be consistently, rationally and homogeneously evaluated in the entire territory, with the necessary awareness. In fact, data acquired by the beach video-monitoring network are uploaded in real time. This feature is interesting not only for scientific purposes, but also for other uses, since this tool is available to all professionals working in this area.
The network configurations are simple enough for an easy end-user experience, and the absence of further management costs allows human and economic resources to be spared. With this tool, coastal managers can monitor beach evolution in real time and may promptly intervene if needed. Moreover, such a high acquisition frequency provides an overall view of the beach and its evolution trend, which is more accurate than what can be obtained by other methods; it therefore minimises the inaccurate interpretation of coastal conditions caused by less precise methods of data acquisition.
Moreover, this web server will have positive effects on tourism as well: tourists will be able to check not only beach status but also weather and sea conditions.

The "status" of the regional coast

State of the art

The Liguria region coastline extends for 350 km, 140 of which are made of high rocky coast, 94 km of beaches and 116 km of artificial coasts (AA.VV., 2006). As for the geomorphological development of Liguria littoral, the region shows a very short continental platform defined by deep canyons leading sediments towards the bathyal plain (Fanucci et al., 1976). Mountains are remarkable and situated close to the sea, to where irregular and rough solid sediment is carried by the few existing rivers of significant dimensions (Magra, Roya, Centa, Entella). The Liguria coast is highly fragmented in several physiographic units, with an alternation of high coasts (enclosing pocket beaches), and littoral plains with rather long beaches (Fanucci et al.1990, Ferrari et al., 2008). Climate is characterised by winds from the southbound sector. Libeccio, the dominant South-Western wave driving force, with a fetch over 800 km, determines the main longshore detritic flow towards east. From the opposite direction, Scirocco, the South-East wind (with a fetch of 200 km), causes a secondary sediment drift (IIM, 1978; AA.VV., 1997).
Liguria shoreline conditions remained unchanged until the 1990s; data collected from 2000s demonstrated 80% of beaches to undergo erosion (Fanucci et al., 1990; Ferretti et al., 2003a). The coastal railway line, built in the second half of 19th century, was decisive in the loss of shoreline equilibrium and the reduction of beach surface (Bensa et al., 1979; Ferretti et al., 2003b). Coastal urbanisation increased enormously, with the construction of hotels and other tourism facilities as well as defence works to protect them, altering the already fragile equilibrium of the Liguria littoral in permanent terms (Ferrari et al. 2008).
Whether due to natural or to anthropogenic reasons, coastal erosion has today become an important socio-economic problem, difficult to handle by national, regional and local authorities. The answer is sustainable territory management, which can be obtained by mixing different approaches to the same subject.
National, regional and local institutions can make use of research to rebalance the conditions of endangered coastlines and avoid causing, or at least mitigate, erosion in nearby areas - a problem already seen in the past (Pranzini, 2004).

Longtime collaboration between regional Liguria government and University of Genoa made it possible to undertake studies aimed at identifying and monitoring erosion in the entire Liguria coast. Within the European programme BeachMed, the analysis of five morphosedimentary parameters (Ferrari et al., 2004) sampled during field work, collected from bibliographic studies and integrated in a geo-database (Ferrari et al., 2005), provided for an erosion index and littoral classification according to the type of maintenance needed (Ferrari et al., 2008)

Recently, the Liguria littoral has been monitored as part of ResMar European project, where GIS proved to be a flexible system particularly useful for the identification of coastal vulnerability (Doukakis, 2005) especially in view of its important function in the comparison of previously georeferenced cartographic data.

The product was the creation of standardised catalogues of coastal data, which were subsequently stored and elaborated by a geographical information system based on official databases belonging to the public administration of Partner Regions. The raw data of a relational database included in GIS software comprises: shorelines from different years; bathymetric data sampled with Single and Multi Beam ecosounder methodology; and granulometric analyses resulting from surveys carried out along the entire Liguria coast.

Most data came from monitoring new defence works and marinas built up in the past decade. In fact the Dipartimento Ambiente of Regione Liguria introduced a law in 2003 (D.G.R. 222/2003), with a corresponding technical note (D.G.R. 1793/2005), requesting a monitoring plan for each defence work, considering a period of 3 or 5 years. Thus, a large amount of recent local morphological and sedimentological data has been collected by Regione Liguria.

The graphic and statistical analyses carried out by GIS could represent a useful tool for the elaboration of a regional plan that could work as a decision support system to regulate beach management and monitoring in the future.

A Regional Centre for data acquisition, processing and distribution

DiSTAV Dipartment (University of Genoa) and the Environmental Department (Ligurian Region) worked together in Action A of ResMar European project, joining forces for the creation of a monitoring network able to provide an accurate assessment of coastal erosion. Shoreline equilibrium, depending mainly on environmental conditions and anthropic actions (EUROSION, 2005, Ferrari et al., 2008; Ferretti et al., 2003a) and its eventual erosion rates could be controlled and estimated by GIS as it was possible for shoreline position from different periods and sources to be acquired.

The geographic information system used to analyse and manage data was MapInfoâ., primarily for its mapping desktop function (Vertical Mapper) which allows tri-dimensional land models to be easily managed and volumetric comparison grid and sections to be created. The software analyses digital maps in relation to alphanumerical data. Both spatial and attribute elements are organised in layers which are displayed through the following files:

- *.tab is the text file describing the layer structure;
- *.dat is the file collecting the attribute table;
- *.map is the file describing the graphic objects with their original geometric coordinates;
- *.id is the file necessary to link the object to its relative attribute.

The raw bathymetric data corresponding to X, Y, Z (latitude, longitude and depth) point coordinates, relating to different littoral sites and monitored during several years, were converted into the same projection system (Gauss Boaga, Roma 1940) and uploaded to MapInfo. Bathymetric grids and the corresponding depth contour lines were created using the Vertical Mapper analysis T.I.N. interpolation based on the triangulation method (Fig. 4).

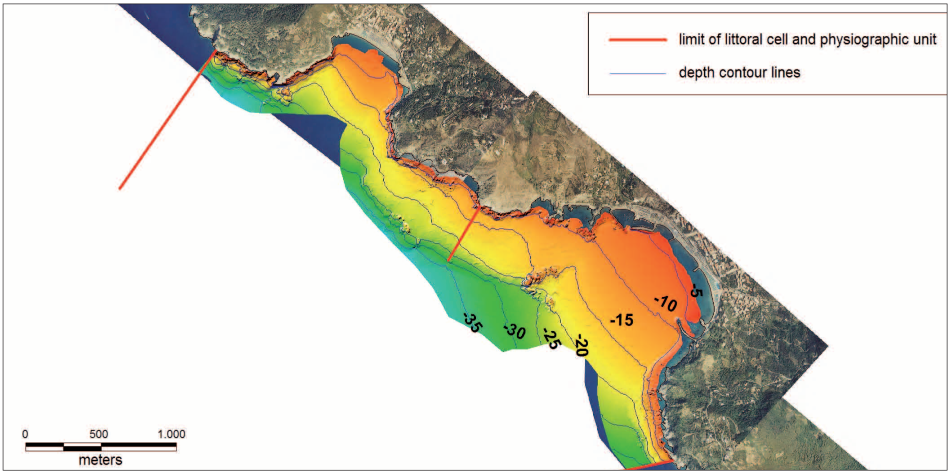

Figure 4 - Levanto and Bonassola sites. Grid and depth contour lines calculated from x,y,z data of bathymetric survey of 2010.

The comparison of bathymetric maps based on subsequent monitoring and on further data coming from the digitalisation of historic maps (from the end of 19th century, provided by Hydrographic Marine Institute - I.I.M.) (Fig. 5), proved to be very useful for calculating erosion and/or accretion(Fig. 6). Also raw data (X,Y,Z) referring to sediments sampled on dry beach and nearshore areas were uploaded and displayed as graphic data in MapInfo (Fig. 7).

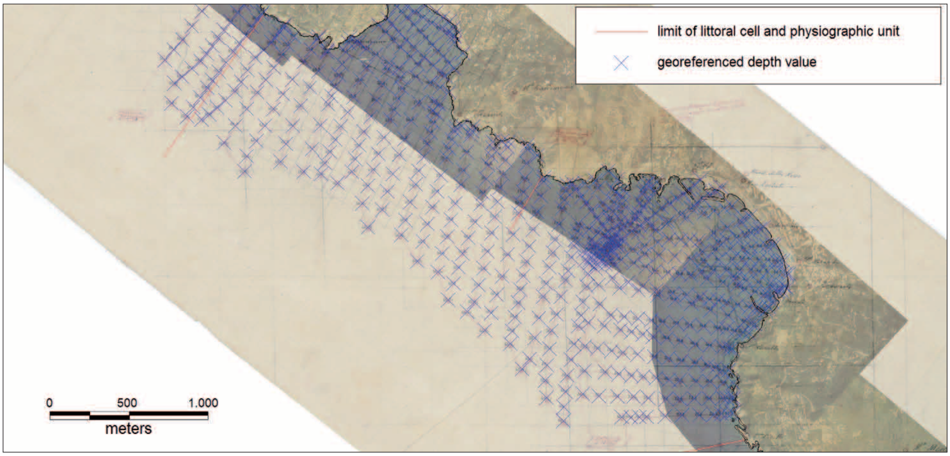

Figure 5 - Levanto and Bonassola sites. Depth values extrapolated and georeferenced from cartography of 1885.

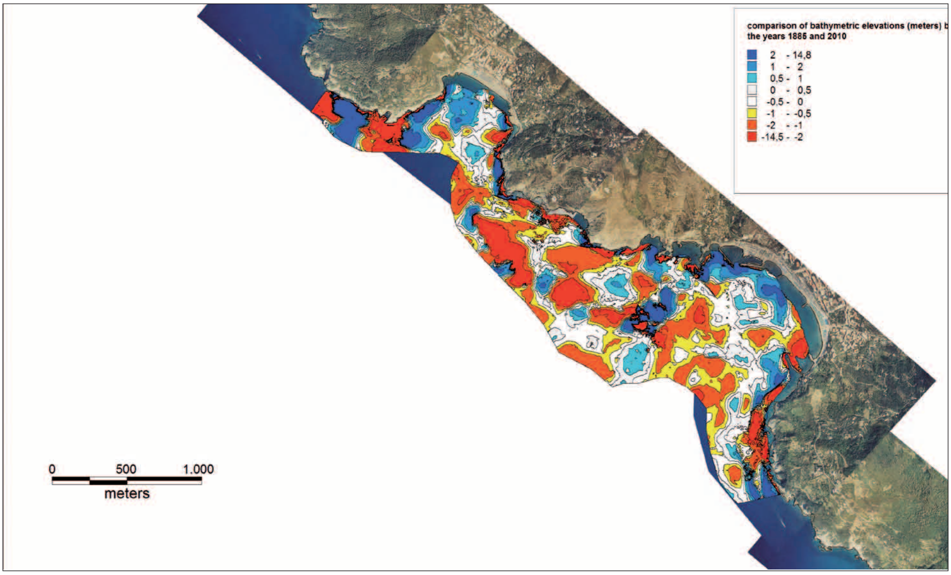

Figure 6 - Levanto and Bonassola sites. Grid comparison deriving from bathymetric survey of 1885 and 2010.

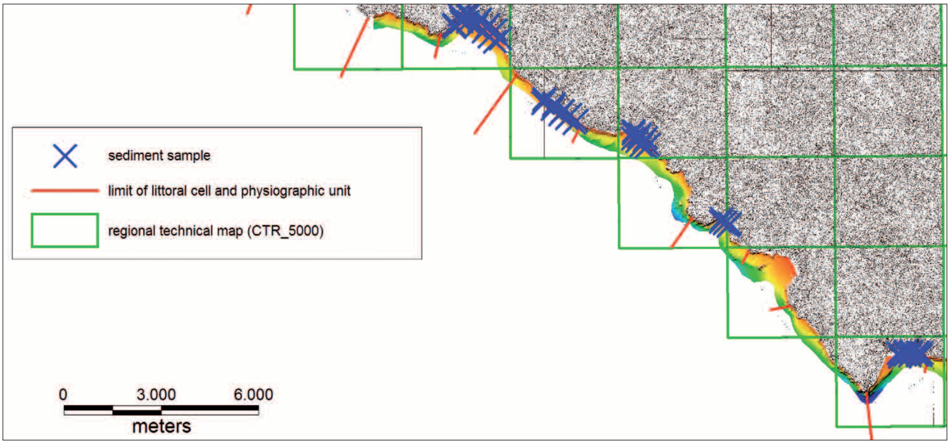

Figure 7 - The Ligurian coast among Punta Baffe and Punta Mesco. Sampling of sediment during bathymetric survey of 2010.

Moreover, a specific *.dat file (STATION.dat) with sediment characteristics was created: a table including data on sampling distance from the shoreline, information about sampling sites, matrix characteristics and methodology used to analyse sediments were all loaded on the regional information system shared by ARPAL and Ligurian Region (SIRA) (Fig. 8).
Each sampling was assigned a code subsequently employed in a new window (ANALYSIS.dat) where results of the analysis are linked to this parameter, which was examined with a specific method and linked to a characteristic environmental matrix (PMC).
PMCs and their codes, used to classify the results of granulometric analyses according to Wentworth classification (Wentworth, 1922) are shown in Fig. 9.

PMC	parameter code	parameter	method code	method	compartment code	compartment
S128SETMS0	S128	SEDIMENT KEPT MM128	SET	sieving	MSO	land
S064SETMS0	S064	SEDIMENT KEPT MM64	SET	sieving	MSO	land
S032SETMS0	S032	SEDIMENT KEPT MM32	SET	sieving	MSO	land
S016SETMS0	S016	SEDIMENT KEPT MM16	SET	sieving	MSO	land
S112SETMS0	S112	SEDIMENT KEPT MM11,2	SET	sieving	MSO	land
S008SETMS0	S008	SEDIMENT KEPT MM8	SET	sieving	MSO	land
S566SETMS0	S566	SEDIMENT KEPT MM5,66	SET	sieving	MSO	land
S004SETMS0	S004	SEDIMENT KEPT MM4	SET	sieving	MSO	land
S283SETMS0	S283	SEDIMENT KEPT MM2,83	SET	sieving	MSO	land
S002SETMS0	S002	SEDIMENT KEPT MM2	SET	sieving	MSO	land
S141SETMS0	S141	SEDIMENT KEPT MM1,41	SET	sieving	MSO	land
S001SETMS0	S001	SEDIMENT KEPT MM1	SET	sieving	MSO	land
S071SETMS0	S071	SEDIMENT KEPT MM0,71	SET	sieving	MSO	land
S005SETMS0	S005	SEDIMENT KEPT MM0,5	SET	sieving	MSO	land
S354SETMS0	S354	SEDIMENT KEPT MM0,354	SET	sieving	MSO	land
S025SETMS0	S025	SEDIMENT KEPT MM0,25	SET	sieving	MSO	land
S177SETMS0	S177	SEDIMENT KEPT MM1,77	SET	sieving	MSO	land
S125SETMS0	S125	SEDIMENT KEPT MM0,125	SET	sieving	MSO	land
S088SETMS0	S088	SEDIMENT KEPT MM0,088	SET	sieving	MSO	land
S063SETMS0	S063	SEDIMENT KEPT MM0,063	SET	sieving	MSO	land

sieve size

Figure 8 - Example of STATION.dat file loaded in SIRA database.

code_station	description_site	abbreviation	latitude	longitude	station_depth	bottom_depth	distance_shoreline	istat_code	APR_code	network_monitoring	puntual_station	areal_station	cage_station	probing
	baia_alassio1AAA	alassio1AAA	4.873.795	1.434.522	0	0	0	009001		04	1	0	0	0
	baia_alassio1AA	alassio1AA	4.873.782	1.434.538	0	0	0	009001		04	1	0	0	0
	baia_alassio1A	alassio1A	4.873.775	1.434.546	0	0	0	009001		04	1	0	0	0
	baia_alassio1B	alassio1B	4.873.724	1.434.607	2	2	64	009001		04	1	0	0	0
	baia_alassio1C	alassio1C	4.873.694	1.434.641	3	3	110	009001		04	1	0	0	0
	baia_alassio1D	alassio1D	4.873.663	1.434.675	5	5	154	009001		04	1	0	0	0
	baia_alassio1E	alassio1E	4.873.637	1.434.706	7	7	192	009001		04	1	0	0	0
	baia_alassio1F	alassio1F	4.873.606	1.434.738	9	9	237	009001		04	1	0	0	0
	baia_alassio2AAA	alassio2AAA	4.873.599	1.434.299	0	0	0	009001		04	1	0	0	0
	baia_alassio2AA	alassio2AA	4.873.599	1.434.309	0	0	0	009001		04	1	0	0	0
	baia_alassio2A	alassio2A	4.873.584	1.434.315	0	0	0	009001		04	1	0	0	0
	baia_alassio2B	alassio2B	4.873.530	1.434.377	2	2	63	009001		04	1	0	0	0
	baia_alassio2C	alassio2C	4.873.499	1.434.414	3	3	111	009001		04	1	0	0	0
	baia_alassio2D	alassio2D	4.873.470	1.434.447	5	5	154	009001		04	1	0	0	0
	baia_alassio2E	alassio2E	4.873.442	1.434.479	7	7	197	009001		04	1	0	0	0
	baia_alassio2F	alassio2F	4.873.415	1.434.509	9	9	237	009001		04	1	0	0	0
	baia_alassio3B	alassio3B	4.873.305	1.434.166	2	2	41	009001		04	1	0	0	0
	baia_alassio3C	alassio3C	4.873.268	1.434.210	3	3	99	009001		04	1	0	0	0
	baia_alassio3D	alassio3D	4.873.238	1.434.247	5	5	146	009001		04	1	0	0	0
	baia_alassio3E	alassio3E	4.873.209	1.434.281	7	7	189	009001		04	1	0	0	0
	baia_alassio3F	alassio3F	4.873.183	1.434.313	9	9	232	009001		04	1	0	0	0
	baia_alassio4AAA	alassio4AAA	4.873.140	1.433.899	0	0	0	009001		04	1	0	0	0
	baia_alassio4AA	alassio4AA	4.873.135	1.433.904	0	0	0	009001		04	1	0	0	0
	baia_alassio4A	alassio4A	4.873.124	1.433.918	0	0	0	009001		04	1	0	0	0
	baia_alassio4B	alassio4B	4.873.079	1.433.972	2	2	55	009001		04	1	0	0	0
	baia_alassio4C	alassio4C	4.873.039	1.434.021	3	3	118	009001		04	1	0	0	0
	baia_alassio4D	alassio4D	4.873.004	1.434.064	5	5	172	009001		04	1	0	0	0
	baia_alassio4E	alassio4E	4.872.970	1.434.106	7	7	227	009001		04	1	0	0	0
	baia_alassio4F	alassio4F	4.872.941	1.434.141	9	9	273	009001		04	1	0	0	0
	baia_alassio5AAA	alassio5AAA	4.872.887	1.433.731	0	0	0	009001		04	1	0	0	0
	baia_alassio5AA	alassio5AA	4.872.883	1.433.735	0	0	0	009001		04	1	0	0	0
	baia_alassio5A	alassio5A	4.872.878	1.433.742	0	0	0	009001		04	1	0	0	0
	baia_alassio5B	alassio5B	4.872.830	1.433.801	2	2	56	009001		04	1	0	0	0
	baia_alassio5C	alassio5C	4.872.788	1.433.852	3	3	121	009001		04	1	0	0	0
	baia_alassio5D	alassio5D	4.872.747	1.433.903	5	5	186	009001		04	1	0	0	0
	baia_alassio5E	alassio5E	4.872.708	1.433.952	7	7	249	009001		04	1	0	0	0
	baia_alassio5F	alassio5F	4.872.675	1.433.992	9	9	302	009001		04	1	0	0	0
	baia_alassio6AAA	alassio6AAA	4.872.641	1.433.568	0	0	0	009001		04	1	0	0	0
	baia_alassio6AA	alassio6AA	4.872.639	1.433.571	0	0	0	009001		04	1	0	0	0
	baia_alassio6A	alassio6A	4.872.629	1.433.581	0	0	0	009001		04	1	0	0	0
	baia_alassio6B	alassio6B	4.872.590	1.433.629	2	2	51	009001		04	1	0	0	0
	baia_alassio6C	alassio6C	4.872.545	1.433.683	3	3	121	009001		04	1	0	0	0
	baia_alassio6D	alassio6D	4.872.500	1.433.739	5	5	193	009001		04	1	0	0	0
	baia_alassio6E	alassio6E	4.872.459	1.433.787	7	7	257	009001		04	1	0	0	0
	baia_alassio6F	alassio6F	4.872.423	1.433.831	9	9	313	009001		04	1	0	0	0
	baia_alassio7AAA	alassio7AAA	4.872.384	1.433.399	0	0	0	009001		04	1	0	0	0
	baia_alassio7AA	alassio7AA	4.872.382	1.433.401	0	0	0	009001		04	1	0	0	0
	baia_alassio7A	alassio7A	4.872.376	1.433.408	0	0	0	009001		04	1	0	0	0
	baia_alassio7B	alassio7B	4.872.330	1.433.465	2	2	60	009001		04	1	0	0	0
	baia_alassio7C	alassio7C	4.872.285	1.433.519	3	3	129	009001		04	1	0	0	0
	baia_alassio7D	alassio7D	4.872.236	1.433.578	5	5	205	009001		04	1	0	0	0
	baia_alassio7E	alassio7E	4.872.191	1.433.632	7	7	274	009001		04	1	0	0	0
	baia_alassio7F	alassio7F	4.872.158	1.433.672	9	9	325	009001		04	1	0	0	0
	baia_alassio8AAA	alassio8AAA	4.872.114	1.433.241	0	0	0	009001		04	1	0	0	0
	baia_alassio8AA	alassio8AA	4.872.111	1.433.244	0	0	0	009001		04	1	0	0	0
	baia_alassio8A	alassio8A	4.872.106	1.433.251	0	0	0	009001		04	1	0	0	0
	baia_alassio8B	alassio8B	4.872.064	1.433.301	2	2	47	009001		04	1	0	0	0
	baia_alassio8C	alassio8C	4.872.007	1.433.370	3	3	134	009001		04	1	0	0	0
	baia_alassio8D	alassio8D	4.871.963	1.433.423	5	5	204	009001		04	1	0	0	0
	baia_alassio8E	alassio8E	4.871.917	1.433.476	7	7	270	009001		04	1	0	0	0
	baia_alassio8F	alassio8F	4.871.887	1.433.513	9	9	317	009001		04	1	0	0	0
	baia_alassio9AAA	alassio9AAA	4.871.851	1.433.096	0	0	0	009001		04	1	0	0	0
	baia_alassio9AA	alassio9AA	4.871.846	1.433.103	0	0	0	009001		04	1	0	0	0
	baia_alassio9A	alassio9A	4.871.836	1.433.117	0	0	0	009001		04	1	0	0	0
	baia_alassio9B	alassio9B	4.871.793	1.433.163	2	2	49	009001		04	1	0	0	0

Figure 9 - Creation of PMC (parameter-method-compartment) and its respective codes.

The scope of SIRA database is the management of information relating to any marine monitoring programme carried out in Liguria Region.
Shoreline coordinates (X,Y raw data) have been sampled with GPS systems in all monitoring studies, and were also compared to data deriving from photogrammetric rendering of aerial ortophotos from years 1944, 1973, 1983, 1993 and 2003.
By overlapping data deriving from the different sources and years, MapInfo displays the shoreline evolution trend with the accretion and erosion zones of the dry beach (Fig. 10).
Dividing the littoral into several beach profiles and considering the mean sea level as the seaward edge, it was possible to calculate and compare dry beach volumes in successive monitoring years.
As conclusion, the system has proved to be a very useful tool to monitor and manage the littoral.
Although only the Ligurian coastline has benefited of such continuous survey until the present date, the evolution of this technique should lead to the creation of a unique Geographic Information System including standardised data related to the coast and shared by all components of ResMar project.

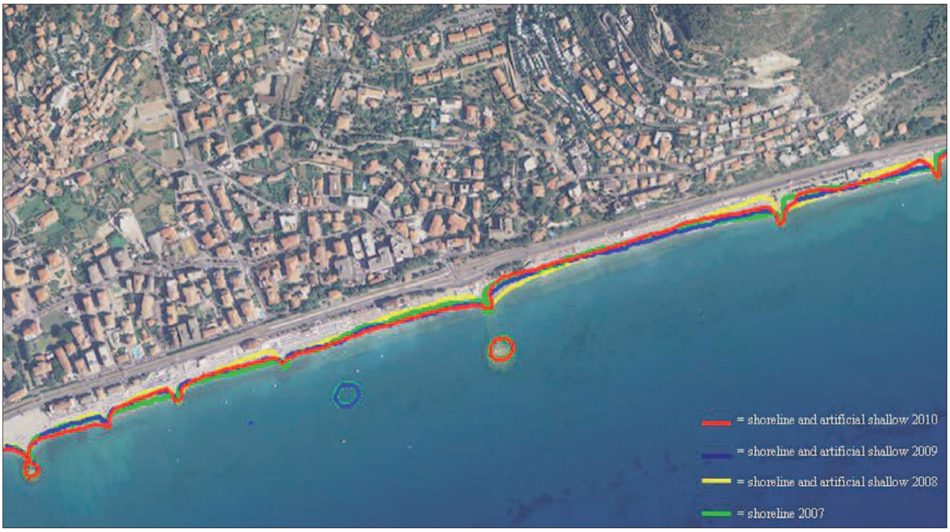

Figure 10 - The littoral of Borgio Verezzi (SV). Variation of the shoreline from 2007 to 2010.

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The activity of "osservatorio coste e ambiente naturale sottomarino" (oceans) and the implementation of a monitoring network and study methodology for sedimentological and morphodynamic processes of mediterranean microtidal wave-dominated beaches (Sardinia)

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Abstract
The monitoring network, set up in 2005 for Project "Gestion intègrèe de l'environnement à haute risque d'èrosion" (Interreg IIIA GERER), was initially based on 4 sample beaches in Corsica and Sardinia, and was later extended, including other 31 beaches over a 6 year-period. A methodology for the study of sedimentary processes and morphodynamics of microtidal wave-dominated beaches in a Mediterranean environment was also implemented. A database was created by the "Coastal and Marine Geology Group" using the monitoring network and study methodology. Data from aerial photographs and satellite images, and on bathymety-topography (DTM), sedimentology, wind and wave energy and hydrodynamics of the beach systems were collected, catalogued, archived and analysed.
A cross-border centre for the study of littoral dynamics ("Centro Transfrontaliero per lo studio della dinamica dei litorali") has been recently developed as part of the P.O. Marittimo Res.Mar "Rete per l'ambiente nello spazio marittimo" – Sub-project B.
Data flow is originated at Osservatorio Coste E Ambiente Naturale Sottomarino - OCEANS from where it is made available to the centre ("Centro Transfrontaliero per lo studio della dinamica dei litorali").
Free use of OCEANS lighthouse has been granted to the university, which has been using it for institutional objectives, mainly by researchers from the Coastal and Marine Geology Group, coordinated by Prof. Sandro DeMuro.
Research results are available in scientific publications, popular publications and on a webgis (www.osservatoriocostesardegna.eu).

Introduction

The beaches of Gallura and Sardinia in general, undergo strong infrastructural pressure which increases during the summer due to tourism.

The response of the beach systems to this increment of "workload" is influenced by ongoing global climate change. As a result of this well-known situation of climatic instability the equilibrium of the beach-dune systems is even more delicate and critical. Signs of environmental distress are already evident in many beaches such as: changes to sedimentary systems, withdrawal, reduction or fragmentation of dune habitats caused mainly by the lack of efficient management.

The extraordinary quality of the Sardinian beaches and the beaches of Gallura is also attributable to the unique composition and structure of the sands. These sands are disappearing and being eroded due to the incorrect use of the resource. The negative experience of Poetto's beach nourishment (Cagliari) is a good example showing that these materials are not artificially reproducible.

The Sardinian beaches are an invaluable resource and should be protected as such.

In 2008, the Osservatorio Coste E Ambiente Naturale Sottomarino (OCEANS), well aware of this serious emergency situation, began a detailed study to understand and use a new monitoring method. It was created by the Coastal and marine Geology Group of Cagliari University and based on scientific knowledge acquired.

Efficient management practice inspired by sustainable development was experimented and promoted on the foundations of this new knowledge.

In this sense, the use of scientific data is of fundamental importance for planning; the database is constantly updated and constitutes a valid support instrument for town councils, PULs (Littoral Use Plans) and good management practices in general. Regional Law DGR 29/15, from 22.05.2008, has given directions for the elaboration of a Coastal Usage Plan, and regulated uses in the territorial sea and in the public maritime domain (owned by the state).

This policy regulates the local authority functions related to the use of National maritime property and areas of territorial sea, as well as recreational use of Nation-owned areas by tourists, regulated by PULs. The scientific knowledge acquired so far shows that a thorough and urgent review of this policy is urgently required, as it does not consider the extreme dynamism of beaches and dunes (also related to the climatic variations underway and the impact of incorrect use of resources).

The creation of this database, aimed at sample beaches, was possible due to to the experience that OCEANS researchers have acquired in implementing the European Project "*Gestione Ambientale Integrata in Località ad Elevato Rischio d'Erosione GERER*" (INTERREG III A) and from the experience gained from the study and monitoring of dune systems in the project Life+ Nature & Biodiversity PROVIDUNE, which OCEANS is coordinating on a national scale.

These two projects, INTERREG IIIA-GERER and LIFE+ PROVIDUNE, are 'pilot projects' based on solid scientific knowledge, providing a concrete contribution on the complex issues related to the dynamics of coastal sand bodies and the management and use of beach systems, for the use of the local authorities directly involved.

The following phases were carried out to create the Database on Coastal Observations:

- reorganization and integration of existing data, using the laboratories, means and

advanced instruments available to OCEANS for the monitoring of beach systems;
- enlargement of the cognitive framework regarding the functional mechanisms of beach systems;
- elaboration of monitoring information from sample beaches to highlight the main criticality and to formulate management proposals for the use of coastal resources according to sustainable development guidelines;

The aim was to obtain a basic computerized picture of the 35 beaches studied that is easy to consult and implement, allowing the following (Fig. 1):
- preparing documents and preliminary research activities required to define a Pilot Project for integrated management of the coastal zone;
- planning and testing a database on Sardinian beaches;
- providing management support and guidelines for local authorities;
- continuing information exchange between the University (institution for research and higher education) and intermediate local government bodies in charge of territorial control (institutions for management).

The first objective reached by the Observatory was to contribute towards a deeper understanding of the historical-geographical evolution of sample beaches located along the entire Sardinian coast. The collection and analysis of these initial data constituted an essential basis required for reaching a second objective: construction of an experimental database containing basic and easily readable information related to the beaches studied, whereas offering the necessary statistics for setting up a model for an integrated coastal zone environmental management programme (see www.osservatoriocostesardegna.eu website).

An important third objective (management orientation) was reached by charting the main threats and criticality of the dune areas of the 35 sample beaches monitored and studied by OCEANS.

The fourth and possibly the most difficult objective aimed at establishing a continuous and regular exchange of information between the world of research and the world of local authorities; it has been partially reached. The different hydrodynamic and morpho-bathymetric responses in the bars-and-trough zone (the most dynamic area of the beach above and below sea-level) of all 35 beaches were studied according to the main wind directions included in the onshore wind sections. Slope variations and changes in volume and the position of the shoreline were studied; numerical models based on high precision measurement techniques were created. Measurement was carried out seasonally (bathymetrical-topographical and sedimentological surveys at dry beach and nearshore were integrated, on some sites, using webcams and weather stations.

The coastline and continental platform of Gallura have been subject of numerous geomorphological, sedimentological, geophysical and geological studies, carried out sporadically since the 1970s, mainly by the University of Cagliari, as part of national and international projects. The launching of OCEANS, located at Punta Sardegna Lighthouse, centre of the database, the laboratories and Scuola di Geologia Ambientale Subacquea (school of underwater environmental geology) (Fig. 2), have provided a new input of research activity through the development and management of national and international projects. Through the Coastal Marine Geology Group, OCEANS has also worked on the

Figure 1 - Position of the 35 nodes of the Monitoring Network maintained by Coastal and Marine Geology Group.

renovation and organisation of Punta Sardegna Lighthouse (Fig. 2), on the preparation of two research boats and on supporting and promoting good management practices (www.osservatoriocostesardegna.eu).

The "Coastal and Marine Geology Group" used, tested and implemented a series of protocols and methodological standards for the study and monitoring of 35 beaches. The network was based on three beaches in the north of Sardinia and one in the south of Corsica: Cala di Trana, La Sciumara, Venalonga (Palau) and Paragan (Bonifacio) [3] [4] [5]

Figure 2 - Picture of Punta Sardegna Lighthouse and OCEANS headquarters.

[7] [8] [9] [11]. It was created in 2005, for the Interreg IIIA GERER Project "Gestion intègrèe de l'environnement à haute risque d'èrosion", and was extended in 2006 to the beaches of Solanas (Sinnai) and Santa Margherita di Pula [7] [8] [10] [17] as part of the project "Sistema di controllo Ambientale e gestione territoriale del Golfo di Cagliari", funded by Research, University and Instruction Ministry (M.I.U.R./Ministero Istruzione Università e Ricerca) (Fig. 1).

In 2009, the network was further extended, thanks to Project LIFE+ Providune, to 8 other beaches in the south of Sardinia: Piscinnì, Su Giudeu, Campana, Sa Colonia (Domus de Maria) and Porto Giunco, Simius, Is Traias and Punta Molentis (Villasimius) [6] [12] [16] [17]. Finally in 2010 4 more beaches were added (Is Arenas in Narbolia, La Cinta (San Teodoro), Cala Budoni and Poetto (Cagliari) [1] [2] [20] [21] [22] [23]) thanks to the contribution of research projects and scholarships funded by the Sardinian Regional Government through Regional Law L.R. 7/2007 (RIsposta e Adattamento dei sistemi costieri della Sardegna alle variazioni climatiche globali – RI.A.S. and Beach Environment, management

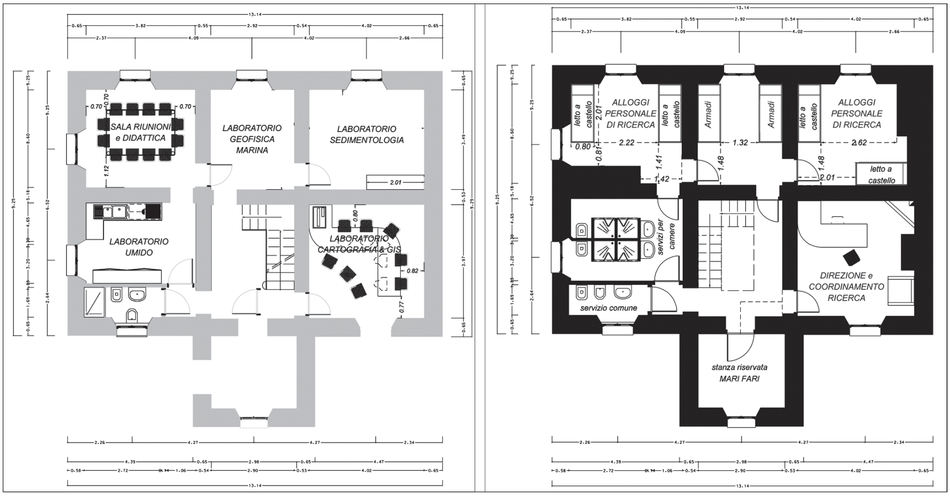

Figure 3 - Plan of the Lighthouse, ground floor and first floor.

And Coastal Hazard – B.E.A.C.H.). Later, the framework for the running of OCEANS permitted the network to include 17 other beaches: Lu Litarroni (Aglientu), Rena Majori (Aglientu), Badesi (Badesi, Trinità d'Agultu e Vignola), La Colba (Santa Teresa di Gallura), Porto Liscia (Santa Teresa di Gallura, Palau), Porto Pollo (Palau), Le Saline (Palau, Arzachena),

Figure 4 - Punta Sardegna Lighthouse, operating headquarters for OCEANS and the "Centro Transfrontaliero per lo Studio della Dinamica dei Litorali" (cross-border centre for the study of coastal dynamics), before and after renovation.

Figure 5 - Punta Sardegna Lighthouse, inside before and after renovation.

Cala Ciaccaro (La Maddalena), Cala Portese (La Maddalena), Cala Corsara (La Maddalena), Cala Majore (La Maddalena), Cavalieri (La Maddalena), Grande Pevero (Arzachena), Capriccioli (Arzachena), Cala Sassari (Golfo Aranci), Le Saline (Olbia) and Cala Brandinchi (San Teodoro) [19]. Today we have a total of 35 beaches being monitored.

All data are stored into the database situated in Punta Sardegna Lighthouse (OCEANS headquarters), created and managed by the Coastal and Marine Geology Group (Fig. 4 and Fig. 5).
The beaches are studied seasonally with the aim to evaluate sedimentary and morphodynamic processes, anthropic impact, criticality and evolution trends, and also to provide management guidelines.

Methodology

The studies are carried out according to the chart in Fig. 6. This illustrates the configuration of instrumentation used, the work performed and the data obtained [7] [9].

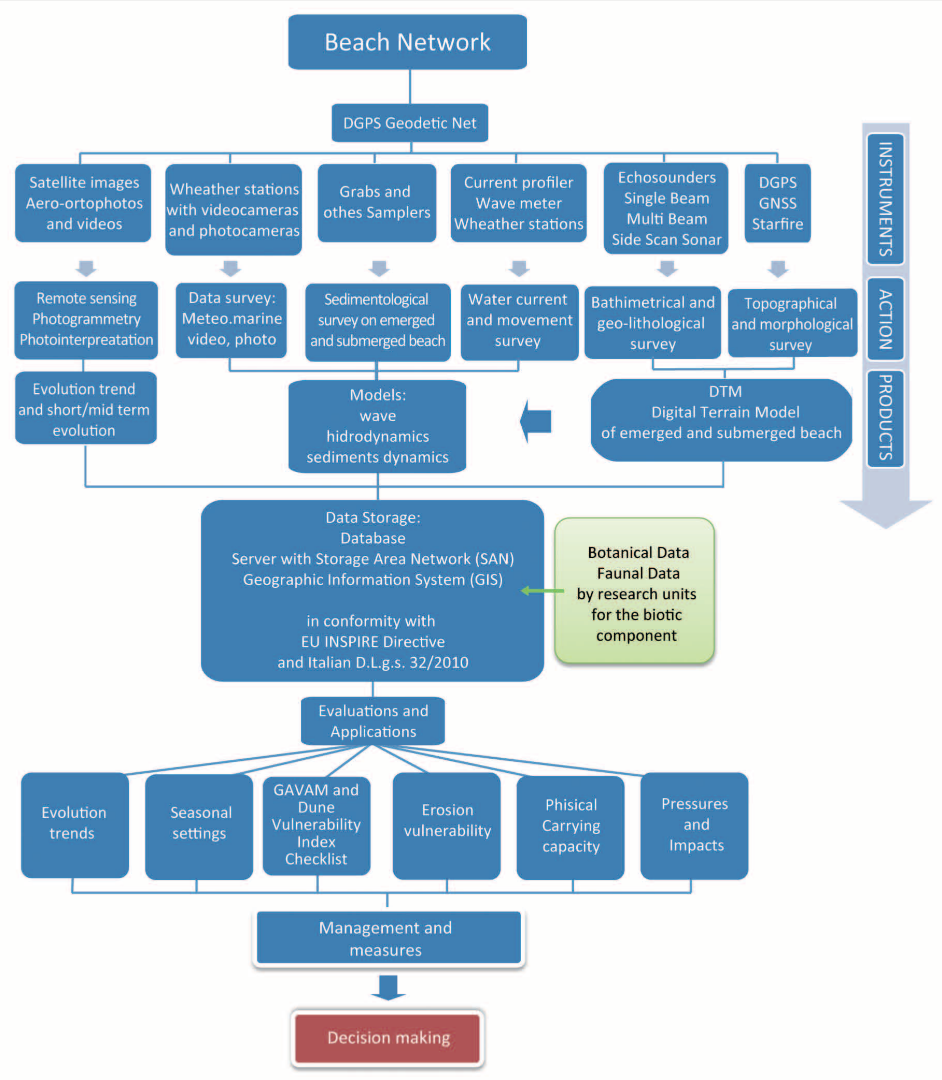

Figure 6 – Methodological chart created with Interreg IIIA GERER Project [7] and implemented with project LIFE+ Providune [13] [14].

The historical reconstruction of evolution in the area is carried out for each beach using the interpretation of aerial photographs, in order to identify “macroindicators” [19] such as: extension of the dune area, position of the shoreline, distribution of marine phanerogams (e.g. *Posidonia* etc.), anthropological elements (buildings and coastal infrastructure, for example) and hydrography. This allows evaluating the evolution in the area in short and medium term studies. All the data acquired are linked to the geodetic network points created on all the beaches (Fig. 7).

Figure 7 - Implementation of geodetic network.

The topographical data are acquired using DGPS or GNSS and/or StarFire systems with a point sampling frequency of 1Hz. An Echosounder/DGPS system is used for the beach below sea level together with a navigation software with a sampling frequency of 5Hz. All results are referred to the UTM – WGS84 *Datum* coordinating system (Fig. 8).

Figure 8 – Morpho-bathymetrical and topographical findings in the study sites.

The sediments collected from the morpho-sedimentological units (dune, beach above and below sea level) (Fig. 9 a, b) are dealt with according to standard sedimentological methods (texture, composition and facies analysis - Fig. 9 c, d).
Current direction and speed are simultaneously verified and measured (Fig. 10) and meteorological and video data from the sample sites are collected using a remote control system of video cameras and meteorological stations (Fig. 11).

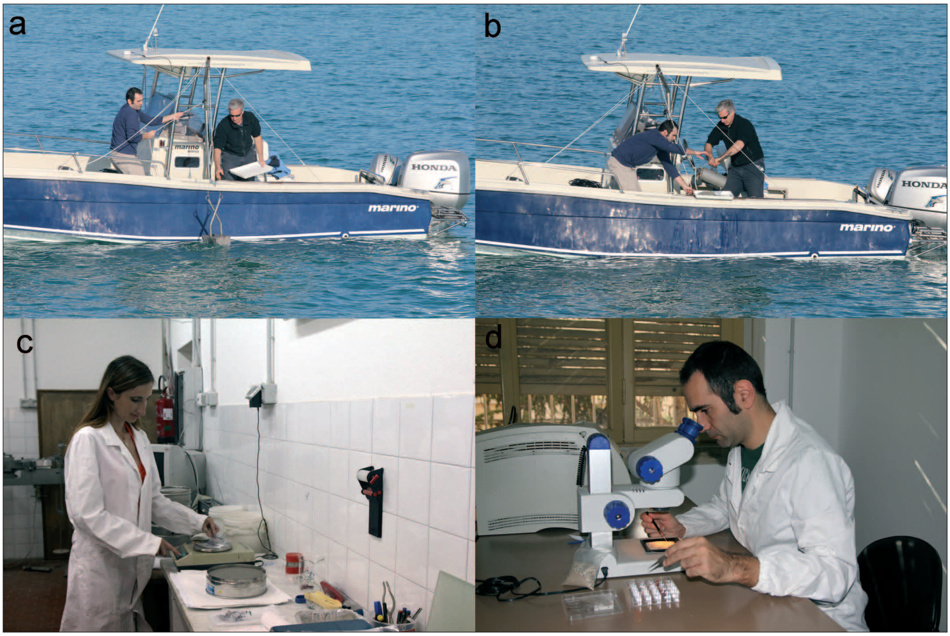

Figure 9 - Collection of sediment samples using the Van Veen grab (a, b); analysis of sediments in laboratory (c, d).

This allows video-monitoring of the areas, evaluating for example: movement of the shoreline, areas affected by overwashing, duration of stranded seagrass (*Posidonia)* deposition and elimination processes, etc.

Figure 10 - Current speed and direction survey.

Meteorological stations collect and record other important data (wind direction, intensity and persistence, etc.) directly at the study area.
Models of beach wave and hydrodynamics are created from the wind direction and intensity detected in the study area (Fig. 12).

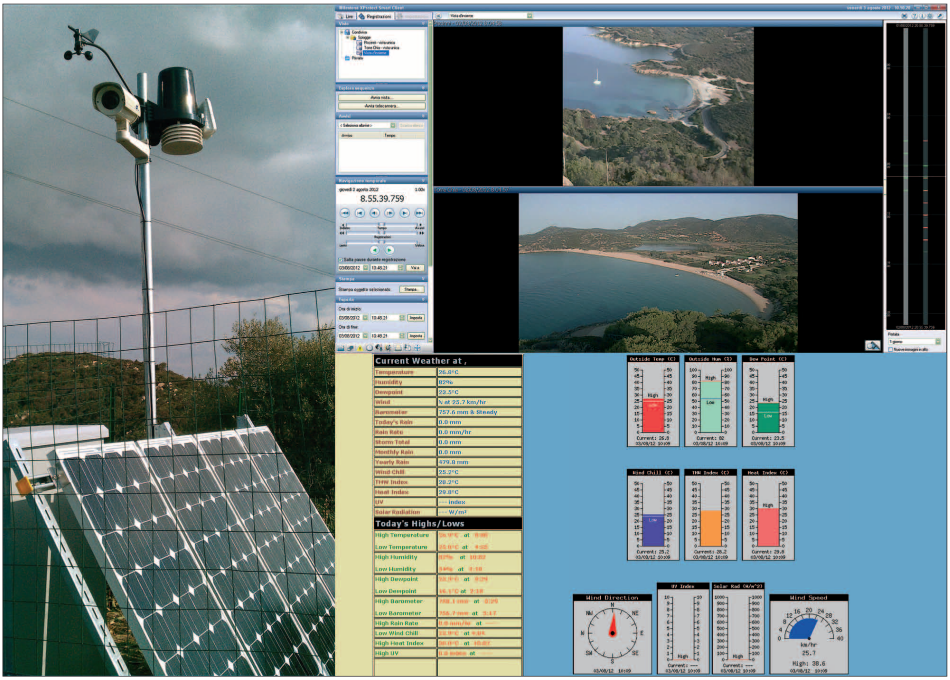

Figure 11 - Remote control system with Video-Meteo centre (a); acquisition software screen for video images (b); meteorological data acquisition software screen (c).

They are based on Digital Terrain models (DTM), built from bathymetric-topographical data, and from the results of sedimentological analyses and meteorological-climatic and current speed/direction analyses.
The methodology described in projects Life+ Providune and Res.Mar "Centro Transfrontaliero" was implemented through the construction of a database infrastructure formed by Server and SAN (Storage Area Network) for archiving purposes.
The territorial geographical, aerial-photogrammetric, satellite images, cartographical, bathymetrical-topographical (DTM), sedimentological, wind, wave and hydrodynamic (in raster and vectorial format) data was constructed, archived and indexed in GIS format, in accordance with EU INSPIRE normative and Italian Law D.L.g.s. 32/2010.

Through the elaboration and interpretation of all data, scientific results are obtained, providing the basis for applications and evaluations such as: detection of evolution trends, seasonal sequences, dune vulnerability (DVI/GAVAM checklist [12]), erosion vulnerability, physical load capacity, pressure and impact on the beach system.
The method provides information for the elaboration of management guidelines and for the planning of conservation works.
The results are available to a wide public of potential users in scientific publications and journals and in a WebGIS (www.osservatoriocostesardegna.eu).

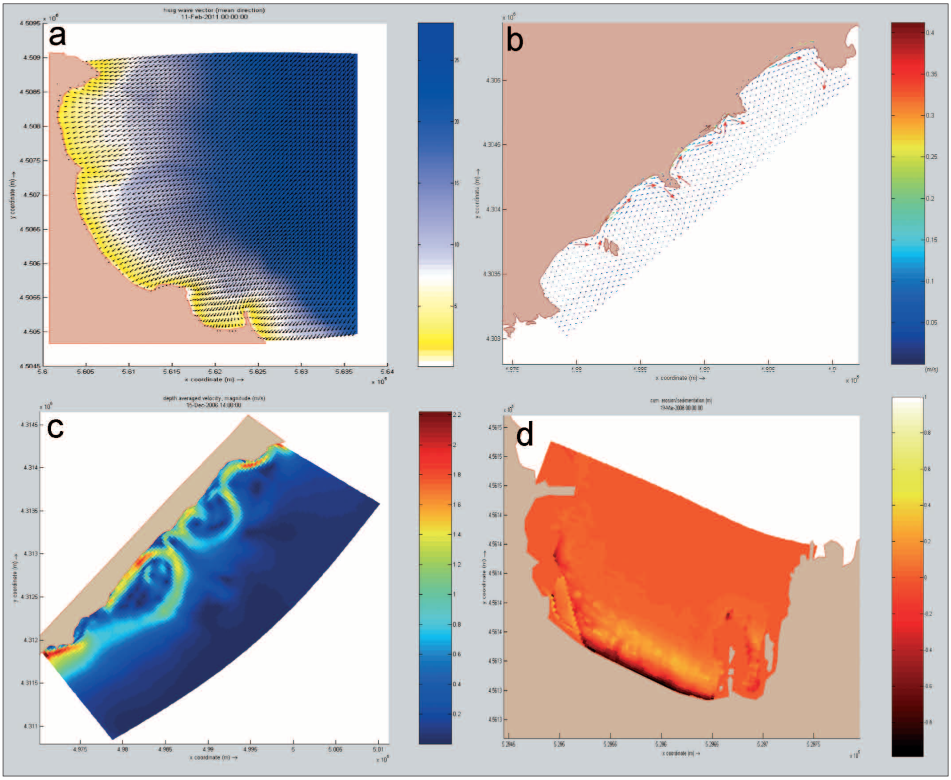

Figure 12 – Examples of wave refraction and hydrodynamics: a) vectors of the wave front; b) vectors of the hydrodynamic flow; c) representation of energy associated to hydrodynamic flows; d) representation of bar-and-trough area (surf zone).

Conclusions

The Osservatorio Coste E Ambiente Naturale Sottomarino, OCEANS, was created thanks to the work of the Coastal and Marine Geology Group – University of Cagliari, at Punta Sardegna Lighthouse (OCEANS). The numerous research projects carried out since 2000 have provided information to create a network for the study and monitoring of 35 beaches in Sardinia. A new methodology has been experimented and implemented since 2005. This has focused on the study of sedimentological and morphodynamic processes of wave-dominated microtidal beaches in a Mediterranean environment. The study began in 2005 as part of the Interreg IIIA GERER Project, and was applied and developed within Project Progetto LIFE+ Providune. In 2010, the network was extended to include a total of 35 sites under study and monitoring, as part of projects L.R. 7/2007 RI.A.S. and B.E.A.C.H., and Res.Mar Sottoprogetto B "Centro Transfrontaliero studio dinamica dei litorali".
The extension of the methodology used, permitted OCEANS to create a database for collecting, cataloguing, archiving and analysing aerial-photogrammetric, satellite image, cartographical, bathymetrical-topographical, sedimentological, wind, wave and current data related to the beach systems studied by the "Coastal and Marine Geology Group" from University of Cagliari.

The data collected, catalogued, archived and analysed has been published in the usual scientific channels and also on a WebGIS platform on the OCEANS website (www.osservatoriocostesardegna.eu) and are stored in a server, created by and housed in the Department of Chemical and Geological Sciences of the University Cagliari.
Data flow is made available from OCEANS to the "Centro Transfrontaliero per lo studio della dinamica dei litorali" (cross-border centre for the study of coastal dynamics).
Together, the methodology, database system and publication through WebGIS allow providing, for a large number of beaches in Sardegna guidelines for management and planning of conservation works, accessible to a wide public of potential users.

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Sardinian Center for Coastal Monitoring and Assessment

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Abstract
Article 16 of the ICZM Protocol identifies the functional tools for integrated management as appropriate mechanisms for coastal monitoring and observation, existing or newly established. The sardinian governamental agency Conservatoria delle coste within its institutional mandate for the coordination of ICZM activities in Sardinia has set up a Sardinian Center for Coastal Monitoring and Assessment. As in many other Mediterranean countries the coastal areas observation and monitoring activities in Sardinia are performed by several institutional stakeholders. The main objective of the Center is to provide coordination of the different stakeholders including evaluation and monitoring of the implementation and development of integrated coastal management policies. To this aim the Center provides information needed to assess main impacts generated by natural and human activities on marine and coastal environments, as referred to the objectives of ICZM, throught the use of a significant set of monitoring indicators. At the same time the Center proposes concrete solutions for adaptation according to ICZM objectives acting as a decision support system for policy making at regional and local level. The methodological approach behind the implementation of the Center for Coastal Monitoring and Assessment recognises the coordination role that Conservatoria may have regarding local authorities and regional stakeholders responsible for the management of coastal areas.

Introduction

The contents of this document aim at the identification and definition of the principles and conceptual background needed for the construction of the Sardinian Center for Coastal Monitoring and Assessment, which shall be named the "Centre", consistent with the Integrated Coastal Zone Management criteria.
The document is organised as follows:

- the strategic and institutional framework, which identifies the basic ICZM principles and criteria and the minimum requirements for coastal monitoring and observation, considered in the ICZM Protocol;
- the framework of competences in the field of territorial observation and monitoring articulated by various institutional levels in Sardinia;

- the aims and objectives proposed for the setting up of a regional Coastal Zone Observatory, named as "Centre";
- the thematic fields of observation that structure the scope of the Centre, based on ICZM principles and criteria;
- the minimum requirements of the different fields of view considered to be the functional structure of the Centre, part of which is proposed as an initial list of indicators and spheres of relationships in support of the evaluation of the ICZM implementation status in the regional context .

Institutional strategic framework

ICZM is widely considered the most efficient approach for achieving sustainable development of coastal areas. ICZM recognizes an approach to environmental, socio-cultural and territorial planning, and integrated resource planning, in relation to their different uses. In this sense, the integrated management is conducted with the overall objective of achieving sustainable development of the coastal area, through a strategic approach that is based on sustainable management of natural resources on a long-term perspective, respect for socio-cultural issues, involvement of local communities and a better coordination of activities and institutional responsibilities.

ICZM in the Mediterranean refers to two types of policy drivers, which come from the United Nations and the European Commission. The United Nations Environment Programme (UNEP) has been active in the Mediterranean since 1975, with the adoption of the Mediterranean Action Plan (MAP), that was introduced by the Barcelona Convention (Convention on the Protection of the Mediterranean Sea against Pollution), by which Integrated Coastal Zone Management (ICZM) initiatives have been brought forward. Since 1995 the European Commission (EC) launched a Demonstration Programme on ICZM in order to assess the state of the art in the coastal areas of the member states. The work of the European Parliament and of the Council has finally led to the publication of the Recommendation from 30 May 2002 concerning the implementation of Integrated Coastal Zone Management in Europe (2002/413/EC), which determines the principles and national strategies that Member States should achieve, in cooperation with regional and interregional authorities, to promote and implement integrated management.

Italy, already a party to the Barcelona Convention, has also signed the Protocol on Integrated Coastal Zone Management (ICZM Protocol), adopted under the Plenipotentiary Diplomatic Conference held in Madrid on 20 and 21 January 2008 and *"Since furthering knowledge of coastal systems is a key condition for the development of management policies, the Protocol includes an article on monitoring and observation mechanisms and networks"* (Billé and Rochette, 2010).

Article 16 of Part Three of the Protocol, in particular, identifies the functional tools for integrated management as appropriate mechanisms for coastal monitoring and observation, existing or newly established. In detail, it highlights the need to maintain regularly updated national inventories of coastal zones regarding information on resources, activities, institutions, legislation and planning tools. In this context, the monitoring and observation of coastal areas must be developed within a network of cooperation and organisation along the Mediterranean, scientifically and institutionally. To this end, the Protocol refers to the need to identify, between the Contracting Parties, tools and reference procedures for the

standardisation of the information contained in the national inventory.
The observation of coastal zones is interpreted as a structured repertoire of available information regarding the status and trends of coastal areas, so as to be made accessible to local communities and all relevant territorial stakeholders, both public and private.

Overview of competences on coastal zone observation in Sardinia

Regional Law n. 9, from 12 June 2006 (LR 9/2006), represents the first effort to transfer powers from Sardinia Region to Local Authorities, implementing Legislative Decree no. 234 (17 April 2001), in accordance with the principles laid down in Articles 118 and 119 of the Constitution, as well as Article 10 of the Constitution Act (18 October 2001), no. 3 (Amendments to Title V of Part II of the Constitution).
With particular regards to the functions of the Region in the field of environmental protection, art. 43, paragraph 1, a) of the same LR 9/2006 states that the Region concentrates all duties and functions related to, among other things, the "definition of general criteria for interventions on the protection and observation of the coastal zone."
For this purpose the preservation, protection and enhancement of coastal ecosystems is a specific competence of the "Conservatoria delle coste della Sardegna" (the Sardinian coastal conservation agency), established by article 16 of Regional Law no. 2/2007. The Statute reports the institutional purposes (Article 2 of the Statute), and establishes the need for preservation, protection and enhancement of coastal ecosystems, and integrated management of coastal zones of particular landscapes and environments.
Among the functions (article 3, paragraph 1 of the Statute), stands the coordination of regional initiatives on integrated management of coastal zones from other Italian regions (a), the elaboration of guidelines and criteria for interventions on protection and observation of coastal areas (d), as well as the exercise of powers of the Regions in the field of public maritime domain adjacent to the coastal conservation areas entrusted to the Agency (g), and the determination of forms and tools for collaboration and exchange of information with the local government system and with other institutions and organisations responsible for land management (l).
In the light of these regulatory provisions concerning the "Assignment of Functions and Responsibilities to Local Authorities", contained in LR 9/2006, Art. 44 paragraph 1, a), the region has attributed to local authorities the functions of environmental protection ("protection and observation of coastal areas within the province"). Article 5, paragraph 1 of this Regional Law sets out the functions conferred to the province, such as:
a. gather and coordinate proposals from municipalities, for the purpose of assessing Regional economic, territorial and environmental impact;
b. contribute to the determination of acts of regional planning in accordance with rules dictated by regional law;
c. formulate and adopt, with reference to the provisions and objectives of the regional programme acts, its multi-annual programmes, both general and sectorial, and promote the coordination of activities in the municipalities;
In particular, the following paragraph 3 stipulates that the Province takes on the functions and tasks that affect large inter-municipal areas or the entire province, whose materials are included in "soil conservation, protection and enhancement of the environment and prevention of disasters "and" protection of flora and fauna, parks and nature reserves."

Therefore, in carrying out protection and observation activities coastal provinces must comply with the guidelines and criteria defined by the *Conservatoria delle coste*.

Observation of coastal zones: aims and objectives

The preliminary analysis of the Sardinian context shows that currently coastal areas observation and monitoring activities are performed by several institutional stakeholders.

The main objective of the Centre is to provide coordination of the different stakeholders including evaluation and monitoring of the implementation and development of integrated coastal management policies.

In order to steer integrated management on the Sardinian coastal zones in the right direction, the centre has, the following key tasks:

- to promote the integration of planninq and policy of the sectors and policy-making levels by monitoring new developments in planning and policy, and by playing a part, in an advisory capacity, during the realization thereof.
- to foster cooperation between the policy-making levels and sectors via consultative meetings, and by citing, as much as possible, initiatives at other levels or in other sectors and by actively encouraging cooperation.
- to act as an point of contact for lntegrated Coastal Zone Management for the various levels of government and other key players on the coast and to offer every private individual, agency or government body the opportunity, via a centralized forum, to ask coast-related questions.
- to monitor Mediterranean and European developments in Integrated Coastal Zone Mangement by participating in coastal forums or other consultative platforms on coastal zone management.

In addition to these four key tasks, the centre will also:

- monitor significant activities that serve to develop the coast and try and shed light on the motives thereof within an overall strategy of sustainable development;
- keep a record of the data and then, out of that, distil a set of effective sustainability indicators for the coastal zone;
- keep an up-to-date inventory of ongoing and new projects and initiatives in the coastal zone;
- commission others to make goal-oriented studies;
- communicate about integrated management at the Sardinian coastal zones.

These issues require the definition of:

- a framework to coordinate data acquisition and collection, and the construction of a structured database;
- the definition of interpretative models and their systems of functional indicators to monitor the status of the development and implementation of integrated management of the Sardinian coast.

The conceptual model behind the activation of the Centre recognises the coordination role that Conservatoria may have regarding local authorities and regional stakeholders responsible for the management of coastal areas.

The contribution of the Conservatoria delle coste, with specific expertise in the field of integrated coastal management, should therefore address the selection of relevant informa-

tion fields (thematic dataset) as well as the acquisition, processing and eventual promotion of initiatives aimed at the production of new data.
The final aim is to make an assessment of the implementation state of sustainable development policies and at the same time to monitor the status and evolution of integrated coastal management processes in the regional context.

Conceptual background

Integrated coastal zone management is developed with the overall objective of achieving sustainable development in the coastal zone, through a strategic approach that is based on sustainable management of natural resources on a long-term perspective, respecting socio-cultural development of local communities and promoting better coordination of activities and institutional competences.
According to the proposed approach the following principles will inspire the activities of the Centre:
a. coherence between actions and regulatory instruments within the same territorial jurisdiction field (the coast) of European, national and regional policies. In this context, it should be supported by the monitoring of all the legal and administrative acts for the transfer of functions and tasks related to the various levels of government. Based on need and function surveys, the Conservatoria delle coste promotes specific corrective actions for the institutions involved;
b. coherence between planning instruments and planning at different institutional levels, both vertical (Regions, Provinces, Municipalities) and horizontal (including regional). These aspects should be implemented through the use of tools provided by law (e.g. Strategic Environmental Assessment) with the aim of verifying the external coherence between local and supra-local planning instruments. However, in this context it is worth checking that the degree of coherence can direct the action of the Conservatoria delle coste to the proposition of corrective activities on two levels of intervention: Operational (definition of sustainability criteria for different coastal contexts in the region) and strategic (proposal of incentives aimed at promoting integration);
c. in view of the evaluation model selected (eg. DPSIR model), the Conservatoria processes the most appropriate models of interpretation for the evaluation of the relationships between factors of pressure and state of resources, in order to verify the implementation status of integrated coastal zone management processes;
d. assessment of the degree of participation of local stakeholders involved in the process of selecting strategic options implemented at different institutional levels.
The level of correlation between the different thematic fields of observation declines through an iterative and cyclic process so that the cognitive elements developed within each field of analysis

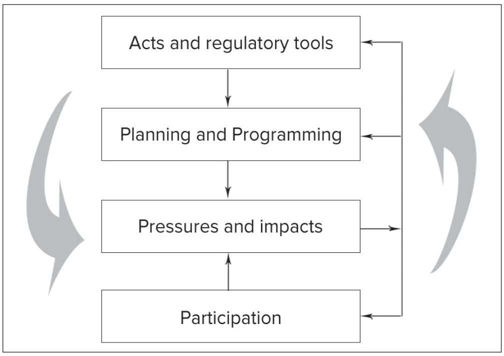

Figure 1 - Level of correlation between different thematic fields of observation.

are, at least in part, useful and influenced by the findings of its other thematic fields. The system of relation is graphically represented below.

Minimum requirements for field of observation

A fundamental prerequisite for the definition and implementation of the minimum requirements related to the fields of observation is the definition of the spatial reference. In this regard, it is believed that the coast as identified by the Regional Landscape Plan (PPR) represents the appropriate context of reference.

On this basis, in order to take into account the specificities of the different naturalistic, environmental, socio-economic and urban contexts in relation to the state and the evolution dynamics of the coastal zone, the analysis is referred to the Physiographic Units defined in the PPR.

The spatial unit of reference can be represented by the Watersheds underlying the Physiographical Unit and extended at least to the border defined by the setback zone according to the PPR.

For the purpose of observation of the marine zone the reference unit can be extended to include *Posidonia oceanica* or the territorial sea (12 nautical miles from the coast).

It should be noted, moreover, that such spatial reference units pose the need to carry out an analysis of the information available on administrative scale related to the same unit. These are generally related to the factors of human pressure detectable in the community (for example, demographics, tourist flows, production activities, etc.). While the acquisition and processing of data is carried out on the basis of local and supra local administrative areas (municipalities and provinces), the evaluation analysis and its results will be related to the scale of the Physiographic Unit.

The following lists the minimum requirements for the acquisition and analysis of information in the different fields of observation:

a. the purpose of monitoring the state of horizontal (same institutional level) and vertical (different institutional level) coordination of programming and planning actions at the regional level, the issues considered relevant are:

- assessing the level of consistency between plans and programmes of the same and higher levels, with particular reference to reports and inference;
- assessing the level of coherence between the objectives of plans and programs and environmental

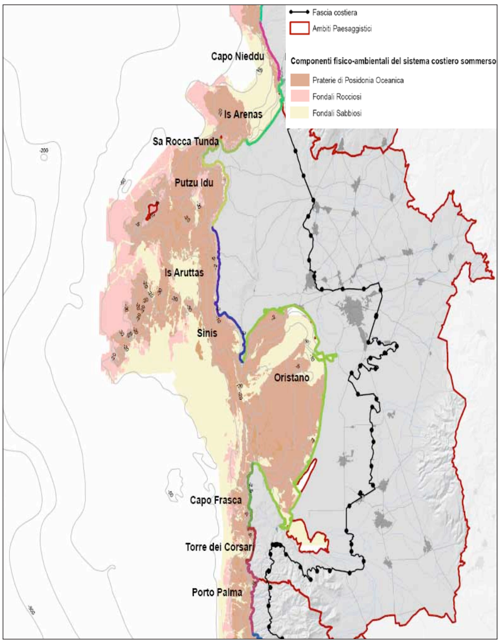

Figure 2 - Example of Physiographic Unit in the central-western coast of Sardegna, and limit of setback zone according to PPR.

sustainability criteria promoted by sustainable development policies in coastal areas;
- recognising the implementation of monitoring activities within implementation of plans and programmes and their effects on the coastal and marine environments.

These minimum requirements are functional on the one hand to check the implementation status of ICZM processes by means of territorial government, and secondly to refine the objectives of ICZM as a trade-off between regional and local needs.

In this context, the observation of the regulatory framework is embodied in the creation of a structured repertoire of functions and institutional capacity for the analysis and evaluation of existing relations in the fields of:

- marine and coastal area protection;
- maritime domain management;
- urban settlement;
- aquaculture or fisheries related activities;
- agriculture and zootechnics;
- industrial activities;
- maritime infrastructures and ports;
- tourism;
- historical, archaeological, cultural and landscape assets;
- energy resources.

On this basis, local and regional institutions that are the subject of monitoring activities in their respective areas of responsibility are, as a priority, identified as:

- Environmental Protection Department, Nature Conservation and Soil Protection Department;
- Department of Local authorities, Finance and Planning, Directorate-General for Local authorities and Finance (Regional Property and assets) and Directorate-General for Planning and supervision of construction (Planning, Information System and Territorial transformations);
- Department of Industry;
- Department of Public Works and Services, roads and transport infrastructure and service operations in the territory;
- Department of Transportation;
- Department of Tourism and handcrafts;
- Regional Agency for Environmental Protection of Sardinia (ARPAS);
- Regional agency for the implementation of programs in the field of agriculture and rural development (Laore);
- Basin Authority, River Basin District Agency of Sardinia;
- Regional Forests Agency.

b. The Centre intends to provide the basic information needed to identify main impacts generated by the action of natural processes and human activities on marine and coastal environments and at the same time to propose concrete solutions for adaptation according to ICZM objectives.

In this sense, the activity of the Centre is more complex than a mere collection and update of information. The most ambitious aim of the Centre is to become a decision support system for policy making at regional and local level.

In this context, the acquisition of information and control of their evolution status can be directed to:

- the analysis of relationships between ecosystems, urban and socio-economic development, in order to assess the current or potential conflicts between different uses for the sustainability of environmental resources in the coastal area. In particular, the assessment of current or potential interference should go through knowledge, analysis and processing of cognitive data regarding the natural and anthropogenic pressures and the related impacts in the coastal area, to this extent; in addition to the creation of the environmental matrix, the analysis of pressures cannot be separated from the recognition of the existing projects in terms of works and infrastructure projects in marine and coastal areas (roads, defence works, harbour works, etc.);
- the evaluation of the relationship systems which are activated at contextual and multiple uses of marine and coastal resources. In this sense, it would be appropriate to proceed to the analysis of cumulative impacts on the environment as well as the interference generated, in terms of conflicts or synergies, which are activated in the same multiple uses of environmental resources.

c. The reconstruction of the strategic debate conducted in the area, as part of institutional initiatives that promote a widespread participation of local stakeholders, is an essential element for the verification and assessment of how the participatory processes have generated shared lines of action with the common aim of achieving a more sustainable development of the coastal areas.
The minimum requirements for an effective monitoring of participation activities related to the implementation of sustainable coastal processes are identified as:

- research and classification of participatory processes on the basis of legal and administrative procedures, developed or voluntary;
- research and classification of participatory processes according to stakeholder involvement methodologies;
- verification of the level of participation of local stakeholders according to their typology (stakeholder, public, public-private partnerships, etc.)
- checking the level of consistency between policy options shared in participatory processes and type of actions actually implemented at the local level.

The system of indicators
The assessment of the state of the environmental components and the effects generated by uses and activities, as referred to the objectives of ICZM, is related to the identification of a significant set of monitoring indicators. In particular, in the selection of indicators it is desirable to consider the following characteristics:

- Relevance: relevance of the indicator to the criteria and principles of ICZM;
- Significance: the ability of the indicator to represent the issues, clearly and effectively;
- Indicators: data availability;
- Upgradability: possibility of new values of the same series that allow updating the indicator;
- Cost-effectiveness: balanced use of resources for the retrieval of data useful for indicator definition in relation to information contained in the same indicator;

- Highest level of significant detail: ability to represent the spatial distribution of the geo-referenced information;
- Communicability: immediate comprehension by an audience composed of technical and non-technical participants; ease of interpretation and representation through the use of tools such as tables, charts or maps;
- Sensitivity: the ability to record significant changes in environmental components induced by uses and activities,
- response time sufficiently short: so as to reflect changes resulting from uses and activities on the components;
- spatial footprint: in order to represent the performance space of the phenomena to which it refers (if geo-referenced information is available, GIS maps can be used for a better explanation of the process).

The choice of indicators can be assessed from indicators of sustainable development (Sustainable Development Indicators) proposed by the "Indicators and Data" Working Group (WG-ID) of the European Union and those adopted by the Environmental Action Strategy for Sustainable Development in Italy, defined by the Ministry of Environment. The WG-ID was created by the European ICZM expert group to draw up a list of indicators and to provide assistance and coordination to member states and candidate countries on how to create databases. The indicators proposed by WG-ID at the end of 2003 are divided into two types:

- Progress indicators - indicators identified to measure progress in the implementation of ICZM;
- Indicators of Sustainable Development (ISD) - a set of 27 indicators, made in 46 sizes for monitoring sustainable development in coastal areas.

However, with respect to the lists of indicators for sustainable development adopted by the Ministry of Environment for the "Environmental Action Strategy for Sustainable Development in Italy", they have been defined for the four different thematic priority areas in which the Strategy was articulated (the same indicated by the Sixth Environmental Action Plan of the EU) in line with the indicators of the Report on the State of the Environment in Italy in 2000.

The system of relations between uses and activities in coastal areas

The analysis of the interference generated between the different uses of the marine and coastal environmental resources must highlight the conflicting relationships or synergies that are activated between uses and activities in coastal areas. The minimum requirements for the relation analysis must have the following activities:

- Conservation of habitats and species
- Preservation of cultural heritage
- Tourism
- Yachting and Cruising
- Fishing
- Aquaculture
- Agriculture
- Shipping
- Maritime Infrastructure

- Industry
- Production of energy
- Coastal Defence
- Urbanisation

Conservation of habitats and species can have a positive impact on the development of tourism in coastal areas when the protection is directed also to the enhancement of coastal ecosystems, as is often pursued in Natura 2000 sites, where many economical activities are compatible with the need for conservation. Tourism development, characterised by a strong demand for accommodation, often close to coastal ecosystem services (such as beaches and wetlands), frequently opposes the needs of environmental conservation, creating significant impacts on the natural environment, sometimes with irreversible effects.
Industrial activities and intensive agriculture, on the other hand, may experience specific negative interference on the development of productive activities related primarily to the potential growth of tourism (attracted by the enhancement of environmental quality in the coastal area) and aquaculture (e.g., because of nitrate contamination of water bodies - surface and underground).
Coastal defence interventions, in particular those realised through soft techniques, that respect natural coastal dynamics, can have a positive impact on the conservation of coastal habitats, while at other times the need for action for mitigating coastal erosion contrasts with the need to establish or expand port facilities (existing or new).
Finally, the widespread urbanisation in the coastal zone can cause significant interference on the conservation and protection of marine and coastal natural resources and environmental systems, both directly, with the removal of soil and permanent occupation of ecosystems, and indirectly, with the alteration of spontaneous evolution processes of environmental components, which may occur through flooding, coastal erosion and slope instability.
Below there is a summary of possible interference relationships (positive or negative) that can be activated between different activities and resource uses.

Table 1 - Relation Matrix between activities and uses.

	Coastal habitat conservation	Cultural heritage conservation	Tourism	Yachting and Cruising	Fishing	Aquaculture	Agriculture	Shipping	Maritime Infrastructure	Industry	Energy production	Coastal Defence	Urbanisation
Coastal habitat conservation		X	X	X	X	X	X		X	X	X	X	X
Cultural heritage conservation	X		X	X								X	
Tourism	X	X		X	X	X	X		X	X			X
Yachting and Cruising	X		X		X			X	X	X			
Fishing	X		X	X		X				X			

Aquaculture	X		X		X					X			X
Agriculture	X		X			X				X			X
Shipping				X					X	X			
Maritime Infrastructure	X		X	X								X	
Industry	X		X	X	X	X	X		X		X	X	X
Energy production	X								X	X			
Coastal Defence	X	X	X			X			X				X
Urbanisation	X	X	X			X	X					X	

Management of the centre

The contents emerged so far point to the need of defining a hypothesis of technical-functional operational management tools and procedures for the Centre. In detail, a list of minimum required fields and their professional roles is presented:

- regulatory and administrative and legal aspects (lawyers);
- issues concerning urban and regional planning (engineers and architects);
- issues concerning environmental matters, with competence in the physical processes and abiotic environmental components of coastal and marine systems (geologists, geomorphologists, environmental scientists);
- issues concerning environmental matters, with expertise on biological processes and biotic characteristics of the coastal and marine systems (biologists, naturalists);

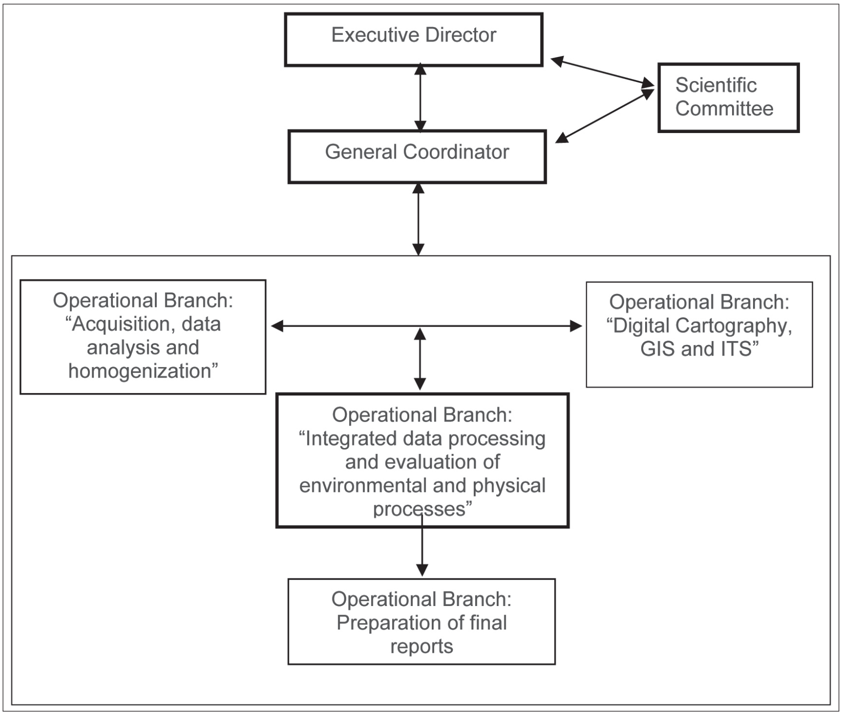

Figure 3 - Management structure of the Centre.

- aspects of hydraulics and maritime infrastructure (sea and coastal engineering);
- aspects of economic and social issues, with expertise in local and sustainable development (economists);
- aspects of digital mapping and processing techniques using GIS/Geographic Information Systems and Management (engineers, naturalists, geologists, etc.).

A first draft of the Centre management structure is presented in the following chart.

As part of its activities, the Centre has the opportunity of representing in a concise and practical way the state of Sardinian coastal areas with reference to environmental conservation and economic development within a framework of integrated coastal zone management.

A periodic publication (a "Regional Report on the State of Sardinian Coastal Zones") will be prepared by the Conservatoria delle coste as the result of the analysis and evaluation carried out by the Centre. These reports will include:

- • a snapshot of the current and previous processes taking place in coastal areas;
- • proactive actions, strategic options to support territorial policies, corrective actions in line with the ICZM Protocol.

Reports must first address regional and local Public Administrations, in order to promote strategies and policies aimed at achieving a balance between use and conservation of resources. Secondly, the reports can be oriented to increase public awareness of local communities, in particular by providing a section for the non-technical summary of the findings. Reports can be produced on a yearly basis.

The following is an example of articulation of minimum contents as required for the reports.

- Aims and objectives- Principles and conceptual aspects for ICZM
    - international level
    - regional level
- State of coastal resources
    - Acts and legislative instruments
    - Projects and planning
    - Environment
        - Biotic and abiotic characteristics
        - Levels of protection and preservation
    - Rural and urban development
    - Socio-demographic or
    - Economic activities
- Evaluation of potential or existing conflicts between uses and resources
    - pressure
    - impacts
    - risks, weaknesses, threats and trends
- Progress of the strategies and policies at different institutional levels
    - Region
    - Province
    - Municipalities
- Needs and proposals for action

  - cognitive gap
  - regulatory and institutional gap (skills, functions, etc.).
  - procedural (ownership, decision support systems, etc.).
  - prevention and mitigation of pressures and impacts
  - strategies and innovative actions
- Attachments (cartography, graphic and text documents, methods and models used)
- Non-technical summary.

Conclusions

This paper proposes a conceptual and strategic framework for the definition and the implementation of the Sardinian Observatory of Coastal Zones, laying the groundwork for the design of a methodological approach for the definition of operational functions and structure of the instrument background consistent with the principles and criteria of ICZM. In these terms, the contribution defines the thematic fields of observation and the minimum requirements necessary for the implementation of a tool for monitoring, control and evaluation of integrated coastal management implementation processes with respect to the regional context.

Therefore, the contents proposed are functional to the elaboration of a technical project and operational tools and procedures pertinent to the achievement of a Sardinian Observatory of Coastal Zones. This project will necessarily meet the minimum requirements drawn here by defining criteria and guidelines consistent with the provisions of the regulatory provisions in force.

In particular, it is noted that the process of selecting indicators and their characteristics should be closely related to the evaluation model defined at the planning stage. In this regard, the list of indicators hereby proposed is consistent with the structure of analysis and evaluation considered to be representative, and therefore non-exhaustive.

In a similar manner the identification of competences of the different government levels, regarding the acquisition, observation and monitoring of the processes influencing the coastal zone suggests that stakeholders may become part of the coastal zone observation network. This network system highlights the need to identify not only the objects of observation but also the tools and procedures for the definition of acquisition modes and protocols that govern the flow and exchange of data.

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A coastal WebGIS for data sharing and distribution

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Abstract
In accordance to the goals of ResMar subproject B, the two partners, Provincia di Olbia-Tempio and Provincia di Livorno, through their cross-border centreoffices (OCEANS and CReStDiL) have developed a data sharing system in the form of two Web-based Geographical Information Systems (Web-GIS). Because of the different morphology of Sardinian (a large number of small pocket-beaches) and Tuscan (200 km of relatively wide beaches) coasts, the two platforms were structured differently. Provincia di OlbiaTempio developed an Atlas of Gallura beaches as a set of test sites; the contents are cartographic data derived from an aerial photogrammetric historical set (from 1954 to 2006), sedimentological and geomorphological data and hydrodynamic, wave and sedimentological models. Provincia di Livorno used a platform known as GEO-T, where users can frame any stretch of the Tuscan coast to view the different layers, and interact to obtain additional information as available from the database. Because of the considerable length of most Tuscan beaches, Provincia di Livorno developed a Web-GIS where there is no data gap between the northern and southern borders (with Liguria and Lazio, respectively).The landscape background is created using orthophotos andCTRs, and the shorelines drawn are replaced by lines from surveys and photo-interpretation, from 1938 until today. Each physiographic unit has been divided into 250 m long sectors, with a colour line showing shoreline evolution from 1984 to 2005. Another relevant layer is represented by the database containing data on coastal defence structures and ports, while territorial information is completed with data on the regional ecological network, hydrography and coastal dunes. The aim of both centres is to standardise other available data in order to permit their publication, and collect further data to allow for continuous monitoring.

Introduction

ResMar subproject B is based on the creation of a cross-border centre for the study of littoral dynamics. At this moment the centre includes two offices in Italy, one located in Sardinia and one located in Tuscany. The Tuscan center has been developed by Provincia di Livorno and is called CReStDiL (Regional Centre for the Study of Littoral Dynamics), whereas the Centre in Sardinia is managed by Coastal and Marine Geology Group of Cagliari University, through the Coastal and Natural Submarine Environment Observatory (*Osservatorio Coste E Ambiente Naturale Sottomarino* - OCEANS), with the financial support of the Provincia di Olbia-Tempio. According to the cross-border cooperation programme, partners have developed a data-sharing system that allows external users to gain access to the information. Both Provincia di Livorno and Provincia di Olbia-Tempio developed two Web-based Geographical Information Systems (WebGIS) fed with data collected on field, and platforms will be available on the official website of project Res.Mar (according with INSPIRE EU protocol [1][2]).

Shared database

There are many differences between the territories studied by the two partners: the Tuscany coast has approximately 200 km of relatively wide beaches interrupted by headlands that subdivide them into ten physiographic units. The Olbia-Tempio province, on the other hand, is mainly formed by pocket-beaches, as does the Tuscan archipelago. Therefore, the WebGIS developed by the Sardinian partner is considered as a set of test sites composed by the beaches studied, and it is possible to reach the page dedicated to the point of interest without needing to get through the global map. Because of the considerable length of most Tuscan beaches the map was organized as a dataset without a gap between the northern border (with Liguria) and the southern one (with Lazio). Moreover, some themes that may be significant at Tuscan coasts, such as the description of existing coastal defense structures or strategies are irrelevant in Sardinia, where their presence is negligible. These and other differences led to the decision of keeping two separately managed platforms with a minimum common content, though both partners are free to add all data they have collected.

The Sardinian WebGIS platform

The Olbia-Tempio Province has been supported by the Coastal and Marine Geology Group (CMGG) of Università degli Studi di Cagliari, which founded and developed the Coastal

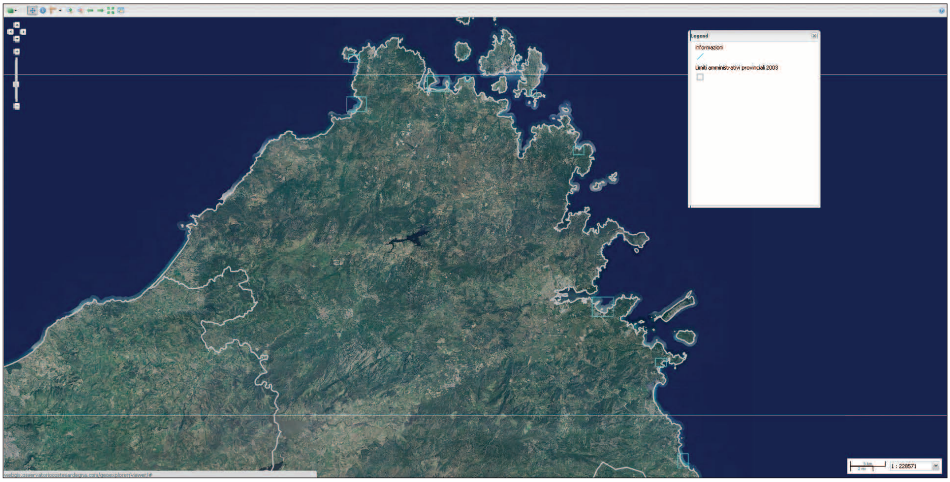

Figure 1 – Map index of sample sites.

and Natural Submarine Environment Observatory (Osservatorio Coste E Ambiente Naturale Sottomarino - OCEANS). The CMGG developed an Atlas of Gallura beaches[9], which represents an experimental dataset with information on the historical-geographic evolution and trend of ten beaches [6][8](Fig.1).

The Atlas is proposed as a support tool for local governments since it offers essential elements, required to start a successful integrated environmental management programme.

The contents of this Atlas are cartographic data derived from an aerial photogrammetric historical set (from 1954 to 2006), sedimentological and geomorphological data and hydrodynamic, wave and sedimentological models[3][4][5][7][10].

Part of these data have been converted to GIS format and published on a WebGIS platform, currently posted on the www.osservatoriocostesardegna.eu website (Fig.2).

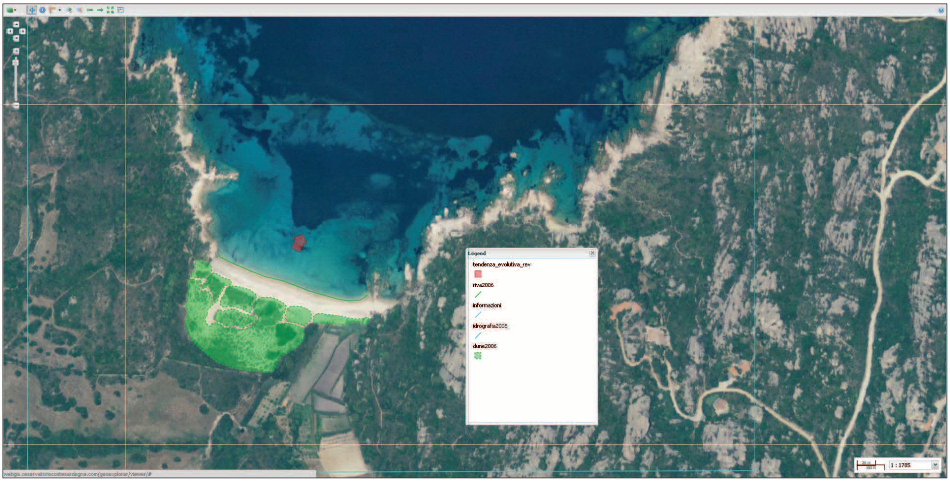

Figure 2 – Section of the Sardinian WebGIS platform (example: Cala di Trana beach).

Figure 3 – Shoreline evolution at Porto Liscia beach.

The system uses an open source software platform named GeoSuite. This enables management and display of several information layers, using a navigation software called GeoExplorer.

WebGIS will be also reachable from the ResMar website and, consistent with the project specifications, will enable the display of information layers concerning:

- shoreline position (by aerial photography interpretation) (Fig. 3);
- shoreline evolution trend;
- bathymetry;
- location of sedimentological samples;
- layers of information from Sardegna Regional agency "Regione Autonoma della

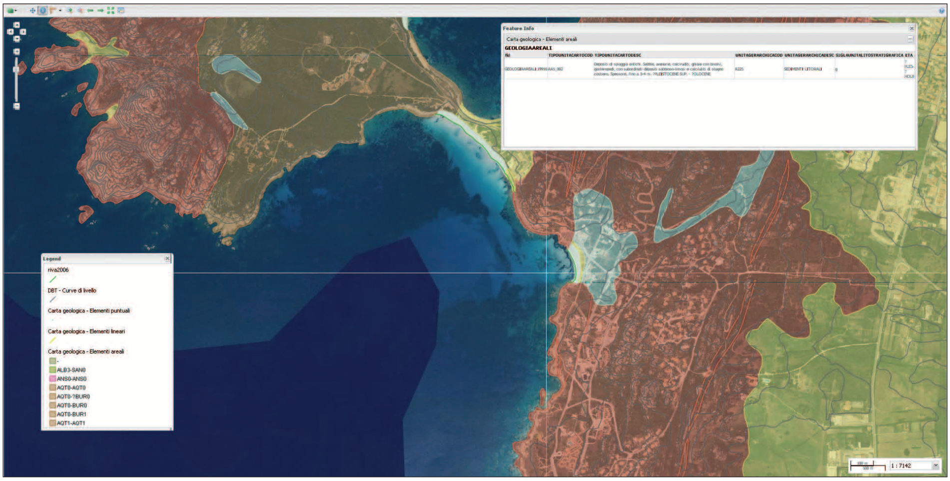

Figure 4 – Geological information layers at La Colba beach.

Figure 5 – Dune area evolution at Rena Maiori beach.

Sardegna" RAS (Eg.SCIs, SPAs, geology, orthophotos etc.) (Fig. 4);
- extent of the dune area (Fig. 5);
- main hydrography.

The GeoExplorer navigator allows viewing different layers superimposed on orthophotos from several years. These aerial orthophotos are available from the *"Regione Autonoma della Sardegna"* database.

Data come from new surveys and from the interpretation of historic aerial photographs, available from the "Regione Autonoma della Sardegna" (RAS).
The aerial photography interpretation was performed using CAD and GIS software on geo-referenced orthophotos from different years. Positioning is referenced, in accordance to RAS database, to Gauss-Boaga Roma40 datum, but positioning of all data is also available on UTM WGS84 datum.

The Tuscan WebGIS platform

Provincia di Livorno used a platform known as GEO-T, elaborated by a private company; at the centre of the architecture there is a map server (Map Guide Open Source) that interacts, usingFDO technology, with heterogeneous geographic data sources, file-systems and database servers.
It's possible to access the platform trough an authentication, in administrator or read-only mode.
The homepage of the application shows a map of Italy zoomed on Tuscany; in this way it is possible to see almost all upload layers, although at this scale most of them are hardly discernible (Fig.6). Users can frame any stretch of the Tuscan coast to view the different layers, and interact with them to obtain additional information as available from the database.

The landscape background is created using CTRs (Regional Technical Maps from Regione Toscana, and by orthophotos taken by AGEA in 2010 at the scale 1:10000 . These were provided, as other datasets, by Regione Toscana through the Geoscopio WMS system. The

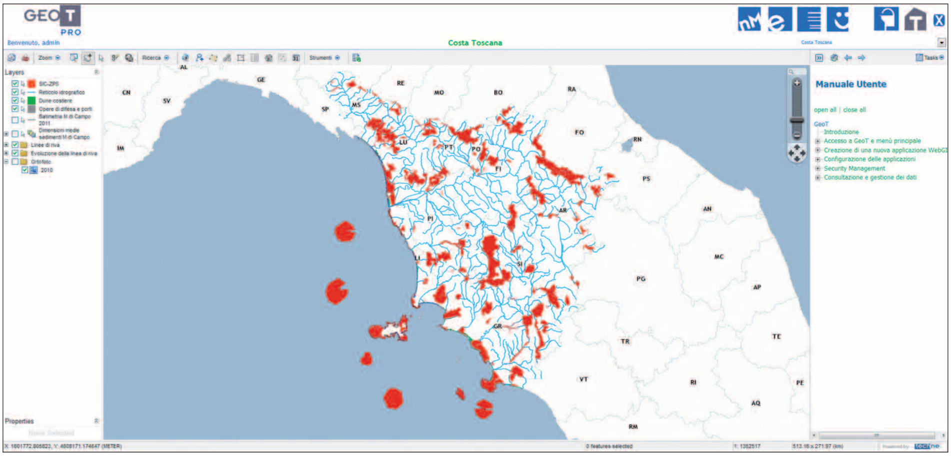

Figure 6 - Homepage of the Tuscan coast map.

CTRs are opportunely cut with a buffer at 2 km from the sea; shorelines drawn over them are replaced by lines obtained from surveys and photo-interpretation. A large amount of coastline data has been collected by the Dipartimento di Scienze della Terra dell' Università di Firenze, from the digitization of 1938 maps until recent surveys[12]. Figure7 presents an example related to the zone of Viareggio Harbour.

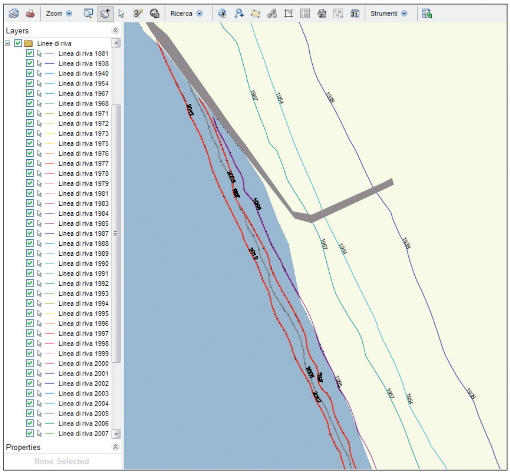

Figure 7 - Shoreline position in different years, south of Viareggio Harbour.

The datasets of 1954, 1973, 1984 and 2005 covers the entire length of beaches on continental Tuscany, and they have been used for a report on shoreline evolution during the past decades[11].

Each physiographic unit has been divided, obstacles such as harbours and headlands permitting, into 250 m long sectors. These are symbolized by colour lines(Fig. 8) that represent shoreline evolution during the period from which we have the most recent complete dataset on the Tuscan territory (1984-2005). Selecting a sector, or any object on the map, properties are displayed and it is possible to read values from the other periods investigated.

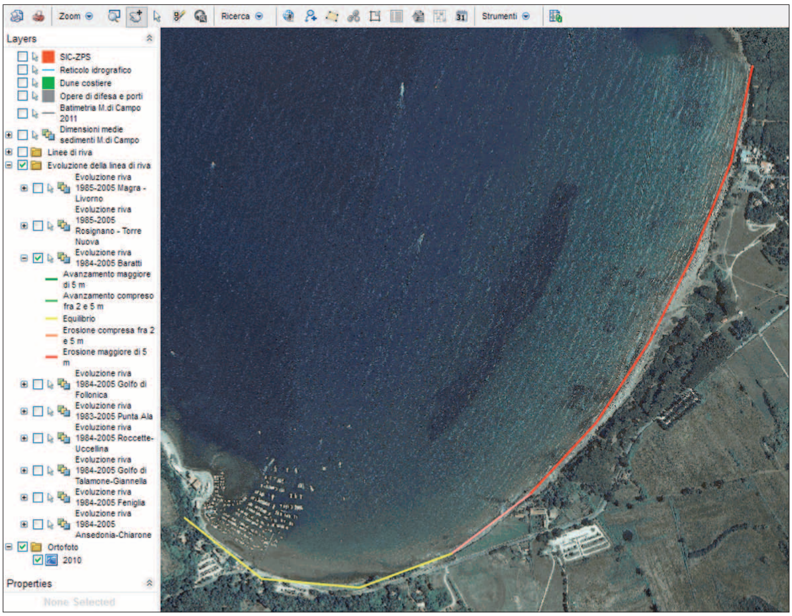

Figure 8 - Shoreline evolution in the Gulf of Baratti.

The Tuscan coast is often interrupted by coastal defense structures and ports, and it is useful to maintain an atlas that represents them, followed by an information sheet presenting their main characteristics. An inventory of coastal defense structures, published by Regione Toscana in 2007[13], has been reviewed and updated as part of this study, adding new structures and correcting information related to old structures that had been destroyed or reshaped. Each structure was represented by a polygonal shape digitized from orthophotos and CTRs, and described in a database containing several pieces of information:

- Site
- Position, identified by the coordinates of the centroid
- Type of structure (groyne, breakwater, etc.)
- Length

These data can be reached, as can all layers, by selecting a single element (Fig. 9) or by opening a separate information sheet. Further information concerning characteristics and history of the structure, as well as aerial and ground photographic documentation, are still being updated, and will be accessed through hyperlinks.

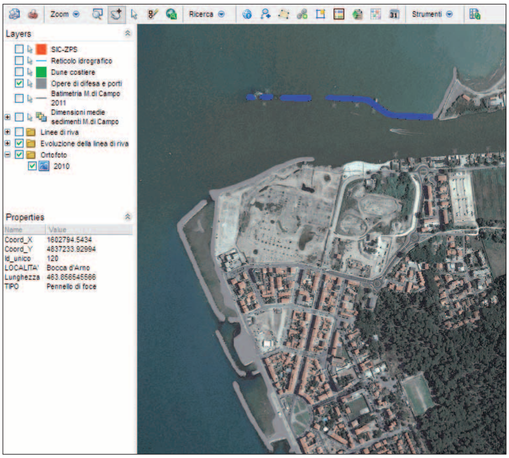

Figure 9 - Coastal defense structures at Marina di Pisa. The selection of the object allows to display the information.

Bathymetric and granulometric data from one of the test sites[14] has been loaded to show a possible development of the WebGIS. Figure10 presents two maps of the beach of Marina

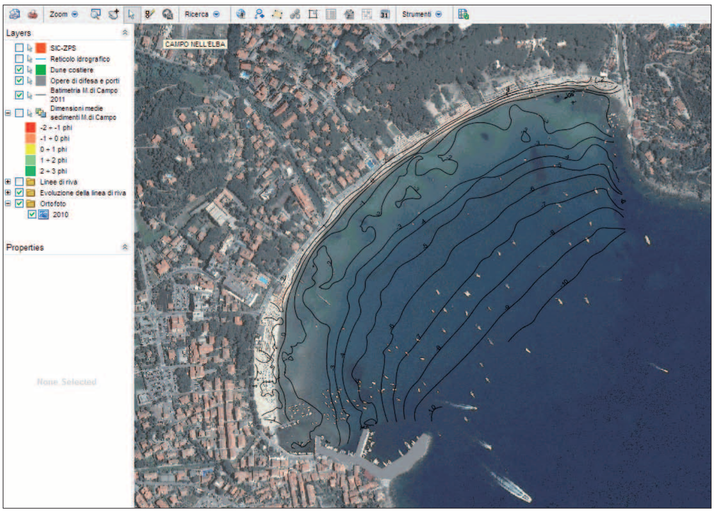

Figure 10a - Bathymetric map of the beach of Marina di Campo (Elba island).

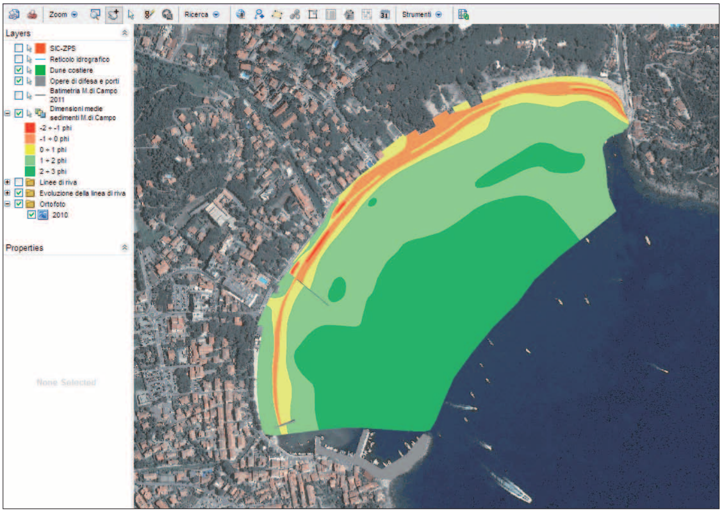

Figure 10b - Average size of sedimentsin the beach of Marina di Campo (Elba island).

di Campo (Elba island) that indicate bathymetry and the average size of the sediment. The aim is to align the product to the one edited by Provincia di Olbia-Tempio, where mapping of the seabed was published for each beach. This type of data is currently widely available in Tuscany but still requires standardization before data can be shared in the WebGIS. Regione Toscana gave permission to share other layers of information which are relevant to the management of the coastal zone, such as the databases from the website of the regional ecological network, and on hydrography and coastal dunes.

Future Developments

The amount and range of the information contained in the two WebGIS should not to be considered as definitive and should not be restricted to the duration of the ResMAr project. Some layers could become obsolete in a short time, because of the speed of changes to the coastal territory, and the intention of both centres is to keep collecting data so that monitoring can be continuous. Development of new contents may also be possible; for the Tuscan platform, for instance, the available sedimentological and bathymetric data could be published, whereas worksheets could be completed for each work of coastal defence structure, adding information on the technical and structural characteristics and uploading project documents and photographs.

Regarding Sardinian study area a data increasing is foreseen by new sedimentological data, extent of *Posidonia oceanic* seagrass meadow, mapping seabed etc.

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Coastal monitoring through video systems: best practices and architectural design of a new video monitoring network at Marina di Massa (Tuscany, ITALY)

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Abstract
As part of Action System A of ResMar Project (Reseau pour l'environnement dans l'espace maritime), a new video monitoring network was developed in the administrative province of Massa-Carrara (Northern Tuscany). The entire costal area had been experiencing severe problems of coastal erosion in the last decades. A large beach nourishment was recently carried out in Marina di Massa, and a new video monitoring network was required to assess its evolution. This paper focuses on best practices to be adopted in the creation of a new video monitoring network. It describes technical features as well as mitigation measures that could minimise the impacts on the coastal area. Once active, the ResMar video monitoring network of Marina di Massa will allow information concerning beach morphology to be acquired with temporal continuity and spatial homogeneity. It will particularly monitor the evolution of this new beach nourishment, which is considered to be economically vital for the future of this entire coastal area.

Introduction

Measuring the location of the shoreline and monitoring foreshore changes through time represent a fundamental task for correct coastal management at many sites around the world. Several authors (Takewaka and Nakamura , 2000; Davidson et al., 2004; Kroon et al., 2007; Van Koningsveld et al., 2007, Archetti, 2009) demonstrated video systems to be an essential tool for increasing the amount of data available for coastline management. These systems typically sample at least once per hour (Plant and Holman, 1997; Holman and Stanley, 2007) and they can provide long-term datasets showing variations over days, events, months, seasons and years. In the past few years, due to the wide diffusion of video cameras at relatively low price, the use of video cameras and of video images in analyses for environmental control has increased significantly (Archetti et al., 2008, Archetti and Zanuttigh, 2010). Even if video monitoring systems are often used in the research field (Morris et al., 2001; Alexander and Holman, 2004; Salmon et al., 2007; Almar et al., 2008), they are most often applied with practical purposes including: i) identification and quantification of shoreline erosion, ii) assessment of coastal protection structure and/or beach nourishment performance, and iii) basic input to engineering design in the coastal zone (Davidson et al., 2004, Turner et al., 2004; Archetti and Romagnoli, 2011).

Here we present the guidelines for the creation of a new video monitoring network in Marina di Massa (Tuscany, Italy), developed in the framework of the ResMar (Reseau pour l'environnement dans l'espace maritime) project. The highly urbanised northernmost sector of the Tuscany coastline is situated between the harbours of Carrara (mostly used for cargo shipping) and Viareggio (used for recreational and fishing activities). This 30 km-long tourist district connecting Marina di Carrara, Marina di Massa, Forte dei Marmi and Viareggio consists mainly of summer residences, hotels and other recreational structures available to fulfil the local demand from tourists, including people who move temporarily to the coast during summer, and other more occasional visitors (Anfuso et al., 2011). In recent decades, several engineering structures were built in order to solve urgent local erosion problems. As a result, almost all types of protection structures were built along this coast: groynes, detached breakwaters and artificial islands, seawalls and rip-rap revetments, and jetties (Anfuso et al., 2011). More recently, alternative measures were carried out, such as nearshore scraping (Cipriani et al., 1999), construction of submerged geotextile groynes (Aminti et al., 2004) and creation of gravel beaches (Cammelli et al., 2006).

The area of Marina di Massa experienced severe problems of coastal erosion in the past decades (Cipriani, 1999, Morelli and Cipriani, 2011). A large beach nourishment has been recently planned in the area, and a new video monitoring network was required to assess its evolution. This was developed within the framework of ResMar Project.

This paper focuses on best practices to be adopted in the creation of this new video monitoring network. We describe the architectural design of the network and the mitigation measures to be carried out to minimise impacts on the coastal area. Thus, the aim of this study is to provide a robust protocol for the creation of a video monitoring system network which could couple effectiveness with minimal impact on coastal landscape.

Methods

Study area

Marina di Massa is located in northern Tuscany (Fig.1). The study area is part of a larger physiographic unit that stretches for approximately 63 km, from Sarzana to Livorno. In the study area, prevailing winds blow from W and SW during spring and summer, while in autumn and winter NNE winds progressively increase their frequency. Major storm waves arrive from SW (Aminti et al., 2004; Anfuso et al., 2011).

In this coastal section, a potential southward longshore net sediment transport of 150.000 m^3/yr was estimated to occur (Aminti et al., 1999). The Magra River provides the main sediment input for the beach of Marina di Carrara and Marina di Massa, discharging at the northern edge of the physiographic unit and feeding beaches down to Forte dei Marmi (18

km southwards), as demonstrated by sediment petrography (Gandolfi and Paganelli, 1975). The construction of an industrial harbour at Marina di Carrara in the early 1920's caused the interception of the southward longshore drift, inducing rapid accretion updrift and erosion downdrift. The beach of Marina di Carrara experienced circa 300 m shoreline accretion after harbour construction, even if in recent years (1985-1998) this trend has changed (Cipriani and Pranzini, 1998) and the shoreline retreated due to significant reduction in the sediment load of Magra River (Pranzini, 1995).
However, Marina di Massa, which is located downdrift, has been experiencing severe erosion phenomena since the early 1930's, even if in those years the harbour updrift jetty was 400 m long (instead of the current 900 m length). In 1930 the first seawall barrier was built to protect the coast, and in 1957 a series of breakwaters were added, even if the beach had already vanished along 2 km south of the harbour (Morelli and Cipriani, 2011).
In the meantime, shoreline retreat gradually shifted southwards, and a series of hard structures, such as seawalls, breakwaters, groins and submerged breakwaters were built along the coast by the Ministry of Public Works, following a demand from bathing establishment concession holders to the Municipality of Massa - even if there was proof that these structures would induce erosion at the neighbouring beach of Forte dei Marmi, one of the most popular and trendy beach resorts in Italy. As a consequence, a 6.7 km-long stretch of coast south of the harbour was protected by 9.3 km of hard structures (1.4 km of hard structures per km of coast).
At the end of the 1990's, the shift of competencies to the regional government directed research from public institutions (such as Universities) to identify the causes of beach erosion and failure of "archaeostructures"; in addition, Regione Toscana promoted new studies and projects at a smaller scale.
The first example is the "General study of the Northern Tuscany Physiographic Unit - Definition of general guidelines for coastal defence between Bocca di Magra and Viareggio - Preliminary and Experimental projects for the restoration of Marina di Massa beach". The study was financed by Regione Toscana for approximately 1 Million Euro during the summer of 1997 and lasted for 2.5 years. It was coordinated by Regione Toscana and the Regional Agency for the Protection of the Environment in Tuscany, and implemented by three research Institutes (Consorzio Pisa Ricerche, Dipartimento di Scienze della Terra dell'Università di Firenze and Centro Studi Prato Ingegneria).
Within this project, an experimental geotextile submerged groin

Figure 1 - Topographic sketch of the study area "Ronchi". Arrows indicate the location of the 4 beach resorts (courtesy of SVM srl).

was built and monitored for two years and three similar structures were later added and monitored with funding from Municipality of Massa. As a result shoreline retreat of 4 m/year was halted in the test area located downdrift of the hard shore protection structures of Marina di Massa (Pranzini and Farrell, 2006).

In view of these results, a preliminary project for the restoration of the stretch of coast located between Marina di Carrara harbour and the Versilia river outlet was designed.

The area of Marina dei Ronchi represented the major focus of the R*esMar* Project. This coastal tract (including four beach bathing establishments: VV.FF., Stefania, Villa Freschi, Merida, see Figure 1) develops for approximately 2400 m and is located between the mouths of River Frigido and River Poveromo.

Video monitoring network

A 3-year monitoring programme for the coastal area between the mouths of River Frigido and River Poveromo was conceived within the framework of Project ResMar. The video monitoring network should consist of a sufficient number of video monitoring stations ("video-stations") allowing the whole area (~2400 m) to be covered without gaps.

Each video-station is composed of multiple devices (i.e. webcams and video cameras) placed at a different elevation and distance from the shoreline. This allows achieving detailed images of the whole coastal section subject to monitoring.

Image analysis will allow monitoring beach response to different oceanographic events and in particular:

- Variations and width of the beach;
- Variations in nearshore sand bar topography;
- Wave run-up;
- Dispersion of suspended sediments.

A single image is not able to provide this information. Thus, image post-processing should be carried out to provide for the quantitative information listed above (Holman and Stanley, 2007). Four different types of images are usually used for such purposes: Snapshot, Time Exposure, Variance and Day Timex (Holman and Stanley, 2007, 7 Kuo et al., 2009). A snapshot image is a simple photo of the beach site where the video-station is installed. It is used to document environmental conditions at the site and offers low quantitative information (Brignone et al., 2012). Time Exposure (or timex) images are obtained by digitally averaging image intensities over fixed time duration (amount of minutes) of image acquisition. It is created by processing and superimposing snapshot images of an acquisition cycle. This process eliminates random transitory sea conditions and removes variability in run-up height (Aarninkhof et al., 2005; Brignone et al., 2012). This image processing increases pixel colour intensity, making it possible to distinguish peculiar beach features such as sand bar topography (Lippmann and Holman, 1989), shoreline (Quartel et al, 2006; Kroon et al, 2007), intertidal beach profile (Plant and Holman, 1997, Archetti, 2009), intertidal beach slope (Madsen and Plant, 2001), and morphology formations in beach face (Holland, 1998; Almar et al, 2008). Variance images are acquired at the same time as Time Exposure images, but they also enhance the contrast achieved by timex processing. This allows for better recognition of submerged foreshore structures and identification of regions that are changing/not changing during acquisition time. Day Timex images are obtained by averaging all images acquired in one day. This elaboration eliminates the effects of tidal

variation and variation in light intensity due to sun angle changes during the day (Brignone et al., 2012; Morris et al, 2001).
Detailed fieldwork of the coastal section was carried out in order to define the total number of video-stations to be installed as well as their correct location according to the guidelines described above. In addition, the presence of pre-existing structures (i.e. bathing establishments; flagpoles, etc.) able to host video-stations was evaluated. This usually avoids building new structures which could affect coastal landscape. When necessary, detailed analysis of the environmental impact of new structures was performed according to legal requirements. In addition, landscape impact analysis was carried out in order to minimise changes to the original coastal landscape.

Results and discussion

Creation of the video-monitoring network.

According to technical features of the devices used in this work, we divided the study area into sections not exceeding 350 m. The minimal elevation was set in 16 m to ensure useful images are obtained from each video-station. The analysis of existing infrastructure did not identify any buildings suitable for installation of video-stations. For this reason, it was decided to use four temporary poles. The spatial framework of this video monitoring network (consisting of four video-stations) is shown in Fig. 2.

Figure 2 - Explicative scheme of the video monitoring network (modified from Google Earth).

Three of the four video-stations have two recording devices each, whereas one is composed by only one recording device.

Each video-station is equipped with the following devices (Fig. 3):

- 1 reflex digital camera (10.1 Mega pixel (3.648 x 2.736)) with 18 - 55 or 75-300 optical zoom;
- 1 USB CCD Video Camera (2 Mega pixel) with CMOS 1/3" sensor and 10X optical zoom (8.0-80.0 mm)
- Both devices are kept in waterproof cases and can be connected to the hosting structure (i.e. bathing establishment roofs, flagpoles, etc.) through a 400 mm arm.

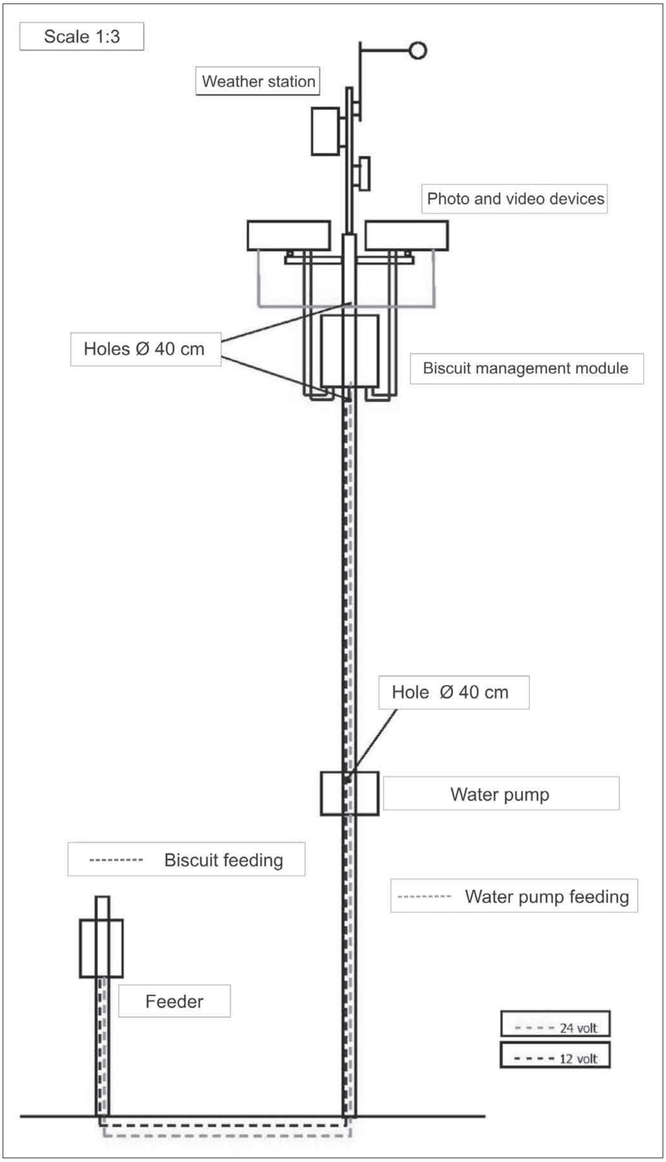

Figure 3 - Technical scheme of the video monitoring station.

In addition, two video-stations (1 and 4, Fig. 3) will also be equipped with a wireless weather station which will acquire data on wind, rain, air pressure and temperature.
A "biscuit" management module (Computer Control Unit 1.6 Mhz - HD 160 Gbite; network interface controller Ethernet, Modem UMTS/GSM/GPRS) completes the set-up of each video-station. This allows systems to be remotely monitored and settings to be changed on-line.
The software package is composed of three modules:

- VM95 Software for system management. It controls image acquisition (from all devices of the video-station) and their processing and uploading on the web-server using FTP protocol.
- VMView Software for remote connection and on-line services (setting changes, etc.). It allows real time monitoring of camera/video camera and of the images captured. It also allows the setting of the system to be modified on-line.
- VMR Software for relocating the images on the web-server. This software is installed on the web-server. It allows downloading images from the data repository. The VMR (Video Monitoring Rectification) performs image rectification. It consists of projecting the entire image captured, or a portion of it, from the image reference system on a user-specified horizontal plane. By image rectification we mean the transformation from image coordinates to world coordinates of the entire scene captured - or a portion of it. A projective transformation of a plane at the sea water level is normally used. It is based on a matrix of transformation from image coordinates (U, V) to geographic coordinates (x, y, z mswl). The process involves establishing pairs of Ground Control Points (GCPs) which are visible in the images and in the real world.

In order to extract useful information, ground control surveys should be carried out. They include identification and location of permanent and temporary GCPs placed on the beach and in the sea (i. e., poles showing roundhead structures) in the field of view of each camera.
In summary, the technological architecture of this video monitoring system is composed of three modules (Fig. 4): acquisition, management and publication. Wire connection operates between acquisition and management modules whereas connection between the management module and the publication server is UMTS based.

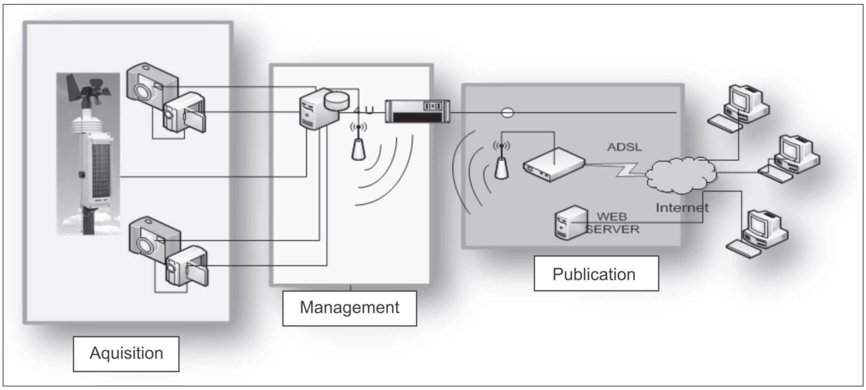

Figure 4 - Technological architecture of the video monitoring station (courtesy of SVM srl).

System setting

The system setting procedure follows the following steps:

- Video camera setting for variance images:
- 1 image 4 times per day. Each image is composed of 1400 frames (acquisition speed 2.5 frames/second) in about 10 minutes.
- Video camera setting for time-exposure images:
- 1 image 4 times per day. Each image is composed of 1400 frames (acquisition speed 2.5 frames/second) in about 10 minutes.
- Camera setting for single snap images
- 1 image (3.888 X 2.592 pixel) 4 times per day.
- Weather station setting
- 1 complete scanning of all parameters 4 times per day
- Automatic system reboot
- A reboot of the system is automatically scheduled at the end of each operative day.

Video stations will operate from 8 am to 6 pm and, according to the steps above, daily monitoring will provide 4 variance images, 4 time exposure images, 4 snap images and 4 scans of wheatear parameters. Relocation of images on the web-server will be carried out at the end of the day. Images will then be post-processed (i.e. rectification and geo-referencing, see section 3.1).

Technical and scientific support

The whole operative period of the video monitoring network will be technically supported on-line and on-site. As stated in section 3.1., both hardware and software can be remotely monitored. This makes it very simple to check the correct functioning of each video-station as well as setting modifications. A further on-site check-up of all network components should be scheduled once a year.

Data analysis will be implemented by scientific experts from the University of Bologna. They will also participate in the calibration phase which should be performed soon after network installation. In particular, the following preliminary activities will be carried out.

- DGPS positioning of at least 3 GCPs.
- DGPS shoreline position mapping.
- correction of camera distortion effects
- lens calibration
- VMR software calibration

Coastal landscape impact analysis

The construction of the new 16 m-long temporary poles will modify the coastal landscape. Coastal landscape impact analysis identified four suitable locations for pole installation (Fig.5). The whole coastal area has been severely modified in the past 60 years and several flagpoles, antennas and electricity poles can be currently observed in the wide beach area.

For this reason, we tried to minimise the negative impacts caused by the installation of another four poles. Locations were selected as far as possible from the shoreline and in areas not showing peculiar cultural heritage. We decided to place the poles near existing infrastructures such as bathing establishments or other similar structures.

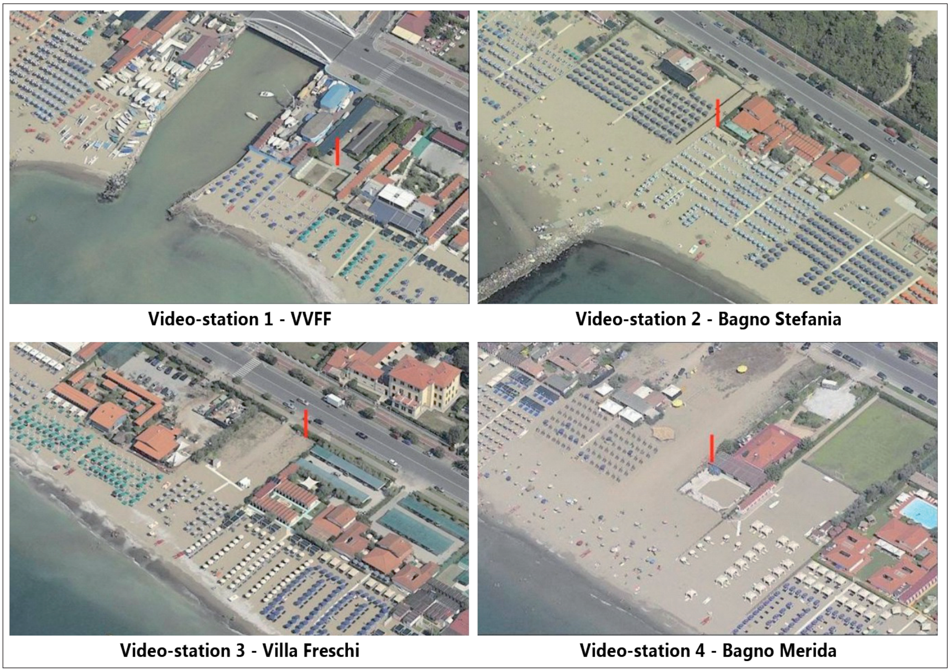

Figure 5 - Environmental framework of the selected location of the new temporary poles hosting the video-stations (courtesy of SVM srl).

This allows reducing the visual impact on coastal landscape, as poles are clustered with other structures that are already present. In addition, video-station poles are not permanent and will be completely removed after the end of the monitoring period.

A rendering of the final impact of poles on the coastal landscape is shown in fig 6. Construction will conform to current environmental legislation.

Figure 6 - Rendering of the visual impact of each video monitoring system on the surrounding environment (courtesy of SVM srl).

Conclusion

The new video monitoring network planned for Marina di Massa within the framework of Project ResMar represents a significant balance between effectiveness and minimal impacts on coastal landscape. In this paper, we coupled the technical description of video-stations with the guidelines for their correct management. The ResMar video monitoring network of Marina di Massa will allow information on beach morphology to be acquired with temporal continuity and spatial homogeneity. It will particularly monitor the evolution of a recent beach nourishment, considered to be of vital economical importance for the future of this entire coastal area.

Once active, this monitoring system will provide a significant input for the planning and design of littoral interventions, becoming a fundamental tool for proper coastal management and rationalisation of economic resources.

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Biocenosis monitoring: the ecological role of defence structures along the Tuscany coasts

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Abstract
The worldwide threat of coastal erosion has led to widespread usage of armouring infrastructure. Recent studies have demonstrated that such artificial habitats can cause several ecological impacts on marine assemblages of shallow waters. The present study is a comparative analysis of the artificial barriers in Tuscany, based on the monitoring of the most important biotic assemblages (epibenthos, ichthyofauna and macrobenthic infauna); it evaluates the ecological implications of such structures, aiming at the creation of new tools for management policies. Rocky and geotextile breakwaters act as fish attractors and appear to be highly colonised by epibenthic species, even if most are typical of disturbed environments. Conversely, the ecological effects of barriers on soft bottom fauna are negligible. Our results highlight the importance of targeted monitoring programs, calibrated according to specific local features, and provide important suggestions in the perspective of integrated management.

Introduction
Coastal defence structures (jetties, groynes and breakwaters) have the primary function of preventing floods by preventing erosion of sedimentary beaches. Coastal erosion is a phenomenon that has been increasing worldwide, and threats have led to widespread implementation of armouring infrastructure along the world's coasts. Such transformation of coastal landscapes will probably accelerate in the future, in response to the exponential growth of human populations and to global changes, such as sea-level rise and increased frequency of extreme climatic events. The proliferation of defence structures can affect over 50% of shorelines in some regions and may result in dramatic changes to the coastal environment (Airoldi and Beck 2007).
In recent years there has been growing interest on the ecological implications of such changes on shallow water habitats and their assemblages of marine organisms.
The construction of artificial structures in intertidal areas and shallow waters can lead to fragmentation and loss of natural habitats and to their replacement with artificial ones (Bulleri and Chapman 2010, Bacchiocchi and Airoldi 2003).

Several studies have shown that assemblages living on artificial structures can differ from those on adjacent natural rocky reefs (Chapman and Underwood 2011) in terms of epibenthic composition (Airoldi et al. 2005, Martin et al. 2005, Bulleri and Chapman 2004) and mobile fauna (Chapman 2003), especially where the natural native habitat is formed by sandy bottom. The provision of novel hard habitats along sedimentary shores can modify natural patterns of species dispersal, or facilitate the spread and establishment of non-native species, altering local and regional biodiversity (Bulleri and Chapman 2010).

In addition to the provision of new habitats for benthic assemblages, artificial structures can also attract many species of reef fishes (Rilov and Benayahu 2000, Clynick et al. 2008) and contribute to increase fish biomass (Fabi et al. 2004). The novel habitats are often colonised by fish species that are also common in nearby rocky reefs (Rilov and Benayahu 2000, Chapman and Clynick 2006), whereas fish assemblages can show higher or lower diversity and abundance, depending on the local context (Rilov and Benayahu 2000, Clynick 2006, Clynick et al. 2008).

Moreover, coastal defence structures may determine substantial changes to benthic assemblages inhabiting the surrounding soft bottoms, due to their effects on physical parameters, such as water circulation, sediment dynamics (Cuadrado et al., 2005; Martin et al., 2005), bottom topography and granulometry (Dugan and Hubbard 2006), and organic content in sand (McLachlan and Brown 2006).

Higher species richness and different community structure were found in macrobenthic assemblages inhabiting the sand at sheltered sides of breakwaters in the Adriatic Sea, as compared to the exposed and partially exposed sides (Bertasi et al. 2007). Similarly, macrofauna associated to the depositional side of a groyne in Southern Queensland, Australia, showed significantly higher abundance than the macrofauna inhabiting the erosional side (Walker et al. 2008).

As described above, there are large evidences of the ecological effects of artificial structures: the introduction of novel habitats and fragmentation of the original ones; colonisation by phytobenthos, zoobenthos and ichthyofauna that are typical of rocky shores; induced changes on the infauna of surrounding sandy bottoms. The role of these structures is strongly dependent on coastline morphology and topography as well as on the original habitats; they can act as surrogate for rocky shores (Clynick et al. 2008) when local context allows migration from nearby natural rocky areas, or create real novel habitats with peculiar assemblages (Chapman and Underwood 2011).

The awareness that most coastal structures cannot be removed led to an increase in research efforts towards the definition of new forward-looking policies for the construction of artificial structures. The main objective is to define criteria that meet engineering requirements, but it also aims at an increase of the ecological value of artificial structures as peculiar habitats, as stated by Airoldi and Bulleri (2011). In this context, many attempts have been carried out to increase the ecological potential of these artificial habitats, such as changing the slope of walls, enhancing their overall complexity, or adding different types of microhabitats (Chapman and Underwood 2011). Another study evaluated the feasibility of using coastal defence structures for the conservation of threatened marine species through the transplantation of macroalgal key-species (Perkol-Finkel et al. 2012). The incorporation of several natural elements, such as wetland vegetation, seagrass, coarse woody debris, or shellfish reefs into projects of shoreline stabilisation has also been tested.

This kind of solutions can reduce the ecological impacts of structures without impinging on their efficacy in halting erosion (Bulleri and Chapman 2010).
The modern approach of integrated management policies needs to consider such synergy between engineering requirements and ecological characteristics, for a more comprehensive analysis of the cost-benefit trade-off (Airoldi and Bulleri 2011). However, the biological responses to environmental changes are often site-specific, depending on a great variety of local factors and dynamics (Martin et al. 2005). For this reason, the definition and implementation of monitoring plans is becoming increasingly important for an adequate management of coastal environments..

The BiBAT project

The project "Artificial reefs along Tuscan coasts: their role within costal biodiversity management - Bi.B.A.T.", sponsored by Regione Toscana (POR-ESF 2007-2013 funds, Axis 4 Objective 2), aims at developing an action plan for the monitoring and management of artificial barriers in Tuscany (Fig. 1) for the sake of protecting coastal biodiversity. The goal of this plan is to implement a management system for the coasts of Tuscany, by means of careful monitoring of the biocenosis inhabiting the artificial structures: it will compare the features of different barriers with their impact on biotic communities, in order to create tools for integrated assessment.

Figure 1 - Panoramic view of artificial barriers in Tuscany (Gombo, Pisa).

The monitoring of communities has been performed on artificial defence structures (rocky and geotextile; Fig. 2 and 3), sampling on the barriers and surrounding sandy bottoms. Natural undisturbed rocky areas have also been sampled to perform comparisons and assess the impact of barriers on biotic communities.
Data collected will be used to estimate the effects of various barriers on biotic communities, as well as their ecological functions in different morphological, topographical and geological contexts; this will be used to propose new arguments (in terms of E.I.A.) useful for the planning of interventions on the coast. The comparative study between rocky and geotextile artificial structures will also provide new elements to evaluate their degree of impact, providing useful guidance for coastal management in the future.
The project has lasted for three years (April 1st 2010 – March 31st 2013), with the following objectives:

- Characterisation of biological communities inhabiting the structures. In particular, we have studied phyto- and zoobenthic assemblages present on breakwaters, and fish fauna that colonise the surrounding area.
- Comparison between communities on artificial and natural substrates (natural rocky reefs and beachrock along the shore). Such comparison will improve knowledge on

Figure 2 - Emerged artificial breakwater made of limestone blocks at Gombo (Pisa).

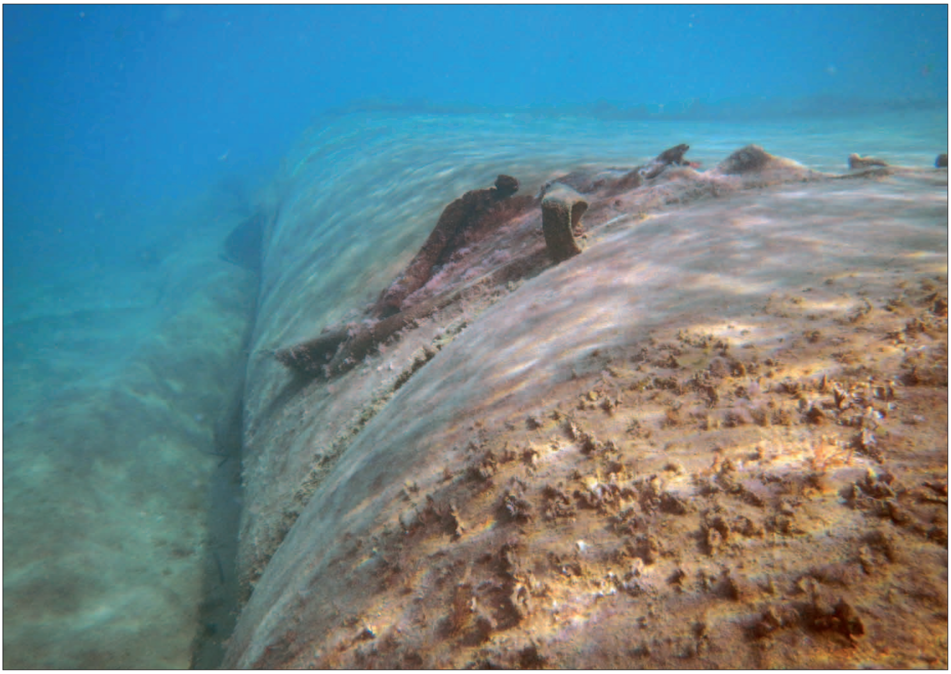

Figure 3 - Submerged artificial breakwater made of geotextile at San Vincenzo (Livorno).

differences between these new coastal habitats and habitats that are naturally present in the area, in terms of biodiversity, species composition and relative abundance. This will make it possible to assess the ecological role of these structures, and identify their potential ecosystem functions (e.g. nursery-role, restocking, stepping stone effect).

- Spatial evaluation of the impact determined by artificial structures on surrounding sandy bottoms. The sandy bottom fauna is closely dependent on sediment characteristics, which could be altered by the presence of breakwaters. Thus, the presence and extent of this type of impact have been evaluated through comparison of assemblages sampled at increasing distances from the barriers.

The results of Bi.B.A.T. project are currently being processed and are still under analysis. In this chapter we present an overview of the principal lines of research, with preliminary results and conclusions on the impact of coastal infrastructures on intertidal and subtidal assemblages, and the potential role of management in increasing their ecological value.

Materials and methods

Study area

The Tuscan coast is naturally composed by sandy beaches and rocky reefs. Tuscan shores are faced by two seas face: Ligurian Sea to the north and Tyrrhenian Sea to the south. As detailed in Figure 4, sampling has been carried out during the past three years on natural reefs (rocky shores and beachrock), artificial substrates (breakwaters, geotextiles) and sur-

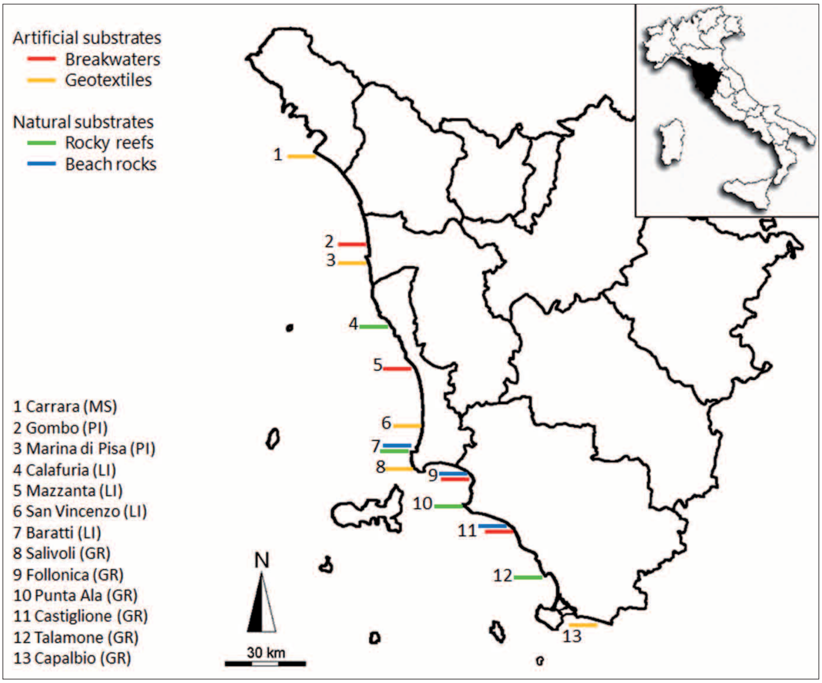

Figure 4 - Sampling sites along the Tuscan coast. The nature of substrates and the names of localities are reported in the legends.

rounding soft bottoms, for a total of sixteen sampling sites at thirteen localities.
Four locations with breakwaters, similar in exposure to wave energy, distance from the coast (30-50 meters), water depth (2-4 meters) and shading extent, were chosen along the coast: Gombo, Mazzanta, Follonica and Castiglione della Pescaia (Fig.4, red lines).
Four locations with natural rocky reefs were chosen as control for breakwater sites: Calafuria, Baratti, Punta Ala and Talamone; each control site was located within 30 km from its corresponding experimental site (Fig.4, green lines).
Beachrock outcrops in the intertidal zone were individuated at three localities, all chosen as sampling sites: Baratti, Follonica and Castiglione della Pescaia (Fig.4, blue lines).
Sampling was carried out on different geotextile coastal interventions, at five localities: Marina di Carrara, Ronchi, San Vincenzo, Salivoli and Capalbio (Macchiatonda) (Fig.4, yellow lines).

Collection of data on epibenthic assemblages

Relative abundance of phytobenthos and the presence of macrozoobenthos were recorded at four artificial barrier sites, four sites presenting natural rocky shores, three beachrock sites and five sites presenting geotextile interventions (see Fig. 4). Data were recorded by scuba divers through visual census methods using 25 cm x 25 cm quadrats (Fig. 5), with an adequate number of replicates. Data about turbidity (Secchi disk), pH and sedimentation rate were also recorded at artificial barriers and rocky shores.

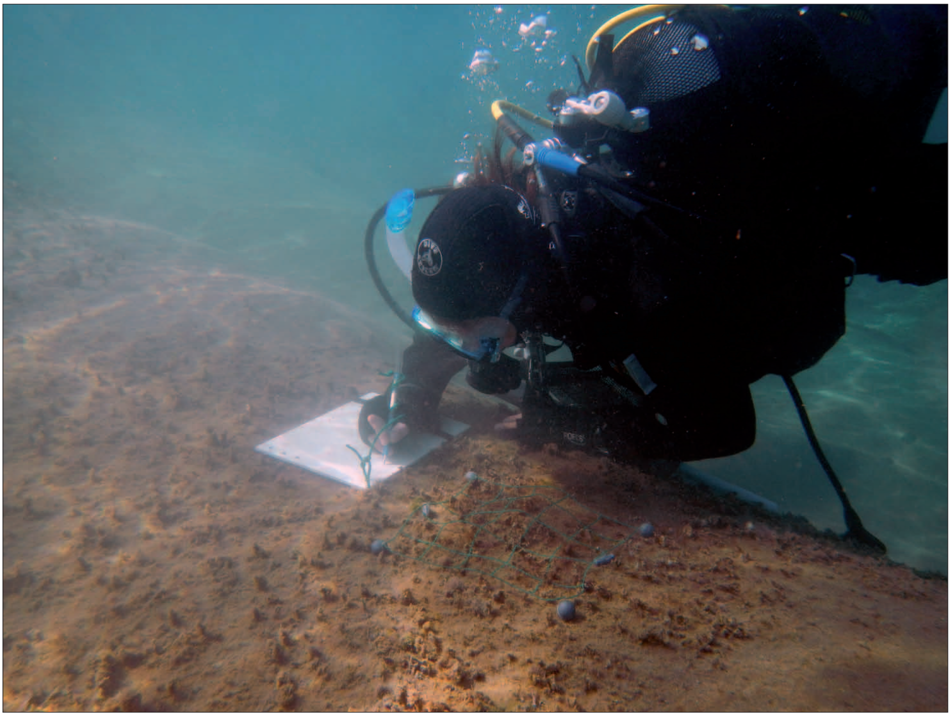

Figure 5 - Epibenthic coverage data collection on geotextile breakwaters.

Phytobenthos data were recorded as functional groups according to literature (Steneck and Dethier 1994), and these well-known groups were then adapted to our data. The functional groups considered in this study were filamentous algae (FG2), foliose algae (FG3), corticated foliose algae (FG3.5), corticated macrophytes algae (FG4), leathery macrophytes (FG5), articulated calcareous algae (FG6), crustose algae (FG7) and crustose coralline algae (FG7.5). Acetabularia acetabulum, a unicellular macroalgae, was recorded separately.

Collection of data on fish assemblages

Data on the presence and abundance of ichthyofauna were collected by scuba divers through visual census method (Fig. 6) at localities with artificial barriers and natural rocky shores, along 20 m long and 2 m wide transects, with an adequate number of replicates. All fish recorded were also classified according to their typical environment: reef-associated, benthopelagic and demersal (data from FishBase.org, Froese and Pauly (2009)).

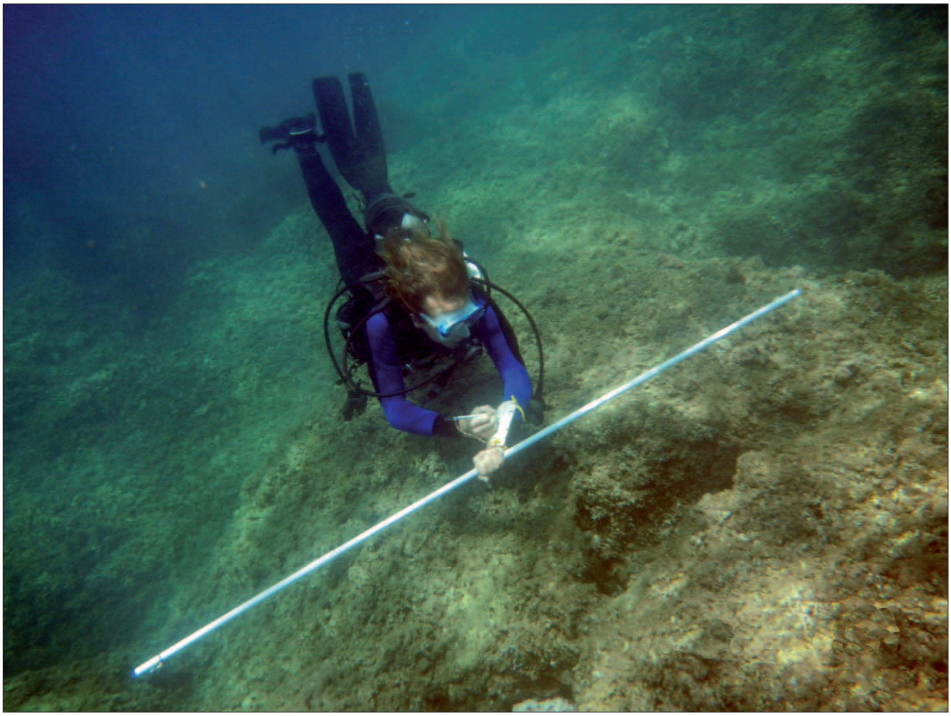

Figure 6 - Visual census of fish assemblages at natural sampling site (Talamone, Grosseto).

Collection of data on infauna from sandy bottoms

At two breakwater sites, Follonica and Castiglione della Pescaia, macrobenthic assemblages inhabiting the surrounding sandy bottoms were sampled using a Van Veen grab (0,1 m2 ; about 15 l volume, Fig. 7). Samples were collected laterally to the breakwaters and in parallel to the beach, at four increasing distances (5, 15, 50, 100 m) from the structures at both exposures (upstream and downstream the main alongshore current).

Assemblages were evaluated considering their ecological quality status, through M-AMBI index (Muxica et al. 2007).

Figure 7 - Soft-bottoms infauna: Van Veen grab (left) and sorting (right) of the samples.

Results

Epibenthic assemblages

Tuscan artificial breakwaters, in spite of showing abundant algal coverage, host benthic assemblages with less biodiversity than natural reefs. As shown in Figure 8, based on benthic assemblages colonising the substrates, breakwaters resulted markedly different from natural rocky reefs, but they partially overlapped beachrock distribution. Breakwaters are highly colonised by turf, while we recorded very low percentages of "habitat-forming algae", mainly belonging to FG4, FG5 and FG6, that are abundant on rocky shores and beachrock instead. Particularly, natural reefs were characterised by a high number of taxa and functional groups; beachrock showed a predominance of Halopithys incurva, habitat-forming algae, and Haliptilon virgatum (FG4 and FG6, respectively).

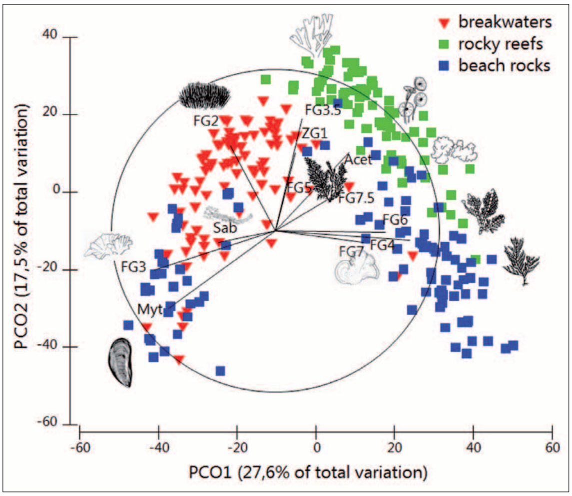

Figure 8 - Benthic coverage in natural and artificial substrates. The PCO ordination plot shows rocky reefs, beach rocks and breakwaters discriminated on the basis of phyto- and zoobenthos coverage; the explained variation of the axes is reported.

The morphological characteristics of barriers (block shape, water turbidity and depth) led to reduced availability of microhabitats and overgrowth of those algal species that are typical of disturbed environments.

In particular, water turbidity and sedimentation rate, both higher near breakwaters than next to rocky reefs (Fig. 9), resulted highly correlated to the composition of benthic assemblages.

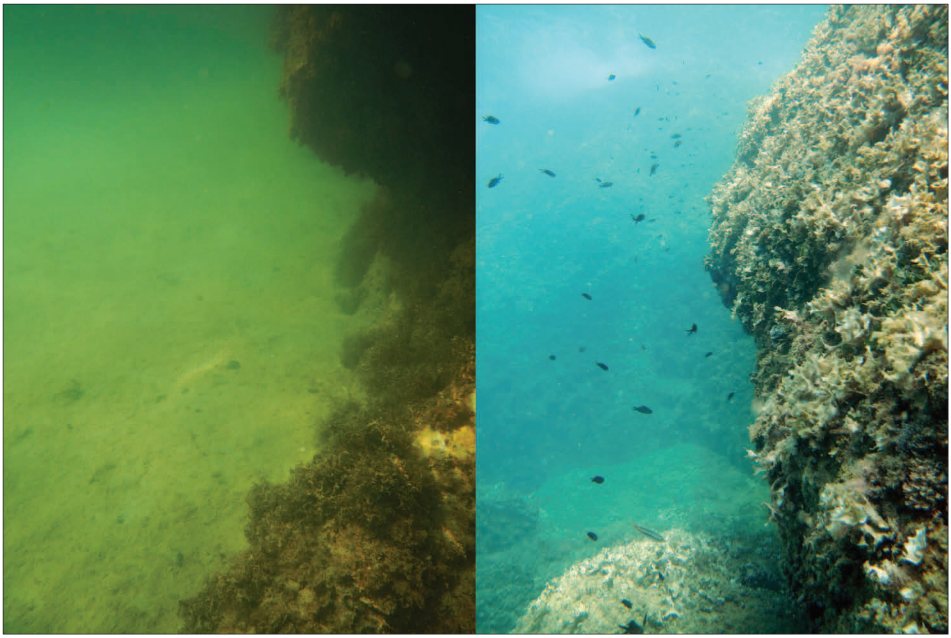

Figure 9 - Turbidity of water around an artificial barriers (left, Gombo) and a natural rocky reef (Right, Talamone).

Fish assemblages

As for epibenthic assemblages, the fish fauna recorded near breakwaters resulted less biodiverse than in natural rocky reefs; the same structural features seem to act as limiting factors for species richness, although fish densities resulted highly abundant.

Breakwaters resulted to be a particularly favourable environment for species which are able to take advantages from the availability of shelters (blennies which occupy rock cracks), food (mullets which feed in proximity of soft bottoms) and both of them (seabreams and sand steembrass, particularly interesting for recreational fisheries, which seem to appreciate the transitional environment between rock and sand) (Fig.10).

Figure 10 - Blenny (left), mullet (center) and seabream (right) on barriers.

The resulting assemblage composition is highly different from that in natural reefs (Fig. 11). Moreover, as to benthic composition, fish assemblages resulted to be correlated to water turbidity and sedimentation rate.

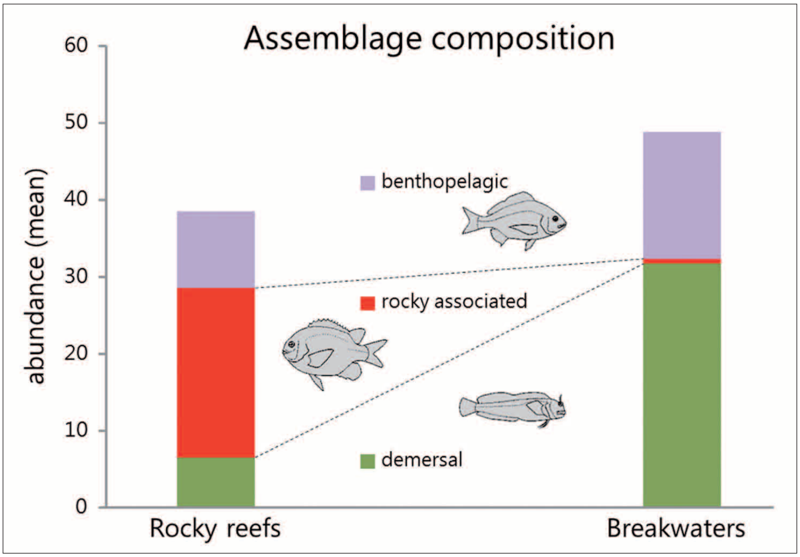

Figure 11 - Fish assemblages composition around natural rocky reefs and breakwaters, using the FishBase-classification of spatial distribution.

Soft-bottoms macrobenthic assemblages

The local context, in terms of sediment physical characteristics, coastal morphology and nearshore currents, proved to be important in determining the composition of macrobenthic infauna in soft bottoms around the artificial barriers studied. Only in a few sampling stations breakwaters demonstrated to have weak influence on benthic fauna, downstream the main alongshore current. Where present, these effects were limited to an area of a few tens of meters. However, in general soft bottom stations were characterised by a "Good" or "High" ecological quality status through M-AMBI index (Fig. 12), showing clear predominance of sensitive species, typical of undisturbed environments.

All benthic assemblages belonged to the "fine sands in very shallow waters" reference biocenosis. A total of 4493 individuals detected were distributed among 88 taxa, with clear

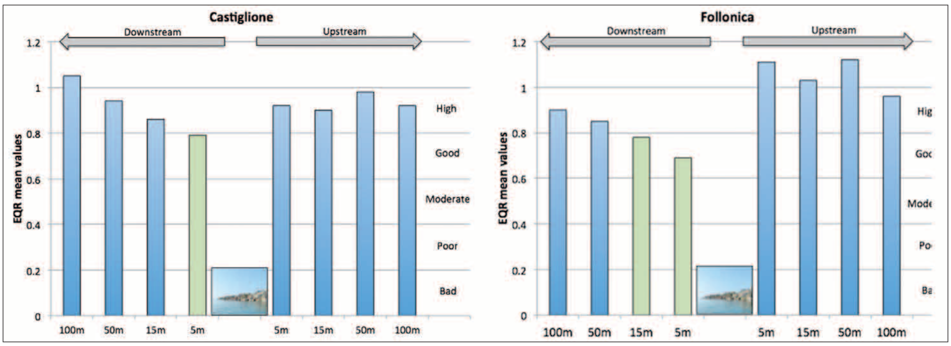

Figure 12 - Ecological Quality Ratio of benthic assemblages at Castiglione (above) and Follonica (below) in relation to the increasing distance from the breakwaters. Respective boundaries of Ecological Quality Status are reported on the right.

dominance made up of Anellida, Mollusca and Crustacea (respectively 30, 26 and 24 taxa, Fig. 13); only a few taxa were identified as Echinodermata, Nemertea, Phoronida, Enteropneusta and Cnidaria. In particular, the site in Castiglione della Pescaia was dominated by Mollusca and Crustacea, while Anellida was the main group found in Follonica.

Figure 13 - Some of the most abundant macrobenthic infaunal taxa from soft bottom sampling. From the top left to the bottom right: Bathyporeia sp., Chamelea gallina, Eurydice sp. and Aricidae simonae.

Geotextile epibenthic assemblages

The geotextile monitoring was conducted on coastal structures that differed in terms of age and orientation, making it impossible to perform any comparative analysis. Assemblages belonged to “infralittoral algae” reference biocenosis Fig. 14, left), even if they

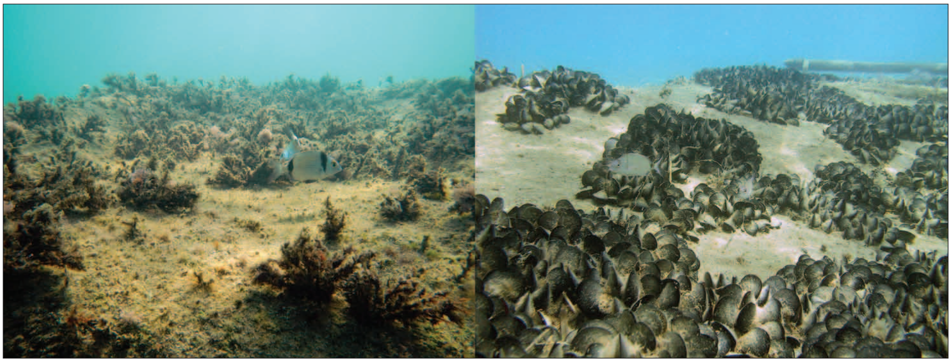

Figure 14 - Epibenthos on geotextiles: algal colonization (left) and Mytilus galloprovincialis. (right).

showed some differences in composition and abundance, probably in relation to their different wave exposure and age.

Moreover, geotextiles appeared to act as recruitment sites for the Mediterranean mussel, Mytilus galloprovincialis, which was highly abundant at almost all sampling stations (Fig. 14, right). Geotextiles appeared to attract mobile fauna (fish, cephalopods, crabs, shrimps) and were inhabited by diverse sessile zoobenthic fauna (Fig. 15).

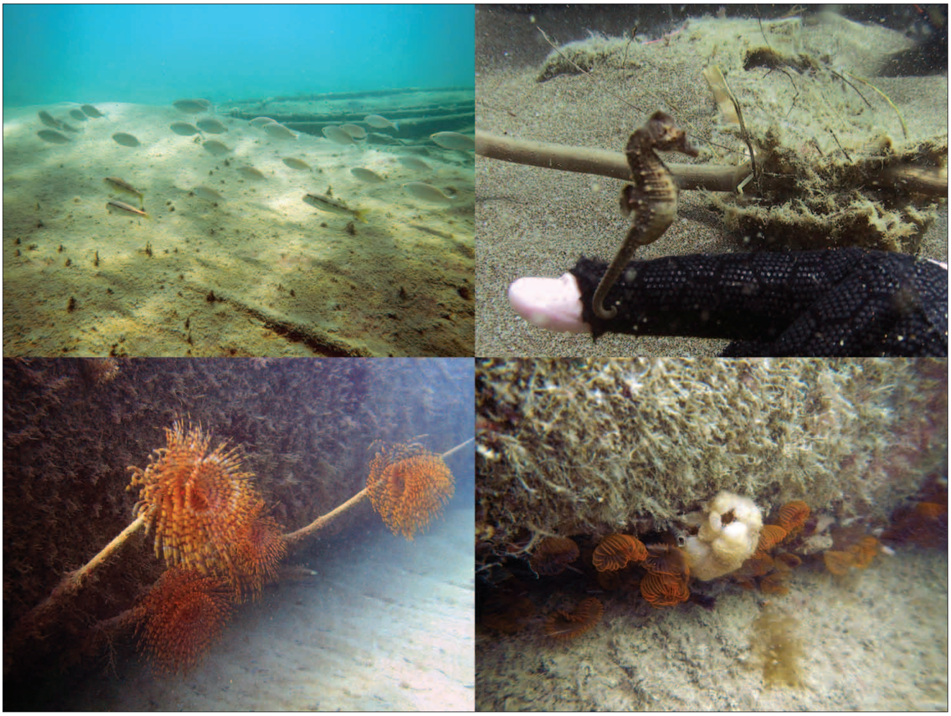

Figure 15 - Zoobenthos inhabiting geotextiles: mullets and seabreams (top, to the left), seahorse (top, to the right), spirographs (bottom, to the left) and a tunicate surrounded by spirographs (bottom, to the right).

Conclusions

Our study revealed differences between benthic assemblages inhabiting artificial and natural substrates. Rocky breakwaters, as well as geotextile structures, appeared to be dominated by species that are typical of disturbed environments, and particularly by species belonging to the algal turf complex (FG2). Conversely, natural substrates showed high abundance of "habitat-forming algae" as Halopithys incurva, and FG4, FG5 and FG6 groups, which contribute to enhance the availability of microhabitat for fauna and, consequently, the biodiversity of benthic assemblages.

The high abundance of turf on artificial barriers could be determined by the physical factors that characterise these artificial habitats (such as turbidity and sedimentation rate). Particularly, suspended materials and sediments could represent important limiting factors for the establishment of some less tolerant taxa, due to their abrasive and light-filtering actions.

The beachrocks monitored, outcropping on sandy bottoms, are also highly exposed to sand abrasion; nevertheless, they showed high abundance of Halopithys incurva, an important habitat-forming algae. This record suggests that the establishment of rich and biodiverse assemblages is also possible on substrates highly exposed to sand abrasion, supporting the hypothesis that the age of structures is another important factor in determining assemblage composition. Indeed, artificial substrates should need a longer time to host more complex communities.

Tuscan artificial structures also seem to act as fish attractors for ichthyofauna that is typical of rocky substrates, as shown also in other studies (Rilov and Benayahu 2000, Clinick et al. 2008, Chapman and Underwood 2011). Nevertheless, their fish assemblages were different from the ones found on natural reefs, being composed by species with peculiar spatial behaviour. In fact, the difference between fish assemblages on natural and artificial substrates seems to be due to their use of those structures, or rather to the microhabitat availability, as offered by the structures themselves (Charbonnel et al. 2002).
Interestingly enough, breakwaters resulted to be a particularly advantageous environment for species like mullets, blennies, seabreams and sand steembrasses. Thus, the abundance of these taxa could enhance the recreational use of the areas studied, as some are particularly exploited for recreational fisheries. Moreover, these assemblages could have an important ecological role in terms of restocking for nearby natural rocky reefs.

Breakwaters were found to have little impact on the benthic fauna inhabiting the surrounding sandy bottom, with very short spatial extent, if present. Moreover, the M-AMBI index has assigned "good" or "very good" ecological quality status to the entire sandy area investigated, highlighting the absence of substantial sources of environmental disturbance. Macrobenthic assemblages were mainly composed by sensitive species, with just a small percentage of tolerant species, showing the typical features of undisturbed environments.

The preliminary monitoring conducted on geotextile substrates showed that they were colonised by flora and fauna that are typical of hard substrates, and seemed to attract several marine species.

The characteristics of the Tuscan coast appeared to be crucial in determining the ecological role of the artificial structures: along the coasts of Tuscany, soft and hard bottom coasts are interspersed, and the artificial reefs placed to defend sandy beaches are never far from the natural rocky shores. The artificial structures monitored harbour only non-native species that are already well established on natural reefs too (e.g. the ubiquitous Caulerpa racemosa), and did not seem to have a relevant role as stepping stones among suitable habitats: this was true for native and non-native species. This could be mainly determined by the morphology of the Tuscan coast, where rocky shores already support connectivity among natural populations and facilitate their dispersal. Moreover, the coast is characterised by the presence of natural beachrock outcrops which show similar characteristics to artificial barriers. The breakwaters monitored were poor in benthic and fish species, and this is probably due to their limited availability of microhabitats. On the other hand, they could potentially mimic the beachrock environment, if built in natural rock and not in concrete. We could also determine a trend where the number and abundance of species increases as age increases, as stated in a previous study (Ortolani et al. 2012). In this context, transplantation of Halopithys incurva, abundant in natural beachrock when surrounded by sandy bottom, could accelerate the natural process of ecological climax establishment and increase biodiversity of benthic and fish assemblages, ultimately enhancing the availability of microhabitat.

In the Tuscan context, it could be possible to apply forward-looking policies, sinergically developed between authorities, engineers and ecologists. Careful selection of structure type and construction material, minimisation of their maintenance, and experimental transplantation of habitat-forming algae, are strategies that could be integrated to management policies in order to minimise the impact of coastal structures and increase their ecological value.
The evaluation of project risks and effects is mostly performed by engineers (as opposed to ecologists). In spite of that, monitoring the ecological effects induced by artificial structures is especially important since the available data are not fully suitable to modelling, and considering that such a continuous control may be useful for statistical analysis. Previous studies showed that impacts on marine organisms are different from place to place, with local effects at some areas and more general rules at others. This is probably due to a combination of ecology and environmental conditions. Structure impacts may be different at each location, making it difficult to provide designs that may be universally applicable (Chapman and Underwood 2011).
In view of the new "ecological engineering" science, accurate monitoring of the biocenosis inhabiting artificial structures represent a crucial step in evaluating the ecological response to engineering practices, in order to provide consistent indications to management policies..

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The Atlantic Coast of New York Monitoring Program along New York's Ocean Shoreline, USA

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Abstract
The Atlantic Coast of New York Monitoring Program (ACNYMP) collected seasonal beach profiles and aerial photography along the south shore of Long Island, New York, USA between 1995 and 2004. Beach profiles were measured twice a year at 426 stations about 0.6 km apart all along the south shore of Long Island. Forty-four parameters were tabulated for each profile. Analysis of ACNYMP data showed reasonable trends related to regional geomorphology. Beach widths, for example were found to increase from the western end of the study area until midway along the coast to the east. Further east, beach width decreased. Dune volumes increased to the east and are generally above the Federal criteria for adequate protection against a 100-year storm surge. A combination of properties was used to delineate areas of vulnerability to storm events or persistent erosion. Thirteen areas of consistent high vulnerability were identified.

Introduction
Along New York's coast, the "Great Nor'easter" of December 1992 was both a memorable and alarming event. A nor'easter is not a hurricane but rather an extratropical storm characterized by strong winds from the northeast across along New York's ocean shoreline, the south shore of Long Island, New York. Nor'easters can persist for days producing historic, coastal flooding over several high tides. The event in 1992 lasted three days from December 11, to December 14, 1992. Sustained winds reached 70 knots off the New York coast. Thousands of people were evacuated from coastal areas and the barrier beach was breached in two places (Terchunian, 1995).
In 1989 a series of workshops had been held to identify management strategies for the south shore (Tanski and Bokuniewicz, 1990). The assembled experts recommended a program of coastal monitoring. In the aftermath, of the Great Nor'easter, a task force was formed by the Governor of New York (Erosion Task Force, 1994). Subsequently, the Atlantic Coast of New York Monitoring Program (ACNYMP) was initiated. Measurements began in spring of 1995 and continued to 2004.

Study Area
Long Island lies in the Coastal Plain province of the eastern seaboard of the United States

(Taney, 1961). The ocean beaches of Long Island cut into relict, outwash of the Wisconsin glacier in the Late Pleistocene (Wolff, 1989) or formed as barrier beaches. The south shore of Long Island is divided into two distinct physiographic provinces, the headland and the barrier beach (Taney, 1961). The headland extends 53 kilometers westward from the extreme southeast tip of the island, Montauk Point. Dunes crest above six meters along this strand; small bay-mouth barriers fronting coastal ponds (Taney, 1961). Barrier beaches form the remainder of the south shore of Long Island. Six inlets break the shoreline into five islands; all inlets have been stabilized with stone jetties (Kassner and Black, 1983). The sandy shoreline is fairly straight, although GPS surveys found shoreline undulations with dominant wavelengths ranging of 1 km to 24 km (Gravens, 1999; Seiver et al., 2007). Beaches typically exhibit seasonal cycles in width and volume related to increased storminess in winter months. However, Long Island is a storm dominated coast and the seasonal cycle has a relatively small amplitude compared to changes due to episodic events. The seasonal cycle was calculated to account for 15% of the total variation of the beach profile (Johnston and Bokuniewicz, 2001). Depending on the timing of storm events and other processes, seasonal extremes were observed to occur independently of yearly maxima and minima (Johnston and Bokuniewicz, 2001).

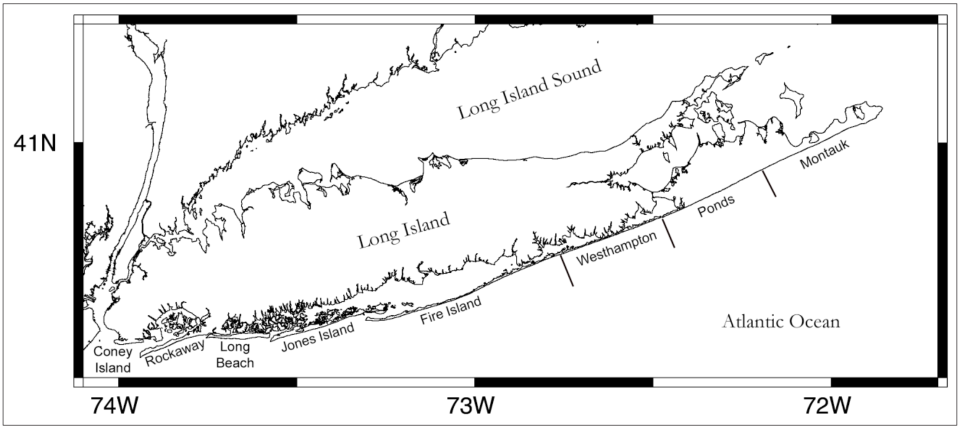

Figure 1. Geographic reaches for the south shore of Long Island as defined by the ACNYMP.

The tides along this coast are semi-diurnal with a mean tidal range of 0.6 m in the east increasing to 1.4 m at the western terminus. One-meter waves with approximately seven-second periods typically come from the southeast; maximum wave heights of between 3 and 3.5 m with 12 to 14 second periods have been observed during storm conditions (Buonaiuto, 2003). Mean sea level is rising at a rate of about 2.7 mm/yr.

Methods

The ACNYMP established 426 stations along the shore about 0.6 km apart. Two benchmarks were set at each location. Surveys were started from the seawardmost benchmark which was typically located on the landward slope of the dune. A second benchmark was established further landward to aid in re-locating the profile line if the seaward benchmark was lost. Many of these stations were on private property and special arrangements were needed to allow access.

Sub-aerial surveys and aerial photography were intended to be completed twice a year, in the spring and in the winter. Data included select, long-range profiles offshore beyond the closure depth. Profiles were measured by standard techniques using a digital total station. Offshore data were collected with a sea-sled. Data were analyzed using the Beach Morphology Analysis Package (BMAP) produced by the U.S. Army Corps of Engineers. In addition to the profile surveys, the ACNYMP collected color aerial photography seasonally along the entire south shore of Long Island. Imagery was usually collected simultaneously with the ground surveys.

Results

Each profile collected under the ACNYMP was evaluated for a total of 44 parameters (Table 1). The "profile id" a three-part identifier consisting of reach name, transect number, and survey date for each profile. Each profile was classified into one of three types: "short" (sub-aerial), "long" (sea-sled survey past depth of closure), and "do not use" (failure of quality control). The parameters and analysis protocols were fully described by Batten et al. (2002). The profiles and aerial photographs themselves can be examined at < http://dune.seagrant.sunysb.edu/nycoast/ > accessed on 26 March, 2013. In this section, the beach width, dune volume and shoreline vulnerability will be briefly discussed as examples of the analyses conducted (Batten, 2003). The complete analysis can be found in Batten (2003).

Table 1 - List of Parameters evaluated for ACNYMP Data.

1	Depth of Closure, distance from shoreline
2	Depth of Closure, below NGVD*
3	Beach Volume, monument to NGVD
4	Beach Width, distance from monument to NGVD
5	NGVD Shoreline Position, Easting & Northing
6	Bar I, Crest Depth, below NGVD
7	Bar I, Volume
8	Bar I, Crest distance from monument
9	Bar I, Crest distance from NGVD
10	Bar I, Maximum Height
11	Bar I, Maximum Height Location, distance from monument
12	Bar I, Width of Bar
13	Bar II, Crest Depth, below NGVD
14	Bar II, Volume
15	Bar II, Crest distance from monument
16	Bar II, Crest distance from NGVD
17	Bar II, Maximum Height

18	Bar II, Maximum Height Location, distance from monument
19	Bar II, Width of Bar
20	Bar III, Crest Depth, below NGVD
21	Bar III, Volume
22	Bar III, Crest distance from monument
23	Bar III, Crest distance from shoreline
24	Bar III, Maximum Height
25	Bar III, Maximum Height Location, distance from monument
26	Bar III, Width of Bar
27	Dune Toe Location, distance from monument
28	Dune Toe Elevation above NGVD
29	Beach Volume, from dune toe to NGVD
30	Beach Width, from dune toe to NGVD
31	Beach Volume, from monument to dune toe above NGVD
32	Beach Volume, from dune toe to -24 foot** depth contour
33	Beach Volume, from monument to –24 foot depth contour
34	Dune Crest Location, distance from monument
35	Dune Crest Elevation above NGVD
36	Maximum Dune Crest Elevation above NGVD
37	Dune Volume, from dune crest to dune toe above NGVD
38	Frontal Dune reservoir above 100 year Still-Water Level
39	Landward Dune Toe Location, distance from monument
40	Dune Volume, from landward dune toe to seaward dune toe above NGVD
41	(+5)foot contour location, distance from monument
42	(-5)foot contour location, distance from monument
43	Beach Slope, (+5/-5)foot contours
44	Geomorphic Unit (barrier, headland, inlet)

* National Geodetic Vertical Datum
**US customary units were used. One foot=0.3048 meters

Beach width became wider to Jones Beach then gradually decreased towards Montauk (Fig. 2). These conditions were thought reflective of the slope of the outwash plain and distance from the moraines. Beach width increases from Coney Island to Jones Beach as the ambient coastal slope decreases under fairly uniform wave conditions. Further east, beach width decreased, as a higher energy wave climate was encountered. Spatial trends in beach volume followed similar trends.

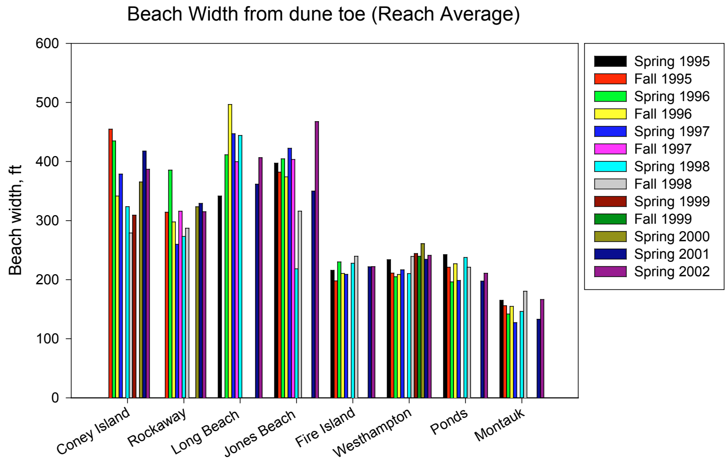

Figure 2 - Average beach width to 2002 by geographic reach.

Dune crest elevation tended to increase in height to the east. Dune volume was measured above the 100-year still water surge elevation (SWL) to give an indication of frontal dune reservoir (Fig. 3). For adequate, erosion protection, the Federal Emergency Management Agency's (FEMA) rating curve requires a minimum cross-sectional area of 20 yd^3/ft (about 51 m^3/m) above the 100-year Still-Water Level (Morang *et al.* 1999). The fact that most of the Long Island ocean shoreline exceeds the FEMA 100-year storm criteria (Fig. 3) does not necessarily mean that protection against coastal flooding was also adequate. Isolated spots of low dune elevation, at, for example, vehicle crossover points or areas of previous washovers, would still be vulnerable to future breaches.

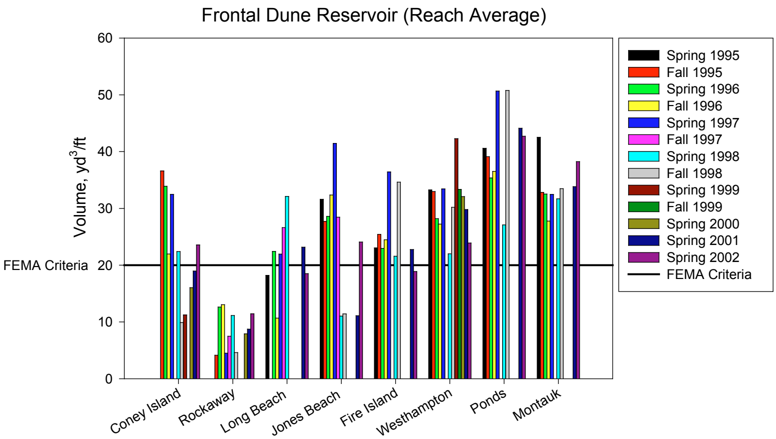

Figure 3 - Frontal dune reservoir volume above the 100 year SWL.

Coastal Vulnerability

Statistical clustering analysis (e.g. Faber, 1994) was used to assess the overall "health" of the beach profile at each station (Batten, 2003). Three model profiles were selected as type-sections in order to "supervise" the clustering (Fig. 4). A low-risk profile category was taken to be a wide beach with a large beach volume and well-developed dune field. A moderate-risk profile was judged to have sufficient beach width and volume to withstand an intense storm, and dune volume above the FEMA 100-year Still-Water Level. A high-risk profile was expected to be one with a narrow, low volume beach, a small, deep offshore bar, if any bar is present at all, and a dune with a volume below the FEMA 100-year Still-Water Level criteria.

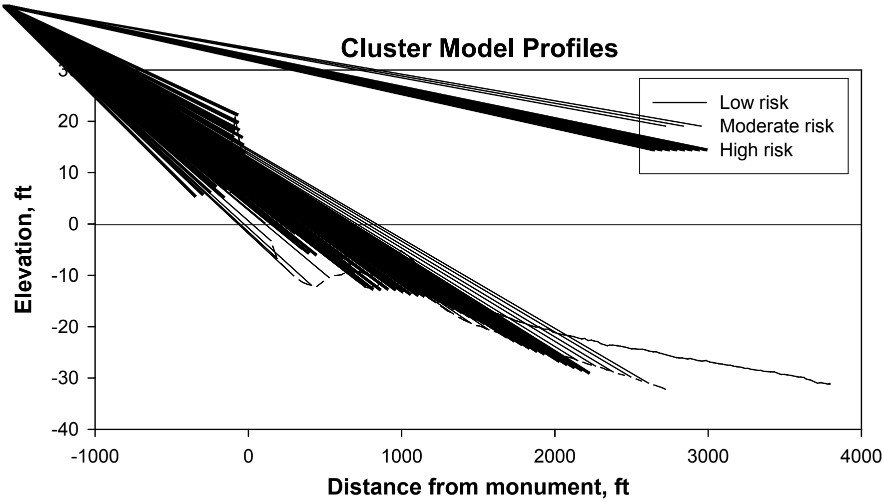

Figure 4 - Model profiles for clustering analysis.

Along the south shore of Long Island, 57% of the profiles fell into the moderate risk category, 24% (fell within the high risk category and 15% fell within the low risk category. Thirteen areas of consistent high vulnerability were found to occur in isolated locations (Fig. 5). One of the areas of vulnerability was found in western Fire Island. Houses had been lost and overwash occurred here in the nor'easter of December, 1992.

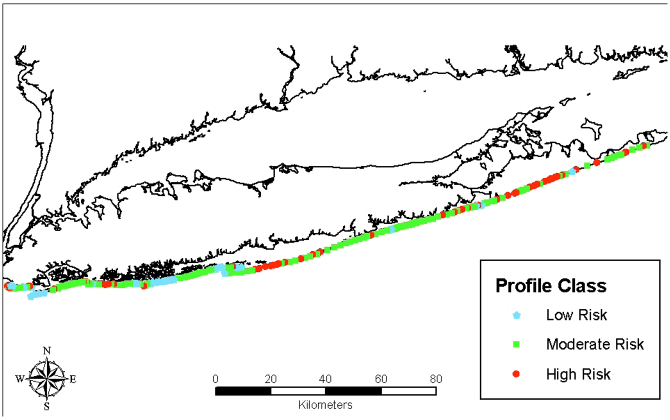

Figure 5 - Example supervised clustering results for the Spring 2002 survey.

Epilogue

Despite limitations, the ACNYMP provided a wealth of comprehensive data used to distinguish conditions along the coast. The majority of trends were attributed to an increase in wave energy to the eastern end of Long Island superimposed on increasing nearshore slopes (Zarillo and Liu, 1988) and changes in shoreline orientation. The cost and effort, however, was very difficult to maintain. Although several significant storms occurred in the study period, none captured public attention like the Great Nor'easter had in 1992. After a final few years of tenuous existence, the ACNYMP was allowed to lapse in 2004.

Then, on October 30, 2012, Hurricane Sandy produced a record storm surge along the Long Island coast. Along the western barrier islands, the water level reached 3.6 m above the National Geodetic Vertical Datum (NGVD), over a meter higher than the previous storm of record. Sea water flooded coastal properties, streets, tunnels, and subway lines. Shore and dune erosion was extensive and three inlets were opened along the ocean shoreline. Damage estimates put the cost of Hurricane Sandy at approximately $70 billion, the second costliest storm in U.S. history after Hurricane Katrina in 2005. Planning is underway to revive the ACNYMP.

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Coastal erosion monitoring in Colombia: overview and study cases on Caribbean and Pacific coasts

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Abstract
Tourism is one of the fastest growing activities in Colombia; the coast represents the favourite destination for both national and foreign visitors. However, coastal erosion is an actual problem, with high erosive rates in some areas. This chapter shows a general overview of the coastal erosion problem in Colombia and emphasizes the institutional framework used in monitoring. Four study cases are included to present a wide diagnosis of relevant erosive processes, both on Caribbean and Pacific coasts. Findings show erosive rates due to human interventions in all coastal departments on the Caribbean Sea; highest values were recorded in Cordoba (3.3 m/yr), Magdalena (5.3 m/yr) and La Guajira (3.2 m/yr). In addition, monitoring of barrier islands indicated that erosive processes on the Pacific coast are essentially due to natural phenomena, i.e. tsunami and El Niño events. In conclusion, long-term coastal erosion monitoring is urgently required in order to make adequate decisions and assess their effectiveness, with special concern to the correct location of coastal infrastructure and the management of coastal risks.

Introduction

Human occupation along the world's coastlines has been increasing in the past decades especially due to coastal tourism-related activities, which emerged as one of the largest industries in the world (Jones and Phillips, 2011).

Spain plus Italy, France, Greece and Turkey account for *'the most significant flow of tourists…. a sun, sea and sand (3S) market'* (Dodds and Kelman 2008); tourism is expected to grow at a rate of 4.0 % per year over the next ten years.

In the Caribbean countries, tourist arrivals have increased fivefold, from 166 million in 1970 to 935 million in 2010. Cruise arrivals grew more rapidly over the same period increasing from 1.3 in 1970 to 20 million in 2010 (CTO, 2011). Barbados beaches are an example, where cruises contributed to the local economy with more than US$13 million in 2010 (Dharmaratne & Braithwaite, 1998).

On the other hand, despite the fact that Colombia has been affected by a number of social, political and security problems that have limited coastal tourism development, it currently record an average revenue per arrival of 1,500 US$/per tourist (UNWTO, 2008).

Hence, due to the actual degree of coastal tourism development and its continuous growth, all environmental impacts on coastal areas are very important and may acquire further significance in future years especially when associated to climatic change processes, e.g. increase in storminess and sea level rise (Jones and Phillips, 2011). Despite causes of coastal erosion, littoral retreat always corresponds to flooding and/or beach and dune erosion. Such processes do not only affect or threat beaches, which are worth billions of tourist dollars (Clark, 1996), but also human activities and infrastructure, becoming in this sense natural hazards.

Characterising natural coastal dynamics, behaviour and trend are a basic preliminary step in order to minimise beach erosion. Shoreline position fluctuates in a variety of time scales, a behaviour that introduces many difficulties when reconstructing medium-term coastal trends. In fact, variability in coastline position may be the response to a single factor or to a combination of factors. Main causes of coastal erosion or accretion include individual large storm events or tsunamis, seasonal variability in wave energy, multiyear to decadal-scale variations in storminess, wave energy and coastal morphodynamics, and long-term variations in the relationship between climate and sediment supply (Forbes et al., 2004; Zhang et al., 2002; Orford et al., 2002).

In this sense, coastal studies and particularly monitoring programmes acquire the utmost importance. Specifically, coastal changes are surveyed using a wide variety of methods and datasets according to the time spans of the study. Studies on short-term shoreline dynamics are usually carried out at small spatial scales, in a time span less of than 10 years (Crowell et al. 1993). The most common technique used is beach topographical profiling or 3D survey, repeated at regular intervals, in order to measure daily to annual variations in shoreline position and beach volume. Most used tools are the theodolite, total station, DGPS and terrestrial LIDAR ("Light Detection and Ranging").

Vertical aerial photographs, satellite imageries, maps and charts all represent a very useful tool to reconstruct coastline changes at long (>60 years) and medium (between 60 and 10 years) temporal scales (Crowell et al., 1993), and large and medium spatial scales; in addition, they also display coastal type distribution, land uses and dune field evolution. The precision and accuracy of aerial photogrammetric measurements depend on their own characteristics (Moore, 2000) and on the difficulties of locating shoreline position, typically taken as the high water line or identified in mesotidal environments as being the seaward vegetation limit, dune toe or cliff top. Over the last two decades, airborne laser ("LIDAR") surveys have been largely developed and used in coastal morphological studies (Robertson et al., 2007). This remote sensing technique, usually carried out from a small aeroplane, allows detailed 3D surveys to be undertaken, but its application is limited due to rather expensive costs.

Institutional framework of beach erosion monitoring in Colombia

Competences in Colombia concerning coastal erosion monitoring are not very clearly distributed and there are several institutions in charge of this issue. The main bodies are the Maritime General Direction (DIMAR - its acronym in Spanish), the Colombian Oceanic Commission (CCO) and the Ministry of Environment and Sustainable Development (MADS). Despite the existence of these authorities, advances in coastal erosion monitoring started only five years ago and results are still partial, especially considering the magnitude of erosive processes recorded in the Caribbean and Pacific coasts.

The main institution with competences in coastal issues is DIMAR, which was created in 1984 as the national maritime authority, according to Law 2324. In spite of the new challenges in coastal management, administration of common goods in coastal areas is among the DIMAR responsibilities that have not changed during the past 28 years. In fact, several themes as climate change, sea level rise, coastal erosion and beach tourism are not yet among the responsibilities of DIMAR.

With regard to the decision making process DIMAR is supported by two research centres, one on the Pacific coast (CCCP) and one on the Caribbean coast (CIOH). Both of them have research programmes in coastal management and geomorphologic issues but unfortunately most of the results obtained are published only in Spanish or are not accessible at all. Another important effort made by this institution was the use of LIDAR technology to scan all the coastline of Colombia during 2005 to 2007; unfortunately, access to this information is not possible, due to national security restrictions. Finally, DIMAR is part of the Navy and thus a highly centralised organisation; this point favoured the protection of the coast from short-term developments, but on the other hand they often took too much time in decision-making (Avella et al, 2009).

A second institution deeply related to coastal issues is the Colombian Oceanic Commission (CCO). It is composed by 14 ministries and 4 national level institutions, leaded by the Vice-president of the Republic; it is therefore the highest level arena for decision-making on oceanic and coastal themes. The more remarkable achievement of CCO was the National Oceanic and Coastal Areas Policy, approved in 2008, although its implementation is currently less effective than expected. The highest level of this commission is a consultancy and advisory board and its decisions constitute only guidelines that can be easily disregarded (Avella et al, 2009).

The third institution is the Ministry of Environment and Sustainable Development (MADS) which was created in 1993 and underwent two structural reorganisations (in 2003 and 2011). Since its creation, this ministry has never been a single division or department in charge of oceanic and coastal issues. Only in 2012, after the last reorganisation, a department of marine environment was established in the third hierarchical level. In spite of that, the Integrated Coastal Management Policy was approved in 2000, and was economically supported by a specific budget established by National Government; unfortunately, this Policy is currently much less applied than expected.

Within this institutional framework, the coastal erosion monitoring has been a frequent issue, but no one has legal responsibility for its implementation. The main development has been the National Programme for Research, Prevention, Mitigation and Control of Coastal Erosion in Colombia (Guzman et al., 2008), established for the 2009 – 2019 period and leaded by INVEMAR, a national research centre in marine issues linked to MADS. In this programme there are five clear goals for coastal erosion monitoring, three of which were to be reached before 2011 - no information is available to check their level of implementation.

The importance of coastal erosion monitoring in Colombia relates to four main issues: Tourism, Risk Management, Urban Population and Infrastructures. Tourism is of increasing

interest in Colombia, as the country aims at developing the "3S" market as an engine to local economies. In 2010, the Ministry of Trade, Industry and Tourism created the public position of 'National Beach Manager', who should be in charge of developing a National Policy of Beach Tourism; this effort has been joined by several projects financed by the National Tourism Fund (Botero and Sosa, 2011). However, coastal erosion is never mentioned in such initiatives, forgetting that it constitutes the main threat for the "3S" market.
The other three issues have a similar axis: contingency. Unfortunately, initiatives to control coastal erosion in Colombia have been triggered by emergencies, as the well-known "km 19" case in the highway between Barranquilla and Santa Marta, two of the biggest cities on the Caribbean coast. In 2010 storm waves reached a line just a few meters from the highway and a multimillionaire public work was urgently approved to control increasing erosion; concrete blocks were emplaced in front of the highway to reduce wave impact, although public knowledge about the success of this project is still unknown. It is a precise example of coastal erosion management within an institutional framework where nobody is directly in charge of it.
It is also important to underline the existence of a monitoring programme carried out by INVEMAR from April 2009 to April 2011 in the Caribbean and Pacific littorals of Colombia. The main objective was to understand geomorphologic, tectonic and in general terms geologic and climatic characteristics of the littoral in order to review and adjust the existing legal regulations to coastal management. The main achievements have been the realisation of eight workshops, the elaboration of a basic legal regulation document and a conclusive report.

Coastal trend in the Caribbean Sea and in the Pacific Ocean
A total amount of 4.5 million inhabitants (DANE, 2010), e.g. 11% of national population, lives along coastal areas of Colombia. This includes 46 coastal municipalities: 30 along the Caribbean Sea and 16 along the Pacific Ocean, grouped in thirteen territorial units called 'Departments' (Figure 1). Such municipalities have significant land resources and natural ecosystems which represent the base of important economic activities. In spite of that, development of many coastal towns was not in accordance to natural resource distribution and coastal processes. This led to high environmental impact of natural processes (coastal erosion, flooding, etc.) on the quality and availability of marine and coastal resources, quality of human life and economic development of coastal areas (CONPES, 2002).
The study and understanding of coastal erosion in order to control, counteract, prevent and mitigate its negative effects on the littoral should have therefore become an imperative issue, of national importance, in Colombia. Specific studies carried out by government authorities and universities have demonstrated that erosion processes have increased significantly in past three decades. Representative cases are observed in the Department of Cordoba and in the Urabá Gulf. At Urabá many square kilometres of land devoted to agricultural and livestock areas were lost at Turbo River mouth (CORPOURABA-UNAL, 1998) and at Arboletes, between the Departments of Cordoba and Antioquia (Correa et al., 2007). Close to Cartagena city, coastal erosion degraded marine seaweeds and coral reefs (CARDIQUE, 1997; INVEMAR, 2005). In the Department of Atlantico, coastal erosion was enhanced by the contraction of a jetty at the mouth of River Magdalena and natural ecosystems were largely damaged at Mallorquin coastal lagoon and in the littoral spit of Galerazamba (Correa et al., 2005; INVEMAR, 2006).

In the Valle del Cauca, the most important tourist centres such as Juan Chaco and Ladrilleros have been affected by coastal erosion, especially along sectors characterised by cliffs consisting of very vulnerable sedimentary rocks. Furthermore, sea level rise linked to El Niño phenomenon caused the disappearance of large extensions of land in barrier islands and beaches; it also caused eroded sediments to be deposited in the nearshore area, forming sand bars that constitute a problem to fishing activities and navigation (INVEMAR, 2006).
Coastal erosion also affected Colombian islands: threatened areas can be observed at San Andres and Providencia islands (Posada and Guzmán, 2007). Four study cases will be presented, three on the Caribbean Coast (A) and one on the Pacific shores (B).
Finally, erosion processes reduced beach width and induced the construction of different structures. Examples can be seen at Santa Marta, Cartagena de Indias, Tolú and Turbo, where high erosion rates were counteracted in the past decades by the progressive and disorganised emplacement of numerous groins and, secondarily, seawalls and rip-rap revetments (Rangel et al., 2011; Stancheva et al., 2011).

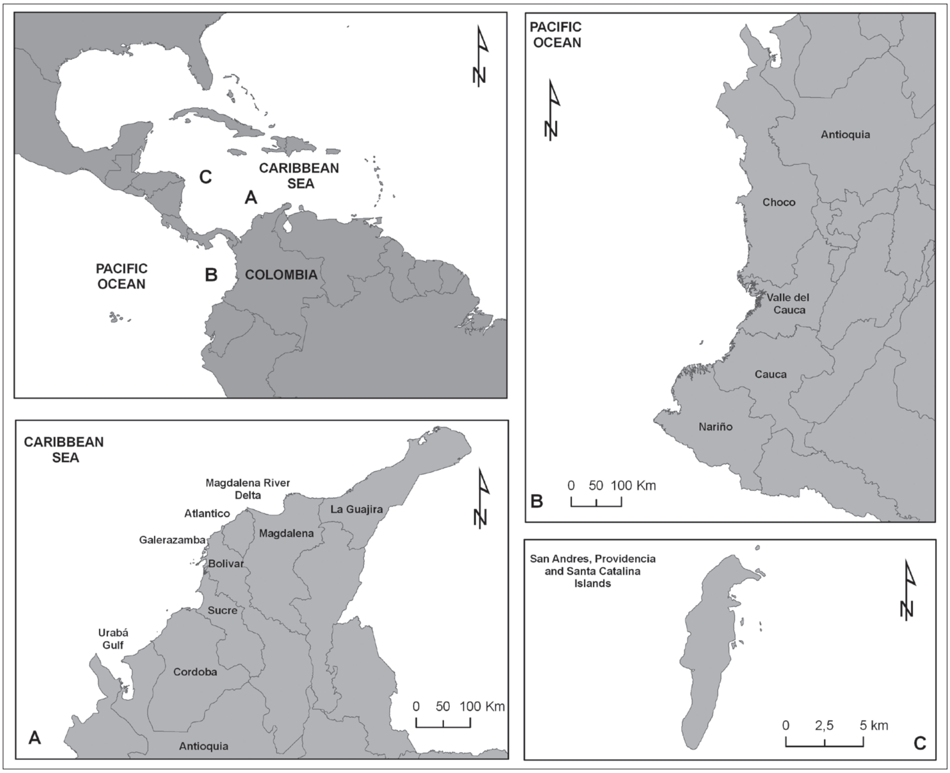

Figure 1 - Study area with the Caribbean (A) and Pacific (B) coast of Colombia.

Coastal erosion overview in the Department of Cordoba

The Department of Cordoba is located in the SW part of the Colombian Caribbean littoral. The coastline is composed by sandy beaches and cliff sectors developed along numerous

"log spiral" bays formed downdrift of rocky headlands linked to structural faults and/or diapiric volcanoes (Correa et al., 2007).
The analysis of shoreline changes clearly evidenced severe erosive processes (Figure 2).

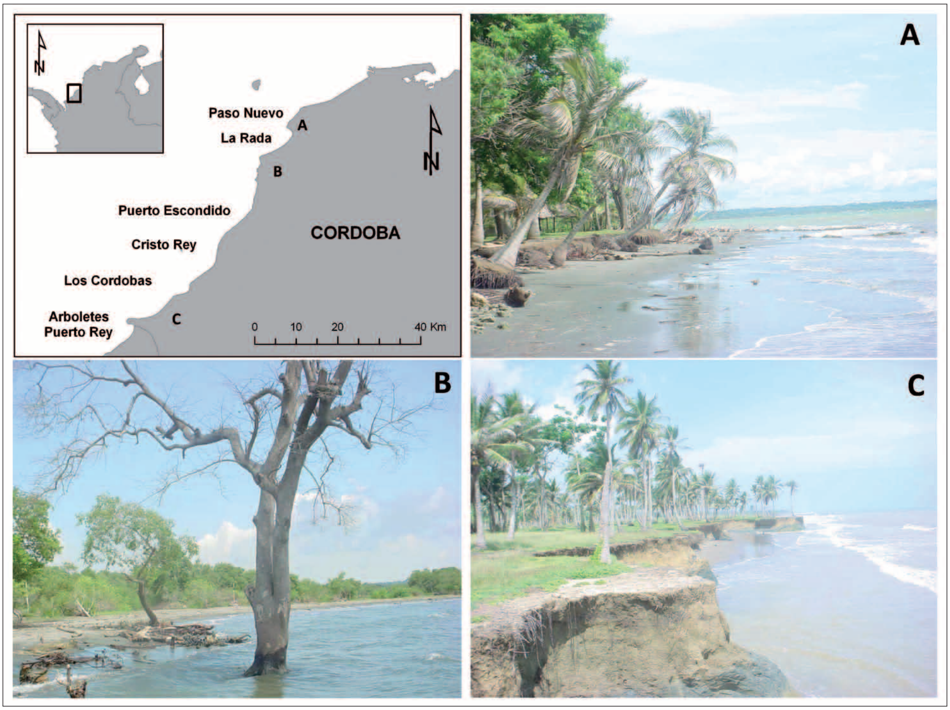

Figure 2 - Erosion examples at Cordoba department (Caribbean coast). Vegetation destruction at Paso Nuevo and La Rada villages (A and B). Cliff erosion at Los Cordobas (C).

In the southern part, e.g. the Arboletes-Puerto Rey sector, land loss recorded average retreat values of 60-100 m during the past 80 yrs, with peak values of 1.5 km at Puerto Rey where the morphological point of Arboletes totally disappeared (INVEMAR, 2003; Mazorra, 2004; Correa et al., 2007).

Mazorra (2004) and Correa et al., (2007) identified high erosion rates between Puerto Rey and Punta Brava linked to retreat values of 93 m (for the period 1938 – 2005), at the Los Cordobas river mouth and values of 220 m (for the 1938-2005 period) close to Punta Brava, e.g. retreat rates of 1.4 m/yr and 3.3 m/yr respectively. In the central sector of the Department, between the coastal villages of Puerto Escondido and Cristo Rey, retreat values of 63 m between 1938 and 2005 (e.g. 0.97 m/yr) were observed. Similar values were observed by Mazorra (2004), Correa et al., (2007) and Gonzáles (2007) at Puerto Escondido (0.62 m/yr). In the northern part of the Department, between the coastal villages of La Rada and Paso Nuevo, along a sector of circa 8.5 km long, about 138 m of land (2.12 m/yr) were lost between 1938 and 2003 (Rangel & Posada, 2005)

Coastal erosion overview in the Department of Magdalena

The coastline of the Department of Magdalena is essentially formed by cliffs located at the base of the *Sierra Nevada de Santa Marta* (SNSM), a mountain chain limited northward by the Oca fault and composed by different geological units ranging in age from the Precambrian to the Neocene.

Shoreline variations were obtained by means of aerial photographs from different years (1954, 1978, 1991, 1995 and 2004). At the city of Santa Marta, retreat recorded maximum values of 23 m, e.g. 1.7 m/yr (between 1991 and 2004). Maximum retreat values (61 m, 2.53 m/yr) were recorded between 1954 and 1978; during the 1978-1991 period, maximum retreat was recorded south of Punta Gloria, with values of 77 m, or 5.3 m/yr (Figure 3). There are no data available for the sector between San Juan and Punta Betín, but erosion, particularly affected rocky headlands along the coastline of Tayrona Natural National Park (Figure 3). The Guachaca - Cabo San Juan sector recorded, during the 1958-2004 period, maximum erosion of 10 m (0.4 m/yr) at the Piedra River mouth (Rangel & Anfuso, 2009a). Coastal changes along the sector between Los Muchachitos and Palomino were investigated through the use of 1958, 1979 and 2004 aerial photographs. Maximum erosion (3.2 m/yr) was recorded east of Palomino, at San Salvador, and maximum accretion (0.16 m/yr) was observed west of San Agustin headland. Specifically, in the 1958-1979 period, maximum retreat occurred at San Salvador (almost 100 m coastal retreat, e.g. c. 4.6 m/yr). In the 1979-2004 period, maximum erosion was 73 m at Palomino coastal village. No quantitative data are available for the Los Muchachitos cliff sector but there is plenty of evidence of a severe coastal retreat process (Figure 3).

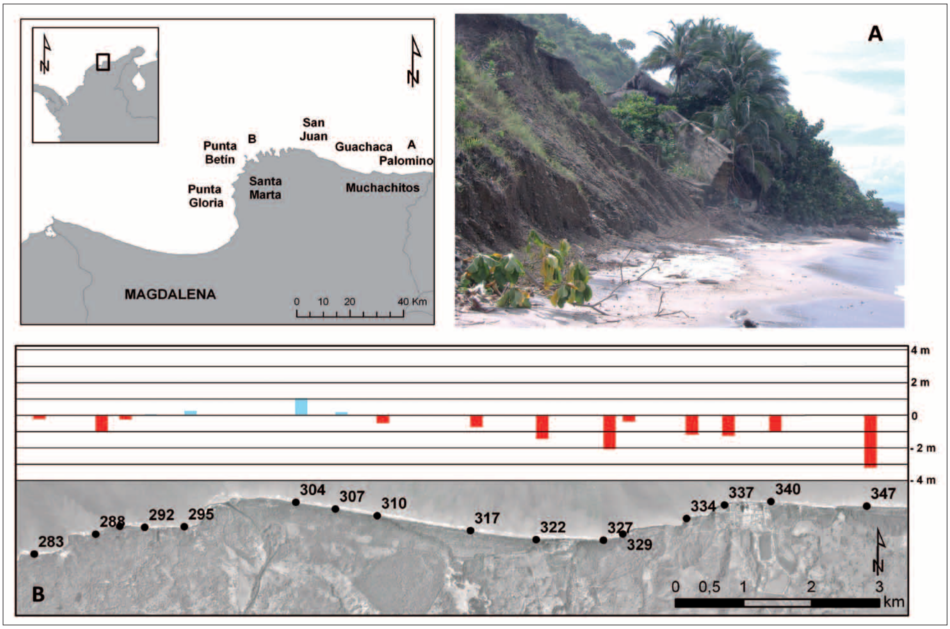

Figure 3 - Coastal erosion at Magdalena department (Caribbean coast). Cliff erosion and house collapsing at Los Muchachitos area (A) and erosion rates at Palomino (B).

Coastal erosion overview in the Department of La Guajira

This Department is located in the northeastern part of Colombia; it consists mainly of a peninsula with beaches, dunes, cliffs and coastal lagoons at sites used for salt harvesting. From an administrative perspective, it includes the coastal municipalities of Dibulla, Riohacha, Manaure and Uribia.

Maximum erosion and accretion rates were respectively recorded west of Dibulla (3.23 m/yr) and at Ancho River (1 m/yr). Considering the 1958-1979 period, 65 and 13 m of coastal erosion were respectively observed. For the 1979-2004 period, maximum erosion was near 40 m, with erosion rates of 1.5 m/yr (Rangel & Anfuso, 2009b).

At Riohacha municipality, which includes a deltaic system and coastal lagoons, erosive rate of 1.85 m/yr were recorded, e.g. c. 105 m in 57 years (Figure 4).

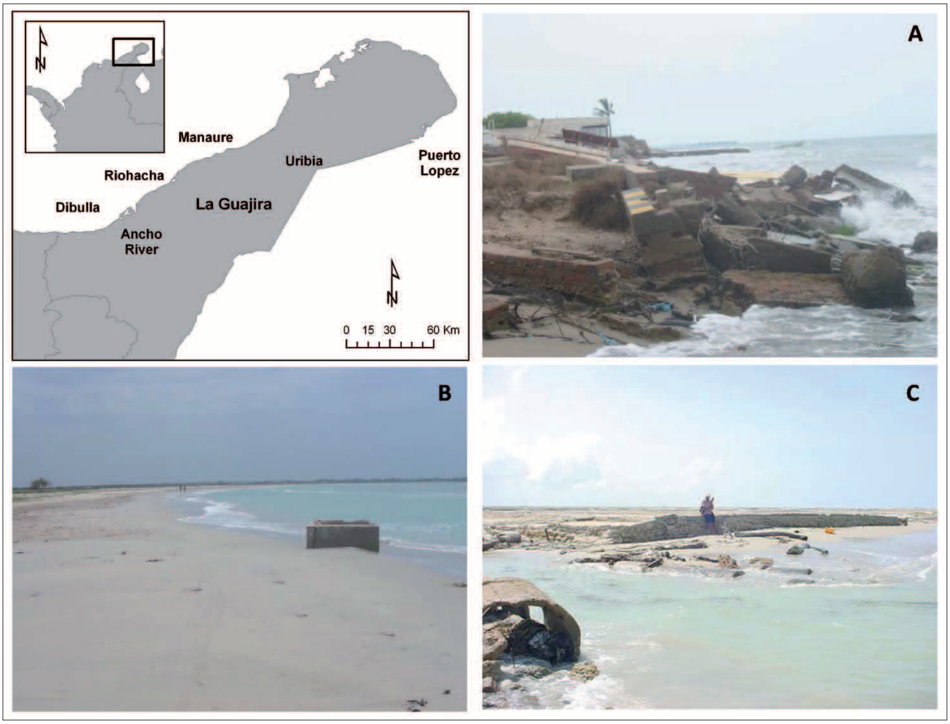

Figure 4 - Erosion at La Guajira department (Caribbean coast). Collapsing of human structures (A) and erosion of a natural beach (B) at Riohacha. Collapsed structure at Manaure (C).

In the municipality of Manaure, the beach accreted 34 m in 32 years (e.g. c. 1.5 m/yr) and a similar trend (c. 95 m in 32 years, e.g. 2 m/yr) was recorded at Puerto Lopez village (Rangel & Anfuso, 2009b).

Coastal erosion monitoring of barrier islands along the Pacific coast

Located just eastwards of the subduction zone of the Nazca plate under the South American plate, the Pacific coast of Colombia is a humid tropical region with mean temperatures about 27°C and annual rainfalls between 3 and 10 m/yr (West, 1957; Velez et al., 2001; Correa and Restrepo, 2002; Correa and Morton, 2011a, 2011b). It is a tectonically active, high-seismic risk region with a present coastline of circa 1300 km, between Punta Ardita (Colombia-Panama border) and Cabo Manglares (at the Ecuadorian border) (Duque-Caro, 1990; Paris et. al, 2000; Cediel et al., 2003). The Pacific coast is mostly a low-developed, difficult access and relatively pristine region, proverbial for its luxuriant vegetation and natural beauties, and with a high potential for future development, including touristic activities. High water discharges and sediment supplies derived from the adjacent Andes of Colombia combined with meso- to macro-tidal ranges and medium wave energy in the late Holocene caused the formation of numerous, extensive fluvio-deltaic plains dominated by sandy barrier islands and ebb tidal deltas, funnel-shaped coastal lagoons/estuaries and wide muddy tidal flats vegetated by species of mangrove ecosystem penetrating in some places up to 30 km landward from the present coastlines (Martínez et al., 1995, 2000; Correa and Morton 2011a, 2011b).

Detailed studies of the geomorphology and historical evolution of the Pacific coast of Colombia began in the past two decades and were driven in part by the urgency of assessing the medium term morphological response of the littoral zone to the effects of shallow-depth, historical high magnitude seisms. – from which the most famous were the 31 January 1906 (M 8.8) and the 12 December 1979 (M 6.5) Tumaco earthquakes (West, 1957; Herd et al., 1981, González and Correa, 2001).

The 31 January 1906 event is considered as one of the six strongest seisms in the world (M 8.8) and affected around 300.000 km2 of the (at the time) almost undeveloped coastal zones of northeast Ecuador and southern Colombia; there were approximately 400 human casualties related to the impact of a 5 m high wave tsunami that barred the littoral zone and penetrated the coastal land as a wave bore, reaching further than 15 km inland, through the interconnected tidal channels and creeks (Ramírez, 2004). The 12 December 1979 earthquake (M 6.5) had its epicentre 50 km northwest of Tumaco and generated at least 3 tsunami waves that hit the southern Colombian Pacific coast killing approximately 150 persons at San Juan de la Costa Village, a developing centre located on a frontal barrier island 60 km north of the Tumaco bay (Herd et al., 1981). Coseismic subsidence values estimated along the littoral zone for above seisms range between 20 and 160 cm, well enough for accelerating pre-existing erosion trends or triggering erosion in new sites, along the southern Pacific coast of Colombia. Tumaco city (at the southern tip of the Tumaco bay) has had double fortune: it is fronted by extensive offshore sandy barriers that caused tsunamis waves to break some hundreds of meters offshore and these waves arrived during low tide, in a zone where a tidal range is 3.5 m.

Events like the above mentioned (and more recent coseismic subsidence related to non tsunamigenic, modern seisms) have strongly influenced the progressive erosion and rapid thinning of the longest barrier islands of the Pacific Coast of Colombia considered appropriate for future coastal and tourism development.

The largest barrier islands on the Pacific coast are typically multiple beach ridge sandy-muddy deposits, currently 12-14 km long and 4-5 km wide, whose formation began around 500 yr B.P. according to radiocarbon dates obtained at the El Choncho barrier island, San Juan River delta (González and Correa, 2001; Correa and Restrepo, 2002) (Figure 5). Both this barrier spit and the spit of San Juan de la Costa (Patia River delta, Figure 6a) were

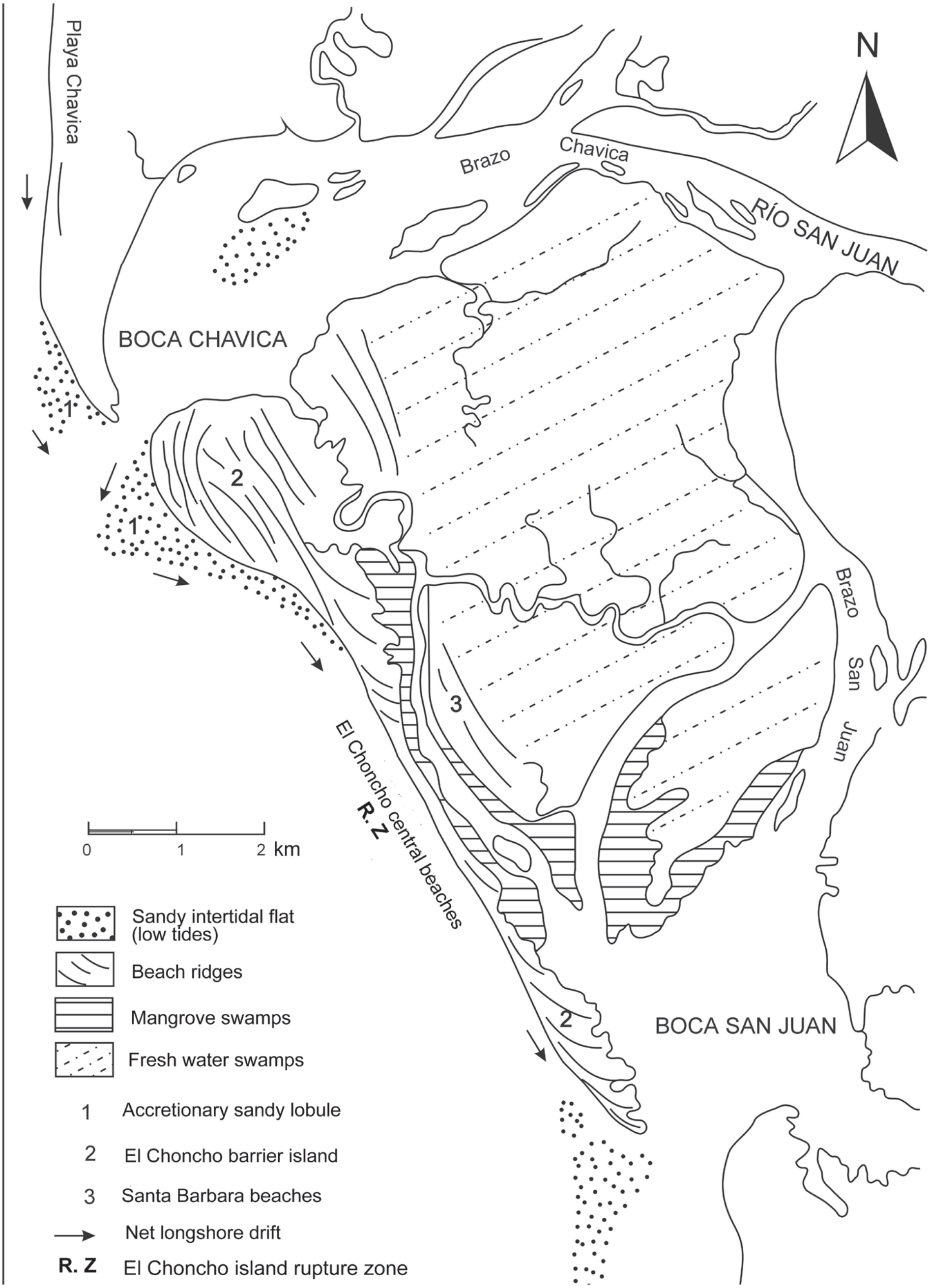

Figure 5 - Geomorphological map of the southern lobule of the San Juan River delta and location of El Choncho barrier island.

studied in detail to establish the possible causes of their definitive rupture (breaching) that took place between June and September of 1996 (Morton et al., 2000). Based on the

Figure 6a - Aerial photograph showing the rupture zone of El Choncho barrier island (August 1998).

inventory of coastline changes, elaborated further to aerial photographs, radar images and planimetric surveys dated 1968 – 2004, we conclude that breaching and segmentation of these barrier islands result from the combined actions of three different natural processes that included, in sequential order:

- the progressive starvation of sand in the central shores of both barriers islands due to the formation of extensive sandy intertidal deltas along updrift areas, which reduced significantly the longshore transport of sand to the distal parts of the islands and consequently triggered net erosional trends of approximately 1m/yr in these shores.
- the coseismic subsidence of the islands, associated to the December 12 earthquake in the San Juan de la Costa barrier island (1.5 m subsidence) and to the November 12, 1998 earthquake in the El Choncho barrier island (estimates subsidence of 0.3 m at the central part of the island). Coastal subsidence of both islands caused a sharp increase in the number of yearly inundations of its central segments (coinciding with the highest annual tidal amplitudes in March and October) that rose from 2 to 14 (approximately one flooding per month) at the El Choncho barrier island. A rapid increase in the already existing shoreline erosion trends was also observed.
- positive mean sea level anomalies of 20-30 cm along the Pacific coast of Colombia caused by temperature anomalies of 3 to 4ºC during the El Niño 1997-1998 event. High water and wave levels during the highest tides of this period caused extensive overwash events along the central parts of the islands and determined their definitive segmentation by widening the pre-existing small channel formed in June 1996 which rapidly evolved to a conspicuous tidal channel tens of meters wide and over 5 m depth.

Further observations and research based on comparisons of historical remote sensing materials have evidenced similar rupture patterns for other barrier islands of the Pacific coast of Colombia, namely several islands located between the border with Ecuador and Tumaco bay. New elements related to littoral hazards and vulnerability have thus emerged and enhanced the importance of considering medium to long term evolution of barrier islands, particularly when future sea level rise is considered. Of special interest has been the positive response of barrier island inhabitants to the relocation of coastal villages landward from the actual beaches and promoting their adaptability to changes by constructing their houses entirely in wood materials (Figure 6b).

Figure 6b - The New Choncho village, relocated inland of his former location, on the Santa Barbara beaches, an ancient barrier.

Conclusions

According to the findings of this study, it is evident that Colombian beaches are being widely impacted by coastal dynamics and in many cases locally by the inadequate development of different kinds of human structures constructed in the past decades. However, coastal tourism is currently one of the fastest growth economic activities in Colombia, as this is the fifth country in Latin America with the maximum average revenue per arrival.

The four study cases shown in this document give a clear overview of the intense erosive processes that occur along the Caribbean and Pacific littorals of Colombia. Nevertheless, the causes of coastal erosion on each coast are different. On the Caribbean coast, several studies carried out by universities and research institutes evidence coastal retreats of 1.5 km in the last 50 years in points as Punta Rey (Department of Cordoba), with maximum erosion rates ranging from 3.2 m/yr to 5.3 m/yr. Human interventions, such as jetties, breakwaters and groins, become the main reasons for current erosive processes.

On the Pacific coast erosion processes are essentially caused by natural reasons. In spite of environmental impacts due to Buenaventura and Tumaco cities (which sum together almost half million inhabitants), human impacts along the Pacific littoral are not important because of the small human pressure. The main causes of coastal erosion are due to natural progressive sand starvation, coseismic subsidence and sea level anomalies.

Concerning the response of policy-makers and managers in Colombia to coastal erosion, short-term and punctual human interests prevailed on long-term strategic goals despite the fact that ICZM general principles should prevail over local ones. Many examples on the Caribbean coast prove that coastal infrastructures have been more of a problem than a solution. Furthermore, the relationship between scientists and managers is very weak in Colombia; The National Program for Research, Prevention, Mitigation and Control of Coastal Erosion is hardly in its first stages of implementation.

Stable and long-term coastal erosion monitoring does not exist and for this reason is not possible to evaluate the consequences of the decisions adopted. Nowadays, some improvement can be seen due to the development of environmental studies, collaborations with research entities and the elaboration of general ICZM guidelines at a regional and national level. Information already obtained with 'LIDAR' technology could be a crucial input for future monitoring, but first a harmonic institutional framework should be developed to support data acquisition and analysis.

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Community Participation in Coastal Monitoring: A Case Study from Western Australia

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Abstract
The Western Australian coast is under increasing pressure from population growth and urban development, partly fuelled by the recent mining boom. Many towns located immediately north of the Perth metropolitan area were established on highly dynamic sandy landforms which are particularly prone to inundation by flooding and storm surge. The majority of studies commissioned in Western Australia to assess coastal changes are undertaken in settlements with larger population densities where financial resources are more readily available. Consequently major data gaps exist in the coastal datasets of smaller and often more vulnerable coastal settlements. This chapter describes some of the challenges that coastal managers face when making planning and management decisions and demonstrates the importance of engaging local communities in coastal management. The chapter also provides examples of how some coastal managers in the Northern Agricultural Region (NAR) of WA have involved the local community to help overcome skill, knowledge and data shortages prevalent within their region, specifically through community beach monitoring programs and coastal management discussion seminars.

Introduction

This final chapter aims to describe the challenges faced by coastal managers in the Northern Agricultural Region of Western Australia (WA). The chapter describes how variables within the physical and socio-economic environments of the region have created significant barriers to coastal management. These barriers are replicated in other similarly vast regions of the Australian continent. The authors have worked for almost a decade within the Natural Resource Management (NRM) sector, specifically focusing on coastal management in this remote region of WA. This chapter attempts to share their knowledge of and experience in the coastal governance system, and describes some of the challenges of, and successes in overcoming significant shortages in technical skills, knowledge and data, by engaging local communities in coastal management. This chapter focuses on two initiatives to address these shortcomings: community beach monitoring programs and coastal management discussion seminars.

Western Australia's Northern Agricultural Region (NAR)

The Northern Agricultural Region of Western Australia has a coastline that stretches for over 500 kilometres north of Western Australia's capital city of Perth. Many of the coastal

Figure 1 - Copyright to the Commonwealth of Australia (2006) and the Department of Environment and Conservation (2009). Map produced by Emma Jackson (NACC GIS Officer).

towns in the region have grown from fishing settlements (Cervantes, Lancelin, Port Gregory), around natural harbours (Geraldton and Dongara) and at the mouth of rivers (Guilderton, Dongara and Kalbarri). Some ungazetted squatter villages made of small fishing shacks still remain (Wedge and Grey). Most of the towns have been established on highly dynamic sandy landforms such as cuspate forelands, tombolos and mobile sand dunes particularly prone to inundation by flooding and storm surge (Henessy et al. 2007).
The NAR has largely been isolated from the state's major population centre in the Perth metropolitan area. Until recently the region relied on traditional economic activities such as fishing and farming. However, today the mining sector is becoming a significant economic driver in the region. Such mining developments are designed to help meet the insatiable resource demands of China's economic growth. Subsequently large public and private investments are spent on infrastructure developments such as road, rail, ports, and energy. The abundance of natural minerals and export activities is luring people to the region attracted not only by financially rewarding job opportunities but also by a desirable beach lifestyle. Eighty five percent of the population in Western Australia resides within 50 kilometers of the coastline (ABS 2010).

Figure 2 - Cervantes, Western Australia. Photo courtesy of Paul Robb.

The NAR is characterised by a Mediterranean climate with mild, wet winters and hot, dry summers, interspersed with the influence of tropical cyclones during the summer months (BoM 1998). Coastal landforms are shaped by the strong prevailing southerly to south-southwesterly summer winds (sea breezes) that blow parallel to the coastline, high energy waves with large fetch generated in the Indian Ocean and by locally generated wind waves.

Figure 3 - Erosion at Port Denison, Western Australia. Photo courtesy of Chiara Danese.

High wave energy is dissipated by offshore reefs and islands protecting much of the coast; however higher water levels associated with La Niña over the past two years have caused an unusual acceleration of erosion rates of coastal landforms across the region. Sea level rise will only exacerbate this phenomenon (Commonwealth, 2009; Preston and Kay 2009; IPCC 2007). This biophysical environment creates significant challenges for coastal managers in the NAR.

Data Gaps

The majority of studies commissioned to assess the local biophysical environment are mainly undertaken in settlements with larger population densities where financial resources are more readily available due to a larger rate-paying base (such as Geraldton). Such studies are usually commissioned by local government and carried out by external consult-

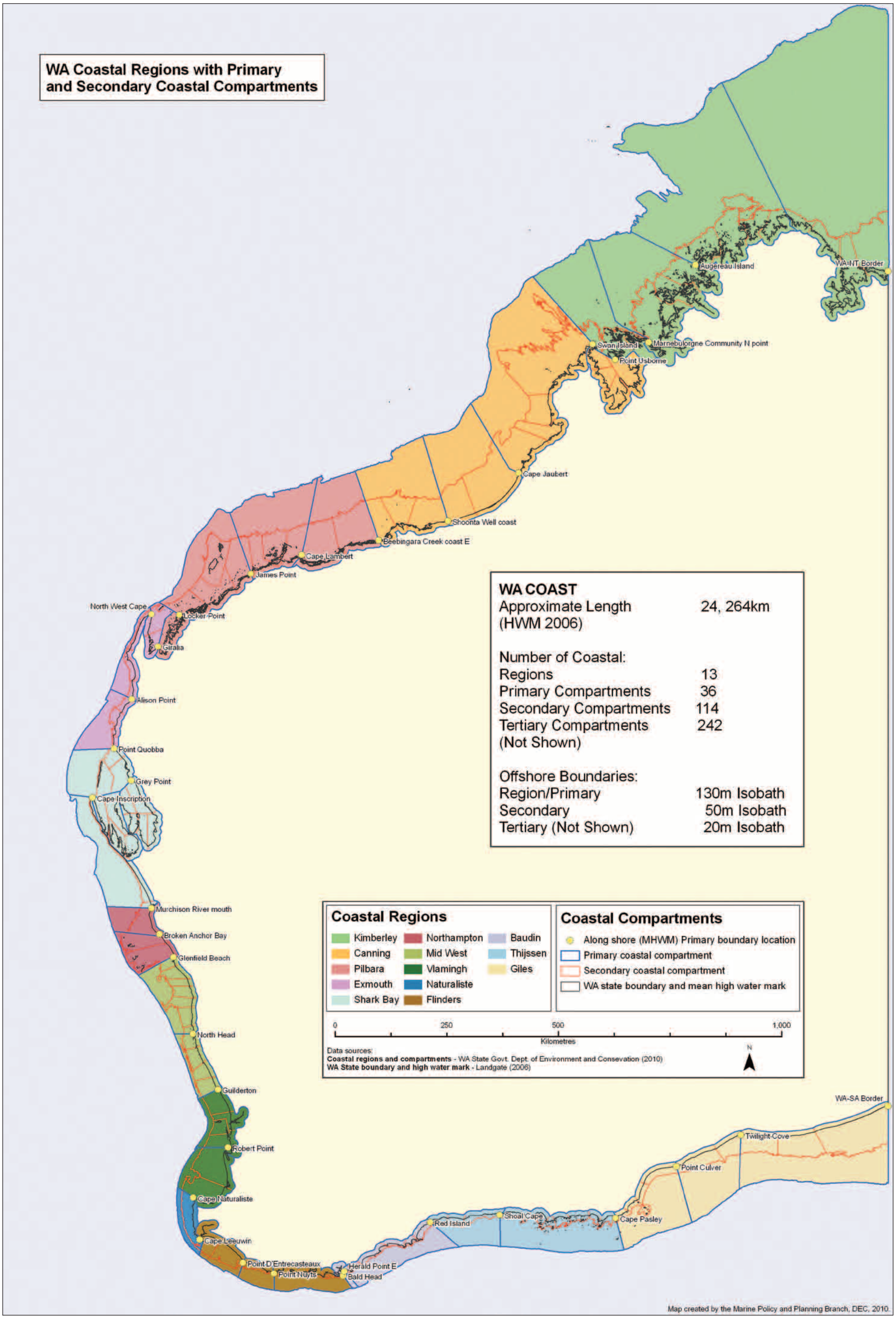

Figure 4 - Coastal Compartments of Western Australia: a Physical Framework for Marine & Coastal Planning. Image courtesy of Department of Environment and Conservation DEC WA).

ants or universities, often for the construction and maintenance of harbours, marinas and other boating facilities. Consequently major data gaps still exist in the coastal datasets of smaller coastal settlements (Oceanica, 2009). Meteorological, ocean and estuarine data is currently acquired, analysed and managed by regional Port Authorities and the WA Department of Transport. Tide gauge measurement is available from 1896 along the West Australian coast, although only the Fremantle tide gauge has a history that is sufficient for establishing long-term patterns of sea level change (Lambeck & Chappell 2001). Other tide gauge stations have records of only 30 to 50 years long (Belperio 1993).

Wind records, water levels, tide records and storm records are available from 1971. However, between 1971 and 1994 measurements were sporadic in nature, typically through comparatively short term distributions of one to four years. Consequently, observations are unevenly distributed around the state and have varied lengths of recording history. Instrumentation has also varied in frequency and accuracy.

Aerial photography is available from 1950 and the analysis of imagery using the vegetation line as an indicator of shoreline position movement is still common practice where LiDAR terrestrial mapping is not available. Offshore bathymetry data is mainly available in the proximity of ports and marinas. This is still a major gap in regional areas of WA while bathymetric LiDAR has only been undertaken for highly developed coastal areas (Perth to Cape Naturaliste).

The State Government has recently commissioned a study to map coastal stability and susceptibility to change in the coastal zone of Western Australia. This will be a useful tool for local scale coastal management and planning decision-making, vulnerability and risk assessments, and marine conservation planning (Eliot et al 2011). Similar frameworks have been used in the United Kingdom and in the USA. Such data shortages combined with a challenging biophysical environment creates significant challenges for coastal managers in the NAR.

Coastal Governance

Australia has a federal system of government, involving six states and two territories. Three layers of government include Federal, State and Local, who all play varying roles in managing the coast of the NAR. The Federal Government's responsibilities with regard to coastal management are somewhat limited due to Australia's constitutional arrangements. For instance there is no overarching national coastal policy or legislation despite numerous recommendations since 1975 (1975 – Australian Advisory Committee on the Environment, Coastal Land Report No.5; 1980 – Management of the Australian Coastal Zone, Report House of Representatives Standing Committee on Environment and Conservation; 1991 – The Injured Coastline, Report House of Representatives Standing Committee on Environment, Recreation and the Arts. 1993 – Coastal Zone Inquiry, Resource Assessment Commission; 2010 - Federal Government's inquiry into Climate Change and Coastal Communities).

State governments exercise statutory powers in relation to coastal planning and management through a range of legislation and agencies. The State Government through the Western Australia Planning Commission (WAPC) prepares and adopts coastal policies and advises local government on strategic land use planning, town planning schemes, subdivision and development approvals. The State Government also provides funding for coastal management and coastal protection works to local government through funding programs. Applicants are often required to match State grant funding on a 50:50 ratio. There is no specific coastal management legislation in WA. Instead, the State Government involves itself in coastal management through the functions of its government departments: such as land use planning, land management, environmental protection, transport, infrastructure development, primary industry and mining.

Generally much of the responsibility for coastal management resides with local government authorities (Harvey and Caton 2010). Local government is responsible for the day-to-day maintenance of beaches, coastal facilities and foreshore reserves, and shares with the State Government the task of shoreline protection.

In recognition of the need for whole of catchment approaches to natural resource management, in 2002 the Australian Government supported the establishment of 56 not-for-profit natural resource management organisations across the country. These organisations receive funding to facilitate integrated approaches to natural resource management (NRM) and play a significant role in supporting government and the community to manage natural resources, including those in the coastal zone.

Other parties such as Aboriginal groups, research institutions, community groups and private enterprise also play a key role and have a strong influence on decision-making processes that affect coastal management.

State and local government departments in WA typically provide public services to extremely low population densities, resulting in significant service delivery challenges and strains on government resources. Recent cuts to State Government spending by the Western Australian Government have caused further strain on government departments who are responsible for meeting the increased demand for new infrastructure and services caused by the growing mining sector. Western Australia's unemployment rate of 3.5% (ABS 2011) demonstrates a high demand for skilled labour to service the state's growing economy. Like other sectors in the NAR, coastal management remains relatively under-skilled and under-resourced.

Community based coastal management

In 2006 the Framework for a National Cooperative Approach to Integrated Coastal Zone Management (ICZM) was endorsed by the Federal Government (Commonwealth of Australia 2006). Of note is that very little national integration has been achieved since the development of the Framework or as a consequence of the numerous national coastal inquiries (Harvey & Caton 2003, Sorensen 1997), resulting in a fragmented approach to ICZM in Australia. This is reflected in the variety of coastal legislations, policies, funding programs and most particularly the varying sea level rise factors for policy guidance adopted by each state. Nevertheless, the adoption of the Framework resulted in a positive trend across Australia toward greater community involvement in coastal management and increased public awareness of coastal issues. The Framework recommended the participation of all stakeholders in determining how coastal resources are managed, and specifically encouraged coastal managers to involve the community in management of the coast. However, generally speaking governments remain cautious about public involvement, particularly where management involves sensitive economic or political issues. Participatory approaches can also be perceived as costly and time-consuming processes with little value. A growing public awareness about the value of the natural environment has also encouraged increased community involvement in decision-making processes. This is often the case where decisions may have negative environmental consequences and partly as a result of planning policy developments.

Between 1997 and 2003 the West Australian government commissioned a series of inquiries and reforms to assess the effectiveness of the coastal management and planning system (DPI 2002, WAPC 2002). These inquiries identified the need for a more integrated planning framework that would allow decision-making to be more transparent to the community, hopefully encouraging community participation throughout decision-making processes. As a result, provisions for community consultation, participation and engagement in coastal management and strategic planning were incorporated into the State Coastal Management Policy for Western Australia (WAPC 2003; Section 5.1):

- Ensure that adequate opportunity is provided to enable the community to participate in coastal planning and management including the support and guidance of activities undertaken by voluntary coast care groups (WAPC, 2003).
- The coastal planning strategy or foreshore management plan should be developed in consultation with the broad community and relevant public authorities, and achieve the approval of the local land manager and the WAPC if appropriate (WAPC, 2003).
- Community involvement in coastal zone management and planning in Western Australia has also been encouraged through the development of funding programs such as 'Coastwest'. Since its establishment in 2004 the Coastwest program has been distributing small grants to community groups for implementing recommendations made within coastal management plans, through coastal restoration, community education, monitoring, and conservation projects.

With these programs and policies in place, there is now a significant expectation on coastal managers to involve the community throughout various components of coastal management and planning. The following sections provide examples of how some coastal managers in the NAR involved the local community to help overcome the aforementioned skill, knowledge and data shortages prevalent within their region, specifically through community beach monitoring programs and coastal management discussion seminars.

Community Beach Monitoring Program

The WA Coastal Protection Policy (WAPC 2006) recommends that 'local coastal processes are understood' and that 'adequate monitoring' is undertaken prior to any coastal protection works taking place. However a range of land managers with varying levels of technical skills, knowledge, datasets and access to financial resources means that elaborate coastal protection works are often constructed despite a poor understanding of local coastal processes. While State Government funding provides financial assistance for monitoring programs through the Coastal Protection Grants (50:50 requirements), the skill, knowledge, data and resource shortages make a consistent and coordinated approach to beach monitoring across the state and even within a region difficult to achieve. As a result, coastal managers are deprived of sound baseline information and long-term, reliable datasets.

Due largely to limited resources stemming from small population densities, employees within local governments are often responsible for a range of duties, of which coastal management is usually a minor role. Subsequently local governments often lack specialist knowledge and skills and therefore have a limited ability to interpret and translate information and data relevant to coastal management. Despite this, independent peer review is yet to be adopted as a necessary mechanism for ensuring a high standard of quality and accuracy.

A gap analysis report undertaken for the NAR in early 2010 identified a lack of information on long-term coastal change, creating significant challenges for evaluating coastal hazards (Oceanica 2010). Consequently, coastal hazards are often discounted within local decision making processes. A community study conducted at the same time found considerable concern for the condition of the coastal environment (Beckwith Environmental Planning 2010). To overcome these barriers and increase community engagement in coastal management, the Geraldton Volunteer Beach Monitoring Program was designed in 2010 as a pilot beach monitoring program.

Geraldton is the region's largest coastal settlement and is located on low-lying sandy coastal compartments. Geraldton's coastal zone is under increasing pressure from population growth, urban development, and subsequent commercial and recreational use. Widespread beach and dune erosion is already placing private and public property and infrastructure at risk from coastal erosion and inundation. Subsequently, the Geraldton Volunteer Beach Monitoring Program was developed by the region's natural resource management body, the Northern Agricultural Catchments Council (NACC), in collaboration with local government and coastal engineers from the WA Department of Transport. The program was primarily funded through the WA Department of Planning's coastal community grants program: Coastwest.

The aim of the program was to develop a method for utilizing community skills and resources in order to create a long term photographic record of coastal change, that would complement other datasets such as ocean current, wave and sediment distribution data, and be transferable to other local government areas in the NAR and across WA. It was important for the program to learn and integrate methods and lessons learnt from previous state, national and international programs.

Following the design of the programa team of community volunteers was identified and trained to take digital photos at key beach monitoring sites, at varying intervals depending on the season, and then upload to an online photo-sharing repository. Uploaded photos are labeled according to date, time, and monitoring site, and geotagged to permit the future production of an interactive, virtual aerial map for use by coastal managers as well as the community. At each site, volunteers are asked to include field-of-view reference points to ensure the same image profile is captured at each site.

Increased pressures on coastal land from urban development, commercial and recreational use and climate variability means that gathering information to understand coastal processes is a high priority. This complimentary dataset will help scientists and coastal managers better understand how and why local beaches are changing. Additionally, the region's nearshore environment is habitat to significant seagrass meadows. Therefore this dataset will also provide important information to coastal managers regarding the movement of seawracks[1] along the region's coastline.

Implementing the program has not been without its challenges though. The important link between taking site photos and uploading them to the online repository has

1 Seawracks are composed largely of seagrasses and seaweeds.

Figure 5 and 6 - beach monitoring photos taken by Geraldton volunteers. 21st June 2012 (a) and 1st June 2011 (b). Photo courtesy of Tom Brady.

been identified by volunteers as a somewhat arduous task and has been one of the most significant barriers to developing consistent datasets at each monitoring point. Advancements in digital technology have created an opportunity for program coordinators to develop a smartphone application that will allow volunteers to automatically upload photos to the database immediately after taking the photos on site.

Despite this and other challenges, to date over 1,000 photos covering 28 sites have been uploaded online since the program's inception by up to 20 volunteers (photos available at http://www.flickr.com/groups/gbmp/). This has encouraged the NACC and Department of Transport to support the program's expansion from Geraldton to across a range of coastal settlements within the NAR, adding valuable coastal datasets to the relatively poor pool of data available for coastal managers within the NAR.

The Coastal Conversations Series

The 2009 and 2011 Coastal Conversations Series were two series of coastal management discussion seminars developed by practitioners at the NACC to address a range of factors that included:

- Vast distances from coastal settlements in the NAR to Perth, which created barriers for coastal managers and decision makers who were looking to increase their coastal planning and management skills and knowledge;
- No university or coastal research institute in the region;
- Skill shortages created by the mining sector;
- Employees of local governments within the NAR who are often responsible for a range of duties, of which coastal management is usually a minor role and one that they have no or very little training in;
- An increasing expectation of coastal managers to involve the community throughout various components of coastal management and planning processes, and,
- An understanding that participatory approaches to coastal management and planning can be of higher value when participants are well informed about local level issues.

In response to these factors, the NACC identified a need to better understand community and coastal manager learning requirements. A community study and a survey to local government staff helped identify key coastal planning and management topics where knowledge and skill levels were deemed relatively low compared to the duties and decision making responsibilities of the surveyed respondents. Subsequently, in 2009 the NACC developed a series of coastal management discussion seminars, aimed at raising awareness of key coastal planning and management issues that provided opportunities for learning and discussion with coastal planning and management specialists from other areas of WA, Australia and internationally.

The result was a series of 24 seminar events held over 3 years, delivered with a variety of partners and coastal specialists in coastal towns throughout the NAR, with funding support from Coastwest. Sessions averaged 25 participants covering a diverse cross-section of the community including: support staff and executives from government departments (local government, planning, environment, fisheries); education sectors (schools and universities); industry groups, community groups and general community members. Topics included geology and geomorphology, coastal ecosystem services, impacts of climate change on the coast, coastal risk assessment, legal and liability issues of coastal development and

Figure 7 - Session 1 of the 2011 Coastal Conversations Series in Geraldton, Western Australia. Photo courtesy: NACC

sea level rise, methods for protecting coastal infrastructure, climate change impacts in the marine environment, coastal biodiversity, and others.

Each conversation event included a 45 minute presentation from the technical specialist and a 20 minute discussion time hosted by a facilitator who helped to ensure discussions stayed on topic. Participants were encouraged to stay for a light meal after each event in order to encourage informal discussion and networking activities. Events were held during lunch times for professional staff and repeated in the early evenings to accommodate other sections of the community.

Participants at each event were requested to complete feedback forms in order to gauge appropriateness of the topic, the event format, changes in the participants' perceived knowledge levels before and after each event, and any other comment participants wished to make. Feedback analyses of the two series reflected a 35% or better increase in the perceived knowledge levels of attendees across all topics presented. Other outcomes observed included more informed and active community comment within local level planning processes and public comment periods, strengthened coastal management networks and relationships, and an increased community understanding of the complexity of a variety of coastal planning and management issues. A series of videos of the events were developed to ensure content was available to a wider audience. These videos have been uploaded online and are frequently referred to by coastal managers and community throughout the region (videos available at http://nacc.com.au/pages/4851/videos). The series format has since been adopted by other regions within Western Australia.

While these outcomes have been extremely encouraging, assessing their impact on coastal management in the region is much more difficult to measure. Some recent coastal projects and coastal management decisions that have been made since the two series occurred seem contrary to certain content provided by specialists throughout the series. Of course, despite available information, decisions made that affect the coastal zone will always be subject to political prioritizations. In saying this, anecdotal evidence suggests that the two series have had a largely positive impact on coastal management in the region.

Conclusions

While coastal management of the Northern Agricultural Region remains a significant challenge for coastal managers, our experience demonstrates valuable potential to utilize community interest and resources to help overcome some barriers currently inhibiting the management of the region's coastal zone. It is important to note that these are complementary activities that need to be supported by other key activities that may also help to overcome significant barriers being experienced by coastal managers in the NAR. Some of these activities may include:

- Collaboration with other regions within and outside of Australia. This would help to strengthen support networks for coastal managers working in isolated regions, and ensure lessons learnt and new methodologies are shared across regions. Rapid developments in digital technology provide many opportunities for these possibilities to be realised.
- The development of a centralised regional depository for coastal data to help ensure greater consistency in coastal monitoring across a region, support joint monitoring strategies and programs, allocating resources (expertise) and finances to the task of monitoring, maintain networks and partnerships and improve data knowledge and management.
- Continue to involve the community in coastal management in more meaningful and transparent ways.

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