Shoreline Management between Marina di Ragusa and Punta d'Aliga (SE Sicily)

G. Alessandro [(1)], G. Biondi [(1,2)], B. Di Vita [(3)] and M. Tagliente [(4)]

(1) ***Ragusa Regional Province, Geological and Geognostical Department***
Via G. Di Vittorio, 175 – 97100 Ragusa, Italy.
Tel: +39 932 675553 Fax: +39 932 675522
E-mail: giuseppe.alessandro@tiscali.it
(2) ***E-mail: giovannibiondi@tin.it***
(3) ***Environmental Engineering Consultant***
Via Gen Cascino, 86 – 97019 Vittoria (RG) Italy
E-mail: alettablu@yahoo.it
(4) ***University of Messina, Department of Earth Sciences***
Salita Sperone, 31 – 98166 Messina Italy
E-mail: mtagliente@unime.it

Abstract

The coast between Marina di Ragusa beach and Punta d'Aliga headland (South East Sicily) is of notable naturalistic value, owing to the presence of biotopes characterised by natural elements and fauna specifically belonging to the Mediterranean region; part of it is already a protected area (R.S.N.B. "Macchia Foresta del Fiume Irminio").

The present study has defined a whole series of elements which, taken together, have contributed to a general degradation of the area. These elements, linked to both environmental and anthropic factors, have caused over time a number of alterations in the complex environmental balance of the area.

The significant erosive processes characterising the beaches of the Ragusa province have resulted, over the last decades, in the building of protective structures consisting for the most part in attached emerged breakwater barriers. This study takes as its starting point the analysis of the negative evolutionary trend of the coastline, to propose in particular solutions for the same area consisting of more varied interventions with a decidedly less violent environmental and scenic impact.

Introduction

The coastline of Ragusa, until 30 years ago, was characterized by a wide system of dunes extending along all the low sandy beaches. The study area, defined to the West by the residential area of Marina di Ragusa and to the East by Punta d'Aliga, now includes the only remaining fragment of this ecosystem, surviving in the Nature Reserve area of the Irminio River Mouth. Today, this river mouth represents an area of "macchia mediterranea" (Mediterranean vegetation) among the most beautiful and best-preserved in Sicily (Randazzo, 2002) (Fig. 1).

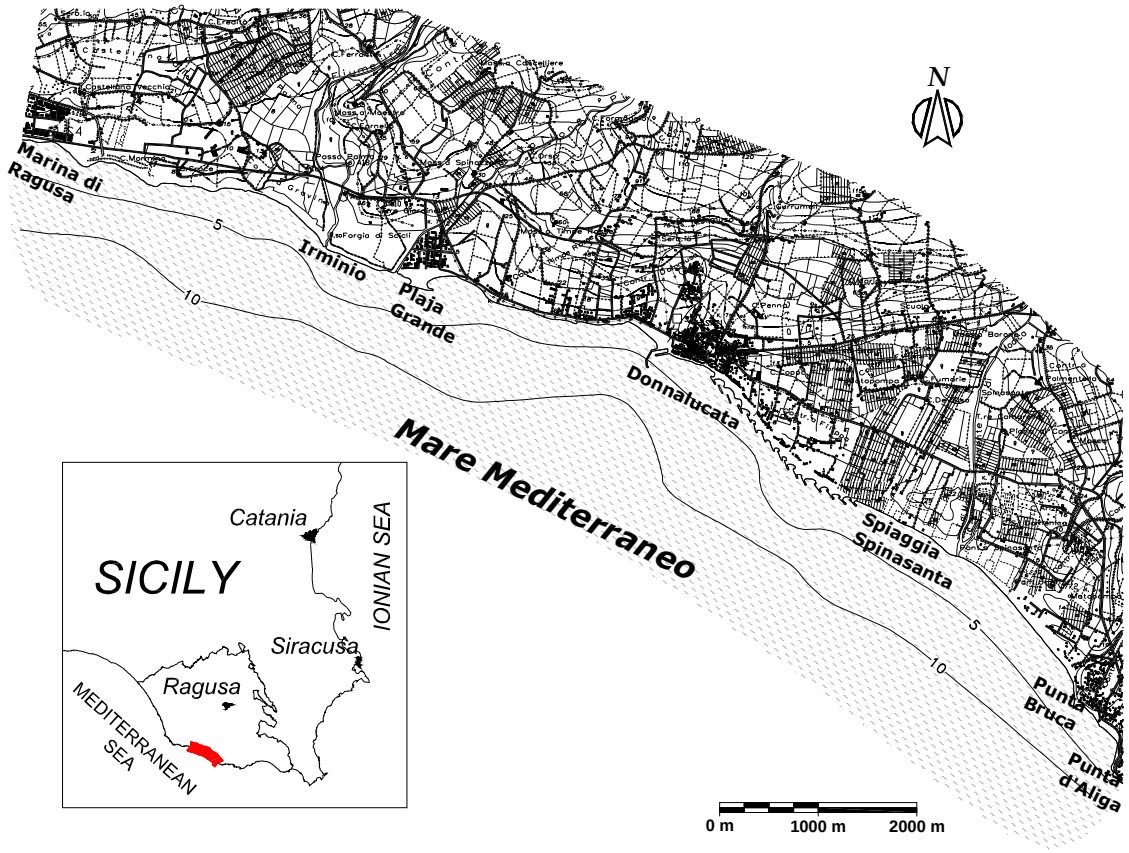

Fig. 1: Location of the study area.

The study area consists of about 9.5 km (~ 64%) of low sandy or coarse clastic beaches, and a further 5.5 km (~ 36%) of rocky calcarenitic shores, never rising to more than 4 m above sea level. The area also includes the nature reserve known as "Macchia

Foresta del Fiume Irminio" which is an area of specific environmental interest, very vulnerable and subject to considerable erosion of the beaches.

The involution of the coastal system has led to the creation of a number of rigid protective constructions to protect the coastline. These have had positive results only locally, by moving the erosive processes downdrift (Amore et al., 1988). Such undesired effects are in conflict with the objectives of coastal planning adopted at the provincial level (Ragusa Regional Province, 2001) which aim to achieve economic development based on protection of the environment and re-qualification of the coastal area.

The present study offers suggestions for the recovery of the coastal area, taking into account the need for an effective system of protection from erosion with the smallest possible negative environmental impact.

Climate Data

The Climate data of the study area was obtained from the historic series referred to the meteorological station of Cozzo Spadaro of the Italian Hydrographic Department, situated at 50 m. a.s.l.. From the observations related to the period from 1921 - 1996, it can be seen that the average annual rainfall is about 412 mm; the rainiest months are October and January, with an average of 60 ÷ 70 mm; while June, July and August are the driest months, with averages of less than 5 mm (Fig. 2).

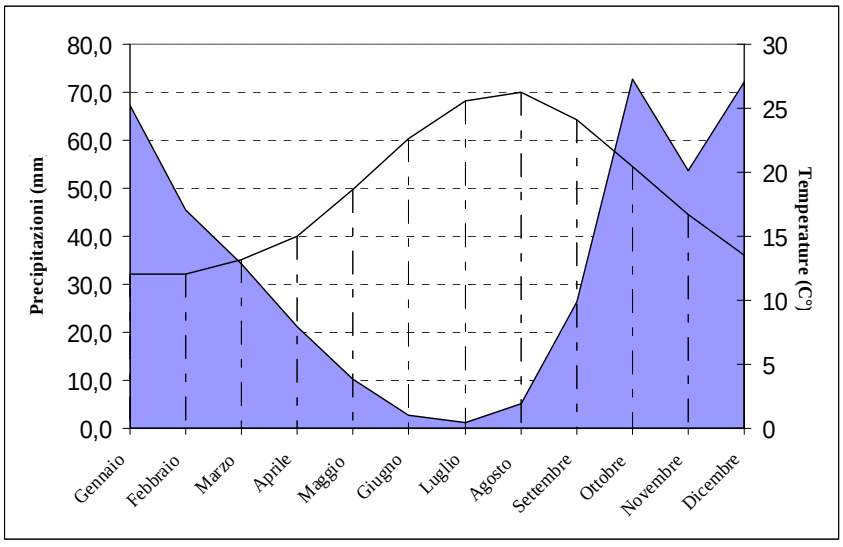

Fig. 2: Meteorological data.

The average annual temperature is 18°C, with monthly averages varying from 12°C in the winter months to 25 ÷ 26°C in July and August; the minimum average value

for the coldest month (9.1°C) and the maximum average value for the warmest month (29.7°C) were recorded respectively in January and August.

As a result, the study area is one of the driest and hottest in all Sicily, characterised by the presence of the summer anticyclone and prevalently winter rainfall, due to the west winds and the cyclonic depressions, so that the summers are hot and dry and the winters warm and not particularly rainy. According to the classification of Koppen (1940), the area presents a warm-temperate (mesothermic) climate of a subtropical type, steppic subtype, with a thermal curve that is always above zero, dry summer seasons and damp winters.

The data concerning winds and waves referred to the Hyblean coast was obtained from the Data Report made out by HR-Wallingford (2003) for the Ragusa Regional Province. The wind direction is indicated with reference to the four quadrants, each of which contains three 30° sectors of origin. The data, considered over the period 1 october 1986 and 31 march 2002, also includes the frequency of occurrence of events, and is expressed as a windrose in Fig. 3.

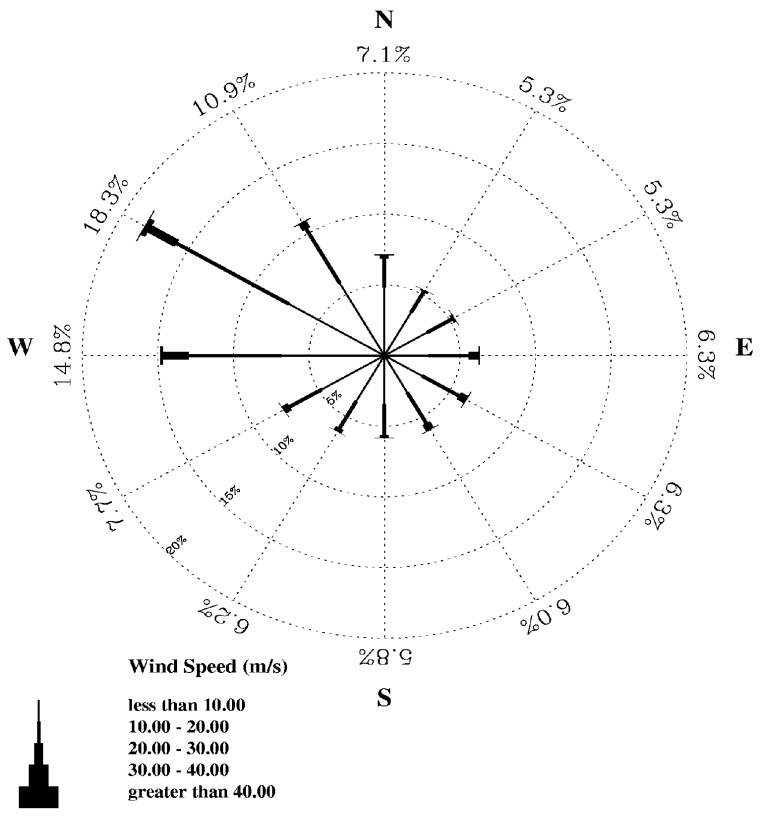

Fig. 3: Anemometric data.

Analysing the percentage frequencies of appearance and the speeds for each direction, it is clear that the most common winds are those within the sector 270°- 330° N with maximum frequencies for the winds coming from the North-West (18.3 %) and from the West (14.8 %). The sector of origin between 300°-330° proves to include the

direction of the dominant wind (North-Westerly) which at times reaches a speed of over 40 m/s. The sector between 270°- 300°N (Westerly) proves subordinate to this, with wind speeds between 30-40 m/s.

The direction of dominant wave approach is included between 135° N and 290° N. In the stretch of sea facing the study area there is a clear prevalence of wave movement from the direction 270°N which leads us to imagine also a probable West-East direction for littoral sediment transport.

There is little information available on the near-shore circulation of surface currents; this is partly due to the complex and irregular circulation of currents along the coastal strip. Off-shore marine currents data was obtained from the Atlas of Surface Currents in Italian Seas produced by the Italian Naval Hydrographic Institute (1982), which is a compendium of all the studies made and readings taken by national and international groups and researchers and includes twelve monthly plates illustrating the trend of surface currents circulating in the Italian seas. In the stretch of sea overlooked by the coast of Ragusa the superficial off-shore currents are seen to proceed from West to East with an average speed of between 0.5 and 1.2 knots; these values are not sufficiently high to have any effect on the shoreline regime.

Evolutionary Trend of the Shoreline

For the study of the shoreline evolution, taking into account the main sources of error (scale, optical aberration, etc.,) the decision was made to use the Zoom Transfer Scope (ZTS) method suggested by Fisher and Simpson (1979) and the Softcopy Photogrammetry-GIS Methodology by Overton et al. (1996), suitably modified for local application.

The study was based on complete collection of maps and aerial photographs. The following steps were then carried out with computer acquisition of all the cartographic and photographic data available; geo-referencing of the raster images; comparison of the coastlines over time by superimposing the maps.

To obtain a more complete description of the events a distinction was made between the western sector (from Marina di Ragusa to Plaja Grande beaches), the central sector (from Plaja Grande to Spinasanta beaches) and the eastern sector (from Spinasanta beach to Punta d'Aliga headland).

On the basis of the analysis of the coastlines referred to the years 1967-1994-1999 it was therefore possible to calculate which sectors of the shoreline studied were eroding, stable and accreting.

Western Sector

The coastal zone included in the Western sector extends for about 5 km. from the east of the residential area of Marina di Ragusa as far as Plaja Grande beach (Fig. 4). Between 1967 and 1994 there was a general tendency of the beach to retreat, made

irregular in places by the presence of cliffs; the beach area was reduced by about $6.3 \cdot 10^3$ m^2, about $1.7 \cdot 10^3$ m^2 of which situated in the most western sector.

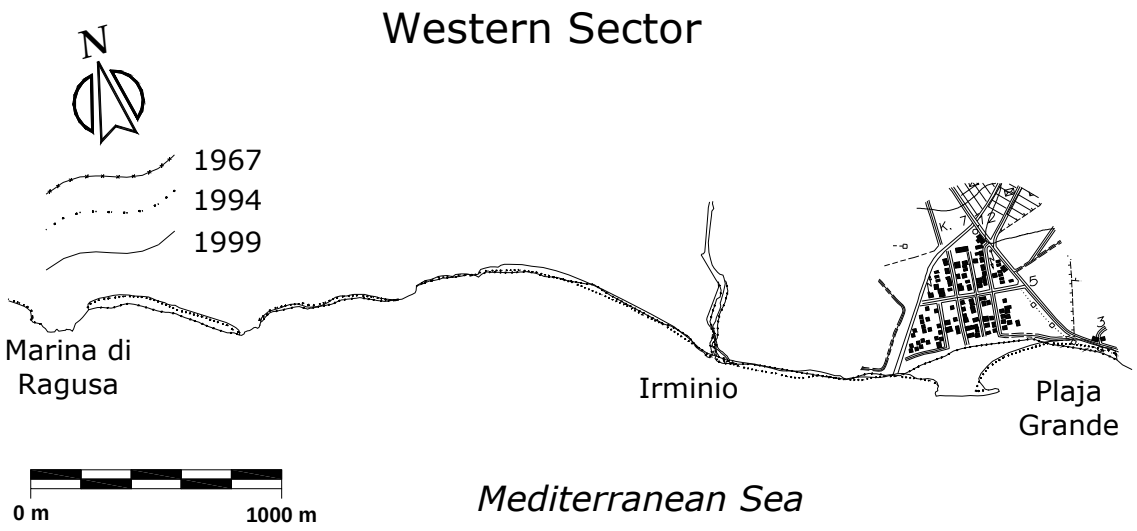

Fig. 4 : : Western sector.

The advancing areas are at the extreme edges except for the area of Plaja Grande, where during the early 1970's a breakwater barrier was built, parallel to the shoreline. This construction led to the tombolization of the beach and to a local increase in area of about $5.1 \cdot 10^3$ m^2, therefore blocking the replenishment of the downdrift area which is seen to be suffering from erosion. From 1994 to 1999 the trend continued negative, with a loss of about $4.2 \cdot 10^3$ m^2 and some local advancement.

On the whole, the tendency between 1967 and 1999 must be considered in terms of withdrawal, with the greatest loss of surface area in the outlying sector at the far western rocky promontory. The causes for this phenomenon may be sought in the man-made interventions taking place between 1976 and 1981 with the building of the Santa Rosalia Dam, about 20 km from the Irminio river mouth, which acts as a trap for the larger components of the solid river load.

It is also important to underline that the mouth of the River Irminio has undergone a gradual change of direction, from N-S to NW-SE. These phenomena must be put down to a littoral drift prevalently oriented from West to East, transporting and accumulating along this stretch of beach the sandy materials resulting from the eroded stretches further west (Amore and Randazzo, 1997).

These major coastal erosion factors are also slightly aggravated by the diminishment of the meadows of *Posidonia Oceanica* and by the considerable drop in the quantity of solid load transported by the River Irminio. The former, no longer dissipating the aggression of the waves, have favoured the increase of erosive phenomena. The diminished quantity of solid load transported by the River Irminio, due to the use of the water upstream and to the indiscriminate removal of dissolved materials from the river-bed, has drastically reduced or completely eliminated the replenishing activity of the river, already deprived of most of its solid load by the Santa

Rosalia Dam. At present, already at some km from the river mouth, the River Irminio dries up. The flow of water re-emerges in fact a few km nearer the sea with an insufficient quantity of water and therefore capable of transporting only suspenden load.

Central sector

This part of the coastal area stretches from the Plaja Grande breakwater barrier to the beginning of Spinasanta beach, and is about 4.6 Km long (Fig. 6).

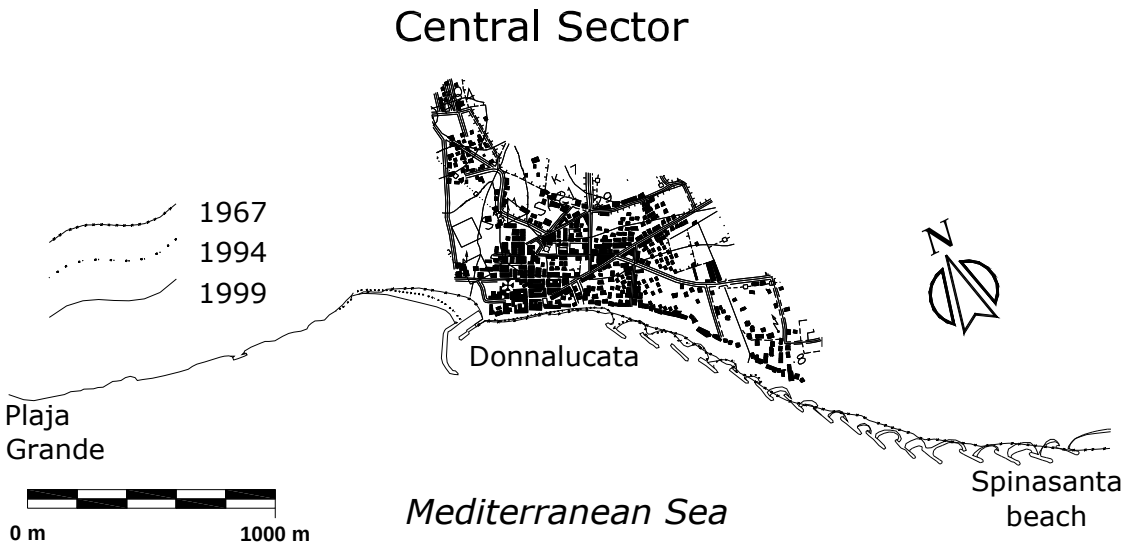

Fig. 5: Central sector

The evolution of the shoreline in this sector has been influenced to a great extent by the total anthropization of the entire coastal zone, and by the presence of the small harbour of Donnalucata.

The harbour was born as a small marina for local sea traffic but from the 1970's on has suffered considerable changes, notably the prolongation of both its quays. As a consequence of the protective measures adopted along the banks of the river Irminio, the eastern shore of Donnalucata has suffered a deep and uncontrollable process of erosion. This event led the local authorities to carry out a first protective measure in the early 1980's, in order to minimise the erosive action of the waves. To this purpose seven emerged breakwater barriers were placed in a pseudo-parallel direction with respect to the shoreline. The effect of these first barriers was to reduce the energy of the waves and therefore to permit the beach to regain its original dimensions. Nevertheless, the erosion continued in the immediate downdrift area, leading to the positioning of nine more breakwater barriers of the same type. These in their turn only moved the erosive process down to the adjacent area. The intervention led the emerged beach to advance, in fact a comparison between the shorelines in 1967 and 1994 shows a strong advancement corresponding to a total surface area of about $8.8 \cdot 10^3$ m^2, with the formation of classic tombolos corresponding to the protected areas of beach.

Over the same period of time (1967-1994) there was also an advancement in the western part of the western quay, equal to a surface area of about 13.5 $\bullet 10^3$ m^2, while the strip of coast immediately east of the eastern quay shows erosive tendency. The explanation of these processes can be put down to the positioning of the western quay of Donnalucata harbour, which has blocked the shoredrift current coming from the west. This process leads not only to the blocking of the shore drift but also to an increase in the reflection currents, resulting in the dispersion of solid load in the open sea.

In the period between 1994 and 1999 there was a further growth in accumulated material in the area west of the western quay of the harbour, which increased by a surface area of around $10.5 \bullet 10^3$ m^2, while the situation in the area protected by the barriers remained substantially the same. Therefore in the period of time between 1967 and 1999 the central sector presents an increase of $22.7 \bullet 10^3$ m^2 in the updrift area of the harbour, and an erosion in the downdrift area of about $4.2 \bullet 10^3$ m^2, while the building and positioning of the barriers led to a total increase of about $34.6 \bullet 10^3$ m^2.

Eastern Sector

The Eastern sector goes from Spinasanta beach, immediately beyond the last of the breakwater barriers, to Punta d'Aliga headland, along a beach long approximately 5.4 km (Fig. 6). Along this part of the coast there is the mouth of the Modica River which represents, in this sector, the most direct source of solid load transported to the sea.

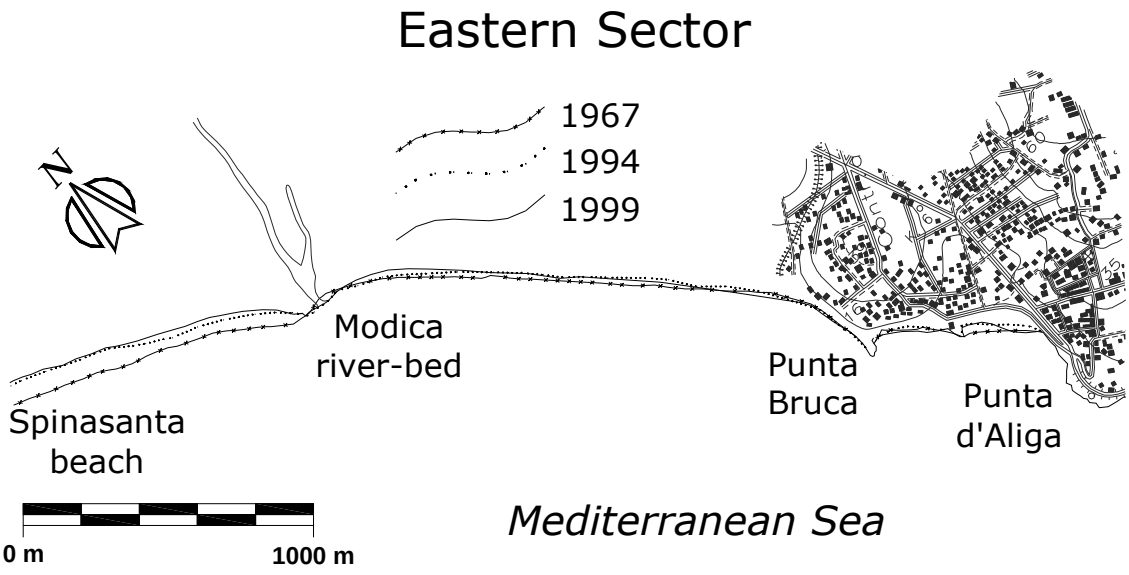

Fig. 6: Eastern sector.

The beach is seen to have increased in the central sector as a result of the breakwater barriers, a comparison between the coastlines in the two periods considered (1967-1994; 1994-1999) reveals for the adjacent stretch of coast (Spinasanta beach) an incipient reduction in the beach area equal to about 73.6 $\bullet 10^3$ m^2. In the part stretching from immediately beyond Spinasanta beach as far as Punta Bruca, there was a

withdrawal of the shoreline in the period between 1967 and 1994, leading to a deficit in terms of surface area of about 20.9 $\bullet 10^3$ m^2. From 1994 to 1999 the situation remained almost unvaried and with a slight tendency to advance. The stretch of beach immediately east of Punta Bruca proves to be in dynamic equilibrium, following a series of erosion and advancements over the period considered. Between 1967 and 1994 the beach of Punta d'Aliga must be considered in a condition of general erosion.

Suggestions for Shoreline Management

In formulating hypotheses for re-organizing and co-ordinating actions to protect the coastline, a variety of types of intervention have been defined. The common factor uniting them is the need for a low impact on the landscape and respect for the present environmental conditions.

Operating along these lines the following three types of intervention have been defined, (Fig. 8): beach nourishment, building of preventive and protective structures and transplantation of *Posidonia oceanica*.

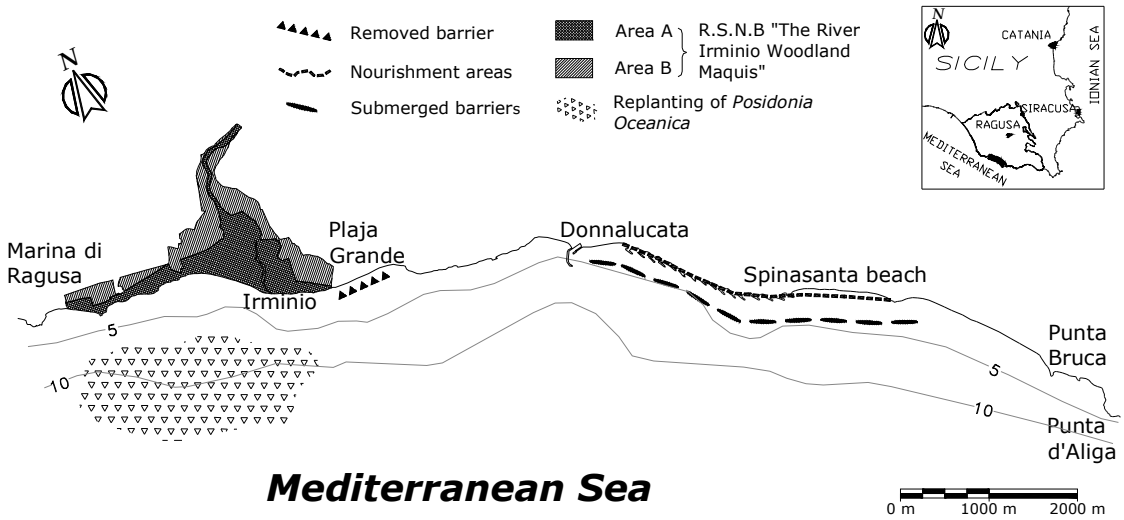

Fig. 6: Project of the recovery interventions on the littoral.

The types of intervention considered suitable for the recovery of the eroded beaches consist in the following: removal of the existing breakwater barriers (the results of which are quite apparent: tombolization of the stretch of protected beach and erosion of the adjacent stretches); and artificial replenishment of the beaches, kept in place by a system of transversal protective constructions such as short groynes and submerged parallel barriers placed at a suitable distance from the coastline, in accordance with the undametric regime of the area.

The use of detached parallel defence systems such as submerged barriers certainly proves to have a less negative effect than attached emerged breakwater barriers, if we consider that the main object of this type of intervention is to reduce the

energy of the waves breaking on the beach by placing the breaking-point further from the beach itself. By favouring the use of submerged barriers for the new protection measures in the eastern sector, and possibly later undertaking a policy for substituting the emerged barriers present in the central sector, it is probably a good idea to take into consideration replenishing the beaches with finer sands than those present along the shore, which would become stabilised as an effect of the mitigation of the waves by the submerged barriers.

The nourishment material could be obtained from the dredging processes connected with the activities to render Donnalucata harbour safer, already in act under the supervision of the Department for Civil Protection; alternatively, from rendering more mobile the sands coming from the Irminio river mouth.

If we consider the abnormal dimensions reached by the Plaja Grande beach, it might be possible in fact to consider removing the defence structures there to permit a greater circulation of sediments in the entire area.

In the sea bottoms in front of the R.S.N.B. "The River Irminio Macchia Foresta", there are meadows of Posidonia which in any case plays an important part in protecting the area beyond it by mitigating the impact of the waves on the shore. *Posidonia Oceanica* represents a real source of oxygen for the underwater environment and a place of refuge for an enormous number of organisms, today in a poor condition due to excessive human pressure.

A project to recover and protect the existing posidonia meadows, including a massive replanting campaign to consolidate the mobile sandy substrate, would be a solution perfectly in harmony with the natural environment and with the other re-naturalising interventions suggested; it would also increase the capacity of the shoreline to defend itself from the erosive action of the sea.

Conclusions

The present coastal landscape between Marina di Ragusa beach and Punta d'Aliga headland is the result of the interaction of a series of factors, both natural and man-made, which have in some way affected the natural equilibrium of the coast.

The decrease in solid river load has led to a general shoreline recession, rendering interventions necessary in order to protect the beaches; these have been inadequately planned and over time have produced both positive and negative effects. In choosing new methods of intervention it has been deemed necessary to take into account the specific areas which, for their particular environmental interest, require the use of soft and eco-compatible measures.

According to the modern approach, the re-qualification of residential "waterfronts" is not a mere defence of the territory from erosion, but also a way to exploit what the coast has to offer in the correct way. The types of intervention suggested in the present study are characterised by their ability to combine an effective

defence and ecological recovery of the coast, resulting in advantages not only for the natural landscape but for tourism too.

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