—*In* : Transformations and evolution of the Mediterranean coastline —

Coastal defence by breakwaters and sea-level rise : the case of the Italian Northern Adriatic Sea

by

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ABSTRACT

The coast of the north-western Adriatic Sea, from Monfalcone to Cattolica, is low and sandy and is subject to natural and man-induced subsidence, in particular in the zones of Venice, Po River Delta, and Ravenna. The widespread erosion, caused or increased by human activities, has been fought first by structures transversal to the coast and soon afterwards by offshore breakwaters. These have however often produced adverse effects on the coastline and on the environmental quality. More recently the method of artificial nourishment, protected by submerged structures to limit sand loss, has been prefered. Sea-level changes induced by eustatism and subsidence will cause in the near future a shift in the shoreline which is estimated here on the basis of previsional numerical models.

RÉSUMÉ

Le littoral de la mer Adriatique nord-occidentale, depuis Monfalcone jusqu'à Cattolica, est bas et sableux, exposé à un affaissement naturel et anthropique, notamment dans la région de Venise, Delta du Pô, et de Ravenna. L'érosion provoquée – ou aggravée – par les activités humaines a d'abord été combattue par des barrages perpendiculaires à la côte, ensuite par des brise-lames parallèles à celle-ci, qui toutefois ont souvent entraîné des conséquences négatives. Récemment, on a préféré la reconstitution artificielle protégée par des structures immergées afin de limiter la perte de sable. Les changements du niveau de la mer provoqués par l'eustatisme et par la subsidence entraîneront un déplacement de la ligne côtière qui est estimé ici sur la base de modèles numériques prévisionnels.

INTRODUCTION

The majority of the world sandy beaches, which represent an important coastal resource and often vital estate for many local communities, are affected by a widespread erosion due to both natural and man-induced processes. Possible causes of erosion include the action of hydrodynamical factors (waves, tides and induced currents) and sediment loss due to human activities such as river management and sand and gravel mining. A variety of coastal protection structures have therefore been developed, including the construction of many breakwaters, as engineering countermeasures. Unfortunately there are many examples where these structures have produced adverse effects on the coastline. The beaches along the northwestern Adriatic coast (Figure 1) present a good example of natural evolution and of anthropic impact, managed with a wide typology of interventions which can well describe different situations. Moreover a remarkable subsidence characterizes the areas from Venice – Po River Delta – to Ravenna and Rimini, which complicates the definition of the defences and makes it urgent to forecast the future evolution of the littoral.

THE NORTHERN ADRIATIC SHORES

The shore of the Adriatic Sea between Monfalcone (Trieste) and south of Rimini (Conca River mouth) is low and sandy and shelters many of the most popular touristic resorts in Italy.

This coast, about 300 km long (Figure 1), borders the Italian widest alluvial plain made up by the Po River (Pianura Padana) and by other minor rivers flowing from the Alps (Isonzo, Tagliamento, Piave, Adige, Brenta) and from the Apennines (Reno, Savio, Marecchia, Conca). Along its strip there are many large beaches, river mouths with a deltaic apparatus, lagoons, salt marshes, beach ridges and barrier islands that enclose lagoons and reclaimed lands. A large belt of the coastal plain lies near or below sea level (about sixty per cent of the area) making the coastal weakness dramatic in many places.

The north Adriatic beaches were formed at the end of the last post-glacial marine transgression which culminated about 6000 yr B.P., when the sea reached its maximum level and the shoreline stopped about 5-20 km inland of the present coast (Figure 1). From that time the shore prograded and cuspate deltas were formed together with lagoons. The depositional model of the modern beaches, based on repeated barrier-lagoon systems, which characterized the last transgressive phases (COLANTONI *et al.*, 1992), is well documented by the sections across the coast shown in Figure 2, where we can also note that the modern coastal wedge is up to about 25 m thick.

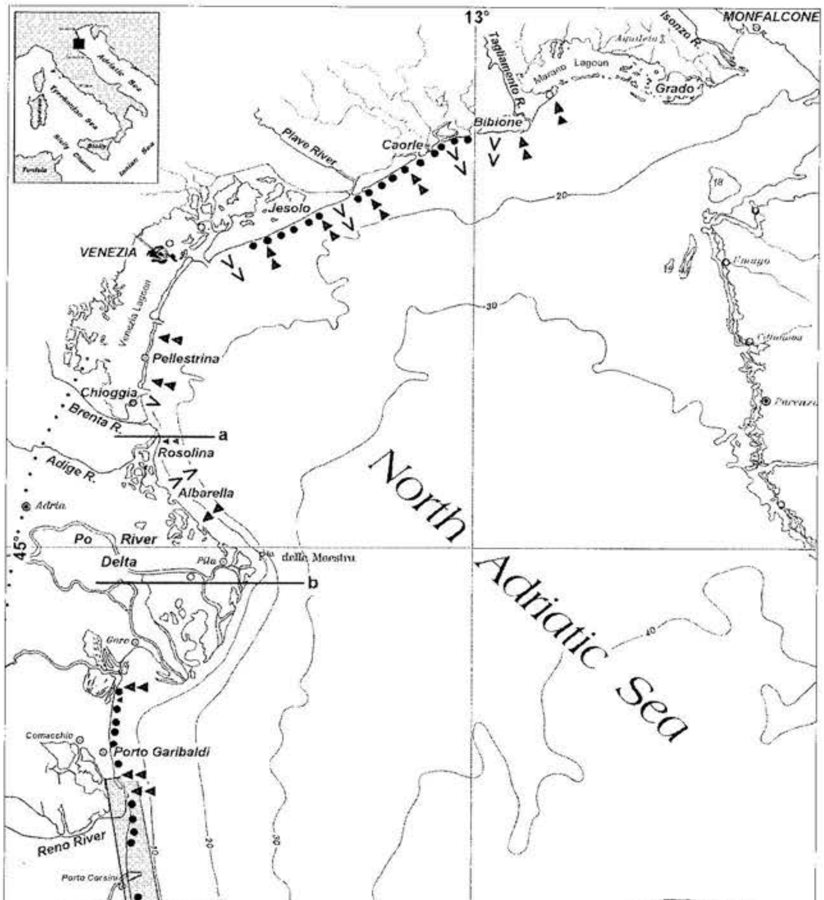


Figure 1 – General map of the northwestern Adriatic coasts.
Legend: 1) areas at elevations between about + 2m and 0; 2) highlands; 3) tendency of coast to advance; 4) tendency of coast to retreat; 5) existing coastal defence structures; 6) locations of the shoreline-normal profiles shown in Figure 2; 7) probable location of the Versilian coastline (about 6 ky B.P.); 8) area of the case studies discussed in this work.

Climatic events, accompanied by different sedimentary inputs, floods and river deviations, but especially human intervention, affected the recent evolution of the coasts. Management of the river basins, to regulate river flow and to reclaim land, began very early. Dykes were erected and rivers were deviated to prevent the silting in the lagoon of Venice since the Middle Age. In the 1950s human activity on the coasts drastically increased with the development of ports, industrial complexes and tourist facilities. Many

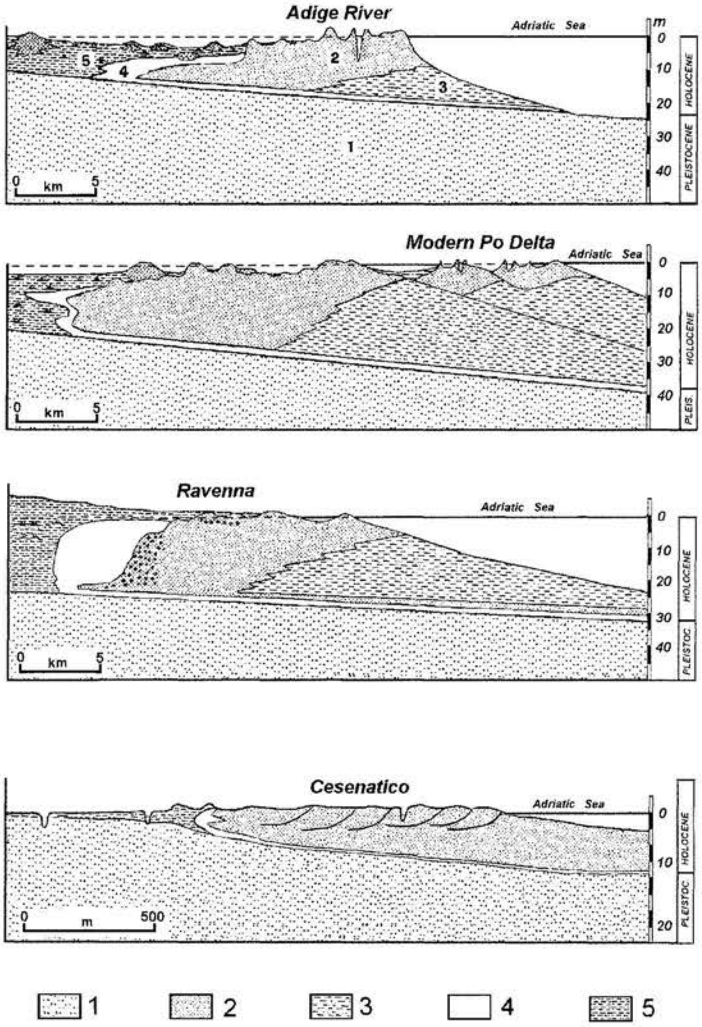


Figure 2 – Schematic geological cross-sections along the NW Adriatic coastal area (modified from COLANTONI and VEGGIANI, 1969; BONDESAN *et al.*, 1995). See Fig. 1 for the location. Legend: 1) Upper Pleistocene continental deposits (mainly sandy and silty facies); 2) Holocene coastal sand facies (mainly barrier-lagoon systems); 3) offshore marine clay and silt facies; 4) lagoonal clay and silt facies; 5) continental (mainly clay) facies.

of the interventions were negative for the environment and at present more than 40 per cent of the littoral suffer strong and diffuse erosion.

An integrated planning for the coastal area took place only in the last 1970s with the "Integrated Plan for Coastal Management" (Regione Emilia Romagna and Veneto). The plan identifies the principal cause of the erosional trend (reduction of fluvial transport, high rate of subsidence, coastal protection and its indirect effects) and introduces legislative tools and projects to reduce the impact of human activity (IDROSER, 1982, 1994).

COASTAL STRUCTURES

A great variety of coastal protection structures have been built along the Adriatic coasts (Figure 1). FRANCO (1985) revised the typology of about 700 rubble-mound detached breakwaters and derived their geometrical parameters. Typical length is about 100 m, gap width 30 m, water depth 3.5 m, distance from shoreline 100 m, crest width 4 m at 1 m above SWL, seaward slope 1:2 to 1:3, and shoreward slope 1:1 (PILARCZYK and ZEIDLER, 1996).

The beaches of the Veneto (between the mouth of the Tagliamento and the Po River Delta) comprise many very popular localities like Bibione, Caorle, Jesolo and Venice, and are intensively protected by a number of structures with only few exceptions (LIBERATORE *et al.*, 1991). At Caorle groins were built around 1950, when erosional effects become evident after the new tourist settlements. Further south, between Livenza and Piave, very massive concrete walls protected by groins were built at the end of the 1960s, following the extreme storm event and flooding of November 1966.

The barrier islands of the lagoon of Venice are protected against the sea by special seawalls called "murazzi" built from 1774 to 1886, while the long jetties set to stabilize the three inlets of the lagoon were built between 1840 and 1933. The *murazzi* of Pellestrina are still working while the *murazzi* at Chioggia are now completely covered by the sand deposited against the southern jetty of the inlet by the littoral drift.

The River Po Delta is undergoing extensive erosion but harbours only a small number of coastal structures to protect local tourist resorts: for example a few groins at Rosolina, artificial renourishments protected by submerged breackwater at Albarella and "Longard tube" together with groins at Cavallari Island.

On the littoral of the Emilia-Romagna region (from the Po River Delta to Cattolica), structures perpendicular to the shoreline were first built to retard erosion. But the construction of new jetties and the extension of the existing ones have trapped the littoral drift since the beginning of this century, favouring the extension of the beaches located south of Rimini, Cesenatico and Porto Garibaldi, and enhancing erosion northward (Figure 1). In the case of Rimini, for example, the beach south of the harbour in the years 1978-1993 has prograded at a rate of 2-4 cm/yr, while north of the harbour the coast suffered tremendous erosion.

To face these problems of erosion the first breakwaters parallel to the coast were built north of Rimini (Viserba) and north of Porto Garibaldi, where at present the beach is completely protected by offshore breakwaters and artificial nourishment obtained by dredged materials (IDROSER, 1994). The form of protection made up by shore-parallel breakwaters was continued for about 60 years and reached its maximum in the years 1960-1980.

At the end of the 1970s about 50 km of breakwaters protected the entire regional littoral which is 130 km long. In 1993 up to 78 km of the littoral was protected by structures comprising off-shore breakwaters (about 50 km), breakwaters or seawalls (9 km), and "Longard tube" protections (5 km). The other 14 km are involved in protected artificial nourishments (IDROSER, 1994).

While off-shore breakwaters defend the beaches by intercepting waves, they present certain disavantages. In fact the capacity of transport by the sea movements along the coast remains constant but, in the downdrift portion of a structure, the shortage of moving sediments intercepted updrift causes erosions. A reaction erosion-protection-erosion is therefore often established.

Moreover, because the water behind the offshore breakwaters often tend to stagnate, the chemical-physical characteristics of the sediments in the sheltered environment are greatly worsened. This is evident for bacteriological parameters as well as for organic matter, organic phosphorus and extractable phosphorus (CORREGIARI *et al.*, 1992) and heavy metals.

To better protect the environment and to counter-balance the lack of sand, the Plan for Coastal Management (Piano Coste, 1981) of the Emilia-Romagna region decided to stop the construction of other breakwaters and to concentrate all the efforts on the nourishment. Nine interventions were thus carried out in the years 1983-1993 to protect 14 km of littoral of the Ravenna and Forli provinces. Two millions m^3 of sand were discharged on the shore, shielded by submerged structures made up by sacks filled by sand to limit the loss of materials (Figure 3; IDROSER, 1994). This innovative and experimental technique has already given very positive results but is still closely monitored in order to improve the structural arrangement.

RECENT EXPERIENCES AND CASE STUDIES

At present a clear erosional trend is visible in several critical points such as the Ravenna coastal area. It is probably due to a sensible reduction of the solid fluvial input and to a remarkable natural subsidence rate on the increase since the 1950s. In fact since this period, both industrial and extractive activities have known a great development in the whole area. One notes in particular that fluvial cusps are progressively eroded by the action of wave motion and that the solid fluvial input is not enough for assuring the local sediment balance.

In response to the problems of marine flooding and accelerated coastal erosion, several works of coastal protection have been carried out in the last 20 years, with the aim of reducing wave energy on the coast and trapping the longshore transport, thus enhancing the deposition of beach materials and reducing shoreline retreat. This protection policy began in the early 1970s and still goes on. The main defensive interventions are the construction of emerged and submerged breakwaters, groins, artificial dunes and nourishments. In particular, sand dunes are an important protective structure because they can prevent the movement of storm tides and waves inland (Figure 3). The destabilization and the degradation of the dune system with a lot of passages constitute therefore a great risk for coastal flooding.

In the littoral area north of Ravenna, between the mouths of the Reno River and Lamone (Figure 4), since the 1960s erosional processes seem to

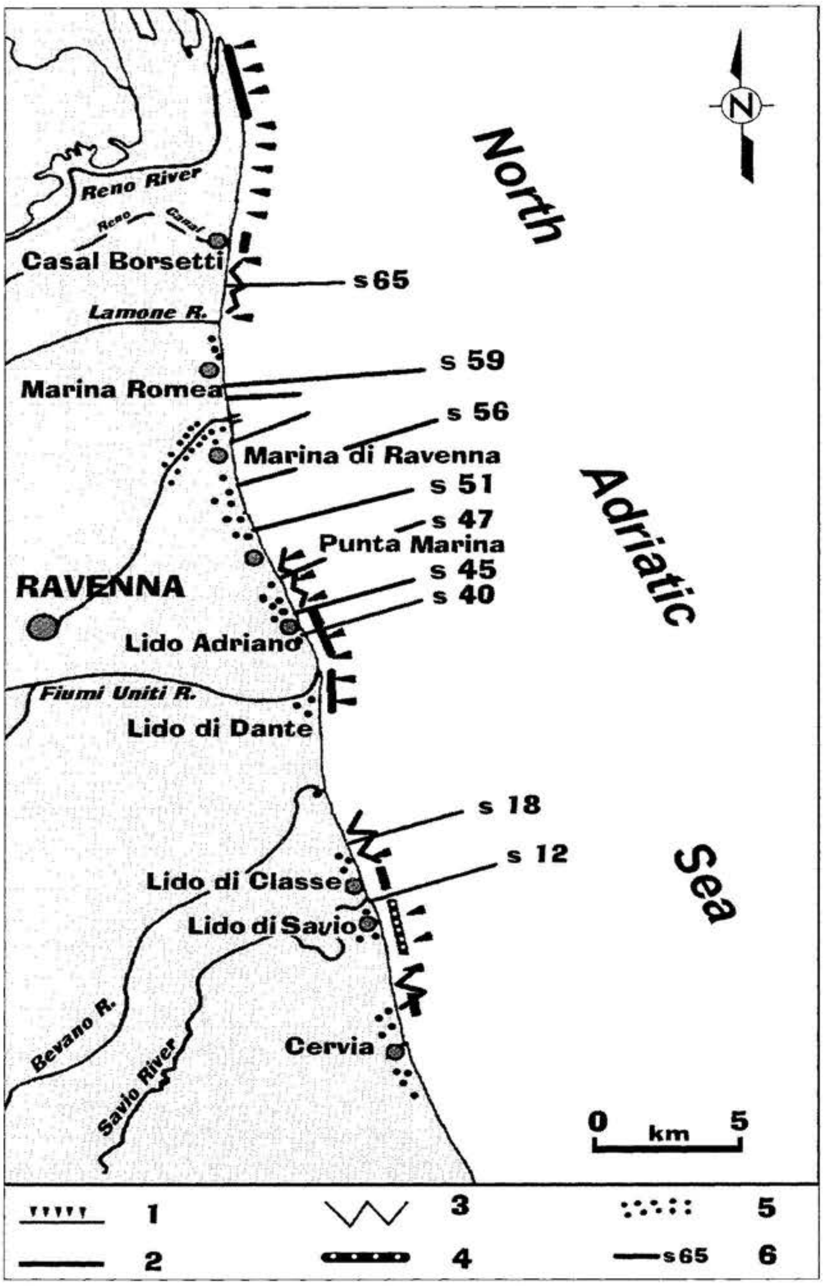


Figure 3 – Schematic map of the central and southern Emilia-Romagna coastal area.
Legend: 1) retreating coasts; 2) seawalls and breakwaters; 3) submerged defences associated with nourishments; 4) experimental semi-submerged breakwater; 5) areas liable to floods (mainly storm surges); 6) location of bathymetric and evolutive cross-section shown in Fig. 9.

increase with the progressive destruction of the Reno cusp (CIABATTI *et al.*, 1978; GABBIANELLI *et al.*, 1994). Now the shoreline is beside the pine-wood, and beaches are protected by seawalls that have the negative impact of increasing reflected wave energy and of accelerating the erosion on the seafloor (but erosion is due also to the greater longshore current induced). At present the fluvial input in this area is insufficient to counter the erosional trend and in the last years the southern zone of the site has been protected by breakwaters, groins and nourishment. Casal Borsetti is today protected and has reached an equilibrium state but at the southern and northern limits of the breakwaters there is a sharp erosional situation. Net deficit of materials in the whole area was about 45,000 m^3/yr between 1968 and 1978, and 27,500 m^3/yr between 1978 and 1984 (IDROSER, 1994).

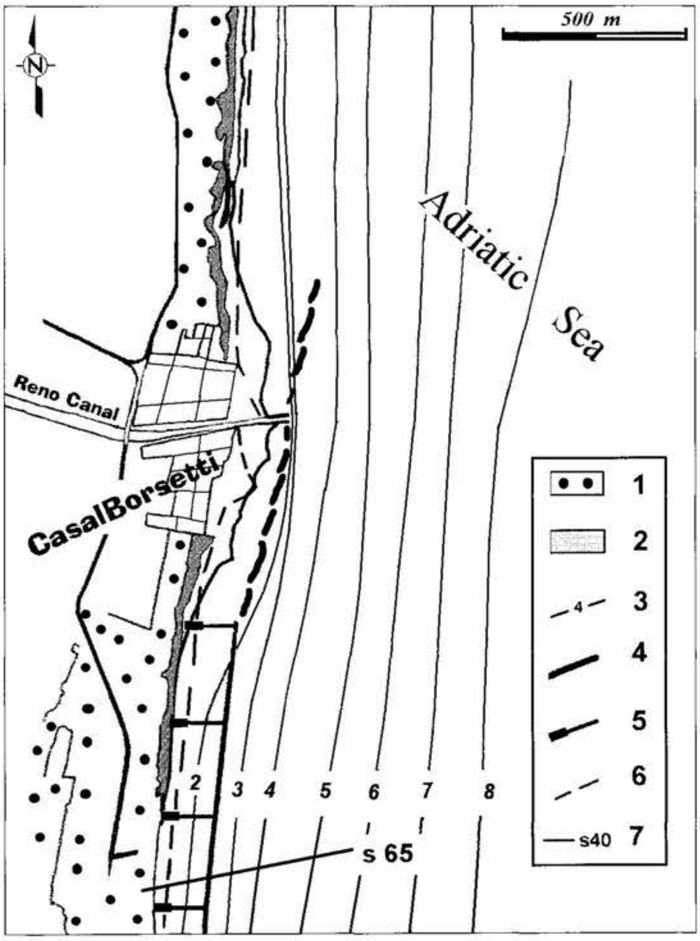


Figure 4 – Casal Borsetti area, 1994 situation.
Legend: 1) pine-wood; 2) dune area; 3) isobaths (1 m interval); 4) breakwaters and seawalls; 5) submerged coastal defence structures; 6) 1968's coastline; 7) location of bathymetric and evolutive cross-section shown in Fig. 9.

In recent years (1988-1991) the mode of protection consisted of a beach nourishment (about 230,000 m^3) protected by a seaward submerged breakwater made of sand-filled sacks and by a series of little groins landward: this, however, does not seem to be so efficient (IDROSER, 1994).

South of Ravenna, the littoral in front of Lido Adriano and Lido di Dante, including the mouth of Fiumi Uniti River (Figure 5), is particulary damaged because of a high subsidence rate and of high water energy. Even in this area the fluvial cusp is progressively dismantled, with a retreat rate of about 4 m/yr or more. Several flooding events occur at Lido di Dante, especially in winter. Lido Adriano is also particulary vulnerable to flooding because of both the lack of a protective dune system and the construction too near shore (about ten meters). The net loss of beach materials in the

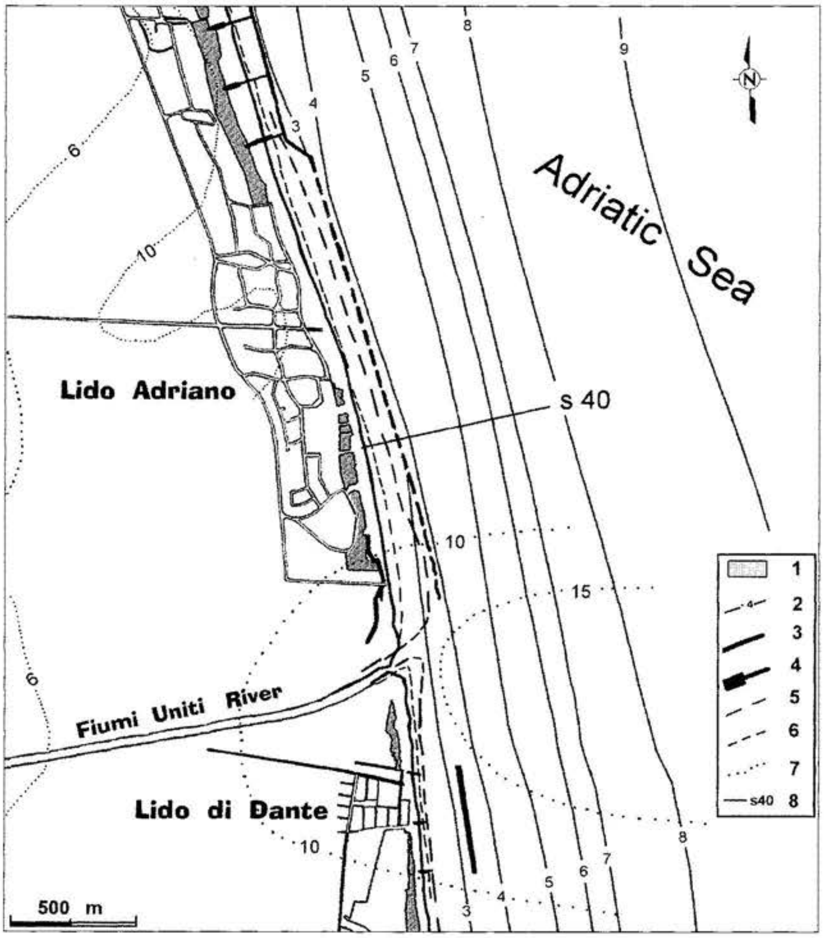


Figure 5 – Lido Adriano-Lido di Dante area, 1994 situation.
Legend: 1) dune area; 2) isobaths (1 m interval) ; 3) breakwaters and seawalls; 4) submerged coastal defence structures; 5) 1957's coastline; 6) 1968's coastline; 7) 1986-1992 subsidence rate in mm/yr; 8) location of bathymetric and evolutive cross-section shown in Figure 9.

period 1968-1978 is about 50,000 m^3/yr, with the biggest retreat values at the extremities of the breakwaters. At present in the area protection measures are experimented with nourishment and semi-submerged breakwaters.

The last critical area of the Ravenna littoral comprises Lido di Classe, the mouth of the Savio River and Lido di Savio (Figure 6). The rate of beach retreat at Lido di Savio is estimated at about 3 m/yr since the 1970's and it is increasing northward, where the fluvial cusp is progressively eroded (IDROSER, 1994). The protection consists of emerged breakwaters in front of Lido di Classe and Lido di Savio : behind the breakwaters a consistent gain of beach can be observed but also much erosion south of the Canale Cupa.

SUBSIDENCE AND SEA-LEVEL RISE

Part of the northern Adriatic Sea and the Po plain represent the foredeep of the Appennine chain. They are therefore characterized by natural subsidence aggravated in recent times by a man-induced sinking of the ground due to land reclamation and excessive water pumping. As a result much of the Venetian and Romagna coastal plain at present lies near or below the sea level. Natural subsidence in the lagoon of Venice has averaged about 1.0-1.5 mm/yr for the last 6000 years (FONTES and BERTOLAMI, 1972), but the ground lowering since the 1900s is thought to be of 3 cm (GATTO, 1984). In the Po delta area the subsidence reached 20-30 cm in 50 years and more than 40 cm since 1902 in Ravenna (CARBOGNIN *et al.*, 1984).

According to BONDESAN *et al.* (1986), land reclamation in the Po Delta area produced sinking of 1-2 m in the newly drained terrains gained over former lagoons and marshes. The worst effects were induced in the years between 1950 and 1970 by excessive water extraction, in particular in the areas of Venice and Ravenna.

In the Venice area the exploitation of ground water began in the years 1930s and greatly increased in the early 1950s. Between 1952-1968 accurate measures showed a subsidence of 6.5 mm/yr at Mestre and 5 mm/yr in Venice, with extreme values of 17 mm and 13 mm registered respectively in the years 1968 and 1969. The decrease of the ground water pumping in the early 1970s led to a reduction of the subsidence rate : a stabilization of the subsidence is thus predicted at the rate of 3 mm/yr until the year 2000 (GATTO and CARBOGNIN, 1981).

Until the 1950s the natural subsidence of the Po Delta was balanced by sedimentation, but the river input became insufficient because of the subsidence induced by the exploitation of gas-bearing waters which increased dramatically in the 1950s and early 1960s. Indeed subsidence rate was estimated to be less than 1 cm/yr until 1950 and it increased up to 25-30 cm/yr afterwards. The exploitation of the methane-bearing waters stopped in the entire delta region in 1965 but in 1982 the subsidence rate was still as high as 2 cm/yr (SESTINI, 1996).

In the Ravenna area historical tide-gauge data and geodetic survey, systematically carried out along the coastal zone by the Ravenna Municipality (COMUNE DI RAVENNA, 1996), show a marked increase in subsidence after 1950, with a peak above 4-5 cm/yr during the 1970s (Figure 7c). Between 1986 and 1992, following the absolute prohibition of taking water from the underground, the subsidence rate was reduced to about 6-10 mm/yr and it is possible that a subsidence rate very close to the natural one be achieved in the near future (COMUNE DI RAVENNA, 1994; BONDESAN *et al.*, 1995; IDROSER, 1994). Today still, in certain areas such as Lido Adriano and the Reno River mouth, observed rates exceed 1 cm/yr. These values are probably connected to a heavy methane extraction from land and offshore reservoirs, that could be reduced with difficulty in the next years (GAMBOLATI *et al.*, 1995; BERTONI *et al.*, 1995).

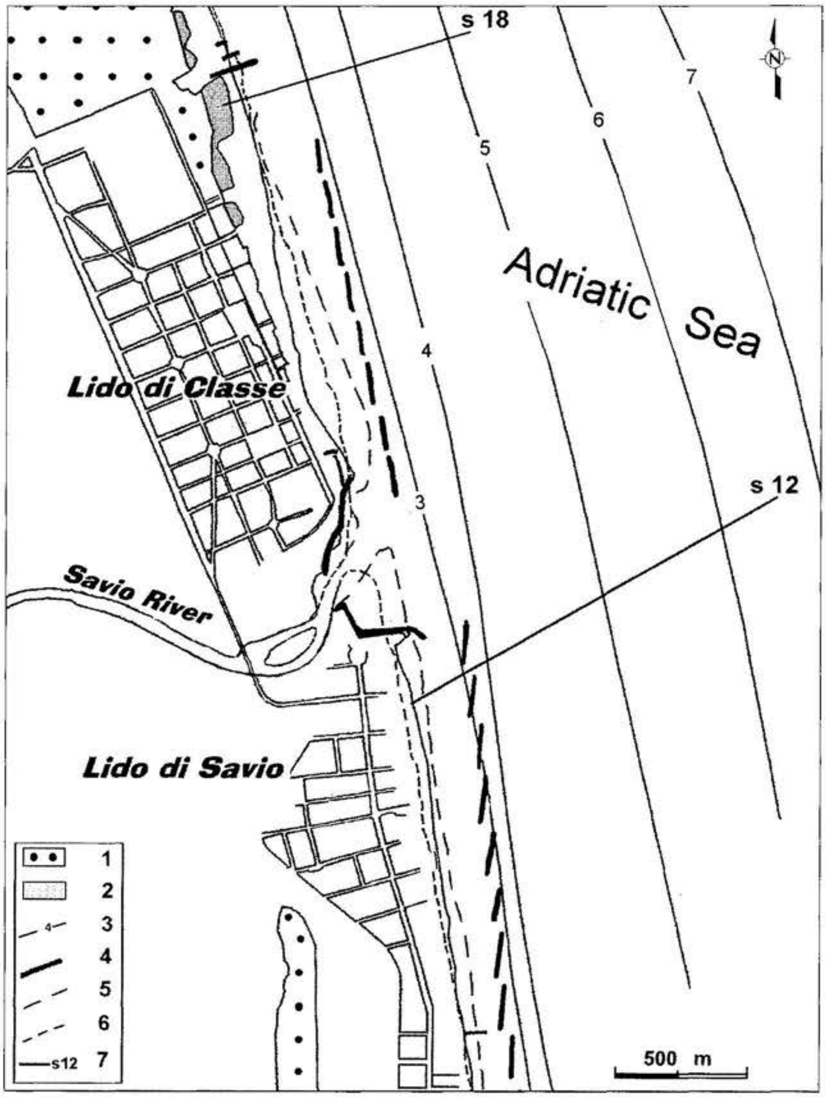
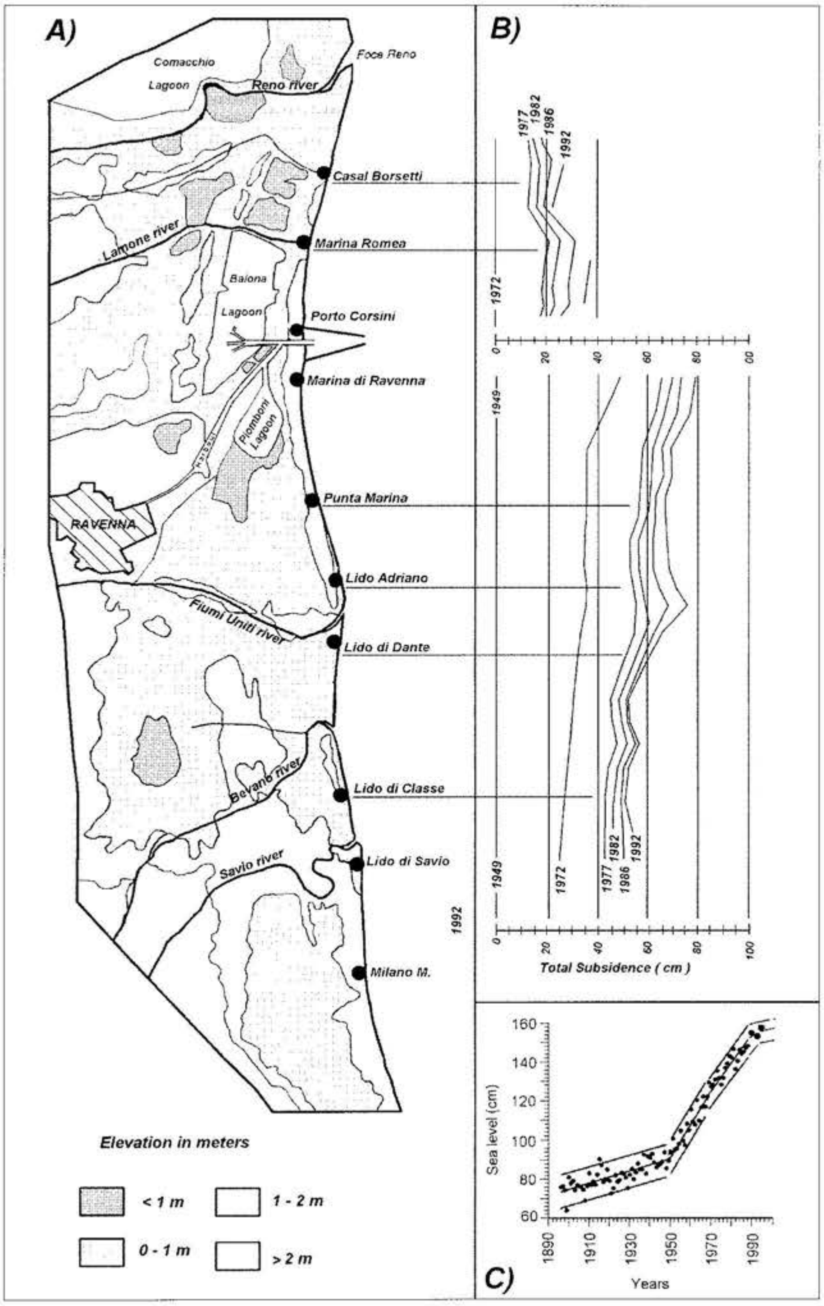


Figure 6 – Lido di Classe -Lido di Savio area, 1994 situation.
Legend: 1) pine-wood; 2) dune area; 3) isobaths (1 m interval); 4) breakwaters and seawalls; 5) 1957's coastline; 6) 1968's coastline; 7) location of bathymetric and evolutive cross-section.



Fgure 7 – Schematic altimetric map (A) and total subsidence rate (B) of the Ravenna's coastal area. The sharp increase in subsidence after 1950's is evidenced by historical tide-gauge measures (C) achieved at Porto Corsini.

BEACH RETREAT AND SHORE PROFILE EVOLUTION

Generally speaking a rise in sea level, together with an insufficient depositional rate, brings about a retreat of the shore line, *i.e.* a marine ingression on the previously emerged land.

A first approach to the evaluation of shoreline displacement due to a given sea-level elevation can be obtained following the method introduced by BRUUN (1962) and BRUUN and SCHWARTZ (1985). This model considers a shore-normal beach profile in dynamic equilibrium in which transport of sediments through the upper border (the line of the dunes) and the end of the profile at a limiting depth is insignificant: in case of sea-level rise sediments eroded from the upper beach are deposited on the bottom of the foreshore, building up the seafloor in equivalent amounts. The model does not take into account long-shore transport (Figure 8).

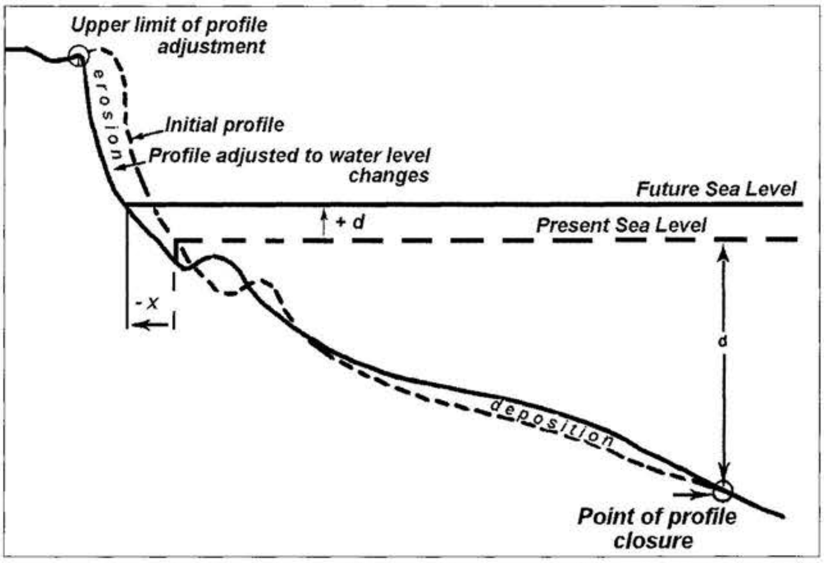


Figure 8 – Theoretical shore adjustment to a variation in sea level (from LEATHERMAN, 1990; modified).

By introducing in his model data on the erosion of the coastal dunes, EDELMAN (1970) eliminated certain shortcomings of BRUUN's model. Another method to evaluate coastal retreat was recently proposed by STEVE and VRIEND (1995), based on the important assumption that the upper shoreface is more active than the lower one and responds on much smaller time scale to forcing.

As an example of coastal planning, these numerical models have been applied to certain profiles of the Ravenna area, trying to estimate possible scenarios for the years 2025 and 2100. While the response pattern of a depositional coast to sea-level variations requires a specific modification of the theoretical models, these general models should be regarded as the mean to estimate an order of magnitude of shoreline retreat or advance (LEATHERMAN, 1990; HEALY, 1991; KAPLIN and SELIVANOV, 1995). For sea-level rise we applied the intermediate "Intergovernmental Panel on Climatic Change" projections (IPCC, 1995) with expected values of 10 cm for the year 2025 and of 49 cm for 2100. For subsidence we projected for the future the same rate as monitored by the Comune di Ravenna in the interval 1986-1992.

Our digital terrain model produced an elevation analysis revised up to the year 1992 (Figure 7). The elevation analysis underlines that in 1992 more than 34 % of the entire coastal area of Ravenna already lied near the sea level (from – 50 to + 50 cm); the highest places (about + 1 to + 2 m) are found along the coast in correspondence with narrow vegetated sandy dunes, where they represent the only defence from floods and storm surges. From the combined actions of erosion, subsidence and sea-level rise, these defences are destined to sink and progressively lose their efficiency. In the worst case, in fact, by the year 2100 their height would be no more than about 50 cm with a consequent general flooding of the entire area. Another bad consequence of sea-level rise and subsidence is the possible infiltration of salt water in coastal aquifers.

The shore line displacements calculated by the different models (BRUUN and SCHWARTZ, 1985; EDELMAN, 1970; STEVE and VRIEND, 1995) are schematically shown in Tables I and II. For the location of the profiles the reader is referred to Figure 3. As we can see, only retreats have been obtained and the results from the different models are generally comparable. While the numerical models applied were defined for stable littorals and should be applied only to coasts of such a kind, in our situation of general instability they can provide at least a general estimate of the effects.

TABLE I

Possible shoreline retreat (meters) for the 2025 scenario, considering a sea-level rise of +10 cm and a 1986-92 subsidence rate locally evaluated (Fig. 7).

Site	Bruun and Schwartz	Edelman	Stive and Vriend
Lido di Classe (s12)	19	20	19
Lido Adriano (s40)	20	21	25
Lido Adriano (s45)	21	22	31
Punta Marina (s47)	21	22	23
Punta Marina (s51)	17	18	21
Marina di Ravenna (s56)	32	32	39
Porto Corsini (s59)	34	35	40
Casal Borsetti (s65)	24	24	30

TABLE II

Possible shoreline retreat (meters) for the 2100 scenario, considering a sea-level rise of + 49 cm and a 1986-92 subsidence rate locally evaluated (Fig. 7).

Site	Bruun and Schwartz	Edelman	Stive and Vriend
Lido di Classe (s12)	83	98	82
Lido Adriano (s40)	82	105	101
Lido Adriano (s45)	88	104	128
Punta Marina (s47)	87	107	98
Punta Marina (s51)	73	84	91
Marina di Ravenna (s56)	134	147	166
Porto Corsini (s59)	142	171	168
Casal Borsetti (s65)	99	116	124

The prevision of the new beach profile related to a supposed shoreline displacement was computed according to BODGE (1992). He refers the shore normal profiles to an exponential shape of the shore with an initial slope that gradually decreases toward off-shore, down to the limiting depth, that in the area is about 4-6 m.

Actually many low sandy coasts in the Ravenna area show a weak upward concavity and a fairly regular slope that often can be approximated to a numerical expression. Nevertheless in many places the general regularity is broken by sandy bars and other sedimentary structures. In this case, the difficulties grow up and the results of the numerical simulations become more approximate.

Some examples of the results achieved on the basis of bathymetric profiles obtained by the Comune di Ravenna during the 1993 special survey are shown in Figure 9.

In particular, profile s12 (Lido di Savio, Figures 3 and 6) points out characters of stability for the sea-level rise probably due to the protective effect of the breakwaters. The same can be said for profile s40 (Lido Adriano, Figures 3 and 5) where breakwaters protect highly eroded beaches. Profile s18 (Lido di Classe, Figures 3 and 6) shows stability probably because of the great dimensions of the dune, one of the last existing in the area, which limits the retreat. Profile s47 (Punta Marina, Figure 3) seems to offer no resistance to the sea-level rise despite the presence of underwater protection

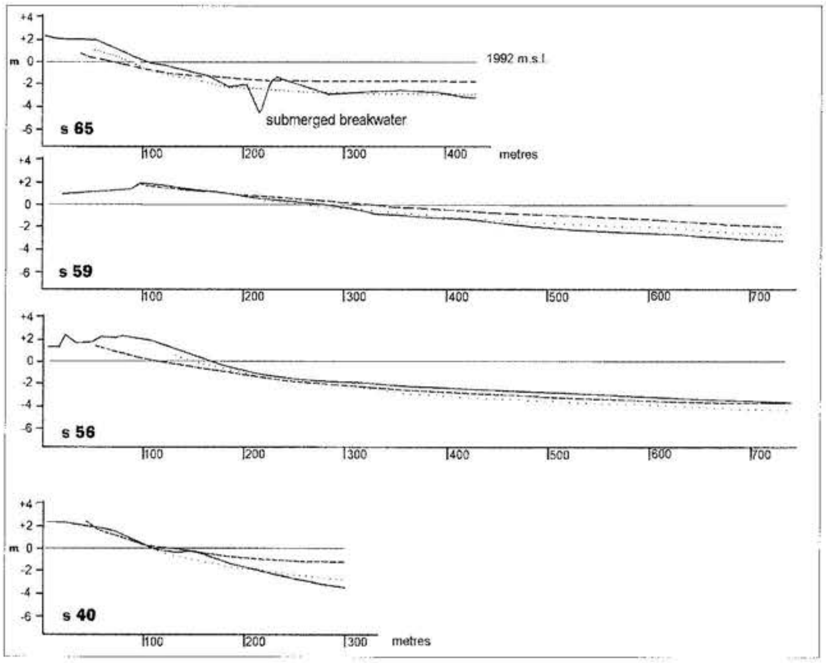


Figure 9 – Representative 1993 shoreface profiles (solid curves) in the Ravenna area and possible future evolution in 2025 (dotted curves) and 2100 (dashed curves). See Fig. 3 for the location of single profiles.

structures likely because their function would be reduced or made vain by the increased water depth. Profile s56 (south of the harbour of Porto Corsini, Figure 3) evidences a good stability for this part of the littoral due to the width of the backshore. Here the greatest values of shoreline retreat are expected, but the block of the littoral drift induced by the jetties seems to assure a good stability to the foreseen events. Profile s65 (Casal Borsetti, Figures 3 and 4), at present protected by submerged structures, could resist the elevation in sea level, only with reinforced coastal protection structures similar to those existing. These are only examples.

CONCLUSIONS

The NW Adriatic coasts have undergone widespread erosion that rapidly increased in the last decades. The causes of this instability are numerous: among them the decrease in sediment supply brought to the sea by rivers seems to be the most important. Adverse human impact is also due to the exploitation of sand and gravel from beaches and dunes and to the building of houses, roads and railways too close to the seashore.

Engineering measures of shore protection comprise offshore breakwaters and a few groins and seawalls. Offshore breakwaters have often triggered processes of "protection-erosion-protection-erosion", causing more damage than benefit. Moreover long jetties to protect inlets and harbours have generally interrupted the active littoral drift, causing sediment deposit updrift and strong erosions of the downdrift beaches. An urgent need is to introduce the possibility of bypassing these structures to restore the shore equilibrium and to avoid the construction of new breakwaters parallel to the coast.

Artificial nourishment of the beach is not yet widely practiced but it is utilized often with complementary submerged structures to limit the sediment loss and protect the sediment fill. This practice needs nevertheless a better understanding of the active processes, before broader application.

A major concern about the vulnerability of the coasts is related to the subsidence of the area which, even after the interruption of river bed mining and gas and water exploitation, is still effective. This phenomenon enhances the legitimate worries surrounding the expected sea-level rise in the next years. All projects for the near future have in fact to consider the expected rate of shoreline displacement, for which we have tried to produce some estimates.

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