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REGIONE
LAZIO

Guidelines for environmental studies related to the construction of coastal defence works

105 bis/2014

MANUALI E LINEE GUIDA

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INTRODUCTION

The Mediterranean coastal zone is characterized by landscapes of outstanding natural value and by a large number of particularly important habitats in terms of biodiversity and functional complexity, but, at the same time, they are sensitive and vulnerable environments. The coast also concentrates many important economic activities such as ports, industries, tourism facilities and infrastructures. Being by definition the land-sea interface, the coast is one of the most critical zones, subject to environmental degradation due to both the concentration of conflicting interests and the typical vulnerability of transitional environments. This vulnerability is increased by erosion, currently affecting 15% of European coasts, i.e. about 15,000 km on a total of 101,000 km of coasts (Eurosion, 2004; Southerland, 2010).

The problems associated with the increasingly rapid and intense coastal erosion, have raised the attention on shoreline protection not only in terms of preserving economic and social resources, but also in terms of protecting and preserving biodiversity and ecological resources, in accordance with the integrated management criteria (ICZM). In fact, although necessary to preserve and protect beaches, buildings and infrastructures from erosion, it is recognised that coastal defence works induce environmental changes that can have significant impacts, especially in the presence of sensitive habitats and/or species. Therefore, during the planning and construction of a coastal defence work, it is necessary to take into account not only its effectiveness in combating erosion, but also the effects that it may produce in the emerged and submerged environments.

This volume presents the "*Guidelines for environmental studies related to the construction of coastal defence works*". They propose a matrix-system which allows to identify *a priori* the potential environmental impacts of coastal defence works as well as the protected habitats and flora and fauna species that could be affected by these impacts. Indeed, coastal defences can produce different types of impacts on the habitats and species involved. The evaluation of these impacts is sometimes extremely difficult, both for the inherent complexity of coastal environments and for the strictly local scale to which the studies generally refer.
Therefore, these guidelines represent an effective tool to support existing legislation on E.I.A. and are thus helpful to both public administrations involved in the assessment of environmental impact studies and technicians involved in their development and drafting.

The methodological approach for the guidelines was developed and shared within the European project Coastance "*Regional action strategies for coastal zone adaptation to climate change*", Component 5, whose coordinator was the Lazio Region (www.coastance.eu). The guidelines were adopted with a formal act by the Regional Area for EIA & SEA of the Lazio Region (regional determination no. A01160 of 20.02.2013).

The matrix-system was developed on a bibliographic non-experimental basis, through the following steps:

- analysis of main types of coastal defence works and description of their main physical effects;
- analysis of possible environmental effects/impacts produced by coastal defence works;
- identification of habitat types *sensu* Habitats Directive and their classification into physiographic categories;
- definition of criteria to associate the protected flora and fauna species with the physiographic categories.

The matrix-system, named “structure/impact *vs* habitat/species”, puts in relation:

- each defence work with the potential effects and impacts on the environment;
- each type of effect/impact with one or more specific physiographic categories potentially involved;
- each type of impact, for each physiographic category, with the protected habitat types and flora and fauna species potentially involved.

Finally, it is important to underline that the matrix-system, although providing a list of the main expected effects and potential impacts on habitats and species, does not quantify their extent. In fact the quantification of impacts requires a thorough understanding of the technical and design aspects of the defence work and of the intervention area’s characteristics, such as morphodynamics and conservation status of habitats and species.

1. COASTAL DEFENCE WORKS AND MAIN PHYSICAL EFFECTS ON THE ENVIRONMENT

Coastal defence works aim to restrain or reduce erosion and to prevent its indirect effects such as flooding, salt-wedge intrusion and, more generally, habitat loss (Nicholls and Laetherman, 1994; Nicholls *et al*., 2009; Bulleri and Chapman, 2010; Dugan *et al*., 2011). Defence works are commonly classified into "active" measures, that alter both hydrodynamics (circulation patterns and wave action) and sediment transport, and "passive" measures that do not substantially modify the littoral transport system.

The most common types of coastal defences adopted in the Mediterranean Sea are:

- alongshore hard structures: revetments, shore-connected breakwaters, seawalls, bulkheads, sea dikes and embankments;
- alongshore soft defence: beach fill;
- detached breakwaters: partially emerged or totally submerged breakwaters, island-platforms and artificial reefs;
- cross-shore structures: groynes and headlands;
- beach nourishment;
- by-pass systems;
- beach drainage systems;
- coastal dune management interventions (dune reprofiling, windbreaks, dune grass planting and access management).

Below it is provided a brief overview of the above mentioned coastal defences, as well as of the main physical effects associated with the changes induced by their construction on the natural coastal dynamics(1), mainly referring to U.S. Army Corps of Engineers (2003a) and Van Rijn (2005).

1.1 Alongshore structures

Alongshore structures (**figure 1.1.1**) are passive defence works usually built by positioning hard structures on shorelines exposed to the wave attack. They are constructed on the emerged zone (parallel and connected to the coastline) and may extend to the backshore, reaching the toe of the dune (if present). Alongshore structures include natural and artificial coastal armouring such as: rubble-mound structures, riprap or stair-step revetments, retaining walls, bulkheads and/or sheet pilings and seawalls (APAT, 2007).
These defences are often built under emergency conditions, to protect coasts and infrastructures from erosion or wave attack, for their effectiveness in both reducing the shoreline movement under mechanical wave action and preventing floods caused by storm surges.
The coastal armouring results in a reduction of the wave run-up and overtopping, by increasing wave reflection and wave energy, but at the same time it may alter local depositional and erosional events, both seaward of the structure and in the up- and downstream beach.
In general, coastal erosion in long-shore directions occurs when the landward portion of the protected beach leads to a sediment loss from the coastal dynamics and, hence, to a significant reduction of the sediment supply downdrift. Moreover, changes can occur in the emerged and submerged beach profile. In particular, the reflection of waves impacting on the structure generally causes an increase of current intensities that leads to the scouring action at the toe of the structure and thus to the transport of re-suspended sediments seaward. In this case, the incoming wave height (and thus wave energy) increases proportionally with the excavation induced by the scouring action (Wallingford *et al*., 2000; APAT, 2007). Therefore, for particularly high-energy events (e.g. storm events), suspended sediments will be transported seaward from the active zone (depth of closure)(2) and definitively subtracted from

(1) The analysis of changes induced on coastal evolution trend is important to identify the areas potentially impacted by coastal defences. The spatial scale to which possible environmental changes can be referred, is generally defined on the basis of the defence size and of intervention area's physical parameters such as: morphology and sedimentology, exposure to marine conditions, sediment balance, etc. (Van Rijn, 2005; Stive *et al*., 2002).
(2) The extension of the active zone (i.e. depth of closure) strongly affects the evolution of coastal systems. It is commonly estimated by the Hallermeir formulation and it is defined as the depth beyond which sediment transport can be considered negligible, thus not significant

the sediment balance, with consequences on sediment dynamics between the emerged and submerged beach (Wallingford *et al*., 2000). Moreover, especially when waves propagate not-perpendicularly to the shoreline, changes in the extension of the up- and downstream emerged beach can be induced. (Pranzini, 2004).
Alongshore structures, partially or completely covering the backshore (up to the toe of dune, if present), can also harden the transition coastal zone and consequently prevent the natural sediment exchange between the emerged and submerged beach (Wallingford *et al*., 2000).

The main expected physical effects of alongshore structures are:
- absence of formation of a new sandy shore landward of the structure;
- local erosional and depositional processes due to coastal armouring that can alter currents and long-shore sediment transport;
- erosion due to local scouring action, that may gradually affect the sediment balance of the downstream beach;
- beach and dune habitat loss (Pranzini, 2004).

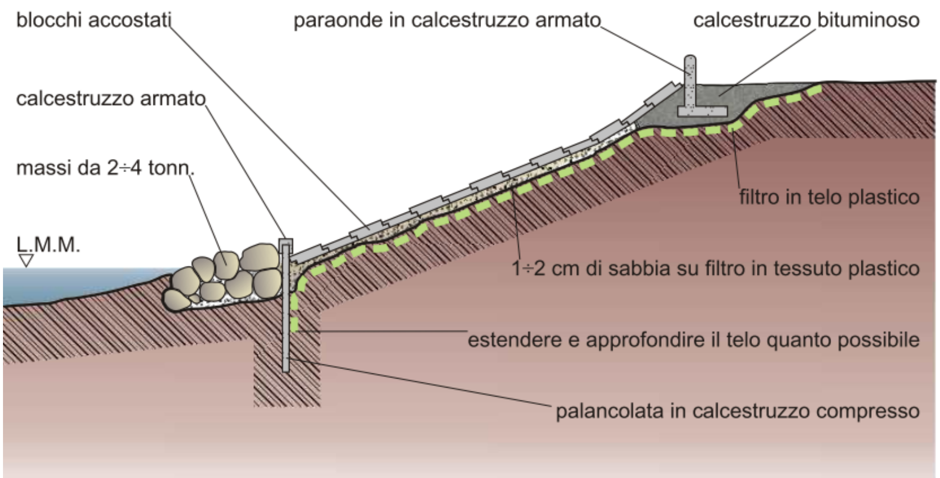


***Figure 1.1.1** – Scheme of an alongshore structure for low coasts with mild wave action. The armour is made of concrete slabs mutually interlocked and resting on a base provided with a filter, of a protection at the base and of a breakwater at the top (APAT, 2007).*

Below a description of the main types of alongshore structures (revetments, riprap, shore-connected breakwaters, seawalls, dykes and embankments) is provided.

Revetments

Revetments are generally used to protect cliffs when the natural beach and the dunes have a too limited extension, and to mitigate flooding effects in areas subject to significant tidal range. They are mostly made of impermeable materials (concrete, mortars, bitumens etc) and of permeable materials (stones, large sharp-edged or rounded boulders, riprap, gabions, articulated concrete blocks or tetrapods, geotextiles) which are placed on the cliff surface either in a definite structural design or simply piled up to a sufficient height. The wave run-up can be reduced by using a steeper or curved shape on the upper part (crest) of the structure (**figure 1.1.2**). In general, revetments have a limited extension with respect to the shoreline to be protected, but they are also built with larger structural footprints on gradual slopes. In the latter case, wave energy dissipation is encouraged through refraction, reflection and breaking of waves impacting the structure. This happens especially for beaches with low slope profiles. The effectiveness of revetments also depends on the building materials that affect their capability to dissipate wave energy and to retain fine sediments within the structure (in particular if it is rough or porous).

changes occur in the beach profile during a typical period of time (Hallermeier, 1981). This is considered a very important parameter for the study of short- and long-term beach evolution (Larson *et al*., 1999; Phillips and Williams, 2007).

Shore-connected breakwaters

Shore connected breakwaters are placed on the emerged beach, parallel to the shoreline. They are built with natural boulders (riprap) or artificial blocks arranged so as to interlock, or simply piled up in a more or less orderly way (**figure 1.1.3**). These structures can be defined as “flexible” because the movement of the hard boulders or concrete blocks can occur on the external surface without affecting their overall stability. They are also considered as “permeable” structures, since they allow wave energy to decrease by dissipation and to radiate by reflection of waves. However, even if wave reflection is reduced, the scouring action at the toe of the structure is only slowed.

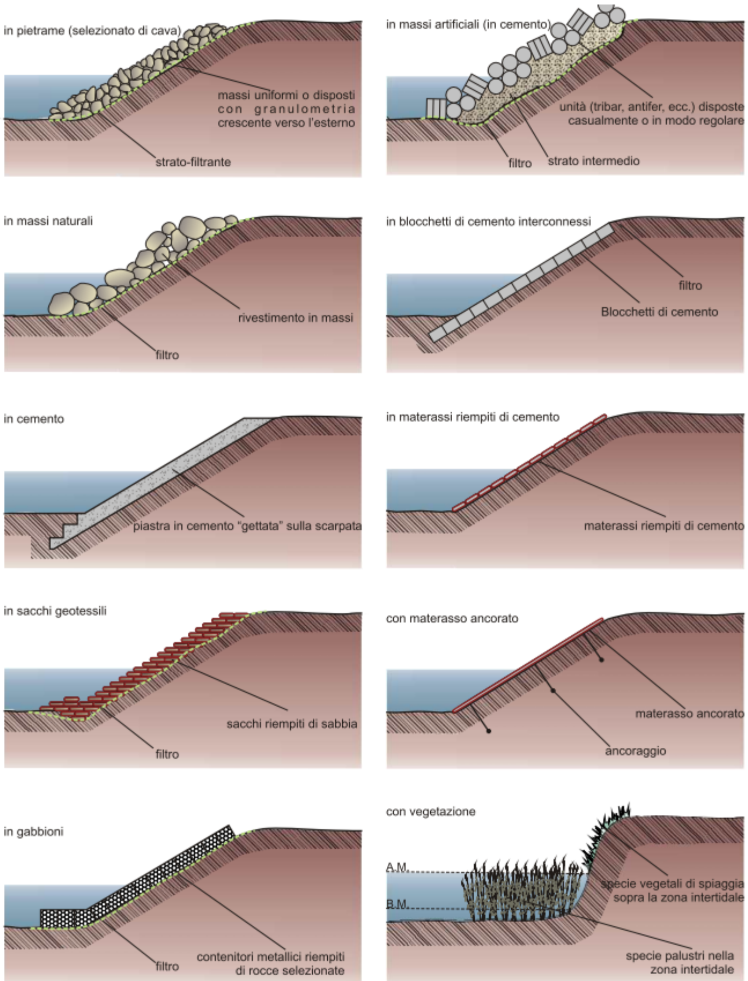


***Figure 1.1.2** - Revetment types (APAT, 2007).*

***Figure 1.1.3** – Some examples of riprap breakwaters: to the left, for a urban settlement protection (Photo by ISPRA); to the right, for a shoreline protection (APAT, 2007).*

Seawalls
Seawalls are mostly vertical or steeply curved solid structures, built parallel to the shoreline as a reinforcement of a part of the coastal profile, to protect roads and buildings at the edge of the natural beach (**figure 1.1.4**). They are mostly used to protect steep coastline and can be constructed in a variety of forms (stepped, curved, vertical etc.), and materials (generally timber, concrete, or tightly interlocked stones etc.). The structure stability with respect to sliding is provided by its own weight. Seawalls can be covered with natural or artificial elements to limit wave run-up (**figure 1.1.4**), which can be reduced also with a vertical or curved structure placed on their crest. Seawalls protect backshore from direct action of waves, but an increase in waves reflection generally produce a greater steepness of the submerged beach profile. Wave energy dissipation is a function of the revetment material, in particular quarry-stone is a good energy dissipater.

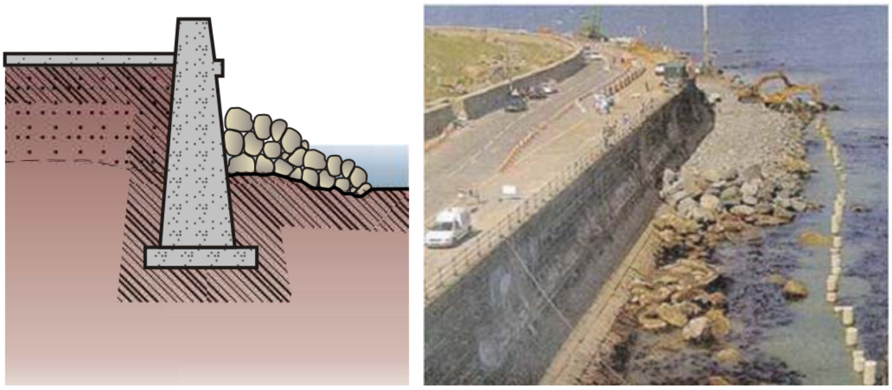


***Figure 1.1.4** - Vertical concrete seawall with a natural rock protection at the toe (APAT, 2007).*

Bulkheads
Bulkheads are vertical structures (**figure 1.1.5**) intended to retain or prevent sliding of the land, increasing its stability and providing a protection from the erosion mainly induced by low energy waves. These structures do not have the capability of resisting wave motion unless adequately reinforced, given that they are best used when protecting the hinterland against flooding and wave action is of secondary importance. Bulkheads are generally built parallel to the shoreline and designed to retain soil or incoherent sediment(3). They are mostly used to protect short stretches of shoreline, especially in steep coasts. Furthermore, a common application of these structures is to maintain an adequate water depth for mooring facilities (i.e. in waterways harbours, marinas and industrialised coastal areas) and to ensure a temporary protection from waves during construction works (docks, dams, land reclamations etc.). Being vertical structures, bulkheads can limit wave energy dissipation and lead to an increase of wave reflection. As in the case of seawalls, being the quarry-stone revetment a good energy dissipater, quarry-stone bulkheads have less adverse effects on the submerged beach than smooth-faced vertical bulkheads. In particular, scouring action can occur at the toe and at the heads of the structure. This could increase erosion near the protected beach.

(3) Bulkheads may be built of many materials (steel, timber or concrete piling, gabions or rubble-mound structures). They can be constructed with circular piles driven into the seabed to a depth equal at least to the structure height on the seabed itself, and anchored with tie rods placed on the vertical wall.

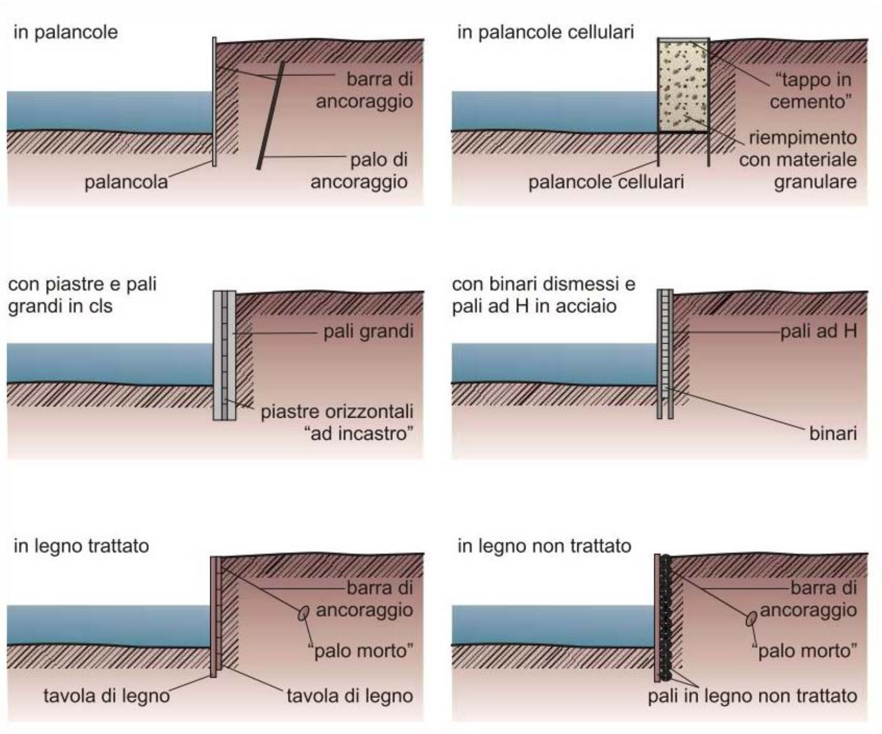


Figure 1.1.5 *- Bulkhead types (APAT, 2007).*

Sea dikes

Sea dikes are onshore structures with the principal function of protecting landward areas against flooding. They are generally only a protective armour and not a retaining structure. Sea dikes are usually built as a mound of fine materials like sand and clay with a gentle seaward slope aiming at reducing the waves run-up and their erosion effects. The dike surface is armoured with grass, asphalt, stones or concrete slabs.

Embankments

Embankments are artificial structures built in a shape specifically designed on the basis of the exposure of the coastal area to wave action. These structures are generally used to protect coasts against flooding. Based on the construction material, they can be divided into sand- and gravel-embankments, geocells- and earthen- embankments. Most commonly they are built placing sand, gravel and pebbles on the seabed.

1.2 Alongshore soft defences

Alongshore soft defences are intended to stabilize exposed sandy beaches, through the placement of a covering of gravel on *in-situ* sediments. Generally, they are used to protect coastal areas of limited extension but considered critical for the safety of coastal infrastructures (roads, railway lines etc.). The placement of coarser sediments (less mobile) reduces erosion since they allow the absorption of breaking waves energy. In addition, wave action induces the vertical movement and sorting of sediments. In particular, this may lead to the cover-up of the gravel component in the submerged beach, while a part of the gravel material can be redistributed in the inner part of the emerged beach, assuming a washover fan shape, thus limiting sediment exchange between the emerged and submerged beach due to a strong reduction of water exchange. At the same time, the main potential effects are related to significant changes in the beach profile, primarily between the berm and the foreshore zone. In particular, a greater steepness of the foreshore zone can occur, as well as the formation of a higher berm crest due to gravel accumulation, which may increase up to form a sort of barrier, especially after storm events.

1.3 Detached breakwaters

Detached breakwaters (nonshore connected nearshore breakwaters) are active-type structures built just seaward of the shoreline with the main function of protecting low and steep coasts reducing the incoming wave heights. Generally, they are built parallel to the shore in shallow waters, mainly when waves propagate perpendicular to the shoreline. However, well-designed layouts are also used for incoming waves non-perpendicular to the shoreline.
Detached breakwaters are categorised as fixed and, more rarely, floating structures. They can be used singly or as a series of multiple detached breakwaters spaced along the shoreline to provide protection for different frontages. They are classified as emerged (with fairly high crest levels) and submerged (with fairly low crest levels) structures, based on the mean water level (m.s.l.). The type and design for placing the material forming the armour layer affect the dissipation and thus the rate of reflected and transmitted wave energy.
Detached breakwaters, especially emerged ones, provide a direct protection from incoming waves by reducing wave heights in the lee of the structure. This reduces the erosion action behind the structure, creating a lower wave energy region (sheltered area). Bottom sediments transported along the beach tend to move into the sheltered area, where they are deposited with the formation of beach spits. In particular, detached breakwaters[(4)] induce morphodynamic changes in the nearshore that are strongly influenced by their specific configuration. These may lead to the formation of slight undulations, salients, and sometimes tombolos, when the beach spit joins with the breakwater. Tombolos formation occur more likely when breakwaters are constructed within the surf zone, and can be prevented or reduced by appropriate design measures.

The main potential physical effects (hydraulic and morphodynamic) of emerged and submerged detached breakwaters are:

- a reduction of the wave energy that reaches the shoreline by forcing the breaking and reflection of waves impacting on the breakwater, the diffraction at the head of the structure, and the penetration and/or overtopping when waves propagate into the sheltered area behind the breakwater;
- an increase in local sedimentation behind the structure, with the formation of symmetrical salients or tombolos (mainly when incident waves direction is perpendicular to the shoreline) and of large salients (when incident waves direction is non-perpendicular to the shoreline);
- changes in longshore sediment transport due to the reduction of net sediment supply behind the structure, with consequent erosion downdrift of the protected beach;

[(4)] Breakwaters are generally rubble-mound structures having a typical trapezoidal cross-section. They usually consist of a stable foundation (basement); a core of finer material covered by big blocks forming the so-called armour layer typically of large stones (quarry material or tout-venant) or of concrete; and a protective element at the base on the sea side. Concrete rocks are used for deep waters and/or for storm conditions, or when suitable borrow pits are not available.

- localised erosion within the breakwater gaps, due to rip currents formation when a considerable water flow occurs offshore (through the gaps and above the structure), if the breakwaters are submerged;
- localised erosion due to scouring action at the toe of the structure, caused by the possible offshore sediment transport resulting from the reflection of wave energy back into the sea.

Detached breakwaters, by interfering with coastal hydrodynamics and sediment transport, may also induce alterations on marine and coastal ecosystems, such as:

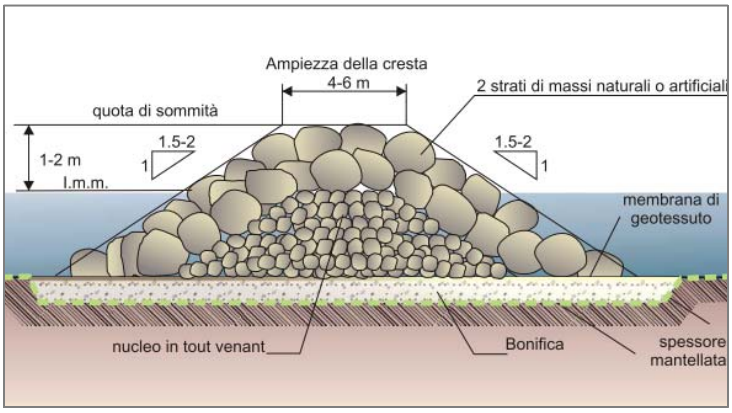
- effects on the habitats occurring along coastal areas, directly or indirectly interested by the morphological changes induced on the beach-dune system (Wallingford *et al*., 2000);
- increase in water turbidity, deposition of the finer sediment fraction (Pranzini, 2004) and algal proliferation (eutrophication) due to the reduced wave action and a consequent decrease of water exchange in the sheltered area behind the structure.

This category also includes island-platforms, i.e. circular, usually emerging structures (Pranzini, 2004).

Emerged breakwaters

A breakwater is defined as "emerged" when its crest is higher than the mean sea level (m.s.l.) (**figure 1.3.1**) or, more precisely, when overtopping occurs only during storm conditions. Wave overtopping degree is variable and dependant both on the structure's crest level and on marine conditions.
These structures are made of quarry stones or artificial boulders and are generally built in relatively shallow waters, within the surf zone. They can be used singly or as a series of multiple structures, spaced along the shoreline to ensure the coastal protection, maintaining at the same time a reasonable coastal circulation and water exchange.
Besides the above mentioned effects commonly induced by detached breakwaters, emerged breakwaters may also be cause of:

- sand deposition in the sheltered area and seabed erosion near the breakwater gaps and near the protected beach, thus making the coastline similar to a series of pocket beaches;
- formation of tombolos, joining the protected beach to barriers, which can capture the longshore sediment transport, thus intensifying the downdrift beach erosion already induced by the presence of the structures (Pranzini, 2004);
- avandune formation for piling up of sand in the backshore, when a stable tombolo occurs (Wallingford *et al*., 2000);
- formation of rip currents with localised seabed erosion within breakwater gaps, especially during severe storm conditions when the mean sea level increases;
- intensification of longitudinal currents flowing in the protected area, especially in presence of partially submerged structures;
- displacement of the longshore current at deeper water (seaward) and formation of a sandy bar system, sometimes of considerable dimensions, at a certain distance from the shoreline;
- accretion of the protected beach for piling up of finer materials.



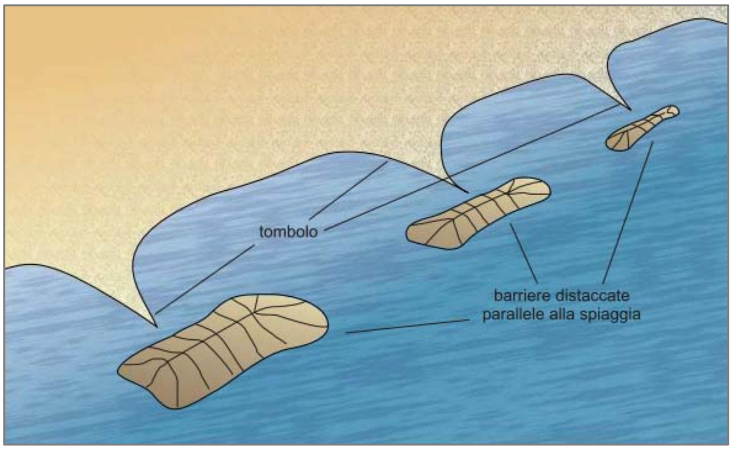


Figure 1.3.1 *- Emerged detached breakwaters scheme (above); effects induced by emerged breakwaters (below) (APAT, 2007).*

Submerged breakwaters

This category includes breakwaters with their uppermost part (crest) always below the sea level or emerged only during low tide conditions (**figure 1.3.2**). Therefore, wave overtopping always occurs when waves propagate behind submerged breakwaters. However, the crest of the structure reduces wave energy that reaches the shoreline by forcing the wave breaking, and thus reduces incoming wave heights into lower depth zones (sheltered areas), more easily erodible.

Submerged breakwaters can consist of a single structure or of series of structures and they can be made of natural stones, artificial boulders or sand bags. In general they are built in shallow waters (nearshore breakwaters), but their foundation (basement) depth may vary greatly if breakwaters are located inside or outside the nearshore zone.

A breakwater placed outside the nearshore zone causes the wave breaking on its offshore side. In this case, the diffraction occurring at the heads leads to the natural nourishment behind the structure, while reducing the formation of tombolos and thus any adverse effects on the downstream beach, if compared to breakwaters built in the nearshore zone.

Unlike a series of emerged (or low crest) breakwaters, the submerged ones allow waves motion behind the structures generally enough to ensure water exchange. In the case of long and uninterrupted structures, the protected shoreline will have a more regular trend. In contrast, in the case of short reefs with openings, the shoreline will have a more festoon-like trend. The effects of submerged breakwaters on coastal processes (reduction of cross-shore and long-shore transport, variation of the shoreline trend, formation of rip-currents, scouring at the toe of the structures, turbidity increase in protected sectors) are less severe compared to the similar effects above described for emerged breakwaters, since the interference with waves motion is only partial.

Moreover, unlike emerged breakwaters, the main expected effects on the coast are:

- positive effects on the backshore and coastal dunes, when breakwaters induced a wide accretion of the emerged beach;

- increase in wave set-up behind the structures, with a corresponding increase in wave run-up on the emerged beach;
- formation of rip currents, with erosion within the openings;
- increase in the mean sea level between the structure and the shore, thus inducing an increase in wave motion and in longshore current intensity that can lead to increased local erosion and to the formation of wide cusps on the protected beach (Pranzini, 2004).

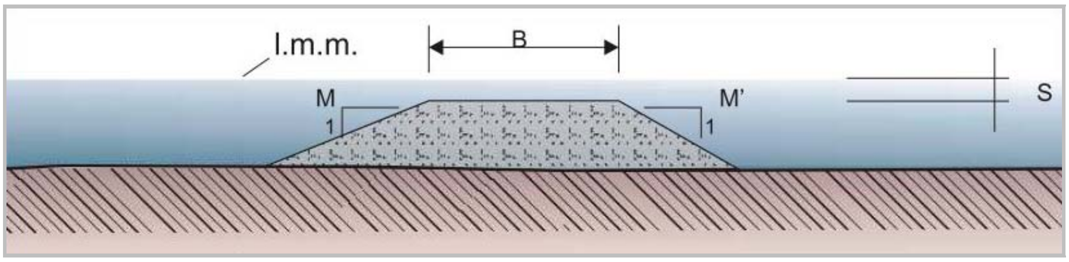


Figure 1.3.2 *- Scheme of a typical submerged breakwater (B= crest amplitude, S= submergence; M= seaward side slope; M' = landward side slope) (APAT, 2007).*

Island-platforms

Island-platforms are usually circular and size limited emerging structures (**figure 1.3.3**). Their design is similar to a groyne-head when they are built of natural large stones or of concrete boulders and they can be adequately reinforced and stabilised by a core of concrete ring (extended from the top-head to the basement). These structures affect the accretion and erosion processes typical of the surf zone (2-5 m depth), interfering with the induced wave currents and encouraging sediment deposition in the sheltered area.

The circular shape dampens the wave reflection. This leads to a faster decrease of reflected wave energy in the sheltered area, thus limiting the scouring at the toe of the structure as well as changes in the beach profile. Furthermore, the longshore sediment transport is only marginally reduced on the updrift- and downdrift- sides. In fact, well-designed island-platforms can lead to the formation of salients and limited emerging tombolos (consisting of finer sediments than the upstream- and downstream- beach) which are easily bypassed by waves and longitudinal currents during storm conditions (Pranzini, 2004). Hence, these structures influence only partially the longshore transport.

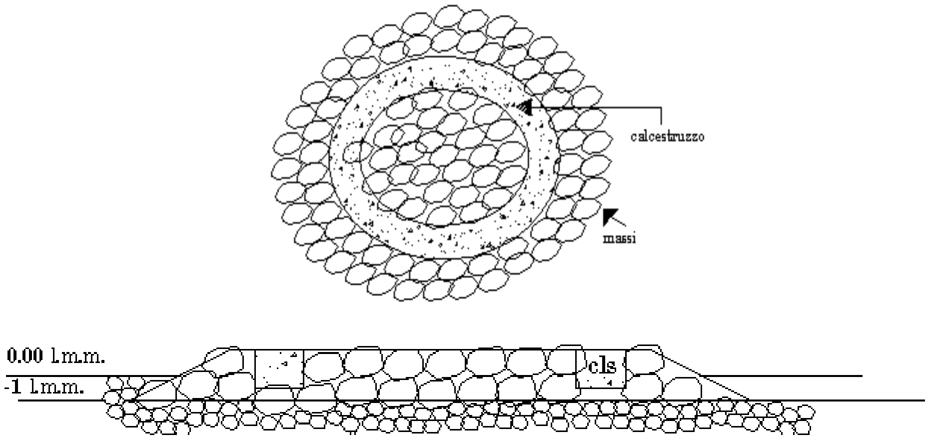


Figure 1.3.3 *- Scheme of an island-platform: plain-view (above); sectional view (below) (Tuscany Region, 2007).*

1.4 Cross-shore defences

Cross-shore defences may be considered as "active" measures and their main function is to intercept (totally or partially) the long-shore sediment transport. These structures are primarily used when incoming waves propagate not-perpendicular to the shoreline. Consequently, cross-shore defences are straight and almost perpendicular to the initial shoreline with a well-designed layout for incident waves direction.
This category includes groynes (impermeable, permeable and composite) and headlands.

Groynes
Groynes are built to stabilise a stretch of natural or artificially nourished beach against erosion mainly due to a net longshore loss of beach material and their function is to redistribute sediments alongshore. They block, either totally or partially, the long-shore sediment transport by allowing the formation of protective up-stream beaches, thus slowing erosion (**figure 1.4.1**). Groynes normally extend from the backshore to the seaward limit of the surf zone in storm conditions. The sediment transport remains active beyond this limit. The landward end of groynes must extend to a point above the high-water line in order to stay beyond the normal zone of beach movement and thereby to avoid outflanking by back scour. For the same reason, groynes must be firmly and securely positioned in the back beach. They can be used as a single groyne or as a groyne system (series of groynes), and can be built in different shapes (straight perpendicular or non-perpendicular to the shoreline, notched, curved, with fishtails, T-head etc.) and geometry (orientation, length, height, permeability, and spacing) based on the project purpose. The groyne's armour(5) can be made of natural stones or artificial blocks properly dimensioned and positioned so as to withstand wave action.
A groyne is defined as "emerged" when its crest is at any point higher than the mean sea level (m.s. l.), and as "partially submerged" when its crest degrades from above to below the mean sea level proceeding seaward. The submergence level of the structure also affects its permeability and thus its capability to intercept the longitudinal sediment transport. In particular, a partially submerged groyne will be more permeable than an "emerged" one reaching an equal depth for the structure head.
Groynes induce the shoreline accretion up-drift (**figure 1.4.1**) and the deposition of coarser sediments approaching to the structure. The seaward shift of the foreshore in front of the groyne induces a steepening of the beach profile (Pranzini, 2004), especially in the lee of the structure. This leads to the subsequent reduction of the sediment transport capability and to a variation in the sediment grain size downdrift. Moreover, a sheltered area can be originated on the downstream side, thus causing the shoreward displacement of the breaking zone. This leads to an imbalance in the mean sea level (m.s.l.) within the sheltered area (i.e. between the protected and unprotected areas) and to the subsequent formation of strong rip currents along the groyne with a possible sediment transport to deeper waters. Therefore, when the sediment is moved seaward beyond the active zone, it can be definitely subtracted from the littoral sediment transport balance. In the particular case of orthogonal incident waves, groynes can also induce the formation of a crescent-shaped beach where typical rip current circulation tends to move in the middle area between two single groynes.
Moreover, a groynes system deeply alters the shoreline and the bathymetry orientation by intercepting the longitudinal sediment transport. This causes a gradual expansion of the upstream beach and erosion of the downstream beach, with formation of a stable "sawtooth" profile(6) (Bush *et al*., 2001; Charlier *et al*., 2005). The "sawtooth" profile can be smoothed by the variability of incoming waves direction and by waves diffraction at the structure head, which favour the formation of crescents between the groynes.

The effects of groynes on local coastal dynamics can vary on the basis of their design and geometric features and thus of their orientation with respect to the mean wave direction (Pattiaratchi *et al*., 2009; Pratap *et al*., 2012). The main expected effects can be summarised as follows:

(5) Groynes generally have a typical trapezoidal cross-section. They usually consist of a stable foundation (basement), a core of finer material covered by one or more layers forming the armour and the upper part (crest).
(6) A geometric and structural parameter that influences the extent of effects produced by a groyne system on the updrift- and downdrift side, is the spacing (or distance) between the groynes. The spacing is usually imposed equal to 2 or 3 times the groyne length. An overestimation of the spacing can lead to excessive shoreline rotation and to a possible outflanking of the groynes. Then an excessive retreatment between consecutive groynes can cause the formation of rip currents.

- interception (or slow down) of the longshore transport rate, causing more or less pronounced erosion (on the downdrift side) and accretion (on the updrift side) events;
- a change in the shoreline orientation, that tends to be perpendicular to the direction of incoming mean wave climate;
- possible outflanking by back-scour, when groynes are not well-positioned in the back beach;
- increase of the updrift beach profile steepness due to the sedimentation of coarser sediments, proceeding toward the structure;
- changes in the downdrift beach profile caused by an alteration of pre-existing sediment grain size distribution;
- possible formation of rip currents along the groyne or in the area within two groynes, which can impair the stability of the structure and deflect the longshore transport away from the shoreline, sometimes with "localised" sediment loss from the littoral sediment balance.

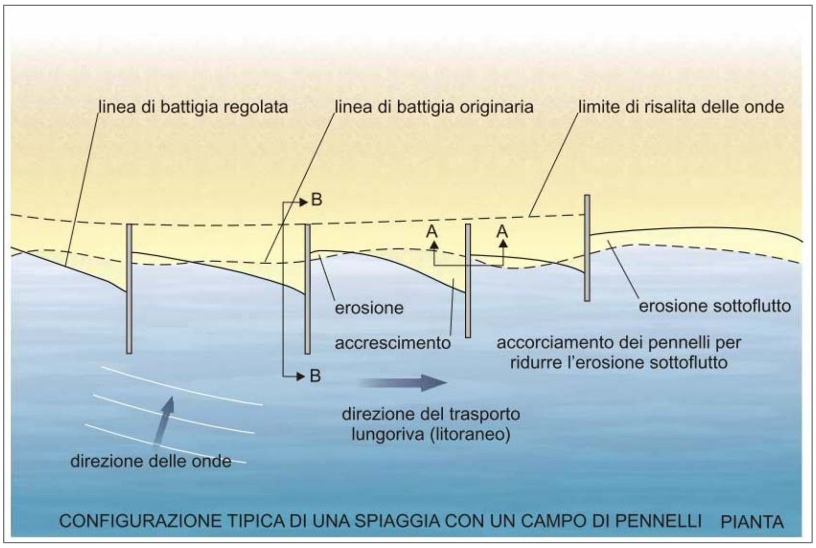


Figure 1.4.1 *- Effects of a groyne field (APAT, 2007).*

Groynes can be impermeable, permeable and composite.

Impermeable groynes

This category (**figure 1.4.2**) includes groynes built with impermeable materials, stabilising groynes and transition groynes (APAT, 2007).

Impermeable groynes can be built with rocks and artificial elements[(7)]. Groynes can significantly reduce the longshore transport if they are built with a high crest elevation (emerged) and a considerable length. In particular, they are classified as "terminal groynes" if they extend seaward enough to block all littoral transport. In this case, the formation of rip currents along the structure can lead to the seaward transport and thus to the loss in deeper waters of sediments accumulated up-drift and close to the head of the structure.

Stabilising groynes are limited-size structures, which extend only part way across the surf zone, usually following the emerged beach profile. They are primarily built to stabilise a stretch of sandy beach, making it maintain a given cross-shore profile, without significantly interfering with the net longshore sediment transport. Their presence may lead to a steeper submerged beach profile resulting from the deposition of coarser sediments near the structure. Stabilising groynes can slow down the longshore transport rate, affecting only the narrow strip between the emerged (a few meters beyond the shoreline) and submerged beach.

[(7)] Impermeable groynes can be constructed using the following materials and/or structures: natural stones (tout-venant) with a sand core and asphalt coating, sand-filled bags, synthetic tubes (e.g. Longard tube) filled with sand or placed on pilings (timber piles, concrete piles or steel-sheets), a box structure on timber piles (crib system).

Transition groynes are constructed to ensure the presence of a natural beach (transition zone) adjacent to the protected coastal zone. In the terminal part of a groyne system, the spacing between consecutive groynes and the length of any single groyne are gradually reduced[8] along the downdrift direction (**figure 1.4.3**). In this way, solid transport at the end of final groynes is ensured, as well as sediment supply to the section of coast remaining unprotected.

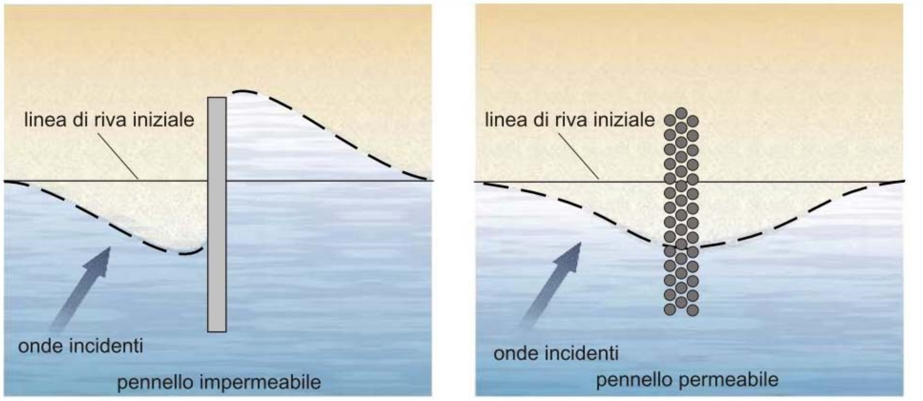


Figure 1.4.2 *- Effects of impermeable (left) and permeable (right) groynes (APAT, 2007).*

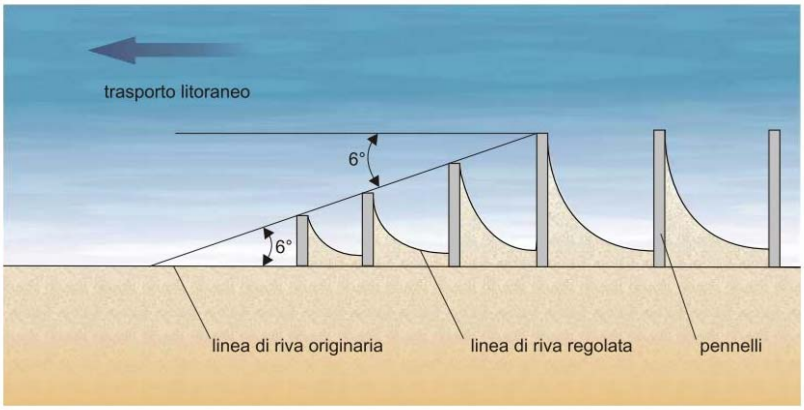


Figure 1.4.3 *- Transition groynes (APAT, 2007).*

Permeable groynes

Premeable groynes have a discontinuous or permeable structure which absorbs part of the wave energy and, at the same time, favours sand deposition on both sides of the barrier (**figure 1.4.2**). They may be built using a mound of stones, but the conventional structures consist of a core of finer material covered by big blocks forming the armour layer. Moreover, they can be constructed by spaced pilings (made of wood or reinforced concrete joined with precast elements) or gabions. This category includes submerged groynes, permeable groynes in the strictest sense[9] and notched groynes[10] (Pranzini, 2004).

Permeable groynes are used to reduce longshore transport, ensuring the presence of coarser material up-drift and a decreased sandy sediment removal downdrift. The transport of sediments having a grain size useful for the beach formation occurs through the structure only after a first filling-up phase. In fact, once buried in the sand, permeable groynes are overtopped by the longshore transport instead of being outflanked at the head, as in the case of emerged impermeable groynes from which they derive (APAT, 2007; Pranzini, 2004). This reduces the erosion on the downdrift side of the structure (which

(8) Generally, the length of a groyne decreases following an ideal line that joins the head of the final groyne with normal length to the downstream beach, forming an angle of about 6° with the rectified shoreline (tapering technique).

(9) Posts driven into the seabed, emerging and positioned at a certain distance from each other, with variable openings (transparency is usually close to 30%).

(10) Emerged groynes characterised by an opening separating the part built on the land from the one offshore.

suffers a sediment deficit only in the initial filling-up phase) and the development of an indented shoreline. The groyne permeability level affects the sediment transport and deposition in the protected area.

Composite groynes

Composite groynes have small lateral sections added to the head usually parallel to the shoreline(**figure 1.4.4**). These allow wave energy dissipation and the formation of stationary eddies circulation They can come in different shapes: spur-shape, sloping, notched, Y-shape, Z-shape, angular, L-shape, T-shape or modified T shape, dog-paw shape (Pranzini, 2004). Composite groynes are intended to bring a stable equilibrium of the beach dynamics in specific points. This shape can favour sand deposition both updrift and downdrift, thus stabilising the beach portions situated between adjacent groynes (APAT, 2007).
Generally, composite groynes are more effective in maintaining the coastline in its previous position, since they reduce sediment drift. Furthermore, this kind of solution is particularly suitable for littorals with coastal dunes because modified shapes (especially T-shape) prevent the scouring at the toe of the groyne. The alignment induced on the shoreline depends on the different layouts of the structures and on the mean wave direction.
The use of T-shaped groyne is advisable when a limited sediment transport supply and several storm conditions perpendicular to the shoreline occur on the protected beach. The principal functions of T-shaped groynes are similar to those of detached breakwaters, even if the downdrift transport can be strongly reduced (**figure 1.4.5**). In the case of composite groynes, beach changes behind the structure essentially depend on the wave action rather than on longshore currents, as it is in the case of detached breakwaters (APAT, 2007). These latter, by interfering with local hydrodynamics, can alter the marine environment quality due to the reduced water exchange behind the structures (U.S. Army Corps of Engineers, 2003b).

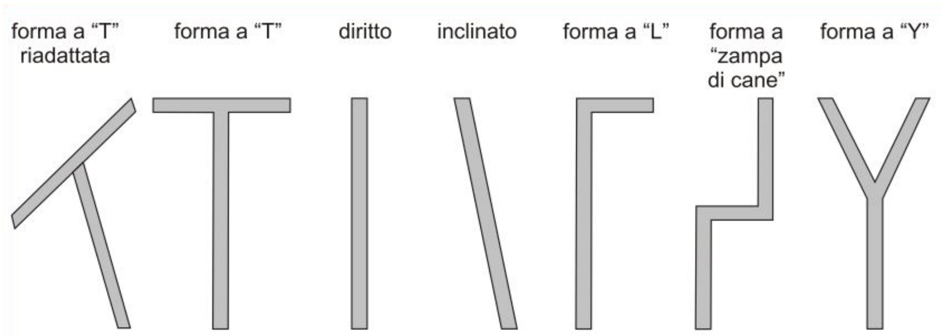


Figure 1.4.4 *- Examples of composite groynes (APAT, 2007).*

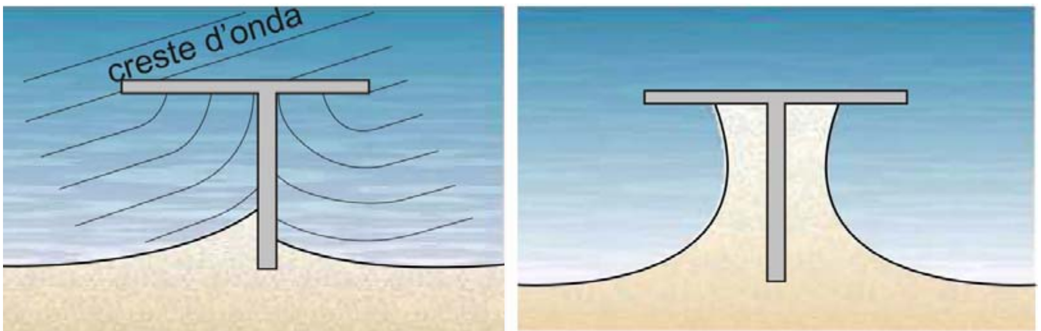


Figure 1.4.5 *- Effects associated with T-shaped groynes (APAT, 2007).*

Headlands

Headlands are used for stabilising the shoreline at regional level and are considered similar to artificial promontories, allowing a gradual control on the evolution of adjacent coastal stretches (Pranzini, 2004). This control can also be obtained by piloting local retreats (**figure 1.4.6**). Their functioning principle is based on the reproduction of the natural hydrodynamic conditions of promontories delimiting small downdrift bays with a curved coastal profile (APAT, 2007).
Headlands are usually parallel or inclined with respect to the shoreline, with orientation varying on the basis of the mean wave climate. They may be built with stones or artificial elements (**figure 1.4.7**). Curved shapes reduce eddies formation and scouring at the toe (APAT, 2007). Headlands are mainly used for the protection of sandy bays, when waves permanently propagate non-perpendicular with respect to the shoreline, and they favour the formation of a crenulated beach, parallel to the prevalent wave front direction (**figure 1.4.6**).

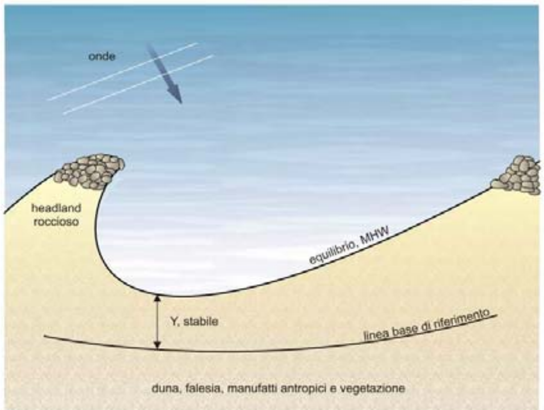


Figure 1.4.6 *- Effects of a headlands built by natural blocks (APAT, 2007).*

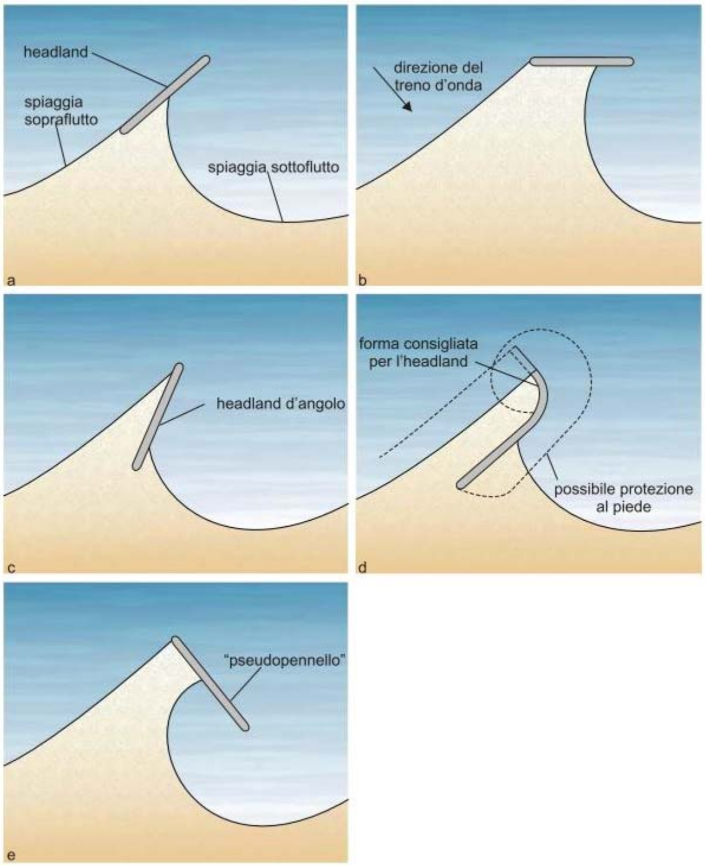


Figure 1.4.7 *- Headlands types and orientation (APAT, 2007).*

1.5 Beach nourishment

Beach nourishment is a "soft" intervention consisting in the placement of suitable sediments, of marine or terrestrial origin, on the eroded section of the emerged and/or submerged beach. The material is partially processed with land equipment (land handling) and partially redistributed along the equilibrium profile by the wave action. Beach nourishment is usually used for prevention or stabilisation of shoreline erosion (**figure 1.5.1**).
Beach nourishment, in fact, compensates for the natural supply of beach material of a coastal stretch, making it positive or zero. Beach nourishment operations can be undertaken in a single phase or with periodic feedings and the total amount of sediment is defined in the project design phase[(11)]. The nourishment of a small eroded stretch of beach can also be achieved by storing a suitable amount of material in the updrift side of the area to be protected, thus taking advantage of the natural longshore transport for the redistribution of the nourished sediment.
The choice of sediments to be used is an essential factor for the success of the nourishment. They must be accurately selected, taking into account grain size, mineralogical and, if possible, chromatic characteristics of original sediments (Douglass, 1995; 1996; Dean, 2002; Klein, 2005). In particular, the mean diameter of the nourished sediments should be comparable to the native grain size sediments (i.e. equal or slightly greater). In fact, although greater grain sizes have higher stability, they may lead to a steeping of the beach profile due to the sediments redistribution under wave action.
As an alternative to the above described beach nourishment, useful especially in case of limited erosion, it is possible to put in place a nourishment integrated with groynes and/or containment barriers at the base (protected nourishment), which delimit real "protection cells" for sediments, limiting as much as possible the loss of refluxed sediments (Di Risio *et al.*, 2010). In particular, the construction of submerged barriers on a stretch of nourished coast has the purpose of fixing the maximum height of waves capable of reaching the coast by causing the breaking of higher waves (in such case it comes to suspended beaches). Groynes, on the other hand, when associated with nourishment have the function of side containment structures, able to reduce the speed of longshore currents by configuring pocket beaches.

Figure 1.5.1 *- Beach nourishment operations (Photo by Regione Lazio).*

[(11)] The necessary sediment amount is calculated taking into account the local marine-weather features, the sedimentary deficit in the considered length of coast, as well as the features of both native sediments and of those to be used for beach replenishment.

With regards to the physical effects associated with beach nourishment, sand replenishment can induce morphological and substrate's grain size variations. These are directly related to the seaward shifting of the equilibrium profile and to the consequent widening of the emerged beach. Another effect is linked to the temporary increase of suspended sediment concentration (and thus of turbidity), which is expected both in the replenishment phase and immediately after the end of the filling operations. This effect can be accentuated in case of intense wave conditions, and it is also favoured by the low compaction degree of the newly replenished sediments. The increase of turbidity in the water column is mainly due to the re-suspension of the sediment finer fraction (Van Dolah *et al*., 1984; Green, 2002). Turbidity values usually return to natural levels shortly after the new equilibrium beach profile is reached (Green, 2002). In fact, the completion of a beach nourishment project includes the time required for sediments redistribution by waves up to form a new equilibrium profile of the emerged and submerged beach.

Persistent increase of turbidity may result from the use of materials with mineralogical characteristics (hardness) too different from those of the native beach. Finally, in case of protected beach nourishments, all the effects normally associated with the construction of hard defences (groynes and breakwaters) should be taken into account, such as scouring at the base, changes in the beach profile and in longshore sediment transport, rip current formation affecting the sedimentary budget, reduction of water exchange with consequent degradation of water and sediment quality etc.

1.6 By-pass systems

Sand by-passing systems are built to restore longshore sediment transport when the presence of jutting sea works (such as ports and cross-shore structures) leads to a significant reduction of the sediment supply downdrift. Their primary function is to minimise any possible changes in the shoreline and submerged beach near the structure.
Sand by-pass systems are designed according to the accretion rate and to the sediment transport features. They are classified into interception and storage systems, on the basis of their operating modes, and into continuous and periodic systems, on the basis of their operating schedules.
Interception-mode systems are mainly used when the sediment storage capacity is low. In this case the by-passing operates continuously, at daily or weekly frequency. Storage-mode systems are preferably used when the sediment transport rate occurs with high concentrations and significant seasonal variability. In this case, sand bay-passing is performed intermittently or periodically, with intervals ranging from a few months to some years.
The main physical effects involve the increase of re-suspended sediments and thus of water turbidity nearby the intervention site, that can occur during the sediment dredging and replenishment phases(12) (U.S. Army Corps of Engineers, 2003b; APAT, 2007).

1.7 Beach drainage systems

Beach drainage systems are based on the assumption that beaches made of well-drained sediments are more stable (**figure 1.7.1**). They are most effective in low and sandy beaches. These systems use the B.M.S. (Beach Management System) or B.D.S (Beach Dewatering System) technique, involving the lowering of the water table with the aim of creating an unsaturated zone within the aquifer (Vesterby and Parks, 1988; Vesterby, 1991; 1994). The unsaturation of sand along the foreshore is artificially induced by inserting drainage pipes in cavities obtained inside the beach, in the swash zone along the shoreline, and connected to a pumping station. Water in excess can be pumped back into the sea or reused for other purposes (Pranzini, 2004). These systems can control (and fight) erosion not only of beaches, but also of the backdunes, if present (Wallingford *et al*., 2000; www.shoregro.com).

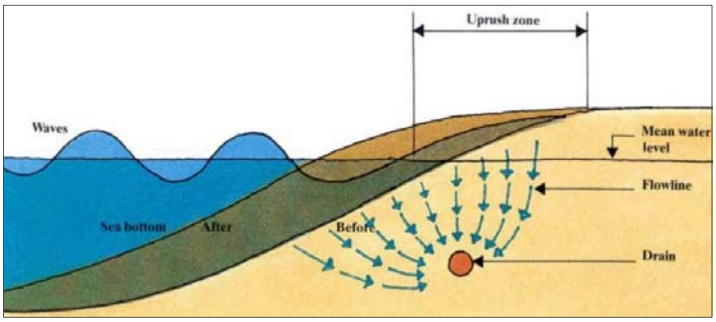


Figure 1.7.1 *– Section of a drainage system (http://www.shoregro.com).*

By eliminating water in the swash zone, drainage systems increase the beach capacity to absorb energy associated with wave motion, thus reducing sand fluidization and favouring deposition.
The deposited sand forms a berm that can protect the dune foot in extreme marine-weather conditions (Wallingford *et al.*, 2000; Vicinanza *et al.*, 2006). Drainage systems allow to obtain a good beach stabilisation, with minimal environmental impacts. However it should be taken into account that the lowering of the water table caused by drainage operations may adversely affect the physical compartment (www.shoregro.com).

(12) Beside traditional by-pass systems, which involve sediment movement by land or sea, other movement/trapping methods could be contemplated, such as: a pumping station fixed to the ground, with dredging head in the dispersion area; a pump with rotating dredging head mounted in a fixed position on the updrift dock (APAT, 2007).

1.8 Coastal dune management

Coastal dune management measures generally result in increased protection of the coastline and in increased amounts of sediments available in case of beach retreat events.
Restoration techniques depend on the size and damage level of a dune system. The main restoration techniques are:

- conventional engineering techniques (dune reconstruction);
- bioengineering techniques (windbreak fences, dune restoration and stabilisation through local native vegetation, access management).

Dune reprofiling

Coastal dune reconstruction is necessary when shape, size or topography of a dune system have changed significantly.
In the case of small passages (i.e. produced by pedestrians), passive collectors(13) of various types and shapes are used (e.g. tables of coconut or jute fibres, pine or eucalyptus waste cuttings, fences, sand plastic parts simulating the friction produced by vegetation). These elements stabilise the dunes by reducing the loss of windblown sand and thus favouring sediment deposition and the growing of vegetation, which is also encouraged by the decomposition of the organic collectors themselves.
When the dune system is severely degraded, with blowouts widened by wind action, the reconstruction (**figure 1.8.1**) will generally include a replenishment with sediments compatible with those existing on site, and a reprofiling of the slope according to the morphological features (Wallingford *et al*., 2000; POSIDUNE, 2007). In all cases, there is a preference for reprofiling the dune so as to minimize the erosion caused by the wind. The impacts on the environment are then limited to the phases of withdrawal and relocation of sands.
Reprofiling operations are often associated with the placing of windbreak fences and/or semi-rigid structures at the dune foot, with the aim of stabilising the newly rebuilt deposit (Dette and Raudkivi, 1994; Wallingford *et al*., 2000). Another solution that serves this purpose is to place foreshore organic material on the surface of the rebuilt dune; this gives the dune extra protection against the wind and wave action (Wallingford *et al.*, 2000).

Dune grass planting

Restoration and stabilisation bioengineering techniques are mainly aimed at favouring and accelerating native plant colonisation and the stabilisation of a dune system (**figure 1.8.1**).
The restoration techniques mainly used are:

- planting of native species (using seeds, plant cuttings, or nursery plants) without using the substrate;
- planting of native species (using seeds, plant cuttings, or nursery plants) using the substrate;
- support to the re-growth of spontaneous vegetation (using only the substrate without planting new plants).

Before the grass planting, the substrate can be prepared by fertilising the soil or by using geotextiles to counter wind erosion. Planting of native psammophilous species aims to activate and/or increase feedback mechanisms between the vegetation and the physical component, which results in the formation, growth and stabilisation of sand deposits.
For best results, the seeds or plant cuttings used for these operations should be picked directly from the site of intervention. This will permit to reproduce communities coherent with the local vegetation and to avoid the introduction of exotic species, as well as any possible effects of genetic contamination caused by species and *cultivars* from different regions or countries (Marino and Piotto, 2010; Piotto *et al*., 2010).

(13) Passive collectors can be placed in rows parallel to prevailing wind directions or around the vegetation growing on the dune. Furthermore, they can be placed at the foot of the dune or inwards. The collectors are driven into the soil at about one third of their length (which is usually 1-2 m). After 4 or 5 years the sand accumulated tends to make the poles disappear; after 6 or 7 years the structure will have the appearance of a dune.

Figure 1.8.1 *- Example of a dune grass planting intervention (POSIDUNE, 2007).*

Windbreaks fences

Windbreak fences are structures built to control and contrast wind erosion and therefore to help sand deposition. This result is obtained by placing porous screens perpendicular to the prevailing direction of the wind, so as to reduce its speed and induce the deposition of transported sediments. Windbreak fences are used when erosion mainly concentrates on the dune ridge or when erosion is limited to embryodunes.

Windbreak fences are usually made of a series of upright poles with a windbreak screen fixed on them. They can be built on the dune ridge, along the ridge (especially if there is a littoral road), on the inland-facing side of the dunes or at the dune's base. They can either be constructed with one series of screens or with several series along separate levels, that partially overlap on one another, or they can form cells whose orientation differs from that of the shoreline, thus running parallel, perpendicular or diagonal depending on the area's wind dynamics and on local morphological and topographical features (**figure 1.8.2**).

Figure 1.8.2 *- Chess-shaped windbreak fences (POSIDUNE, 2007).*

The realization of windbreak fences involves the formation of wind deposits whose size depends on the wind's transport rate. If the deposit contains beached plant material, this could produce a rapid colonisation by psammophilous vegetation which also helps to increase and stabilise the deposit itself. Windbreak fences protect vegetation both directly (mechanical protection) and indirectly (by retaining plants capable of enriching dune sand with nutrients and by condensing and retaining atmospheric humidity, a fundamental water source for the xerophile vegetation). These structures also reduce the size of surfaces subject to trampling action (Bovina *et al*., 2003; POSIDUNE, 2007).

Access management

This category includes all the structures aimed at protecting the dunes from erosion and at safeguarding the vegetation from trampling effects (**figure 1.8.3**). The most common structures used to control beach user pressure on coastal dunes are footways (**figure 1.8.4)**. These can be built using a large array of materials and may have very different characteristics, varying from solid wooden structures to "lighter" footways built with coconut-fiber, bio-nets and chestnut-tree poles.

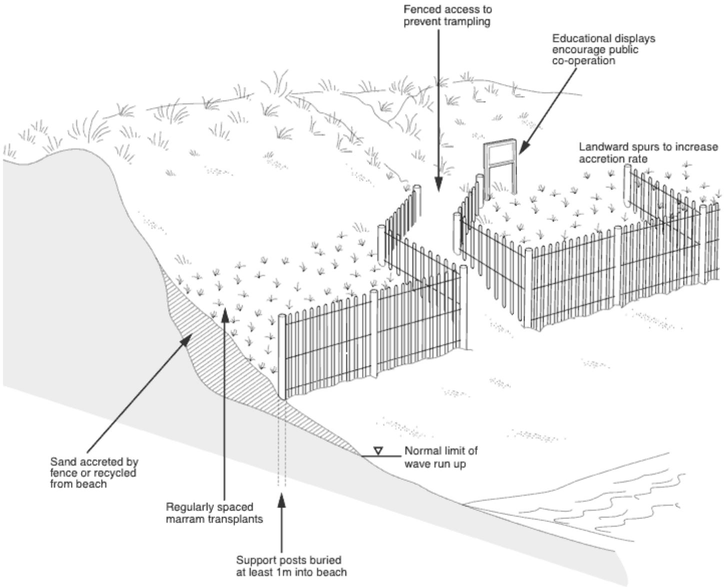


Figure 1.8.3 *- Examples of dune access management (http://www.snh.org.uk/publications/on-line/heritagemanagement/erosion/appendix_1.4.shtml).*

Figure 1.8.4 *– A footway along the littoral zone of Sabaudia (Southern Latium) (Photo by ISPRA).*

Footways constitute fixed pathways on which beach users cross the dunes. They protect the dunes from human trampling, which could cause irreversible damage to the vegetation (Bovina *et al*., 2003; POSIDUNE, 2007). Footways also prevent the creation of preferential trampling paths, which generate erosion lines along which the wind deeply carves the dune, triggering the formation of blowouts(14). During the footway construction phase, which includes the placing of upright poles, the sediment movement and a partial reprofiling of the dune section affected by the footway, it is very important to pay particular attention not to damage the vegetation present.

(14) Blowouts are interruptions in the continuity of the vegetation cover, which create real openings through the dune belt. They give rise to boat-shaped sand lobes that jut into the ground. Blowouts begin where there is an increased possibility for wind erosion, following the reduction of the vegetation cover.

2. MAIN ENVIRONMENTAL EFFECTS OF COASTAL DEFENCE WORKS

This chapter contains a brief bibliographic review of the main effects induced by coastal defence works (hard structures, beach nourishment, drainage systems and coastal dune management interventions) on the biotic field.

Hard structures

The effects induced on beach environments by coastal hard defence structures are quite known with regard to seawalls and parallel breakwaters (Jaramillo *et al*., 2002; Chapman and Bulleri 2003; Martin *et al*. 2005; Dugan and Hubbard, 2006; Dugan *et al.* 2011; Rizkalla and Savage, 2011), while the effects associated with groynes and, more generally with transversal structures (Pinn *et al*., 2005; Walker *et al*., 2008; Martins *et al*., 2009; Fanini *et al*., 2009; Pattiaratchi *et al*., 2009), are less investigated.

The main effects produced by the construction of hard structures are generally a variation and/or a loss of habitats, which strongly affect the composition (diversity, abundance and biomass) and the trophic structure of the associated benthic communities, as observed by many Authors (Fletcher *et al*., 1997; Meyer-Arendt and Dorvlo, 2001; Chapman and Bulleri, 2003; Martin *et al*., 2005; Moschella *et al*., 2005; Dugan and Hubbard, 2006; Bulleri and Chapman 2010).

It is well-known that coastal defence structures create new rocky substrata in soft-bottom marine environments. These new patches of hard bottom can facilitate the settlement and the consequent growth of previously absent sessile species (Bulleri *et al*., 2000; Chapman and Bulleri, 2003; Bertasi, *et al*., 2007). Moreover, the settlement of invasive and predator species can alter interaction mechanisms among species (Chapman and Bulleri, 2003; Bulleri and Airoldi, 2005; Moreira *et al*., 2006; Glasby *et al*., 2007; Bulleri and Chapman, 2010). For instance, Gonzales *et al.* (2008) have observed that the introduction of non-indigenous species causes not only a modification in the original habitat, but also a greater competition among species, with negative effects on the native populations.

The presence of hard structures can also induce important effects on benthic communities like the change of larval supply and food availability, because of possible hydrodynamic variations induced by their realization which can hinder long-shore transport (Pinn *et al*., 2005; Dugan and Hubbard, 2006; Walker *et al*., 2008).

Moschella *et al.* (2005) report that although some types of structures known as low-crested defence structures (LCSs) are considered to be similar to natural rocky bottoms, in concrete they are a poor surrogate of hard substrates. In fact, the epibiothic communities present on these structures, even if qualitatively similar to those found in natural rocky substrates, show quantitative differences in terms of diversity and abundance. Bulleri *et al.* (2000) also observe that populations associated to LCSs are quite different from natural rocky substrates populations present in the surrounding area. This difference is linked above all to factors such as the material composition (woods, masses, concrete blocks etc), the age (the time elapsed since the installation) and the geometry (orientation and exposition). In particular, orientation and exposition prove to be key factors in the development of benthic populations (Connel and Glasby, 1999; Glasby, 2000; Pinn, *et al*., 2005; Gacia *et al*., 2007).

In the study carried out by Martin *et al*. (2005), concerning the ecological effects induced by LCSs, the Authors noticed that they generate significant effects on sediments and the infauna (especially landward), above all when additional structures are present or after a beach nourishment. The effects' intensity mainly depends on the composition of the benthic population originally present. Generally, an increase in biodiversity has been attributed both to the settlement of new species on the artificial hard bottom and to the population changes induced by the grain-size modifications near the structure. However, the LCSs can also function as nursery areas for fish fauna, with a consequent increase in the number of species of commercial value.

Walker *et al*. (2008) have studied the effects produced on benthic microfauna by a 100 m long and 10 m large groyne (Palm Beach, Queensland, Australia). As expected, the Authors have observed variations in beach morphodynamic and in grain size in a range of 10-15 m from the groyne. These changes have generated a variation in the composition of the benthic communities on both sides, even if this effect proved to be spatially limited (as observed within 10 m). Furthermore, the Authors observed an increase in abundance in the northern side (on the downstream side) of the groyne (subject to deposition) compared to southern side (on the upstream side) (subject to erosion).

Another effect of hard structures is to favour the aggregation of mobile fauna, mainly fish, by providing food availability, refuges from predators and suitable sites for reproduction and recruitment. The debate is still open as to whether artificial structures can be beneficial to fish populations only on

a local scale or if they can have positive effects on a broader spatial scale, e.g. for regional fisheries (Sanchez-Jerez *et al*., 2002; Duffy-Anderson *et al*., 2003; Martin *et al*., 2005).
Literature reports also that habitat change caused by hard structures can have significant effects not only on fish fauna distribution, but also on turtles and birds (Moiser and Witherinton, 2002; Dugan and Hubbard, 2006; Rice, 2006; Rizkalla and Savage, 2011). Dugan and Hubbard (2006) noticed that this effects are mainly due to the narrowing of the upper beach and the reduction of the quantity of wracks deposited on the beach, with negative consequences especially for shorebirds. In particular, the armoring structures influence negatively the success of deposition and hatchling of *Caretta Caretta* eggs, as reported by Rizkalla and Savage (2011).

Beach nourishment

Although beach nourishment is an *environmental friendly* coastal defence option, literature reports on significant effects on the different environments like benthic communities, fish populations, marine phanerogams, terrestrial arthropods and avifauna (Nicoletti *et al.,* 2006; Speybroeck *et al.,* 2006; Colosio *et al.*, 2007; Defeo *et al.*, 2009; OSPAR, 2009).
As a whole, the effects of beach nourishment are mainly related to the characteristics of the sediment deposited on the beach (i.g. grain size and mineralogy), to assess whether in relation with the characteristics of the original sediment or to the technical and project modalities typical of the intervention itself such as volumes of nourished materials, timing and season of intervention, and used technologies for transport and deposition of sediments (Speybroeck *et al*., 2006; OSPAR, 2009).
It is known that most significant effects concern benthic and demersal fish populations while those on other biotic components (i.g. plankton) are negligible. Generally, sand replenishment causes suffocation and burial phenomena, alteration of bottoms inhabited by organisms, alteration of population dynamics (with significant consequences on nursery and reproduction areas) and decrease of trophic resources (Nicoletti *et al*., 2006; Peterson *et al*., 2006; Speybroeck *et al*., 2006; Defeo *et al*., 2009; OSPAR, 2009).
There where beach nourishment activities caused important grain size changes, significant variations have been observed even in the composition of the benthic organisms, with consequent alteration of the beach ecology (Rakocinski *et al*., 1996). Literature reports temporary variations of abundance, diversity and specific composition of intertidal fauna, with a variable duration from a few weeks to a few months (BNP, 1995). In fact, immediately after a beach nourishment causing possible defaunation (total or partial) of the directly involved area, the recovery of populations starts through specific recruitment mechanisms like the migration of adults and juveniles from adjacent areas, the vertical migration and the deposition of organisms transported on the beach (van Dolah *et al*., 1984). In particular, the vertical migration proved to be the most effective mechanism to survive after a beach nourishment for some species of intertidal and/or subtidal environment (Maurer *et al*., 1986; BNP, 1995; Green, 2002*).* A fundamental aspect in the assessment of the effects generated by nourishment it is not therefore the temporary loss of organisms living on the beach, already expected, but the recovery time of these communities after beach nourishment.
Beach nourishment can also generate negative effects even on arthropods' eggs deposition because of variations caused on sediment porosity, as observed by Jackson *et al*., (2007) along some beaches in Delware (USA), interested by coarse sediment replenishment and characterized by the presence of the arthropod *Horseshoe crabs* (Limulidae). Other effects of nourishment on arthropod fauna are also reported by Fanini *et al*. (2009).The Authors confirm how arthropod fauna (especially supralittoral species) generally proves to be particularly sensitive to the grain size and to qualitative changes of substrate generated by beach nourishment. However the amphipod *Talitrus saltator* demonstrates to be mainly influenced by other variables, such as the beach extension and the sediment penetrability.
Specific studies carried out along Lazio region's coasts to evaluate the effects of beach nourishment on *Donax trunculus* (a bivalve mollusk of commercial interest) populations (La Valle *et al*., 2007; La Valle and Nicoletti, 2008; La Valle *et al*., 2011) noticed that even though burial causes the species to disappear after nourishment, it reappears about four months later, after the end of the activities. The Authors suppose that by planning nourishment operations in specific period before the juvenile recruitment period, the effects on the species can be reduced, avoiding therefore also important repercussions for local fishing.
Several studies have been carried out to evaluate the effects of beach nourishment on marine phanerogams, particularly on *Posidonia oceanica* (Ruiz *et al*., 1993; Ruiz and Romero, 2003;Nicoletti *et al*. 2005). The short-term effects on *P. oceanica* meadows are mainly linked to the increase of water turbidity.

It is well known that a decrease in brightness caused by the increase of suspended fine sediments reduces the leaf production in the meadow and, if the alteration persists, a reduction of density and a regression of the lower limit can follow (Guidetti and Fabiano, 2000). Another effect caused by nourishment on *P. oceanica* meadows is the over-sedimentation, because of the greater mobility of the sediment recently deposited. Manzanera *et al.* (1998) particularly observed how the reaction of *P. oceanica* is strongly related to the intensity and duration of the phenomena: even small burials (5 cm) can actually cause an important leaf death.
As regards fish populations, the possible effects generated by beach nourishment activities can cause the reduction of abundances during sand replenishment operations, burial of demersal species, damages to fish branchial apparatus (due to sediment increase in the water column) and reduced availability of food (Green, 2002; Wilber *et al*.; 2003).
The effects of nourishment on sea-turtles are also well documented especially as far as egg deposition and survival and nesting success are concerned **(**Rumbold *et al* ., 2001; Byrd, 2004; Nordstrom, 2005**).** Crain et al. (1995) for example, have observed that nourishment can have relevant effects on the success of egg deposition due to nest concealment, alterations of nest chamber geometry and the increase in the beaches' slope that can block turtles, impeding them to reach nesting areas. Finally, nourishment can negatively influence the survival and the development of eggs during the hatching phase.
Regarding terrestrial fauna, Fenster *et al.* (2006) studied the effects of nourishment on coleopterus *Cicindela dorsalis*. In a study carried out along 2 beaches of Chesapeake bay (Virginia, USA) the Authors demonstrated that beach nourishment does not cause negative effects on the distribution and abundance of adults and larvae. In fact this species is able to move quickly, succeeding in finding best habitats for adults foraging, for ovipositing and further larval survival.
Finally, concerning avifauna, the main effects are related to the sediment replenishment which implies the removal and/or the burial of wracks and available preys. Moreover the compactness of the sediment can reduce preys' capture ability, directly influencing shorebird feeding capacity (Peterson *et al*., 2006).

Drainage systems
Little research has been done so far on this type of intervention, therefore information on its effects on the environment is quite limited. With regard to traditional coastal defence works, literature reports that drainage systems bring to a good level of beach stabilization with limited physical (Sato *et al*., 2003) and environmental effects (Ioannidis and Th. V. Karamba, 2007) mainly related to the intake quota of pipes (by type and entity) and their proportions and distance from the shore.
With a specific reference to potential effects that could occur in the process of being constructed on flora and fauna species, the *Danish Geotechnical Institute*[15] highlights that, as sand is gradually deposited, the local flora and fauna can adapt to the morphological changes of beach profile as well as to the variations of the sand density, humidity and temperature. Moreover, contrary to expected effects on physical component concerning groundwater lowering level produced by drainage operations, the Authors did not identify damages to the halophyte vegetation roots present on the beach and coastal dunes, although the effects of such variation are still not fully known (http://www.shoregro.com/pdfs/HV-BD-environment.pdf).

Coastal dunes management interventions
The main disturbances induced by coastal dunes management interventions are those related to trampling (Wallingford *et al.*, 2000). If there are no pre-existing routes to easily access the intervention area, heavy vehicles and trucks used to transport the material required to realize the works can cause the plant communities destruction, the mobilization of stabilized sands and soil compaction. More severe disturbances, can be associated to these actions affecting both the morphologic stability of the system and the survival of the plant communities. Moreover, in the absence of suitable pedestrian paths, the staff working on the intervention area can cause damages to the vegetation and lead to the development of blowouts (**figure 2.1**).
Another aspect to be considered is the impact related to the dispersion in the environment of materials used for the realization of structures, especially when no biodegradable material is used.

(15) The Danish Geotechnical Institute has patented the Beach Drainage System (B.D.S.) in 1985.

Figure 2.1 *- Example of a pathway used as fast access to the beach (Photo by ISPRA).*

With specific reference to the restoration and consolidation of dunes through vegetation another not negligible aspect is linked to the species used. It is therefore essential to use psammophilous local species, selected depending on ecological needs, and on different inclinations to construction in order to avoid changes in the local plant communities and to minimize the possible effects of "genetic contamination" (Wallingford *et al*., 2000; POSIDUNE, 2007). The collection in nature of species to use in these interventions is not recommended because the taking of a relevant number of organisms could lead to sand destabilization, expose them to the action of wind and make them susceptible to sea storm events and overwash (Wallingford *et al*., 2000). It is better to use plants coming from nursery (POSIDUNE, 2007), reproduced starting from native plant material (Piotto *et al*., 2010).
The morphologic reconstruction of a coastal dune using sediments coming from an external source (terrestrial or marine) can induce some important effects, listed below:

- sediments with a different pH can have negative effects on the local vegetation;
- sand deposition along the backshore can increase the quantity of sand transported inland by the wind, thus burying the rearward vegetation or activating/reactivating blowouts;
- the deposition of sand for dune reprofiling can bury both the vegetation and the invertebrate communities, reducing also the stability of the foredune and destroying habitats.
- the use of sediments containing seeds of alien plants can have negative impacts on local plant communities (Wallingford *et al*., 2000).

Generally, small sand additions - though frequent – are less harmful than isolated interventions entailing the handling of large quantities of sediment.

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Other effects induced on the environment by the realization of all coastal defence works, are those caused during the construction phase, by noise and trampling. In fact it is known that noise, associated both with heavy machines and the presence of man, can cause important disturbances on existing fauna (fish, reptiles and marine mammals, birds), thereby a possible leaving of involved species from intervention sites or at times a definitive abandonment can occur.
Similarly, during the construction phase the effects of trampling are not to be underestimated (Moffett *et al*., 1998; Schlacher *et al*., 2008). It has been proved for example that trampling has negative effects on macroinvertebrates living on emerged beach, in particular on arthropodofauna (Weslawski *et al*., 2000; Scapini *et al*., 2005).

3. ENVIRONMENTAL POLICIES AND LEGISLATION

International conventions and agreements represent for signatory countries the main instrument to develop conservation policies and to enact legislation. In the context of the different conventions the approach used is multiple, starting from protection of threatened species through lists (Bern Convention and Bonn Convention), to the conservation of species and their habitat (Barcelona Convention), to the conservation of biodiversity in a broad sense (Rio de Janeiro Convention).
In the European context, the strategy for the conservation of biodiversity adopted by the Commission is mainly based on Birds Directive and Habitats Directive. The main objective of the two Directives is the conservation of fauna and flora species particularly interesting at Community level and the conservation of the natural and semi-natural habitat types relevant for the biogeographic regions included in the European territory. The general approach used is therefore based on the conservation of species and habitats also through the designation of Special Protection Zones and Special Conservation Zones (Natura 2000 Network).

With regard to the Italian situation, flora species are protected according to international Conventions (Bern, Washington and Barcelona Conventions) and to European Directives (Habitats Directive) adopted by Italy. Habitats Directive has been implemented with DPR 357/1997 and subsequent amendments and additions. This decree represents the main Italian normative reference for the conservation of wild fauna and flora species, as well as of natural and semi-natural habitats relevant at community level. To date, a national legal framework for the protection of flora does not exist; this subject is delegated to Regions and Autonomous Provinces, which adopted their own legislation in the field of protection. With regard to fauna in Italy, the main reference legislation remains the Law 157/92, the EU Birds and Habitats Directives and the International conventions (Bern, Bonn, Paris, Washington, Barcelona) with the adoption rules. In addition, at local level a valid protection instrument can be represented by the numerous regional rules (Alonzi *et al*., 2006).

Below, the main international and European legislation for conservation of habitats and species in force in Italy is shortly presented.

Ramsar Convention
The *Convention on Wetlands of International Importanc*e, *especially as Waterfowl Habitat* (Ramsar Convention) is a treaty stipulated in 1971 in Ramsar (Iran) by the parties attending the International Conference on Wetlands and *waterfowls* and it came into force in 1975. In Italy the Convention was ratified with the DPR n. 448 of 13 may 1976 and the subsequent DPR n.184 of 11 February 1987. Conceived as a response to the progressive degradation of wetlands, which are strategic for the survival of migratory birds, the Convention's main objective is the protection of these areas through: identification and delimitation of sites (Ramsar Sites), study and research, implementation of conservation and development programs.
Today there is a network of wetlands of international relevance, or Ramsar Sites, to which Italy belongs with more than 50 sites spread throughout the territory. The Ramsar Sites include a great variety of wetlands, both inland and coastal, natural or artificial water areas, permanent or transitory areas (e.g. rivers, lakes, marshes, salt pans, ponds, peat pogs etc.).

Bern Convention
The C*onvention on the Conservation of European Wildlife and Natural Habitats* (Bern Convention), adopted in Bern on 19 September 1979, has been ratified by Italy with Law n.503 of 5 August 1981 and approved by the European Council with Decision 82/72/CE of 3 December 1981.
The main objective of Bern Convention is the conservation of European wildlife and natural habitats through cooperation among the Countries. Appendix I, II and III of the Convention contain the lists of flora and fauna species to protect, indicating different levels of protection:

- Appendix I (Bern 1): strictly protected flora species. The Convention prohibits the deliberate picking, collecting, cutting or uprooting of such plants.
- Appendix II (Bern 2): strictly protected fauna species. The following actions are prohibited:
    - all forms of deliberate capture and keeping, and deliberate killing; the deliberate damage to or destruction of breeding or resting sites; the deliberate disturbance of wild fauna, particularly during the period of breeding, rearing and hibernation; the deliberate destruction or taking of eggs from the wild or keeping these eggs; the possession and trade of these animals, alive or dead, including stuffed animals and any part or derivative thereof;

- the strict protection of habitats and in particular of wintering, migration, staging, feeding, and moulting areas;

- Appendix III (Bern 3): list of protected fauna species for which must be considered:
  - the controlled capture if done without compromising the conservation status of the species;
  - the period of recess of hunting, and local hunting derogations;
  - the protection of habitats with particular attention of wintering, migration, staging, feeding and moulting areas.

Bonn Convention

The Convention on the *Conservation of Migratory Species of Wild Animals* (Bonn Convention), adopted in Bonn on 23 June 1979, is an intergovernmental treaty, concluded under the aegis of the United Nations, concerned with the conservation of migratory species of wild animals in all their distribution area , with a special focus on species having a bad conservation status. Italy ratified the Convention with Law n.42 of 25 January 1983.

The Convention is composed of 2 appendixes: Appendix I lists migratory species threatened by extinction, and Appendix II lists migratory species that need or would significantly benefit from a grater international cooperation. In order to protect species, the contracting parties undertake to strive towards protecting the habitats of endangered species and eliminate obstacles that can prevent or interfere with the species' migration.

Barcelona Convention and SPA/BIO Protocol

The *Convention for the Protection of The Mediterranean Sea Against Pollution* (Barcelona Convention), is an intergovernmental treaty, concluded under the aegis of UNEP, the United Nations Environment Programme. It was signed in Barcelona on 16 February 1976 by 16 governments and by the EC. It came into force in 1978, and was ratified by Italy with Law n.30 of 25 January 1979. Over the time, the Convention has undergone several amendments; the last one dates back to 1995, when it became the *Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean* and, as such, was ratified by Italy with Law n. 175 of 27 May 1999. Today, the Barcelona Convention has 22 Contracting Parties, including the EC. The Barcelona Convention aims to prevent, reduce, fight and eliminate pollution in the Mediterranean Sea and protect and improve the marine and marine-coastal environment in the area, thereby contributing to its sustainable development. To achieve these objectives, the Convention signed 7 protocols: for the purposes of this study, and with specific reference to the identification of endangered habitats and/or species to protect, the reference agreement was the Protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean (SPA/BIO Protocol).

The SPA/BIO Protocol addresses the need to fill the legislative gap on the conservation of the marine environment, since the Habitats Directive (92/43/EEC) (see next section) (although being a fundamental instrument for biodiversity conservation, is mainly addressed to the terrestrial environment and does not have the same efficacy for the marine environmental protection.

The Protocol foresees three main actions to protect biological diversity in the Mediterranean:

- the creation, protection and management of Specially Protected Areas (SPAs);
- the creation of a list of Specially Protected Areas of Mediterranean Importance (SPAMI), constituted by marine coastal zones, within areas of national jurisdiction and partially/entirely on the high seas;
- the protection and conservation of species.

With Decision n. 1999/800/EC, the European Community has adhered to the protocol and signed its three annexes:

- Annex I, indicating the common criteria for the choice of protected marine and coastal areas that could be included in the "List of Specially Protected Areas of Mediterranean Importance", called "SPAMI List".
- Annex II, listing endangered and threatened species;
- Annex III, listing species whose exploitation must be regulated.

At the same time, in order to support the identification of the Specially Protected Areas, the Regional Activity Centre for Specially Protected Areas (RAC/SPA) has prepared reference lists for the habitats and species to be protected in the Mediterranean, of which 61 habitats and 136 species (excluding birds, specifically protected by the Birds Directive) are present in Italy (Bellan-Santini *et al.*, 2002).

Since these issues are strictly linked to the general contents and objectives of the Habitats Directive 92/43/EEC, the habitats indicated in the reference list prepared by the RAC/SPA are valid for both regulations, though maintaining different reference codes.

Habitats Directive

The Council Directive 92/43/EEC on the *Conservation of natural habitats and of wild fauna and flora* (Habitats Directive)is a legislative EU instrument designed to protect habitat types and species of Community interest. To the Habitats Directive followed the Council Directive 97/62/CE of 27 October 1997 "adapting to technical and scientific progress of the Council Directive 92/43/EEC on the conservation of natural and semi-natural habitats and of wild fauna and flora". Italy implemented the Directive with the DPR n. 357 of 8 September 1997, modified by the DPR n. 120 of 12 March 2003.
The specific objectives of the Directive are:

- the creation of Natura 2000, a coherent European ecological network made up of nature protection areas: Special Areas of Conservation (SACs) and Special Protection Areas (SPAs) designated respectively under the Habitats Directive and Birds Directive;
- the proposal by Member States, according to criteria set out in Annex III, of a list of sites (proposed Sites of Community Importance) indicating what habitat types among those listed in Annex I, and what species listed in Annex II they host;
- the designation by Member States of such Sites of Community Importance (SCI) as Special Area of Conservation, within no longer than six years, establishing priority depending on the importance of the sites for the maintenance and restoration at a favourable conservation status, of habitats and species listed in the Annexes, and for the coherence of Natura 2000 network;
- the evaluation of any plan or project that may have an impact on the site, considering its conservation goals (impact assessment).

The list of the habitat types to protect is reported in Annex I of the Directive, while the Annex II contains the list of fauna and flora species of Community interest, including the most important ones defined as "priority" habitats or species. The other Annexes report the selection criteria of sites eligible to be identified as sites of Community Importance and to be designated as special conservation zones (Annex III), the fauna and flora species that require a specific protection, for which picking destruction, possession, transport and commercialization is forbidden (Annex IV), the fauna and flora species of Community interest whose picking in nature and whose exploitation could represent aim of management measures (Annex V) and prohibited capturing and killing methods as well as transporting modalities (Annex VI).

Birds Directive

The Directive 2009/147/EC, amended and approved by version of the Directive 79/409/EEC, known as the Birds Directive, was issued to create a scheme of protection for all European wild birds. It was adopted unanimously by the Members States in 1979 in response to the increasing concern about the declines in Europe's wild bird populations recognized as a "common heritage" of EU States, resulting from pollution, unsustainable use of environmental resources and loss of habitats, the latter being identified as the main threat to their conservation. Therefore, the Directive places great emphasis on the protection of natural habitats through the establishment of a network of Special Protection Areas (SPAs) that together with SACs (Habitats Directive) form Natura 2000 ecological network.
SPAs comprise all the most suitable territories for the survival of bird species to be protected, listed in Annex I to 79/409/EEC, which also include marine environment species. Annexes II, III and IV regulate activities that threaten birds - such as the hunting and trade of protected species, to ensure that these practices are sustainable for the species listed in the Directive. Finally, Annex V promotes research to underpin their protection and management.
It must be mentioned that in 1995 the ORNIS Committee (Committee for the adaptation to technical and scientific progress of the Habitats Directive) approved a list of 23 bird species to be considered according to Directive 2009/147/EC, as "Priority species included in the LIFE: funding list", (commonly considered as "priority species"), similarly to the priority habitats and species identified by the Habitats Directive.

IUCN Red Lists

Apart from all protection regulations, international treaties and/or conventions, to better identify the flora and animal species, it is advisable to consider the flora and fauna species included in the Red Lists.

Red Lists are lists of species, related to specific geographic areas where for each *taxon* the level of extinction risk is indicated, such status is identified through a standardized assessment process (*Risk Assessment*). Risk Assessment procedures developed by the *International Union for Conservation of Nature* (IUCN), being characterized by replicability and reliability of results, represent to date the international reference standard.

The IUCN Red Lists (www.iucnredlist.org) have been created 30 years ago to help the planning of conservation strategies for the species most threatened by extinction, and are considered to be the most objective and authoritative system for classifying species in terms of risk of extinction.

The current IUCN protocol (IUCN 2001; 2013) is the result of a process improvement started last century in the sixties. The IUCN system was originally born to allow the assessment of the extinction risk of a *taxon* on a global scale, but later the applications on a regional scale have become always more frequent (IUCN 2003; 2012), referred for example to national or continental contexts.

A global Red List represents a priority list for species conservation; a regional Red List (continental, national or local level), even if compiled according to the IUCN protocol (IUCN, 1994) is reasonably valid only if it is applied to the scale at which it was prepared (Rondinini *et al*., 2013).

The regionalization of the IUCN method for the classification of species does not take into account some important parameters such as the trend of the species at a global or continental level, the importance of the regional population compared to the global or continental population, the position of the area examined compared to the area of each species and the feasibility of the conservation interventions required (Rondinini *et al*., 2013). Despite the limits linked to a national approach of the IUCN method for the classifications of species, we suggest both to refer to the global lists and to use the regional Red Lists which provide specific information about the status of species in the particular area. It can occur for example that a species proves to be at low extinction risk at a global scale but at higher extinction risk at a regional scale.

Therefore in Italy for flora and fauna species you should consider the Red Lists completed at national level, which even if not yet exhaustive they are numerous and in many cases recently published (Bulgarini *et al*., 1998; Calvario *et al*., 1999; Cerfolli *et al*., 2002).

Concerning flora the lists published during the nineties can be considered up to date the only National Red Lists for vascular flora (Conti *et al*., 1992; 1997) bryophitic flora (Cortini Pedrotti and Aleffi, 1992) and lichen flora (Nimis, 1992). Moreover, there are some Atlas which provide also information on distribution and bibliography next to the IUCN status (Scoppola and Spampinato, 2005). Furthermore, in Italy following the release of IUCN protocol version 3.1 (IUCN 2001) and of the indications for the use on a regional scale (IUCN, 2003) new Red Lists have recently been produced based on quantitative criteria and in accordance with the new IUCN standards. This activity, coordinated by the Italian Botanic Society (Rossi and Gentili, 2008; Gargano, 2008), led to the publication of the "*Red List for Italian Flora"1. Policy Species and other Threatened Species"* (Rossi *et al*., 2013), including the assessment of 396 *taxa* of Italian flora (297 vascular plants, 61 bryophytes plants, 25 lichens and 13 fungi). In addition numerous assessments conducted in this way have been published on a dedicated editorial space of the journal "Informatore Botanico Italiano" in the form of standard sheets providing very useful information about *taxa* distribution, threats and trends. On a transnational level it is worth mentioning also the "*European Red List of Vascular Plants*" drafted by the European Union (Bilz *et al*., 2011).

With regard to fauna, Red Lists are currently available also at national level, at least for some groups (Rondinini *et al*., 2013). At national level, thanks to the last work of the IUCN Italian Committee, all species of freshwater fishes, cartilaginous fishes, amphibians, reptiles, nesting birds and mammals native of Italy have been assessed. The only exceptions are winter, migratory birds species, which are present in Italy but not nesting there, which have not been assessed and therefore catalogued as NE (Not Evaluated). Also feral and domesticated species have not been assessed according to IUCN Red List categories and criteria. Species of certain introduction at historical times have been catalogued as NA (*Not Applicable*), together with the occasional species (occurring only marginally in the National territory), and recently colonized species.

The taxonomic basis for all species included in the Italian Fauna Red Lists is the Checklist of Italian Fauna by the Ministry of the Environment, Land and Sea. Necessary changes have been made to conform to the classification used by the global IUCN Red List and to follow the latest taxonomy. Methodology used for the assessment is IUCN official methodology.

For *taxa* that do not have specific national Red Lists, please refer to the IUCN Red Lists recently published for the Mediterranean or to the global assessment for species assessed (www.iucnredlist.org).

Here below a synthesis of legal references for biodiversity conservation in force in Italy, indicating case by case, whether the instruments are referred to the individuation of habitats and/or of flora and fauna species (**table 3.1**).

Table 3.1 - *Italian legislative references for the conservation of habitats and species*

Legal instruments	Habitats/Environments	Flora Species	Fauna species
Ramsar Convention	X		
Bern Convention (annex I)		X	
Bern Convention (annex II)			X
Bonn Convention (annex I)			X
Barcelona Convention, SPA/BIO Protocol (annex I)	X		
Barcelona Convention, SPA/BIO Protocol (annex II)		X	X
Habitats Directive (annex I)	X		
Habitats Directive (annex II)		X	X
Birds Directive (annex I)			X
IUCN Red Lists		X	X

4. IDENTIFICATON AND CLASSIFICATION OF PROTECTED HABITAT TYPES (*SENSU* HABITATS DIRECTIVE)

4.1 Classification criteria

The classification of protected habitats is based on habitat types listed under Annex I of the Habitats Directive 92/43/EC and on protected habitats included in the SPA/BIO Protocol of the Barcelona Convention (Bellan-Santini *et al.*, 2002). The classification does not consider wetland types of the Ramsar Convention, since the environment descriptions are less detailed than in the Habitats Directive. The identification of marine-coastal habitats was mainly carried out by taking into account Italy's landscapes. Given the great geographical and environmental variety characterising the Italian peninsula, it is believed that the identified physiographic categories are representative of the entire Mediterranean basin. The purpose of this classification is to identify the environmental compartments that can be directly or indirectly affected by the coastal defences.
In Italy there are 132 habitats of European interest, i.e. included in Annex I of the Habitats Directive (Biondi *et al*., 2009). Among these 132 types, 38 habitats can occur along the coastline; these coastal habitats include emerged and submerged environments, low sandy shores and rocky coasts. Only a few of these habitats are non-exclusive, since they are present both in coastal areas and inland. Examples are the annual herbaceous communities of *Thero-Brachypodietea*, also common inland, or some rocky habitats, less dependent on salty marine winds, that can be found on coastal clifftops but also on inner rocky ridges. Among the identified habitats, 32 have quite extensive distributions including most of the Italian coasts, 3 are endemic communities exclusive of the major Italian Islands and 3 are typical of limited areas along the northern coasts of the Adriatic Sea.

4.2 Physiographic categories and macro-environments

In order to assess the effects induced at ecosystem level by the different coastal defences, the identified coastal habitats (Habitats Directive and SPA/BIO Protocol) were grouped into 11 territorial/environmental units, hereinafter referred to as physiographic categories (**figure 4.2.1**). These units were identified according to morphogenetic, litho-morphological and pedological homogeneity criteria. The physiographic categories represent well-identifiable units also from the vegetation point of view, on the basis of common structural, ecological and physiognomic features, and are quite recognisable in terms of landscape as well.
The use of the physiographic categories allows a wider and more flexible application of the proposed method, even when available information do not permit to classify the environments with the level of detail required by the Habitats Directive. The physiographic categories are in turn grouped in 4 main macro-environments: marine habitats, wetlands and halophytic habitats, dune habitats and cliff habitats.

As shown in **figure 4.2.1**, the "marine habitats" macro-environment includes 3 categories of marine environments, i.e. those areas which are perennially submerged by marine waters (M1, M2, M3); the "wetlands and halophytic habitats " macro-environment includes 3 categories of environments which are alternately emerged and submerged (W1, W2, W3); the "dune habitats" macro-environment includes 4 categories of permanently dry dune habitats (D1, D2, D3, D4); the "cliff habitats" macro-environment includes a single habitat category (C1).

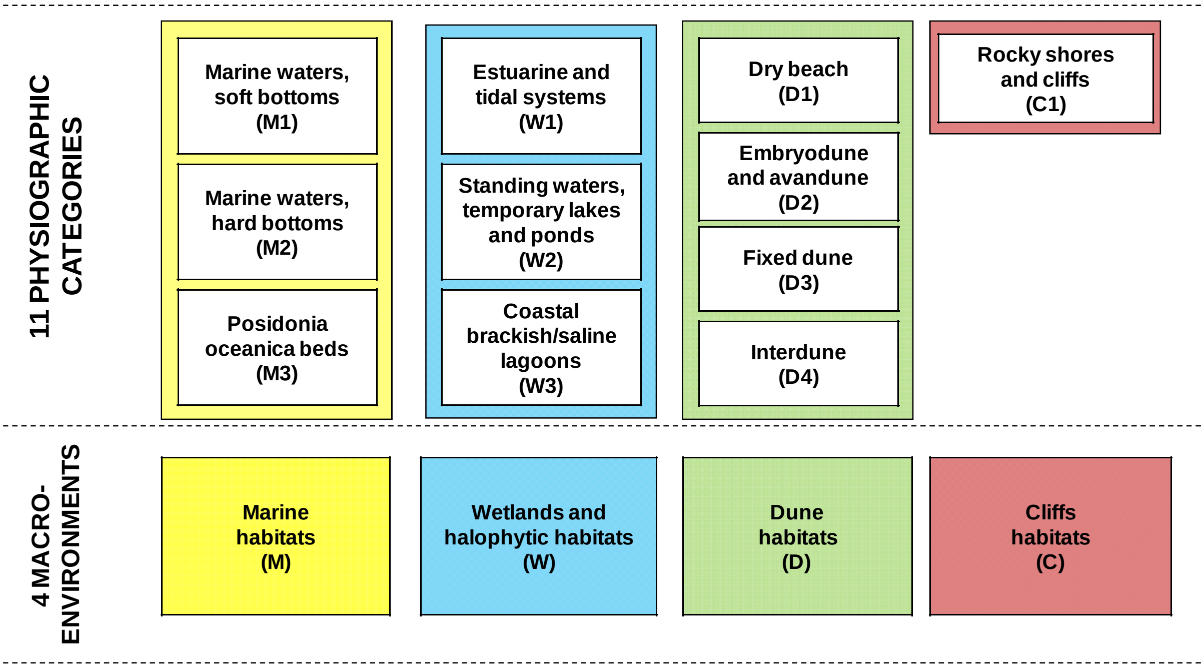

Figure 4.2.1 - *Macro-environment and physiographic categories.*

The identified physiographic categories are briefly described below, examining the habitats occurring within them with reference to Directive 92/43/EEC (**table 4.2.1**) and to SPA/BIO Protocol (Bellan-Santini *et al.*, 2002).
Each described habitat is associated both with the Habitats Directive code and, when matching, with the SPA/BIO Protocol code. In this respect, it should be remembered that protected habitats of the SPA/BIO Protocol refer exclusively to marine environment and, therefore, only few of the habitats listed in Annex I of Habitats Directive coincide with those mentioned in SPA/BIO Protocol.
As for the Italian habitats of European interest, currently the main bibliographic reference is the "Interpretation Manual of the 92/43/EEC Directive habitats" (Biondi *et al.*, 2009), used in this paper as the main source for the descriptions hereinafter. Priority habitats *sensu* Directive are reported with an asterisk following the code.

Table 4.2.1 shows the hierarchy diagram grouping the Italian coastal habitats of European interest in physiographic categories and macro-environments.

Table 4.2.1 - Hierarchy diagram grouping the Italian marine-coastal habitat types of Directive 92/43/EEC in physiographic categories and macro-environments. An habitat occurring in several physiographic categories is marked with the symbol *p.p.* (*pro parte*). Priority habitats are marked with an asterisk (*).

MACRO-ENVIRONMENTS	PHYSIOGRAPHIC CATEGORIES	MARINE-COASTAL HABITAT TYPES OF EUROPEAN INTEREST (DIRECTIVE 92/43/EEC)
MARINE HABITATS (M)	Marine waters, soft bottoms (M1)	1110: Sandbanks which are slightly covered by sea water all the time
		1160: Large shallow inlets and bays, on soft bottoms
	Marine waters, hard bottoms (M2)	1160: Large shallow inlets and bays, on soft bottoms
		1170: Reefs
		8330: Submerged or partially submerged sea caves
	Posidonia oceanica beds (M3)	1120*: *Posidonia* beds (*Posidonion oceanicae*)
WETLANDS AND HALOPHYTIC HABITATS (W)	Estuary and tidal systems (W1)	1130: Estuaries
		1140: Mudflats and sandflats not covered by seawater at low tide
	Standing waters, temporary lakes and ponds (W2)	3120: Oligotrophic waters containing very few minerals generally on sandy soils of the West Mediterranean, with *Isoëtes* spp.
		3130: Oligotrophic to mesotrophic standing waters with vegetation of the Littorelletea uniflorae and/or of the *Isoëto-Nanojuncetea*
		3140: Hard oligo-mesotrophic waters with benthic vegetation of *Chara* spp.
		3170*: Mediterranean temporary ponds
	Coastal brackish/saline lagoons (W3)	1150*: Coastal lagoons
		1310: *Salicornia* and other annuals colonizing mud and sand (*p.p.*)
		1320: *Spartina* swards (*Spartinion maritimae*)
		1410: Mediterranean salt meadows (*Juncetalia maritimi*) (*p.p.*)
		1420: Mediterranean and thermo-Atlantic halophilous scrubs (*Sarcocornietea fruticosi*)
		6420: Mediterranean tall humid grasslands of the *Molinio-Holoschoenion* (*p.p.*)
DUNE HABITATS (D)	Dry beach (D1)	1210: Annual vegetation of drift lines
		1310: *Salicornia* and other annuals colonizing mud and sand (*p.p.*)
	Embryodune and avandune (D2)	2110: Embryonic shifting dunes
		2120: Shifting dunes along the shoreline with *Ammophila arenaria* (white dunes)
		2230: *Malcolmietalia* dune grasslands (*p.p.*)
	Avandune continental side, fixed dune and stabilised sands (D3)	2130*: Fixed coastal dunes with herbaceous vegetation (grey dunes)
		2160: Dunes with *Hippophae rhamnoides*
		2210: *Crucianellion maritimae* fixed beach dunes
		2230: *Malcolmietalia* dune grasslands (*p.p.*)
		2240: *Brachypodietalia* dune grasslands with annuals
		2250*: Coastal dunes with *Juniperus* spp.
		2260: *Cisto-Lavanduletalia* dune sclerophyllous scrubs
		2270*: Wooded dunes with *Pinus pinea* and/or *Pinus pinaster*
		6220*: Pseudo-steppe with grasses and annuals of the *Thero-Brachypodietea*
	Interdune and backdune humid depressions (D4)	1410: Mediterranean salt meadows (*Juncetalia maritimi*) (*p.p.*)
		1510*: Mediterranean salt steppes (*Limonietalia*)
		6420: Mediterranean tall humid grasslands of the *Molinio-Holoschoenion* (*p.p.*)
CLIFF HABITATS (C)	Rocky shores and cliff habitats (C1)	1240: Vegetated sea cliffs of the Mediterranean coasts with endemic *Limonium* spp.
		1430: Halo-nitrophilous scrubs (*Pegano-Salsoletea*)
		5320: Low formations of Euphorbia close to cliffs
		5330: Thermo-Mediterranean and pre-desert scrub
		5410: West Mediterranean clifftop phryganas (*Astragalo-Plantaginetum subulatae*)
		5420: *Sarcopoterium spinosum* phryganas
		5430: Endemic phryganas of the *Euphorbio-Verbascion*
		8210: Calcareous rocky slopes with chasmophytic vegetation

4.2.1 Marine habitats

The "Marine waters, soft bottoms" category includes all types of submerged marine habitats on soft bottoms, ranging from gravel to muddy bottoms. This category comprises two habitats of Annex I of the Directive 92/43/EEC: habitat 1110 "Sandbanks which are slightly covered by sea water all the time" (corresponding to SPA/BIO Protocol codes: III. 2.1, III. 2.2, III 3.1, III 3.2, III 4.1), including infralittoral sand banks covered by sea water at all times –whose level is seldom over 20 m and that are generally surrounded by deeper waters, and the habitat 1160 "Large shallow inlets and bays" (SPA/BIO codes: *Assemblages as in habitats 1110-1120-1140-1170 along the zones from supralittoral (I.), mediolittoral (II.) until infralittoral (III.) on Mud, Sands, Stones and Pebbles, Hard Beds and Rocks*).

The "Marine waters, hard bottoms" category includes the submerged marine habitats on hard bottoms. This category comprises: sea caves (habitat 8330 "Submerged or partially submerged sea caves"); reefs (habitat 1170 "Reefs"; SPA/BIO Protocol codes: II 4.3, vII. 4.3.1, vIV.3.2, IV. 3.2.1, vIV. 3.2.2, IV. 3.2.3, vV. 3.2); and habitat 1160 "Large shallow inlets and bays" which varies greatly according to the morphological characteristics and to the substrate type (rocky or sedimentary) (SPA/BIO codes: *Assemblages as in habitats 1110-1120-1140-1170 along the zones from supralittoral (I.), mediolittoral (II.) until infralittoral (III.) on Mud, Sands, Stones and Pebbles, Hard Beds and Rocks*).

The "*Posidonia oceanica* beds" category includes the priority habitat 1120* "Posidonia beds (*Posidonion oceanicae*)" (SPA/BIO code: III.5). *P. oceanica* (**figure 4.2.1.1**), an endemic species of the Mediterranean sea, can be found on the infralittoral (from few centimetres to 30-40 metres of depth) on rocks, sand and matte[16]. *P. oceanica* beds are one of the most important habitats of the Mediterranean, both for their role in the marine ecosystem (high primary production and biodiversity, reproduction and nursery areas for many species of invertebrates and fish) and for their stabilisation of the soft bottoms (trapping sediments and mitigating wave motion), which also means coastal protection against erosion.

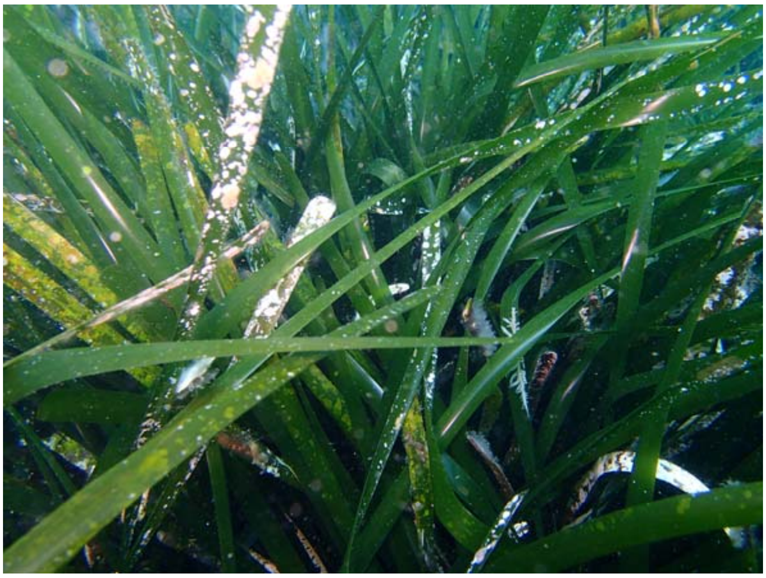

Figure 4.2.2.1 - Posidonia oceanica *bed (Photo by ISPRA).*

[16] The matte is a typical "terrace" formation, composed of a mixture of layers of old rhizomes and roots, and also including the sediments trapped between them and strongly compacted.

4.2.2 Wetlands and halophytic habitats

The category called "Estuarine and tidal systems" includes the complex environments of the downstream part of a river flowing into the sea, influenced by sea currents and by the mixture of freshwater and sea water (habitat 1130: "Estuaries"; SPA/BIO codes: *Assemblages as in habitats 1110-1140 along the zones from supralittoral (I.), mediolittoral (II.) until infralittoral (III.) on Mud and Sands*) as well as habitat 1140 "Mudflats and sandflats not covered by seawater at low tide" (SPA/BIO codes: II. 1, II. 1.1, II. 1.1.1, v II.1.1.2, II. 2, II. 2.1, II. 2.1.1).

The "Standing waters, temporary lakes and ponds" category includes all the habitats typical of shallow, temporary and non-temporary waterbodies on the coast, i.e. lakes and pools, small lagoons and ponds more or less isolated from the sea, and channels temporarily flooded. Waters vary from ologotrophic to mesotrophic and salty, and substrates are poor, muddy or sandy. The plant communities include both aquatic habitat communities (habitat 3140: "Hard oligo-mesotrophic waters with benthic vegetation of *Chara* spp."), and amphibian habitats (habitat 3120: "Oligotrophic waters containing very few minerals of sandy soils of the West Mediterranean with *Isoëtes* spp."; habitat 3130: "Oligotrophic to mesotrophic standing waters with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea"*; habitat 3170*: "Mediterranean temporary ponds").

The "Coastal brackish/saline lagoons" category includes all shallow brackish and saline lagoons, characterized by great seasonal variations of salinity and depth, and which are in direct or indirect contact with the sea. The habitats are characterized by brackish halophilous or sub-halophilous vegetation growing on sandy, muddy or clave soils subject to variations of salinity (from hyper-saline to meso-saline) and humidity (from flooded soils to soils subject to long dry periods). It includes the coastal lagoon communities (habitat 1150*; "Coastal lagoons"; SPA/BIO codes: III. 1, III. 1.1, vIII. 1.1.1, III. 1.1.2, vIII.1.1.3, vIII. 1.1.4, III. 1.1.5, III. 1.1.6, III. 1.1.7, vIII. 1.1.8, III. 1.1.9,III. 1.1.10, III. 1.1.11, III. 1.1.12), the *Salicornia* (habitat 1310: "*Salicornia* and other annuals colonizing mud and sand") (**figure 4.2.2.1a**), coastal zones with *Juncetalia maritime* communities (habitat 1410: "Mediterranean salt meadows (*Juncetalia maritimi*)") (**figure 4.2.2.1b**), *Spartina* perennial grasslands endemic of the North Adriatic coast (habitat 1320: "Spartina swards (*Spartinion maritimae*)"), halophilous perennial scrubs (habitat 1420: "Mediterranean and thermo-Atlantic halophilous scrubs (*Sarcocornietea fruticosi*)" and humid grasslands of tall grasses and rushes (habitat 6420: "Mediterranean tall humid grasslands of the *Molinio-Holoschoenion*"). It is to be noted that habitat 6420 also belongs to the physiographic category called "Interdune and backdune humid depressions", since it can also be found in those environments.

Figure 4.2.2.1a – Salicornia *vegetation (Santa Maria del Mare, Venice lagoon. Photo by S. Ercole).*

Figure 4.2.2.1b *– Mediterranenan salt meadows* (Juncetalia maritimi) *(Punta Sabbioni, Venice lagoon. Photo by S. Ercole).*

4.2.3 Dune habitats

Dune habitats have been subdivided into four physiographic categories with very distinctive morphological characteristics and are located in strips parallel to the shoreline, i.e. perpendicular to the ideal line going from the sea inland. perpendicular to the ideal line going from the sea inland. Along this line, there is a progressive variation of the physical factors (marine spray, sediment grain size and coherence, wind, salinity) influencing the dune communities (psammophilous communities). The foreshore area is called aphytoic zone, since it cannot be colonised by plants **(figure 4.2.3.1a).**

The first physiographic category that can be found going from the sea inland is the "Dry beach", characterized by annual halo-nitrophilous vegetation of the nearshore and of the depositional areas along the beaches (**figure 4.2.3.1b**) (habitat 1210: "Annual vegetation of drift lines"; and habitat 1310: "*Salicornia* and other annuals colonizing mud and sand").

Figure 4.2.3.1a - *Aphytoic zone (Cà Roman, Venice. Photo by S. Ercole).*

Figure 4.2.3.1b - *Sequence of plant communities adjacent to the aphytoic zone: drift lines vegetation (in the foreground), embryodunes and dunes with* Ammophila arenaria *(in the background) (Cà Roman, Venice. Photo by S. Ercole).*

The category "Embryodune and avandune" (**figure 4.2.3.2a**) is adjacent to the previous one, and includes both the area characterized by highly incoherent sands where the embryodunes originate, with *Agropyron junceum ssp. mediterraneum* communities (= *Elymus farctus ssp. farctus* = *Elytrigia juncea*) (habitat 2110: "Embryonic shifting dunes"), and the first dune system defined as 'shifting' or 'white' dunes. These dunes are characterized by the *Ammophila arenaria* community (habitat 2120: "Shifting dunes along the shoreline with *Ammophila arenaria* (white dunes)") (**figure 4.2.3.2b**) and, in the glades, by the annual vegetation of the habitat 2230: "*Malcolmietalia* dune grasslands".

Figure 4.2.3.2a - Embryodunes with Elytrigia juncea *communities, Ostia shoreline. Photo by S. Ercole).*

Figure 4.2.3.2b *- White dunes with* Ammophila arenaria *communities (Photo by A. Acosta).*

Moving away from the sea, there is the physiographic category called "Avandune continental side, fixed dune and stabilized sands" which includes a wide stretch extending from the continental side of the shifting dune (partly protected by salty winds and not reached by sea water) to the sector between the shifting and the fixed dunes (an area where sands are more coherent and where the influence of wind and marine spray is lower). This category includes the entire fixed dune, or 'grey' dune, where the sand substrate is compact and completely stabilized, and many habitats may occur.

The suffruticose vegetation with *Crucianella maritima* grows on the inner side of the shifting dunes with more stable and compact sands (habitat 2210: "*Crucianellion maritimae* fixed beach dunes"), next to the therophytic communities of dry interdunal depressions (habitat 2230: "*Malcolmietalia* dune grasslands").

On the inner dune cordon, characterized by greater stabilization of the substrate, there are Juniper formations (habitat code 2250*: "Coastal dunes with *Juniperus* spp."), *Pistacio-Rhamnetalia* sclerophyllous communities (**figure 4.2.3.3**), garigues replacing the scrubs because of fires or other forms of degradation (habitat 2260: "*Cisto-Lavanduletalia* dune sclerophyllous scrubs"); and, in the glades, the herbaceous communities of the habitat 2240: "*Brachypodietalia* dune grasslands with annuals".

In the inner and more stable part of the dune system, there are littoral pinewoods (habitat 2270*: "Wooded dunes with *Pinus pinea* and/or *Pinus pinaster*"). These are mostly human-made reforestations planted in different periods. In Italy, coastal pinewoods considered as native can be found only in few sites in Sardinia. In glades within these pinewoods there are annual herbaceous communities (habitat 6220*: "Pseudo-steppe with grasses and annuals of the *Thero-Brachypodietea*"), as well as parts of the native wood communities mentioned above, which naturally tend to colonize these areas.

This physiographic category also includes particular psammophilous communities, typical of the temperate macro-bioclimate, which can be found in Italy only along the northern Adriatic littoral (habitat 2130*: "Fixed coastal dunes with herbaceous vegetation (grey dunes)" and habitat 2160: "Dunes with *Hippophae rhamnoides*").

Figure 4.2.3.3 - *Fixed dunes colonized by* Juniper *formations (left) and sclerophyllous scrubs (right) (Piscinas, Sardinia. Photo by S. Ercole).*

The “Interdune and backdune humid depressions” physiograpic category is located in the backdune wetlands occasionally flooded by brackish waters, and is characterized by halophilous and sub-halophilous vegetation growing on substrates with medium-high percentages of sand. This category includes habitats that can also be found in brackish areas (indicated with *p.p.* in **Table 4.2.1**), belonging to another category.
Typical of this environment are the communities with salt meadows (habitat 1410: “Mediterranean salt meadows (*Juncetalia maritimi*)”, and Mediterranean beds of rushes and hygrophilous scrubs (habitat 6420: “Mediterranean tall humid grasslands of the *Molinio*-Holoschoenion”). It is noteworthy that, according to Biondi *et al.* (2009), the habitat 2190: “Humid dune slacks” is considered ‘not present’ in Italy since it can only be found in the Atlantic dune systems. Therefore, according to this interpretation, habitat 2190 is wrongly reported in Italy and should be partly referred to habitat code 6420.
In these environments, at the edge of the backdune brackish depression, on temporary wet clayey salty soils, there can also be halophilous beds belonging to the habitat 1510*: “Mediterranean salt steppes (*Limonietalia*)”. The latter are greatly affected by the salty water aquifer and, during the summer, they dry out forming saline efflorescence.

4.2.4 Cliff habitats

The "Rocky shores and cliff habitats" physiographic category (**figure 4.2.4.1**) includes all the rocky shores and cliff habitats. These habitats are characterized by chasmophytic, rupicolous and halo-rupicolous vegetation, mainly chamaephyte and nanophanerophyte, and by xerophilous frutescent vegetation growing on poor soils. Among the strictly rupicolous communities, there are chasmophytic communities, highly specialized and adapted to the sea aerosol, such as the endemic and micro-endemic communities with *Limonium* sp.pl. (habitat 1240: "Vegetated sea cliffs of the Mediterranean coasts with endemic *Limonium* spp.") and the communities of the limestone cliffs of the north-eastern Adriatic coast (Gulf of Trieste) (habitat 8210: "Calcareous rocky slopes with chasmophytic vegetation").
This category also includes frutescent communities such as nitrophilous or sub-nitrophilous scrubs growing on salty and arid soils of the clifftops (habitat 1430: "Halo-nitrophilous scrubs (*Pegano-Salsoletea*)"; thermo-Mediterranean shrubs dominated by *Euphorbia dendroides;* garigues with *Ampelodesmos mauritanicus*; *Chamaerops humilis* communities, *Periploca angustifolia* communities and thermo-Mediterranean *Genista* spp. communities (all belonging to the habitat 5330: "Thermo-Mediterranean and desert scrub"). There are also sub-halophilous littoral garigues, formed mainly by chamaephyte, such as *Euphorbia* spp. and *Helichrysum* spp., growing on lithosoils, in a stretch among the cliffstops and the Mediterranean scrub communities of adjacent areas (habitat 5320: "Low formations of Euphorbia close to cliffs").
Finally, the category includes the cushion-forming thermo-Mediterranean sclerophyllous formations, know as "phryganas" endemic of Sardinia (habitat 5410: "West Mediterranean clifftop phryganas") and of Sicily and Sardinia (habitat 5420: "*Sarcopoterium spinosum* phryganas" and habitat 5430: "Endemic phryganas of the *Euphorbio-Verbascion*").

Figure 4.2.4.1 - *Rocky coastal habitat (left) and a detail of some chasmophytic species (*Crithmum maritimum *and* Limonium *sp) (Torre Lapillo, Salento. Photo by S. Ercole).*

5. DEFINITION OF CRITERIA TO ASSOCIATE PROTECTED FLORA AND FAUNA SPECIES WITH PHYSIOGRAPHIC CATEGORIES

5.1 Protected, sensitive and/or endangered flora species

In order to assess the impacts of coastal defence works, the plant species that need to be considered are both those protected by international conventions, laws and treaties and those protected by regional legislation or included in the Red Lists.
All the plant species of the Italian littoral environments belonging to the following four categories must be therefore be taken into account:

1. species protected by the Bern Convention (Annex I);
2. species protected by 92/43/EC Directive (Annex II) and SPA/BIO Protocol (Barcelona Convention);
3. species protected by Italian regional laws;
4. Italian endangered species, included in the National and Regional Red Lists (Conti *et al*., 1992; 1997; Scoppola and Spampinato, 2005; Rossi *et al*., 2013).

In order to produce a generally applicable instrument that is also valid for different geographical contexts, it is extremely important to associate the single protected and endangered species (included in the four categories mentioned above) with the physiographic categories already identified. Therefore the association between flora species and habitats is very close in the littoral environments investigated, according to the ecological preferences of each species. These species are characterized by a very high ecological specificity that facilitates the association with the reference physiographic categories. The plant species belonging to each category are characterized by similar eco-physiological adaptations and in general terms they can react in a similar way to stress and disturbances induced by coastal defence works.

For each of the four species categories, some details and examples of important species are reported below, together with the physiographic category.

Species protected by the Bern Convention, the Habitats Directive and the SPA/BIO Protocol
These categories of species are considered of priority importance and can be treated together because many of the species included in the Habitats Directive (with specific reference to the marine environment examined by the Barcelona Convention - SPA/BIO Protocol) are also included in the Convention on the conservation of European wildlife and natural habitats (Bern Convention). Unfortunately, the number of species listed is limited, and they represent only a small portion of the coastal flora that would require protection.
Most of the marine flora species are protected by the Barcelona Convention (Annex 1 to the SPA/BIO Protocol), which lists 16 species.
All Italian flora species included in the Habitats Directive have been recently analyzed in the Red List of the Italian policy species (Rossi *et al*., 2013), which provides information on their status in Italy (IUCN category, version 3.2).
As an example, here below some species protected by the above mentioned regulations are associated with their physiographic category (**table 5.1**). In most cases, these are endemic species living in very limited areas. Endemicity and IUCN threat category are also indicated according to the National Red List of policy species (Rossi *et al*., 2013).

Tabella 5.1 - *Association of some plant species protected by European regulations with their physiographic category.*

MARINE SPECIES	**Bern Conv.**	**Habitats Dir.**	**SPA/BIO Protocol**	**IUCN Cat.**	**Endemicity**
Physiographic category: "*Posidonia oceanica* beds" (Marine habitats)					
Delile Posidonia oceanica (Linnaeus)	X	-	X	LC	endemic of the Mediterranean sea

TERRESTRIAL SPECIES	**Bern Conv.**	**Habitats Dir.**	**IUCN Cat.**	**Endemicity**
Physiographic category: "Coastal brackish/saline lagoons" (Wetlands and halophytic habitats)				
Limonium insulare (Bég. et Landi) Arrigoni et Diana	-	priority	EN	endemic of S-W Sardinia
Limonium pseudolaetum Arrigoni et Diana	-	priority	VU	endemic of Sardinia, Sinis peninsula
Salicornia veneta Pignatti et Lausi	X	priority	LC	-
Kosteletzkya pentacarpos (L.) Ledeb	X	X	CR	-
Physiographic category: "Avandune continental side, fixed dune and stabilized sands" (Dune habitats)				
Anchusa crispa Viv subsp. crispa	X	priority	EN	endemic of Sardinia and Corsica
Galium litorale Guss.	X	priority	NT	endemic of S/W Sicily
Linaria flava (Poir.) Desf. subsp. *sardoa* (Sommier) A. Terracc.	X	priority	EN	endemic of Sardinia and Corsica
Muscari gussonei (Parl.) Tod. [syn. *Leopoldia gussonei* Parl.]	X	priority	EN	endemic of Sicily
Rouya polygama (Desf.) Coincy	X	X	EN	-
Stipa veneta Moraldo	-	priority	EN	endemic of northern Adriatic
Physiographic Category: "Rocky shore and cliff habitats" (Cliff habitats)				
Astragalus maritimus Moris	X	priority	CR	endemic of S/W Sardinia
Bassia saxicola (Guss.) A.J. Schott (syn *Eokochia saxicola)*	X	priority	EN	endemic of southern Italy
Brassica macrocarpa Guss	X	priority	CR	endemic of the Egadi islands (Sicily)
Brassica insularis Moris	X	priority	NT	-
Campanula sabatia De Not.	X	X	VU	endemic of Liguria
Centaurea horrida Badarò	X	priority	EN	endemic of Sardinia
Centaurea kartschiana Scop.	X	X	LC	endemic of Trieste's Carso
Dianthus rupicola Biv.	X	X	LC	-
Limonium strictissimum (Salzm.) Arrigoni	-	priority	VU	endemic of Sardinia N/E
Primula palinuri Petagna	X	X	VU	endemic of the southern Tyrrhenian Italy
Silene velutina Loisel	X	priority	NT	-

Species protected by Regional Laws

A separate consideration must be made for the plant species protected by the regional laws for the protection of the flora. Most Italian regions have devised specific laws to safeguard their spontaneous flora; these laws list the species needing protection, which represent a certain portion of the regional flora (Alonzi *et al*., 2006). For the purpose of this study these group of species whose quantity, selection criteria and protection levels vary from region to region cannot be left out of consideration. While recognizing this lack of homogeneity, and the fact that most of the current laws need to be updated on the basis of new knowledge it is important to also consider this list of species. The group of species protected by single regional laws will also be considered in the study because the Italian species protected at international or European level only constitute a small part of the Italian coastal flora that is actually endangered.

As an example, here are some species protected by the regional law of Lazio Region n. 61 of 19-09-1974 (law for the protection of spontaneous flora), associated with the physiographic categories identified above:

- physiographic category "Coastal brackish/saline lagoons" (Wetlands and halophytic habitats): *Schoenus nigricans L.*
- physiographic category "Embryodune and avandune" (Dune habitats): *Ammophila arenaria* (L.) Link subsp. *australis* (Mabille) Laínz, *Otanthus maritimus* (L.) Hoffmanns. & Link subsp. *maritimus*, *Pancratium maritimum* L. (figure 5.1.1), *Daphne sericea* Vahl.
- physiographic category "Rocky shores and cliff habitats" (Cliff habitats): Chamaerops *humilis* L.


Figura 5.1.1 - Otanthus maritimus *(on the left) and* Pancratium *maritimum (on the right) typical species of dune habitats, and in particular of embryodunes and of mobile dunes (Photo by S. Ercole).*

Red List species

When analyzing risk and impact, it is important to also consider the Italian littoral species of the National and Regional Red Lists (Conti *et al*., 1992; 1997; Scoppola and Spampinato, 2005; Rossi et al., 2013). The importance of these plant species is evident, both because of their quantity and because they live in small, punctiform or detached areas and usually in highly endangered habitats. Many endemisms are also included in the analyses, such as big Italian islands, exclusive endemites of smaller islands (Tremiti, Egadi, Lampedusa, Linosa, Eolie etc.), and some paleo-endemisms. Concerning the specificity of territories, in addition to IUCN national assessment (Conti *et al*., 1992; Rossi *et al*., 2013) it is also useful to consider the regional assessments of the Regional Red Lists (Conti *et al*., 1997).

The following are examples of coastal species included by the Lazio Region in the Regional Red List:

- physiographic category "Dry beach" (Dune habitats): *Matthiola tricuspidata* (L.) R.Br. species of the Regional Red List (CR), *Cressa cretica* L. species of the Regional Red List (CR) and the National Red List (EN).
- physiographic category "Avandune continental side, fixed dune and stabilized sands" (Dune habitats): *Malcolmia littorea* (L.) R. Br. species of the Regional Red List (VU) and the National Red List (CR); *Ambrosia maritima* L. species of the Regional Red List (LR) and of Regional law n. 61 of 19-09-1974.

- physiographic category “Coastal brackish/saline lagoons” (Wetlands and halophytic habitats): *Alopecurus bulbosus* Gouan, species of the Regional Red List (LR); *Plantago maritima* L. species of the Regional Red List (LR); *Kosteletzkya pentacarpos* (L.) Ledeb. species of the National Red List (CR) of annex II to the Habitats Directive, and of Lazio Regional Red List (CR), probably already extinguished in the Region (Ercole *et al*., 2013).

5.2 Protected, sensitive and/or endangered fauna species

Given the high number of protected, sensitive and/or endangered fauna species mentioned in the different international conventions, laws and treaties examined (see **Chapter 3**), and in order to create a universally applicable instrument that is valid for different geographic contexts, we tried to identify a set of "objective" modalities to associate the single protected species with the physiographic categories already identified.

The criterion used to associate the species with the different habitats was the 'habitat use' criterion, which represents and describes how an individual uses the physical and biological resources of a given environment. A species can use a habitat to satisfy different needs, which may be biological, ecological and ethological (e.g. the different phases of the vital cycle like reproduction, feeding, mating etc.). The same species can therefore belong to more habitat categories, and the habitats can vary even in terms of space and time.

For certain avifauna species, for instance, the life cycle (and thus the habitats concerned) can involve different environments and different periods of the year: the reproduction and migrations take place in a certain time of the year and in different geographic areas. Furthermore some species in different seasons can have different feeding needs entailing the use of different habitats. For instance the *Phalacrocorax aristotelis* (European or common shag), species included in annex I of Birds Directive and in annex II of Bern Convention, is a marine bird which nests from November to March on rocky cliffs and feeds mainly on coastal waters. It is a stable species that uses two different habitats for nesting (rocky cliffs) and feeding activities (coastal waters).

In order to provide a single classification for all the animal *taxa* concerned (vertebrates and invertebrates), the 8 habitat use categories have been identified and described below:

- Resident and Sessile (RS): this category refers to organisms using the same habitat for all their needs (feeding, mating, reproduction, hibernation etc.) during all phases of their life cycle.
- Larval Recruitment and Settlement (LRS): this category refers to the larval recruitment and settlement phase and on the substrate and it is specific to invertebrates and fishes
- Feeding (F): this category identifies habitats used by young and adult for feeding.
- Nursery Area (NA): this category identifies areas where juveniles (in particular fish species) are concentrated.
- Reproduction and Mating (RM): this category refers to habitats used by species during the reproduction and/or mating phases.
- Nesting and eggs Deposition (ND): this category refers to habitats used by species during the nesting and eggs deposition phases only.
- Temporary Stop (TS): this category refers to habitats used by some species as shelter and/or for temporary stop for relatively short periods of time, ranging from some days to 1 month, as it is the case for migration stopovers.
- Prolonged Stop and Migration (PSM): this category refers to habitats used by some species as shelter and/or for temporary stop for longer periods of time, as it is the case for winter migratory species and to migration habitats (for example fish migration).

In the definition of habitat use categories it is also important to assess for each fauna species, the habitat use frequency on a temporary scale, that can be perennial or seasonal. In particular, if the habitat use frequency is seasonal, the reference season must also be indicated, with the aim to identify appropriated environmental windows (Dickerson *et al.*, 1998).

Finally, a last aspect to be considered is the habitat use scale, that is the portion of habitat really used by species and that can be local (as it is the case for nesting , ND) or wide (as it is the case for nursery areas, NA).

6. THE “STRUCTURE/IMPACT *VS* HABITAT/SPECIES” MATRIX SYSTEM

The purpose of the "structure/impact *vs* habitat/species" matrix-system, developed on a bibliographic basis, is to provide a simplified multidisciplinary tool of rapid application, which allows the *a priori* identification not only of the expected environmental impacts but also of their potential effects on habitats and protected flora and fauna species.
The matrix-system is intended to support Public Administrations and technicians involved in the assessment and preparation of Environmental Impact Studies. However it cannot be considered as a substitute for the requirements of the existing Environmental Impact Assessment (E.I.A.) legislation, as it aims only at the analysis of habitats and species of EU interest.

The system is organized in 9 “structure/impact *vs* habitat/species” matrices, referring to the specific categories of coastal defences listed below:

- seawalls and dikes;
- nearshore breakwaters (emerged and submerged) and artificial reef (offshore);
- groynes (permeable and impermeable);
- composite groynes;
- headlands;
- beach nourishment;
- beach drainage systems;
- dune reprofiling;
- windbreak fences, dune grass planting and dune access management.

The above-listed matrices group together different types of coastal defences producing similar physical effects on the environment. This choice resulted from the consideration that each physical effect produced by a coastal defence category can be associated with a specific impact on habitats and species.
The analysis of the main physical effects of coastal defences (**Chapter 2**), together with the analysis of the effects on biotic systems (**Chapter 3**), allowed to identify the main possible environmental impacts generated by each type of work. These effects and impacts were considered for both the construction phase (Phase C - Construction phase) and the functioning one (Phase O - Operational phase). The dismantling phase instead has not been considered, since coastal defences generally do not contemplate such phase.
In general, within each macro-environment (marine habitats, wetlands and halophytic habitats, dune habitats and cliff habitats), the matrices put in relation the expected effects and impacts with the specific physiographic categories involved. Within each physiographic category, each potential impact is then associated with the habitat types and their related protected flora and fauna species.

It is important to note that the matrices, though providing a list of the expected effects and impacts on habitats and species, do not provide information on their extent. In fact, the quantification of impacts requires a thorough knowledge of the project’s technical and design aspects and of the intervention area’s characteristics, such as morphodynamics and conservation status of habitats and species.

For the compilation of matrices the following steps have to be followed:

<u>Identification of the reference area</u>. The reference area must be identified through a preliminary survey, based on technical and environmental information acquired during the work design phase. The reference area is defined as the area directly and indirectly affected by potential effects of coastal defence works and it includes both the emerged and submerged environment.
<u>Identification of protected habitat types</u>. The physiographic categories occurring in the reference area must be identified through accurate bibliographic investigations and specific field surveys. The protected habitats types (*sensu* Habitats Directive) present for each categories must also be identified. It is important to note that, for the compilation of the matrix, all the physiographic categories present in the reference area must always be kept. In fact, even in the absence of protected habitat types, the reference area can be characterized by the presence of relevant protected flora and fauna species.
<u>Identification of protected flora species and their association to habitat types</u>. Through accurate bibliographic research and specific floristic field surveys, the flora species occurring in the reference

area must be identified, including both species directly linked to existing habitats and protected species under current legislation.
Identification of protected fauna species. Through accurate bibliographic research and specific field surveys, the census of all fauna species occurring in the reference area must be carried out, taking into account the regulations and conventions in force on fauna protection.
Association of protected fauna species to physiographic categories. Each protected fauna species identified in the reference area must be associated to one or more habitat use categories, specifying the scale of use (local or wide) and the frequency of use (perennial or seasonal), also in order of possibly identifying adequate environmental windows in which the defence works can be put in place thus minimising the impact.

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The 9 "structure/impact *vs* habitat/species" matrices are listed below. For an easier reading and understanding of the matrices, an information chart is provided, containing useful definitions and in-depth explanations.

INFORMATION CHART ON THE MATRIX-SIYSTEM	
Reference area	The area interested by the direct and indirect effects induced by coastal defence structures and including both the emerged and submerged environments.
Impacts on protected habitat and species	In the present work we consider only the impacts related to construction and operational phases of coastal defence structures, paying particular attention to those ones affecting protected habitat and their associated flora and fauna species. An Environmental Impact Assessment will have to take into account all the requirements dictated by current laws.
Accidental impacts and/or impacts deriving from planning and/or construction errors of the defence structures	Not considered.
Impacts on the landscape	Not considered.
Pollutants release into the environment	We assume that the terrestrial machinery and the boats used for the construction/development of the defence structures comply with the current regulations on pollutants release into the environment. This work has not considered the impacts linked to contaminant release from non-natural materials used for the realization of the defence structures (such as non-textile fabrics, geotextiles etc.), because the absence of contaminant-release needs to be previously ascertained.
Sediment accumulation and/or beach accretion, in both its emerged and submerged portions	The beach accumulation and/or accretion phenomena are not considered as impacts in the present work, as the intervention aims at restoring the pre-erosion situation.
The Construction Phase and the Operational Phase	The Construction Phase (C) is the period of time during which the construction works are in progress, and it is characterized by the presence of workers and mechanical vehicles and machines. The Operational Phase (O) is the period of time in which the defence structure is operational. In the particular case of nourishment, the construction phase includes both the phase in which the sediment is dumped and generally distributed with mechanical machines along the whole area of intervention, and the subsequent period of time in which wave motion reshapes the profile of the beach (emerged and submerged), up to the development of an equilibrium profile. This study does not take into account the work's dismantling phase because coastal defence interventions generally only consider the maintenance phases and not the dismissal phase.
Protected flora species	See the protected habitat types *sensu* Habitats Directive.
Habitat Use categories for protected fauna species	Legend: RS – Resident and Sessiles LRS – Larval Recruitment and Settlement F – Feeding NA – Nursery Area

	RM –Reproduction and Mating ND – Nesting and Deposition TS – Temporary Stop PSM – Prolonged Stop and Migration
Physiographic categories and Habitat types *sensu* Habitats Directive	Protected coastal habitat are defined based on the types of habitats listed in Annex I of the Directive 92/43/EEC (Habitats Directive). Habitats are subdivided into territorial-environmental units called "physiographic categories". These units were identified based on morphogenetic, lythomorphologic and pedological homogeneity criteria. Physiographic Categories: M1 - Marine waters, soft bottoms M2 - Marine waters, hard bottoms M3 - *Posidonia oceanica* beds W1 - Estuarine and tidal systems W2 - Standing waters, temporary lakes and ponds W3 - Coastal brackish/saline lagoons D1 - Dry beach D2 - Embryodune and avandune D3 - Avandune continental side, fixed dune and stabilized sands D4 - Interdune and backdune humid depressions C1 - Rocky shores and cliffs habitats Protected habitat types *sensu* Habitats Directive (code): 1110 - Sandbanks which are slightly covered by sea water all the time 1160 - Large shallow inlets and bays, on soft bottoms 1170 - Reefs 8330 - Submerged or partially submerged sea caves 1120* - *Posidonia* beds (Posidonion oceanicae) 1130 - Estuaries" 1140 - Mudflats and sandflats not covered by seawater at low tide 3120 - Oligotrophic waters containing very few minerals generally on sandy soils of the West Mediterranean, with *Isoëtes* spp. 3130 - Oligotrophic to mesotrophic standing waters with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea* 3140 - Hard oligo-mesotrophic waters with benthic vegetation of *Chara* spp. 3170* - Mediterranean temporary ponds 1150* - Coastal lagoons 1310 - *Salicornia* and other annuals colonizing mud and sand 1320 - Spartina swards (*Spartinion maritimae*) 1410 - Mediterranean salt meadows (*Juncetalia maritimi*) 1420 - Mediterranean and thermo-Atlantic halophilous scrubs (*Sarcocornietea fruticosi*) 1430 - Halo-nitrophilous scrubs (*Pegano-Salsoletea*) 6420 - Mediterranean tall humid grasslands of the Molinio-Holoschoenion 1210 - Annual vegetation of drift lines

	2110 - Embryonic shifting dunes 2120 - Shifting dunes along the shoreline with *Ammophila arenaria* (white dunes) 2130* - Fixed coastal dunes with herbaceous vegetation (grey dunes) 2160 - Dunes with *Hippophae rhamnoides* 2210 - *Crucianellion maritimae* fixed beach dunes 2230 - *Malcolmietalia* dune grasslands 2240 - *Brachypodietalia* dune grasslands with annuals 2250* - Coastal dunes with *Juniperus* spp. 2260 - *Cisto-Lavanduletalia* dune sclerophyllous scrubs 6220* - Pseudo-steppe with grasses and annuals of the *Thero-Brachypodietea* 1510* - Mediterranean salt steppes (*Limonietalia*) 1240 - Vegetated sea cliffs of the Mediterranean coasts with endemic *Limonium* spp. 5320 – Low formations of *Euphorbia* close to cliffs 5330 - Thermo-Mediterranean and pre-desert scrub 5410 - West Mediterranean clifftop phryganas (*Astragalo-Plantaginetum subulatae*) 5420 - *Sarcopoterium spinosum* phryganas 5430 - Endemic phryganas of the *Euphorbio-Verbascion* 8210 - Calcareous rocky slopes with chasmophytic vegetation *Priority habitats are reported with an asterisk (*)*
Noise	Noise does not have effects on habitats and associated flora species. For this reason, the ‘noise’ impact has been indicated in the matrices as “non present” (n.p.). The impacts of noise on habitat-related protected fauna categories must however be considered.

MATRIX 1: SEAWALLS AND DIKES

MACRO-ENVIRONMENTS	MAIN PHYSICAL EFFECTS	Phases (C/O)	MAIN POTENTIAL IMPACTS	CATEGORIES, HABITAT AND SPECIES AFFECTED BY IMPACTS		
				Physiographic categories	Habitat types and associated flora species	Habitat Use Categories (fauna species)
MARINE HABITATS (M)	Loss of substrate linked to structure placement operations	C/O	Loss and/or variations of habitat, and flora and fauna species	M1	1110, 1160	RS, LRS, F, ND, RM, NA
	Substrate variations linked to possible down-drift erosion phenomena	O	Habitat loss and/or variations, with effects on the flora and fauna (e.g. changes in species composition)	M1	1110, 1160	
				M3	1120*	
	Turbidity and suspended load linked to movement of sediments	C	Effects on the flora (e.g. a decreased photosynthetic ability) and on the fauna (e.g. a decreased predatory ability)	M1	1110, 1160	RS, NA, F, LRS, RM, PSM
				M2	1160, 1170, 8330	
				M3	1120*	
	Trampling	C	Effects on the flora and fauna	M1	1110, 1160	RS, LRS, ND
	Noise	C	Effects on the fauna (e.g. disturbance in fish and marine reptile species)	M1	n.p.	RS, F, NA, RM, ND, PSM
				M2		
				M3		
WETLANDS AND HALOPHYTIC HABITATS (W)	Turbidity and suspended load linked to movement of sediments	C	Effects on the flora (e.g. a decreased photosynthetic ability) and on the fauna (e.g. a decreased predatory ability)	W1	1130, 1140	RS, NA, F, LRS, RM, PSM
	Noise	C	Effects on the fauna (e.g. disturbance in the bird fauna, reptile and mammals)	W1	n.p.	RS, F, NA, RM, ND, TS, PSM
				W2		
				W3		
DUNE HABITATS (D)	Loss of substrate linked to structure placement operations	C/O	Loss and/or variations of habitat, and flora and fauna species	D1	1210, 1310	RS, LRS, F, ND, RM, TS, PSM
				D2	2110, 2120, 2230	
				D3	2130*, 2160, 2210, 2230, 2240, 2250*, 2260, 6220*	
	Loss of substrate linked to possible down-drift erosion phenomena	O	Habitat loss and/or variations, with effects on the flora and fauna (e.g. changes in species composition)	D1	1210, 1310	
				D2	2110, 2120, 2230	
				D3	2130*, 2160, 2210, 2230, 2240, 2250*, 2260, 6220*	
	Trampling	C	Effects on the flora and fauna (e.g. invertebrates, birds and, in D1, marine reptiles)	D1	1210, 1310	RS, LRS, ND
				D2	2110, 2120, 2230	
				D3	2130*, 2160, 2210, 2230, 2240, 2250*, 2260, 6220*	
				D4	1410, 1510*, 6420	
	Noise	C	Effects on the fauna (e.g. disturbance in bird, reptile and mammal species)	D1	n.p.	RS, F, RM, ND, TS, PSM
				D2		
				D3		
				D4		
CLIFF HABITATS (C)	Noise	C	Effects on the fauna (e.g. disturbance in bird species)	C1	n.p.	RS, F, RM, ND, TS, PSM

MATRIX 2: NEARSHORE BREAKWATERS (EMERGED AND SUBMERGED) AND ARTIFICIAL REEFS (OFFSHORE)						
MACRO-ENVIRONMENTS	MAIN PHYSICAL EFFECTS	Phases (C/O)	MAIN POTENTIAL IMPACTS	CATEGORIES, HABITAT AND SPECIES AFFECTED BY IMPACTS		
				Physiographic categories	Habitat types and associated flora species	Habitat Use Categories (fauna species)
MARINE HABITATS (M)	Loss of substrate linked to structure placement operations	C/O	Loss and/or variation of habitat and of flora and fauna species	M1	1110, 1160	RS LRS F ND RM NA
	Substrate variations linked to the changed hydrodynamic conditions	O	Habitat loss and/or variations, with effects on the flora and fauna (e.g. changes in species composition)	M1	1110, 1160	
				M3	1120*	
	Turbidity and suspended load, linked to movement of sediments	C	Effects on the flora (e.g. a decreased photosynthetic ability) and on the fauna (e.g. a decreased predatory ability)	M1	1110, 1160	RS NA F LRS RM PSM
				M2	1160, 1170, 8330	
				M3	1120*	
	Eutrophication linked to the reduced water exchange	O	Effects on the flora and on the fauna (e.g. algal bloom and anoxia phenomena)	M1	1110, 1160	RS LRS NA F ND RM PSM
	Trampling	C	Effects on the flora and fauna	M1	1110, 1160	RS LRS ND
	Noise	C	Effects on the fauna (e.g. disturbance in fish and marine reptile species)	M1	n.p.	RS F NA RM PSM
				M2		
				M3		
WETLANDS AND HALOPHYTIC HABITATS (W)	Loss of substrate linked to structure placement operations	C/O	Loss and/or variation of habitat and of flora and fauna species	W1	1130, 1140	RS LRS F ND R NA TS PSM
	Substrate variations linked to the changed hydrodynamic conditions	O	Habitat loss and/or variations, with effects on the flora and fauna (e.g. changes in species composition)			
	Turbidity and suspended load linked to movement of sediments	C	Effects on the flora (e.g. a decreased photosynthetic ability) and on the fauna (e.g. a decreased predatory ability)	W1	1130, 1140	RS NA F LRS RM PSM
	Eutrophication linked to the reduced water exchange	O	Effects on the flora and on the fauna (e.g. algal bloom and anoxia phenomena)	W1	1130, 1140	RS LRS NA F ND RM PSM
	Trampling	C	Effects on the flora and fauna	W1	1130, 1140	RS LRS ND
	Noise	C	Effects on the fauna (e.g. disturbance in bird, reptile and mammal species)	W1	n.p.	RS F NA RM ND TS PSM
				W2		
				W3		
DUNE HABITATS (D)	Loss of substrate linked to possible down-drift erosion phenomena	O	Habitat loss and/or variations, with effects on the flora and fauna (e.g. changes in species composition)	D1	1210, 1310	RS LRS F ND RM TS PSM
				D2	2110, 2120, 2230	
				D3	2130*, 2160, 2210, 2230, 2240, 2250*, 2260, 6220*	
	Trampling	C	Effects on the flora and fauna (e.g. invertebrates, birds and, in D1, marine reptiles)	D1	1210, 1310	RS LRS ND
				D2	2110, 2120, 2230	
				D3	2130*, 2160, 2210, 2230, 2240, 2250*, 2260, 6220*	
				D4	1410, 1510*, 6420	
	Noise	C	Effects on the fauna (e.g. disturbance in bird, reptile and mammal species)	D1	n.p.	RS F RM ND TS PSM
				D2		
				D3		
				D4		
CLIFF HABITATS (C)	Noise	C	Effects on the fauna (e.g. disturbance in bird species)	C1	n.p.	RS F RM ND TS PSM

MATRIX 3: GROYNES (PERMEABLE AND IMPERMEABLE)						
MACRO-ENVIRONMENTS	MAIN PHYSICAL EFFECTS	Phases (C/O)	MAIN POTENTIAL IMPACTS	CATEGORIES, HABITAT AND SPECIES AFFECTED BY IMPACTS		
				Physiographic categories	Habitat types and associated flora species	Habitat Use Categories (fauna species)
MARINE HABITATS (M)	Loss and/or variation of habitat and of flora and fauna species	C/O	Loss and/or variation of habitat and of flora and fauna species	M1	1110, 1160	RS LRS F ND RM NA
	Substrate variations linked to the changed hydrodynamic conditions	O	Habitat loss and/or variations, with effects on the flora and fauna (e.g. changes in species composition)	M1	1110, 1160	
				M3	1120*	
	Turbidity and suspended load linked to movement of sediments	C	Effects on the flora (e.g. a decreased photosynthetic ability) and on the fauna (e.g. a decreased predatory ability)	M1	1110, 1160	RS NA F LRS RM PSM
				M2	1160, 1170, 8330	
				M3	1120*	
	Trampling	C	Effects on the flora and fauna	M1	1110, 1160	RS LRS ND
	Noise	C	Effects on the fauna (e.g. disturbance in fish and marine reptile species)	M1	n.p.	RS F NA RM ND PSM
				M2		
				M3		
WETLANDS AND HALOPHYTIC HABITATS (W)	Loss of substrate linked to structure placement operations	C/O	Loss and/or variation of habitat and of flora and fauna species	W1	1130, 1140	RS LRS F ND RM TS PSM
	Substrate variations linked to the changed hydrodynamic conditions	O	Habitat loss and/or variations, with effects on the flora and fauna (e.g. changes in species composition)			
	Turbidity and suspended load linked to movement of sediments	C	Effects on the flora (e.g. a decreased photosynthetic ability) and on the fauna (e.g. a decreased predatory ability)	W1	1130, 1140	RS NA F LRS RM PSM
	Trampling	C	Effects on the flora and fauna	W1	1130, 1140	RS LRS ND
	Noise	C	Effects on the fauna (e.g. disturbance in bird, reptile and mammal species)	W1	n.p.	RS F NA RM ND TS PSM
				W2		
				W3		
DUNE HABITATS (D)	Loss of substrate linked to structure placement operations	C/O	Loss and/or variation of habitat and of flora and fauna species	D1	1210, 1310	RS LRS F ND RM TS PSM
				D2	2110, 2120, 2230	
				D3	2130*, 2160, 2210, 2230, 2240, 2250*, 2260, 6220*	
	Loss of substrate linked to possible down-drift erosion phenomena related to the permeability of the structure	O	Habitat loss and/or variations, with effects on the flora and fauna (e.g. changes in species composition)	D1	1210, 1310	
				D2	2110, 2120, 2230	
				D3	2130*, 2160, 2210, 2230, 2240, 2250*, 2260, 6220*	
	Trampling	C	Effects on the flora and fauna (e.g. invertebrates, birds and, in D1, marine reptiles)	D1	1210, 1310	RS LRS ND
				D2	2110, 2120, 2230	
				D3	2130*, 2160, 2210, 2230, 2240, 2250*, 2260, 6220*	
				D4	1410, 1510*, 6420	
	Noise	C	Effects on the fauna (e.g. disturbance in bird, reptile and mammal species)	D1	n.p.	RS F RM ND TS PSM
				D2		
				D3		
				D4		
CLIFF HABITATS (C)	Noise	C	Effects on the fauna (e.g. disturbance in bird species)	C1	n.p.	RS F RM ND TS PSM

MATRIX 4: COMPOSITE GROYNES						
MACRO-ENVIRONMENTS	MAIN PHYSICAL EFFECTS	Phases (C/O)	MAIN POTENTIAL IMPACTS	CATEGORIES, HABITAT AND SPECIES AFFECTED BY IMPACTS		
				Physiographic categories	Habitat types and associated flora species	Habitat Use Categories (fauna species)
MARINE HABITATS (M)	Loss of substrate linked to structure placement operations	C/O	Loss and/or variation of habitat and of flora and fauna species	M1	1110, 1160	RS LRS F ND RM NA
	Substrate variations linked to the changed hydrodynamic conditions	O	Habitat loss and/or variations, with effects on the flora and fauna (e.g. changes in species composition)	M1	1110, 1160	
				M3	1120*	
	Turbidity and suspended load linked to movement of sediments	C	Effects on the flora (e.g. a decreased photosynthetic ability) and on the fauna (e.g. a decreased predatory ability)	M1	1110, 1160	RS NA F LRS RM PSM
				M2	1160, 1170, 8330	
				M3	1120*	
	Eutrophication linked to the reduced water exchange	O	Effects on the flora and on the fauna (e.g. algal bloom and anoxia phenomena)	M1	1110, 1160	RS LRS NA F ND RM PSM
	Trampling	C	Effects on the flora and fauna	M1	1110, 1160	RS LRS ND
	Noise	C	Effects on the fauna (e.g. disturbance in fish and marine reptile species)	M1	n.p.	RS F NA RM ND PSM
				M2		
				M3		
WETLANDS AND HALOPHYTIC HABITATS (W)	Loss of substrate linked to structure placement operations	C/O	Loss and/or variation of habitat and of flora and fauna species	W1	1130, 1140	RS LRS F ND RM TS PSM
	Substrate variations linked to the changed hydrodynamic conditions	O	Habitat loss and/or variations, with effects on the flora and fauna (e.g. changes in species composition)			
	Turbidity and suspended load linked to movement of sediments	C	Effects on the flora (e.g. a decreased photosynthetic ability) and on the fauna (e.g. a decreased predatory ability)	W1	1130, 1140	RS NA F LRS RM PSM
	Eutrophication linked to the reduced water exchange	O	Effects on the flora and on the fauna (e.g. algal bloom and anoxia phenomena)	W1	1130, 1140	RS LRS NA F ND RM PSM
	Trampling	C	Effects on the flora and fauna	W1	1130, 1140	RS LRS ND
	Noise	C	Effects on the fauna (e.g. disturbance in bird, reptile and mammal species)	W1	n.p.	RS F NA RM ND TS PSM
				W2		
				W3		
DUNE HABITATS (D)	Loss of substrate linked to structure placement operations	C/O	Loss and /or variation of habitat and of flora and fauna species	D1	1210, 1310	RS LRS FND RM TS PSM
				D2	2110, 2120, 2230	
				D3	2130*, 2160, 2210, 2230, 2240, 2250*, 2260, 6220*	
	Loss of substrate linked to possible down-drift erosion phenomena	O	Habitat loss and/or variations, with effects on the flora and fauna (e.g. changes in species composition)	D1	1210, 1310	
				D2	2110, 2120, 2230	
				D3	2130*, 2160, 2210, 2230, 2240, 2250*, 2260, 6220*	
	Trampling	C	Effects on the flora and fauna (e.g. invertebrates, birds and, in D1, marine reptiles)	D1	1210, 1310	RS LRS ND
				D2	2110, 2120, 2230	
				D3	2130*, 2160, 2210, 2230, 2240, 2250*, 2260, 6220*	
				D4	1410, 1510*, 6420	
	Noise	C	Effects on the fauna (e.g. disturbance in bird, reptile and mammal species)	D1	n.p.	RS F RM ND TS PSM
				D2		
				D3		
				D4		
CLIFF HABITATS (C)	Noise	C	Effects on the fauna (e.g. disturbance in bird species)	C1	n.p.	RS F RM ND TS PSM

MATRIX 5: HEADLANDS						
MACRO-ENVIRONMENTS	MAIN PHYSICAL EFFECTS	Phases (C/O)	MAIN POTENTIAL IMPACTS	CATEGORIES, HABITAT AND SPECIES AFFECTED BY IMPACTS		
				Physiographic categories	Habitat types and associated flora species	Habitat Use Categories (fauna species)
MARINE HABITATS (M)	Loss of substrate linked to structure placement operations	C/O	Loss and/or variation of habitat and of flora and fauna species	M1	1110, 1160	RS LRS F ND RM NA
	Substrate variations linked to the changed hydrodynamic conditions	O	Habitat loss and/or variations, with effects on the flora and fauna (e.g. changes in species composition)	M1	1110, 1160	RS LRS F ND RM NA
				M3	1120*	
	Turbidity and suspended load linked to movement of sediments	C	Effects on the flora (e.g. a decreased photosynthetic ability) and on the fauna (e.g. a decreased predatory ability)	M1	1110, 1160	RS NA F LRS RM PSM
				M2	1160, 1170, 8330	
				M3	1120*	
	Noise	C	Effects on the fauna (e.g. disturbance in fish and marine reptile species)	M1	n.p.	RS F NA RM ND PSM
				M2		
				M3		
WETLANDS AND HALOPHYTIC HABITATS (W)	Loss of substrate linked to structure placement operations	C/O	Loss and/or variation of habitat and of flora and fauna species	W1	1130, 1140	RS LRS F ND RM NA TS PSM
	Substrate variations linked to the changed hydrodynamic conditions	O	Habitat loss and/or variations, with effects on the flora and fauna (e.g. changes in species composition)	W1	1130, 1140	RS LRS F ND RM NA TS PSM
	Turbidity and suspended load linked to movement of sediments	C	Effects on the flora (e.g. a decreased photosynthetic ability) and on the fauna (e.g. a decreased predatory ability)	W1	1130, 1140	RS NA F LRS RM PSM
	Noise	C	Effects on the fauna (e.g. disturbance in bird, reptile and mammal species)	W1	n.p.	RS F NA RM ND TS PSM
				W2		
				W3		
DUNE HABITATS (D)	Loss of substrate linked to structure placement operations	C/O	Loss and/or variation of habitat and of flora and fauna species	D1	1210, 1310	RS LRS F ND RM TS PSM
				D2	2110, 2120, 2230	
				D3	2130*, 2160, 2210, 2230, 2240, 2250*, 2260, 6220*	
	Substrate variations linked to the changed hydrodynamic conditions	O	Habitat loss and/or variations, with effects on the flora and fauna (e.g. changes in species composition)	D1	1210, 1310	RS LRS F ND RM TS PSM
				D2	2110, 2120, 2230	
				D3	2130*, 2160, 2210, 2230, 2240, 2250*, 2260, 6220*	
	Trampling	C	Effects on the flora and fauna (e.g. invertebrates, birds and, in D1, marine reptiles)	D1	1210, 1310	RS LRS ND
				D2	2110, 2120, 2230	
				D3	2130*, 2160, 2210, 2230, 2240, 2250*, 2260, 6220*	
				D4	1410, 1510*, 6420	
	Noise	C	Effects on the fauna (e.g. disturbance in bird, reptile and mammal species)	D1	n.p.	RS F RM ND TS PSM
				D2		
				D3		
				D4		
CLIFF HABITATS (C)	Noise	C	Effects on the fauna (e.g. disturbance in bird species)	C1	n.p.	RS F RM ND TS PSM

MATRIX 6: BEACH NOURISHMENT						
MACRO-ENVIRONMENTS	MAIN PHYSICAL EFFECTS	Phases (C/O)	MAIN POTENTIAL IMPACTS	CATEGORIES, HABITAT AND SPECIES AFFECTED BY IMPACTS		
				Physiographic categories	Habitat types and associated flora species	Habitat Use Categories (fauna species)
MARINE HABITATS (M)	Loss and/or variation of substrate linked to sediment dumping on sea bottom	C/O	Habitat loss and/or variations, with effects on the flora and fauna (e.g. suffocation and burial)	M1	1110, 1160	RS LRS F ND RM NA
	Substrate variations linked to the type of sediment dumped	O	Habitat loss and/or variations, with effects on the flora and fauna (e.g. changes in species composition)			
	Turbidity and suspended load linked to movement of sediments	C	Effects on the flora (e.g. a decreased photosynthetic ability) and on the fauna (e.g. a decreased predatory ability)	M1	1110, 1160	RS NA F LRS RM PSM
				M2	1160, 1170, 8330	
				M3	1120*	
	Over-sedimentation (on all types of bottoms) and consequent bottom instability (soft bottoms only) linked to movement of sediments	C	Effects on the flora and fauna (e.g. problems in the larval settling phase, burial)	M1	1110, 1160	RS LRS ND
				M2	1160, 1170, 8330	
				M3	1120*	
	Noise	C	Effects on the fauna (e.g. disturbance in fish and marine reptile species)	M1	n.p.	RS F NA RM ND PSM
				M2		
				M3		
WETLANDS AND HALOPHYTIC HABITATS (W)	Loss and/or variation of substrate linked to sediment dumping on sea bottom	C/O	Habitat loss and/or variations, with effects on the flora and fauna (e.g. suffocation and burial)	W1	1130, 1140	RS LRS F ND RM NA
	Substrate variations linked to the type of sediment dumped	O	Habitat loss and/or variations, with effects on the flora and fauna (e.g. changes in species composition)			TS PSM
	Turbidity and suspended load, linked to movement of sediments	C	Effects on the flora (e.g. a decreased photosynthetic ability) and on the fauna (e.g. a decreased predatory ability)	W1	1130, 1140	RS NA F LRS RM PSM
	Over-sedimentation (on all types of bottoms) and consequent bottom instability (soft bottoms only) linked to movement of sediments	C	Effects on the flora and fauna (e.g. problems in the larval settling phase, burial)	W1	1130, 1140	RS LRS ND
	Noise	C	Effects on the fauna (e.g. disturbance in bird, reptile and mammal species)	W1	n.p.	RS F NA RM ND TS PSM
				W2		
				W3		
DUNE HABITATS (D)	Loss and/or variation of substrate linked to sediment dumping on sea bottom	C/O	Habitat loss and/or variations, with effects on the flora and fauna (e.g. suffocation and burial)	D1	1210, 1310	RS LRS F ND RM TS PSM
	Substrate variations linked to the type of sediment dumped	O	Habitat loss and/or variations, with effects on the flora and fauna (e.g. changes in species composition)			
	Trampling	C	Effects on the flora and fauna (e.g. invertebrates, birds and, in D1, marine reptiles)	D1	1210, 1310	RS LRS ND
				D2	2110, 2120, 2230	
				D3	2130*, 2160, 2210, 2230, 2240, 2250*, 2260, 6220*	
				D4	1410, 1510*, 6420	
	Noise	C	Effects on the fauna (e.g. disturbance in bird, reptile and mammal species)	D1	n.p.	RS F RM ND TS PSM
				D2		
				D3		
				D4		
CLIFF HABITATS (C)	Noise	C	Effects on the fauna (e.g. disturbance in bird species)	C1	n.p.	RS F RM ND TS PSM

MATRIX 7: BEACH DRAINAGE SYSTEMS						
MACRO-ENVIRONMENTS	MAIN PHYSICAL EFFECTS	Phases (C/O)	MAIN POTENTIAL IMPACTS	CATEGORIES, HABITAT AND SPECIES AFFECTED BY IMPACTS		
				Physiographic categories	Habitat types and associated flora species	Habitat Use Categories (fauna species)
MARINE HABITATS (M)	Noise	C	Effects on the fauna (e.g. disturbance in bird, reptile and mammal species)	M1	1110, 1160	RS F NA RM ND PSM
				M2	1160, 1170, 8330	
				M3	1120*	
WETLANDS AND HALOPHYTIC HABITATS (W)	Noise	C	Effects on the fauna (e.g. disturbance in bird, reptile and mammal species)	W1	n.p.	RS F NA RM ND TS PSM
				W2		
				W3		
DUNE HABITATS (D)	Removal/movement of substrate linked to structure placement operations (drainage systems and drainage pipes)	C	Loss of habitat and of flora and fauna species	D1	1210, 1310	RS LRS F ND RM TS PSM
	Loss of substrate linked to structure placement operations (catch basins)	C/O	Loss of habitat and of flora and fauna species	D1	1210, 1310	
	Variations in the piezometric levels of the underground waters	O	Effects on the flora species	D1	1210, 1310	
	Trampling	C	Effects on the flora and fauna (e.g. invertebrates, birds and, in D1, marine reptiles)	D1	1210, 1310	RS LRS ND
				D2	2110, 2120, 2230	
				D3	2130*, 2160, 2210, 2230, 2240, 2250*, 2260, 6220*	
				D4	1410, 1510*, 6420	
	Noise	O	Effects on the fauna (e.g. disturbance in bird, reptile and mammal species)	D1	n.p.	RS F RM ND TS PSM
				D2		
				D3		
				D4		
CLIFF HABITATS (C)	Noise	C	Effects on the fauna (e.g. disturbance in bird species)	C1	n.p.	RS F RM ND TS PSM

MATRIX 8: DUNE REPROFILING						
MACRO-ENVIRONMENTS	MAIN PHYSICAL EFFECTS	Phases (C/O)	MAIN POTENTIAL IMPACTS	CATEGORIES, HABITAT AND SPECIES AFFECTED BY IMPACTS		
				Physiographic categories	Habitat types and associated flora species	Habitat Use Categories (fauna species)
MARINE HABITATS (M)	Noise	C	Effects on the fauna (e.g. disturbance in bird, reptile and mammal species)	M1 M2 M3	n.p.	RS F NA RM ND PSM
WETLANDS AND HALOPHYTIC HABITATS (W)	Noise	C	Effects on the fauna (e.g. disturbance in bird, reptile and mammal species)	W1 W2 W3	n.p.	RS F NA RM ND TS PSM
DUNE HABITATS (D)	Substrate variations linked to sediment dumping	C	Habitat loss and/or variations, with effects on the flora and fauna (e.g. burial, suffocation)	D2	2110, 2120, 2230	RS LRS F ND RM
				D3	2130*, 2160, 2210, 2230, 2240, 2250*, 2260, 6220*	
	Trampling	C	Effects on the flora and fauna (e.g. invertebrates, birds and, in D1 only, marine reptiles)	D1	1210, 1310	RS LRS ND
				D2	2110, 2120, 2230	
				D3	2130*, 2160, 2210, 2230, 2240, 2250*, 2260, 6220*	
	Noise	C	Effects on the fauna (e.g. disturbance in bird species)	D1 D2 D3 D4	n.p.	RS F RM ND TS PSM
CLIFF HABITATS (C)	Noise	C	Effects on the fauna (e.g. disturbance in bird species)	C1	n.p.	RS F RM ND TS PSM

MATRIX 9: WINDBREAK FENCES, DUNE GRASS PLANTING AND DUNE ACCESS MANAGEMENT						
MACRO-ENVIRONMENTS	**MAIN PHYSICAL EFFECTS**	**Phases (C/O)**	**MAIN POTENTIAL IMPACTS**	**CATEGORIES, HABITAT AND SPECIES AFFECTED BY IMPACTS**		
				Physiographic categories	**Habitat types and associated flora species**	**Habitat Use Categories (fauna species)**
DUNE HABITATS (D)	Trampling	C	Effects on the flora and fauna (e.g. invertebrates, birds and, in D1 only, marine reptiles)	D1	1210, 1310	RS LRS ND
				D2	2110, 2120, 2230	
				D3	2130*, 2160, 2210, 2230, 2240, 2250*, 2260, 6220*	

BIBLIOGRAPHY

ALONZI A., ERCOLE S., PICCINI C. (2006) - La protezione delle specie della flora e della fauna selvatica: quadro di riferimento legislativo regionale. Rapporto APAT n. **75**/2006.

APAT - Agenzia per la Protezione dell'Ambiente e Servizi Tecnici dello Stato (2007) - Atlante delle opere di sistemazione costiera. Manuali e linee guida APAT, **44**/2007: 169 pp.

BELLAN-SANTINI D., BELLAN G., BITAR G., HARMELIN J.G., PERGENT G. (2002) - Handbook for Interpreting Types of Marine Habitat for the Selection of Sites to be Included in the National Inventories of Natural Sites of Conservation Interest. UNEP/RAC/SPA: Tunis, TK: 217 pp. URL http://www.rac-spa.org/dl/MSDF.pdf.

BERTASI F., COLANGELO M.A., ABBIATI M., CECCHERELLI V.U. (2007) - Effects of an artificial protection structure on the sandy shore macrofaunal community: the special case of Lido di Dante (Northern Adriatic Sea). *Hydrobiologia*, **586**: 277-290.

BILZ M., KELL S.P., MAXTED N., LANSDOWN E R.V. (2011) - European Red List of Vascular Plants. Publications Office of the European Union, Luxembourg: 144 pp.

BYRD J.I. (2004) - The effect of beach nourishment on loggerhead sea turtle (*Caretta caretta*) nesting in South Carolina. A thesis of the degree requirements for the Master of Science in Environmental Studies at the Graduate School - College of Charleston: 154 pp.

BIONDI E., BLASI C., BURRASCANO S., CASAVECCHIA S., COPIZ R., DEL VICO E., GALDENZI D., GIGANTE D., LASEN C., SPAMPINATO G., VENANZONI R., ZIVKOVIC L. (2009) - Manuale italiano di interpretazione degli habitat della Direttiva 92/43/CEE. Ministero dell'Ambiente e della Tutela del Territorio e del Mare. URL: http://vnr.unipg.it/habitat/index.jsp.

B.N.P. (1995) - Beach Nourishment and Protection. National Academies Press, 12/dic/1995, Washington. D. C.: 334 pp. URL http://www.nap.edu/books/0309052904/html/index.html.

BOVINA G., CALLORI DI VIGNALE C., AMODIO M. (2003) - L'approccio dell'ingegneria naturalistica nella conservazione degli ambienti dunali. In: Regione Lazio (Ed.), "Manuale di ingegneria naturalistica", **2**: 367-381.

BULGARINI F., CALVARIO E., FRATICELLI F., PETRETTI F., SARROCCO S. (Eds) (1998) - Libro Rosso degli Animali d'Italia - Vertebrati. WWF Italia, Roma: 19 pp.

BULLERI F. e CHAPMAN M.G. (2010) - The introduction of coastal infrastructure as a driver of change in marine environments. *Journal of Applied Ecology*, **47** (1): 26-35.

BULLERI F., MENCONI M., CINELLI F., BENEDETTI-CECCHI L. (2000) - Grazing by tow species of limpets on artificial reefs in the northwest Mediterranean. *Journal of Experimental Marine Biology and Ecology*, **255**: 1-19.

BULLERI F., AIROLDI L. (2005) - Artificial marine structures facilitate the spread of a nonindigenous green alga, *Codium fragile ssp. tomentosoides*, in the North Adriatic Sea. *Journal of Applied Ecology*, **42**: 1063-1072.

BUSH D.M., PILKEY O.H., NEAL W.J. (2001) - Human impact on coastal topography. In: Steele, J.H., Thorpe, S.A., Turekian, K.K. (Eds), Encyclopedia of Ocean Sciences. Academic Press, San Diego: 480-489.

CALVARIO L., GUSTIN M., SARROCCO S., GALLO-ORSI U., BULGARINI F., FRATICELLI F., (1999) - Nuova lista rossa degli uccelli nidificanti in Italia, *Riv. Ital. Orn.*, **69** (1): 3-43.

CERFOLLI F., PETRASSI F., PETRETTI F. (2002) - Il Libro Rosso degli Invertebrati. WWF Italia-ONLUS e Ministero dell'Università e della Ricerca Scientifica e Tecnologica.

CHAPMAN M.G., BULLERI F. (2003) - Intertidal seawalls – new features of landscape in intertidfal environments. *Landscape and Urban planning*, **62**: 159-172.

CHARLIER R.H., CHAINEUX M.C.P., MORCOS S. (2005) – Panorama of history of coastal protection. *Journal Coastal Research*, **21**: 79-111.

COLOSIO F., ABBIATI M., AIROLDI L. (2007) - Effects of beach nourishment on sediments and benthic assemblages. *Marine Pollution Bulletin*, **54** (8): 1197-1206.

CONNELL S. D. e GLASBY T. M. (1999) - Do urban structures influence the local abundance and diversity of subtidal epibiota? A case study from Sydney harbour, Australia. *Marine Environmental Research*, **47**: 373-387.

CONTI F., MANZI A., PEDROTTI F. (1992) - Libro Rosso delle Piante d'Italia. Ministero dell'Ambiente, WWF Italia.

CONTI F., MANZI A., PEDROTTI F. (1997) - Liste Rosse Regionali delle Piante d'Italia. WWF Italia, Società di Botanica Italiana e Università di Camerino.

CORTINI PEDROTTI C., ALEFFI M. (1992) - Lista Rossa delle Briofite d'Italia. In: CONTI F., A. MANZI, F. PEDROTTI, F.: Libro Rosso delle Piante d'Italia. WWF Italia e Società di Botanica Italiana, Roma: 559-637.

CRAIN A.D., BOLTEN A.B., BJORNDAL K.A. (1995) - Effects of beach nourishment on sea turtles: review and research initiatives. *Restoration Ecology*, **3** (2): 95-104.

DEAN R.G. (2002) - Beach Nourishment. Theory and Practice. *World Scientific, Advanced series on Ocean Engineering*, **18**: 399 pp.

DEFEO O., MCLACHLAN A., SCHOEMAN D.S., SCHLACHER T.A., DUGAN J., JONES A., LASTRA M., SCAPINI F. (2009) - Threats to sandy beach ecosystems: a review. *Estuarine, Coastal and Shelf Science*, **81**: 11-12.

DETTE H.H. e RAUDKIVI A. J. (1994) - beach nourishment and dune protection. *Coastal Engineering*, **139**: 1934-1945.

DICKERSON D.D., REINE J.J., CLARKE D.G. (1998) - Economic impacts of environmental windows associated with dredging operations. DOER Technical Notes Collection (TN DOERE3), US Army Engineer Research and Development Center, Vicksburg, MS: 18 pp.

DI RISIO M., LISI I., BELTRAMI G.M., DE GIROLAMO P. (2010) - Physical modeling of the cross-shore short-term evolution of protected and unprotected beach nourishments. *Ocean Engineering*, **37**: 777-789.

DOUGLASS S.D. (1995) - Estimating landward migration of nearshore constructed sand mounds, *Journal of Waterway, Port, Coastal, and Ocean Engineering*, **121** (5): 247-250.

DOUGLASS S.D. (1996) - Nearshore placement of sand, 25th International Conference on Coastal Engineering, ASCE, Orlando: 3708-3721.

DUGAN J.E. e HUBBARD D.M. (2006) - Ecological responses to coastal armouring on exposed sandy beaches. *Shore & beaches*, **74**: 10-16.

DUGAN J.E., AIROLDI L., CHAPMAN M.G., WALKER S.J., SCHLACHER T. (2011) - Estuarine and Coastal Structures: Environmental Effects. A Focus on Shore and Nearshore Structures. *Reference Module in Earth Systems and Environmental Sciences, from Treatise on Estuarine and Coastal Science*, **8**: 7-41.

DUFFY-ANDERSON, J.T., MANDERSON, J.P., ABLE, K.W. (2003) - A characterization of juvenile fish assemblages around man-made structures in the New York New Jersey Harbor Estuary, USA. *Bull. Mar. Sci.*, **72**: 877- 889.

ERCOLE S., GIACANELLI V., BERTANI G., BRANCALEONI L., CROCE A., FABRINI G., GERDOL R., GHIRELLI L., MASIN R., MION D., SANTANGELO A., SBURLINO G., TOMEI P.E., VILLANI M., WAGENSOMMER R.P. (2013) - Schede per una Lista Rossa della Flora Vascolare e Crittogamica Italiana. *Kosteletzkya pentacarpos* (L.) Ledeb. *Informatore Botanico Italiano*, **45** (1): 159-162.

EUROSION (2004) - Living with coastal erosion in Europe: Sediment and Space for Sustainability - PART I - Major findings and Policy Recommendations of the EUROSION project: 54 pp. URL http://www.eurosion.org/reports-online/part1.pdf..

FANINI L., MARCHETTI G.M., SCAPINI F., DEFEO O. (2009) - Effects of beach nourishment and groynes building on population and community descriptors of mobile arthropodofauna. *Ecological Indicators*, **9**: 167-178.

FENSTER M.S., KNISLEY C.B., REED C.T. (2006) - Habitat preference and the effects of beach nourishment on the federally threatened northeastern beach tiger beetle, *Cincidela dorsalis dorsalis*: Western Shore, Chesapeake Bay, Virginia. *Journal of Coastal Research*, **22** (5): 1133-1144.

FLETCHER C.H., MULLANE R.A., RICHMOND B.M. (1997) - Beach loss along armoured shorelines on Oahu, Hawaiian Islands. *Journal of Coastal Research*, **13**: 209-215.

GACIA E., SATTA M.P., MARTIN D. (2007) - Low crested coastal defence structures on the Catalan of the Mediterranean Sea: how they compare with natural rocky shores. *Scientia Marina*, **71** (2): 259-267.

GARGANO D. (2008) - La procedura IUCN, generalità. In: Flora da conservare. Iniziativa per l'implementazione in Italia delle categorie e dei criteri IUCN (2001) per la redazione di nuove Liste rosse. *Informatore Botanico Italiano* **40 (**S1): 25-34.

GLASBY T. M. (2000) - Surface composition and orientation interact to affect subtidal epibiota. *Journal of Experimental Marine Biology and Ecology*, **248**: 177-190.

GLASBY T.M., CONNELL S.D., HOLLOWAY M.G., HEWITT C.L. (2007) - Nonindigenous biota on artificial structures: could habitat creation facilitate biological invasions? *Marine Biology*, **151**: 887-895.

GREEN K. (2002) - Beach nourishment: a review of the biological and physical impacts. ASMFC (Atlantic States Marine Fisheries Commission). *Habitat Management Series*, **7**: 174 pp.
GUIDETTI P., FABIANO M. (2000) - The use of lepidochronology to assess the impact of terrigenous discharge on the primary leaf production of the Mediterranean seagrass *Posidonia oceanica*. *Marine Pollution Bulletin*, **40** (5): 449-453.
ICES (2000) - Report of the working group on the effects of extraction of marine sediments on the marine ecosystems, Gdansk, Poland: 172 pp.
IOANNIDIS D. e TH. V. KARAMBA S. (2007) - 'Soft' shore protection methods: beach drain system. 10th Int. Conf. on Environmental Science and Technology, CEST2007, Kos Island, Greece: A-528-535.
IUCN (1994) - IUCN Red List categories and criteria: version 3.1. IUCN Species Survival Commission. IUCN Gland Switzerland and Cambridge, U. K.: 21 pp.
IUCN (2001) - IUCN Red List Categories and Criteria: version 3.1. IUCN Species Survival Commission. IUCN, Gland, Switzerland and Cambridge, UK: 30 pp.
IUCN. (2003) - Guidelines for application of IUCN Red List Criteria at regional levels: version 3.0. IUCN Species Survival Commission. IUCN, Gland, Switzerland and Cambridge, UK: 26 pp.
IUCN. (2013) - Guidelines for using the IUCN Red List Categories and Criteria. Version 10. Prepared by the Standards and Petitions Subcommittee. URL: http://www.iucnredlist.org/documents/RedListGuidelines.pdf.
IUCN. (2012b) - Guidelines for application of IUCN Red List Criteria at regional levels: version 4.0. IUCN Species Survival Commission. IUCN, Gland, Switzerland and Cambridge, UK: 41 pp.
JACKSON N. L., SMITH D.R., TIYARATTANACHAI R., NORDSTROM K.F. (2007) - Evaluation of a small beach nourishment project to enhance habitat suitability for horseshoe crabs. *Geomorphology and Ecosystems*, **89** (1-2): 172-185.
JARAMILLO E., CONTRRAS H., BOLLINGER A. (2002) - Beach and faunal response to the construction of a seawall in a sandy beach of south central Chile. *Journal of Coastal Research*, **18**: 523-529.
HALLERMEIER R.J. (1981) - Seaward limit of significant sand transport by waves: an annual zonation for seasonal profiles. *Coastal Engineering Technical Aid - Coastal Engineering Research Center, U.S. Army Engineer.* Vicksburg, MS, CETA 81-2: 23 pp.
KLEIN M.D. (2005) - Modelling rhythmic morphology in the surf zone. Ph.D. thesis, Delft University of Technology, Faculty of Civil Engineering.
LA VALLE P., NICOLETTI L., FINOIA M.G., ARDIZZONE G.D. (2011) - *Donax trunculus* (Bivalvia: Donacidae) as a potential biological indicator of grain-size variations in beach sediment. *Ecological Indicators*, **11**/5 (2011): 1426-1436.
LA VALLE P., NICOLETTI L. (2008) - Beach nourishment and *Donax trunculus* (Linnaeus, 1758) populations in the Central Tyrrhenian Sea: negative or positive impact? In: Campostrini P. (Ed) A changing coast: challenge for the environmental policies. *Proceedings of the IX International Conference LITTORAL 2008*, Venice, Italy, 25-28 November 2008. Arzanà, Venice. (electronic publication).
LA VALLE P., BELLUSCIO A., NICOLETTI L., PAGANELLI D., ARDIZZONE G.D. (2007) - Effects of beach nourishment on *Donax trunculus* in the Latium coasts (Central Tyrrhenian Sea, Italy). *Proceendings of the Eighth International Conference on the Mediterranean Coastal Environment, MEDCOAST'07*. E. Özhan (Editor), 13-17 November 2007, Alexandria, Egypt.
LARSON M., KRAUS N.C., WISE R.A. (1999) - Equilibrium beach profiles under breaking and non-breaking waves. *Coastal Engineering*, **36**: 59-85.
MANZANERA M., PÉREZ M., ROMERO J. (1998) - Seagrass mortality due to over-sedimentation: an experimental approach*. Journal of Coastal Conservation*, **4**: 67-70
MARINO D., PIOTTO B. (a cura di) (2010) - Il valore economico della biodiversità e degli ecosistemi. Economia della conservazione ex situ. Manuali e linee guida ISPRA 64/2010: 218 pp.
MARTIN D., BERTASI F., COLANGELO M.A., DE VRIES M., FROST M., HAWKINS S.J., MACPHERSON E., MORCHELLA P.S., SATTA M.P., THOMPOSON R.C., SECCHERELLI V.U. (2005) - Ecological Impact of coastal defence structures on sediment and mobile fauna: evaluating and forecasting consequences of unavoidable modifications of native habitats. *Coastal engineering*, **52**: 1027-1051.
MARTINS G.M., AMARAL A.F., WALLENSTEIN F.M., NETO A.I. (2009) - Influence of a breakwater on nearby rocky intertidal community structure. *Marine Environmental Research*, **67**: 237-245.

MAURER D., KECK R.T., TINSMAN J.C., LEATHEM W.A., WETHE C.A., LORD C., CHURH T.M. (1986) - Vertical migration and mortality of benthos in dredged material: a synthesis. *International Revue der gesamten Hydrobiologie*, **71**(1): 49-63.
MEYER-ARENDT K.J., DORVLO A. (2001) - Recreational development and shoreline modification along the north coast of Yucatan, Mexico. *Tourism Geographies*, **3**: 87-104.
MOFFET M.D., McLACHLAN A., WINTER P.E.D., DE RUYCK A.M.C. (1998) - Impact of trampling on sandy beach macrofauna. *Journal of Coastal Conservation* 4: 87-90.
MOISER A.E., WITHERINGTON B.E. (2002) - Documented effects of coastal armouring structures on sea turtle nesting behaviour. Proceedings of the 20th Annual Symposium on Sea Turtle Biology and Conservation: 304-306.
MOREIRA J., CHAPMAN M.G., UNDERWOOD A.J. (2006) - Seawalls do not sustain viable populations of limpets. *Marine Ecology-Progress Series*, **322**: 179-188.
MOSCHELLA P.S., ABBIATI M., ÅBERG P., AIROLDI L., ANDERSON J.M., BACCHIOCCHI F., BULLERI F., DINESEN G.E., FROST M., GACIA E., GRANHAG L., JONSSON P.R., SATTA M.P., SUNDELÖF A., THOMPSON R.C., HAWKINS S.J. (2005) - Low-crested coastal defence structures as artificial habitats for marine life: Using ecological criteria in design. *Coastal Engineering*, **52**: 1053-1071.
NICHOLLS R. J., LAETHERMAN S.P. (1994) - Global sea-level rise. In: Strzepek K. e Smith J. B. (Eds), as climate changes: potential impacts and implications. Cambridge Univ. press, Cambridge.
NICOLETTI L., PAGANELLI D., GABELLINI M. (2006) – Environmental aspects of relict sand dredging for beach nourishment: proposal of monitoring protocol. Quaderno ICRAM n.5: 155pp.
NICOLETTI L., BELLUSCIO A., LA VALLE P., ARDIZZONE G.D. (2005) - Monitoring of Posidonia oceanica meadow after beach nourishment. In: “MEDCOAST ‘05 - *Proceedings of the Seventh International Conference on the Mediterranean Coastal Environment*”, Özhan E. (Ed), 25-29 October 2005, Kusadasi, Turkey: 451-460.
NIMIS, P.L. 1992. Lista Rossa dei licheni d’Italia. In: CONTI, F., MANZI, A., E PEDROTTI, F. 1992. Libro rosso delle Piante d’Italia. Ministero dell’Ambiente, WWF Italia, Società Botanica Italiana: 503-555.
NORDSTROM K.F. (2005) - Beach nourishment and coastal habitats: research needs to improve compatibility. *Restoration Ecology*, **13**(1): 215-222.
OSPAR (2009) - Assessment of the impact of coastal defence structures: 27 pp.
PATTIARATCHI C.B., OLSSON D., HETZEL Y., LOWE R. (2009) - Wave-driven circulation patterns in the lee of groynes. *Continental Shelf Research*, **29** (16): 1961-1974.
PETERSON C.H., BISHOP M.J., JOHNSON G.A., D'ANNA L.M., MANNING L.M. (2006) - Exploiting beach filling as an unaffordable experiment: benthic intertidal impacts propagating upwards to shorebirds. *Journal of Experimental Marine Biology and Ecology*, **338**: 205-221.
PHILLIPS M.R. e WILLIAMS A.T. (2007) - Depth of Closure and Shoreline Indicators: Empirical Formulae for Beach Management. *Journal of Coastal Research*, **23** (2):487-500.
PINN E.H., MITCHELL K., CORKILL J. (2005) - The assemblages of groynes in relation to substratum age, aspect and microhabitat. *Estuarine, Coastal and Shelf Science*, **62**: 271-282.
PIOTTO B., GIACANELLI V., ERCOLE S. (a cura di) (2010) - La conservazione *ex situ* della biodiversità delle specie vegetali spontanee e coltivate in Italia: stato dell’arte, criticità e azioni da compiere. Manuali e Linee Guida ISPRA, 54/2010: 205 pp.
POSIDUNE (2007) - Interactions de *Posidonia oceanica* et Sable avec l’Environnement des Dunes Naturelles - Cahier Technique étendu de Phase B, INTERREG IIIC Beachmed-e: 127 pp. http://www.beachmed.it/Beachmede/SousProjets/POSIDUNE/tabid/99/Default.aspx.
PRANZINI E. (2004) – La forma delle coste. Geomorfologia costiera impatto antropico e difesa dei litorali. Zanichelli Ed.: 245 pp.
PRATAP K.M., SISIR K.P., SATYANARAYAN B., BUDHADEVEV S., UMAKATANTA P., BALAJI B., PRAVAKAR M., UMA S.P. (2012) - Impact of grin on beach morphology: a case study near Gopalpur Port, East Coast of India. *Journal of Coastal Research*, **28** (1): 132- 132.
RAKOCINSKI C.F., HEARD R.W., LECROY S.E., MCLELLAND J.A., SIMONS T. (1996) - Responses by macrobenthic assemblages to extensive beach restoration at Perdido Key, Florida, USA. *Journal of Coastal Research*, **12** (1): 326-353.
REGIONE TOSCANA (2007) - Studio e ricerca per l’implementazione del quadro conoscitivo della costa toscana nell’ambito del piano regionale di gestione integrata della costa. Rapporto Tecnico: 22 pp.
RICE C.A. (2006) - Effects of shoreline modification on a northern Puget Sound beach: microclimate and embyo mortality in surf smelt (*Hypomesus pretoiosus*). *Estuaries and Coasts*, **29**: 63-71.

RIZKALLA, C.E., SAVAGE, A. (2011) - Impact of seawalls on loggerhead sea turtle (*Caretta caretta*) nesting and hatching success. *Journal of Coastal Research*, **27**(1): 166-173.
RONDININI C, BATTISTONI A, PERONACE V, TEOFILI C (compilers) (2013) - Lista Rossa IUCN dei Vertebrati Italiani. Comitato Italiano IUCN e Ministero dell'ambiente e della Tutela del Territorio e del Mare, Roma: 54 pp.
ROSSI G., GENTILI R. (2008) - A partnership project for a new Red List of the Italian Flora. *Plant Biosystems*, **142**: 302-304.
ROSSI G., MONTAGNANI C., GARGANO D., PERUZZI L., ABELI T., RAVERA S., COGONI A., FENU G., MAGRINI S., GENNAI M., FOGGI B., WAGENSOMMER R.P., VENTURELLA G., BLASI C., RAIMONDO F.M., ORSENIGO S. (Eds) (2013) - Lista Rossa della Flora Italiana. 1. Policy Species e altre specie minacciate. Comitato Italiano IUCN; Ministero dell'Ambiente e della Tutela del Territorio e del Mare. URL http://www.governo.it/backoffice/allegati/71184-8693.pdf.
RUIZ J.M., ROMERO J. (2003) - Effects of disturbances caused by coastal constructions on spatial structure, growth dynamics and photosynthesis of the seagrass *Posidonia oceanica*. *Mar. Pollut. Bull*., **46**: 1523-1533.
RUIZ J.M., MARIN A., CALVO J.F., RAMIREZ-DIAZ L. (1993) - Interactions between floodway and coastal constructions in Aguilas Bay (southeastern Spain). *Ocean and Coastal Management*, **19**: 241-262.
RUMBOLD D.G., DAVIS P.W., PERRETTA C. (2001) - Estimating the effect of beach nourishment on *Caretta caretta* (loggerhead sea turtle) nesting. *Restoration Ecology*, **9**: 304-310.
SANCHEZ-JEREZ P., GILLANDERS B.M., RODRIGUEZ-RUIZ S., RAMOS-ESPLA´ A. (2002) - Effect of an artificial reef in Posidonia meadows on fish assemblage and diet of *Diplodus annularis*. *ICES J. Mar. Sci*., **59** (Suppl.): 59-68.
SATO M., NISHI R., NAKAMURA K., SASAKI T. (2003) - Short-term field experiments on beach transformation under the operation of a coastal drain system. Soft Shore Protection, Kluwer Academic Publishers, **7**: 171-182.
SCAPINI, F., CHELAZZI, L., COLOMBINI, I., FALLACI, M. , FANINI, L. (2005) - Orientation of sandhoppers at different points along a dynamic shoreline in southern Tuscany. *Marine Biology* **147**: 919-926.
SCOPPOLA A. e SPAMPINATO G. (2005) - Atlante delle specie a rischio di estinzione (CD-ROM). Ministero dell'ambiente e della tutela del territorio, Direzione per la Protezione della Natura, Società Botanica Italiana, Univ. della Tuscia, Univ. di Roma la Sapienza.
SUTHERLAND J. (2010) - Guidelines on beach monitoring for coastal erosion. Concepts and Science for Coastal Erosion Management – CONSCIENCE. Deliverable D15. URL http://www.conscience-eu.net/documents.
SPEYBROECK J., BONTE D., COURTENS W., GHESKIERE T., GROOTAERT P., MAELFAIT J.P., MATHYS M., PROVOOST S., SABBE K., STIENEN E.W.M., VAN LANCKER V., VINCX M., DEGRAER S. (2006) - Beach nourishment: an ecologically sound coastal defence alternative? A review. *Aquatic Conserv: Mar. Freshw. Ecosyst*., **16**: 419-435.
STIVE M. J. F., AARNINKHOF S. G. J., HAMM L., HANSON H., LARSON M., WIJNBERG K. M., NICHOLLS R. J., CAPOBIANCO M. (2002) - Variability of shore and shoreline evolution. *Coastal Engineering*, **47** (2): 211-235.
U.S. ARMY CORPS OF ENGINEERS (2003) - Coastal Engineering Manual (CEM), Chapter V-3 "Shore Protection Projects". U.S. Army Engineer Research and Development Center (ERDC), Vicksburg, Mississippi., EM 1110-2-1100 (Part V) 31 July 2003: 116 pp.
U.S. ARMY CORPS OF ENGINEERS (2003, b) - Coastal Engineering Manual (CEM), Chapter VII "Coastal Engineering for environmental enhancement". U.S. Army Engineer Research and Development Center (ERDC), Vicksburg, Mississippi., EM 1110-2-1100 (Part V) 31 July 2003: 48 pp.
VAN DOLAH R.F., CALDER D.R., KNOTT D.M. (1984) - Effects of dredging and open-water disposal on benthic macroinvertebrates in a South Carolina Estuary. *Estuaries*, **7**(1): 28-37.
VAN RIJN, L.C. (2005) - Principles of Sedimentation and Erosion Engineering in Rivers, Estuaries and Coastal Seas. *Aqua Publications* (www.aquapublications.nl), The Netherlands: 600 pp.
VICINANZA D., GUIDA A., DI NATALE M. (2006) – Stabilizzazione delle spiagge mediante drenaggio: il caso Ciraccio-Ciracciello (isola di Procida, Napoli). XXX Convegno di Idraulica e Costruzioni Idrauliche - IDRA 2006: 14 pp.
VESTERBY H. e PARKS J. (1988) - Beach management with the coastal drain system. Florida shore and beach preservation association meeting, Florida.

VESTERBY H. (1991) - Coastal drain system: a new approach to coastal restoration. Geo-Coast'91 Conference, September, Yokohama.

VESTERBY H. (1994) - Beach face dewatering: the European experience. Alternative Technologies in Beach Preservations. Proc. of the 1994 Nat. Conf. on Beach Preservation Technology: 53-68.

WALLINGFORD H.R., BRAMPTON A., MOTYKA G., COATES T (2000) - A guide to managing coastal erosion in beach/dune systems. Scottish Natural Heritage. URL http://www.snh.org.uk/publications/on-line/heritagemanagement/erosion/sitemap.shtml.

WALKER S.J., SCHLACHER T.A., THOMPSON L.M.C. (2008) - Habitat modification in a dynamic environment: The influence of a small artificial groyne on macrofaunal assemblages of a sandy beach. *Estuarine, Coastal and Shelf Science*, **79**: 24-34.

WESLAWSKI, J. M., STANEK, A., SIEWERT A., BEER N. (2000) - The sandhopper *Talitrus saltator*, Montagu 1808 on the Polish Baltic Coast. Is it a victim of increased tourism? *Oceanological Studies*, **29**: 77-87.

WILBER D.H., CLARKE D.G., RAY G.L., BURLAS M. (2003) - Response of surf zone fish to beach nourishment operations on the northern coast of New Jersey, USA. *Marine Ecology Progress Series*, **250**: 231-246.

*****

Website consulted (last access: 20 January 2014**):**

http://www.coastance.eu
http://www.iucnredlist.org
http://www.rac-spa.org
http://ramsar.wetlands.org
http://www.shoregro.com
http://www.shoregro.com/pdfs/HV-BD-environment.pdf
http://www.shoregro.com/P01_Home.html
http://www.snh.org.uk/publications/on-line/heritagemanagement/erosion/appendix_1.4.shtml

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