

## Dune habitats vulnerability to the climate change

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**ABSTRACT.** – Italy sandy coasts are characterized by a great diversity of habitats and, at the same time, many of these coastal stretches are in erosive condition. The causes of erosion are represented by multiple factors essentially geomorphological but to which today others of a climatic change can be added. These are linked to the intensification of extreme climatic events and/or sea level rise. Therefore, it is important to understand, in areas where marine erosion is particularly strong, which are the most vulnerable and most threatened habitats. This paper sets out a summary of the results obtained up to now from the survey of dune habitats (*sensu* Directive 92/43/EEC) along the northern Tyrrhenian coast. This investigations, aim to point out the arrangement of these habitats in relation to extreme weather events and dune erosion and the different resilience in the face of important changes in the beach/dune system.

**INTRODUCTION.** – The scenarios envisaged in the context of climate change for the Mediterranean basin highlight strong critical issues related to coastal environments (EEA 1999; Castellari *et al.* 2014; NOAA 2018; Blunden *et al.* 2018). These are mainly determined by an increase in sea level and wind, changing in wave power and shoreline stream (Lionello *et al.* 2014; Marisco *et al.* 2017; Vecchio *et al.* 2019). In addition to this, the rise in temperatures can be decisive in changes in the floristic component of dune vegetation with ingression of alien species (Janssen *et al.* 2016).

Italy has a coastline of about 7,500 km, of which approximately 37% is represented by rocky coasts and 63% by sandy coasts, characterised by a great diversity of habitats of high natural and environmental interest (Biondi *et al.* 2012). In this context, over the 45% of sandy coasts (Valpreda & Simeoni 2003) is affected by erosion, in part linked to

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some changed coastal geomorphogenesis aspects (lower river sediments transport, changes in marine drift currents, etc.) and partly to causes that are still little known and analyzed but unquestionably linked to climate change (Masselink & Russel 2013).

The strong transformation of the biotic characteristics of the plant communities is strongly correlated with the geomorphological traits of the dune ecosystems. Consequently, it is important that the monitoring of significant case studies can be the key to understanding possible changes ongoing and provide future scenarios. These habitats, just because linked to a geomorphologically dynamic environment, are subject to strong transformations and are intrinsically characterized both by extreme fragility and vulnerability and, at the same time, by a great resilience (Feagin *et al.* 2005; Janssen *et al.* 2016).

**DUNE HABITATS AND CONSERVATION.** – Sandy coastal ecosystems, occupying the transition zone between marine and sedimentary terrestrial environments, are susceptible to constant changes in their morphological structure and vegetation landscape (Brown & McLaghan 2002; Maun 2009). At the same time, they show a great biodiversity, in terms of plant species and communities (Prisco *et al.* 2012). The dune environment and the dune habitats that occur there are consequently very sensitive and vulnerable to environmental changes of even less intensity. This makes them particularly worthy of monitoring and protection for their specific ecosystem functions (Doody 2013).

The dune habitats are characterized by specific flora and specific plant associations (Biondi 1999) and, in an undisturbed environmental state, would be placed according to a precise spatial zonation (Acosta & Ercole 2015). Whenever in dunal environments there is a natural or artificial disturbance, we are witnessing the alteration of the natural distribution pattern of the plant communities (fragmentation and a reversal and in the worst cases, the disappearance of a community) (Fig. 1).

The identified and monitored dune habitats, in accordance with Habitat Directive, along the Italian coasts are: 1210 Annual vegetation of drift lines; 2110 Embryonic dunes; 2120 White dunes; 2210, 2230, 2240 *Crucianellion* fixed dunes and *Malcolmietalia* and *Brachypodetalia* dune grasslands; 2250 Coastal dunes with *Juniperus* spp.; 9340 *Quercus ilex* and *Quercus rotundifolia* forests and 2270 Wooded dunes with *Pinus pinea* and/or *Pinus pinaster*. For a more detailed floristic-vegetational characterization of the coded dune habitats, see <http://vnr.unipg.it/habitat/>.

From a conservationist point of view Council Directive 92/43/ECC (commonly called “Habitats”) is a European Community legislative instrument in the field of nature conservation that establishes a common framework for the conservation of wild animal and plant species and natural habitats of Community importance. Annex I is based on the hierarchical classification of European habitats developed by the CORINE Biotopes project, because it was the only existing classification at the European level, while phytosociology affords the main reference for detecting the diagnostic species that have a lead role in defining the habitats (European Commission DG Environment 2007).

WHICH METHODS... – Monitoring in dune environments is usually carried out in the following ways:

1. field surveys by phytosociological approach (Gehu 1992). These are aimed at identifying the flora and vegetation and the diagnostic and characteristic plants/associations of the habitats, whose presence absence and frequency is evidence of the integrity and/or alteration of the same habitat. Normally the initial samplings are followed by subsequent periodic surveys on the same points to identify possible transformations (Sperandii *et al.* 2018).
2. with photo-interpretation of the images from remote sensing (aircraft, UAV, satellite) and, where possible, their diachronic comparison (Bertacchi *et al.* 2009; Malavasi *et al.* 2013).

...AND WHICH AREAS. – An example of great interest is represented by the coast of San Rossore Estate of Migliarino-San Rossore-Massaciuccoli Park (Tuscany, Italy). This stretch of coastline, about 11 km long, is under erosion from about a century but with a strong acceleration from the last 50 years (Fig. 2). In this sector, several investigations, conducted in recent years have shown, together with the presence of the most representative dune habitats, also their vulnerability (Bertacchi *et al.* 2016; Bertacchi 2017). As part of the study of the degradation dynamics of coastal environments, the comparison of historical aerial photos with the current ones was very useful in the survey. In this sector, due to erosion, around 200 ha of sandy shore have been lost since 1954, leaving today only a thin strip of dune of about 55 ha.

However, as a result of the aforementioned marine erosion, to this “richness” of habitat corresponds to a serious state of degradation of the same, in terms of alteration, fragmentation and disappearance, in over two thirds of the coast examined. In fact the marine erosion, determines the submersion of the first stretch of sandy shore, the salification of the

same, the collapse of the dune structure and, finally, with the wave and tide motion, the removal of the sand (Fig. 3).

In our study area, this high erosion has determined the substantial disappearance of some habitats (H2110 embryonic dune with *Elymus farctus* and H2250, fixed dune with *Juniperus* spp.) and the significant degradation of others (H2120, white dune with *Ammophila arenaria*), with the almost disappearance of characteristic species (e.g., *Echinophora spinosa* and, partially, of *Juniperus oxycedrus*) and the dominance of other (e.g., *Euphorbia paralias*). Habitat 1210 (characterized by *Cakile maritima* and *Salsola kali*), shows an important subversion of normal zoning with a fragmentation of the habitat. The different vulnerability of habitats to coastal erosion is clearly related to the different ways in which this is expressed and where it occurs. Those species and plant communities that are not able or not fast enough to running inwards, are destined to disappear. Thus, the first degradation time is the destruction of the normal dune zonation, with habitat fragmentation and, sometimes, inversion. The next moment is the rarefaction and/or disappearance of characteristic species. The final moment is the disappearance of all species.

In this mainland consumption, the species of natural habitats closest to the coastline often fail to follow the erosion process and “move” inwards, especially when this phenomena is sudden and fast. In this dynamic, the annual species (e.g., *Cakile maritima*), the most halophilous species (e.g., *Salsola kali*), or those of habitats constantly in formations (e.g., *Elymus farctus* and/or *Euphorbia paralias*) show greater resilience, even if the habitats that are often used are no longer identifiable. Other species, although dune edifiers (such as *Ammophila arenaria*) show a high vulnerability and, often, disappear definitively in the dune belts particularly subject to erosion (Bertacchi *et al.* 2016; Sperandii *et al.* 2019).

**CONCLUSIONS.** – The constant monitoring and the constantly updated projections of the government agencies as NOAA or IPCC, together other specific investigations, on the average rise of the level of the oceans and the increase of storms on the planet coasts show the high risk in place for the coastal oceanic environments (Sweet *et al.* 2017; Rahmstorf 2017). Similarly, recent scientific papers on the Mediterranean environment, seem to confirm this trend. Also for our closed basin and a potential drowning of the Italian coastal plains (Marisco *et al.* 2017; Vecchio *et al.* 2019).

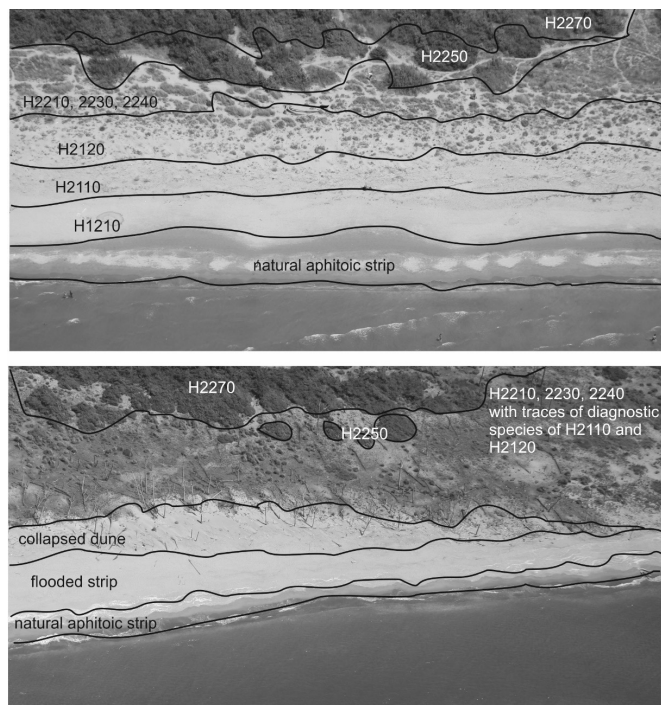
Consequently, the marine erosion of a large part of the coasts of the Italian peninsula can be certainly increased by sea level rise and may become a “marine trasgression”. To this, large storm surges, flooding, strong wave action, and, sometime, human activities, that “wear away” the beaches, can be added. In this scenario the constant monitoring of the plant communities of the dunes and of the habitats that go to characterize becomes of fundamental importance, with the dual purpose of early identifying the symptoms of erosive processes, and of identifying the possible actions to protect habitats.

This trend of dune habitats seem to be the same observed in other coastal areas of the central and southern Italian peninsula, as showed in the recent different investigations (Sperandii *et al.* 2018, 2019).

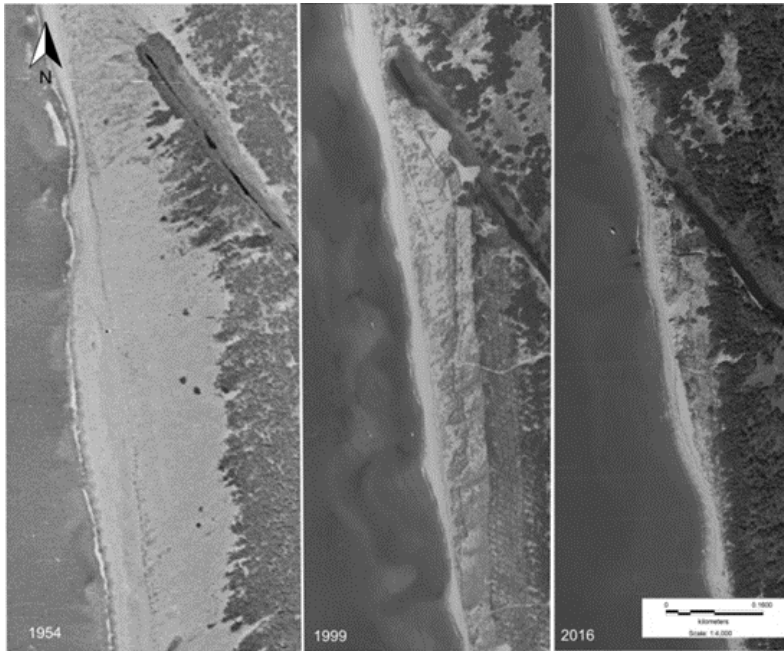
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**FIG. 1.** Natural and undisturbed zonation on dune habitats in sedimentary Tuscany coasts (Calambrone) (*up*); Destruction of dune morphology and degradation of vegetation zonation (San Rossore) (*below*) (Aerial photos from Regione Toscana/Provincia Livorno, modified).



**FIG. 2.** Dune erosion and progressive reduction of dune habitats between 1954 and 2016 (San Rossore, Fiume Morto Vecchio) (from <http://www.regione.toscana.it/-/geoscopio> and licensed under Creative Commons Attribution CC-BY3.0 IT, modified)



**FIG. 3.** The collapse of the dune and the complete disappearance of dune habitats (San Rossore).

