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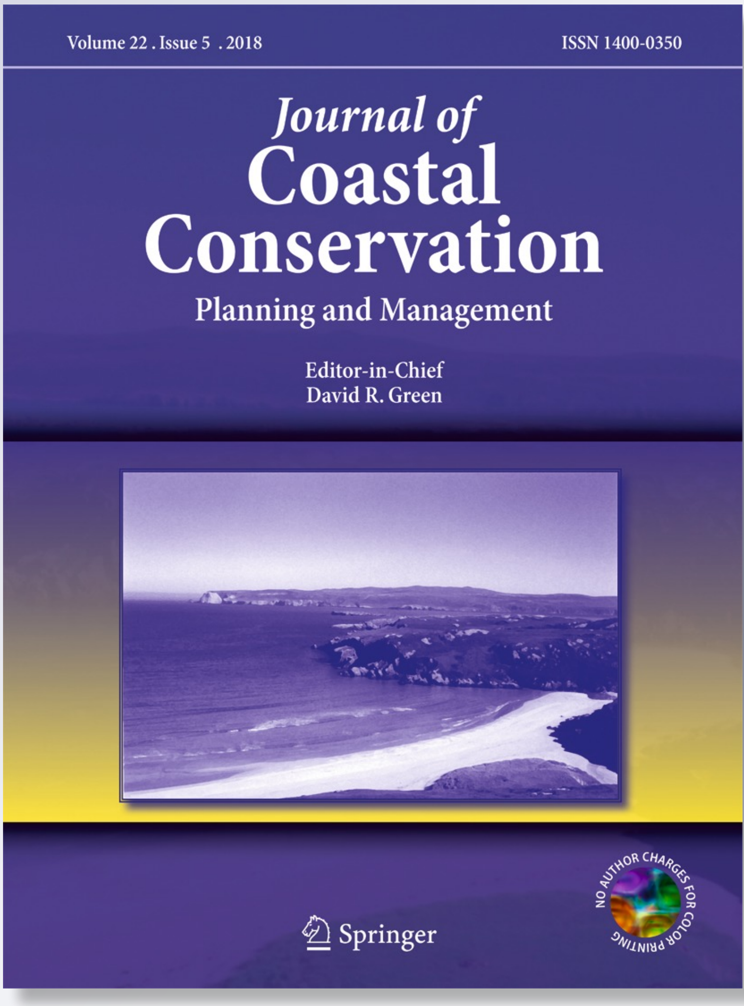

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GUEST EDITORIAL

Editorial – Coastal changes, from past records to future trends: proxy analysis, modelling, and monitoring

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Introduction

Coastal areas represent complex environmental systems, as they are controlled by a high number of interacting variables (forcing factors, processes), acting over different time scales. Coastal landforms and sedimentary bodies, and their dynamics, are the result of the interaction between geological factors, tectonic evolution and surface processes on a local scale, and global variables such as climate and plate tectonics, controlling sea level. Relevant factors enhancing global and local coastal trends are also the local scale boundary conditions, such as those related to the watershed dynamics and anthropic load. For such reasons their study needs a multidisciplinary/holistic approach requiring highly detailed analyses and accurate monitoring activities.

Coasts are high-rate dynamic systems that rapidly vary also in response to low intensity changes in global and local controlling factors. Today coastal environments are the expression of a dynamic equilibrium established soon after the 120 m rise of the sea level due to ice melting occurred after the Last Glacial Maximum. Nevertheless in some contexts the geomorphic responses to environmental changes can also occur over a long-period of time, so an understanding of these issues requires multi-temporal analysis approaches that span from historical to millennia time intervals. Indeed, the shaping of coastal landforms acts at different rates. Low coastal areas, such as sandy coasts, dune systems, spit and barrier islands, respond to the changes of the physical factors on a time scale of decades or few centuries. On the other hand, the evolution of rocky coastal sectors often develops very slowly on a time scale of hundreds of thousands years (Davidson-Arnott 2005), even if abrupt changes can be possible as effect of paroxysmal events such as those related to mass wasting.

Coastal plains are sensitive to the combined effects of subsidence and extreme events, such as storm surges, that can trigger erosional and flooding processes and cause rapid land modifications. Climate change effects can increase the intensity of these processes, enhancing the susceptibility of such areas. Sea level rise and ongoing changes in intensity and frequency of storm events, precipitation, and temperature, are considered the main causes of the negative impacts on beaches and dune systems. Erosion and temporary flooding due to sea level increase, especially if combined with high subsidence rates, are considered the main issues on sandy beaches whereas the reduction in plant cover, due to the increase in temperature and fragmentation of the system, is the main problem affecting the embryo and foredunes development. Beaches, especially sandy beaches, are landforms that rapidly change in response to variations of their boundary conditions. Beach profile and controlling processes coexist in a dynamic equilibrium: the beach spatial variability is linked to changes in wave climate while temporal changes are due to changes in the intensity of the incident waves.

Due to their high vulnerability to sea level impacts, a range of possible scenarios for the Italian coastal plains in the year 2100 have been provided by several authors (Lambeck et al. 2011; Antonioli et al. 2017) taking into account projections for sea level rise that include the isostatic and tectonic components under different climate conditions. These studies highlight how the local effect of the vertical ground movements can induce high differences of the sea level impacts. The high concentration of population and human activities along the

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low coasts and their relevant value led to the consequence that coastal vulnerability assessment and risk evaluation are becoming a key issue to understand the impacts of natural hazard and climate changes.

Coastal cliffs represent the main part of the world's coastline (Emery and Kuhn 1982). Generally, they border coastal uplands produced by uplift of the land and lowering of the sea level through geological time (Bird 2016). The marine erosion processes, occurred after the most recent ice age or during earlier Pleistocene transgressions, formed the majority of coastal cliffs (Hampton and Griggs 2004). Moreover, origin of sea cliffs may have a strong relationship with local faults. From a geomorphological point of view, such relations can be recognizable only at small spatial scale by evaluating the coastal shape and orientation from maps or satellite images (Pranzini 2004).

Active coastal cliffs are exposed to a continuous geomorphic evolution mainly controlled by wave action. Erosion induced by waves can become so deep as to induce the collapse of the overlying rocks (Wilcox et al. 1998; Carter and Guy Jr 1988; Vallejo and Degroot 1988). The resulting cliff retreat can be slow and persistent or rapid and episodic, depending on geological and environmental conditions. Geotechnical and structural properties of rocks outcropping along a cliff face play a fundamental control on retreat rates, as well as on retreat mechanisms. Beside wave action, wind, rain, salt spray, wetting and drying cycles, changes in temperature, bio-erosion, are among the most effective weathering agents that contribute to the geomorphological evolution of cliffs.

Different retreat rates through time are reported worldwide. Average retreat rates (Sunamura 1992) range from mm/yr. (on cliffs molded in granite), cm/year (on limestone or shale), m/yr. (on chalk and sandstone), up to several m/yr. (on glacial drift deposits or volcanic ash). The knowledge of retreat rates is important because it allows one to assess the level of risk for coastal assets (Lee 2002), to mitigate the potential impacts of cliff instability and erosion through various adaptation measures (Moore and Davis 2015), and to predict future trends even without sea level rise (Bray and Hooke 1997). Cliff retreat has been documented using a variety of techniques, the most common of which results in the measurement of receding distances of a cliff top (or edge) on multi-temporal aerial photographs and historic maps (Sunamura 2015). This technique permits analysis over periods ranging from a few tens of years to a century (Moore et al. 1999), and it allows for the calculation of historical recession rates. Disadvantages in the use of historic maps, due to the low positional accuracy of cliff tops or cliff toe (Bray and Hooke 1997) and distortions in the printing process (Lee 2002), allow the capture of only the larger changes, over a long-time period, leading to an overestimate of the rates of changes (Lim et al. 2010). Recent methodologies for monitoring cliff erosion and assessing rates of retreat include measurements performed by means of several geomatic techniques, such as Global Navigation Satellite System (GNSS), Total Station topographic surveying, Digital Photogrammetry, high-resolution Remote Sensing and aerial and terrestrial Laser Scanning.

Content and aim of the thematic volume

This Special Issue focuses on multidisciplinary aspects related to the study of the short- to long-term evolution of coastal areas in sectors particularly exposed to the effects of global scale climate change, such as coastal cliffs and alluvial plains, and in sectors characterized by active tectonics and/or volcanic processes with significant vertical ground deformations. The issue also aims to illustrate scientific contributions related to the adoption of innovative geomatics technologies to coastal area studies for monitoring and modeling of future scenarios.

We collected a coherent set of papers, presented at the Session "*Coastal changes, from past records to future trends: proxy analysis, modelling and monitoring*" of the 88th Congress of the Italian Geological Society "*Geosciences on a changing planet: learning from the past, exploring the future*". The congress was held at the University Federico II, Naples, Italy, in September 2016. In accordance with the multidisciplinary theme of the special issue, the authors came from several research fields, such as geomorphology, stratigraphy, sedimentology, structural geology, geomatics, natural hazard, remote sensing and others. This special issue includes 15 articles that cover three main topics:

- Long- to mid-term coastal evolution;
- Short-term coastal evolution and monitoring;
- Coastal hazard and vulnerability.

Pranzini introduces the volume with an up-to-date historical analysis about the topics of coastal erosion and shore protection. The coastal human colonization spread after the sea level stabilization, approximatively occurred 6.000 yr. B.P.; where severe mountain deforestation was carried out, the author recognizes three main consequences: i) the river sediment input increased tremendously; ii) the coastal settlements were disconnected from the shore; iii) harbor siltation occurred. Shore erosion was a limited process at the time and local solutions were adopted since the Middle Ages. Further human activities, such as riverbed quarrying, wetland reclamation, dam construction and mountain re-afforestation, favored a strong input for coastal erosion that still threatens most world coasts. However, with the current Sea Level Rise, the debate of whether to defend, accommodate or retreat is open.

Long- to mid-term coastal evolution

The first set of papers is related to the integrated analysis of long to mid-term coastal evolution processes with examples from Mediterranean area (Malta, Greece and southern Italy), dealing with stratigraphic, sedimentological and geomorphological features of coastal dune development, sea level rise and tectonic interplay, boulder dynamic, and cosmogenic dating of coastal landslides spanning in Quaternary and Holocene times.

The timing and mechanisms of the development of some deep-seated landslides affecting the northwestern coast of the Island of Malta have been investigated by Soldati et al. The results for exposure dating using the cosmogenic nuclide ^{36}Cl indicate that the oldest block detachment occurred in a subaerial condition at ca. 21 ka, when the sea level was about 130 m lower than at present. Mass movements accelerated when sea level reached the landslide toe during the post-glacial marine transgression.

A multi-proxy approach (sedimentological, palaeoecological and palynological data, and AMS ^{14}C dates) has been adopted in Ruello et al. to reconstruct the Holocene history of the St. Eufemia Plain (western Calabria, Italy). In the early Holocene, eustasy largely prevailed on the tectonic uplift, causing coastline ingression and plain aggradation. From ca. 6900 to ca. 2800 yr. cal. BP, coastal progradation and aggradation were driven by high detrital inputs and slowdown of sea level rise, during a stage characterized by weak subsidence. From ca. 2800 to ca. 1400 yr. cal. BP, higher rates of subsidence favored the establishment of marsh and flooded alluvial plain environments in the back-barrier domain. In the last stage, a substantial stability characterized the St. Eufemia Plain. Noteworthy is the introduction for some lagoon samples of a C_{14} dating correction of 2200 years due to the so called hardwater effect (HWE) or freshwater reservoir effect (FRE).

Donadio, Stamatopoulos et al. have carried out geomorphological and sedimentological studies which allowed a comparative analysis of the Garigliano (Italy) and Elis (Greece) littorals. In both cases, the coastal development has evolved mainly conditioned by climate and sea-level changes, and in a minor sense by the recent anthropization. On both beaches coarse pumices with the same mineralogical and petrographic composition, originating from the Aeolian Arc, have been found and represent a good geo-indicator of long-distance drift.

Short-term coastal evolution and monitoring

The second set of papers is related to the integrated analysis of short-term coastal evolution processes, with study cases along sandy coastlines in Tyrrhenian, Ionian and Adriatic seas, and to the application of innovative geomatics technologies to coastal tuff cliff monitoring and modelling in the Phlegraean Fields.

Di Leo et al. have presented a GIS-supported model describing interactions between archaeological settlement rules, site dynamics, and topographic features around the ancient territory of the Greek town of Metaponto and its *Chora* in the Ionian (i.e. coastal) sector of Basilicata, Italy. The authors suggest that the diffuse occupation of mid-altitude marine terraces and the spreading of agriculture on these sites since the Bronze Age are due to the existence of well-developed soil profiles on them. The farmhouses increment on the terrace top until the Hellenistic period and the modifications of settlement distribution (gradual abandonment of plains) are likely related to the acceleration of alluvial processes. The progressive decrease of human occupation during the late Hellenistic up to the Roman Age is a consequence of the Roman conquest. However, the role played by the increase in flooding occurrence in the coastal plain and floodplains of the main rivers in triggering the abandonment of these areas should not be neglected.

Rosskopf et al. have analyzed the modern dynamics and the shoreline changes of the Molise sandy coasts (central Adriatic Sea). Long-term erosion, occurred during the period 1954–2014, caused an overall coastal land loss, estimated in ca. 940,000 m^2. Most of the studied coasts remained stable or even advanced because of the presence of defense structures for the shoreline protection. The severe erosion processes are mainly limited to coastal segments nearest to the major river mouths and are related to channel adjustments along the Biferno and Trigno rivers since the 1950s. The construction of dams and check dams along their lower courses trapped most of their solid load, so depleting the sediment budget of the river mouth areas and adjacent beaches.

The largest Tyrrhenian coastal plains of southern Italy, i.e. the Volturno and Garigliano river plains, represent key areas for coastal studies, as they are characterized by several critical coastal issues due to the interplay between human actions since Roman times, sedimentary processes, and subsidence. Among these issues, the current vulnerability of dune systems (Donadio, Vigliotti et al.), the shoreline historical variations (Alberico et al.; Donadio, Stamatopoulos et al.), and the Holocene evolution of sub-emerged river delta (Ruberti et al.) are analyzed in this volume.

Ruberti et al. have focused on the analysis of the past shoreline change rates along the Volturno River coastal plain by using historical maps, aerial photographs, topographic maps, and bathymetric data. Two main evolutionary trends have been recognized. Until the 1970s, the erosion of shoreline was almost homogeneous. Then, the pervasive development resulted in the destruction of aeolian dunes and the growth of urban fronts, thus increasing the beach erosion, while the hotspot protections have caused localized beach accretion. Based on the shoreline change rates, a morphodynamic model has been applied to predict evolutionary scenarios also in presence of harbors and defense works.

With reference to the same area, Alberico et al. have stressed the role of historical maps, topographic maps, and satellite images to forecast the rates of coastline changes and to recognize the main features of past landscapes as tools for risk reduction. Starting from the Bourbon reign, the reclamation caused the first great territorial change (wetlands were transformed into agricultural lands and superficial water were regimented) but the negative effects of the intense urbanization of the coastal belt emerged in 1970s. A first trend (1957–1998) pointed out an intensive erosional stage (mean value 5 m/yr) for the Volturno River mouth, attributable to the reduction of sediment supply mainly due to the construction of a dam upstream. A second trend (1998–2012) led to an alternation of sectors affected by erosion or accretion due to a starved condition of the deltaic zone and to protection works.

In Donadio, Vigliotti et al. the analysis of historical cartography, wind direction data, orientation of Volturno River mouth, and shoreline changes through time pointed out a series of morphological changes due to both natural and man-induced processes that occurred along the Domitia coast in Campania, Italy, since the second half of the '50s. A change in wind frequency and direction occurred in the second half of the '70s, with almost complete disappearance of wind calm periods. After 1975, both intensity and frequency increased, thus accelerating coastal erosion in some areas. The morphological response to such environmental changes resulted in different orientation of the Volturno River mouth, which rotated from NW (between the '50s and '70s) to SW (from the mid-'70s until the present).

Geomorphic evolution of sea cliffs has significant impact on coastal settlements, so that evaluation of cliff instability processes and retreat rates are very relevant for coastal risk assessment and management. Esposito et al. have illustrated the application of innovative geomatics technologies to Torrefumo coastal cliff monitoring and modelling in the volcanic area of Phlegraean Fields in southern Italy. A crucial role in the combined use of aerial photogrammetry and LIDAR techniques is the evaluation of different spatial accuracy and co-registration between derived terrain models, so that a robust error analysis has been made. The results showed significant eroded volumes during 1956–1974 and relatively smaller ones in 1974–2008, with mean annual retreat rates of 1.2 m/year and 0.17 m/year, respectively. The significant decrease of erosion characterizing the second period was induced by the sheltering effect at the base of the cliff produced by the construction of a seawall in the early 1980s.

Coastal hazard and vulnerability

The third set of papers deals with coastal hazard and vulnerability issues showing several methodological approaches and GIS applications with examples from Spain and southern Italy.

Rizzo et al. have presented a new methodology to evaluate coastal susceptibility, based on two indices for erosion and flooding processes. The method has been tested in Valdelagrana area, a sandy spit located in SW Spain and included in the Bahía de Cádiz Natural Park. The application has shown that the method is easy and quick to apply thanks to the choice of physical parameters. It allowed identifying coastal stretches with different degree of susceptibility without requiring an intense fieldwork and therefore it can be used to susceptibility assessment in wide coastal stretches.

A first level assessment of the coastal hazard due to marine retrogressive activity in the Aeolian Islands is presented by Casalbore et al. The hazard analysis is based on the use of recent high-resolution multibeam bathymetry surveys carried out around Lipari Island. The results evidenced the presence of several submarine canyons characterized by retrogressive erosion and therefore claimed as a cause of the enhanced subsidence reported in the last few thousand years in the eastern part of the island. Furthermore, slide scar morphometry and simple numerical models have been coupled in order to roughly estimate the potential tsunami wave amplitudes generated by slope failures.

Di Paola et al. have assessed the coastal vulnerability and the exposure degree by using a two-level analysis approach in Gran Canaria coastline (Spain). The first level, based on the regional scale assessment of coastal vulnerability and exposure degree, has allowed identifying the most critical stretches, which deserve further detailed analysis. In the second step, the risk level of Las Canteras Beach has been evaluated by using the Coastal Vulnerability Assessment method that is based on more specific morpho-sedimentary beach features. The results obtained in this study stress the need to develop a strategic approach to coastal management and sustainable development.

A detailed and multidisciplinary study of physical and biotic factors of a coastal sector of southern Italy, the Pineta della foce del Garigliano, is presented by Pennetta et al. The authors evaluated the degree of dune vulnerability and sustainable anthropogenic load (carrying capacity) of the emerged beach. The results of the study provide evidence that several inadequate human practices, such as dune replacement by permanent or ephemeral infrastructures, uncontrolled pedestrian or vehicular access, and inappropriate use of mechanical beach cleaning, appear to be some of the most important factors in controlling the reduction of beach-dune system natural resilience.

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