Environmental Design Criteria through Geoindicators for two Mediterranean Coastlands[1]

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Keywords: adaptive, coastal geomorphology, hazard, Campania, Italy, Peloponnese, Greece

Abstract

This paper examines some interdisciplinary studies that were carried out along the coasts of the Campania region (southern Italy) and the Peloponnese (Greece). The objective of this research is the definition of environmental design criteria for the Mediterranean coasts, using scientific methods in order to identify critical points and devise appropriate instruments. Initially, physical-geographic and geomorphological coastal systems such as beaches, cliffs and technocoasts were defined. Here the concept of geoindicator was introduced taking into account and interpreting tectonic, lithostratigraphic and geomorphologic elements. The geoarcheological structures are also used as useful parameters for the reconstruction of the evolving landscape. Having defined the methodology used to identify the hazard of coast stretches, the parameters were put in relation with the eco-sustainable landscape recovery techniques. To curtail erosion and hydro-geological instability along the urbanized seafront, geoindicators can be employed in the design of transitional environments in relation to the return of the phenomena at different times. The results indicate how the adaptive approach and the non-imposing solutions contribute to reduction of the anthropogenic impacts and environmental hazards in regions where there is a high hazard risk, and how the safety and stability of the coasts in addition to the quality of the projects can be enhanced.

Introduction

Transitional environments are extremely sensitive to external disturbances, while being conservative at the same time they show the prevailing processes that occurred in the past. Their evolution is closely linked to the combined interaction of physical, biotic and anthropic phenomena, and is governed by non-linear physics: the higher the morphological variability of the coasts the greater the complexity of its evolutionary dynamics.

The anthropic action, particularly over the past 200 years, has contributed to the change of the coastal landscapes, especially the urban ones, through a series of actions involving the river basin and the gulf, which occurred in a short time and in limited spaces. In this sense, man operates as an exogenous agent, stiffening the soil and slowing or inhibiting the leveling action of natural agents.

The interventions on the coasts are for settlement reasons, tourism, or even protection against weather-climatic phenomena, according to traditional criteria based on the rigid opposition to the force of natural elements and intensive exploitation of valuable places having a high market value. In most cases the site is restricted to the site of operation, while transitional environments are precisely those where the dynamics of natural phenomena and their rate of the transformation should be considered. Therefore the entire area where related phenomena occur should be studied. These are also places where it is easier to pinpoint the interdependence of events and the need for a trained understanding of their complexity.

Environmental design refers to these principles, according to historical references in scientific literature, from basic ones such as the work of Ian McHarg, who pointed out how each site is the sum of historical, physical and biological processes that should be accounted for. In fact, the dynamism of these processes is closely related to the action of man, as they influence it and in turn are influenced by such action (McHarg, 1969). Philosophical reference is the holistic approach to understanding, problem solving and critical study, aimed at the solution of more aspects

1. The work is the result of collaboration between the authors; in particular, the paragraphs "Introduction", "Design Criteria" and "Conclusions" were written by Renata Valente, the other paragraphs are edited by all authors. We also thank Anna Chiara Menditto who prepared the maps.

and consideration of the concatenations. (This method, with the disposition "to listen" and study the environmental context, is the prelude to an adaptive attitude.)

Sustainable projects on the coasts are those in which the solution enables evolving configurations to address the natural phenomenon in its different forms over time, rather than block transformations with imposed measures. In order to realize such projects the necessary premise is the environmental analysis conducted in an interdisciplinary manner taking into account all physical aspects, weather-climate change, social, vocational and settlements. Moreover, this complex set of data is to be read in its intrinsic mutual relations to understand the evolutionary trends and refer to them (Johnson and Hill, 2002).

The scenarios studied allow one to distinguish the kind of design to be proposed which can be *imposed*, namely with a rigid structure, generally parallel to the coast, regardless of the topography of the site; *covert*, characterized by soft systems, flexible and recyclable, wood, recycled rubber, with the use of vegetation to control erosion or retrieve dune systems, and *hybrid*, halfway between classical archetypes and the typical solutions of non-urban surroundings (Dern, 1992; Valente, 1999). In several instances alternative configurations include dumps, transverse structures, excavations into the mainland, the shoreline stiffeners with coasts fleshed out. Several can also be the technical choices for the realization of such sets of structures, from elements of reinforced concrete or steel, or defense works composed of modular elements, up to floating modules, submerged barriers, drainage pipes and wells, coasts nourishments, consolidations with bioengineering techniques.

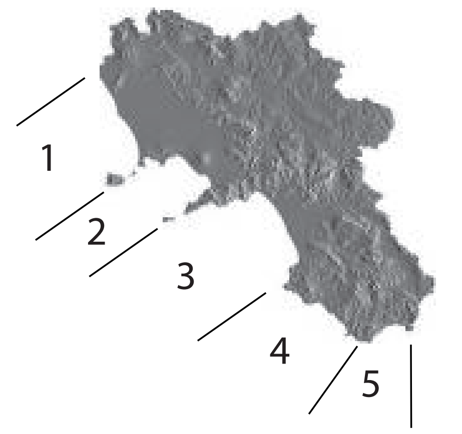
To appropriately select an adequate option reading geomorphological aspects is of greater benefit to subsequent environmental design strategies along the shore. Having defined the classification of stretches of coastline on the case study of Campania region in Italy (Donadio et al., 2014) it is compared with the stretches of the Peloponnese coast in Greece, by iterating the scientific methodology.

The alternation of short hot-arid climatic crises and cold-humid ones related to astronomical causes with cycles ranging from 150-200 years and 10-40 years (Ortolani and Pagliuca, 1994; Mazzarella, 2007), the global sea-level rise, the vertical soil movements at a regional and local scale, all contribute to the retreat of shorelines and coastal risk increase. This phenomenon is intense in many densely urbanized coastal plains, where the effects of accelerated subsidence are recorded. Typical examples of induced feedback by anthropic actions are the coastal defence works, designed to remedy the consequences of environmental changes, natural or induced, which have often amplified this phenomenon or started a new erosion focus. Therefore, these structures are surely resistant, but not resilient. Today Campania's coastal landscapes (Monti et al., 2003) show both different tectonic styles and typical geoindicators of morpho-climatic systems that are no longer active. Starting from the recognition of these issues, this paper develops a methodology for the study of coastal environments in order to propose strategies for adaptive type environmental design, where solutions of an evolving landscape are in harmony with natural transformations (Beck, 2013). This approach therefore starts by studying the physical characteristics of the places and major phenomena in them.

Coastal systems

According to morphological aspects, a *coastal physiographic unit* (CPU) is an area of coastline that borders on the edge the littoral drift along the emerged and submerged beach. Therefore the effects of a construction built on the coast does not extend outside the CPU. The boundaries of the area may not be fixed in time as a result of various events that alter

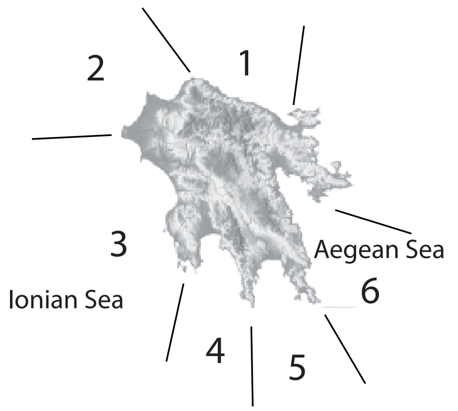
Table 1 – Coastal Physiographical Units in Campania (Italy) and their extension. The index of the structure I indicates the ratio of the total length of the coastal defences and coastal extension (average value in italics).



n°	Coastal Physiographical Unit	km	*I*
1	Gulf of Gaeta (mouth F. Garigliano-Monte di Procida)	58	0.21
2	Gulf of Napoli (Monte di Procida - P. Campanella)	305	0.38
3	Gulf of Salerno (P. Campanella - P. Licosa)	84.5	0.16
4	Cilento (P. Licosa - C. Palinuro)	112	0.13
5	Gulf of Policastro (P. degli Infreschi - Sapri)	34.5	0.11
		594	*0.20*

the dynamics of the changing coastal physiography. When observation time increases, separate CPUs can join, for example as a result of intense prolonged erosion over time or as exceptional sea storms which determine consistent sediment movements not previously implemented. The identification of the CPU can be based on various physical elements: the physiography of the shoreline, petrographic and textural composition of sediments, marine forecast system and the presence of human activities. Along the Campania coast there are five main PCUs (Table 1), six in the Peloponnese (Table 2), from the Northwest to the Southeast. *Coastal geomorphic units* (CGU) which represent segments of coastline with homogeneous morphotype features and geomorphic processes (De Pippo et al., 2008).
The comparison between the two regions, both at high morphological variability, shows that the length of the Peloponnese is about 49% greater than Campania, although some CPUs partly fall in contiguous regions and therefore the regional administrative perimeters do not coincide with the physiographic ones. This condition frequently means that the impact of the implementation measures along the coast often cause induced consequences in distant sites, too.

Table 2 – Coastal Physiographical Units of Peloponnese (Greece) and their extension. The index of the structure I indicates the ratio of the total length of the coastal defences and coastal extension (average value in italics).



n°	Coastal Physiographical Unit	km	*I*
1	Gulf of Korinth (C. Ireo - Rio)	151	0.12
2	Gulf of Patras (Rio - C. Kyllini)	90	0.10
3	Gulf of Kyparissia (C. Kyllini - C. Akritas)	188	0.01
4	Gulf of Messinia (C. Akritas - C. Tenaro)	150	0.03
5	Gulf of Lakonia (C. Tenaro - C. Malea)	152	0.02
6	Gulf of Argolis (C. Malea - C. St. Emilianos)	246	0.02
		977	*0.05*

Coastal geomorphotypes

The Campania coast stretches for 480 km, 256 km of which (60%) are high rocky coasts and 224 km (40%) lower clastic coasts (Monti et al., 2003); among them, 95 km (42%) of shorelines show erosion.
The Peloponnese coast stretches for 977 km, of 637 km of which (65%) are high rocky coasts and 340 km (35%) lower clastic coasts; among them, 110 km (32%) of shorelines show erosion. From the morpho-type point of view we can distinguish three main CPUs: the beaches, the cliffs and the technocoasts.
Maritime works are of various types: the ratio of the lengths of coastal defences and coastal extensions which provide the structuring I index, whose average value in Campania is four times greater than that of the Peloponnese (Tables 1 and 2).

Beaches
Beaches are stretches consisting of sandy and/or pebbly deposits, with good lateral continuity (Figure 1). The beaches studied are better developed when inland there is a flood plain and estuary. Some are at the foot of the cliffs. The beaches in many cases are still bounded by barrier dunes, but often have relict shapes and some wetlands behind them. The shoreline has a slightly concave or straight shape, with a slight convexity at the mouth of the rivers Volturno and Sele in Campania, Piros and Alfios in the Peloponnese. The sediment supply to beaches from the rivers in both regions has decreased since the 50s for over-mining and construction of river dams.

Cliffs
Cliffs are rocky coastlines with a significant gradient, usually 30% > (Figure 4). At the base there are often pebble beaches or debris cones, due to erosion of the outcropping lithotypes for the wave action and weathering. In Campania stratified carbonatic rocky cliffs on the Sorrento Peninsula and Mt. Bulgheria are found; terrigenous deposits (flysch), in Cilento; volcanic rocks in the Phlegrean Fields, Ischia and Procida islands, Mt. Somma-Vesuvius. The profile of the cliffs is more variable in lava rocks and/or pyroclastics; cliffs with pebble beaches or foot debris cones are widespread in the Phlegrean volcanic district, in the islands, in Sorrento Peninsula and Cilento in Campania. In the North and West Peloponnese the cliffs are modeled mostly in conglomerates, in Korinth, Patras and Kyparissia; secondary in limestones and marls in the South, in Messinia, Lakonia and Argolis, and to C. Vàrdia there are flysch strips.


Figure 1 – The sandy beaches with dunes of Castel Volturno (a) in Campania (photo P. De Stefano, 2006) and C. Araxos in the Peloponnese (b) (photo L. Stamatopoulos, 2012).


Figure 2 –The cliffs with piles of landslide of the promontory of Posillipo in Campania (a) (photo C. Donadio, 2013) and Karavostasi in the Peloponnese (b) (photo L. Stamatopoulos, 2012).

Technocoasts

Technocoasts refers to the artificial, engineered coast. Often they overlap with degraded beaches, where the construction of works or the intense urbanization have made the previous natural environment unrecognizable (Figure 5), as is visible in the areas of Naples, Pozzuoli and Salerno, in Campania, and Korinth, Patras and Xylokastro in the Peloponnese, where it is represented by the *waterfront*. This stems primarily from the high population density along these coastal areas (index of littoral), as well as the difficulty in protecting the coast. The works are distinguished by type, location and size. Along the sandy coastline rigid defense systems were built, sometimes emerging or submerged. Longitudinal adherent defences were built to protect coastal infrastructure where there had previously been a wide dune ridge. Along the rocky coasts direct interventions to curb the phenomena of collapse and overturning were implemented, before or after, to reduce the undermining by the foot swell. The first consist of coatings with rods and nets or walls, barriers, for the latter the works are similar to those of longitudinal protection of beaches. In the technocoasts the following factors can determine critical phenomena: coastal erosion, flooding, storm surges, landslides, seismicity and volcanism, anthropogenic activities and works.

Geoindicators

The methodology of identification of critical areas is based on the use of geoindicators (Hammond et al., 1995; Elliott, 1996). These, according to the IUGS (*International Union of Geological Sciences*), are described as " measures of geological phenomena or processes that occur on the Earth's surface or close to it, which vary significantly in periods of less than 100 years and provide significant information for the assessment of the environment". Within the framework of Environmental Planning Commission (*Commission on Geological Sciences for Environmental Planning* – Cogeoenvironment) of IUGS,

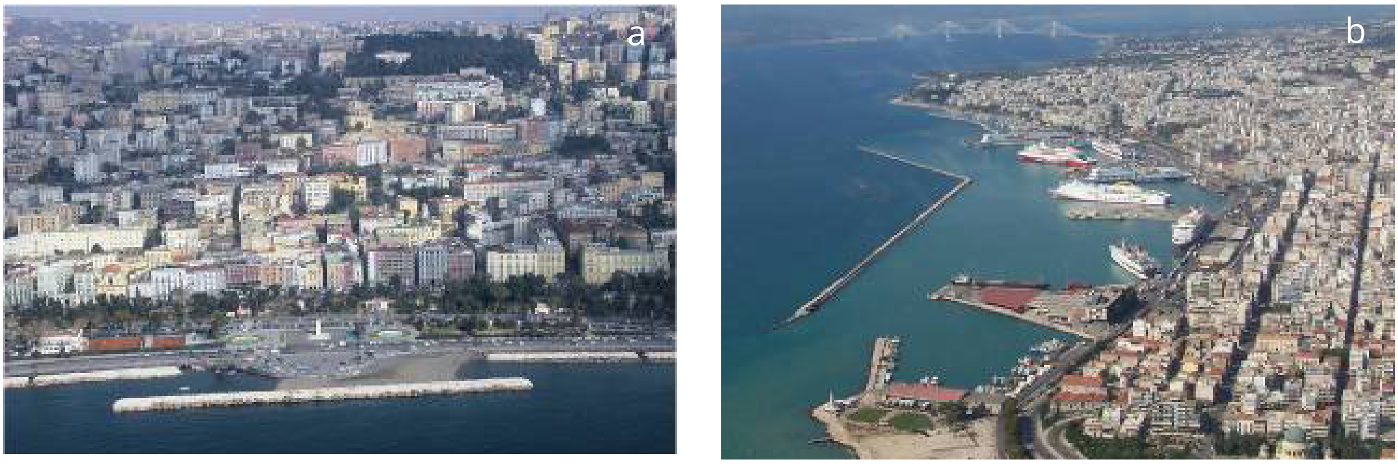


Figure 3 – Engineered coasts (technocoasts) of Naples (a) in Campania (photo P. De Stefano, 2001) and Patras in the Peloponnese.

a multidisciplinary work group (*Geoindicators Working Group*) drew up an list of 27 geoindicators with a global value (Berger and Iams, 1996). This represents a support tool for integrated assessment of natural environments and ecosystems and has a wide variety of applications in coastal risk assessment (Berger, 1997; Bush et al., 1999). This methodological approach provides a good interpretation of parameters upon which the main evolutionary processes depend. Some were chosen among the global geoindicators list by Berger and Iams (1996), considered the most significant in relation to the different and specific geoenvironmental, morphodynamic and man-made caused features. Potential critical phenomena at shorelines resulting from the examination of geomorphological aspects and regional coastal dynamics are related to six major geoindicators: coastal erosion, flooding/river flooding in coastal area, storm surge/*tsunami*, landslides, seismicity/volcanism/bradyseism/ subsidence, anthropogenic activities and works.

The values determined for each geoindicator can be attributed to stretches of coastline with physical elements (high, low and artificial coastland) and homogeneous morphodynamic processes. These values must be relative and much as possible, non-qualitative and objective. In this way the allocation of the numeric value is derived by adding together the various active phenomena in that segment, expressed by a score.

The degree of coastline criticality, dependent on each locally significant geoindicator must then be translated into a total value, resulting from the sum of the values of all the indicators considered important at large scale. Mutual influences between geoindicators which are analyzed by interaction matrix (cause/effect) where one distinguishes factors that influence the system (*cause*) and those that are affected (*effect*) by the system. This matrix (Figure 4) is used to quantify the overall criticality by indexing the intensity and the reoccurrence of various factors in each CGU (De Pippo et al., 2008 e 2009).

To quantify the different importance of interactions a semi-

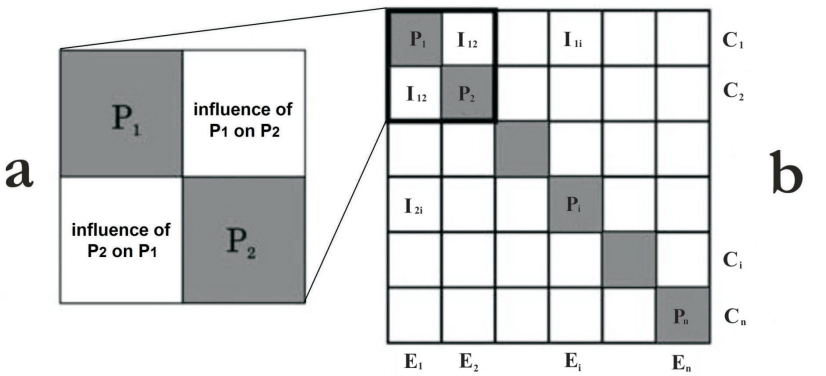


Figure 4 – Descriptive matrix of interactions of hazard. Along the diagonal there are six main geoindicators (gray squares, top to bottom): coastal erosion, floods, storm surges, landslides, seismicity and volcanism, man-made structures. The matrix indicates the influence of parameters on the system (cause of the phenomenon) or of the system on each parameter (effect of the phenomenon) [scheme a]. The cause-and-effect diagram for N parameters [scheme b] shows how the interaction matrix works: I_{12} box represents the influence of P_1 on P_2 (cause); on the contrary, the I_{21} box shows the influence of P_2 on P_1 (effect). The mechanism is repeated for each parameter of the diagonal of the matrix (after De Pippo et al., 2009).

quantitative coding is used that defines the percentage of incidence of each single parameter. For each CGU different levels of criticality factors are taken into account (Ik, from 0 to 4), to multiply individually by the resulting coefficient of the application of the matrix (Xk, from 1 to 6), which is the percentage of incidence that each factor has on GCU. The resulting weighted sum calculates the actual overall degree of criticality (Kt) with the following expression:

$$K_t = \Sigma_{n(1-6)} \cdot Ik_n \cdot Xk_n \quad (1)$$

The result of weighted summation (1) corresponds to the degree of criticality of the coastal segment varying from *low* L to *extreme* E, expressed in a map (Figures 5 and 6). The passage from the notion of *criticality*, *i.e.* territorial susceptivity of a sector to the onset of destructive phenomena, to that of *hazard*, *i.e.* probability that one or a series of natural events might occur in the future in a certain area, is dictated by the estimated return time (t_r) of events, even of anthropic origin, recognized as possible risk factors. Shorter return times, expressed in years and divided into at least four classes should be considered (Table 3).

The fourth class (D) refers to those natural events whose return

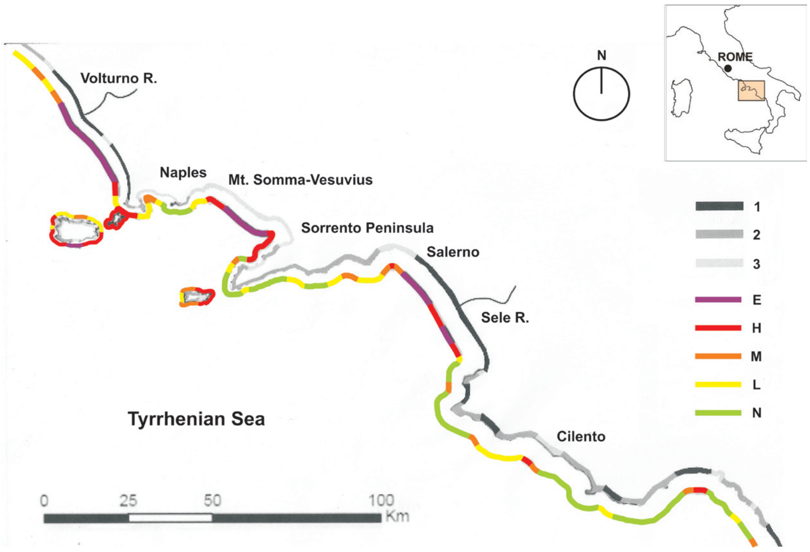


Figure 5 – Campania (Italy): Map of the Coastal Geomorphic Unit: 1, beach; 2, cliff; 3, technocoast and overall hazard along the coasts: E, extreme; H, high; M, average; L, low; N, negligible. The highest values are recorded primarily in the techno-coast UGC and the beach (after Donadio et al., 2014).

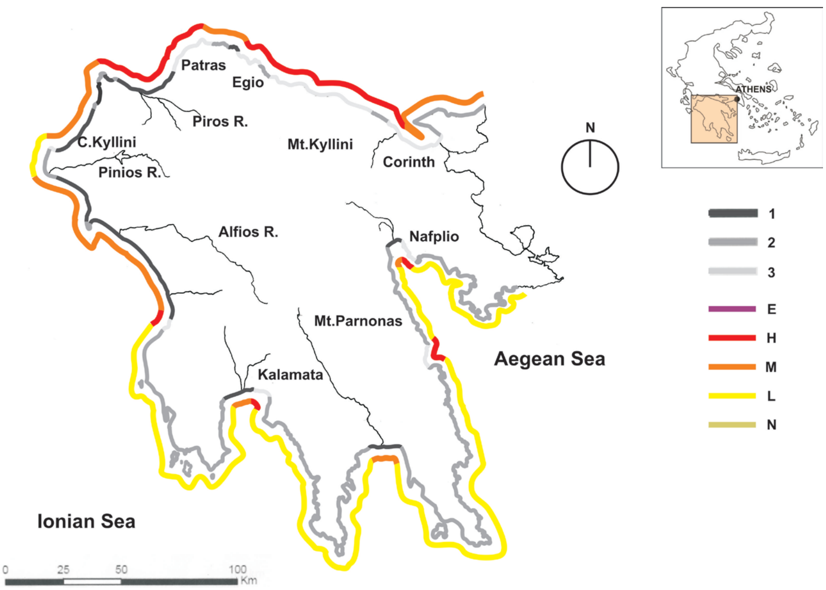


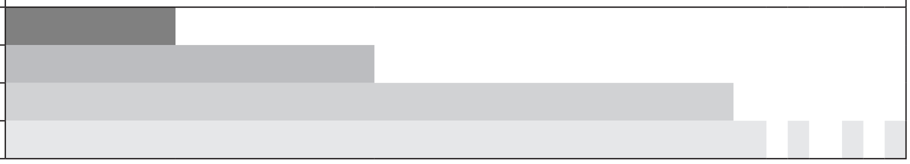
Figure 6 – Peloponnese (Greece): Map of the Coastal Geomorphic Unit: 1, beach; 2, cliff; 3, technocoast and overall hazard along the coasts: E, extreme; H, high; M, average; L, low; N, negligible. The highest values are recorded primarily in the techno-coast UGC and the beach.

periods are not well defined (such as earthquakes, volcanic eruptions, *tsunamis*) or are long compared to the average timing design. Each class is attributed a descending value between 4 (A) and 1 (D). The degree of danger is the product of critical values expressed by the application of interaction (see matrix of Fig. 1) and those of return times (see Tab. 3). The overall hazard, called geomorphological (see Figures 5 and 6), is obtained from the integration between the different hazards for each significant event, with increasing values depending on the criticality and return time (De Pippo et al., 2008 e 2009).

On the basis of the previous methodologies, the study of the Campania and Peloponnese CGUs highlights specific criticalities and hazard in similar locations as follows.

Table 3 – Classes of return time (t_r) in the short term (years) of natural events and/or anthropogenic origin recognized as potential critical coastal factors and its numeric value. The timeline shows the possible overlapping of return times allocated to six geoindicators in each CGU (after Donadio et al., 2014).

class	return time tr (years)	value	time chart
A	0 - 2	4	
B	2,1 - 5	3	
C	5,1 - 10	2	
D	> 10	1	



Campania

Ischia and Procida islands (CPU 1-2)

On Ischia high hazard is registered in technocoasts to the North and West (Ischia Porto, Forio d'Ischia), the hazard is extreme to the South due to exposure to storm surges of II-III quadrant, despite recent nourishments, and is low or negligible in the remaining sections. In Procida the hazard is high everywhere for undermining to the foot of the tuff cliff, erosion of beaches exposed to storms of the IV quadrant and in short sections of technocoast.

Island of Capri and the Sorrento Peninsula (CPU 2)

On Capri high hazard occurs in the northeastern stretch for undermining the foot in the presence of a shallow marine terrace (Pennetta & Lo Russo, 2011); medium-high hazard is registered in the North technocoast and in the cliffs in the South due to landslides. In the remaining areas it is low. On the Sorrento Peninsula the hazard is high and extreme in the technocoasts and cliffs of the northern slopes due to storms especially of the IV quadrant, for undermining the foot and landslides, while low in the southern ones.

Phlegrean and Naples coast (CPU 2)

Tuffaceous paleocliffs, modeled in subaerial environment and then submerged between -10 and -25 m are present in the Neapolitan area (Donadio and Valente, 1995). In the area west of Naples, and between Torregaveta and Castel dell'Ovo, Roman ruins which submerged down to -12 m indicate variations of the coast over the past 2500 years due to bradyseismic causes (De Pippo et al., 2002). Many partially submerged caves, man-made from the Roman Age, are along the tuff cliffs. The terraces are modelled in tuff and lava down to -50 m, while paleosea-notches only in the tuff at -1.8 and -3.7-m (Baia, Posillipo). The hazard is high in technocoasts (maritime works and waterfronts) and medium in pyroclastic cliffs exposed to storms of II-III quadrant, for undermining the foot and landslides.

Vesuvian coast (CPU 2)

The coastal sector at the foot of Mt. Somma-Vesuvius, between Portici and Torre Annunziata, is densely populated. Some Roman ruins at-4.5 m indicate coastal changes due to volcano-tectonic phenomena post-79 AD (De Pippo et al., 1996). In technocoast stretches of beach and cliffs the hazard ranges from extreme to high for exposure to storm surges of II-III quadrant and landslides.

Falerno-domitio and Sele littorals (CPU 1-3)

Beach dune systems of Garigliano, Volturno (falerno-domitio littoral) and Sele rivers show the same morphosedimentary aspects (Pennetta et al., 2011). In both, the dune is transformed by human intervention, while in others it has disappeared to erosion or appears in relict forms. The technocoast and the adjacent beaches are characterized by a high hazard to extreme, even for frequent flooding. The causes are related to the entrapment of sediments in artificial reservoirs and overmining sediment from the riverbed, reducing sediment supply to the sea through river mouths.

Cilento and the Gulf of Policastro (CPU 4-5)

This area is characterized by high and steep carbonatic cliffs and low terrigenous units, alternating with pebble-sandy pocket beaches. The shoreline retreat in recent years has accelerated due to the construction of a dam and a port. The high hazard is registered in the technocoasts and adjacent beaches.

Peloponnese

Gulfs of Korinth and Patras (CPU 1-2)

The Gulf of Korinth is a tectonically active area. Most of the coastal areas between Korinth, Egio and Patras are intensely anthropogenic. Hazard ranges from high in the technocoasts to medium in the beaches at the foot of the little craggy cliffs, exposed to waves of I-II quadrant. Dune-beach systems of Patras and Kyllini show the same morphosedimentary features (Stamatopoulos et al., 2014). The hazard is high for erosion due to storm surges of the III-IV quadrant and local floods.

Gulf of Kyparissia (CPU 3)

In this section the hazard is medium in the beach of the wide bay between C. Katakolo and Kyparissia, eroded by storms of the III quadrant, and at the mouth of Alfios river due to some flood, while high in urban stretches. Low hazard is recorded along the cliffs of Channel of Zakynthos, north of the bay and as far south as C. Akritas, due to some landslides.

Gulf of Messinia, Lakonia and Argolis (CPU 4-5-6)

These three sectors show similar morpholithologic features: the more or less steep cliffs are characterized by numerous pocket beaches. The hazard ranges from low to medium for exposure to storm surges of the II-III quadrant, undermining of the foot swell and a few landslides. High hazard only occurs in the technocoast of Nafplio.

Among the various geoindicators to consider in the morphoevolutionary recent dynamics of Mediterranean high coast one should definitely monitor the present-day sea notches along the cliffs, their morphology and depth, together with geostructural and the lithostratigraphic parameters, the height and steepness of the slope, the facing seabed morphology and the presence of landslide piles. Regarding littoral prisms, besides historical cartographic aspects, the presence of persistent erosion berms should be carefully monitored, due to storms and undermining at the foot of dunes, as well as relations between decrease in beach width, increase of the slope and sediment diameter of threshold of the shoreline (Limber et al., 2008), usually for the beaches examined, around 0.125 mm. In addition, assessment should be made of the conservation status and naturalness of the entire dune ridge and its vegetation succession, morphosedimentary and submerged aspects of bars and seabed down to -10 m depth. In both coastal morphotypes the presence of submerged structures and ruins, how deep they are and how dated are contributing factors to morphoevolution knowledge and vertical movements dynamics (accelerated subsidence, bradyseism) in man-made coasts.

Design Criteria

Considerations so far exposed explain the importance of careful assessment of temporal components of the various degrees of criticality of stretches of coastline. Physical differences and return time of previously classified events allow the setup of a methodology that is based on the dynamics of the place, on the reoccurrence of phenomena and their foreseen intensity in order to determine appropriate project strategies (Beck, 2013).

A first analysis can be carried out on the consequences normally induced by the type of settlement patterns on high rocky or low clastic coasts, as already illustrated with a chart by Valente (1999), analyzing the relation of every modification of the site in the medium term, with the aid of a plan and section. This makes it possible to record the transformations of the sites, landscape and how defense works undergo damage due to these relatively rapid changes. These physical natural and artificial alterations are then overlapped every time by the presented geoindicators that later bond with the forces normally in place. In addition, it is essential to consider further aspects such as the degree of urbanization of the sites under consideration, in addition to the quality of the settlement and the land uses. The hazard rate of the sites is evaluated multiplying criticality by the overall value of the place, in cultural, social, and natural setting terms.

Reflecting on the relationship between hazard and density, it looks like it is actually outside Europe with lower settlement concentrations where areas affected by severe catastrophic natural phenomena such as floods or storm surges could even be abandoned. On the contrary, in Mediterranean Europe and in southern Italy in particular, the concentration of population along the coastline is typically due to the special conditions of the climate and landscape. In these circumstances obviously there is a higher risk of hazard and difficulty in securing safety, control and use in the settlements. So in many cases the higher recursion of events is, paradoxically, to be considered as a safety index, just like the temporal distance between the phenomena tends to give false assurances on how to use certain places. We underline how geomorphologic information about evolving *trends* is noticeably used for environmental design besides using this information for the study of critical conditions and moreover in relation to every possible class of physical changes that could occur.

The methodological approach proposed is to consider the evolutionary process of the site as a matter to be dealt with in order to be in tune with it and avoid destructive events where the natural element takes the upper hand on the landscape created by man. Such an attitude also allows inhabitants and visitors to remember natural phenomena of the site and thus be able to benefit, in a conscious and therefore more responsible way, from an active environmental education.

This approach makes it possible to greatly increase the security of places where the population will be able to recognize the same geo-indicators or at least see the main signs of transformation adjusting human activities to natural dynamics. Examples of the adaptive project strategy proposed here are those where the increase in the level of water or land due to bradyseism or floods are addressed using floating structures that create transitory configurations of the coast in relation to the different levels of water.

In an effort to systematize in a scientific manner possible project alternatives in different conditions, plans of criticalities of the coasts of Campania (Figure 5) and the Peloponnese (Figure 6) have been studied. For morphological conditions and lighter human settlement, the Greek coasts show in general characteristics of lower criticality and greater homogeneity than the characteristics of resilience.

By comparing morphological characteristics, the degree of settlement and referring to previous authors' scientific works, two CGUs, Torre Annunziata-Castellammare di Stabia and Salerno in Campania, comparable to the CGU of Patras and Cape Ireo-Rio on the Peloponnese were chosen. For each CGU tables of the types of appropriate action in relation to the six geo-indicators and relative return time (Tables 4, 5, 6 and 7) were drawn up. This was done by initially using the semi-quantitative values indicated by De Pippo et al. (2008) for the coast of Campania and developed by analogy for the Peloponnese.

Table 4 – Appropriate actions for the CGU Torre Annunziata-Castellammare di Stabia (H, high hazard)

CGU 9: Torre A.-Castel. St., H	*geoindicator*	*return time tr (years)*	*type of action according to the site*
	coastal erosion /prograding	**2,1-5**	settlement withdrawal, RSA
	flooding / river or torrential flooding in the coastal area	**0-2**	settlement withdrawal, raised structures, floating structures, transient uses, spectacle
	significant meteo-marine event	**2,1-5**	settlement withdrawal
	landslide phenomena	**>10**	barring-down, grout, bio-engineering
	seismicity / vulcansims / bradyseism / vertical movement from load and/or compaction	**>10**	anti-seismic structures, alert system
	man-made activities and works	**0-2**	submerged protection, de-structuring margins on the water, removable structures

Table 5 – Appropriate actions for the CGU from Cape Ireo to Rio (H, high hazard)

CGU: Capo Ireo Rio, H	*geoindicator*	*return time tr (years)*	*type of action according to the site*
	coastal erosion /prograding	**2,1 - 5**	dewatering, restoration of hydrological regime / sediment intake
	flooding / river or torrential flooding in the coastal area	**5,1 - 10**	restoration of hydrological regime, permeabilization of soils, settlement withdrawal
	significant meteo-marine event	**2,1 - 5**	buildings withdrawal, dewatering
	landslide phenomena	**> 10**	barring-down, grout, bio-engineering
	seismicity / vulcansims / bradyseism / vertical movement from load and/or compaction	**5,1 - 10**	anti-seismic structures, alert system
	man-made activities and works	**0-2**	submerged protection, de-structuring margins on the water, removable structures

Table 6 – Appropriate actions for the CGU Salerno (H, high hazard)

CGU 21: Salerno, H	*geoindicator*	*return time tr (years)*	*type of action according to the site*
	coastal erosion /prograding	**2,1 - 5**	settlement withdrawal, dewatering, removable structures, recovery of dune systems
	flooding / river or torrential flooding in the coastal area	**5,1 - 10**	settlement withdrawal, raised structures, floating structures, transient uses, alert system
	significant meteo-marine event	**2,1 - 5**	withdrawal, floating structures, alert system, predisposition of escape routes
	landslide phenomena	**> 10**	barring-down, grout, bio-engineering
	seismicity / vulcansims / bradyseism / vertical movement from load and/or compaction	**—**	—
	man-made activities and works	**0-2**	submerged coastal protection, de-structuring margins on the water, respect of protected areas

Table 7 – Appropriate actions for CGU Gulf of Patrasso (H, high hazard)

CGU: Golfo di Patrasso, H	*geoindicator*	*return time tr (years)*	*type of action according to the site*
	coastal erosion /prograding	**0-2**	dewatering, restoration of water regime/sediment provision, recovery of dune systems
	flooding / river or torrential flooding in the coastal area	**2,1 - 5**	restoration of water regime / sediment provision/ settlement withdrawal /raised structures, floating structure, transient uses /alert systems
	significant meteo-marine event	**2,1 - 5**	submerged protection, de-structuring margins on the water
	landslide phenomena	**> 10**	bio-engineering
	seismicity / vulcansims / bradyseism / vertical movement from load and/or compaction	**> 10**	anti-seismic structures, alert system
	man-made activities and works	**2,1 - 5**	submerged coastal protection, de-structuring margins on the water, bio-engineering

The iteration of this process has enabled us to verify the hypothesis of synoptic framework of sustainable actions for Mediterranean CGUs. Such a framework includes general physical characteristics of high and low coasts and geoindicators present (Table 8). The table shows on top the arrow indicating the greater frequency of the phenomena. At the opposite end of the arrow, which indicates a minor recurrence of events are classified the cases where it is possible to reduce the number of actions but not the degree of attention by the authorities responsible for safety control.

In particular the results obtained show that some phenomena are not dangerous for high coasts some others for the lower ones. Examples include landslides, seismicity, flooding or tsunamis, for high coasts, or landslides for low coasts. While in general the withdrawal from the shore line of settlements is a common denominator, some particular interventions, such as the floating structures, are appropriate within several conditions such as flooding, storm surges or bradyseisms with return times that are not long. It is in these cases that among the suggested strategies there is the spectacularization of some natural phenomena to increase the tourist value of certain places. An example may be the way in which in 1985 William Wenk designed the George Wallace Park in Denver (USA), where in recreational spaces during times of flooding concrete structures become obstacles for flooding, creating scenic and attractive waterfalls.

In the presence of the beaches affected by erosion the following are used: techniques such as the RSA (recovery and stabilization of beaches through the drainage of beaches or dewatering), the choice of transitional destinations, removable and repositionable structures and, in the presence of dune barriers behind, the protection and consolidation of dunes with bioengineering techniques. However, in relation to the comparison with the return times, when immediate results are needed for high frequencies, protection and consolidation of the dunes with vegetation are associated with structures for the interdiction of crosswalks and wooden barriers against sand dispersion.

Characteristics that show the good quality of technical interventions on a beach (Blakemore and Williams, 2008), are the presence of fine and clear sands, low slope and a depth not exceeding 50 m. An overall view of the interested watershed should be taken into account, providing corrective works in the presence of dams (desilting, bypassing and hydroflushing), the increased connectivity with the recovery of the banks and river rapids modeling.

In the presence of cliffs in landslide, in addition to restoring the existing sandy and/or pebble beaches at the foot, rather than massive consolidation works, such as rivets or similar techniques, after appropriate operations of barring-down it is useful to apply grout to gravity, consisting in a mixture of cement and sand made from local rocks in fractures to close them and prevent the infiltration of meteoric and disruptive action of roots of some plant species. In addition, depending on the inclination of the slopes, it is always useful to consider the advantages offered by the use of vegetation in application of bioengineering techniques.

In the case of areas affected by flood phenomena, as well as the prediction of transient uses for floodable areas, structures that can be elevated or floating should be used.

The stretches defined as techno-coast, where man made works prevail, pose the problem of a rigidity that offers resistance but not the resilience to weathering elements. In order to dissipate the energy of the phenomena it is preferable to use submerged barriers and where possible the restructuring of the margins on the water, allowing different configurations and discontinuity.

Table 8 presents the planning of an alert system applicable in many contexts for extreme events aimed at maintaining contact with the population along the coast, in order to give warnings, information and safety guidelines before, during and after high intensity events. Design systems services, communication and information systems should be used as updated useful tools of the environmental design. Replacing the rigid defense structures with intangible elements such as networks and software that manage the timing of the inflow of persons (e.g. in the case of flooding), it is possible to envisage a return to a dynamic transformative nature of many landscapes whose evolutions have been fossilized by man, but may change again and be in harmony with natural processes.

Table 8 – Overview of appropriate actions for Mediterranean CGUs.

		return time tr (years) ← frequency of phenomena							
		A = 0 – 2 years		**B = 2,1 - 5 years**		**C = 5,1 - 10 years**		**D = > 10 years**	
		high coasts	low coasts	high coasts	low coasts	high coasts	low coasts	high coasts	low coasts
Geoindicator category	coastal erosion	*reconstruction of the beach at the foot of the cliff* *protection with submerged barriers*	*settlement withdrawal* *transient uses* *dewatering* *restoration of water regime* *removable structures* *protection and consolidation of dunes with vegetation*	*reconstruction of the beach at the foot of the cliff*	*settlement withdrawal* *dewatering* *restoration of water regime* *removable structures* *protection and consolidation of dunes with vegetation*	*reconstruction of the beach at the foot of the cliff*	*settlement withdrawal* *restoration of water regime* *removable structures* *protection and consolidation of dunes with vegetation*		*settlement withdrawal* *protection and consolidation of dunes with vegetation*
	flooding / river or torrential flooding in the coastal area	—	*settlement withdrawal* *transient uses* *raised or floating structures* *restoration of water regime* *alert and scenic system*	—	*settlement withdrawal* *restoration of water regime* *transient uses* *raised structures* *floating structures* *alert system*	—	*settlement withdrawal* *restoration of water regime* *transient uses* *raised structures* *floating structures* *alert system*	—	*settlement withdrawal* *restoration of water regime* *raised structures* *alert system*
	significant meteo-marine event / *tsunami (D)*	—	*settlement withdrawal* *transient uses* *floating structures* *predisposition of escape routes* *alert system*	—	*settlement withdrawal* *floating structures* *predisposition of escape routes* *alert system* *dewatering* *destructuring of margins on the water* *submerged protection*	—	*settlement withdrawal* *predisposition of escape routes* *alert system*	—	*settlement withdrawal* *alert system*
	landslide phenomena	*barring-down* *grout with local rocks* *prevention from use*	—	*barring-down* *grout with local rocks* *bio-engineering*	—	*barring-down* *grout with local rocks* *bio-engineering*	—	*barring-down* *grout with local rocks* *bio-engineering*	—
	seismicity/ vulcanisms/ bradyseism/ vertical movement from load and/ or compaction	*antiseismic structures*	*antiseismic structures* *floating structures*	*antiseismic structures*	*antiseismic structures* *floating structures*	*antiseismic structures*	*antiseismic structures* *alert system* *floating structures*	*antiseismic structures*	*antiseismic structures* *alert system*
	man-made activities and works	*environmental restrictions*	*submerged protection* *destructuring of margins on the water*	*submerged protection* *destructuring of margins on the water* *bio-engineering*	*submerged protection* *destructuring of margins on the water* *bio-engineering*	*submerged protection* *bio-engineering*	*submerged protection* *destructuring of margins on the water* *bio-engineering*	*submerged protection* *destructuring of margins on the water* *bio-engineering*	*submerged protection* *destructuring of margins on the water* *bio-engineering*

Conclusions

Based on the information provided on recurrences and recursion of the main evolutionary phenomena, the geoindicators prove to be indispensable tools to define the most appropriate strategies of environmental design. The comparison between the two Mediterranean regions with similar physiographic features and settlement supports the objective of systematization of the type of appropriate actions. This can be effective operational planning technical support.

Non-coercive interventions are revealed as the most adaptive along the coastline and need to be suitably calibrated in relation to the return times of active phenomena in the cases under consideration. The schemes presented as a result of the observation of the Peloponnese and Campania Region are useful for the choice of techniques to be adopted for durable works and the energies needed for maintenance, in addition to possible new sustainable ways of using and protecting the sites. The environmental friendliness of the interventions does not only depend on the size or use of the areas but above all on the design strategies and technologies chosen to carry out the works.

These ideas contribute to the construction of innovative methodologies of environmental regeneration that can transform the countries that adopt them as global references for the protection and enhancement of the landscape. It is an effort to be made, in particular in times and areas of crisis, because the economic resource represented by the special quality of the places has the unique characteristic that it cannot be moved. This constitutes a guarantee for those companies who invest in scientific research to assure that what was built/created remains where it was generated and should not be moved in quest of seemingly more competitive conditions.

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