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# The influence of anthropic actions on the evolution of an urban beach: Case study of Marineta Cassiana beach, Spain

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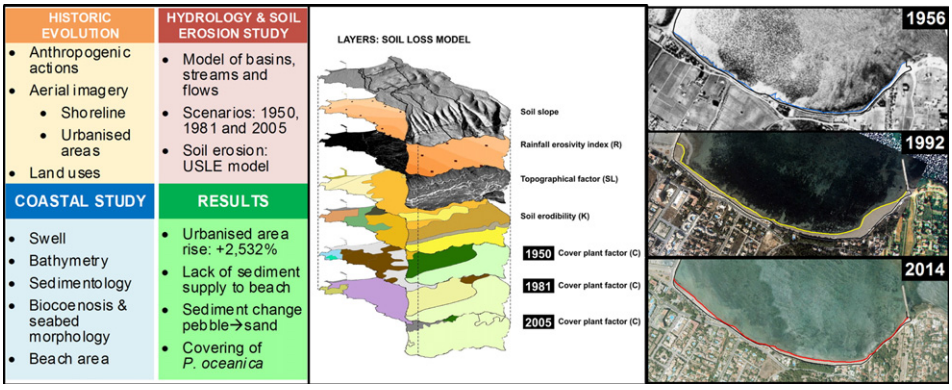
## HIGHLIGHTS

- Evaluation of the Marineta Cassiana beach changes during 65 years (1950–2015).
- Urbanised area has increased by 2532%.
- Anthropic actions have resulted to an imbalance in the studied area.
- The change in the sediment grain size has affected the beach profile.
- The covering of the *P. oceanica* meadow has led to its regression.

## GRAPHICAL ABSTRACT

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## ABSTRACT

Coastal areas have been historically characterized as being a source of wealth. Nowadays, beaches have become more relevant as a place for rest and leisure. This had led to a very high population pressure due to rapid urbanisation processes. The impacts associated with coastal tourism, demand the development of anthropic actions to protect the shoreline. This paper has studied the impacts of these actions on the Marineta Cassiana beach, in Denia, Spain. This particular Mediterranean beach has traditionally suffered a major shoreline regression, and the beach nourishments carried out in the 1980s would not have achieved the reliability desired. This research has analysed the historic evolution of the beach and its environment for a period of 65 years (1950–2015). A Geographic Information System (GIS) has been used to integrate and perform a spatial analysis of urban development, soil erosion, stream flow, swell, longshore transport, submerged vegetation species and shoreline evolution. The results show how the anthropic actions have affected the shoreline. After the excessive urban development of the catchments, there is no natural sediment supply to the beach. The change in the typology of the sediment, from pebbles to sand, during the beach nourishments has led to a crucial imbalance in the studied area. Moreover, the beach area gained has disappeared, affecting the *Posidonia oceanica* meadow, and incrementing the erosion rates. The findings obtained are relevant, not only in the management and maintenance of the beaches, but also, in the decision-making for future nourishments.



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## 1. Introduction

Coastal zones have been occupied by humans since time immemorial. However, the reasons behind this and the way to do it have changed throughout history. Since the earliest ages, humans have been attracted to the littoral zone, owing to the high productivity of its ecosystems (Kay and Alder, 1998). Coastal villages were built in relation to fishing activities. As time went on, the improvements in navigation techniques increased the value of the coastal settlements. Numerous villages emerged close to the natural harbours, thus, becoming places of great geo-political and economic value due to its military and commercial potential.

Nowadays, coastal margins occupy about 8% of the earth surface. Two-third of the biggest cities are placed on the coast (Crooks and Turner, 1999), where almost 70% of the earth's population live (Brown and Tompkins, 2012). Urban development, marine industry, exploitation of natural resources and tourism are some of the human activities that take place in the coastal areas. Likewise, they are also environments that are of key ecological importance (Defeo et al., 2009; Schlacher et al., 2007), with essential functions, such as the protection against the energy of atmospheric and oceanic phenomena, leisure or extraction of mineral and biological resources (Jiménez et al., 2011). Those sources of wealth have been exploited indiscriminately during the previous century. Threats from these main anthropogenic pressures have been widely reviewed in literature (Clark, 1996; Defeo et al., 2009; Kay and Alder, 1998; Schlacher et al., 2007). Dams on adjacent rivers or massive tourist developments have been built in many coastal areas, thereby, modifying the littoral dynamic. The effects of these on dunes destruction or beach morphology are evident (Siemens et al., 2006).

Beaches are sedimentary environments with a high-dynamic capacity located in the interface between sea and land. They have a close and complex interaction with the coastal dunes and littoral drift through a continuous storage, transport and exchange of sediments, which is modulated by the relationship between atmospheric and oceanic elements as well as by the coastal geomorphology (Komar, 1998; Nordstrom, 2000; Schlacher et al., 2007).

Coastal erosion is another topic that is broadly studied. The changing nature of the littoral zone makes the beach change occur in a different time scale, from days (for example, due to a storm) to several years. In that case, it is more difficult to identify the causes of the changes, as they do not obey only one factor; they are the result of the confluence in time and space of different processes. The vulnerability of beaches are related to its morphological features (length and width) and the sedimentary dynamics (Jiménez et al., 2011). The study of the shoreline, as the physical feature where the land and sea meet, is one of the tools widely used by coastal engineers to analyse the sedimentary trend of a beach (Defeo et al., 2009; Schlacher et al., 2007). An additional reference line is needed in order to quantify the rates of coastal erosion. This line allows for measurement of the lineal movements of the shoreline (beach width at a certain point) and the beach area. Features commonly used in shoreline mapping are the dune or vegetation line, the base of cliffs or the contact line with structures, as buildings or promenades. The invariant nature of these elements make them an appropriate choice as references in long-term studies (Johannessen and Chase, 2003; Ojeda et al., 2010; Pajak and Leatherman, 2002). Historical maps or nautical charts are used as data sources for shoreline position, however, its reliability is often limited (Fenster et al., 1993). Aerial photographs or high-resolution satellite images are the most common sources used to acquire the shoreline position from different dates. The accuracy of the shoreline measurements are enough to perform historical analysis of the beach rate-of-change. Moreover, this is a cheaper method, as it does not require an extensive field work (Baily and Nowell, 1996; Ojeda et al., 2010; Rodríguez et al., 2009).

Besides, beaches are susceptible to changes in its natural dynamics due to external factors, such as heavy rains on an urbanised environment that affect the streams discharge or the anthropic actions carried out. For example, beach nourishment, with a sediment mean grain-size lower than the previously existed. As a consequence, beach profile becomes less steep than the original, and a higher volume is needed to obtain the same beach width (Dean and Yoo, 1992). Other anthropic actions are the works done to protect the shore against the storms, such as breakwaters, dikes, groins, etc. (Dilley and Rasid, 1990; Foster et al., 2010). Sometimes, the longshore transport are disrupted, resulting in an unexpected development (Marchand, 2010; van Rijn, 2011), and may have negative effects on the shore protection, quality of the waters or the leisure interest for tourists (Ariza et al., 2008; Schlacher et al., 2007).

In addition, the internal processes inherent to the study area was also affected. The most common seagrass species in the Mediterranean Sea is *Posidonia oceanica* (Koch et al., 2006). Within the colonised area, there is an increase in the flow drag as well as a decrease in the velocity (Nepf, 1999). The leaves attenuate wave and current action thereby, increasing sedimentation (Koftis and Prinos, 2011; Nepf and Ghisalberti, 2008). Vegetation species can also attenuate the wave energy incoming to the beach (Dalrymple et al., 1984; Dubi and Torum, 1996; Mendez and Losada, 2004).

The complex relationship among the described agents that are involved in the coastal dynamics makes the coastal two-dimensional methods difficult to use. Geographic Information Systems (GIS) are a very useful tool in managing spatial data and in performing advanced studies in fields, such as land management (Chapman, 2009; Rodríguez et al., 2009), coastal hazards evaluation (Brown, 2006; Budetta et al., 2008), or in analysing the evolution of seabed and cliffs (Dawson and Smithers, 2010; Humphries and Ligdas, 2003). GIS allows for the homogenisation and integration of all the available information into a geodatabase, in order to access data, generate thematic cartography, and perform spatial and geostatistical analysis of the complex environments. This characteristic is especially useful to improve the knowledge of the coastal processes (Robin and Gourmelon, 2005), taking into account all the agents that take part in the littoral dynamics. Moreover, remote sensing can be effective in monitoring the dynamics of the coastal zones, such as the coastline movement or urban expansion (Chen et al., 2005).

This research has analysed the anthropogenic actions carried out within the same study area, as: (i) the beach nourishment with a different type of sediment (from pebbles to sand); (ii) the construction of a breakwater to reduce the incoming wave energy into the beach and (iii) the increase in the urbanised area on the catchment, which supplies the beach with sediments. All these within an already complex system, with a port to the north of the beach and the presence of *P. oceanica.* A historic evolution analysis of the study area was carried out, covering a period of 65 years (1950–2015), investigating the agents involved in the beach evolution. The aims of the work are: (i) find out what is the factor which have more influence in coastal erosion; (ii) analyse how the beach nourishments have caused the death and regression of the *P. oceanica* meadow, a high ecological value and common Mediterranean vegetation specie; (iii) study how the strong urban development carried out in the catchment have affected the flow of the ravines and its effects on the beach and (iv) propose a methodology for the study of the factors that affect the coastal environment, in order to avoid that human actions can cause imbalances in the future.

The pressures that this beach has suffered are common along the Mediterranean coast, so the framework proposed in this research will help the coastal engineers and decision-makers to perform the multidisciplinary studies needed to take the right decisions for the maintenance and protection of a complex environment as our coast is.

## 2. Study area

### 2.1. Regional setting

The study area is located in Denia, Alicante, Spain (Fig. 1a, b). The Mediterranean Sea at the east, the Marquesado plain at the north and