Science of the Total Environment 626 (2018) 87–95

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Study of the evolution of gravel beaches nourished with sand

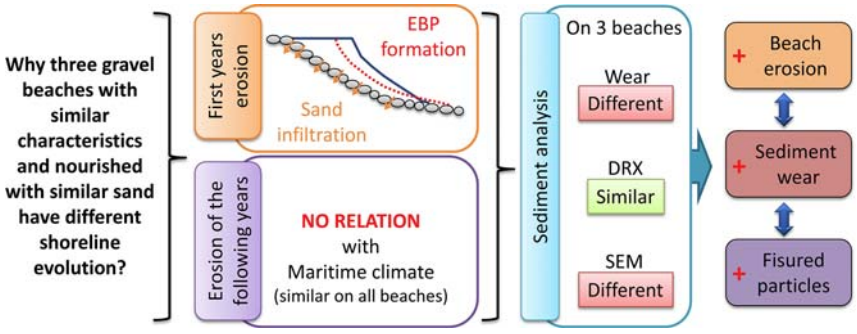
Pagán J.I., López M., López I., Tenza-Abril A.J., Aragonés L. *

Dept. of Civil Engineering, University of Alicante, Carretera San Vicent del Raspeig s/n, 03690 Alicante, Spain

HIGHLIGHTS

- Erosion in the first years after nourishment is due to infiltration and profile formation.
- Study of the shoreline evolution using aerial images since 1956
- The erosion rates are different in beaches with similar characteristics.
- The greatest erosion occurs at beaches where sediment particles are more fractured.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 14 December 2017
Received in revised form 2 January 2018
Accepted 3 January 2018
Available online xxxx

Editor: D. Barcelo

Keywords:
Shoreline evolution
Gravel beaches
Sand beaches
Sand mineralogy
Sand morphology
Beach nourishment

ABSTRACT

Coastal erosion is a worldwide problem, so accurate knowledge of the factors involved in the shoreline evolution is of great importance. This study analysed three gravel beaches that were nourished with sand from the same source. However, the evolution of their shoreline was different in each case. For its analysis, different factors were studied such as the shoreline and cross-shore profile evolution, the maritime climate, sedimentology and mineralogy. From the results, it should be noted that Centro beach is the most stable with a loss of surface after the first regeneration of 12.8%, while Carrer de mar is the most instable with a loss of 20.9%. The *Posidonia oceanica* meadow is one of the factors that make Centro beach the most stable despite being the one that receives the most wave energy. Another factor is its mineralogy and more specifically the composition of the particles that form the sample. Thus, it is observed how the cracking or the formation of particles by different minerals with a fragile union, are factors that make the beaches behave differently against erosion. For this reason, it is concluded that in order for the shoreline to be as stable as possible over time, a previous study of the sediment to be used for nourishment is necessary, as well as its possible effect on the ecosystem, since the future shoreline evolution will depend on it.

1. Introduction

Nowadays, although only 8% of the earth's land area corresponds to coastal areas, two thirds of the major cities of the word are located on the coast (Crooks and Turner, 1999) where roughly 70% of the world's population lives (Adger et al., 2004). This preference of modern society towards the coast derives in an important urban development and a growing exploitation of the coasts, and especially beaches. Beaches are susceptible to regular large morphological variations on a much shorter time scale than most geographical features, showing noticeable changes, even over the course of hours (Martínez, 2013). In the short-term, the main causes of coastal erosion are large storms (Donnelly et al., 2001; Stone et al., 1997). In long-term, however, variations are caused by the relationship between climate and sediment supply

* Corresponding author.
E-mail address: laragones@ua.es (L. Aragonés).

https://doi.org/10.1016/j.scitotenv.2018.01.015
0048-9697/

(Orford et al., 2002). Hence, the need to know the causes that produce the movement of the shoreline.

The shoreline is constantly changing, due to movements provoked and influenced by seasonality and sediment transport, which can be misinterpreted as a process of erosion or sedimentation, if taken from an inadequate time perspective. (Serrato et al., 2013). Therefore, in order to study its long-term evolution, it is necessary to have access to numerous databases in order to be able to make an accurate survey of the shorelines, and their subsequent comparison. These databases are mainly historical maps and nautical charts, and aerial photographs (Fenster et al., 1993). The latter provide the largest number of data and most reliable, but their application is restricted to the last few decades, being the document most used, currently, for calculating erosion and/or accretion rates, allowing us to assess the consequences of anthropogenic actions on the shoreline (Baily and Nowell, 1996; Jiménez et al., 1997; Pagán et al., 2017). In recent years, this technique has been perfected with digitally restored orthorecapitalized photograms, which considerably reduces possible errors caused by the displacement of stereoscopic images (Moore and Griggs, 2002; Ojeda Zújar et al., 2002).

Another important aspect in the study of the evolution of the shoreline is to know the sediment characteristics. For example, it is known that gravel beaches have a great advantage over sandy beaches due to the capacity of energy absorption, because of the infiltration of the waves between the gaps of the material (McCall et al., 2015; Quick, 1991). However, this advantage quickly disappears as the fraction of sand increases, as the finer material will reduce the permeability of the beach so that, under wave attack, the slope of the beach will flatten out and more material will move seaward (Horn and Walton, 2007; Quick and Dyksterhuis, 1994). Thus, for example, Pagán et al. (2016), observed that the nourishment of a originally gravel beach with sand caused permanent instability on the shoreline (originally stable).

Thus, authors such as Demarest and Kraft (1987) relate the movements of the shoreline to the movements of sediments above the depth of closure (DoC) as they are repositioned within the profile. While sediments beyond the DoC will be very difficult to return to the beach (Hallermeier, 1980, 1978; Stauble and Cialone, 1997), tending to move through gravitational movements towards the abyssal plains (Aragonés et al., 2016). The sediment is usually transported by suspension due to the action of waves and currents. This is a selective process, since the materials which deposit first of all will be the coarsest and heaviest, and as the energy decreases, the process will continue towards finer particles (McLaren and Bowles, 1985). This results in a movement of sediments that shows a tendency to classify them seawards (Guillén and Hoekstra, 1997; Niedoroda et al., 1985; Stauble and Cialone, 1997). Therefore, the size of the sediment will depend on the source of sediments, the morphology of the beach and the wave energy (Guillén and Hoekstra, 1996). Therefore, grain size analysis can provide important clues to sediment source, transport history and deposition conditions (Bui et al., 1989). However, other authors suggest that erosion not only depends on the median sediment size (D_{50}) or proportion of fine particles, but also on density (Roberts et al., 1998) or possible wear of sediment particles (I. López et al., 2016; M. López et al., 2016).

Therefore, although many factors influence coastal erosion, this article aims to analyse the motives and main factors why the nourishment with sand of three original gravel beaches have completely different behaviours from each other. For this purpose, a study of the evolution of the shoreline of these beaches over the last 50 years is carried out. Secondly, the waves are analysed taking into account the energy both in deep water and in the onshore zone, considering the possible reduction

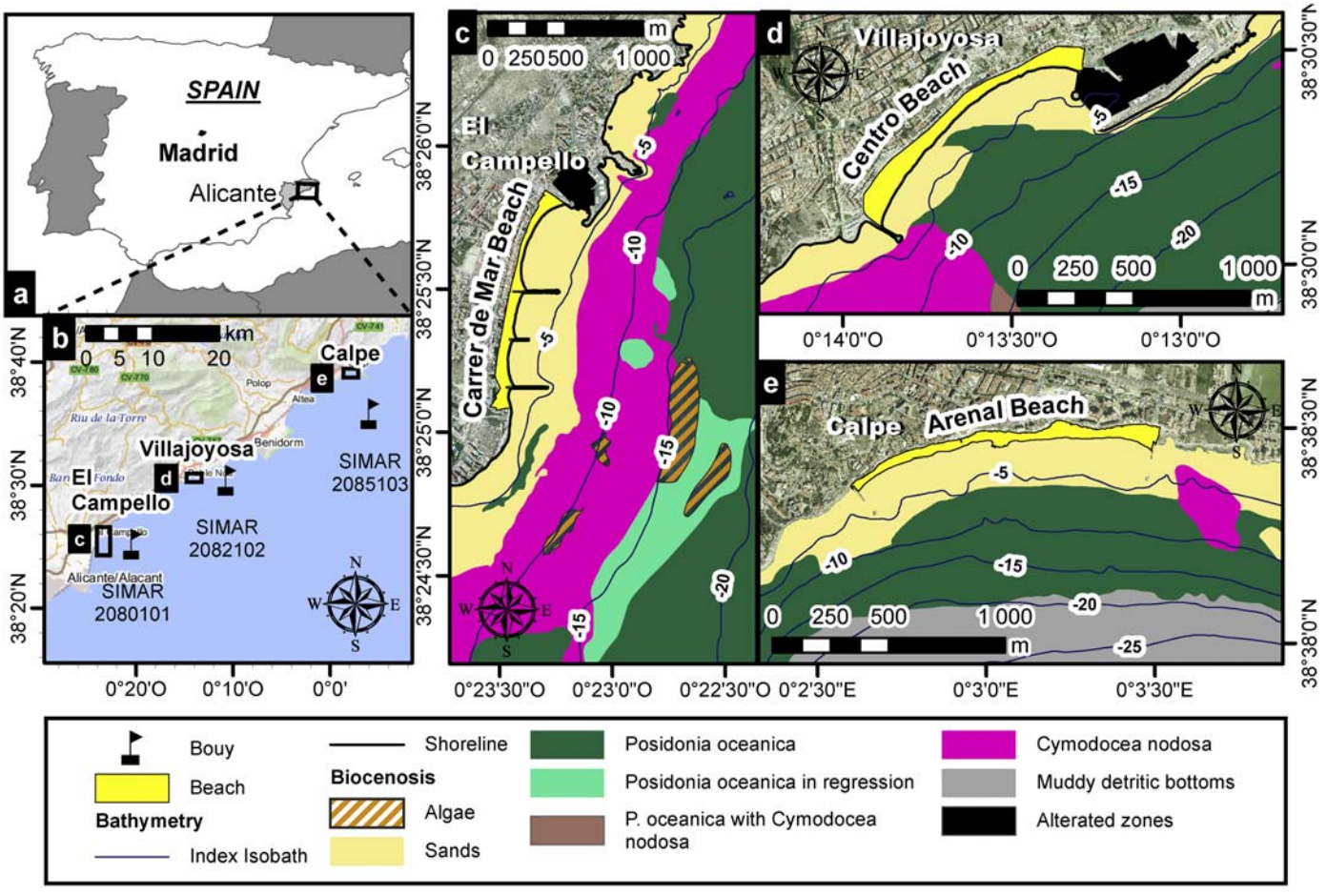


Fig. 1. a) Location of the studied area. b) Beaches and position of SIMAR nodes. c) Carrer de mar beach. d) Centro beach. e) Arenal beach.