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Beach nourishment impact on *Posidonia oceanica*: Case study of Poniente Beach (Benidorm, Spain)

L. Aragonés[a,*], J. García-Barba[a], E. García-Bleda[a], I. López[a], J.C. Serra[b]

[a] *Department of Civil Engineering, University of Alicante, Carretera San Vicent del Raspeig s/n, 03690 Alicante, Spain*
[b] *Department of Transportation, ETSI Caminos, Polytechnic University of Valencia, Camino de Vera s/n, 46022 Valencia, Spain*

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ABSTRACT

The importance of nourishment processes on the beaches of Mediterranean Sea has been increasing since the end of the 20th century due to its socio-economical awareness (tourismboost) and environmental implications (possible impact on *Posidonia oceanica* meadows and important processes of dredging and earth movements). However, in many cases, and especially in eastern Spain, relevant actions have been made which had caused that, after 20 years, the beaches in which these works were carried out will be in a similar situation with the original one.

The present study analyzed the Poniente Beach (Benidorm, Spain), a beach where the nourishment works of 1991 have caused the disappearance of the *Posidonia oceanica* meadows and a regression process that will lead to the disappearance of the beach in a few years.

To this end, data from bathymetry, georeferenced orthophotos, grain size analysis and swell study have been obtained and analyzed, understanding the importance of the works done to be consistent with the environment in which they were developed, and providing a work process which can ensure the existence of the nourished beach starting from the maintenance of *Posidonia oceanica* meadows.

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1. Introduction

Artificial nourishment of beaches consisting of sand dumping on the dry beach is more common in recent years than the construction of rigid structures, becoming the main alternative in fighting erosion processes (Hamm et al., 2002; Medina et al., 2001). In much of the Comunidad Valenciana's coast, located in eastern Spain, this type of actions have been concentrated on, within a short period of time, in such a way that only considering those interventions which include twenty-nine artificial nourishment of dredging sand were carried out between 1985 and 1999 (Beachmed, 2003).

These types of “soft” actions, so called because they do not introduce rigid elements on the beach, are often considered the most environment-friendly option. Nevertheless, it is well known that some nourishments can cause damage to the adjacent *Posidonia oceanica* meadows (Fernández Torquemada and Sánchez Lizaso, 2005; González-Correa et al., 2008) as they may significantly increase the turbidity of the water and thus reduce the incidental light on the meadow, leading to drastic changes in its growth and its subsequent disappearance (Medina et al., 2001). On the other hand, beach replenishment can also lead to the burial of the plant in extreme cases. If the deposition of sand is moderate, not involving a prolonged burial, the plant will be able to resist since the average vertical growth rate has been evaluated at 1 cm/year in the Mediterranean Sea (Marbá and Duarte, 1998). However, if sediment deposition is very strong and persistent, the plant may have difficulties to grow fast enough, dying as a result of the burial. In this regard, Manzanera et al. (1998) carried out an experiment in which several plants of *Posidonia oceanica* were completely buried, causing that after 200–300 days a hundred per cent of rhizomes were dead.

In some other cases, it has been observed that the contribution of sand has led to a considerable decrease in the health of the nearby *Posidonia oceanica* meadows. This is the case of the nourishment of Lisa Beach, in Santa Pola (Spain) in 1985 (González-Correa et al., 2008), or the expansion and construction of the Port of Altea (Spain), which produced a negative impact in the distribution and structure of the *Posidonia oceanica* meadow due to the turbidity increase and epiphytes load, which caused the reduction of the light in the area (Fernández Torquemada and Sánchez Lizaso, 2005).

This conflict in line with the key environmental elements of the coast has caused an environmental concern that explains the decrease of this type of actions in the Mediterranean coast since the 1990s (Medina et al., 2001). The impact of Posidonia oceanic

* Corresponding author. Tel.: +34 690716678.
E-mail addresses: laragones@ua.es (L. Aragonés), javier.garciabarba@ua.es (J. García-Barba), e.garcia.bleda@gmail.com (E. García-Bleda), isalopu.il@gmail.com (I. López), jserra@tra.upv.es (J.C. Serra).

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could be highlighted from both the negative (dumping area of material) and the area of extraction (Landaeta, 2001).

However, there are some nourishments out from Comunidad Valenciana, carried out from the criterion of sustainability, which shows the need to take the biocenosis of the area into account, such as the replenishment that was conducted in the Saint George Bay in Malta in 2004 (Borg et al., 2006). It shows that *Posidonia oceanica* was chosen as a biomarker for the biological component of the EMP (Environmental Monitoring Programme), due to its wide distribution and sensitivity to anthropogenic perturbations (Pergent-Martini et al., 2005). In this case, the monitoring showed that an important offshore transport of sediments had occurred and that beach replenishment work did not produce negative effects in the marine environment (Borg et al., 2006).

On the other hand, *Posidonia oceanica* provides other advantages that could be lost if they disappear. The three-dimensional structure of rhizomes form a certain reinforcement for the sandy sediment of the submerged beach which, along with the roots and leaves, hinder the sedimentary movements of the seabed, consolidating the sandy substratum and making the submerged beach profile changes much slower than what they would be in the absence of the meadow (Medina et al., 2001). In addition to the reinforcement of the sandy soil, the foliage of the meadow increases the roughness of the seabed, facilitating the wave energy dissipation (Gacia et al., 1999). The absorption of wave energy might be in some cases between 30% and 40% of the total energy (Bouderesque and Meinesz, 1982).

There are references that support the profile change observed after the death of part of the meadow, for instance, the case of the beach erosion on the Gulf of Giens (France), where the partial disappearance of the *Posidonia oceanica* meadow, caused the disappearance of sandy substrate and the erosion of the seabed, due to the spill in two points of a wastewater treatment plant, which tended to reach a new equilibrium profile (Maggi, 1973).

Maggi (1973) also noted that there was an increase in the average size of the beach particles, which attributed to the dragging of the thickest grains that had been trapped by the roots of the plants and was released after their death.

This paper will discuss a particular case which will provide important information that can be extrapolated worldwide, especially to the Mediterranean Sea, since *Posidonia oceanica* is an endemic seagrass from this zone (Medina et al., 2001). The nourishment carried out on Poniente Beach (Benidorm) in 1991 is an exemplary project to study beach nourishment's effects on *Posidonia oceanica*, since part of the meadow was buried during its execution. In order to evaluate the possible consequences of that artificial replenishment in subsequent beach erosion processes, the historical evolution of different beach descriptors has been studied up to the present. From the results obtained, how the nourishment process should be carried out was analyzed, suggesting a more sustainable practice that meets both the physical demands of a beach nourishment project as well as the marine environmental protection requirements including the criteria of marine environment maintenance and beach functionality (Borg et al., 2006).

2. Study area

The area under study corresponds to Poniente Beach (Benidorm, Spain) (Fig. 1), located in the Spanish Mediterranean, and it represents a very important point for the tourism of Comunidad Valenciana (Mazón, 2010). Part of this success is due to its two beaches of fine sand (0.300 mm), Poniente Beach and Levante Beach, with lengths of 3008 m and 2261 m respectively (Ecolevante, 2006). Both beaches are included in a closed littoral system, forming a headland embayment. This is important, since its study could be compared to other authors' investigations related to similar coastal systems (Grunnet et al., 2004). Their location in the western Mediterranean makes them to be afflicted with some frequency by sea storms that cause economic damages to the activities implemented in the littoral (Olcina and Torres, 1997). However, since these beaches are south-facing and they are protected by the massif of Sierra Helada, only E–SE swells really reach the beaches, remaining the excluded E directions (most frequent sea storms), E–NE and NE. Therefore, the storms impact is lower than the one in other parts of Eastern Spain.

High frequencies of the swells from the E–SE direction were, indeed, what prompted the research on, ultimately, the nourishment of the East side of Poniente Beach in 1991 (MOPT, 1991). The beach replenishment was developed over 1350 m of coastline, corresponding to the section between the Benidorm port and the mid-point of the beach, where the regressive trend disappears.

These actions were conducted as an emergency measure to the E–SE sea storms that took place in those years, with waves impacting on the maritime promenade wall causing structural damage on it and even mismatch problems in its base (MOPT, 1991).

The adopted solution was the artificial contribution of sand in the eastern half of the beach (Poniente Beach, Fig. 1) of 710,847 m^3 coming from the dredging of the seabed next to Sierra Helada mountain (MOPT, 1991). The nourished beach length was 1350 m, so, the unit volume of sand dumped was higher than 500 m^3 per linear meters of beach, this increase the initial beach width from 20 m to 100 m after the process (Fig. 2). This width increase required the creation of a breakwater to contain the sand and prevent the port from silting up (Fig. 3).

3. Methodology

This section describes the methodology used studying the behavior of Poniente Beach over time.

3.1. Historical coastline evolution

The analysis of the historical evolution of the coastline was realized by the superposition of series of georeferenced orthophotos (Ojeda et al., 2013) from 1956 until 2012 (Fig. 4). Specifically, the studied orthophotos correspond to years 1956, 1981, 1986, 1990, 1992, 1994, 1996, 1998, 2005, 2007, 2009 and 2012, and their analysis has allowed to observe the coastline trend before and after nourishment. To this end, the surfaces won and lost between each pair of compared orthophotos have been calculated, distinguishing between the eastern half of the beach, the western half and the beach as a whole.

In order to define in greater depth the evolutionary trend of the beach in plant the net longshore solid transport was calculated. As first approximation, the theoretical transport was calculated using the CERC formulation, considering default values for its two calibration coefficients (SPM, 1973). Since this formulation assumes the condition of unlimited availability of material, it can provide quantitative results far removed from reality, although it is qualitatively valid to define the direction of net transport. Therefore, the real annual transport between 1991 and 2006 has also been calculated and analyzed the sedimentary balance on the beach, through the volume variations observed by comparing cross-shore beach profiles. Thus, not only the real transport is quantified, but also the validity of the CERC formulation can as well evaluated in the study area.

Also, based on wave data from Alicante Coastal Buoy 1616 (38.25°N; 0.41°W), provided by the public institution Ports of the

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