Evolution of a beach-dune system after artificial nourishment: The case of São Joao da Caparica (Portugal)

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1. INTRODUCTION

Costa da Caparica seafront margins a low-lying strand-plain where conflicts have coexisted throughout the last seven decades between development and conservation (cf. Veloso-Gomes et al. 2007; Pinto et al. 2007). Development grew exponentially after the 1950's, bringing housing and other infrastructures too close to the shoreline, and this was accompanied by construction of hard coastal defences in the early 1960's including a groin field anchored in a seawall, both having been damaged by the winter 2013/14 Christina storm.

Since the early 2000's the strategy of intervention switched to beach nourishment and dune restoration, adopted as adaption methods to cope with impacts of long- term erosion trend, storm-driven inundation, damages to hard engineering structures and preservation of beach recreational value. Main objectives of this study are the characterization of morphological evolution of São João da Caparica (SJC) of the beach-dune system following artificial nourishment operations and evaluation of hard and soft interventions performance.

2. STUDY AREA

This study focuses on the 1.3 km-long coastal stretch of SJC, in the Atlantic coast of the municipality of Almada (south of Lisbon, mainland Portugal). This beach consists of medium-fine, well to moderately well sorted sand and is limited by two groins; a seawall bounds the southern third of the beach length, whereas to the north it confines with a dune system that has been rehabilitated in 2015 under ReDuna project (http://www.lifebiodiscoveries.pt/sites/default/files/projeto_reduna.pdf). SJC and beaches extending further south along the Caparica seawall and groins for 3.9 km were artificially nourished in the summers of 2007 to 2009 (total ~2.5 M m^3), 2014 and 2019 (1 M m^3 each). Nourishments used dredged sand made available by the Lisbon port authority in the scope of channel maintenance operations (Pinto et al. 2020).

3. METHODS

Topographic data were acquired to characterize seasonal beach changes, as well as to quantify longer-term evolution trends and map volumetric changes over the beach–dune system. Data were acquired by means of repeated RTK-GPS field surveys and photogrammetric processing of imagery captured by unmanned aerial vehicles. These were merged with information obtained under the COSMO monitoring programme (https://cosmo.apambiente.pt/) and unpublished data collected in the scope of projects carried out by Faculdade de Ciências da Universidade de Lisboa, the Portuguese Environmental Agency and the Municipality of Almada (eg., Andrade et al. 2019). Data were processed using Agisoft and ArcGIS Pro to obtain digital elevation models, interpolate selected profiles and obtain beach and dune volumes above mean sea level (MSL) and 2 m (MSL), respectively.

4. RESULTS AND DISCUSSION

Long-term beach erosion in SJC is indicated by consistent decrease of the overall beach volume between successive replenishments: -44,000 m^3/yr. (2009 –2014 and 2014 –2019) and -59,000 m^3/yr. (2019 –2021). Beach responded differently alongshore within the same time window and in distinct periods between nourishments (+0.15 to -0.19 m^3/m day). This is interpreted as resulting from persistently negative sediment budget (cf. Santos et al. 2015) related with longshore processes that is superimposed by shorter-term, cross-shore dominated changes in volume related with seasonal wave regime and beach rotation. Periods of sand loss are separated by abrupt increases in volume determined by artificial sand replenishment of the beach berm. Such operations were conducted in SJC in the summer of 2007 (~29x104 m^3), 2008 (28 x104 m^3), 2009 (28x104 m^3), 2014 (38x104 m^3) and 2019 (17x104 m^3) and increased the berm width (by about 60-70 m) in addition to raising the berm height up to 3-3.5 m MSL. The southern beach sector showed higher susceptibility to erosion and resumed pre-nourishment morphology and volume shortly after post-replenishment storms. This is due to the seawall enhancing reflection of wave energy and precluding temporary profile retreat during storms together with blockage of northward net littoral drift promoted by the groin at the southern beach end and explains the higher performance of nourishments at the northern beach section.

Estimations of total beach volumes and losses over time suggest that the longevity of the nourishments is of 4-5 years, and that a new replenishment should be required not later than 2024 to maintain protection offered by the beach-dune system. Moreover, field monitoring of morphology and of landward reach and impact of wave swash before and after significant storms (observed in the field and reported by media) suggest that a volume bigger than 30x104 m^3 is satisfactory to grant effectiveness in protecting dunes from wave erosion, and to allow for unconstrained beach-foredune aeolian sand transport (cf. Andrade et al. 2019). A critical volume of 16x104 m^3 requires urgent beach refill given the high risk of full beach overwash and dune breaching/overtopping.

Sand fences and vegetation introduced in 2015 under ReDuna restoration, following erosion by Christina storm, led to in situ growth of a small primary dune, shifting the coastline 10-20 m seaward. The new dune grew rapidly in the first year following fence deployment and more slowly in the following two years. Storm erosion and dune overtopping in 2017 and 2018 interrupted the growth pattern at the centre and southern dune sections. Fences were reconstructed after damaging episodes, allowing for aeolian processes to resume increase in dune volume. Following the 2019 replenishment, a second positive pulse in dune growth is noticeable. Field observations indicate that despite erosion and overtopping, the obstacle provided by this dune proved effective in protecting the dune ridges located further landward, which host several beach restaurants.

5. CONCLUSIONS

Hard engineering structures built at, and further south of, SJC beach were effective in halting coastal retreat but this triggered loss of the subaerial beach. In consequence, maintenance of the recreational values of beaches requires regular artificial renourishment of groin field cells. The northern section of SJC has been solely subjected to beach nourishment and dune restoration; altogether this strategy was also quite effective to counteract long term erosive trends with the additional advantage of preserving environmental and recreational values.

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