MONITORING BOUNDARIES TO EVALUATE BEACH AND SHOREFACE NOURISHMENT EFFECTIVENESS AND PERFORMANCE

Celso Aleixo Pinto, Portuguese Environment Agency (APA), celso.pinto@apambiente.pt
Bruno Pires, Portuguese Environment Agency (APA), bruno.pires@apambiente.pt

INTRODUCTION

Current coastal protection strategy in mainland Portugal defines beach and shoreface nourishment as a valid measure to mitigate coastal erosion in some erosional hot-spots. Here we discuss the relevance of setting appropriate monitoring boundaries to assess the effectiveness and performance of three nourishment interventions and therefore to conclude about their success or failure regarding pre-established objectives (e.g. mitigation of coastal erosion and risk; improvement of the recreational use and value of the coast).

METHODOLOGY

The efficiency of a nourishment, as proposed by Roest et al. (2021), can be calculated as the volume of sand remaining within the initially nourished boundaries after a certain time period. To assess different efficiencies, volume calculations were performed within the initial placement area (i.e. to assess local efficiency) and within the entire survey domain (i.e. to assess feeder efficiency) (Figure 1) and were obtained through the comparison of high-resolution topo-hydrographic surveys performed in the three study areas: Costa Nova; Costa de Caparica; and Vale do Lobo (Figure 1a, 1b, 1c).

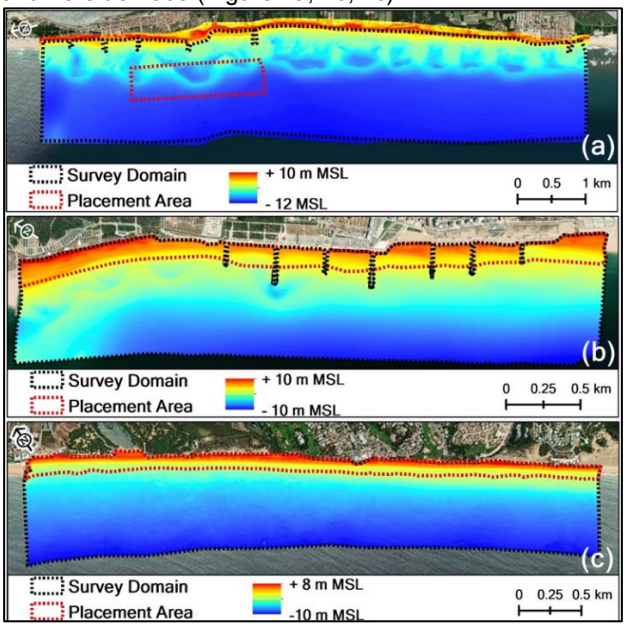

Figure 1. Placement areas and survey domains

In Costa Nova (Figure 1a), the placement area is located in the shoreface, between - 6 m MSL and -10 m MSL bathymetric contours, while the survey domain (12 km^2) extends off-shore until -12 m MSL. In Costa da Caparica (Figure 1b) and Vale do Lobo (Figure 1c), placement areas were in the dry beach, typically above MSL, in order to increase beach width. Survey domain extends until -10 MSL in Costa da Caparica (3 km^2) and - 8 MSL (3.4 km^2) in Vale do Lobo.

RESULTS AND DISCUSSION

The nourishment projects comprised the following features: (1) Costa Nova - placement of 2.4 x 10^6 m^3 of sand in 2020 in the shoreface (Pinto et al., 2022); (2) Costa de Caparica - placement in the dry beach of 1 x 10^6 m^3 in 2019 (Pinto et al., 2020); (3) Vale do Lobo - placement in the dry beach of 1.25 x 10^6 m^3 in 2010 (Pinto & Teixeira, 2022).
Tables 1 and 2 synthetize volume changes and % losses within, respectively, the placement areas and survey domain.

Table 1 - Volume changes and losses (placement area).

	Placement area (km^2)	Remaining volume (m^3)	Losses (%)	Monitoring time period (years)
Costa Nova	1	1.3 x 10^6	40 %	0.6
Costa de Caparica	0.8	0.55 x 10^6	45 %	1
Vale do Lobo	0.7	0.38 x 10^6	70 %	10

Table 2 - Volume changes and losses (survey domain).

	Survey domain area (km^2)	Remaining volume (m^3)	Losses (%)	Monitoring time period (years)
Costa Nova	12	1.4 x 10^6	30%	0.6
Costa de Caparica	3	0.75 x 10^6	25 %	1
Vale do Lobo	2.4	0	100 %	10

a) In Costa Nova, a high-energy wave-dominated coast, results show rapid (ca. 6 months) morphological change over the placement area, with a decrease of about 40% of the initial volume (Table 1). Fast onshore sediment redistribution explains part of this change, placed sand having merged with the pre-existing bar system increased the volume of the shallower nearshore (Pinto et al., 2022). Longshore transport is reflected by increasing the robustness of the bar downdrift of the placement area and also explains the negative sediment budget (0.75 x 10^6 m^3) of the survey domain, which corresponds to losses of 30% through its southern boundary.
In this case, a high percentage of losses in only 0.6 years in the placement area are desirable, given that one of project objectives is that this shoreface nourishment is expected to diffuse in the cross-shore and longshore directions and dissolve in the system, thus mitigating coastal erosion and reducing storm damage in the adjacent beach and southward for a given period, as previously identified by Pinto et al. (2022). Linear extrapolation into the future of the mean annual net longshore drift indicates that, despite the large magnitude

of the most recent intervention, the permanence of placed sand within the survey domain (12 km^2) is of 2-3 years, suggesting the need for frequent renourishment operations.

b) In Costa de Caparica, a medium to high-energy wave-dominated coast, coastal processes and beach evolution are partly influenced by Tagus estuary ebb-delta sediment circulation cell and its associated complex morphodynamics (Fortunato et al., 2021), making it difficult to assess and fully understand the performance and behaviour of beach nourishments in this area.
Results show that initial losses in the placement area (i.e. dry beach) over a 1 year period are significant (45 %) (Table 1). However, in the survey domain losses are lower (25 %), which means that a large proportion of the sediment is still in the active zone of the beach profile, which seems positive. Given that the boundaries (north and south) of the survey domain coincide with the placement area, feeder efficiency cannot be evaluated.
Considering the time period between 2014 and 2019, annual losses are ≈ 0.2 to 0.25 x 10^6 m^3 in the survey domain (Pinto et al., 2020), suggesting an average lifetime of a 1 x 10^6 m^3 nourishment of ≈ 5 years.

c) In Vale do Lobo, a low-energy wave-dominated coast, the entire volume of the beach nourishment performed in 2010 has already abandoned the survey domain (2.4 km^2) (Table 2), with annual losses of 1.3 x 10^5 m^3/year, that can be assumed as an estimate of the residual net longshore drift. In the placement area losses are of 70 %, which means that after 10 years, 30 % of the placed volume is still retained on the dry beach, in apparent contradiction with the above mentioned. According to Pinto & Teixeira (2022), such behaviour must be related to the increase in the grain size of the placed sand in relation to the native sand, which will have imposed a new equilibrium configuration on the profile, giving it greater stability and, simultaneously, increasing efficiency of the dry-beach fill.
Likewise in Costa de Caparica, given that eastern and western boundaries are the same for the survey domain and placement area, feeder efficiency cannot be evaluated. However, considering eastward longshore sediment transport direction, it´s foreseeable that adjacent eastern beaches (i.e. Faro beach) benefit from the sediment that leaves the survey domain.

CONCLUSIONS

This work addresses beach fill efficiency, performance and lifetime in three different coastal areas, over diverse time periods (months to decades) and with different coastal protection objectives.
Results obtained by comparing volume differences between the placement area and survey domain show the importance of setting the adequate boundaries for assessing correctly nourishing efficiency, lifetime and its degree of success.
In Costa Nova shoreface nourishment, the sand is intended to disperse and diffuse over the survey domain and, at a larger scale, over the coastal cell, contributing to the sediment balance and thus mitigating coastal erosion. Considering this objective, losses in the placement area must be considered positive, with the feeder efficiency parameter being the best performance indicator.
In Costa de Caparica, the main objective of the nourishment is to maintain a relatively wide beach berm and that the sand is retained in the survey domain for as long as possible. Here, feeder efficiency evaluation is not relevant or adequate as a performance indicator, being local efficiency the most suitable. Nevertheless, survey domain provides valuable information regarding lifetime of the nourishment and sediment budget, complementing the information provided by local efficiency indicator.
In Vale do Lobo, the 2010 beach nourishment achieved the objectives initially established (i.e. maintain a wide beach berm for at least 10 years), even surpassing the initially estimated lifetime. Local efficiency is the most suitable performance indicator, being feeder efficiency not applicable. Given the remaining volume in the placement area, a new renourishment operation must be planned in the short term.
The selection of the most appropriate performance indicator depends on the type of nourishment (i.e. shoreface or beach) and the project's objectives. It is recommended that the monitoring boundaries of the survey domain be more extensive than those of the placement area, so that the latter is completely covered by the former, thus not limiting the use of the feeder efficiency indicator.
Results show that the established coastal protection strategy in Portugal, focused in counteracting the existing sediment deficit throughout beach and shoreface nourishments, is meeting, in a general way, the objectives of shoreline protection and coastal erosion mitigation.
Accurate and repeatable monitoring data are essential in performing these kind of assessments, highlighting the need to maintain systematic coastal monitoring programmes through time, like the COSMO Program https://cosmo.apambiente.pt/.

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