Power and limitations of Nature-Based solutions to enhance coastal resilience

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BACKGROUND

Coastal communities are unquestionably threatened by sea level rise and storm intensification. Their vulnerability is primarily function of their exposure, increasing in time, resulting into cascading effects affecting the spatial and temporal risk variability along shorelines. Many coastal communities, fearing for their future, are considering interventions aimed at improving their resilience, in particular, Natural and Nature-Based Features (NNBF) to respect the functionality of the local ecosystem and minimize negative feedback effects, that are often induced by interventions. While such features are appealing, their long-term efficiency in a changing environment is not always anticipated, and sometimes misunderstood or overestimated.

In the present study, which is sponsored by the United States (US) NOAA's "Effects of Sea-Level Rise (SLR) 2021, Coastal Resilience" Program, building on over a decade of hazard and risk assessment studies along the US New England shoreline (e.g., Grilli et al., 2017, 2020; Schuh et al., 2023), we assess the efficiency of selected NNBF in changing climate conditions, while integrating local concerns, observed trends, and supporting local ecosystem and people's way of life. Specifically, we focus on beach barrier systems along sections of the New England shoreline, in particular, in this paper, along the Rhode Island southern shore. Beach barrier systems act as "ecosystem engineers" (EE), protecting the back bays from direct wave impact and reducing storm surge and flow passing through their inlets and naturally adapting to slowly evolving SLR and wave climates by regressing or transgressing. Observations have shown that environmental and anthropogenic changes challenge the natural adaptability of these EE. In this respect, current predictions of large changes in future SLR and wave climate, are concerning as these could imbalance the EE's dynamics through cascading effects leading to potential destruction of the dune systems. Here, we address the overarching research questions: (1) can we predict future changes in functionality of these local EE; (2) can we quantify the protective ability of NNBF in a changing climate?; (3) can we design NNBF to preserve the EE multiple functionality ? These questions are approached through numerical modeling.

METHODOLOGY

The impact of extreme storms in the coastal zone is estimated at high resolution (5 m), in the regional and local areas of focus, using a suite of nested numerical models combining: (i) the hydrodynamic flow model ADCIRC coupled with the wave model SWAN for propagating storms across the Atlantic Ocean; (ii) the 2D-XBeach (Roelvink et al., 2009) hydro-morphodynamic model for propagating storms in coastal areas and assessing the resulting erosion and morphological changes to the shoreline; (iii) the 1D-ShorelineS model (Roelvink et al., 2020) to address the long term changes of the shoreline; and (iv) the fully nonlinear phase resolving Boussinesq model FUNWAVE to estimate at high resolution nearshore wave propagation and inundated areas, and their impact on coastal structures. The approach is based on scenarios combining historical tropical and nor'easters storms and SLR in the near future, focusing on 2050 as the target year.

These simulations allow identifying vulnerable areas, both present and future, for which, using a similar scenario approach, we simulate the implementation of NNBF to assist the natural coastal EE in improving coastal resilience and assess their efficiency. Results of NNBF scenarios, in terms of hazard impact and structural risk, are compared to the no-intervention base case. These include enhanced vegetation, dune reinforcement, artificial offshore reef, and beach nourishment. Scenarios are selected in consultation with representatives of local communities and designed based on best engineering practice or state-of-the-art research, integrating the multifunctionality specific constraints imposed by the local partners. In each case, we discuss the NNBF impact in reducing the exposure of the local communities to future tropical storms and nor'easters.

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