

PREPROPOSAL SEAGRANT

02/15/2023

Combining monitoring and numerical simulations of Nature and Nature Based Solutions to coastal erosion: Block Island, a numerical test site.

**PIs: Annette Grilli, Christopher Baxter, Stephan Grilli, Bryan Oakley, Nathan Vinhateiro
Senior Advisor: Malcolm Spaulding**

Statement of the Problem

Over the past decade, the perception of vulnerability to storm hazards in coastal communities has significantly shifted, from an unlikely future threat to a permanent concern. The latter is exacerbated by sea level rise (SLR) and storm intensification that are increasingly affecting people's way of life and sense of security. As a result, Rhode Island's coastal communities have been seeking protective measures, preferentially "soft" or "green" infrastructure, such as Natural and Nature Based [NNB] solutions, that minimize the effect of the mitigation measures to the environment and the local ecosystem. Many studies have addressed hazards, risk, and resilience associated with extreme storms, along the Rhode Island shoreline, using a range of methodologies (e.g., Grilli et al., 2017, 2020; Schambach et al., 2018; Ginis et al., 2020; Becker and Kretsch, 2019; Witkop et al., 2019; Ullman et al., 2019), leading to user-friendly hazard assessment tools (e.g., Spaulding et al., 2016, 2020a, 2020b). In addition, the U.S. Corps of Engineer recently published a Coastal Storm Risk Management Report for Rhode Island (USCOE, 2023), specifically addressing the feasibility of potential solutions grey or green, however most often grey.

Past and current coastal hazard and risk assessment efforts in Rhode Island (RI) have largely favored relatively high-density communities on the mainland and have ignored Block Island despite its status as the most exposed coastal area in the state. While Block Island is sparsely populated (1,410 inhabitants on 25 km² from the 2020 RI Census [RI Division of Statewide Planning, 2023]), there are numerous reasons to include the island into state-of-the-art regional hazard assessment and mitigation studies. Block Island has a unique and preserved historical heritage and contributes to the specificity and character of the state of Rhode Island; in fact The Nature Conservancy (2023) describes Block Island as one of the "last great places in the western hemisphere." However, one of the most compelling arguments is the geology of the site, associated with a very particular mode of vulnerability and risk. Block Island is composed of two distinct segments of glacial end moraine (Beacon Hill to the south, Corn Neck to the north), united by barrier spits formed as sediment eroded from the moraine was transported by longshore currents (Sirkin, 1982). Corn Neck Road running along this barrier system serves as the only access road between the moraine segments. As such, the geographical unity of the island relies on the resilience of the barrier system

The integrity of this fragile component is threatened by the effects of SLR and storm intensification, which jeopardize the future geographic cohesion of the community. Corn Neck Road is perched on the barrier spit between the ocean and the Great Salt Pond. Having little to no foredune, this barrier has recurrently been over-washed and damaged by storms, including during Superstorm Sandy (2012) [Figure 1]. In addition, the island's long-time inhabitants are fighting fiercely to protect their heritage from many threats including those to be addressed by this research project.

The proposed study will investigate solutions to the increasing threats to critical infrastructure on Block Island from erosion and increasingly intense storms combined with SLR. As such, this

project has direct relevance to RI Sea Grant's *Resilient Communities and Economies* thematic focus area. In particular, this research will focus on infrastructure connecting the northern and southern sections of the island. The latter includes critical infrastructure including the ferry landing and the airport, which are the transportation hubs that connect the island to the mainland.

Outline of project objective and goals

The goal of this project is to assess the feasibility and efficiency of a range of NNB solutions to protect the most vulnerable site on Block Island, the recurrently over-washed section of Corn Neck Road. The site is located along the island's east coast, directly north of New Shoreham Old Harbor [Figure 2]. We propose to use a scenario-based modelling approach to simulate NNB solutions, using hydro-morpho-dynamic numerical simulations to assess and compare the protection offered by each solution to the shoreline morpho-dynamics during storm events. Selected storms combined with SLR scenarios will be considered.

The modeling efforts will be supplemented with periodic beach surveys of the Corn Neck Road area using a combination of standard methods (e.g. Real-Time Kinematic GPS elevation surveys) and a crowd-sourcing coastal imaging system, "Coastsnap"

(<https://mycoast.org/ri/coastsnap/about>; Harley et al., 2019; Harley and Kinsela, 2022).

Coastsnap relies on photographs of the shoreline taken by the public from geo-referenced stands [Figure 3], which can then be processed to document shoreline change. This approach has an added benefit of engaging the public in citizen science, which can lead to raised awareness of the threats facing Corn Neck Road and improved acceptance of mitigation measures. The modelling efforts and Coastsnap stations will also leverage existing beach profiles, measured by community scientists on the island since 2013 under the supervision of one of the project PI's (Oakley) [Figure 4].

The main objectives of the project are to:

- Simulating site-specific NNB solutions using numerical hydro-morpho-dynamic models.
- Assess the protective ability of each NNB solution for a range of storm events including SLR.
- Assess the potential negative feedback effects of each solution.
- Implement a crowd-sourced beach monitoring program that combines Coastsnap and standard topographic surveys that can be used to validate model scenarios.

Methodology

Based on the site characteristics, we will design a range of NNB solutions and simulate their impact on the barrier beach system using the 2DH model XBeach (Roelvink et al., 2009). The model simulates storm surge, wave and current propagation evolving in the time domain during a storm event, as well as the resulting associated morphological changes (erosion/accretion) occurring in the surf zone, along the shoreline, and in inundated areas. Specifically, we will simulate design storms, with and without SLR scenarios, to assess the expected morphological changes occurring without any mitigation solution implemented [base case] and for a range of NNB solutions. The latter results will be compared to the "base case" results for similar storm/SLR scenarios.

Solutions will be selected among: (1) solutions known to be promising to protect highly exposed beach barrier systems, such as aggressive enhanced vegetation combined with dune reinforcement by geosynthetic bags (Naser al Naser, 2018; Maggi et al. 2019, 2019a, 2022, Li et al., 2023), (2) solutions designed to limit wave impact in high wave energy environment, such as

a perched beach (Gonzalez et al., 1999) or an artificial reef (designed for high energy environment; Schuh et al, 2023), or (3) solutions suggested by the local community or the regulatory agency in charge of coastal permitting (RI CRMC) (in the limit of the modeling abilities).

The protective abilities of each NNB solution will be presented in terms of expected subaerial morphological changes (with the NNB solutions implemented relative to no NNB solution) for the selected storm/SLR scenarios. This information can be summarized in maps and volumetric calculations for town officials. Negative feedback effects will also be assessed.

A Coastsnap beach monitoring platform will be installed at one or two locations along the beach at Corn Neck Road to collect photogrammetric data of shoreline change. The specific locations will be selected in consultation with the Block Island SLR Committee, which is regularly involved in these efforts on the island. The results of the beach monitoring program will be combined with existing RI Coastsnap datasets at Misquamicut and East Matunuck and linked to environmental conditions (e.g. wind, tide, currents, etc.) from the Northeast Coastal Ocean Forecast System (NECOFS; <https://p5.neracoos.org/projects/necofs.html>) to understand both the environmental forcing and resulting shoreline changes.

Impact Statement

Proposing and evaluating NNB solutions according to a scenario approach is a powerful way of helping the community and coastal managers design a meaningful management plan. Results of the study will be available to the local coastal community (e.g., Block Island SLR committee) and local management agencies (e.g., Coastal Resources Management Council, CRMC), to help assess the impact of each scenario on the dune system and nearby infrastructure, both with and without mitigation measures. Results will be presented in a user-friendly interactive web-based viewer, allowing the user to map and compare morphological changes associated with selected scenarios. The monitoring system will be designed to outlive this proposal and provide a consistent data base to check long-term changes at the site and verify the modeling scenarios.

Outreach Plan

To ensure this project is relevant to community stakeholders we plan to meet with town officials and members of the Block Island SLR committee at the project onset, to ensure model scenarios and NNB solutions are aligned with the town's long-term planning goals. At the project conclusion, a workshop will be organized to share the results of the study to all stakeholders and coastal planning partners.

Results of the study will also be shared through an interactive web site, where users can visualize expected changes at the site, for selected design storm events, both with and without the NNB solutions implemented.

We also plan to engage with the Rhode Island Sea Grant legal program to clearly address any potential legal issues associated with implementation of the solutions.

Anticipated Budget Request

The estimated cost for this project is \$125,000 per year for two years. Match for the requested funds will come from academic-year release time from co-PIs Baxter and Grilli. There may also be in-kind support from New Shoreham town officials (e.g. GIS) and the Block Island SLR committee (e.g. access to newly installed tide gauge data).



Figure 4: Corn Neck Road after Sandy (2012) (Block Island Time, 2012)

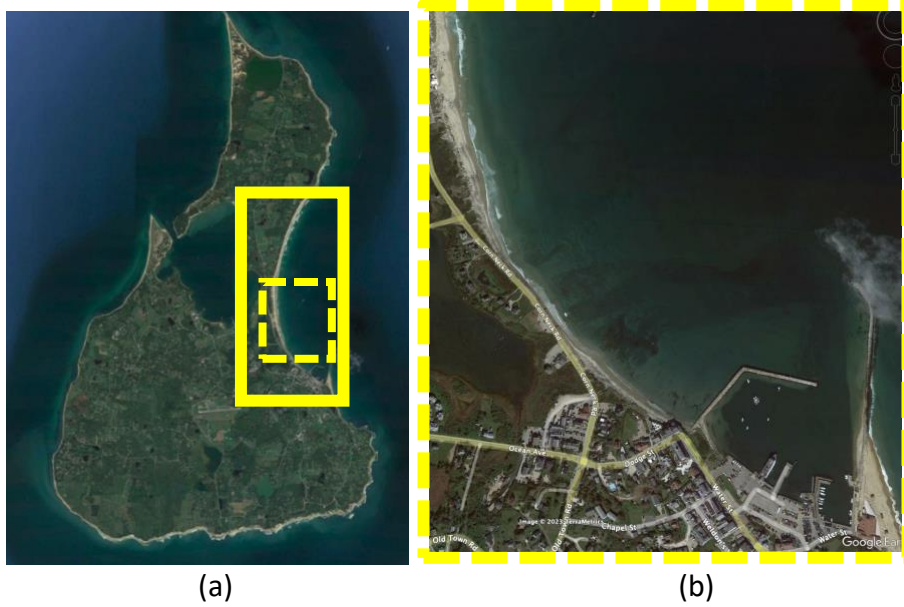


Figure 2: (a) Block Island study site [plain yellow] with area of focus [dash yellow] enlarged in (b) Extracted from Google Earth, Accessed, February 9.



Figure 3: CoastSnap monitoring location at North Narrabeen Beach in New South Wales, Australia including the geo-referenced phone stand and educational display (photo taken by co-PI C. Baxter).

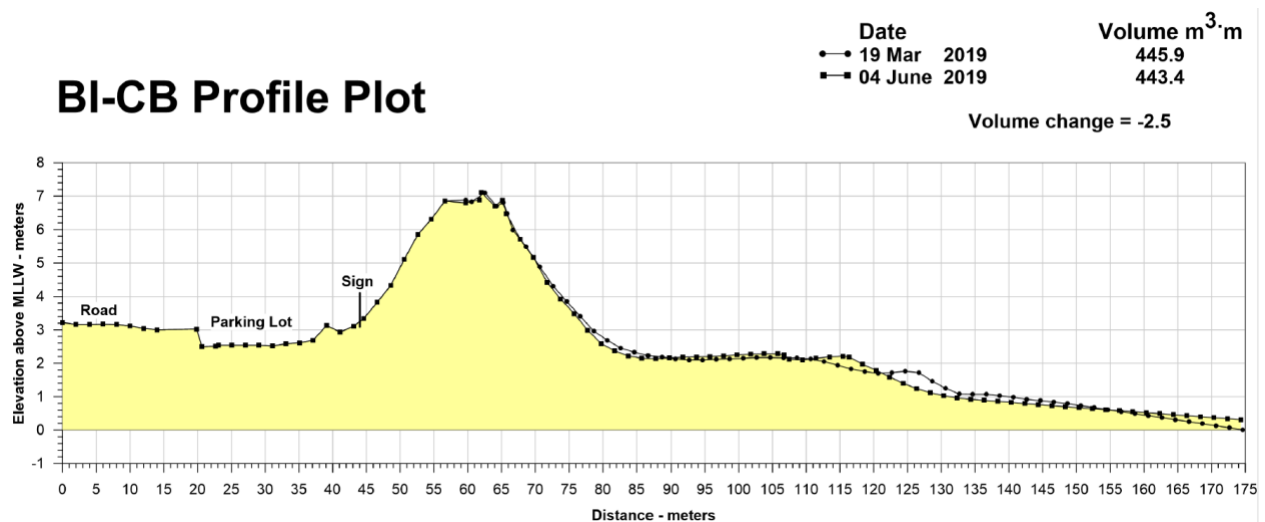


Figure 4: Measured beach profile from station BI-CB (Block Island, Crescent Beach). This is one of eight profiles around the island measured quarterly by community-scientists under the supervision of co-PI Oakley. BI-CB is located just north of the pavilion at the town beach near the northern end of the focus area.

References

Al Naser, N., Grilli, A., Grilli, S., Baxter, C., Bradshaw, A., Maggi, B., 2018. Land use and mitigation effects on barrier beach erosion in storms: case study in Rhode Island. In Coastal Engineering Proc., ICCE, Baltimore, MA, August 2018.

Becker, A. and Kretsch, E., 2019. The leadership void for climate adaptation planning: Case study of the port of providence (Rhode Island, United States). *Frontiers in Earth Science*, 7, p.29.

Block Island Time (2012): <https://www.blockislandtimes.com/article/council-exploring-coast-guard-station-uses/51730>; Accessed February 14, 2023.

Harley, M.D., Kinsela, M., Sánchez-García, E. and Vos, K. 2019. Shoreline change mapping using crowd-sourced smartphone images, *Coastal Engineering*, 150, 175-189, <https://doi:10.1016/j.coastaleng.2019.04.003>

Harley, M.D. and Kinsela, M. 2022. CoastSnap: A global citizen science program to monitor changing coastlines, *Continental Shelf Research*, 245, 104795, <https://doi.org/10.1016/j.csr.2022.104796>

González, M., Medina, R., Losada, M.A., 1999. Equilibrium beach profile model for perched beaches. *Coastal Engineering*, 36(4), pp.343-357.

Grilli, A.R., Westcott, G., Grilli, S.T., Spaulding, M.L., Shi, F., Kirby, J.T., 2020. Assessing coastal hazard from extreme storms with a phase resolving wave model: Case study of Narragansett, RI, USA. *Coastal Engineering*, 160, p.103735.

Grilli, A., Spaulding, M.L., Oakley, B.A., Damon, C., 2017. Mapping the coastal risk for the next century, including sea level rise and changes in the coastline: application to Charlestown RI, USA. *Natural Hazards*, 88, pp.389-414.

Li, Y., You, Z.J., Ma, Y., Ren, B., 2023. Quantitative assessment of the shoreline protection performance of geotextile sandbags at an in-situ coastal experimental station. *Geotextiles and Geomembranes*.

Maggi, B., Baxter, C.D.P., Grilli, A., Licht, S., Stegagno, P., Bradshaw, A. and Al Naser, N. 2019. Field Performance of Reinforced Dunes for Improving Coastal Resilience, ASCE GeoCongress 2019, Philadelphia, PA.

Maggi, B., Baxter, C.D.P., Bradshaw, A., Grilli, A. and Al Naser, N. 2019a. Geosynthetic Reinforced Dunes and Bluffs: No Longer Just an Emergency Solution for Shoreline Protection and Improving Resiliency?, IFAI Geosynthetics 2019, Houston, TX.

Maggi, B., Baxter, C.D.P., Grilli, A. 2022. Fragility Analysis of Dunes Reinforced with Geosynthetic Sand Containers, International Conference on Coastal Engineering, Sydney, Australia.

RI Division of Statewide Planning, 2023. <https://planning.ri.gov/ri-census-2020>, Accessed February 14, 2023

Roelvink D., Reniers A., van Dongeren A., van Thiel de Vries J., McCall R. , Lescinski J. (2009). Modelling storm impacts on beaches, dunes and barrier islands. *Coastal Engineering*, 56(11–12), 1133–1152

Schambach, L., Grilli, A.R., Grilli, S.T., Hashemi, M.R., King, J.W., 2018. Assessing the impact of extreme storms on barrier beaches along the Atlantic coastline: Application to the southern Rhode Island coast. *Coastal Engineering*, 133, pp.26-42.

Schuh, E., Grilli, A., Groetch, F., Grilli, S., Ginis, I., Crowley, D., 2023. Assessing the morphodynamic response of a New England beach-barrier system to an artificial reef. In preparation for *Coastal Engineering*.

Sirkin, L. A., 1982, Wisconsinan glaciation of Long Island, New York to Block Island, Rhode Island, in Larson, G. J., and Stone, B. D., eds., *Late Wisconsinan glaciation of New England: Dubugue, IA, Kendall/Hunt*, p. 35-60.

Spaulding, M.L., Grilli, A., Damon, C., Crean, T., Fugate, G., Oakley, B.A., Stempel, P., 2016. STORMTOOLS: coastal environmental risk index (CERI). *Journal of Marine Science and Engineering*, 4(3), p.54.

Spaulding, M.L., Grilli, A., Damon, C., McKenna, B., Christensen, M., Vinhateiro, N., Boyd, J., Fugate, G., 2020a. STORMTOOLS, Coastal Environmental Risk Index (CERI) Risk and Damage Assessment App. *Journal of Marine Science and Engineering*, 8(2), p.129.

Spaulding, M.L., Grilli, A., Damon, C., Hashemi, R., Kouhi, S., Fugate, G., 2020b. STORMTOOLS Design Elevation (SDE) Maps: Including impact of sea level rise. *Journal of Marine Science and Engineering*, 8(4), p.292.

The Nature Conservancy, 2023. <https://nature.org> ; Accessed February 9, 2023.

Ullman, D.S., Ginis, I., Huang, W., Nowakowski, C., Chen, X., Stempel, P., 2019. Assessing the multiple impacts of extreme hurricanes in southern New England, USA. *Geosciences*, 9(6), p.265.

USCOE, 2023. Rhode Island Coastline Coastal Storm Risk Management Project, New England District, Concord. MA.
<https://www.nae.usace.army.mil/Missions/Projects-Topics/Rhode-Island-Coastline-Coastal-Storm-Risk-Management-Project/>

Wikipedia [BI] : https://en.wikipedia.org/wiki/Block_Island; Accessed February 9, 2023.

Witkop, R., Becker, A., Stempel, P., Ginis, I., 2019. Developing Consequence Thresholds for Storm Models Through Participatory Processes: Case Study of Westerly Rhode Island. *Frontiers in Earth Science*, p.133.

