Shoreline Transformation: Forward-Looking Nature-Based Adaptation Strategies

Daniel Cardona[*1]; Andre de Souza de Lima[1]; Tyler Miesse[1]; Celso Ferreira[1]; Ali Shahabi[2]; Navid Tahvildari[2]*

[1] Department of Civil, Environmental and Infrastructure Engineering, George Mason University, Fairfax, VA

[2] Department of Civil and Environmental Engineering, Old Dominion University, Norfolk, VA,

AGU24

EP43B-1299

- **Natural and Nature-Based Features (NNBF)** are emerging as adaptive coastal protection solutions where traditional engineering falls short, though their efficacy depends on physical attributes and environmental conditions.
- This research focuses on evaluating the performance of NNBFs in attenuating waves through innovative field-scale prototypes and the natural environment. Here we aim to deepen our understanding of how these interventions can contribute to enhancing coastal resilience.

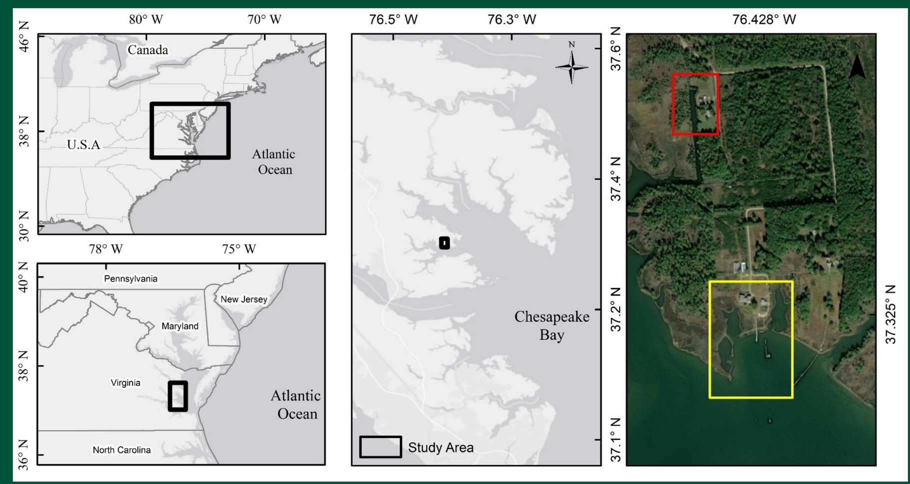

Figure 1: At the Chesapeake Bay Planning Access Authority's (MPCBPAA) Captain Sinclair Property, the Whittaker Creek Canal study site is outlined in red, and the Severn River Shoreline study site is outlined in yellow.

Figures 2, Credits: Flood Hazards Research Lab Archive, 2024.

Figures 3, Credits: Flood Hazards Research Lab Archive, 2024.

- *The Whittaker Creek Canal site employed an innovative approach by combining locally dredged materials placed into geotextile containment tubes (Geotubes™, Figure 2), prefabricated concrete oyster reef structures (Figure 3), and transplanted native salt marsh plants from nearby saltmarshes, while its inland location offered a protected setting to analyze NNBFs under* ***controlled conditions****.*

Figures 4: Oyster bag sills (visible below the water surface) and adjacent marsh grasses. Credits: Flood Hazards Research Lab Archive, 2024.

- *Severn River Shoreline site featured a combination of oyster bag sills made from native Chesapeake Bay oyster shells, rock sills, and native salt marsh plants. Due to its vulnerable location, the site allowed for the analysis of NNBFs under* ***exposed conditions.***

Controlled Conditions

- Two field experiments were conducted before (07/2023) and after (07/2024) the installation of the NNBFs, utilizing a combination of varying speeds and weight loads to create a diverse range of boat wakes.

Figure 5: Overview of the North bank at low tide, highlighting the prefabricated concrete reefs and Geotube. Credits: Flood Hazards Research Lab Archive, 2024.

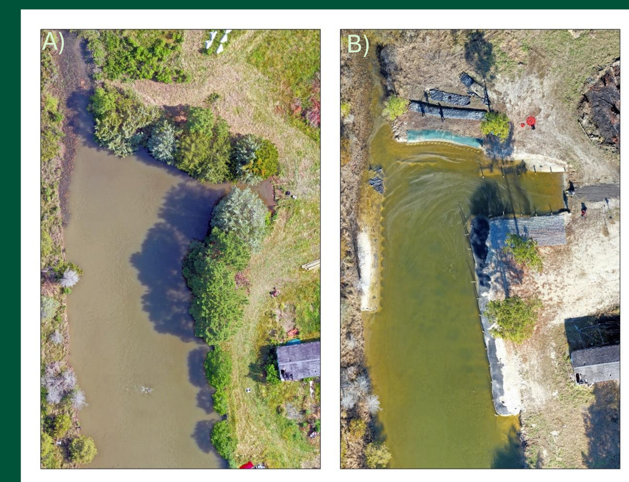

Figure 6: A) Aerial overview of study area from June 2023, before the construction; and B) from December 2023, after the construction. Credits: Old Dominion University, 2024

Boat Run	Boat Speed	Speed Range (MPH)	Boat Weight Type	Boat Weight (lbs)
1	Slow	3 - 5	Light	2,360
2	Medium	7 - 9	Light	2,360
3	Fast	13 - 17	Light	2,360
4	Slow	3 - 5	Light	2,360
5	Medium	7 - 9	Light	2,360
6	Fast	13 - 17	Light	2,360
7	Slow	3 - 5	Light	2,360
8	Medium	7 - 9	Light	2,360
9	Fast	13 - 17	Light	2,360
10	Slow	3 - 5	Heavy	2,760
11	Medium	7 - 9	Heavy	2,760
12	Fast	13 - 17	Heavy	2,760
13	Slow	3 - 5	Heavy	2,760
14	Medium	7 - 9	Heavy	2,760
15	Fast	13 - 17	Heavy	2,760
16	Slow	3 - 5	Heavy	2,760
17	Medium	7 - 9	Heavy	2,760
18	Fast	13 - 17	Heavy	2,760

Figure 8: Table details each boat run, indicating the speeds categorized as slow, medium, and fast, as well as the weights associated with light and heavy boat types.

- During both visits, a series of **RBR solo-D wave** loggers were deployed to record wave action, obtaining data before and after the NNBF's implementation.

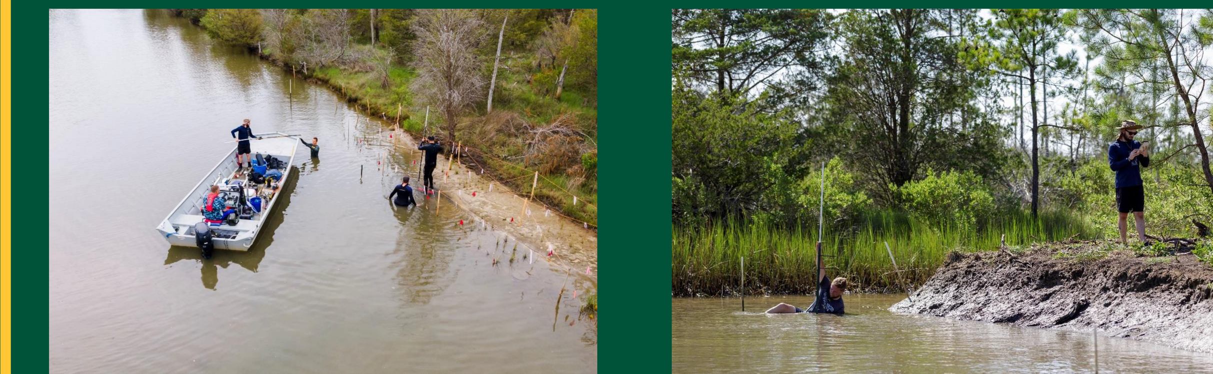

Figure 7: Team of researchers from GMU and ODU deploying wave sensors at Whittaker Creek. Credits: Lathan Goumas, Virginia Sea Grant.

Figure 9: Boat wakes being generated at Whittaker Creek during the field experiment before the site construction

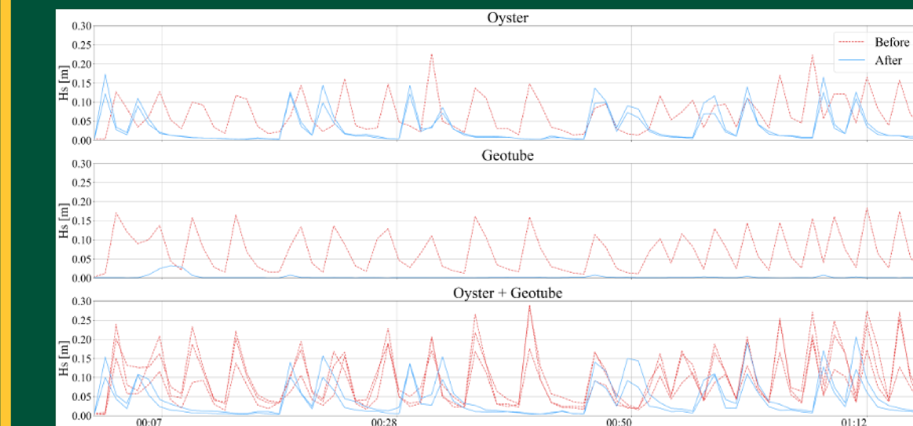

Figure 10: Time series of Significant Wave Heights (Hs) demonstrating the differences in wave magnitude before and after the construction and highlighting the performance of each individual component of the NNBF in reducing wave energy.

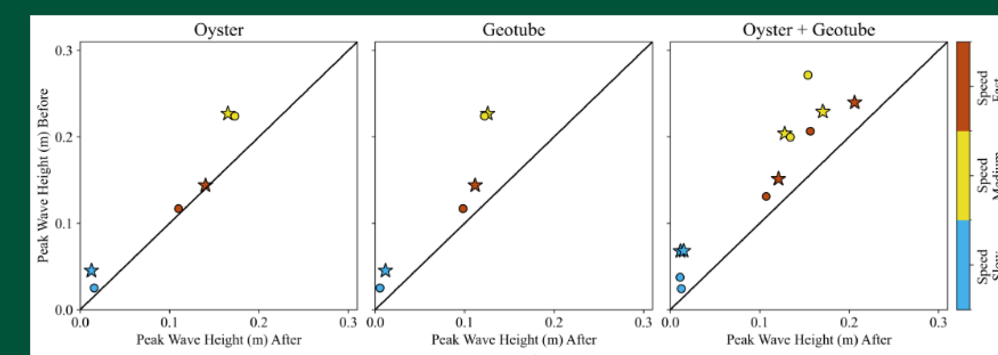

Figure 11: Comparison of **peak wave heights** before and after site construction, demonstrating the effectiveness of each NNBF component in reducing wave energy under different boat weight loads and speeds.

The data reveals a significant difference between the effects of a single NNBF and multiple NNBFs:

- At higher speeds, oyster reefs alone resulted in only a 5% decrease in peak wave height.
- A combination of NNBFs during the same trial achieved a remarkable 30% reduction.
- At lower speeds, the combination of Geotubes™ and oyster reefs demonstrated exceptional effectiveness in the reduction of peak wave height, with percent reductions reaching as high as 80%.

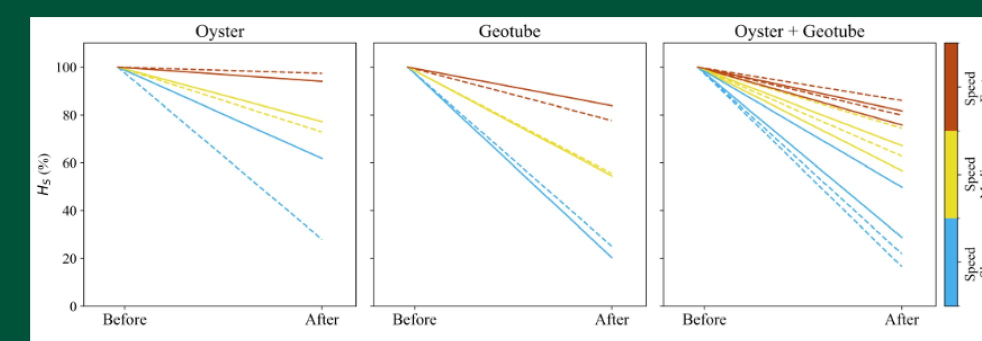

Figure 12: Percentage **reduction in wave energy** before and after site construction, demonstrating the effectiveness of each NNBF component in reducing wave energy under different boat weight loads and speeds.

Exposed Conditions

- **RBR Solo-D wave** loggers were deployed across four transects to monitor wave action over an eight-month period. Sensors were strategically placed before and after each type of NNBF, within those transects; This allowed us to observe the impacts of each individual NNBF type.
- Time series data for significant wave height and water depth from each transect were analyzed to identify wave events.

Figure 13: A) The map displays sensors across all four transects at the Severn River Shoreline site, with each dot representing a sensor. The transects are color-coded: Transect 1 is blue, Transect 2 is green, Transect 3 is red, and Transect 4 is grey. B) Transect 1 showing the sensor before NNBFs (blue), the sensor after oyster bag sills (orange), the sensor at the salt marsh edge (red), and the sensor after the salt marsh (green).

Figures 14: Ariel image of transect 1, shows Oyster bag sills in orange, salt marsh edge in red, and salt marsh in green. Credits: Flood Hazards Research Lab Archive, 2024.

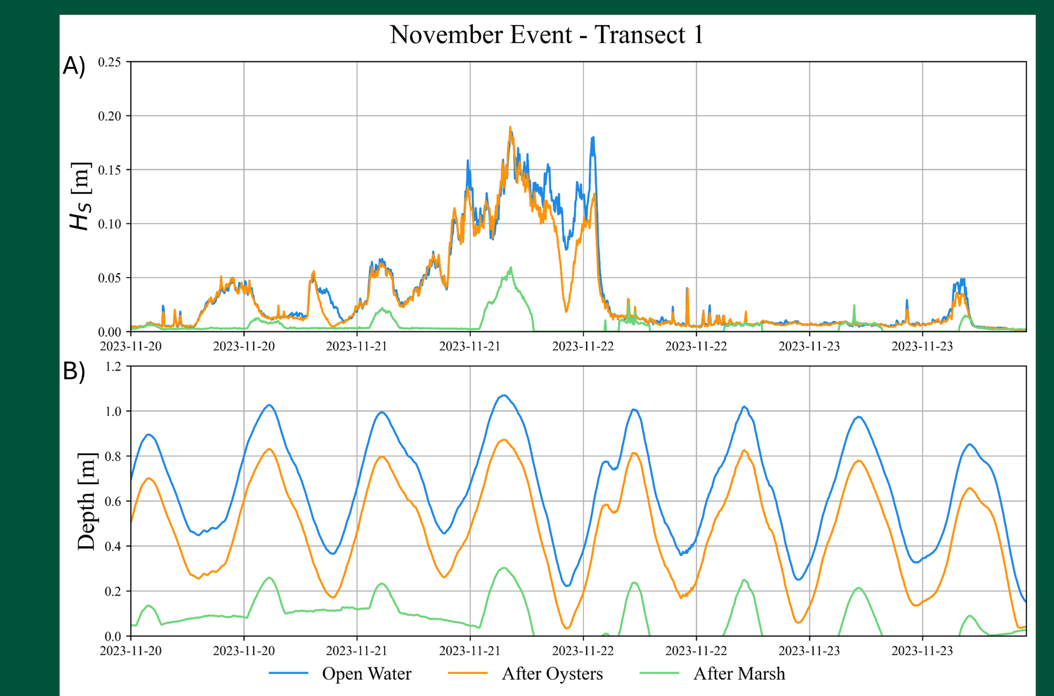

Figure 15: A) The time series show significant wave height (Hs) during a November 2023 wave event, highlighting **the reductions in wave energy** seen following each NNBF. B) Time series of water depth during the same event, illustrating how NNBFs interact with **varying tidal conditions.**

$$\frac{\left(\frac{1}{H_1} - \frac{1}{H_0}\right)}{(x_1 - x_0)} = \alpha$$

Figure 16: The equation shown calculates the wave attenuation coefficient (α) under the assumption that waves impact NNBFs perpendicularly. The formula evaluates the reduction in wave height (H) over a specific distance (x) along the transect, providing a quantitative measure of wave energy dissipation across each NNBF

The data indicates that the ability for NNBFs to attenuate wave energy is dependent on water levels:

- **During rising tides**, oyster sills become less effective at attenuating waves, while salt marshes start to attenuate waves at comparable rates.
- **During receding tides**, oyster reefs play a more significant role in wave attenuation as salt marshes remain dry and less involved in the process.

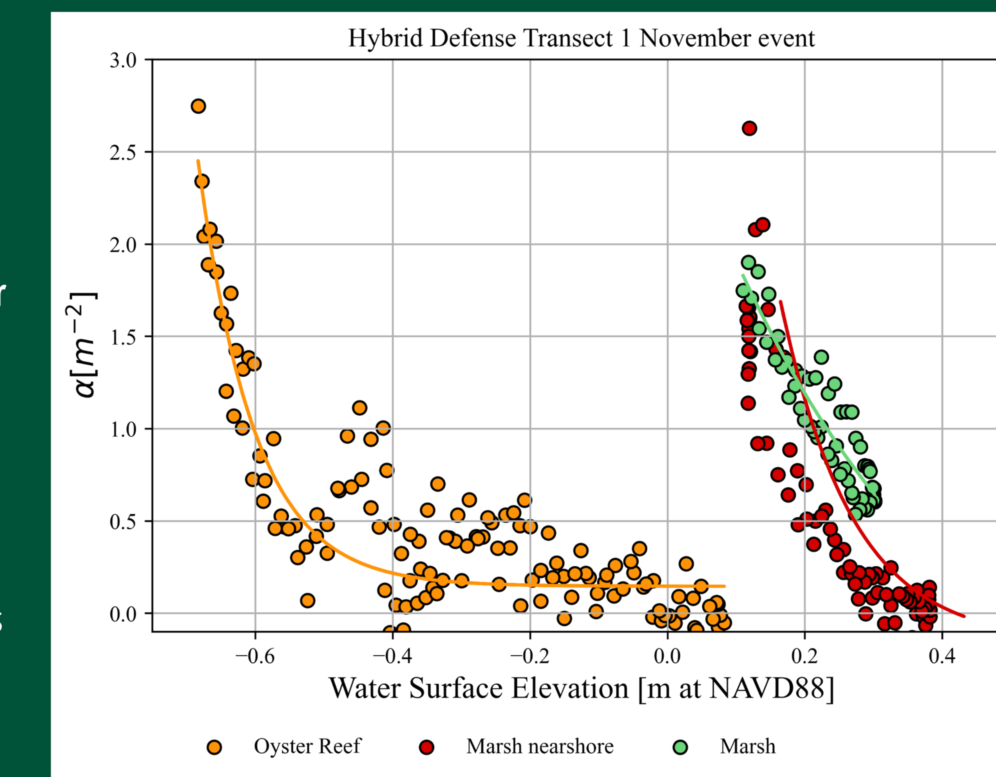

Figure 17: The scatter plot displays wave attenuation coefficients (α) as a function of water surface elevation during the November wave event, calculated from significant wave height (Hs) measurements from three different sensors along Transect 1. The data points and fitted curves represent attenuation across three zones: oyster reef, nearshore marsh, and inland marsh. The curves illustrate how the oyster sill, nearshore marsh, and inland marsh interact under varying tidal conditions to attenuate wave energy.

This research was conducted using Federal funds under award NA180AR4170083, Virginia Sea Grant College Program Project R/72155Y and 77877B, from the National Oceanic and Atmospheric Administration's (NOAA) National Sea Grant College Program, U.S. Department. of Commerce. The statements, findings, conclusions, and recommendations are those of the author(s) and do not necessarily reflect the views of Virginia Sea Grant, NOAA, or the U.S. Department of Commerce.

*Email: dcardon2@gmu.edu