Boat Wakes Dictate Bank Erosion and the Loss of Oyster Filtration Services in a Small Fetch Estuary

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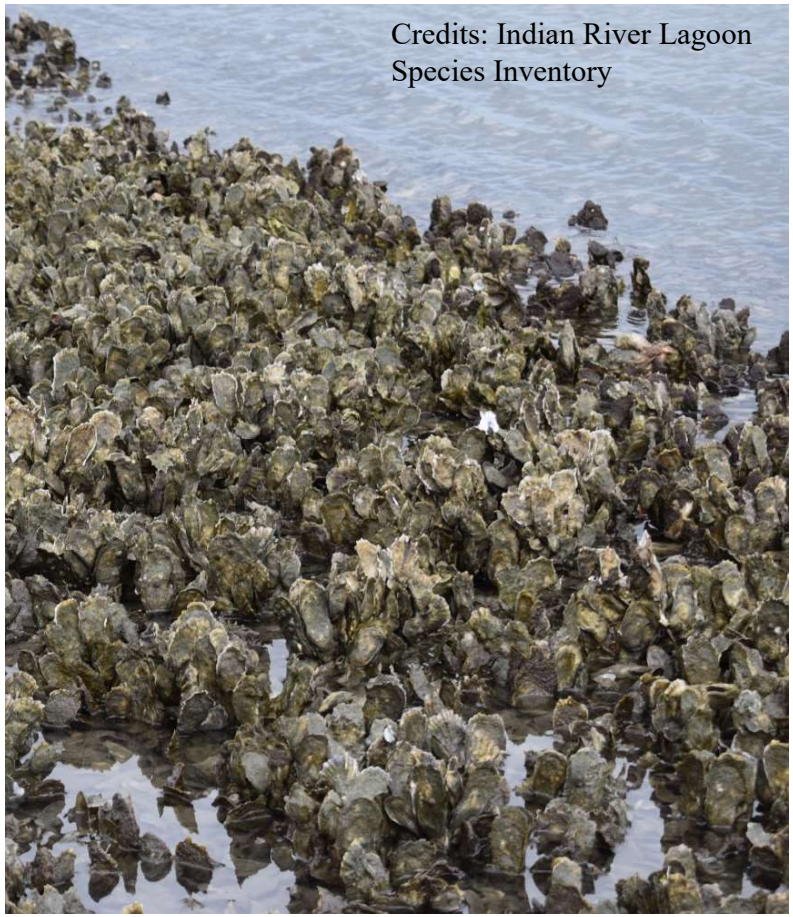
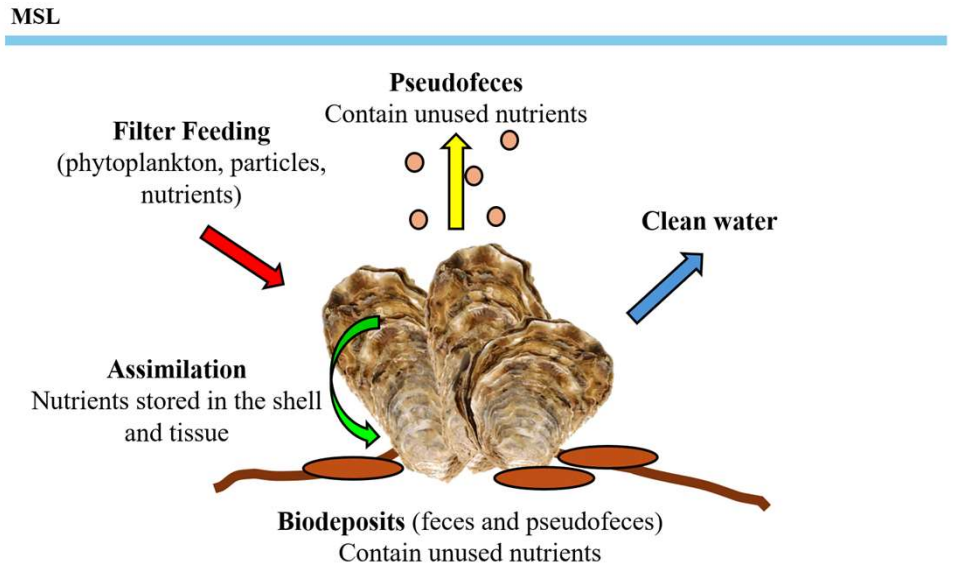
Daniele Pinton

Oyster Workshop
04/15/2026

Filtration Services of Estuaries: The Role of Oyster Reefs


Credits: Indian River Lagoon Species Inventory

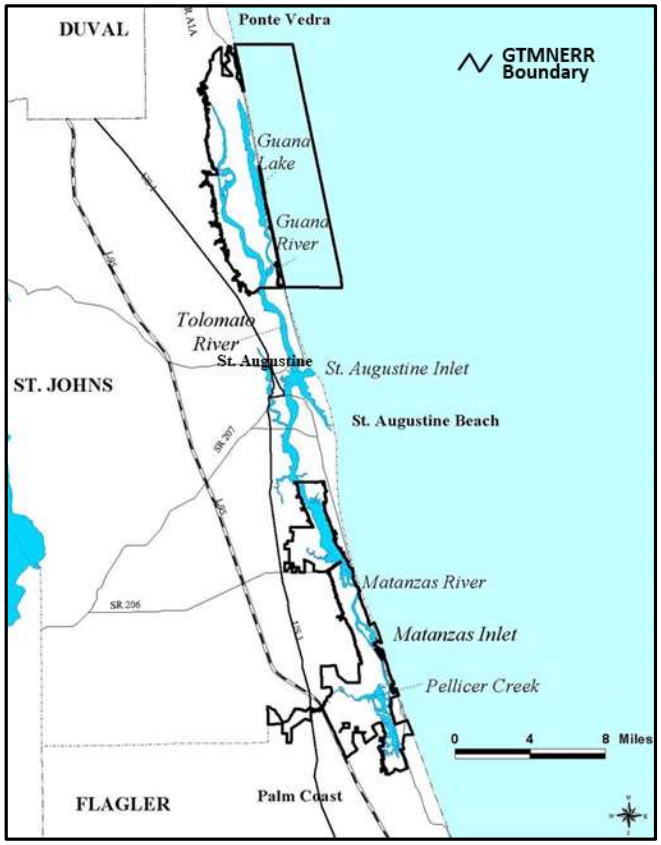


What are Filtration Services?

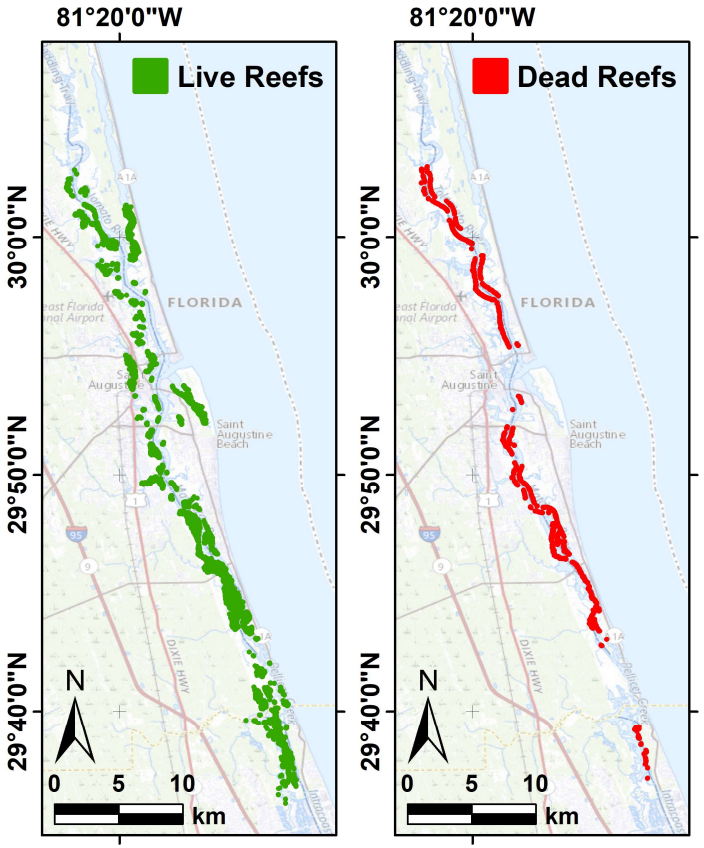
- A single oyster can filter up to 50 gallons of water per day, improving water clarity and quality

<u>Are filtration services more significant where resident time is larger?</u>

Study Area and Oyster Reefs



Study area



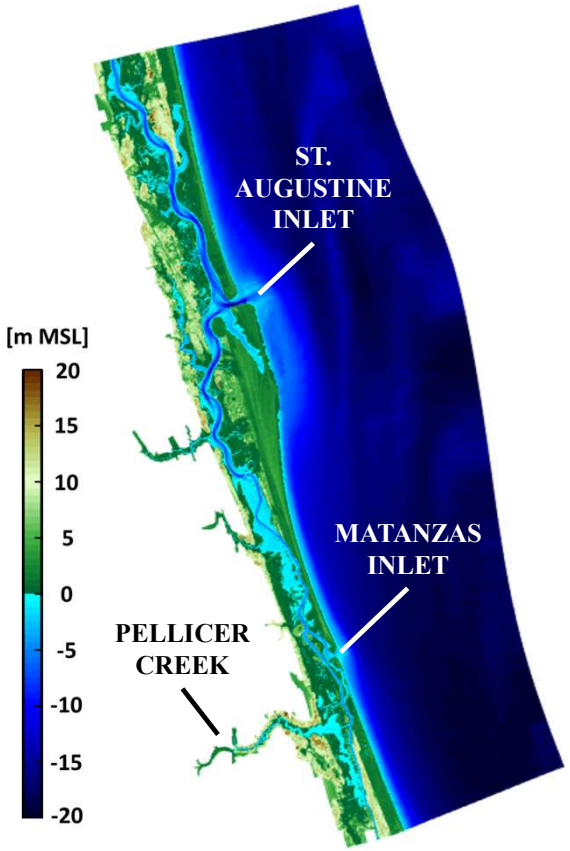
The distribution of the oyster reefs with living and dead oyster populations

The GTM is home to an expansive population of Eastern oysters, *Crassostrea virginica*

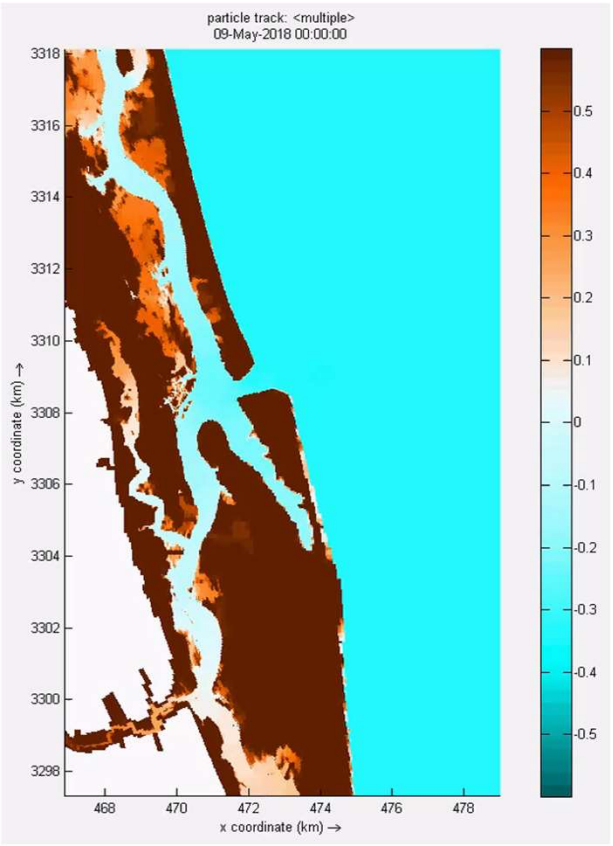
Fish and Wildlife Research Institute, FWRI:

- ~ 4800 reefs with alive oysters
- ~ 400 reefs with dead oysters

Hydrodynamic and Particle Tracking Numerical Models (Delft3d)



The Delft3D-FLOW model domain



The Delft3D-PART simulation

Delft3d – FLOW (Hydrodynamic)
Cells: ~15×20 m

Delft3d – PART (Particle Tracking)

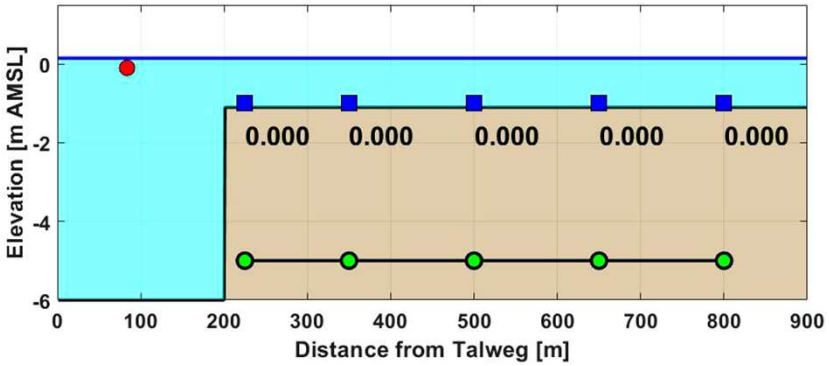
- Injection points: Regular grid 50m×50m on the domain (wet areas)
- 6 injections (1 every two hours from t=0)

Simulation Length and Time Step

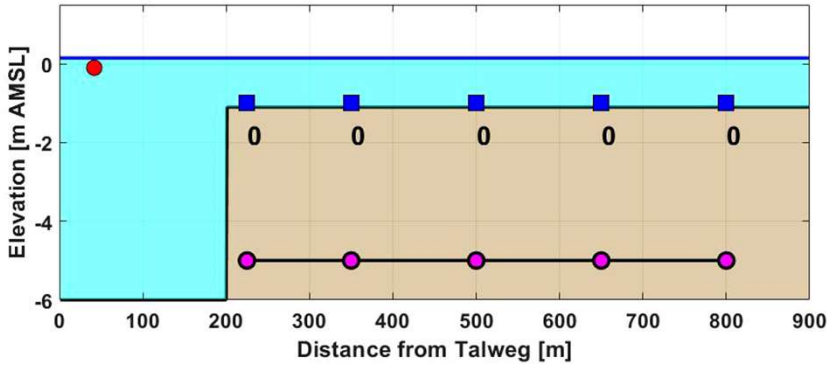
- 9th May – 10th June 2018
- 1 minute time step

1D Downstream Effect

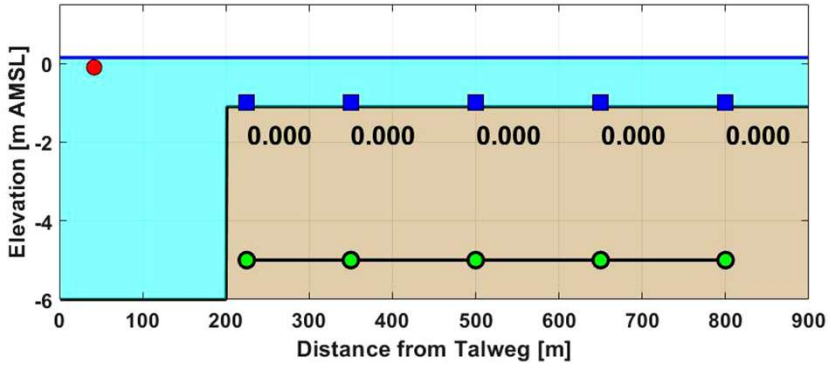
Scenario 1: uniform tidal vel., uniform filtr. 40% particle mass



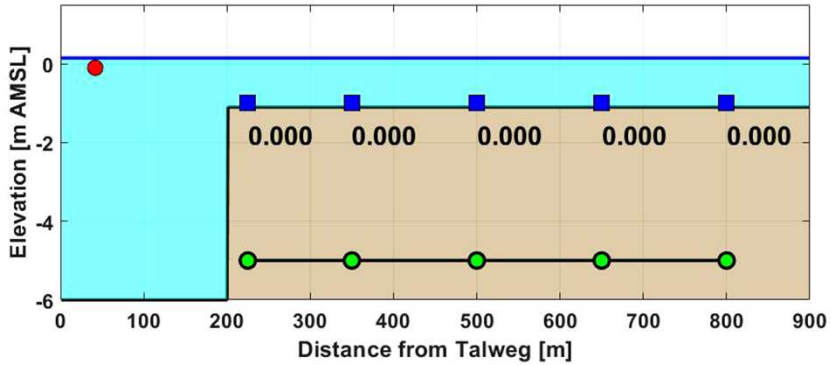
Scenario 2: non-uniform tide, only particle count



Scenario 3: non-uniform tidal vel., uniform filtr. 40% particle mass

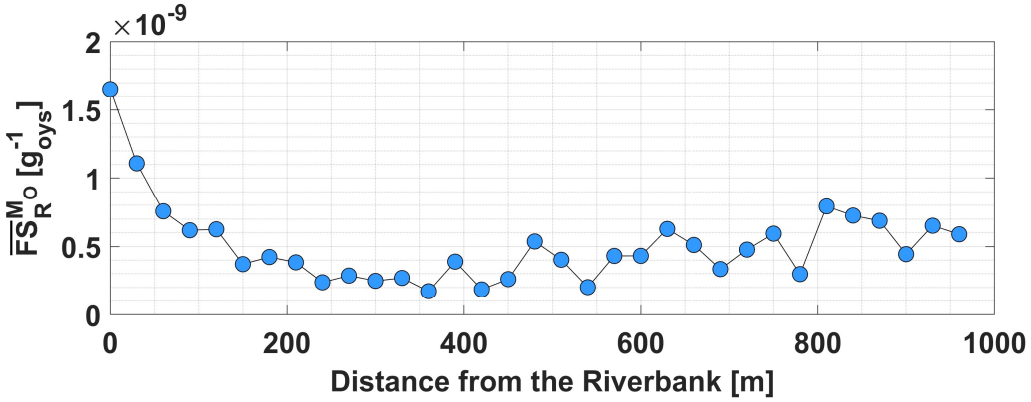


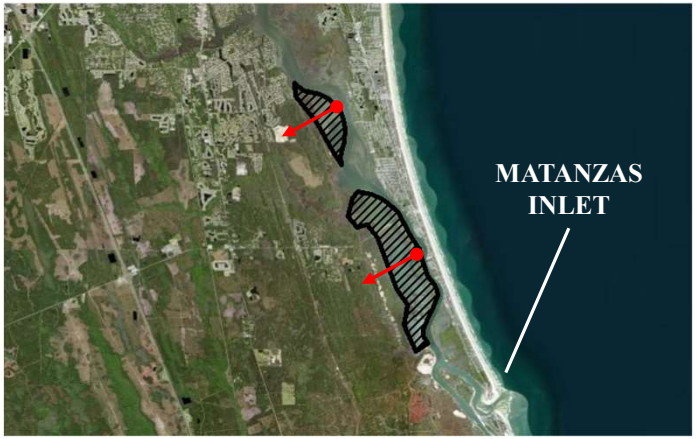
Scenario 4: non-uniform tidal vel., filtration 40% particle mass prop. RT

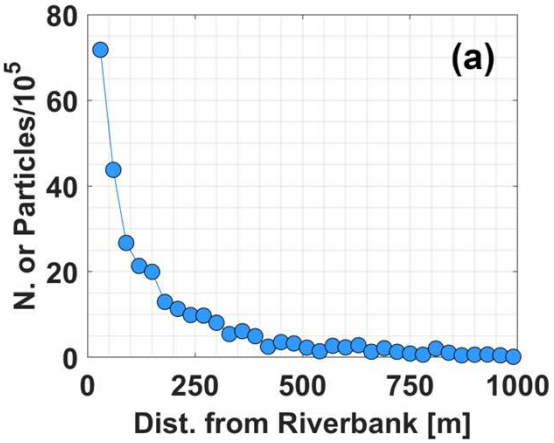


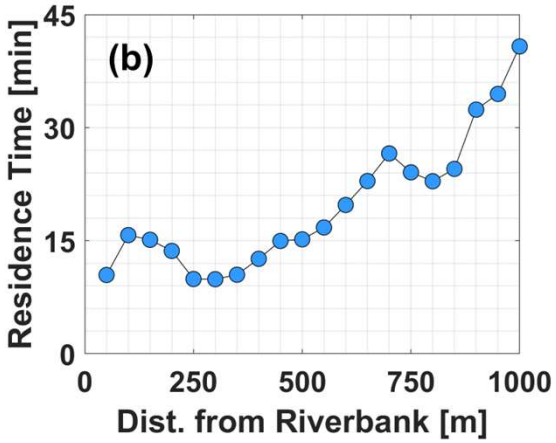
Particle Oyster reef Filtered mass Particle entrances

Oyster Reefs Metrics and Filtration in the Scenarios vs. Bank Erosion







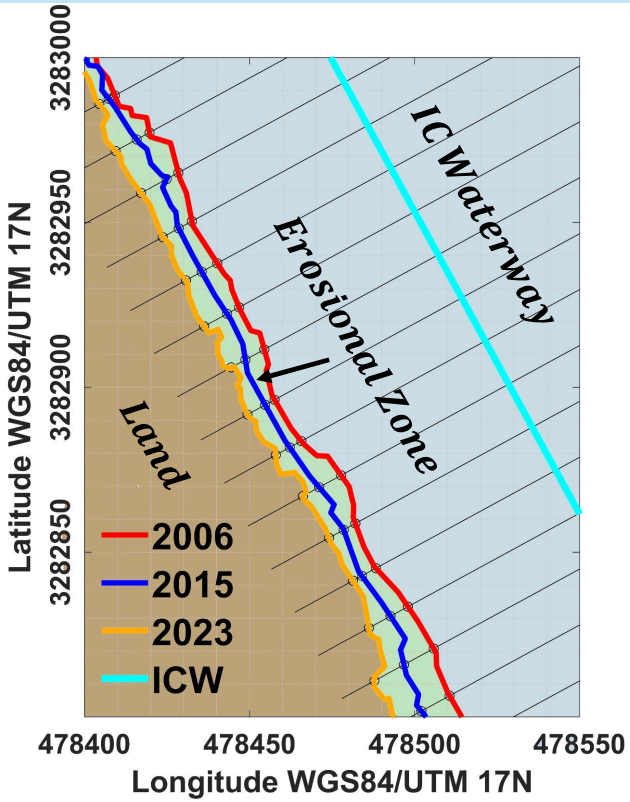


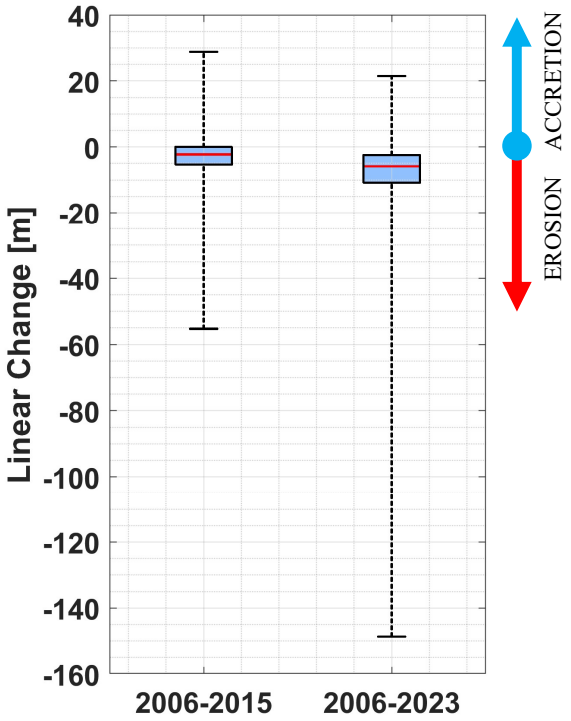
- Filtration services per unit dry weight is larger close to the channel edge
- This is due to the large number of particles passing above them
- The effect of residence time on FS is **negligible** compared to the importance of the location of the reefs

Assess the impact of bank erosion on oyster reef mortality in the GTM Estuary

Bank erosion measured from Airborne Images.
Datasets:

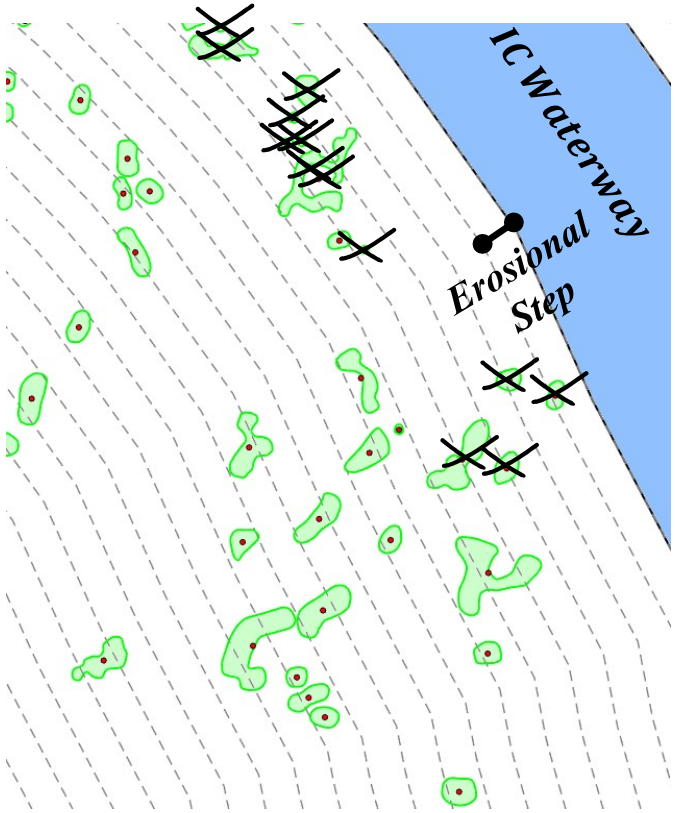
- USGS images (2006)
- NOAA images (2015 and 2023)



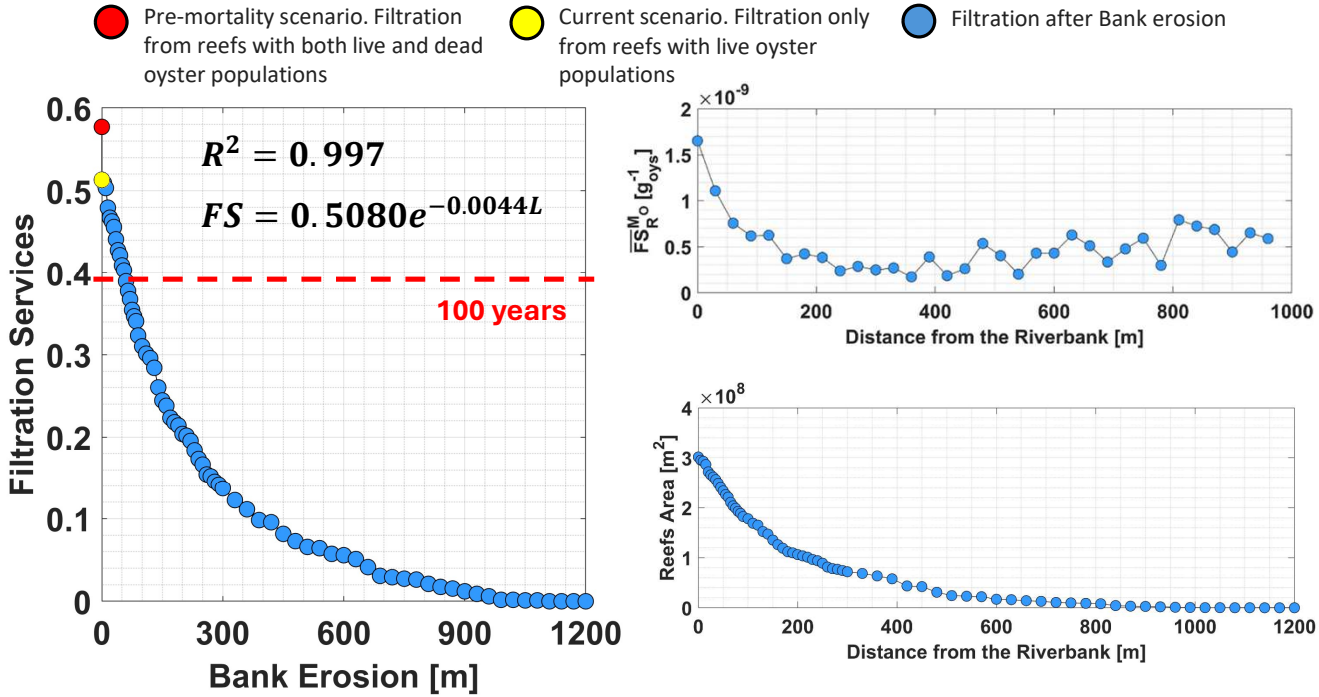


2006-2015: spatially average erosion: -3.30 m → -0.30 ± 0.93 (mean ± standard deviation) m/year
2006-2023: spatially average erosion: -8.30 m → -0.50 ± 0.74 m/year

Filtration Services vs. Bank Erosion/Reef mortality



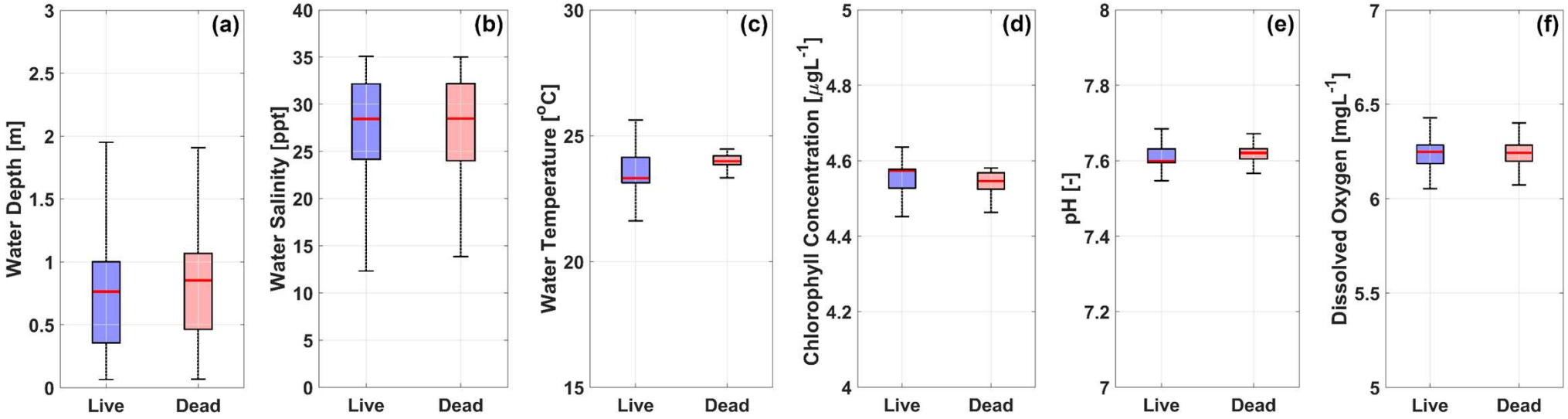
We prescribe an erosional rate of 0.5 m/year



- FS reduces exponentially because of bank erosion
- This is due to:
  - The exponential reduction in the areas of reefs filtering water
  - The removal of the reefs that are contributing more to FS

What causes reef mortality in the GTM?

Effect of Environmental Variables of Live vs Dead Reefs



No significant differences are found in the values of these variables between the dead oyster reefs and the live reefs

The same consideration applies to **predator abundance** and the **presence of disease**, based on literature review and field data collected in the estuary

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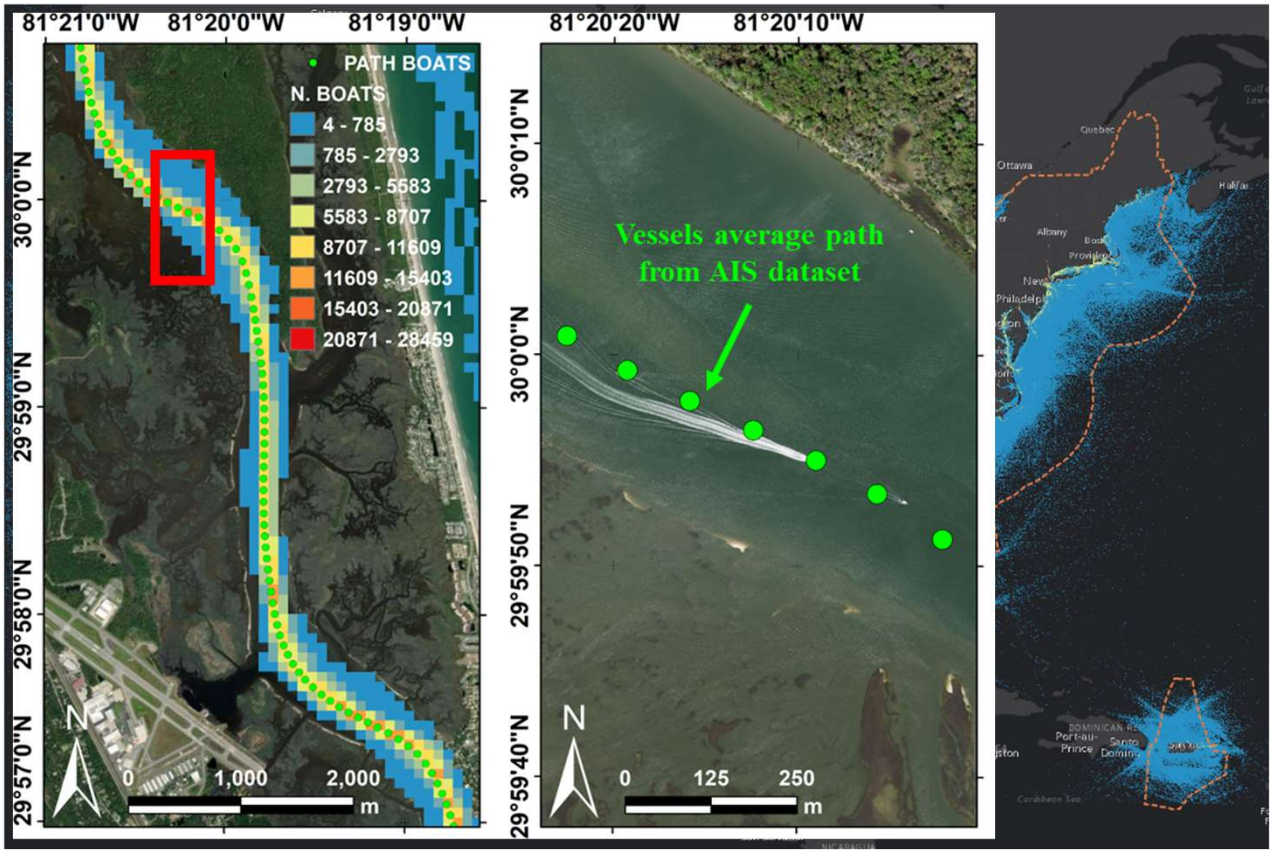
What about wind waves and boat wakes?

Boat Wakes – Vessel Traffic/Automatic Identification System (AIS) Dataset



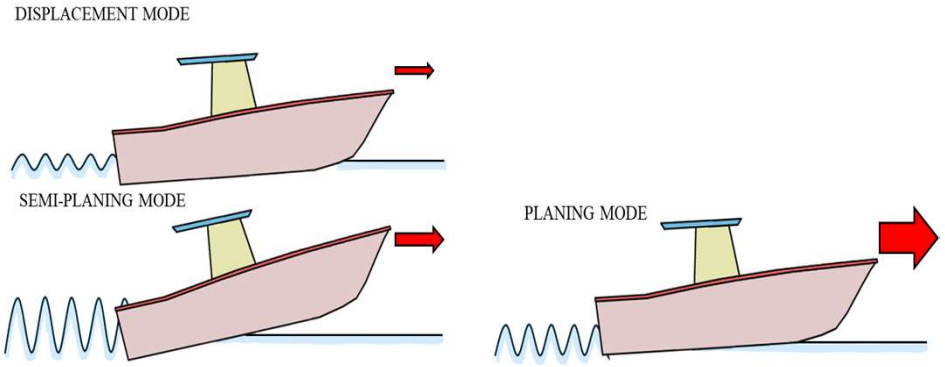
- Collected by the U.S. Coast Guard
- Gathered through an onboard navigation safety device that transmits and monitors the real-time location and characteristics of vessels
- Data includes information on vessel location, time, type, speed, length, beam, and draft

- **Most complete dataset: 2015-2023**

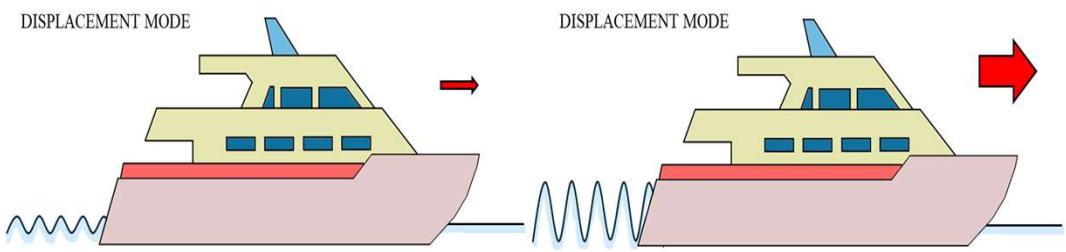
https://hub.marinecadastre.gov/pages/vesseltraffic

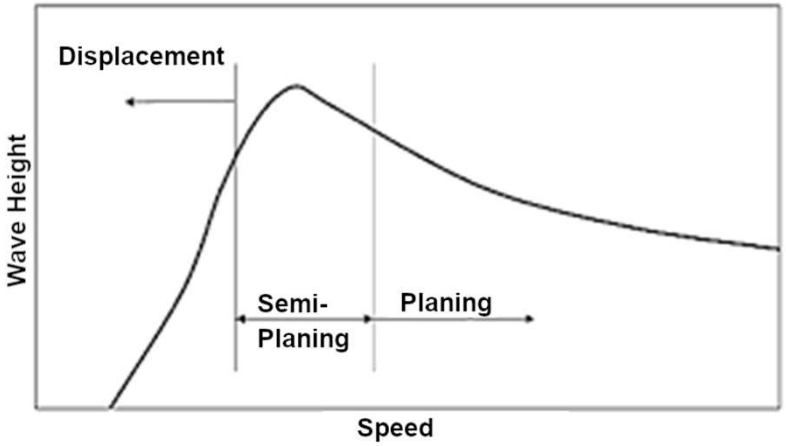
Boat Wakes – Boats Path and Mode

PLANING BOATS

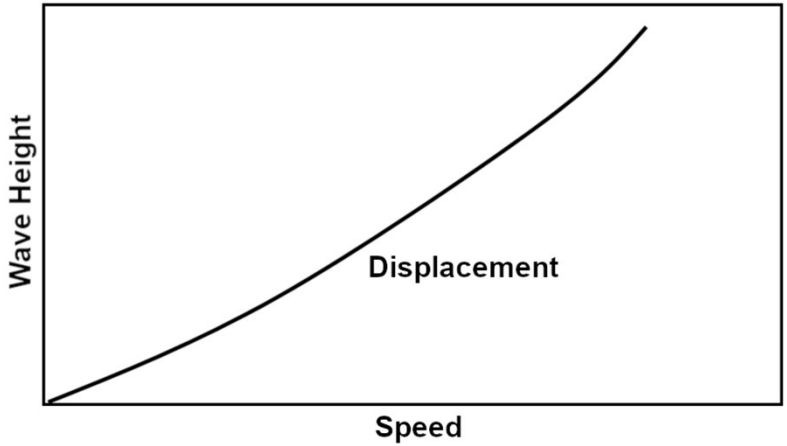


DISPLACEMENT BOATS



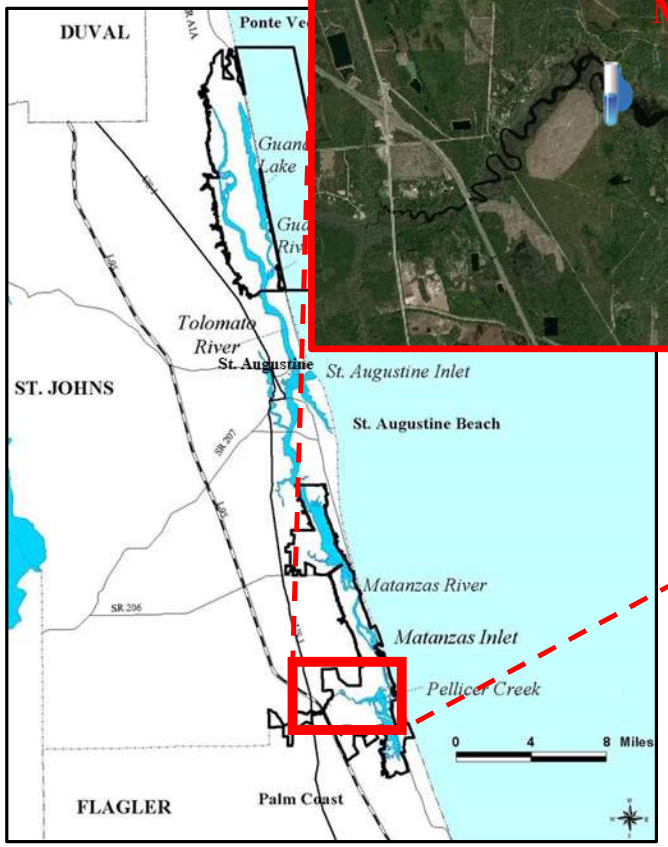


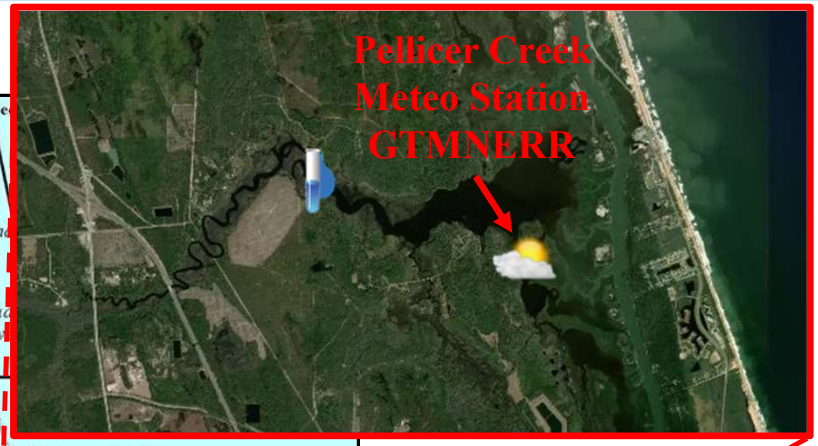
Wave Height vs. speed trends in planing vessels (Maynord, 2005)

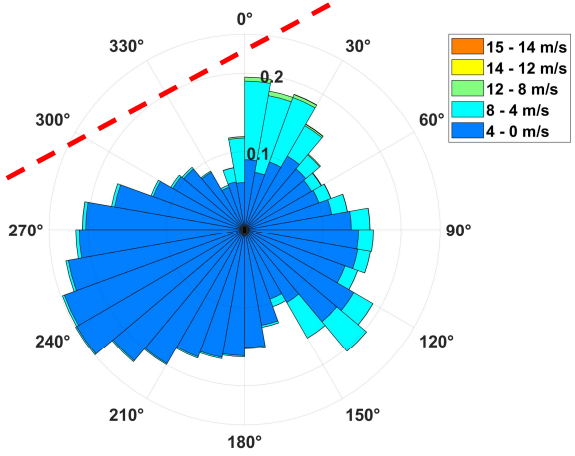


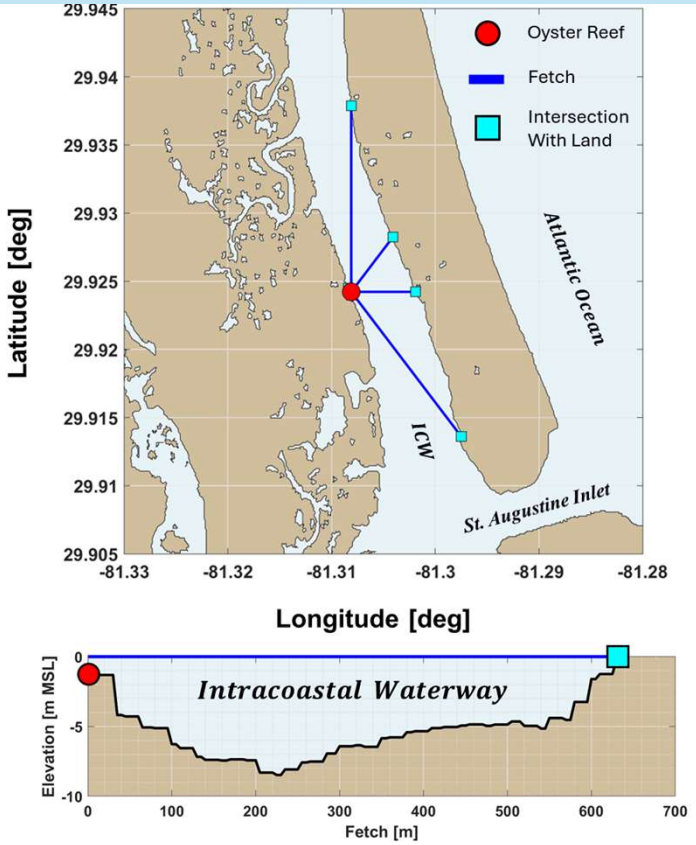
Wave Height vs. speed trends in displacement vessels

Wind Waves – Wind, Fetch, and Bathymetry



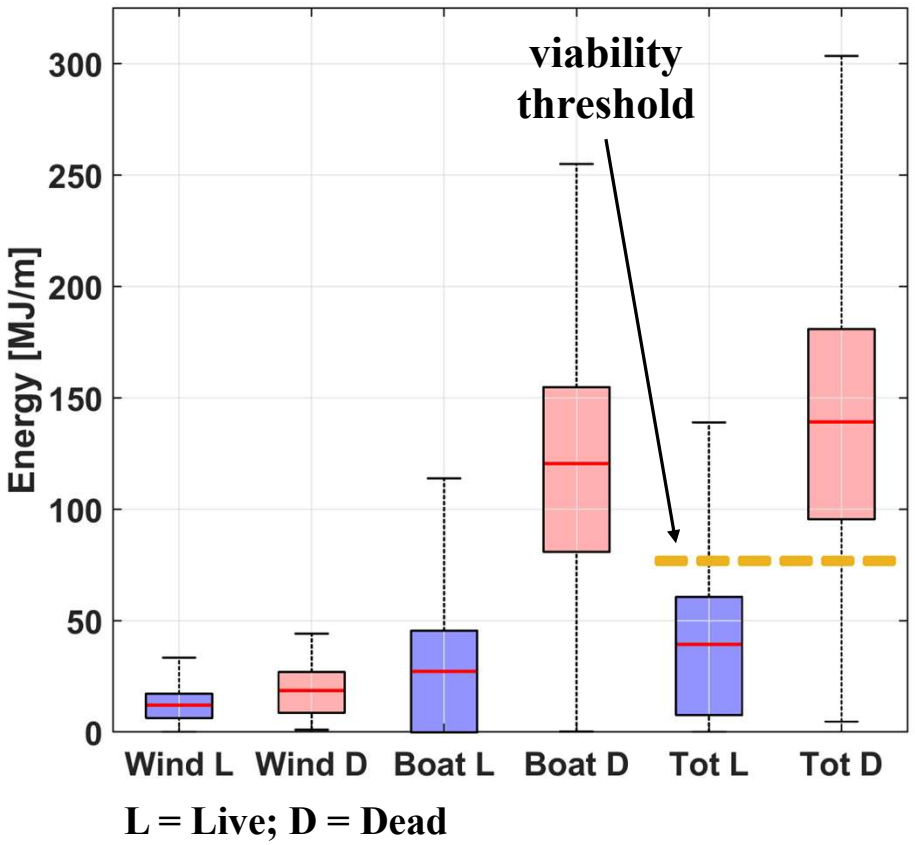






Solve wave energy conservation equation (Pinton and Canestrelli, 2025)

Wind Waves vs. Boat Wakes



L = Live; D = Dead

- Dead reefs receive significantly higher energy levels compared to live reefs, especially from boat wakes, which contribute about **three times more energy to dead reefs than to live reefs**
- Over 75% of dead reefs are exposed to total energy levels above 95 MJm^{-1}, while most live reefs experience energy below 60 MJm^{-1}
- **A viability threshold for oyster reefs can be set at approximately 77 MJm^{-1}.** When divided by the 9-year study period, this corresponds to an annual viability threshold of ~8.55MJm^{-1}

Overall conclusions

- Large boat wake energy increases the likelihood that a reef dies.
- Boat wakes mostly impact reef that are close to the banks of the waterways, which are the reef that filter the most, thus causing a sharp decrease in filtration services.
- If oyster restoration is planned, the position where the reef is restored does matter for filtration services!

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Beyond Residence Time: Quantifying Factors that Drive the Spatially Explicit Filtration Services of an Abundant Native Oyster Population

M. W. Gray, D. Pinton, A. Canestrelli, N. Dix, P. Marcum, D. Kimbro & R. Grizzle

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