Wrack as a Roughness Element:

Nonlinear Effects on Airflow and Sediment Deposition in a Coastal Dune System

Phillip P. Schmutz[1], Joseph Agin[1], Samantha R. Seals[2], & Peter Tereszkiewicz[3]

[1] Department of Earth and Environmental Sciences, University of West Florida, USA
[2] Department of Mathematics and Statistics, University of West Florida, USA
[3] Coastal Hydraulics Lab, US Army Corps of Engineers Research and Development Center, Vicksburg, MS, USA

1 WHY THIS MATTERS

Coastal dunes are shaped by interactions among wind, waves, sediment supply, vegetation, and roughness elements, and they provide important protection from storm surge and erosion. Beach wrack is organic material such as seaweed and seagrass deposited along the shore. Although wrack is often removed for aesthetic reasons, growing evidence suggests it supports dune development by trapping sediment and contributing to early-stage recovery. Despite this, fine-scale process understanding is limited. This study examines how wrack modifies near-surface airflow and influences sediment deposition.

2 OBJECTIVES

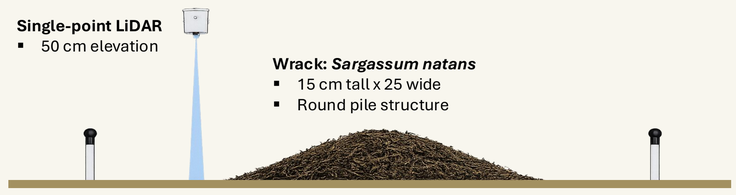
Determine how wrack modifies near-surface airflow across varying wind speeds and directions

Examine how airflow modification by wrack affects sediment deposition and erosion

Compare GLM and GAM to characterize airflow and sediment transport responses

3 METHODS

Single-point LiDAR
- 50 cm elevation



Wrack: *Sargassum natans*
- 15 cm tall x 25 wide
- Round pile structure

Upwind Anemometer
- 15 cm elevation
- 50 cm upwind

Downwind Anemometer
- 15 cm elevation
- 50 cm downwind

Santa Rosa Island, Florida

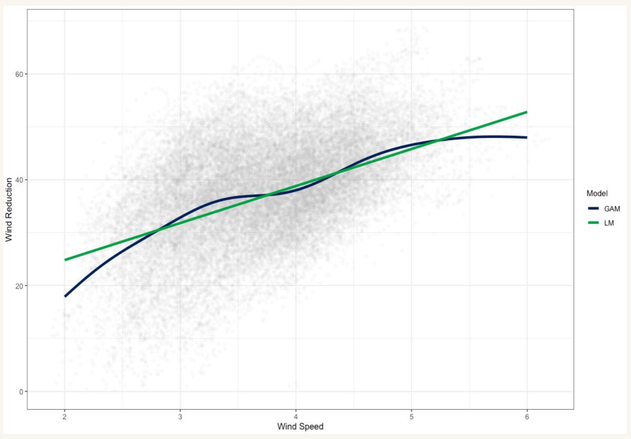
Data Smoothed w/ 10 second Gaussian filter

All sensors logged at 1 Hz

GLM & GAM models constructed in R

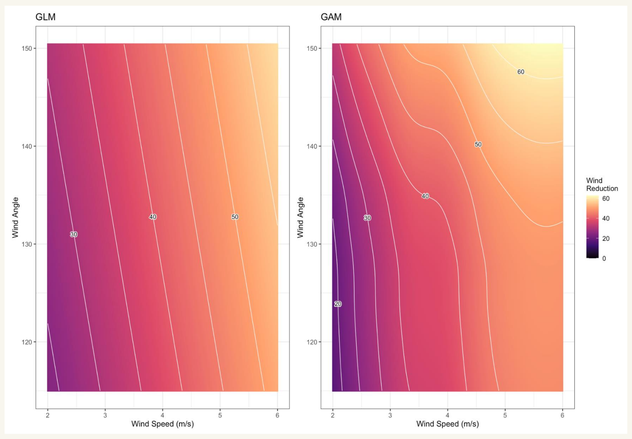
4 RESULTS – Airflow Reduction

Wind Reduction vs Wind Speed



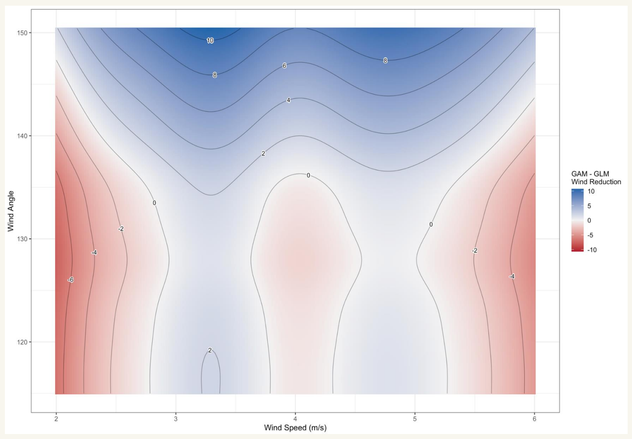
GAM captured a nonlinear response, with rapid increases at low wind speeds, stabilization at intermediate speeds, and a secondary increase before leveling off under higher wind conditions.

Wind Reduction % by Wind Speed & Angle



GAM revealed nonlinear responses across wind speed and angle, whereas GLM assumed uniform linear change throughout the parameter space.

GAM - GLM Differences (Wind Reduction %)



Differences between GAM and GLM were generally modest (<4%), although GAM predicted substantially greater wind reduction under localized conditions.

Key Highlights

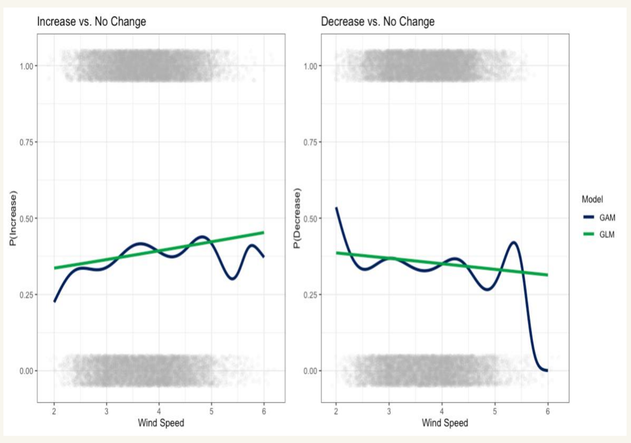
Wind speed and wind angle were significant predictors of wind reduction, $p < 0.001$

GAM outperformed GLM
- $R^2 = 0.276$ vs 0.261
- Δ AIC = 612.7
- $\chi^2 = 636.88$, $p < 0.001$

GAM and GLM wind reduction estimates differed by 8–10% under certain wind conditions.

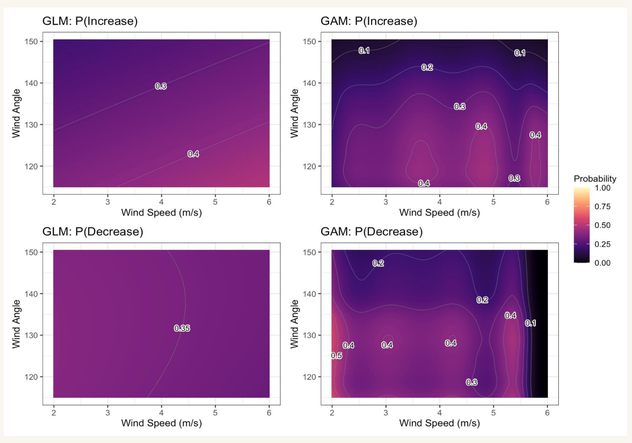
5 RESULTS – Sediment Deposition

Probability of Change vs Wind Speed



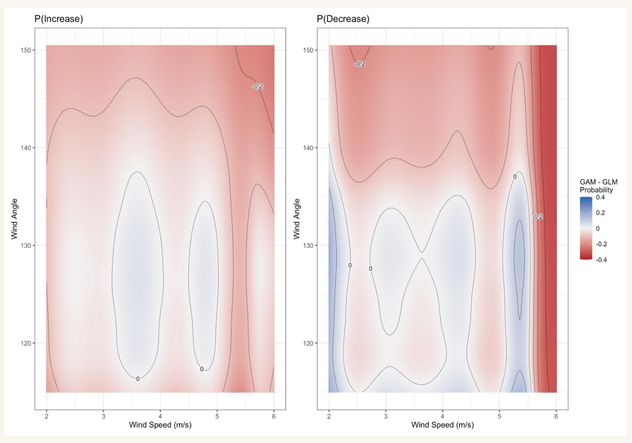
GLM indicated a positive relationship with sediment accumulation (OR - 1.12, $p < 0.001$) but no significant association with sediment loss, whereas GAM revealed significant nonlinear patterns for both outcomes (edf = 6.02 & 4.34, $p < 0.001$).

Probability of Change by Wind Speed & Angle



GLM predictions exhibited relatively uniform probabilities of sediment accumulation and loss, whereas GAM identified localized highs and lows in deposition probability.

GAM - GLM Differences (Probability of Change)



For sediment accumulation, differences between modeling approaches were generally modest (<0.2). In contrast, sediment loss predictions exhibited larger discrepancies, particularly under high wind-speed conditions.

Key Highlights

Deposition responses were condition-dependent and nonlinear across wind regimes.

GAM outperformed GLM
- $R^2 = 0.002$ vs 0.009
- Δ AIC = 16,913
- $\chi^2 = 16{,}961$, $p < 0.001$

Sediment loss exhibited stronger nonlinear responses, with localized probability differences exceeding 0.3.

6 CONCLUSIONS

Wrack altered near-surface airflow, but the magnitude of wind reduction depended strongly on wind speed and angle.

Enhanced airflow reduction did not always correspond to increased deposition, suggesting additional controls on sediment retention.

Nonlinear models revealed environmental responses not captured by linear approaches.

Wrack functions as a condition-dependent roughness element whose influence on airflow and sediment deposition varies across environmental conditions.

QR code: Project Webpage

UWF Department of Earth and Environmental Sciences

UWF Department of Mathematics and Statistics

Coastal and Hydraulics Laboratory

ERDC

University of West Florida