Aquaculture, Wave Energy Converters, and Offshore Wind Turbines: A Co-Location Case Study

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Introduction

Co-locating aquaculture, wave energy converters (WECs), and offshore wind turbines (OWTs) can provide renewable-powered food production and increase the longevity of OWTs [1,2]. South Fork, a developing wind farm off the coast of Rhode Island, was chosen for this study because it meets the oceanic requirements for farming Atlantic salmon.

Understanding how oscillating bodies in the ocean affect the motion of nearby bodies and the wave field (hydrodynamic interactions) is crucial to predicting power production and fatigue reduction. Therefore:

a realistic hydrodynamic model is required to justify co-location

Co-location concept - an example for aquaculture and OWTs [3]

Methodology

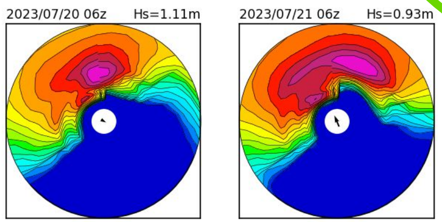
SWAN is a 3rd generation mild-slope wave propagation model whose strength lies in predicting the far-field effects on the wave environment. Surveying the large-scale wave field is necessary to determine the direction and strength of shadowing effects, which are beneficial for aquaculture and OWTs but damaging to WEC power production. Additionally, the wave data from SWAN can inform a boundary element method (BEM) solver to model more accurate near-field affects. The near-field interactions alter WEC power production, and configurations can be optimized for maximum power output.

Inputs:

1. wave spectral density
2. bathymetry
3. bodies (turbines, WECs)

Outputs:

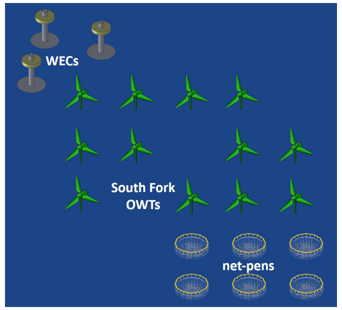
1. significant wave height
2. boundary conditions for boundary element model (BEM)



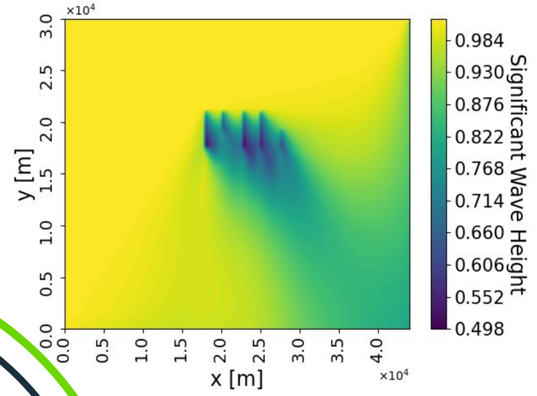
Wave rose showing probability density of wave height and direction in Rhode Island Sound [4]

Research Highlights

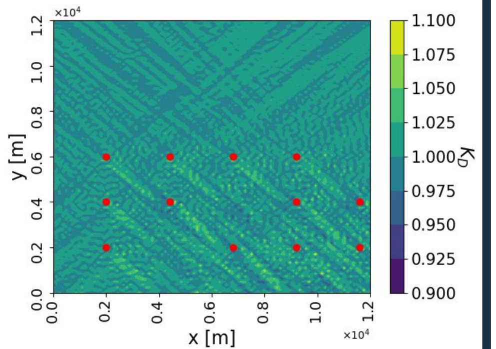
A co-location strategy is feasible for a mid-sized aquaculture farm powered by 3 WECs, but will require zoning of each subsystem



Results



Far-field solution of South Fork wind farm simulated in SWAN



Near-field solution from BEM solver

Discussion

The far-field solution indicates WECs must be placed NW of the turbines to extract the wave resource. The near-field solution indicates the WECs would struggle to oscillate at resonance if placed between turbines. Aquaculture netpens should be placed SE of the turbines to benefit from the shadowing effect. Future work involves coupling the SWAN and BEM models and adding in WECs and netpens. Once all components are modeled, recommendations on spacing and configuration can be made.

References

[1] Clark, C. (2019) Risk- and Reliability-Based Design Optimization of Offshore Renewable Energy Systems. dissertation. [2] D. Silva, E. Rusu, and C. Guedes Soares, "The effect of a wave energy farm protecting an aquaculture installation," Energies, vol. 11, no. 8, p. 2109, 2018. doi:10.3390/en11082109. [3] M.-C. T., G. Krause and B. Buck, "Marine aquaculture within offshore wind farms: Social aspects of multiple-use planning," Gaia ecological perspectives for science and society, vol. 18, no. 2, pp. 158-162. [4] NOAA National Centers for Environmental Prediction (2005) GFS-Wave Product Viewer, Environmental Modeling Center / Marine Modeling and Analysis Branch.

Acknowledgements

This work was supported in part by Sea Grant Regional Research Project No.: R/ATD-18-NESG