Pacific Northwest
NATIONAL LABORATORY

Offshore Aquaculture and Wave Energy in Puerto Rico

September 5, 2024

Mikaela Freeman, Lysel Garavelli, Molly Grear

Pacific Northwest National Laboratory (PNNL)

U.S. DEPARTMENT OF ENERGY BATTELLE

PNNL is operated by Battelle for the U.S. Department of Energy

Today's webinar

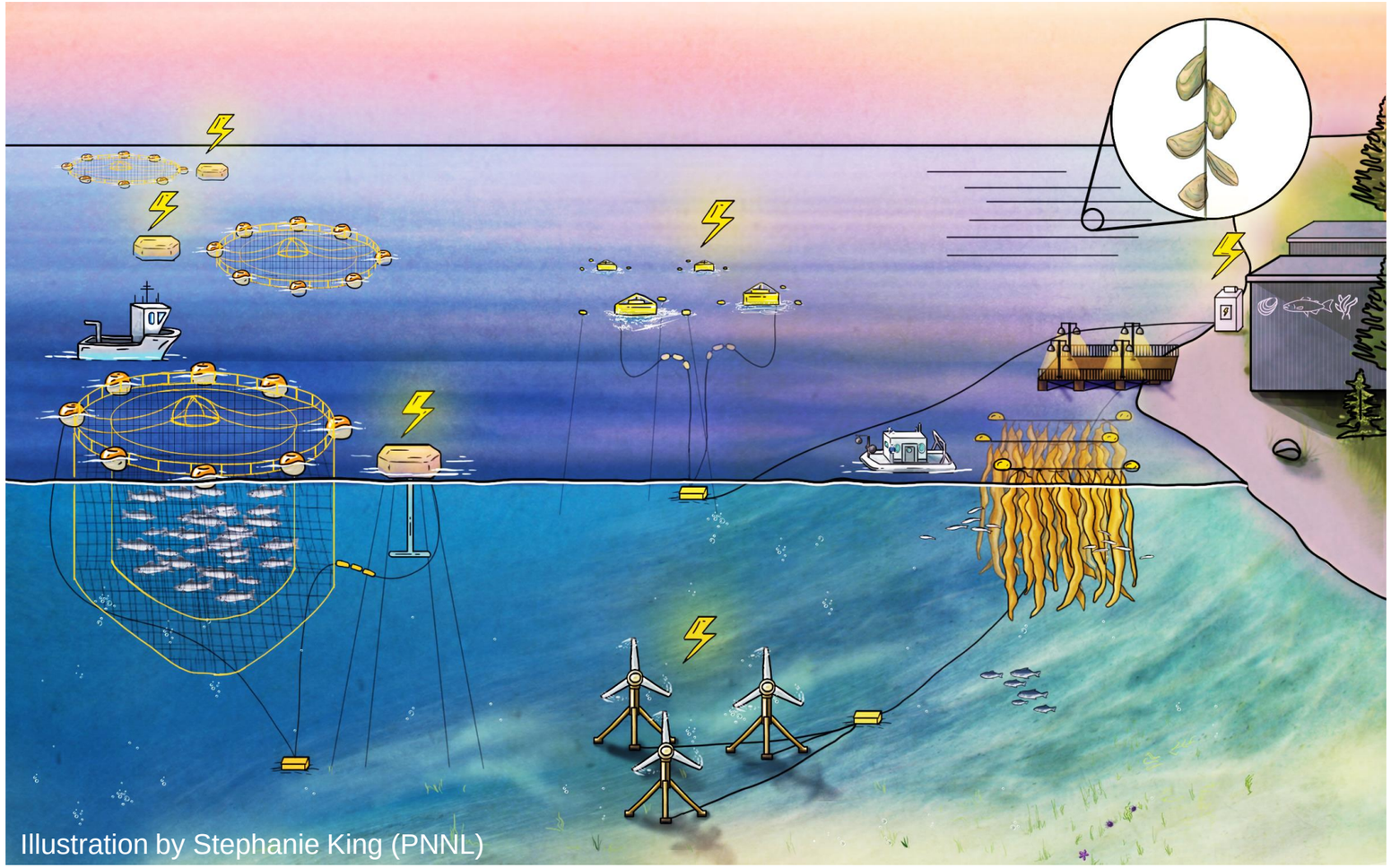
Goal: Share information on PNNL's research study on co-locating marine energy and offshore aquaculture in Puerto Rico and report on progress to date.

Agenda:

1. Background – marine energy and co-location
2. Overview of research study
   - Updates from the past year
3. Next steps
4. Questions

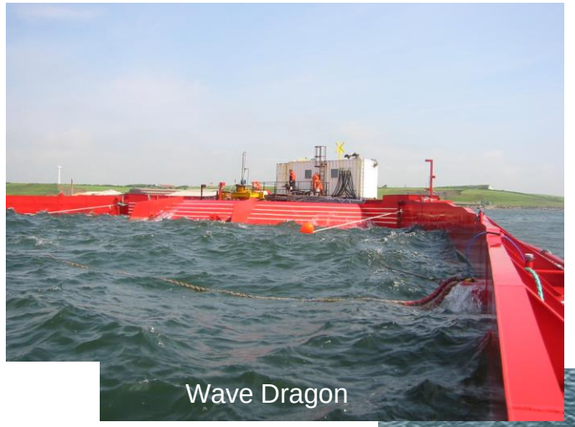
Co-location of Aquaculture and Marine Energy

- Marine uses developed within the same space and time scales; specifically focuses on integrating and powering aquaculture with marine energy

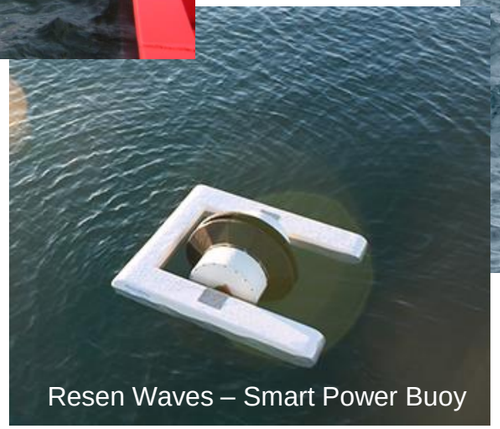


Marine Energy

- Energy from waves, tides, ocean currents, and salinity and temperature gradients
- Wave energy is a predictable, reliable, renewable source that can provide power-at-sea


Wave Dragon


Aqua Power Technologies – MANTA


Resen Waves – Smart Power Buoy

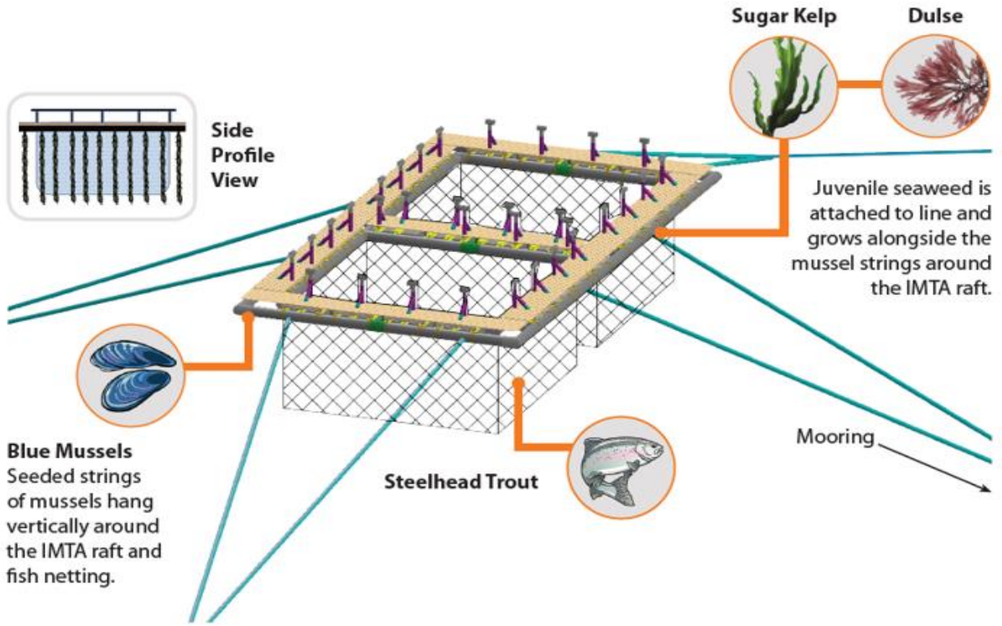
OPT – Power Buoy

CalWave – xWave

AMOG Consulting – AMOG WEC

Integrated Multi-trophic Aquaculture

- Multiple species (seaweed, shellfish, finfish) grown together within a single structure
- Sustainable solution to meet growing demand



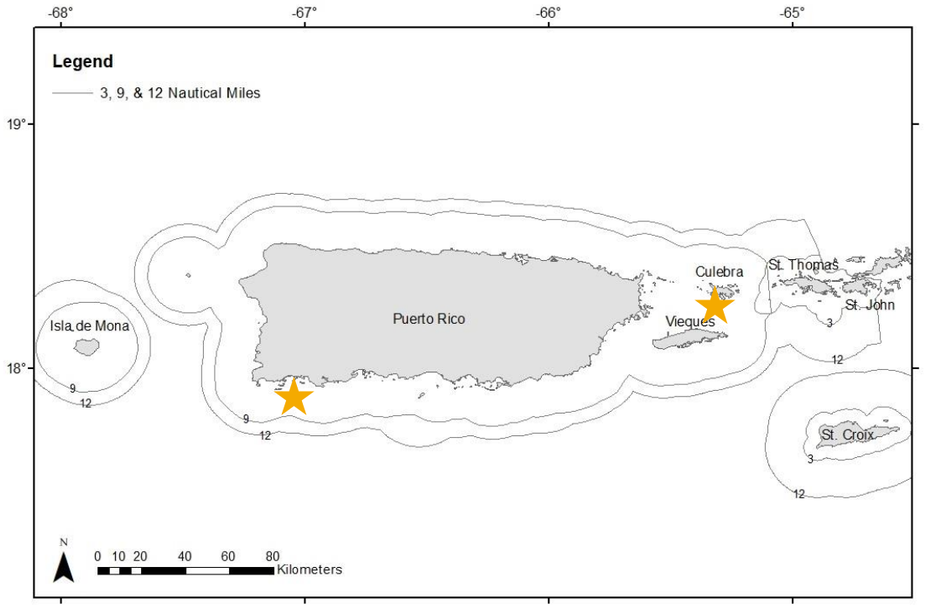
Images courtesy of New Hampshire Sea Grant

Puerto Rico

- Electricity infrastructure mainly uses fossil fuels
  - Shift to renewable energy sources
- Marine energy = opportunity to increase renewable energy usage
  - Deliver power-at-sea to offshore industries

<u>Marine aquaculture</u>:

- Offshore aquaculture farm, Culebra (snapper, cobia) – Snapperfarm Inc.
  - Successful fish production
  - Constraints prevented expansion of production and led to cessation of activities (e.g., long permitting timelines and finances)
- Macroalgae demonstration, La Parguera – Marine Biological Laboratory, Woods Hole
  - Pilot research project
  - Help develop sustainable aquaculture



Research Study Overview

Goal: Investigate real-world suitability and opportunities for co-locating offshore aquaculture and wave energy in Puerto Rico

Objectives:

1. Understand challenges and benefits of co-location
   - Outreach and engagement with stakeholders and communities in Puerto Rico

2. Assess potential for co-location of offshore aquaculture and wave energy
   - Spatial analysis to identify suitable areas

3. Explore technical aspects of co-location – how to integrate wave energy and aquaculture, permitting, etc.
   - Environmental monitoring
   - Wave energy technologies
   - Develop guide for co-location between aquaculture and marine energy

1. Outreach and Engagement

- Gather feedback from stakeholders and local community
- Understand local perspectives and needs
- Identify barriers/challenges and opportunities for co-location

San Juan, Puerto Rico, workshop – February 2023

Timeline of Events

2022

- Conversations to understand history of aquaculture
- Online workshop for initial input on spatial analysis (Aug)

2023

- In-person stakeholder workshop (Feb)
  - Visited land-based aquaculture operations in Puerto Rico
- In-person meet up during fieldwork (Jul)
- Spatial analysis preliminary results feedback (Oct/Nov)
- Presentation to PR100 Advisory Group (Nov)

2024

- Culebra virtual community meeting (Feb)
- Research progress update – today's webinar (Sept)

Summary of Feedback Received

- Assess feasibility comprehensively, beyond aquaculture and marine energy
  - Social and economic effects, supply chain, workforce, jobs, education, environment, fishers
  - Balance various perspectives and needs (community/local, technical, business, environment)
- Understand lessons learned from previous developments in Puerto Rico
  - Aquaculture, other infrastructure projects (land-based wind, sugar cane processing, desalination, etc.)
- Opportunity to communicate with communities and discuss marine energy and aquaculture in Puerto Rico
  - Prioritize engagement with stakeholders and local communities, learn from and incorporate perspectives
  - Explore synergies (fishing or tourism around co-location) and potential benefits (food security)
- Overall, interest for continued discussions on co-location
  - Necessary to understand location-specific needs and challenges as part of feasibility assessment
    - ✓ Interest in co-location, but also have essentials that still need to be met
  - Community-led, participatory approach with transparent communication
  - Suggested to prove technologies via pilot research project
- Other interest for marine energy – desalination, emergency preparedness, etc.

2. Spatial Analysis

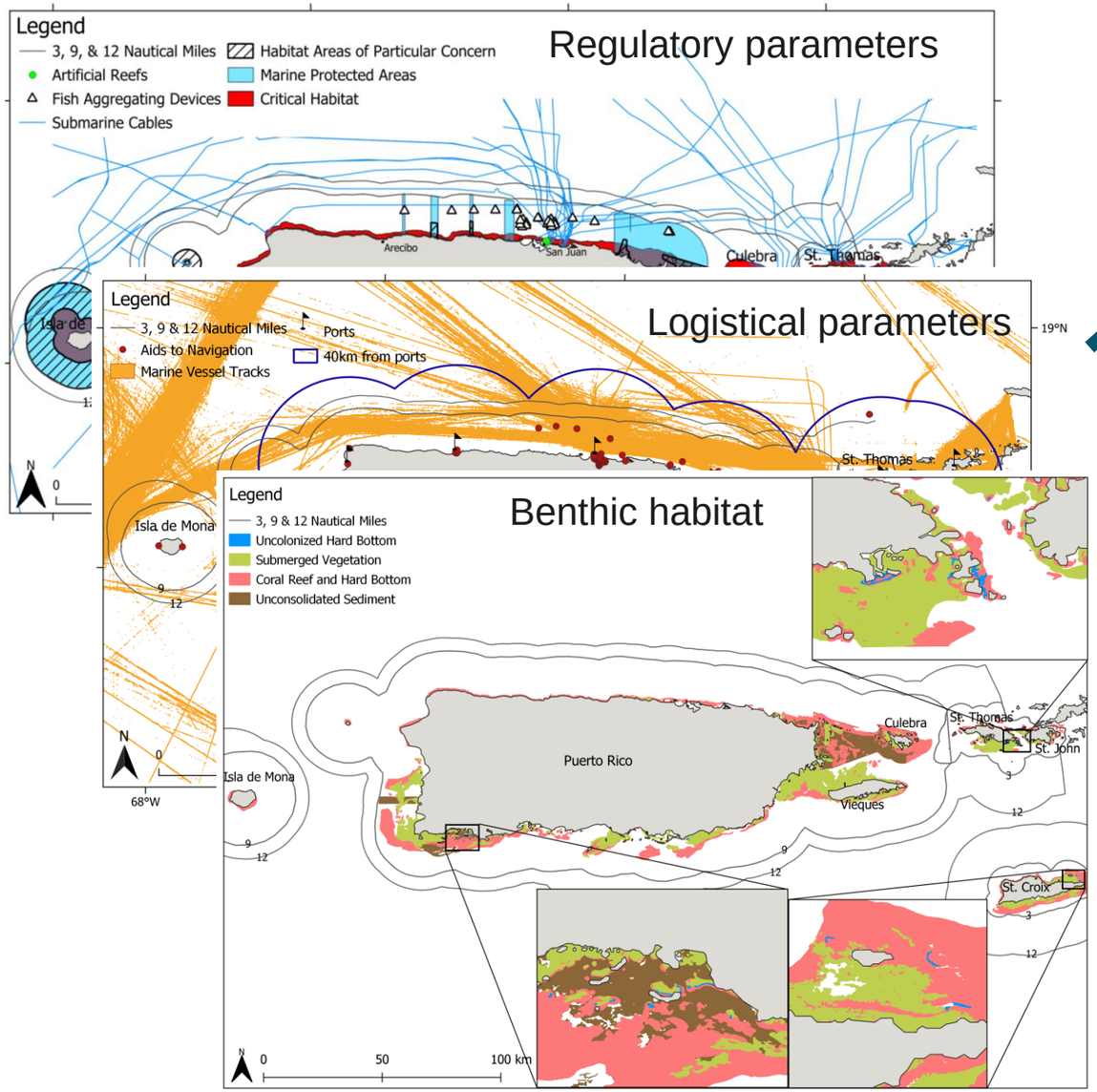
- Define parameters and considerations for co-location
  - Based on current research and interviews with experts (Garavelli et al. 2022)
- Included environmental, logistical, and regulatory parameters
- Assess feasibility by identifying suitable areas for co-location

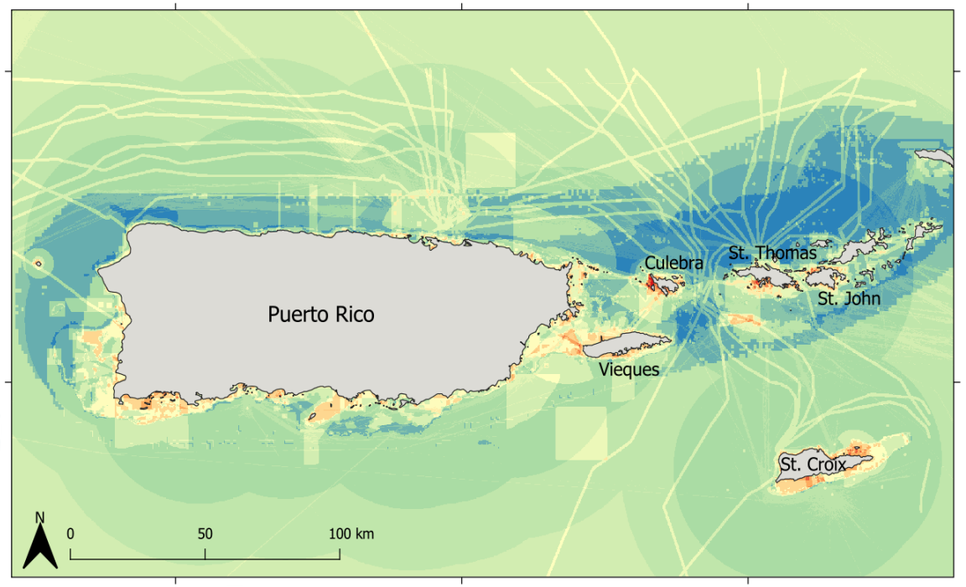
Key Parameters for Co-location

Parameter	Considerations
Wave height	0 – 2.5 m
Wave power density	5 – 30 kW/m
Current velocities	0 – 1 m/s
Bathymetry	15 – 80 m
Benthic habitat	Soft bottom habitat (sand & mud)
Distance to Ports	0 – 40 km

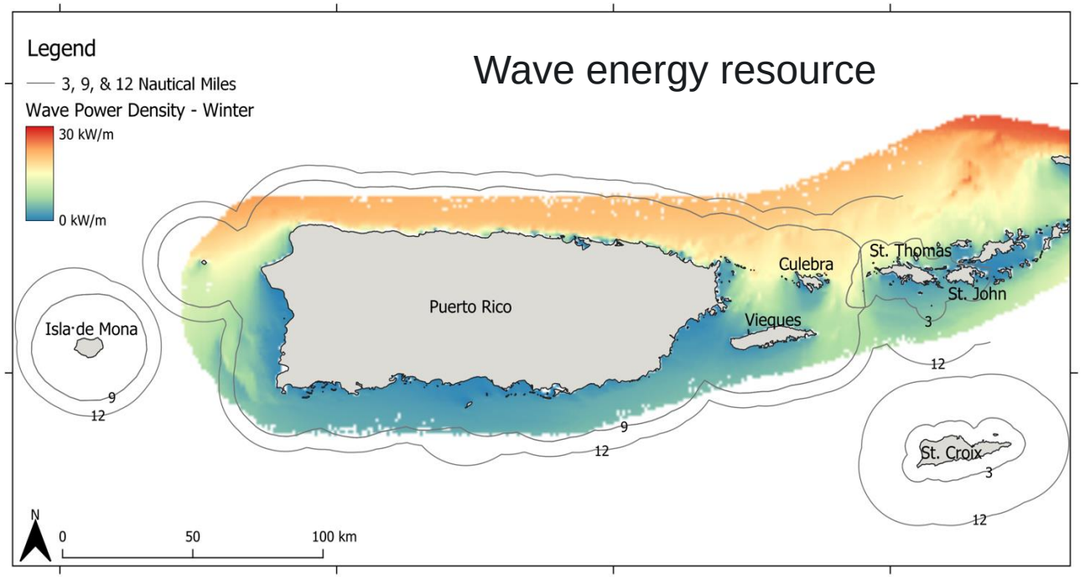
Spatial Analysis – Method

Overlay layers



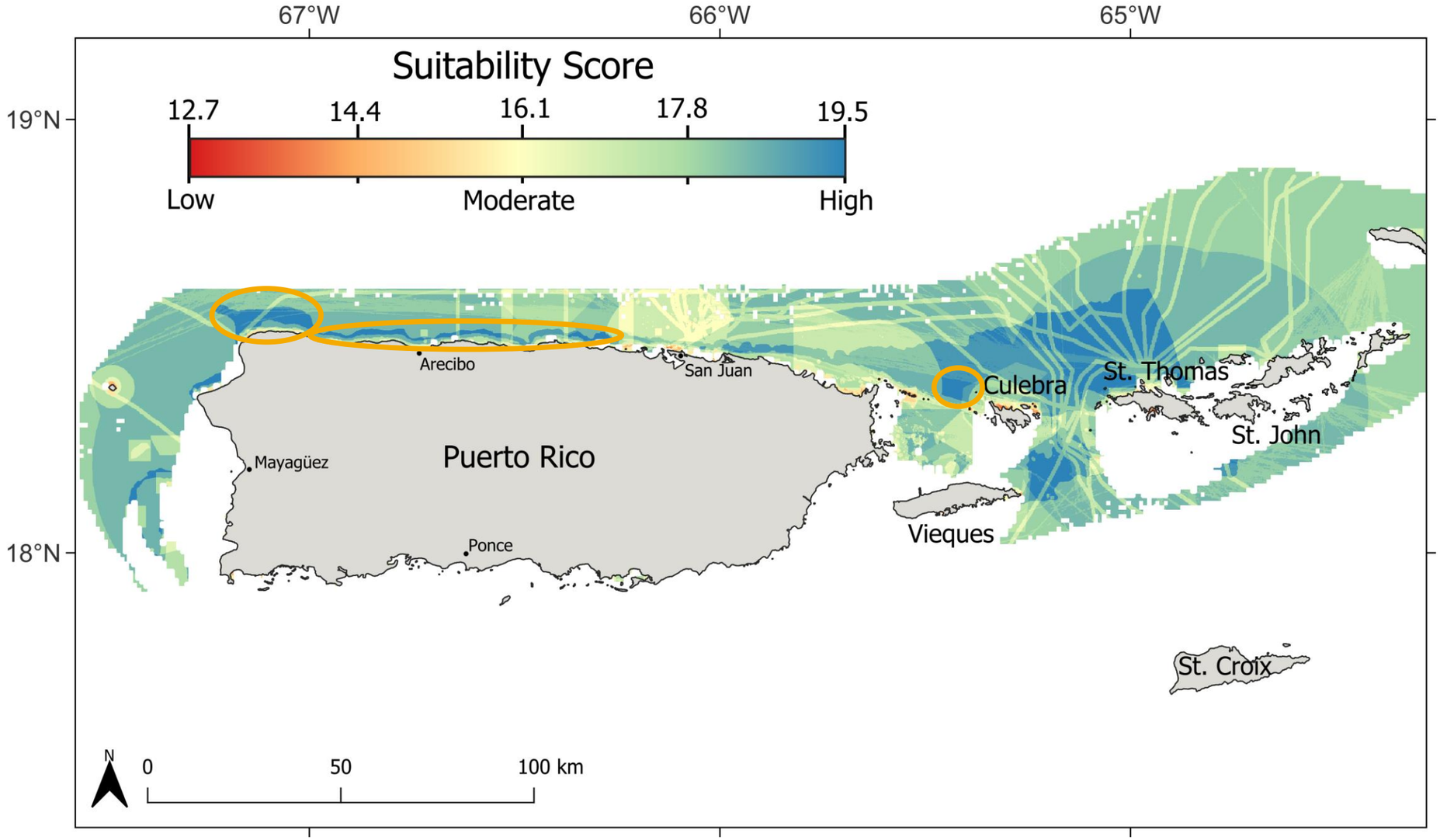


Restrict results by available wave energy resource



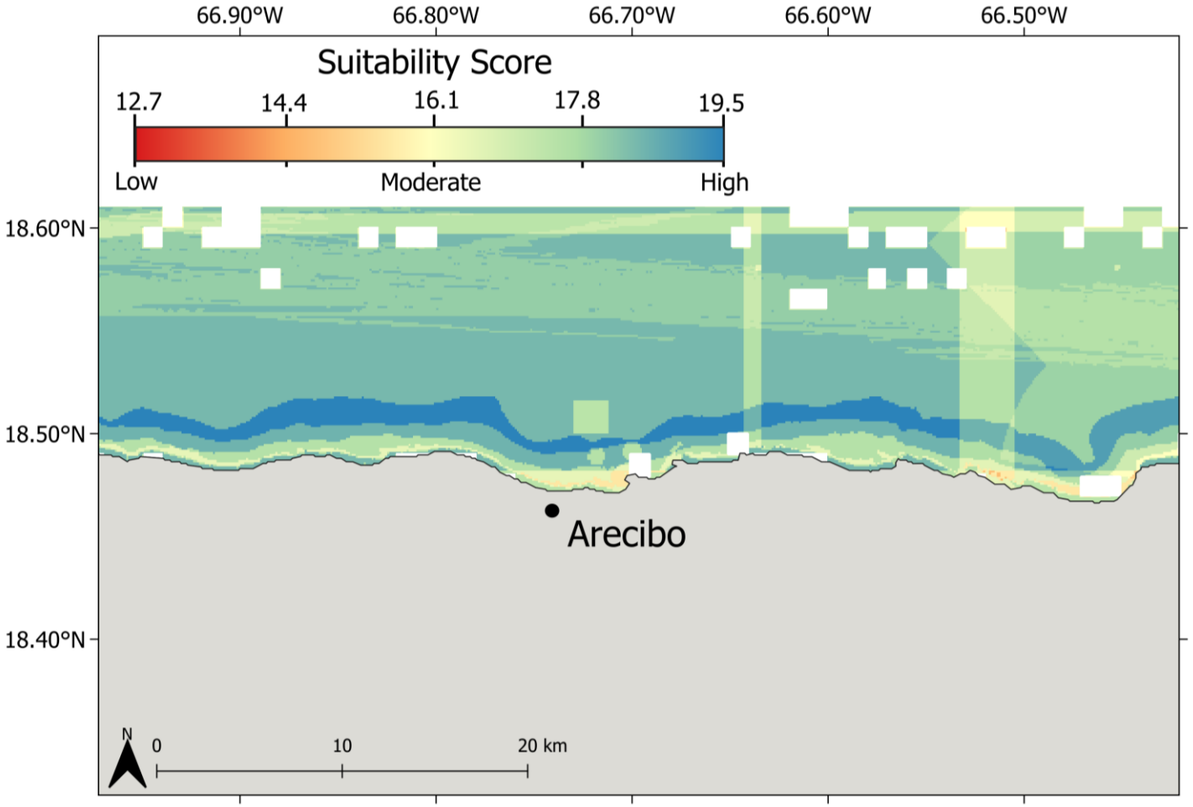
Spatial Analysis – Suitable Area Results

Higher suitability score = greater convergence of ideal conditions for co-location

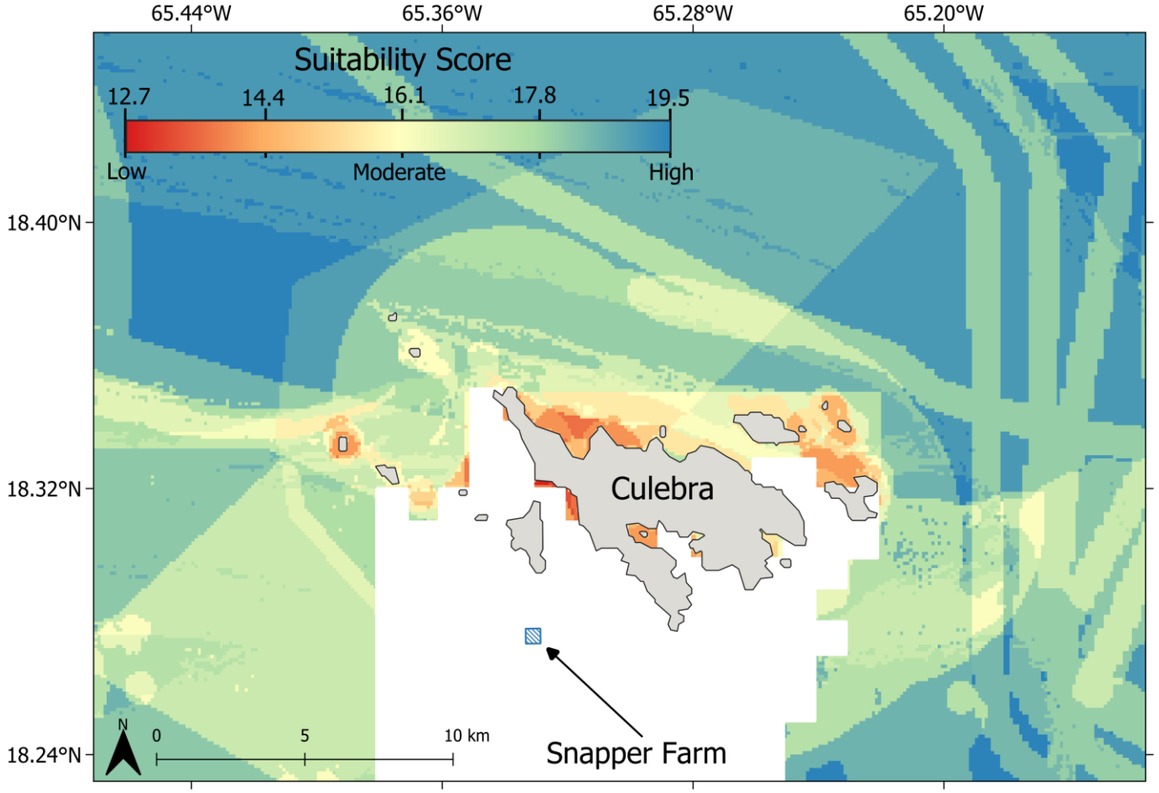


Spatial Analysis – Suitable Area Examples

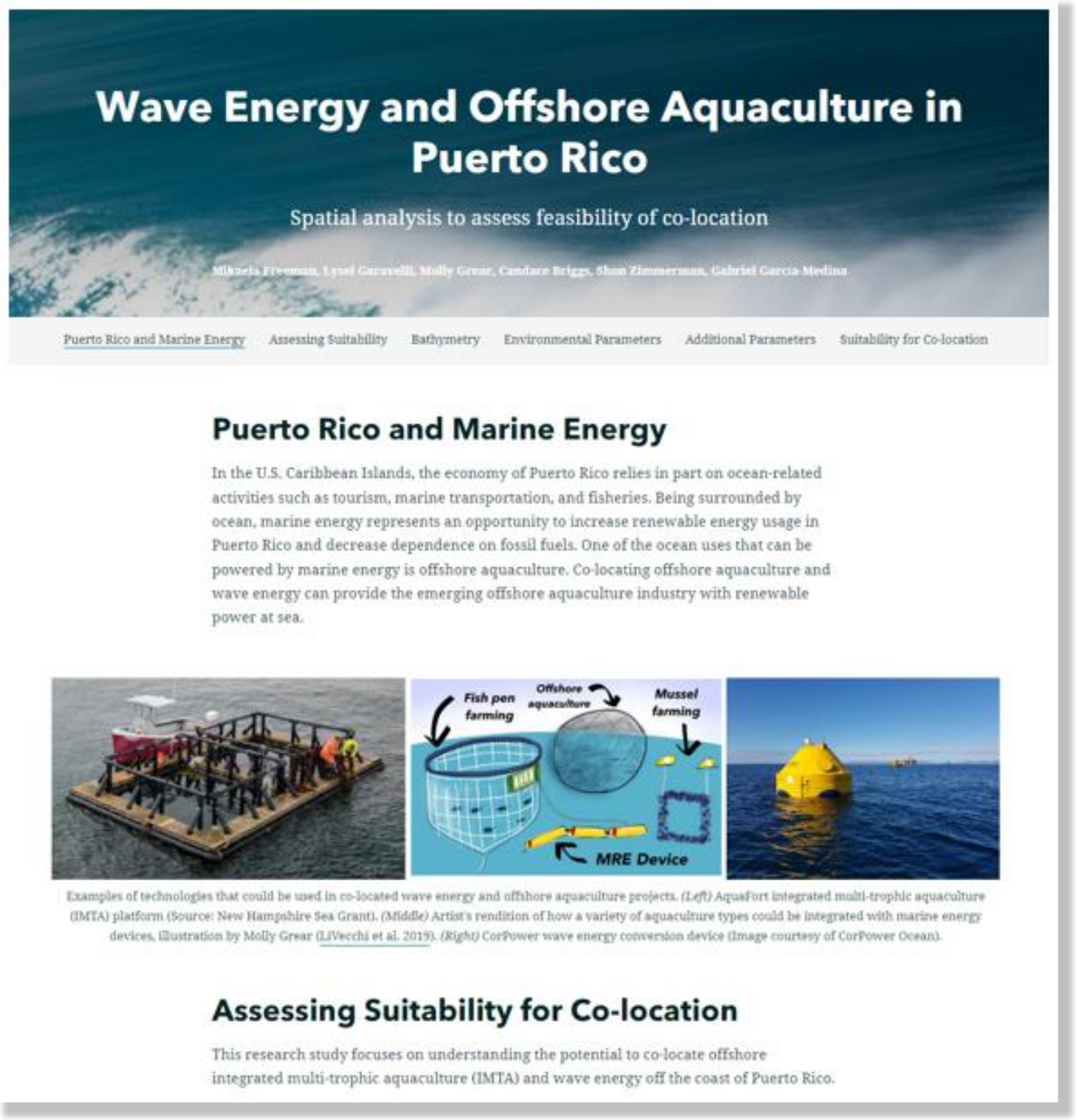
Arecibo



Culebra

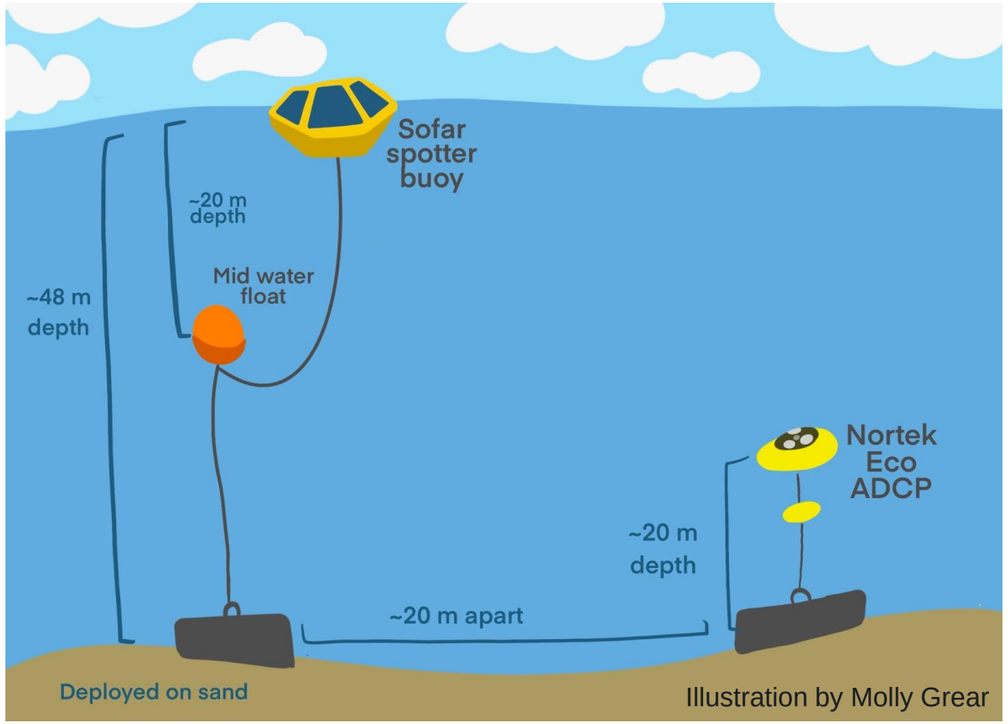


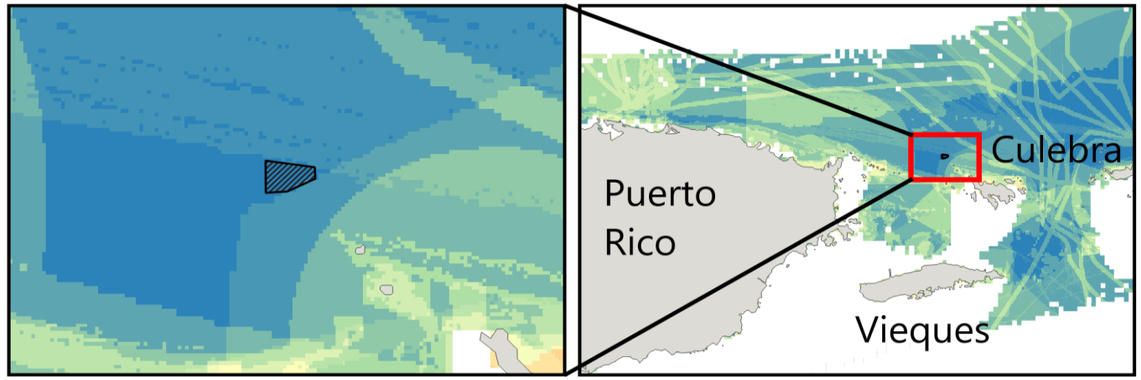
Online Interactive Tool – StoryMap

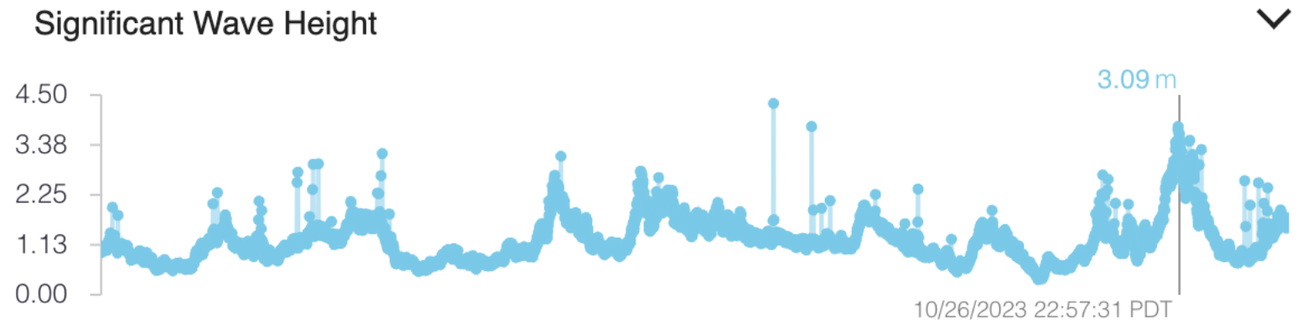


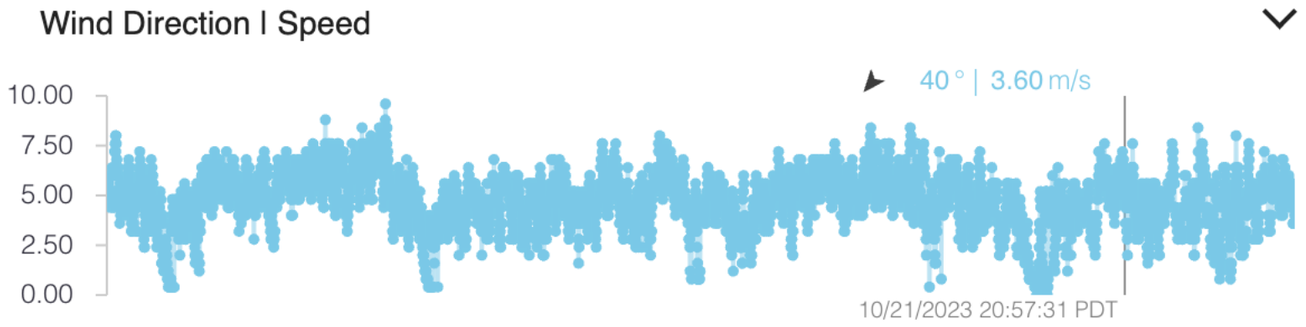
https://tinyurl.com/StoryMapMarineEnergy

3. Environmental Monitoring



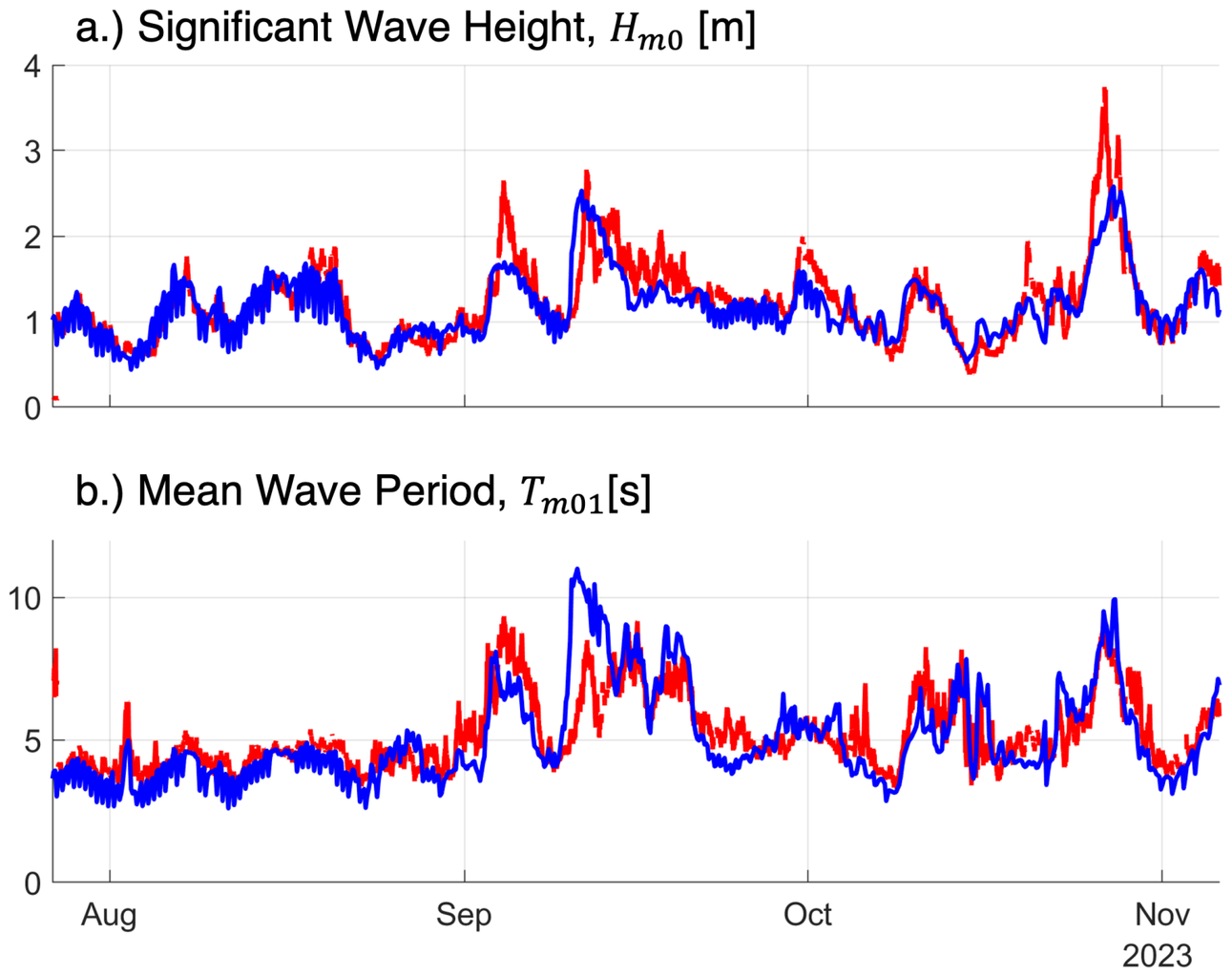






Environmental Monitoring

- Comparison between observations and model (Canals Silander & García Moreno, 2019)



Model
Observations

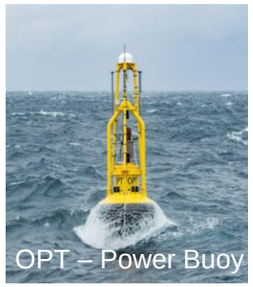
3. Wave Energy Technologies

- Surveyed wave energy companies to understand what a wave energy device for aquaculture might look like
  - Provided wave conditions for potential suitable sites in Puerto Rico and California

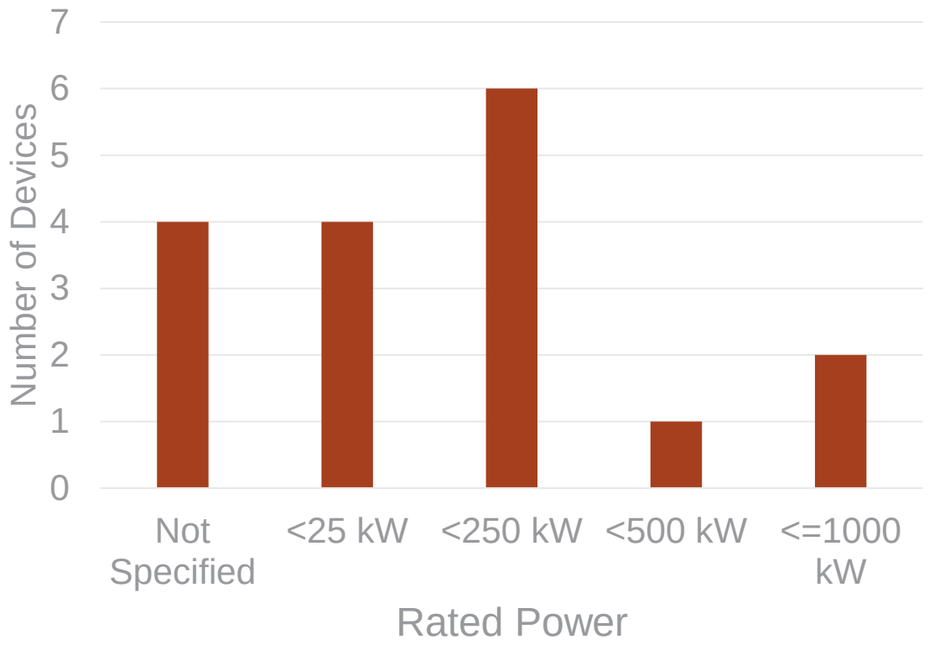
- Findings from devices:
  - Power output ranged from 3 kW to 1 MW
  - Size ranged from 0.06 m to 45 m, with larger devices creating more power
  - Some devices designed to integrate into aquaculture systems, others designed to be connected with a power cable

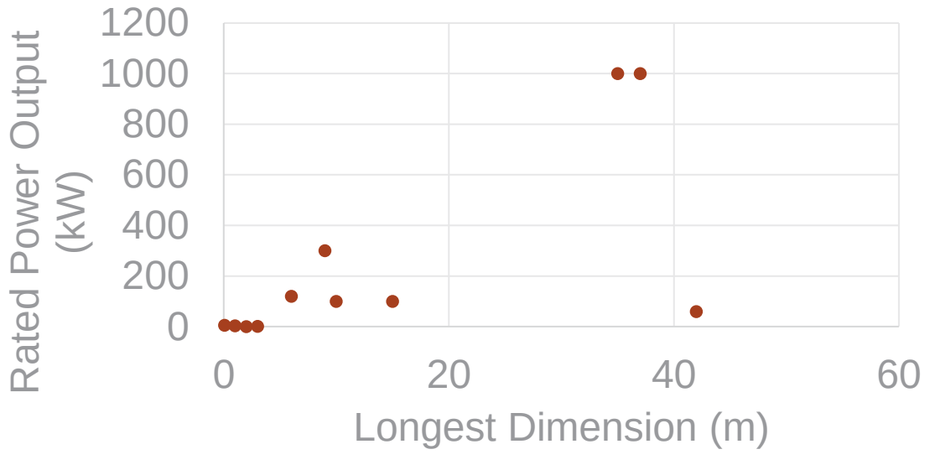

CalWave – xWave

Oscilla Power – TritonC


OPT – Power Buoy


Carnegie – MoorPower Buoy





Summary

- Aquaculture and marine energy sectors are interested in co-location, presents an opportunity for sustainable development
- Suitable areas for co-location exist around Puerto Rico
- Remains a need to examine at a local-scale to further understand feasibility: technical, permitting, social, etc.

Next Steps

- Continue research on feasibility
- Parallel efforts to work towards demonstration of co-location at research facility to work on integration in situ

Learn More

PNNL Website:

Marine Energy for Aquaculture

https://www.pnnl.gov/projects/marine-energy-aquaculture

Freeman et al. (2022)

Thank you!

Mikaela Freeman
mikaela.freeman@pnnl.gov

Lysel Garavelli
lysel.garavelli@pnnl.gov

Molly Grear
molly.grear@pnnl.gov

Thank you to the U.S. Department of Energy,
Water Power Technologies Office