Co-locating wave energy and offshore aquaculture in Puerto Rico

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I. Introduction

MARINE energy has large potential to provide clean energy and reduce greenhouse gas emissions. While marine energy is usually thought of as bringing power to the grid, it can also be used to power activities at sea, particularly offshore. One of the offshore industries that can be powered by marine energy is offshore aquaculture. Offshore aquaculture is a growing sector worldwide. While growth has been slow in the US, there is much interest in expanding offshore seafood production [1], [2], [3]. Offshore aquaculture requires energy for several operations such as feeding systems, lighting, refrigeration, or monitoring.

Recent studies have assessed the feasibility of co-locating marine energy and offshore aquaculture in the US [4] but are lacking real-world applications. Co-location is defined as marine uses developed within the same space and time scales, and specifically focuses on integrating and powering aquaculture with wave energy, and offshore is defined as areas with depths of 25 m or more. In the Caribbean Sea, the economies of Puerto Rico rely in part on ocean-related activities such as tourism, marine transportation, and fisheries. Small-scale fisheries have particularly been impacted by extreme climate events such as Hurricane María in September 2017 [5] and the Covid-19 crisis [6]. Hurricane María also caused commercial landings to fall by 20% because of the loss of production, extended power outages, and loss of customers.

With a strong wave energy resource, the use of marine energy for Puerto Rico represents an opportunity to increase renewable energy usage, which will aid in achieving clean energy goals and decreasing the dependence on fossil fuels. Aquaculture currently exists on land and nearshore in Puerto Rico. Previously offshore aquaculture was shown to be viable in Puerto Rico, though has ceased due to permitting and financing constraints. In Puerto Rico, the development of co-located offshore aquaculture and marine energy could help boost the ocean economy and bring a supplementary source of revenue to local fishers.

This study aims to assess the feasibility for co-locating offshore integrated multi-trophic aquaculture (IMTA) and wave energy off the coast of Puerto Rico. IMTA allows the co-farming of fed species (e.g., fish), extractive species (e.g., shellfish), and macroalgae, increasing the sustainability of aquaculture by creating an integrated system. The feasibility for co-location was determined through outreach to Puerto Rico stakeholders to understand local perspectives, a regional assessment to identify the key parameters to consider for co-location, and field work to collect environmental data. The combination of these methods highlights the potential for co-locating offshore IMTA and wave energy off the coast of Puerto Rico as well as important factors to consider if a future development of these activities is to occur in the region.

II. Outreach and engagement

The potential for co-locating offshore aquaculture and marine energy is still in the early stages, with few pilot deployments or research studies worldwide [7]. Due to this and the fact that both offshore aquaculture and marine energy are newer industries, key for any successful co-location development will be stakeholder and community outreach and engagement.

This study is one of the first assessments of the potential for co-location in the US and as such, outreach and engagement has been undertaken to understand local perspectives on this opportunity. To date, this effort has included one-on-one meetings and a virtual workshop with key stakeholders and advisors and an in-person workshop in Puerto Rico with regional stakeholder, local organizations, and community members. Through this outreach and engagement, feedback has been received on data and information to include in the regional assessment so that it is comprehensive and includes environmental, regulator, and logistical parameters; opportunities and challenges regarding co-location in Puerto Rico; recommendations for co-location including suggested locations; and general feedback about offshore aquaculture and marine energy for Puerto Rico.

III. REGIONAL ASSESSMENT

Information on environmental, regulatory, and logistical parameters relevant to offshore IMTA and wave energy were gathered from the literature and from aquaculture experts. The methods in this study followed those used in [5].

A. Relevant parameters for co-location

Relevant parameters for co-location were categorized as environmental, logistical, and regulatory. Environmental parameters included wave height, wave power, bathymetry, current velocities, and benthic habitat. Wave power and wave height were obtained from a wave hindcast model by University of Puerto Rico.[1] Current velocities were obtained from the American SEAS (AMSEAS) model.[2] Regulatory and logistical parameters need to be considered to avoid conflicts with other marine uses and to avoid any areas that may be restricted in use based on regulations. In Puerto Rico, there are various regulatory and logistical parameters such as navigation routes, distance from ports, critical habitat, marine protected areas, and submarine cables.

B. Wave resources and marine uses in Puerto Rico

To power offshore IMTA in Puerto Rico, wave power density needs to be higher than 5 kW/m. Average wave power density in Puerto Rico higher than 5 kW/m mainly occurs off the west coast, all along the north coast, and in the southwest around Culebra (Fig. 1).

Fig. 2 shows a subset of regulatory and logistical parameters. Critical habitats are typically in areas closer to shore surrounding all the islands in the study area and exist between the mainland and the Puerto Rico islands of Culebra and Vieques. Marine protected areas and habitat areas of particular concern are spread throughout the study area. Submarine cables exist mainly to the north of Puerto Rico as well as all around the US Virgin Islands. Fish aggregating devices are located north of Puerto Rico and artificial reefs are present along the shore southwest and northwest of Puerto Rico.

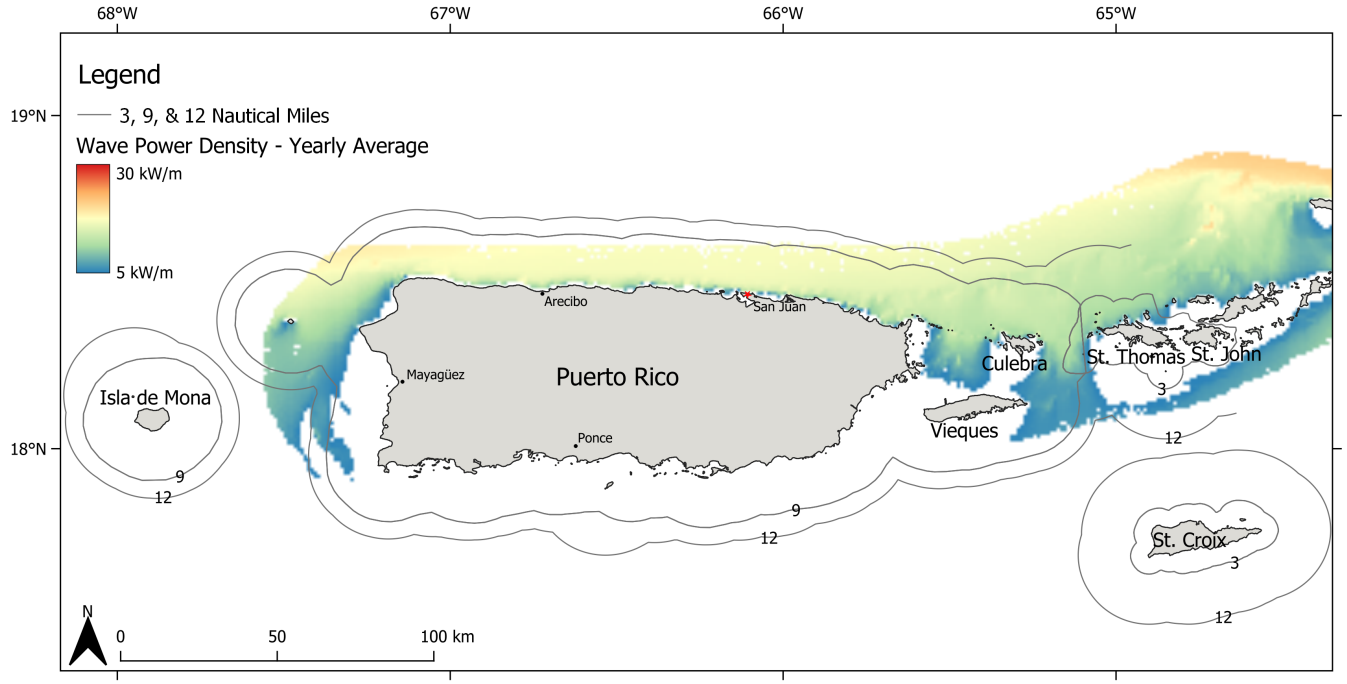

Fig 1. Yearly average of wave power density in Puerto Rico and U.S. Virgin Islands between 5 kW/m (blue) and 30 kW/m (red). Dark grey lines represent the 3 nm (US Virgin Islands) and 9 nm (Puerto Rico) state and 12 nm federal water boundaries. Note: data were not available around St. Croix.

[1] http://www.canalsresearch.com/wave-climate-atlas

[2] https://www.ncei.noaa.gov/products/weather-climate-models/fnmoc-regional-navy-coastal-ocean

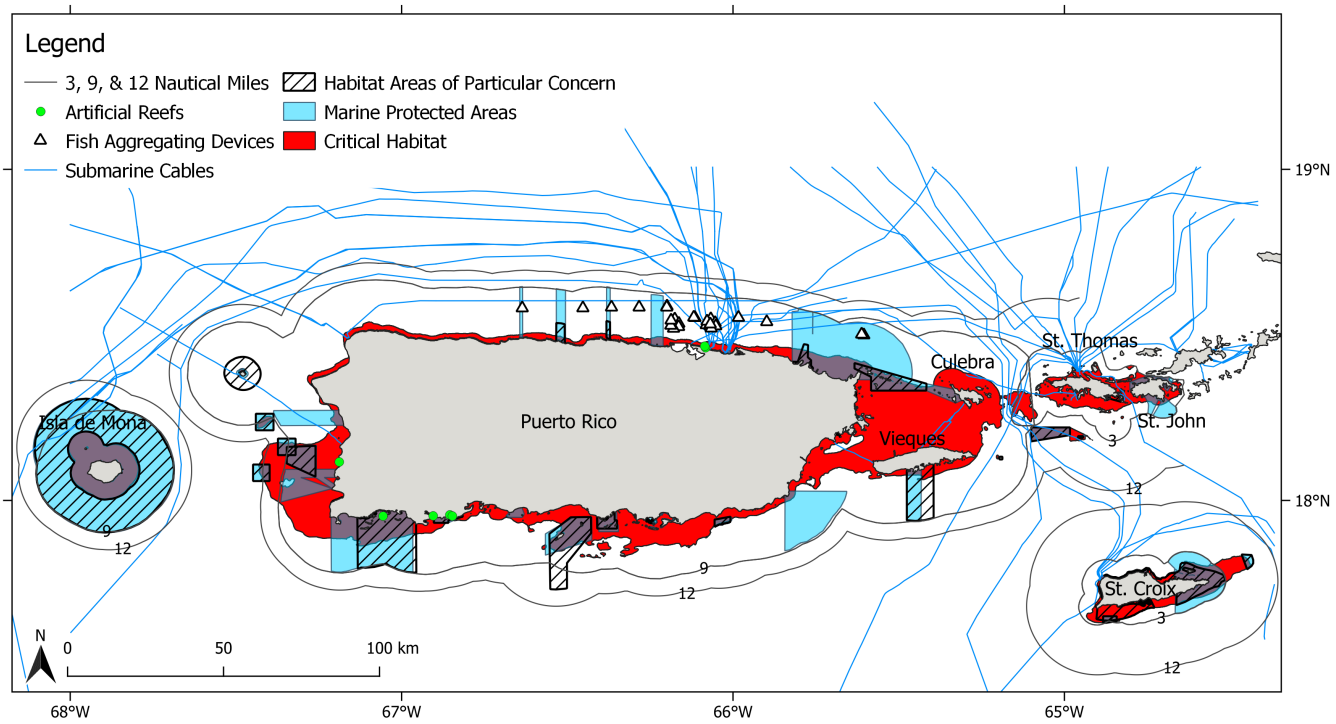

Fig 2. Subset of regulatory and logistical parameters in Puerto Rico and U.S. Virgin Islands including artificial reefs (green circles), fish aggregating devices (white triangles), submarine cables (blue lines), habitat areas of particular concern (hatched areas), marine protected areas (light blue areas), critical habitat (red areas).

IV. Environmental Monitoring

While existing knowledge on key parameters for co-location can narrow down regions to explore for co-locating marine energy and IMTA, the resolution of some of the data is too low to fully rely on for siting. To close that gap, an instrumentation package was designed to provide site-specific data to inform a future co-located marine energy and aquaculture project.

The instrumentation package measures wave height, wave direction, wave period, and temperature at the surface, and current speeds in the top 30 m of the water column (Fig. 3). The first instrument in the package is a Sofar Spotter Buoy which will send back data and position continuously via satellite at 1-hour intervals throughout the 6-month deployment. The second instrument is a Nortek Eco Acoustic Doppler Current Profiler (ADCP). It will record data at 20-minute intervals, which will be stored internally and recovered at the end of the deployment. While there is not an actual co-located project planned in Puerto Rico at this time, this fieldwork will demonstrate the necessary tools to characterize a site and help identify the next steps in planning for co-location.

A representative site was selected off the west coast of Culebra that meets the environmental, regulatory, and logistical requirements for co-location. This site will be monitored for 6 months to observe two seasons of data, which will provide a better understanding of the potential suitability at this representative site. The planning, engineering and deployment of this instrumentation package will all provide insight and lessons learned about how to characterize and plan for co-located aquaculture and wave energy projects.

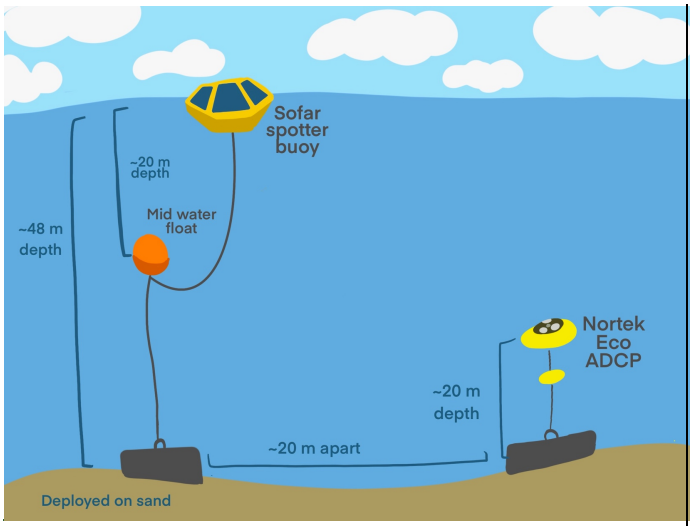

Fig 3. Illustration of instrumentation schematic for environmental monitoring. (Illustration by Molly Grear).

V. Conclusion

Using the information gained from the outreach engagement, the regional assessment of key parameters for co-location, and the environmental monitoring, this study will highlight the opportunities and challenges for co-locating offshore IMTA aquaculture and wave energy in Puerto Rico. In the next phase of the study, the key environmental, regulatory, and logistical parameters relevant for co-location will be included in a spatial analysis to prioritize them in terms of importance for siting and co-location of offshore IMTA aquaculture and wave energy

and assign weights based on the prioritization. Suitable areas for co-location will then be identified and will be shared with stakeholders to gather any feedbacks.

A feasibility assessment for co-locating wave energy and IMTA system in the identified areas of Puerto Rico will be performed. This feasibility assessment will consider all the relevant parameters to co-locate wave energy and IMTA system and will determine if such project is viable in Puerto Rico.

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