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Marine Hydrokinetic Energy Assessment: Balancing Efficiency and Environmental Concerns

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Introduction

Presented herein is a robust approach that allows the marine renewable energy industry to maximize power output when evaluating the potential environmental effects of marine hydrokinetic (MHK) devices. A Spatial Environmental Assessment Tool (SEAT) has been developed that applies metocean models to various array layouts to examine the tradeoff between power extraction and potential environmental risk.

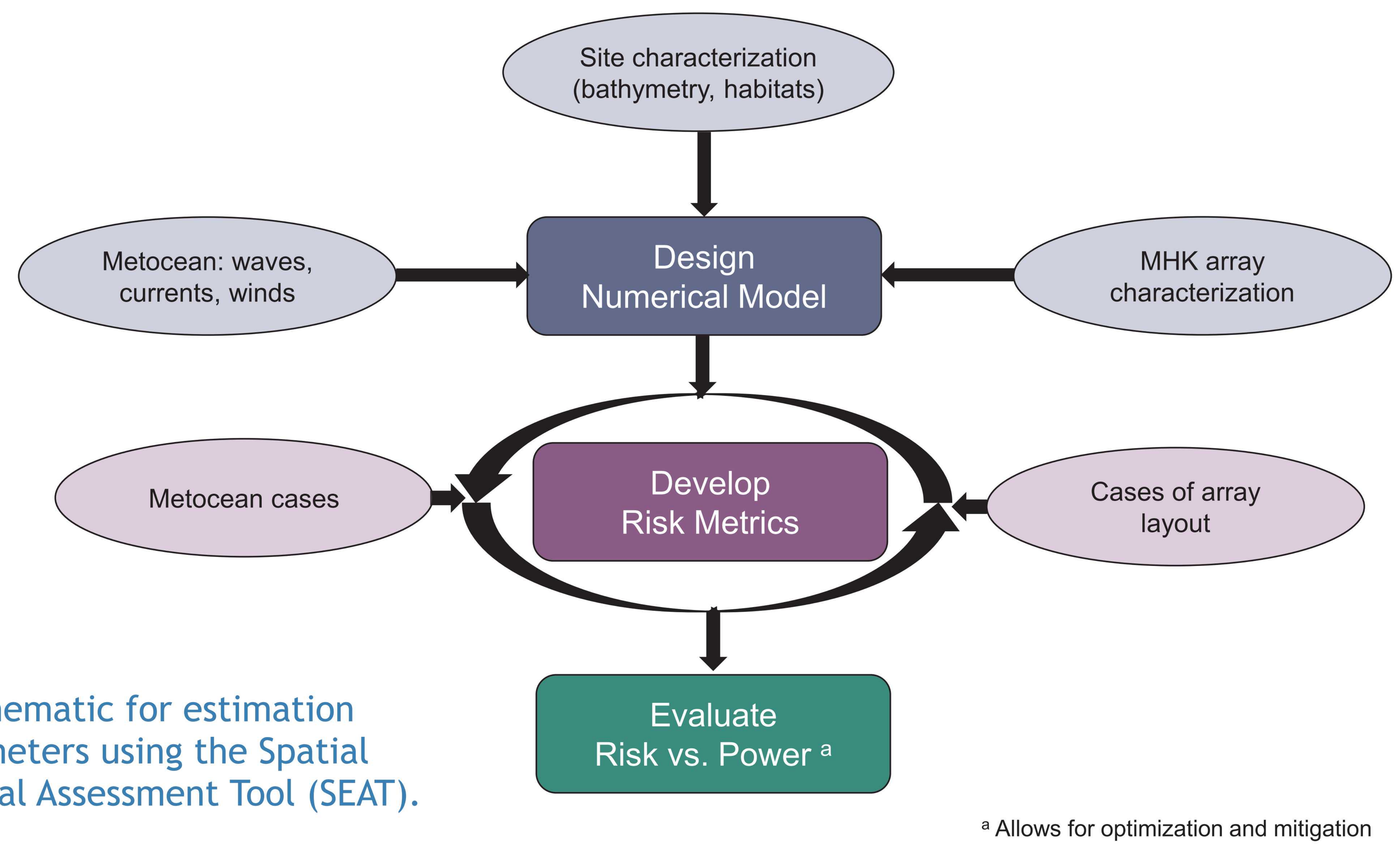

Figure 1. Schematic for estimation of risk parameters using the Spatial Environmental Assessment Tool (SEAT).

Numerical Model

A wave, circulation, and sediment transport model was developed for a case study site along the coast of Oregon. Wave propagation and simulated wave energy converters (WECs) were modeled using the Simulating Waves in the Nearshore (SNL-SWAN) module developed by Sandia National Laboratories (SNL) and incorporated into the open source Delft3D framework (Gerritsen et al. 2008; Ruehl et al. 2015).

Risk Metrics

Sediment Mobility. Changes in bottom shear stress can either increase or decrease sediment erosion or accretion, depending on the relation of the modeled shear stress to the critical shear stress associated with the sediment layer at the sediment–water interface.

Bed Elevation. Physical processes such as tides, waves, and sediment transport result in a change in effective seabed elevation relative to that of a quiescent ocean. The presence of WECs can influence variability in seabed elevation and affect benthic habitats.

Larval Motility. Changes in bottom velocity can either impede or improve larval motility, depending on the relation of the modeled bottom velocity to the critical velocity associated with larval motility.

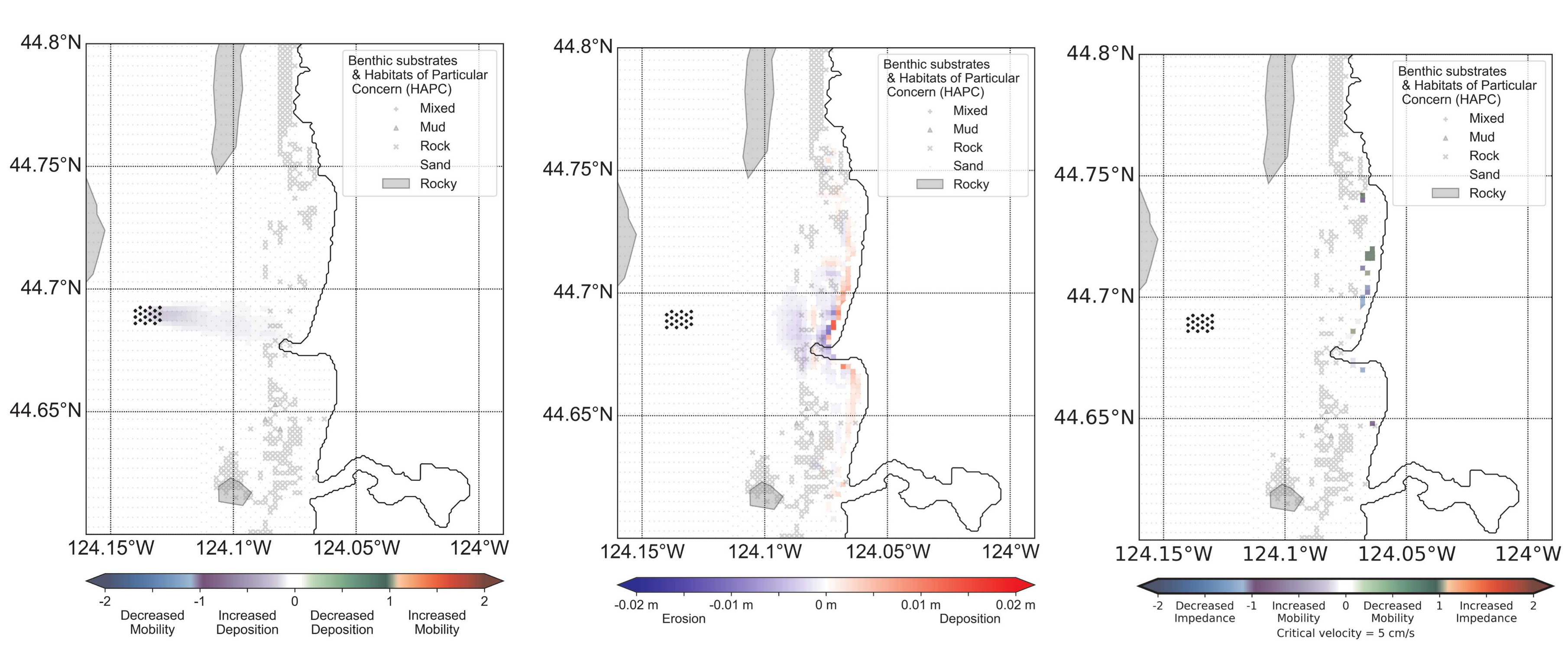

Figure 2. Risk maps for changes to sediment mobility, bed elevation, and larval motility.

Risk metrics were developed for each of the above parameters. The metrics probabilistically take into account environmental changes associated with wave events over climatological scales.

Metocean Cases

SNL conducted a comprehensive analysis of expected wave conditions on the Oregon coast using 7 years (2005–2011) of modeled wave conditions. The number of events analyzed was then reduced to a computationally tractable set of events using a k-means clustering analysis similar to the methodology used in the Wave Energy Prize (Bull and Dallman 2017; Jones et al. 2018).

Cases of Array Layout

Eight types of WEC array configurations were examined using the SEAT model framework. The number of WECs in the array was fixed to 28 elements, with 4 elements in the horizontal and 7 elements in the vertical. Inter-element spacings were then varied, while ensuring that the outer boundary of the WEC array remained consistent over all configurations.

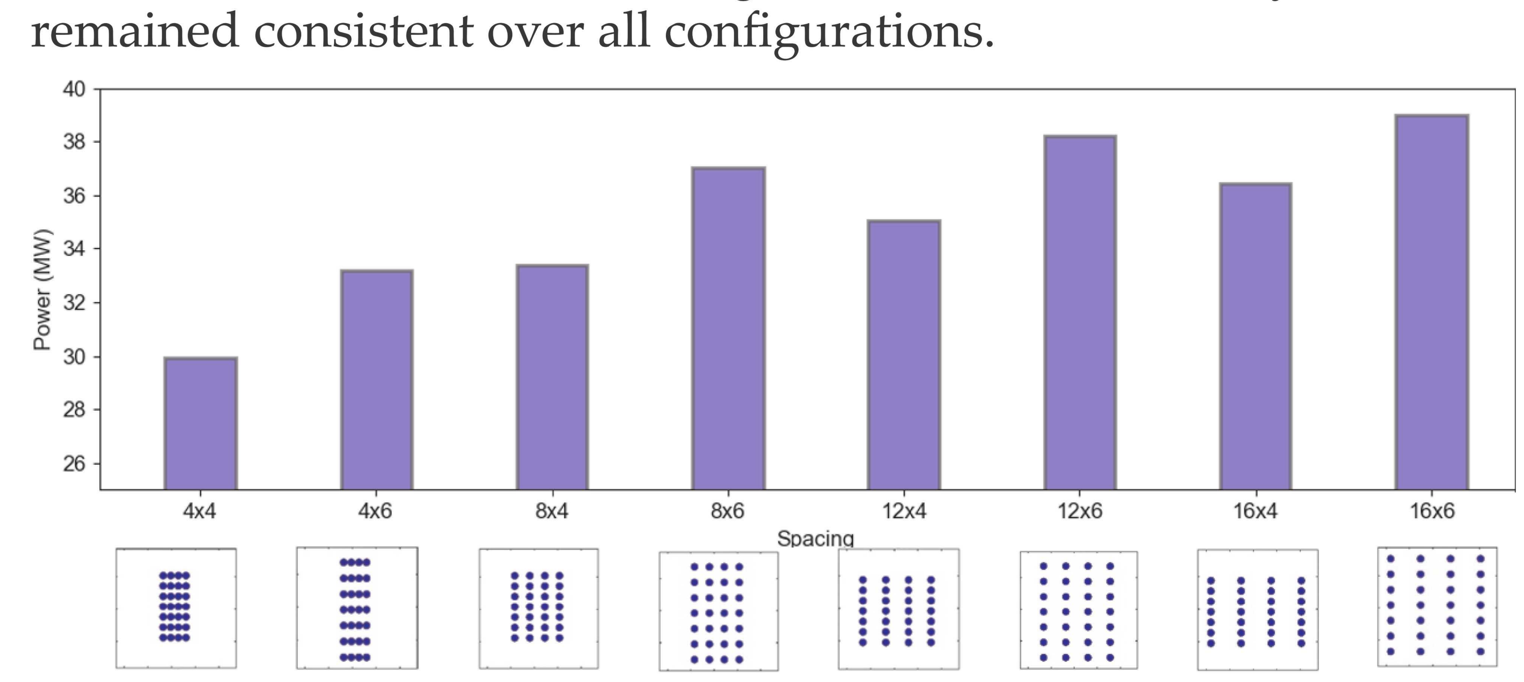

Figure 3. Power absorption as a function of array geometry over the annual set of wave cases.

Risk and Power Evaluation

The 4 × 4 array absorbs the lowest amount of power due to its tight cluster, which causes neighboring elements to undergo increased wave shadowing resulting in lower power absorption. Conversely, the array layout with the largest inter-element spacing, the 16 × 6 array, has the largest power absorption.

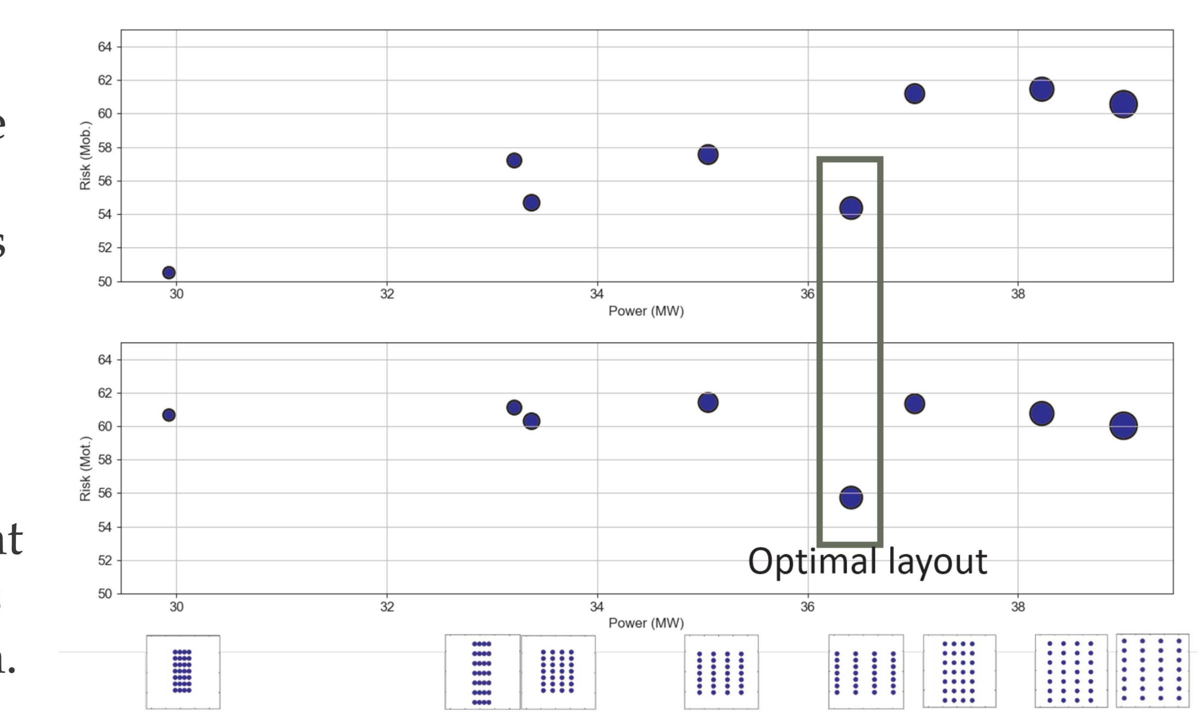

Figure 4. Effect of array shape on power extraction, risk of sediment mobility, and larval motility.

Conclusions

This work demonstrates the utility of SEAT in informing stakeholders, regulators, and developers about the benefits of a data-driven analysis that takes into account characteristics of array layouts, site-specific modeling, and knowledge of wave dynamics to yield array shapes and layouts that satisfy multiple, often competing, requirements.

References

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