A Wave-Powered Water Pump to Promote Growth in Macroalgae Aquaculture

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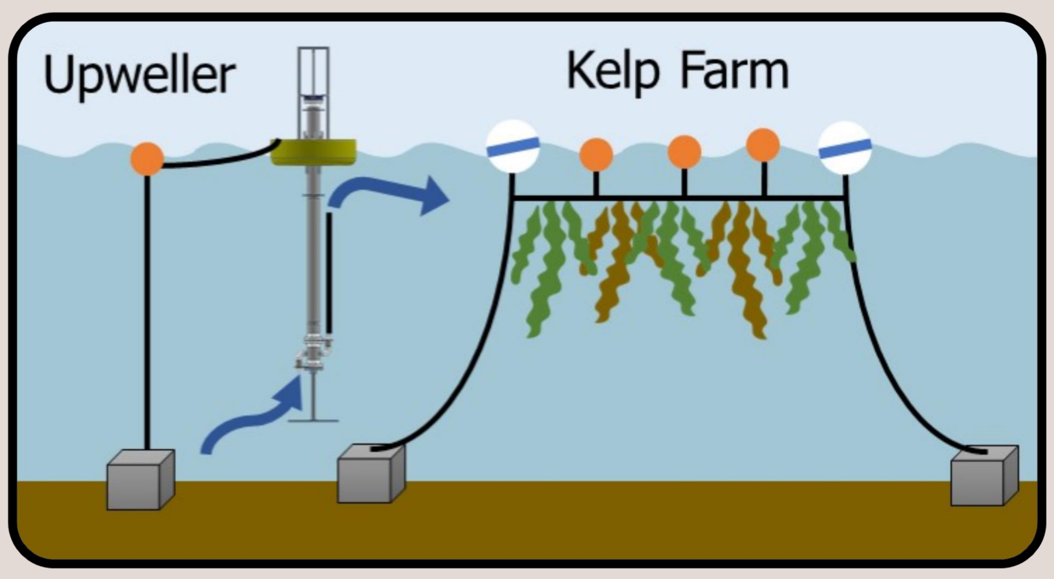
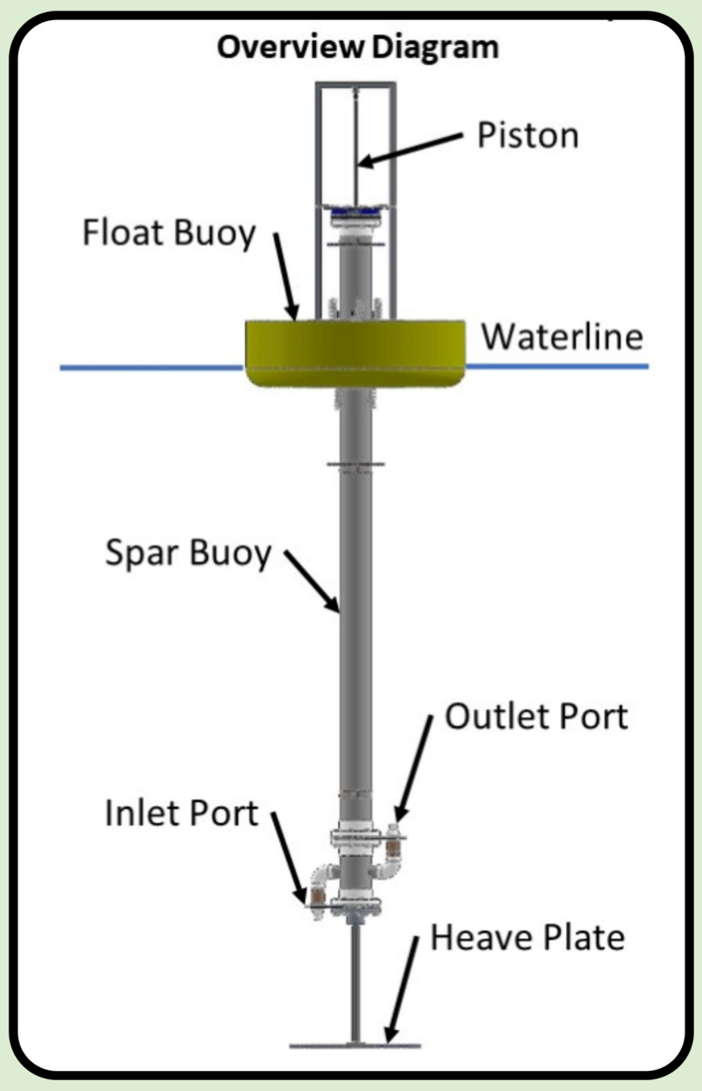
Background

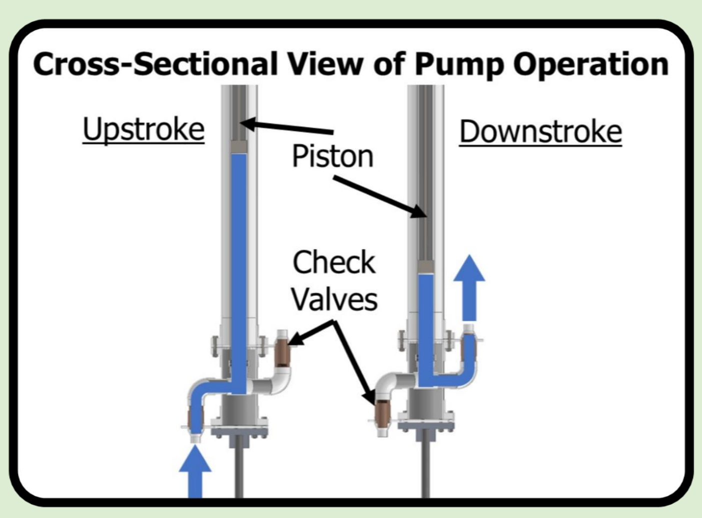
Wave Powered Water Pump uses wave energy to upwell cold, nutrient rich water to the photic zone where kelp is grown. Designed to increase productivity of macroalgae.



Project Goals:

1. Numerically model flow rates with various wave conditions in WEC-Sim
2. Collect field deployment data of device and validate numerical model[4]
3. Use results to guide design changes and increase pump efficiency





WEC-Sim PTO-Sim Set Up

Modified PTO-Sim RM3 Hydraulic Model[6]

- 2 one-way check valves and piston
- Bulk modulus of sea water in bottom, open to air in top

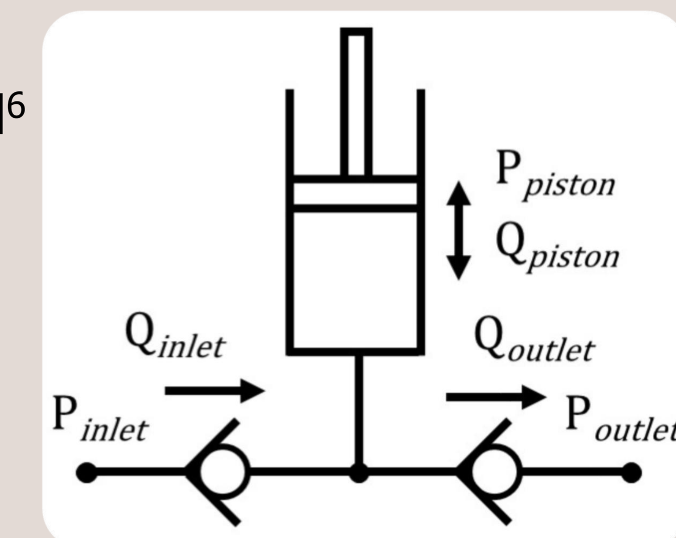
$$\int \frac{B(Q_{valves} - Q_{piston})}{x_{rel}A_{piston} + V_{piston}} dt = P_{piston}$$

$$Q_{valves} = Q_{inlet} - Q_{outlet}$$

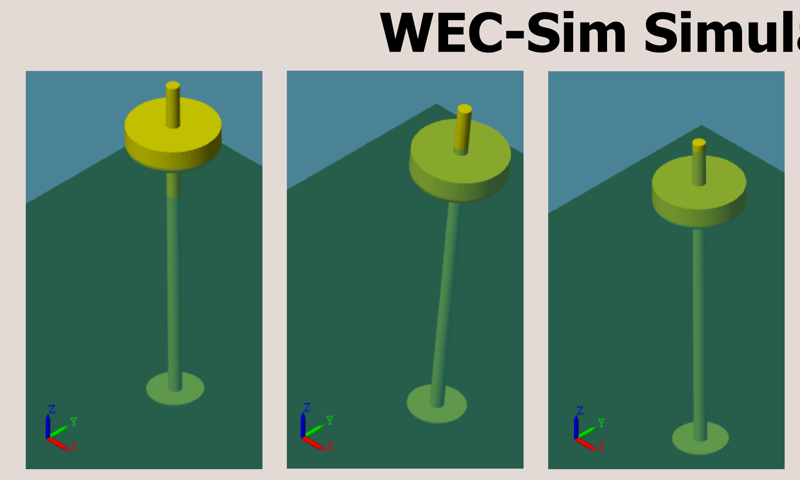
$$Q_{piston} = A_{piston} \times \dot{x}_{rel}$$

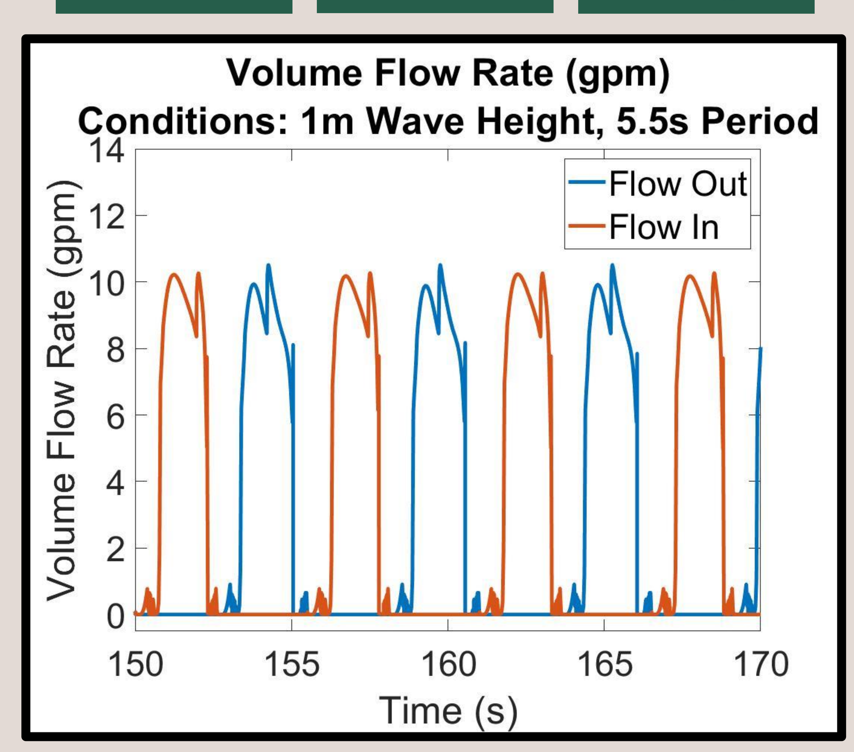
A: Area
P: Pressure
V: Volume

B: Bulk modulus
Q: Volumetric flow rate
x_{rel}: Spar & float relative position



WEC-Sim Simulation Results





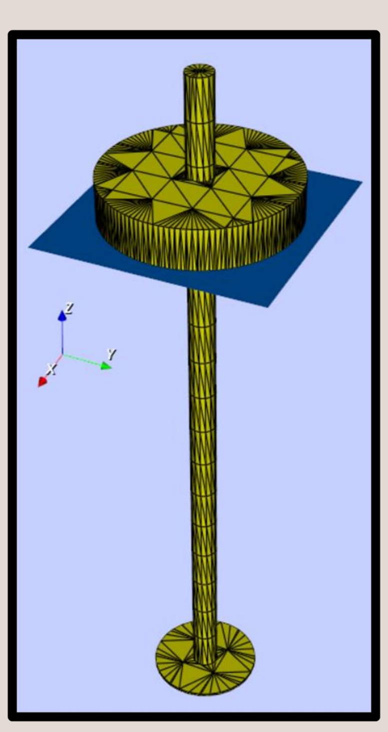
Dynamic motion results in animation, device moves from one wave crest to trough (shown upper left).

Volume flow rate results of steady state 20 second window (shown lower left). 10 gallon per minute maximum meets expected flow rate for 1m wave, 5.5s period conditions.

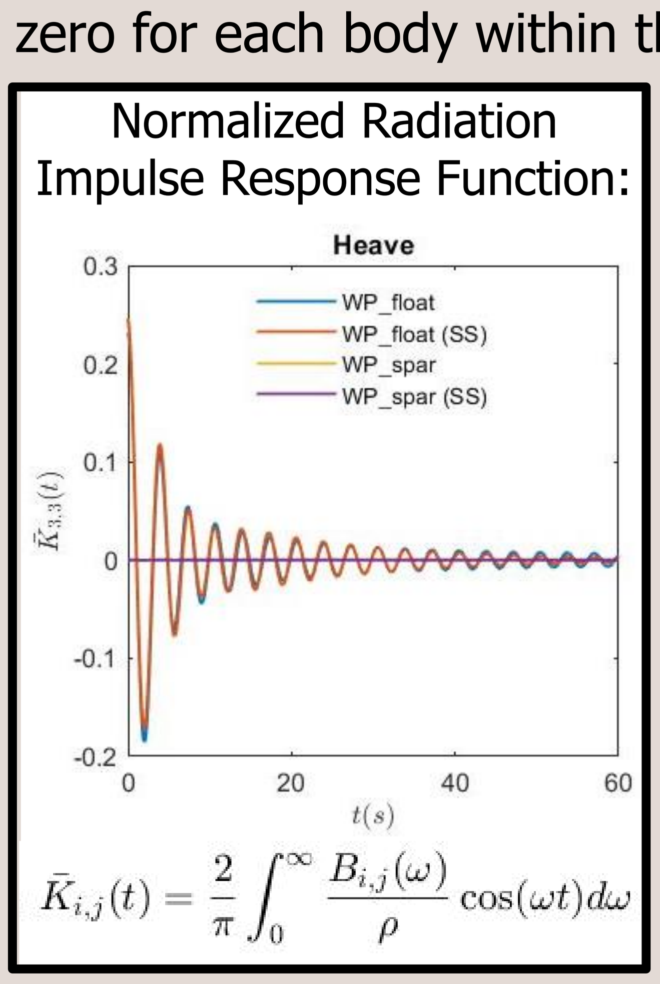
When inlet valve is open, outlet valve has zero flow rate (and vice versa).

Mesh Model & BEM Analysis

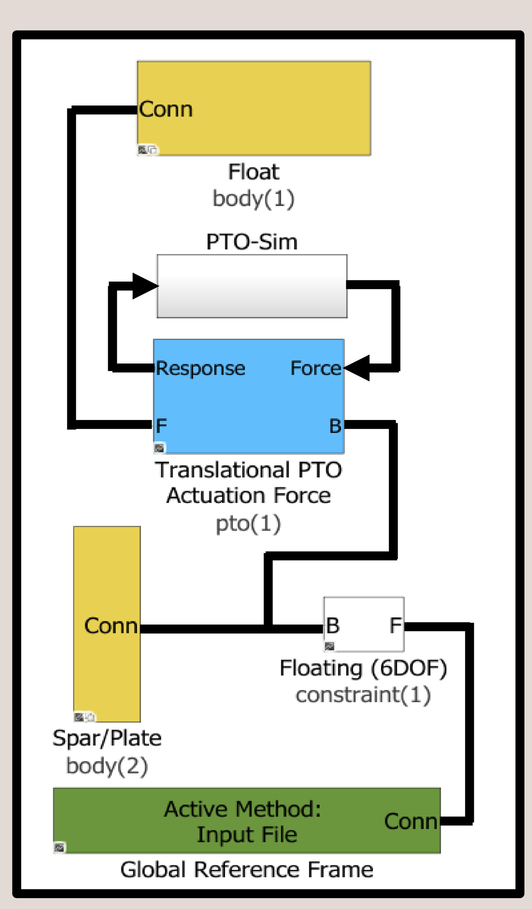
- A simplified SolidWorks CAD model converted to a finite element mesh file of both float and buoy using Meshmagick[3] (below, left)
- Hydrodynamic response (below, middle) from Capytaine[1] & WEC-Sim[5]
  - ➢ Indicates large relative motion between float and spar
  - ➢ Tends towards zero for each body within the time frame



Normalized Radiation Impulse Response Function:



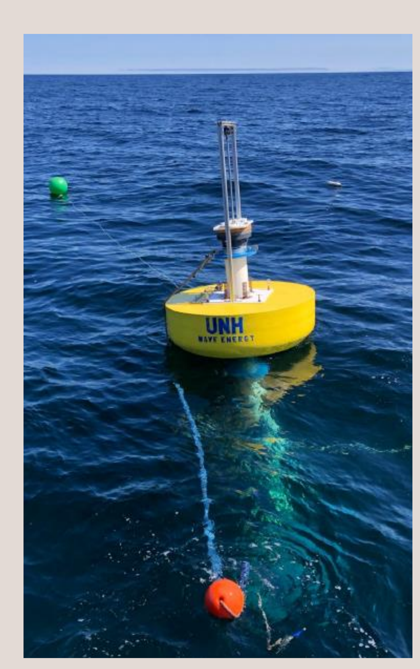
$$\bar{K}_{i,j}(t) = \frac{2}{\pi}\int_0^\infty \frac{B_{i,j}(\omega)}{\rho}\cos(\omega t)d\omega$$

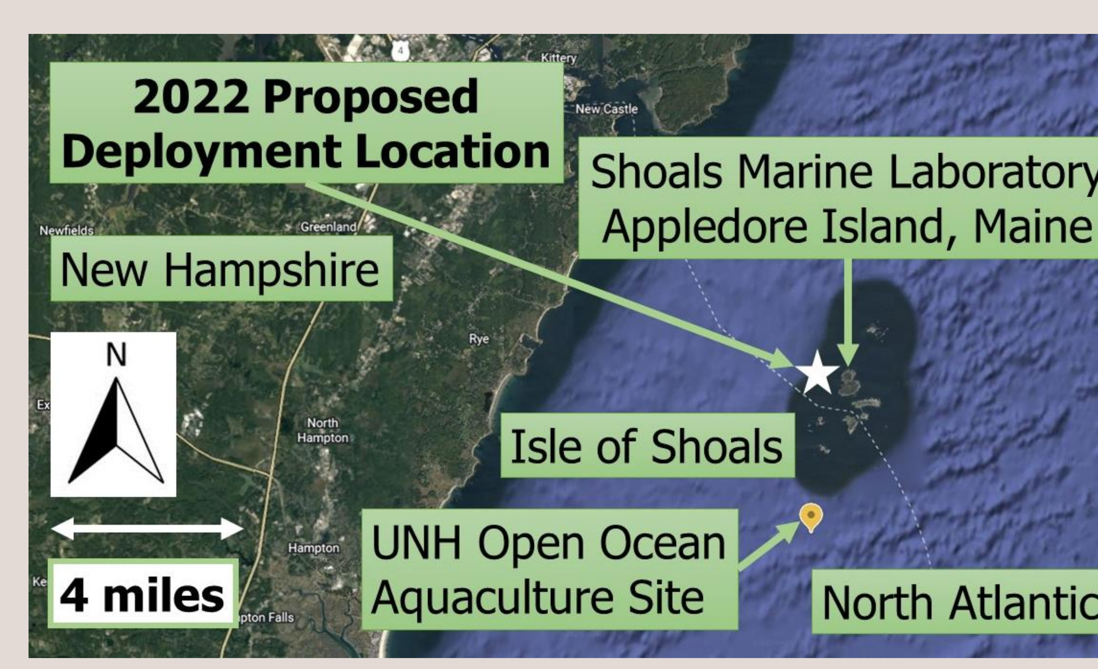


WEC-Sim Set Up & Simulink Model

- Model basis: Reference Model 3 (RM3) developed by WEC-Sim team (above, right)[5]
- 6 Degree of Freedom (DOF) constraint for system → free floating
- Translational Power Take Off (PTO) has motion constrained to Z (vertical) axis, reflective of design
- Wave inputs: 1m height with 5.5s period (reflect expected site conditions during deployment)[2]

Upcoming Field Deployment Plan





Instrumentation:

- Flow Meter: pumped flow rate
- Lidar: relative heave motion
- IMU: overall motion tracking
- Precise time synchronization using GPS
- Telemetry to send data ashore for real time monitoring
- DAQ programmed using Arduino microcontrollers
- Monitor nearby wave conditions with separate Sofar spotter buoy
- On-board and shoreside cameras for environmental monitoring

References

[1] Ancellin et al., (2019). Capytaine: a Python-based linear potential flow solver. Journal of Open Source Software, 4(36), 1341, https://doi.org/10.21105/joss.01341
[2] Bouret, Thorne, and Walsh. 2021. "Wave Powered Water Pump." TECH 797 Ocean Projects, Final Report, University of New Hampshire.
[3] F. Buisson and F. Rongere, "Meshmagick." [Online]. Available: http://130.66.47.2/redmine/projects/meshmagick/wiki/Wiki
[4] IEC TS 62600-103, Marine energy – Wave, tidal and other water current converters – Part 103: Guidelines for the early stage development of wave energy converters – Best practices and recommended procedures for the testing of pre-prototype devices
[5] Kelley Ruehl, David Ogden, Yi-Hsiang Yu, Adam Keester, Nathan Tom, Dominic Forbush, and Jorge Leon. (2021, October), WEC-Sim (Version v4.4), DOI 10.5281/zenodo.5608563.
[6] R. So, S. Casey, S. Kanner, A. Simmons, and Brekken, T. K. A., "PTO-Sim: Development of a Power Take Off Modeling Tool for Ocean Wave Energy Conversion," in Proceedings of the IEEE Power and Energy Society General Meeting, PES 2015, Denver, CO, 2015.

Acknowledgments

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