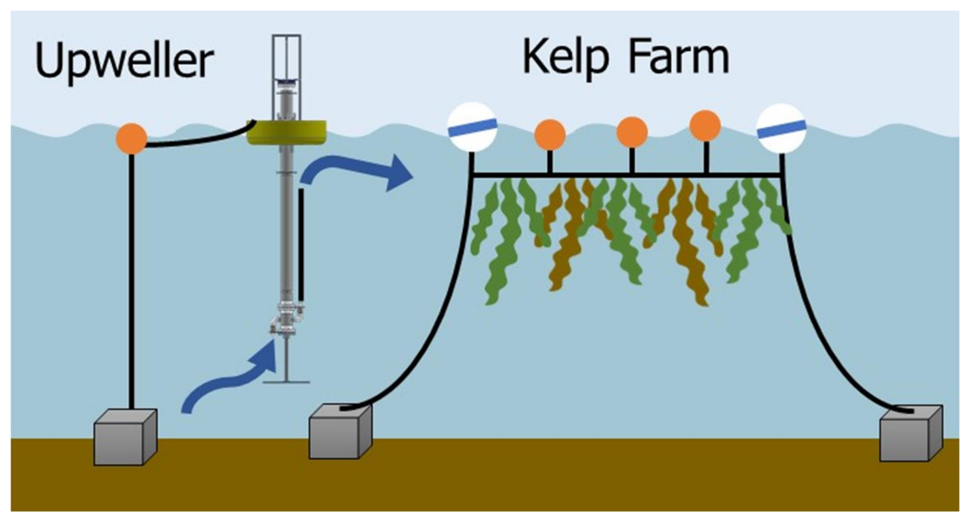
Wave-Powered Water Pump – Ocean Field Deployment

Chelsea Kimball

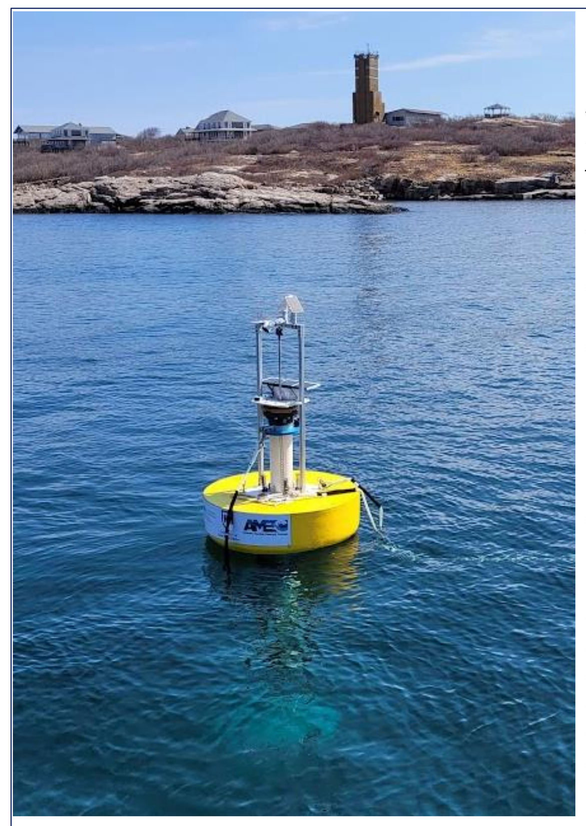
Department of Mechanical Engineering, University of New Hampshire, Durham, NH 03824

Introduction

Wave-Powered Water Pump uses wave energy to upwell cold, nutrient rich water to the photic zone where kelp is grown (shown in figure). Designed to increase productivity of macroalgae aquaculture[1,2].



Methodology


March 21st, 2023 – Image courtesy of Martin Wosnik

UNH student designed wave pump[2] adapted for ocean field test, outfitted with sensors:

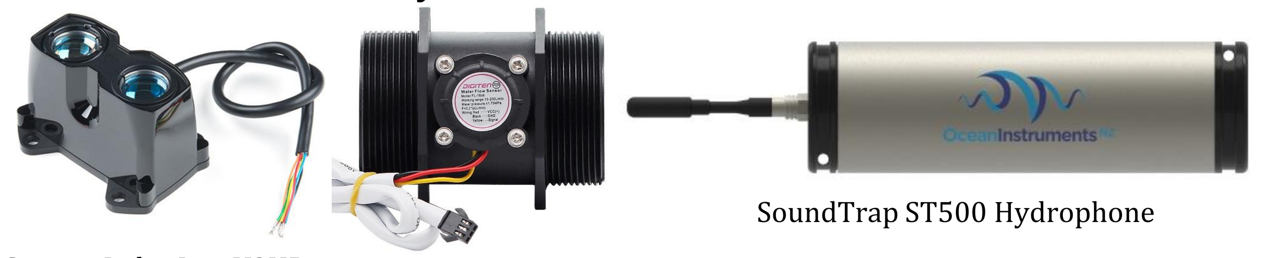
- Improved hardware durability
- Flow meter and lidar sensors
- Solar-powered data acquisition (DAQ) system records data and GPS clock
- Test plan in accordance with IEC test standards[3]

Deployed device at the Appledore Island, ME Shoals Marine Laboratory mooring field.

Sensor Specifications

Wave Pump Sensors & DAQ

- Calibrate lidar and flow meter pre- & post-deployment
- Sampling frequencies: lidar 59Hz, flow meter 1Hz
- DAQ power system projected to last 50+ days in field
- GPS time accuracy ±0.006s



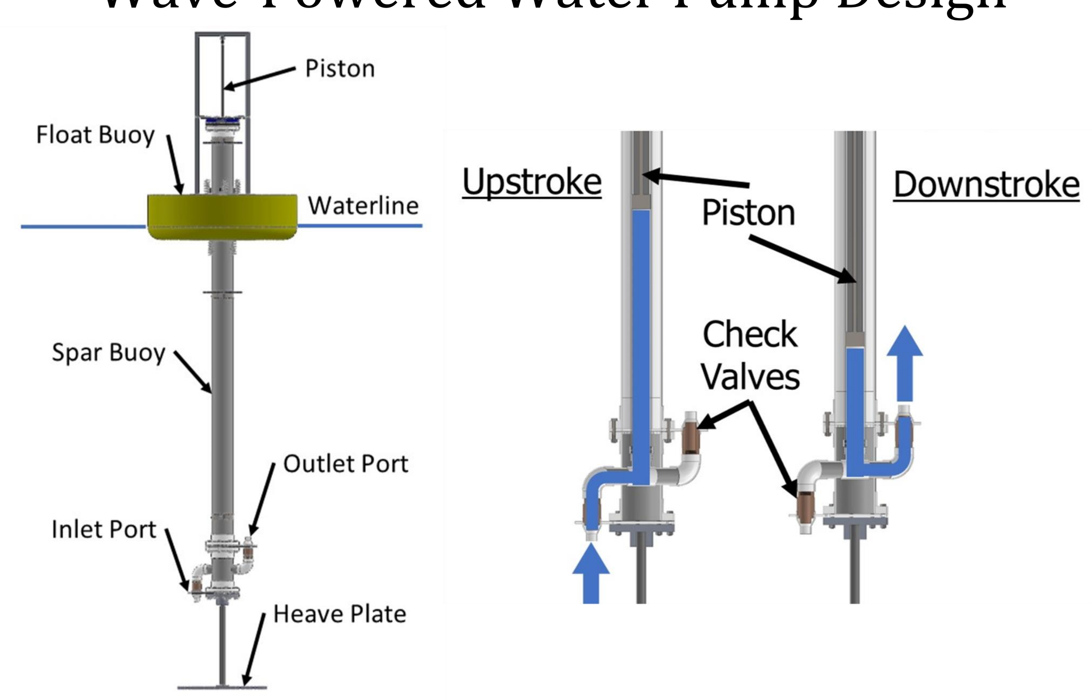
Garmin Lidar Lite V3HP   Digiten 2" Flow Meter   SoundTrap ST500 Hydrophone

Environmental Monitoring

- Sofar Spotter buoy located ~300 feet from Wave Pump on separate SML mooring; recorded wave and weather data
- Two SoundTrap ST500 Hydrophones deployed on Sofar mooring recorded continuously at 144kHz
- Two environmental monitoring cameras installed on Wave Pump captured motion triggered videos

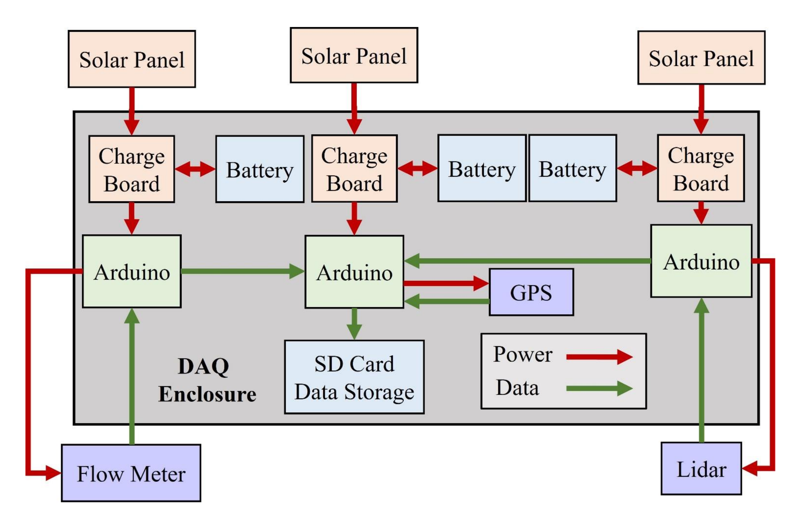
Design and Operation Details

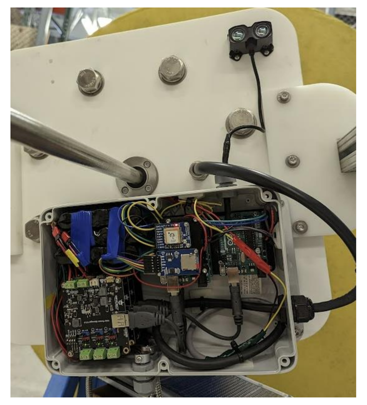
Wave-Powered Water Pump Design

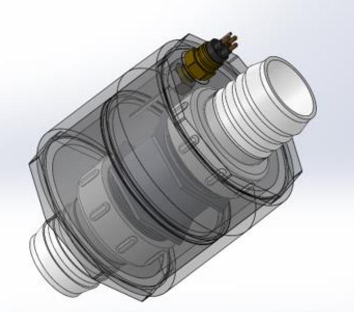


Wave Pump Overview Diagram (left) and Cross-Sectional Pump View (right)

Data Acquisition System and Sensor Design







DAQ System Overview Design (top left)
DAQ installed on device with Garmin lidar (top right)
Digiten flow meter in custom housing (bottom right)

Ocean Field Deployment – March 2023

Wave-Powered Water Pump (left) and Sofar Spotter Buoy (right)

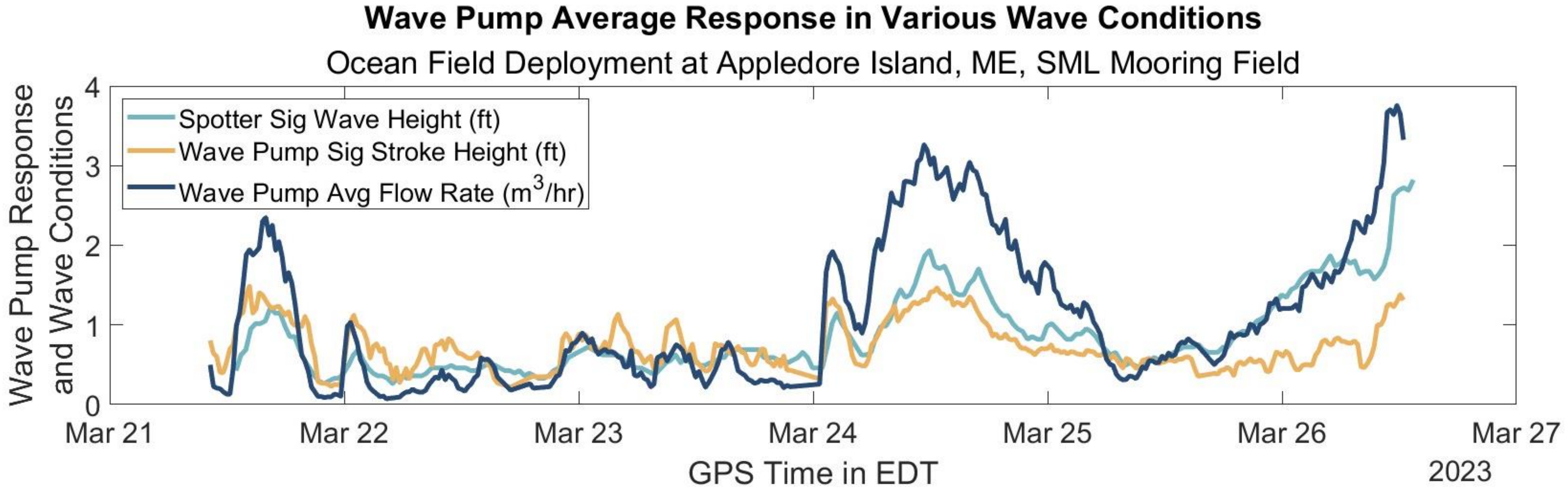

March 21st, 2023 – Image courtesy of University of New Hampshire

Wave Pump (left) deployed on SML Mooring with R/V Gulf Challenger shown in background, facing towards NH coast

Sofar Spotter buoy (right) deployed on SML Mooring with Appledore Island, ME shown in background


March 23rd, 2023

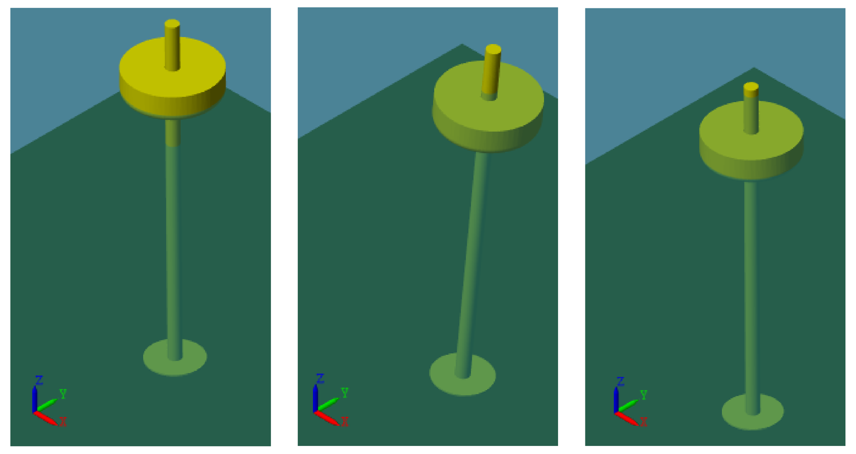
Preliminary Field Deployment Data – Averaged Time Series

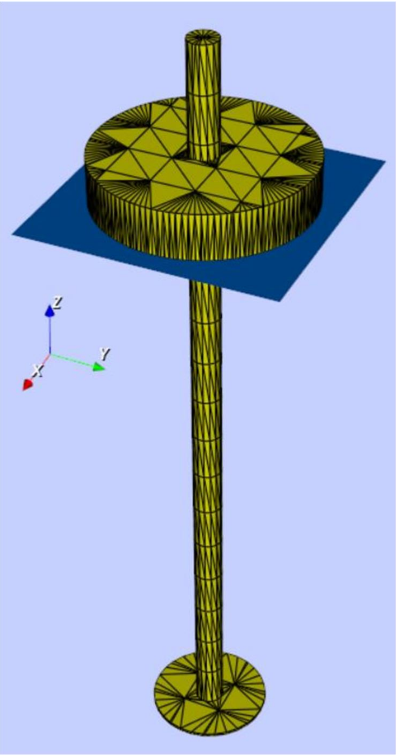


30-minute averaged Sofar Spotter buoy data for significant wave heights are in feet. These correlate strongly with Wave Pump's 20-minute averaged lidar significant stroke height (in feet). Wave Pump's 20-minute averaged flow meter values closely correlate with wave height and stroke height; however, due to being a volumetric flow rate (m^3/hour), magnitudes are expected to differ. Timing of peaks and valleys for all three data sets closely align, indicating a high degree of responsiveness of Wave Pump in changing sea states.

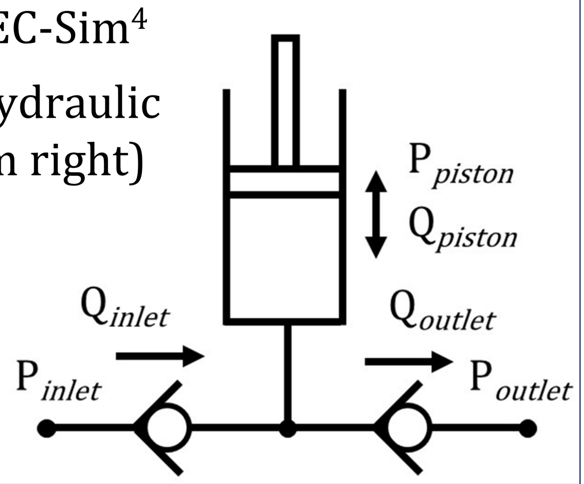
WEC-Sim Numerical Model

Wave Pump WEC-Sim[4] numerical model developed using Reference Model 3





- Simple SolidWorks CAD model converted to a finite element mesh using Meshmagick[5] (top right)
- Hydrodynamic Boundary Element Model (BEM) response created from Capytaine[6] & WEC-Sim[4]
- Modified PTO-Sim RM3 Hydraulic Model[7] (pump diagram bottom right)
  - 2 one-way check valves, piston
  - Bulk modulus of sea water in bottom, open to air in top



Future Work

- Develop overall device performance metrics using field data
- Validate WEC-Sim numerical model of wave pump by comparing field data performance
- Iterate design to increase durability, efficiency
- Analyze hydrophone and environmental monitoring data

Acknowledgements

This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Energy Efficiency and Renewable Energy, Water Power Technologies Office under Award Number DE-EE0009450.

Special thanks to Professor Rob Swift, Professor Martin Wosnik, UNH's Department of Ocean Engineering, the R/V Gulf Challenger team, and Shoals Marine Laboratory team.

References

[1] J. J. Bolton and K. L¨uning. "Optimal Growth and Maximal Survival Temperatures of Atlantic Laminaria Species (Phaeophyta) in Culture". In: Marine Biology 66.1 (1982 [Online] https://doi.org/10.1007/bf00397259), pp. 89–94.
[2] Bouret, Thorne, and Walsh. 2021. "Wave Powered Water Pump." TECH 797 Ocean Projects, Final Report, University of New Hampshire.
[3] 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
[4] 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.
[5] F. Buisson and F. Rongere, "Meshmagick." [Online]. Available: http://130.66.47.2/redmine/projects/meshmagick/wiki/Wiki
[6]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
[7] 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.