WAVE ATTENUATION THROUGH SUBMERGED OYSTER AQUACULTURE CAGES

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Abstract

- The opportunity exists to combine aquaculture and coastal defense in Maine, given the prevalence of coastal erosion in the area as an issue, and the large economic sector of shellfish farming.
- This study looks to examine this potential by quantifying the wave attenuating properties of submerged oyster aquaculture cages, using in-situ wave measurements and a Smooth Particle Hydrodynamics computational fluid dynamic model.
- Wave decay of up to 80% for ~4 second waves was seen over 30 m of oyster cages, where less-steep waves and shorter waves were attenuated more. Added mass drag dominated wave attenuation compared to friction, supported by KC (Keulegan Carpenter Number). Wave attenuation likely affected mean water levels through gradients in radiation stresses, and set up in mean water levels reached up to 5 cm when including tidal currents, indicating that scaled-up versions of bottom oyster farms could have implications on coastal circulation in semi enclosed systems
- Future research should explore optimization of bottom oyster farms to reduce a broader range of wave environments, while assessing the secondary effects of wave attenuation on ambient hydrodynamics.

Introduction

Coastal and estuarine shorelines are some of the most eroded in the world due to:

- Their sensitivity to **sea-level rise**.
- **Increased wave energy** from storms and human industrial and recreational interactions.

Much of Maine's coastline is formed by "bluffs" or steep cliffs made of loose granular material that, depending on their stability, can be **highly erosive**.

Small amount of coast is sandy beach (5%), but loss is **economic concern.**

Engineers can protect the coast by **reducing wave heights** and increasing the **stability of shore.**

With the abundance of **aquaculture** in the waters of Maine, as well as previous research in **shellfish based coastal protection**, it is important to understand the wave attenuation properties of oyster aquaculture.

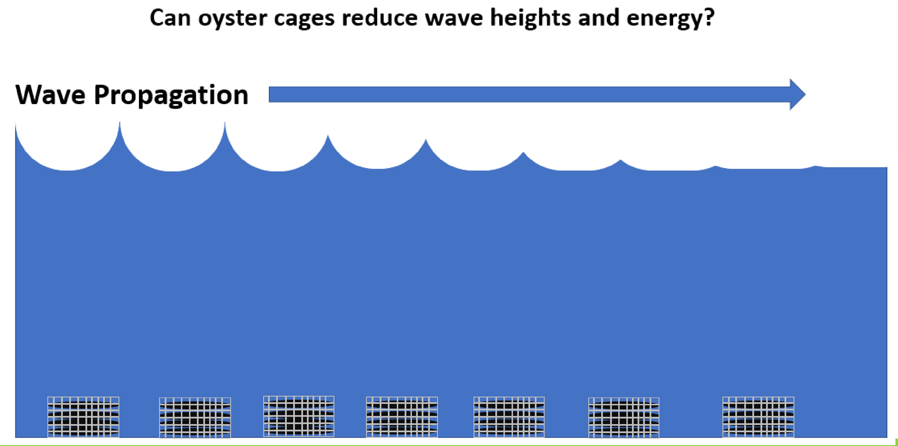
This study looks to:

- Study the **wave attenuation performance of bottom-lying oyster cages** their potential effects on **mean water levels.**

By :

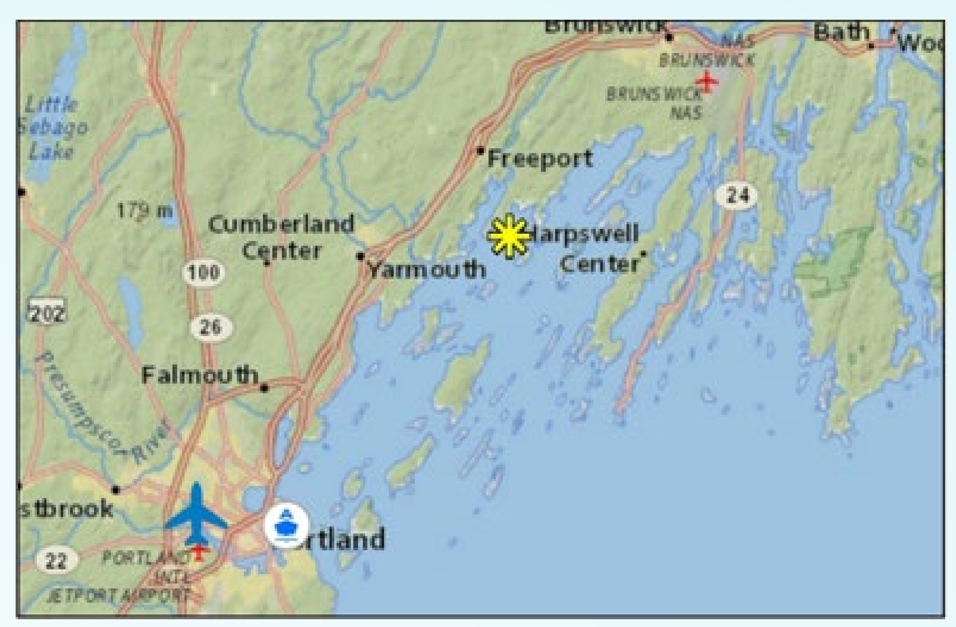
- Quantifying the wave attenuation properties of bottom lying oyster cages with **field investigations of an overwintered oyster farm in Casco Bay in Maine.**
- Utilizing a **validated numerical model** to investigate the **wave attenuation mechanism, along farm decay, and applicability of an established empirical formula** for submerged breakwaters.
- Use empirical formulas to inform **wave decay induced setup** in idealized scenarios.

Can oyster cages reduce wave heights and energy?

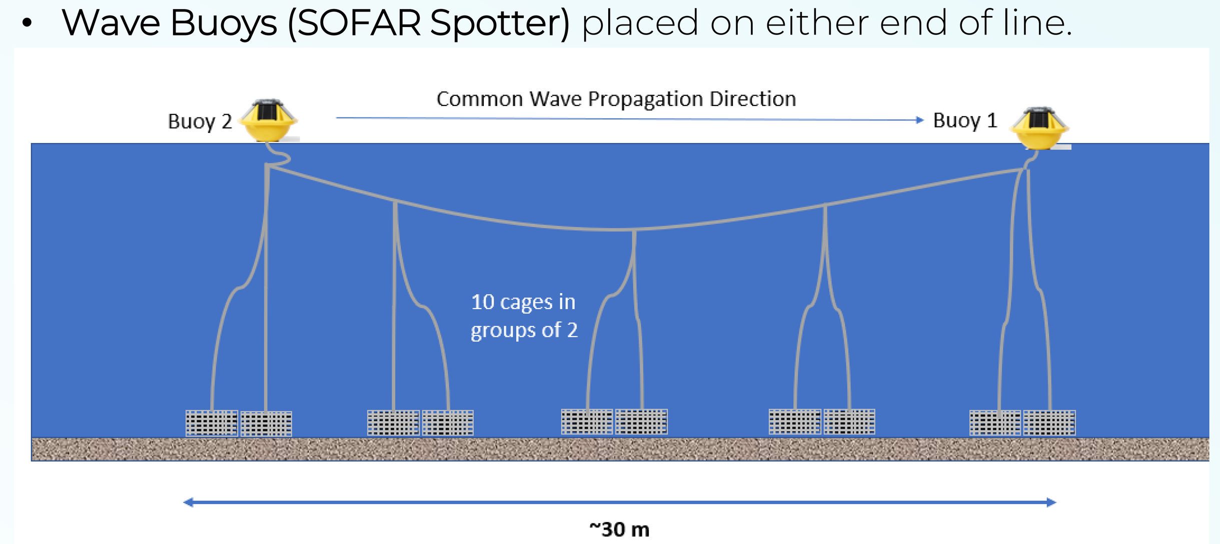


Methodology

Field studies were performed at Maine Ocean Farms, an oyster farm in Freeport, Maine. The study site was **70 overwintered cages** laid out in groups of 10 over 7, 30 m long-lines, held in the central southern part of an unnamed bay.

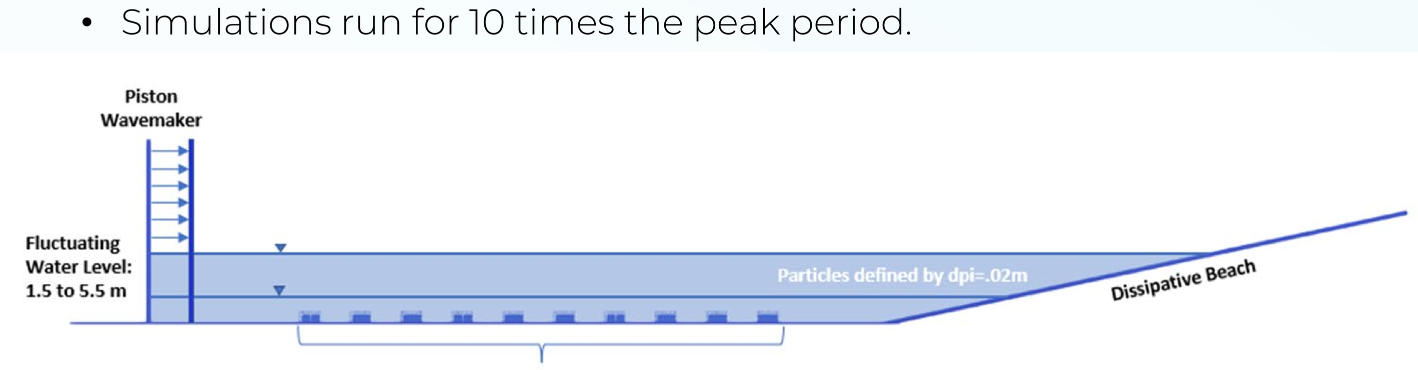


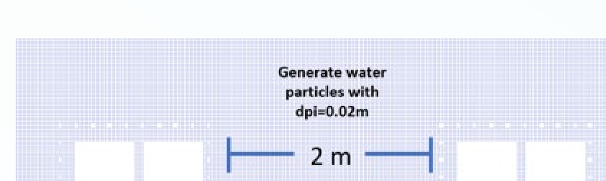
- Cages dropped every 5 meters in groups of 2.
- Cages were 1.2 m long, 0.9 m wide, and 0.6 m tall.
- **Wave Buoys (SOFAR Spotter)** placed on either end of line.



A 60-m long numerical flume was generated in **DualSPHysics**, a Smooth Particle Hydrodynamic Model. The flume was created in 2D with a i_{dp} of 0.02m.

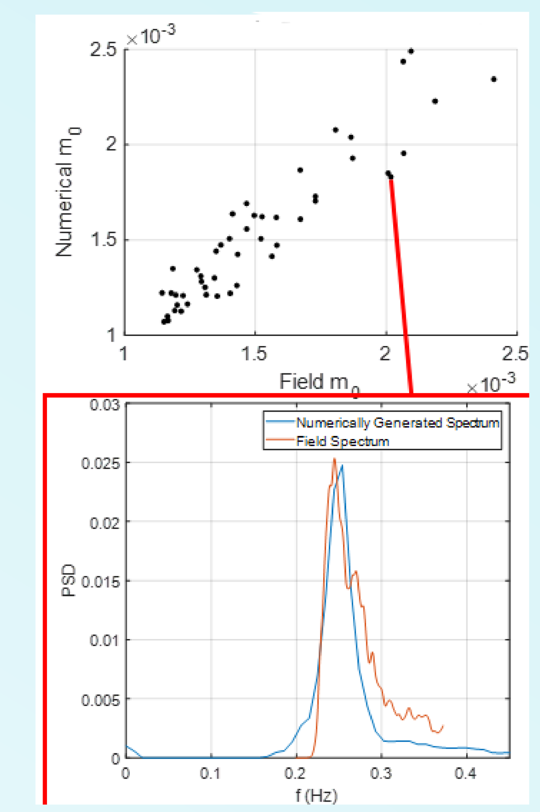
- Floating oyster bags were given a relative weight of .9 to allow for some buoyancy.
- Simulations run for 10 times the peak period.

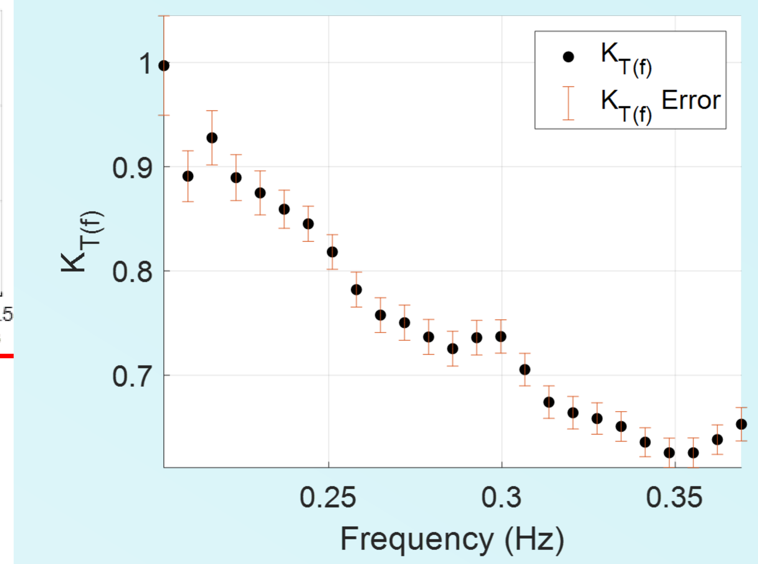




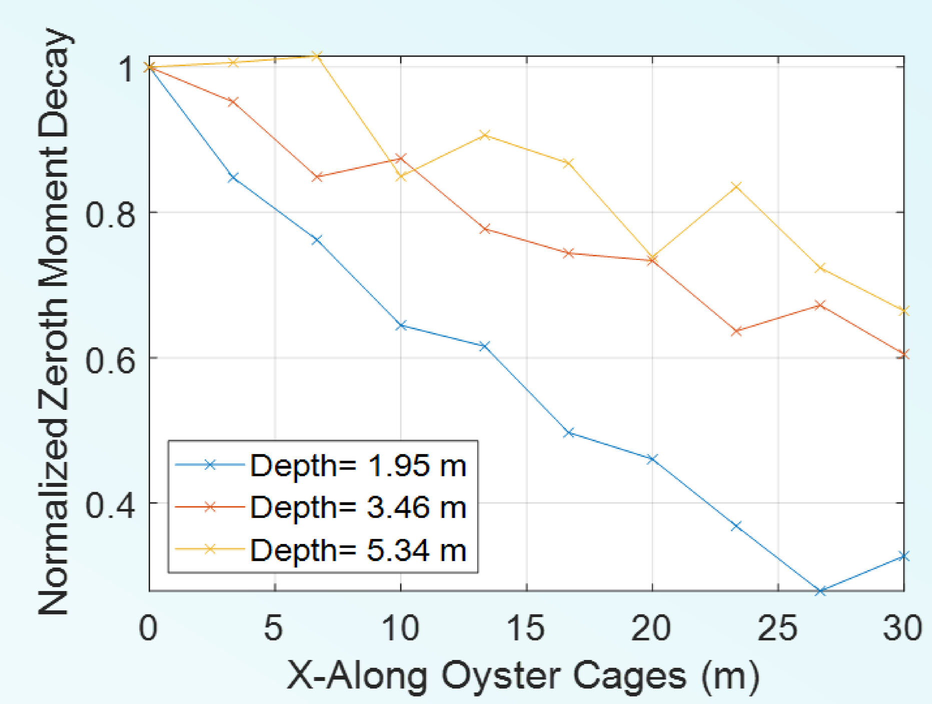
Results

- Numerical model was **validated to fit wave attenuation** seen in field measurements.
- 30 cases were run based on their **larger wave height** and **orientation to the farm direction.**
- Wave attenuation, K_T generally over or underpredicted by the model, with model results showing high inverse relationship to water depth, not always seen in field results.

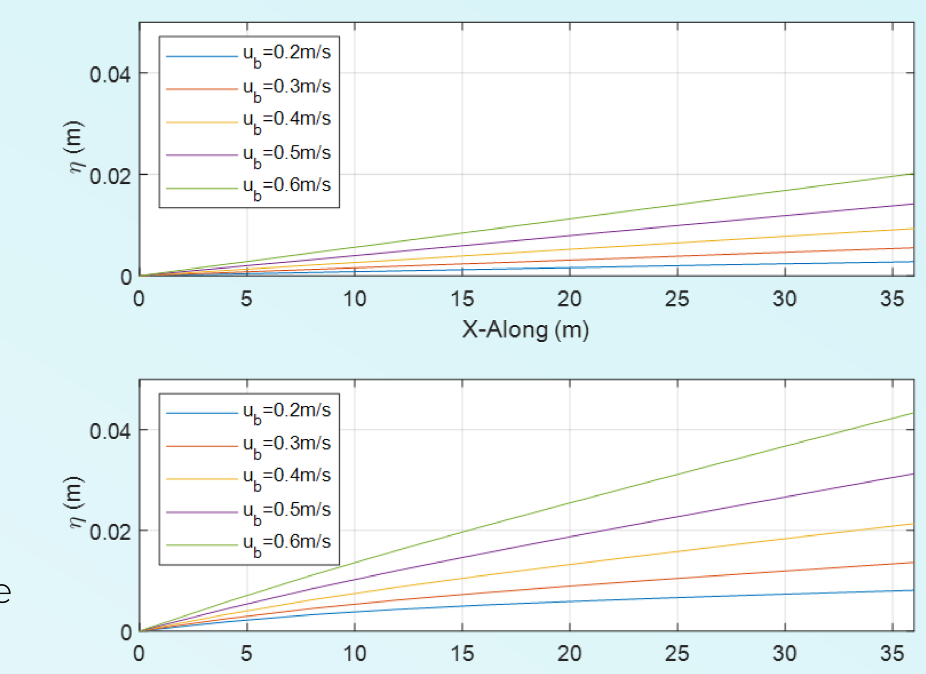




- Spectral energy for each frequency bin, a transmission coefficient as a function of frequency, K_T(f), could be derived by taking the **ratio of the transmitted and incident integrated spectral energy.**
- **Shorter length waves were attenuated more** with in the frequency bounds studied.



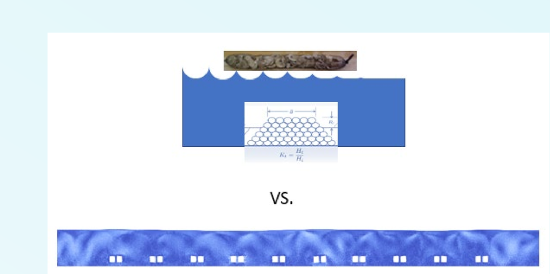
- Along farm decay was measured with 10 water level measurements across the longline in the numerical flume at 3 m spacing.
- Decay was seen to be **very linear, with some fluctuations** at higher water depths

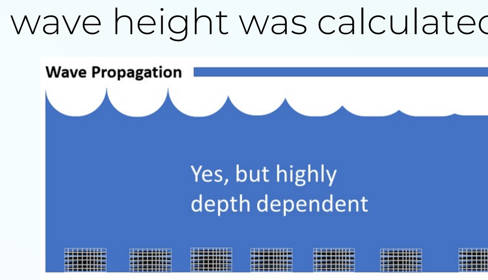


- Decay induced setup was calculated using the cross-shore momentum balance equation.
- For a 0.6 m/s current acting against the direction of wave decay, setup as high as **greater than 4 cm** can be seen.

Discussion/Conclusion

- To determine effectiveness as a coastal protection strategy, its important to compare the effectiveness of this method to studies on **other submerged structures** used in industry.
- Decay was compared to the **Seabrook and Hall** solution using a progressive decay equation, where a KT was assigned to each cage as a breakwater, and a transmitted wave height was calculated **for each cage.**





Concerns:

- Tidal Range
- **Seasonality** in Wind and Wave Direction
- Overwintered **Position**

Further research should include:

- Effectiveness of oyster cages at **low water depths**
- Attenuation over **larger and denser farms**
- **Increased methodology** with laboratory studies and higher computing numerical models.

- Overall wave decay was **higher over the line of cages compared to a single oyster bag breakwater** for the same water depth and structure crest height scenarios.