Design of an Offshore Whale Safe Mussel Farm

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Introduction and Project Goals

The goal of this project is to design an offshore mussel farm that is both whale safe and promotes profitable growth of blue mussels. The proposed farm will be located off the coast of Jenness Beach in North Hampton, NH. Most mussel farms are made almost entirely of rope, posing a risk of entanglement for North Atlantic Right Whales. As aquaculture becomes more prominent, the potential of entanglement and the risk of ghost-gear increases. Shifting to ropeless designs significantly reduces the risk of entanglement and ghost-gear, promoting sustainable seafood practices and a healthy ocean ecosystem.

Entangled NARW in ghost gear

North Atlantic Right Whale (*Eubalaena glacialis*)

- The NARW is critically endangered. . .

< 350

left in the wild

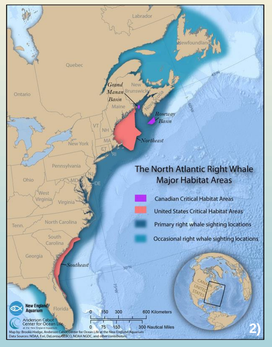
- NARW's have an easier time seeing colors with RED and ORANGE hues rather than colors like greens or blues.

As a result, the system will utilize Owens Corning PINKBAR® Fiberglass Rebar for its visible color

- NARW's are baleen whales, meaning they feed by filter feeding through baleen, increasing their risk of entanglement.
  - They also feed within the first 10 meters of the water column, making entanglement even more likely

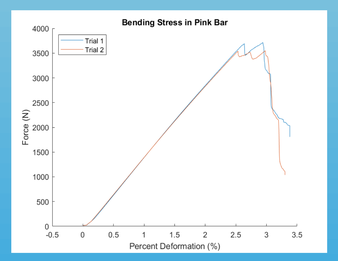
Example of baleen structure

- When entangled, the whales first instinct is to spin, causing them to become more tangled.



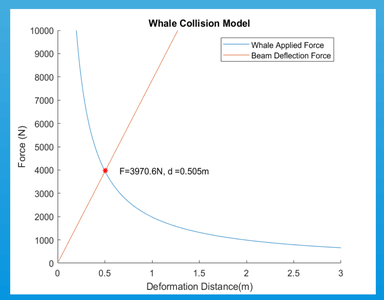
The coast of Jenness Beach in North Hampton is within the United States Critical Habitat Area as well as a primary place for North Atlantic Right Whale sightings.

Fiberglass Bending Strength and Whale Collision Strength

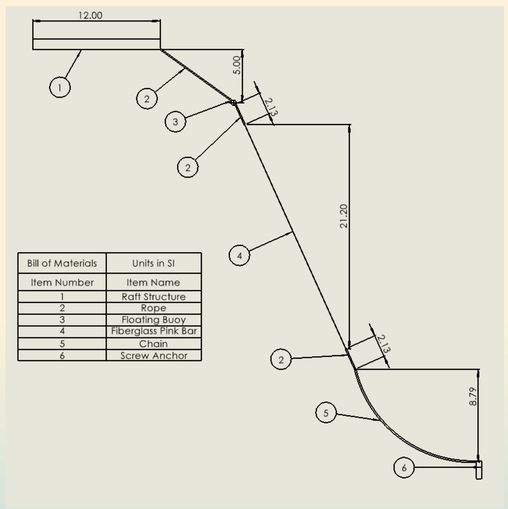


- To reduce the amount of rope in the system, the mooring line will be made of fiberglass rebar
- Bending strength testing was performed to determine the ultimate bending strength of the Owen's Corning PINKBAR® Fiberglass Rebar
- 2 sizes were tested: 0.5" and 0.375" diameters
- The 0.5" rebar did not break under maximum force of the Zwick bending machine while the 0.375" rebar reached its ultimate strength on average at about **139.6 MPa**

- The collision between the whale and fiberglass rod was modelled to determine the force the rod will need to withstand
- The force needed to fully stop the whale from 2.58m/s was modelled assuming linear deceleration
- The force the bending rod exerts as it bends was modelled as a function of deformation
- The model shows the whale will exert **3970.6 N** on the fiberglass rod. Exceeding the strength of the 0.375" but well below the ultimate strength of the 0.5" diameter rod.

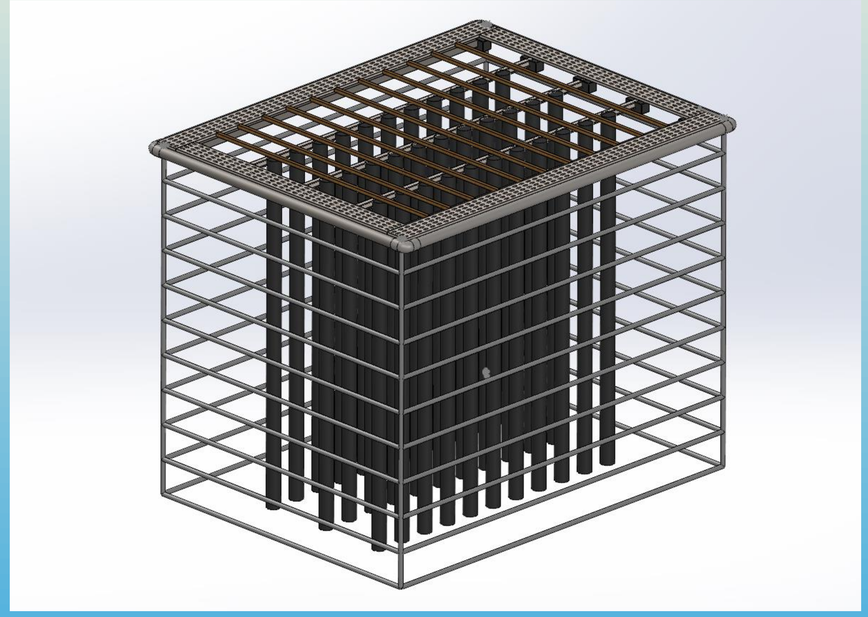


Cage Design Mussel Farm

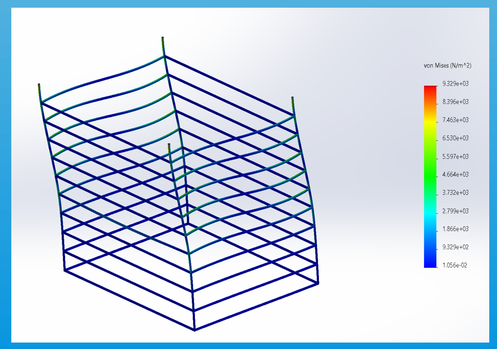


Bill of Materials	Units in SI
Item Number	Item Name
1	Raft Structure
2	Rope
3	Floating Buoy
4	Fiberglass Pink Bar
5	Chain
6	Screw Anchor

- For the mooring system of the mussel farm, Owens Corning PINKNBAR® fiberglass rebar was used to prevent whale entanglement
- Fiberglass rebar was chosen as the material to use instead of rope due to its rigidity ,which prevents whales from becoming trapped in long lines of rope
- This fiberglass rebar design works in two ways
  - It will not allow the whale to become entangled as it will bounce off the fiberglass rod
  - The whale will be able to see its bright pink color and avoid it
- The mooring line will be secured with the use of a screw anchor and 1.5" link chain

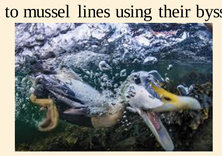


- Mussels grow well on dangling rope that can sway with the ocean movements
- To prevent whale entanglement with these mussel droppers, a High Density Polyethylene cage was designed around the mussel dropper area.
- The cage extends down 10 meters, to the depth of the mussel droppers
- The spacing between bars is 0.9 meters, this will prevent young NARWs from entering the structure
- A Stress Deformation test was conducted by modelling the whale as a point load force
- The model withstands the expected stresses



The Blue Mussel (*Mytilus edulis)* and System Economics

- On available surface area these filter feeders attach to mussel lines using their byssal threads while still in their larval stage
- It takes 18 months or longer for Blue Mussels to reach an acceptable size to be sold
- Blue mussels can grow to a size of about **1.5"** and weigh about **16.02 grams**

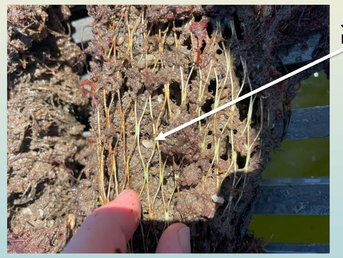


Eider Duck (*Somateria mollissima*) diving for mussels

Biodegradable mesh on mussel droppers

- Frayed, "fuzzy" rope was deployed at an offshore location in September 2023 to collect the spat, or juvenile mussels, released by adult blue mussels during the fall spawning season
- Mesh protects mussels on the lines while they are securing byssal threads and protects from predators such as Eider ducks throughout the growing process
- It was seen that the mesh covering also helped in preventing the degree of biofouling seen on the lines

- **WITHOUT MESH** there is estimated to be a **50% loss** of mussels due to predation and a high biofouling



Biodegradable mesh used on our mussel line, resulting in more mussel growth and less biofouling

Without biodegradable mesh, resulting more biofouling and mussels are left more susceptible to predators

Revenue Projection

Length of Rope (m)	Weight of Mussels (lb.)	Price Per Mussel lb.	Revenue
1	16.4	$1.52	$24.93
2	32.8	$1.52	$49.86
3	49.2	$1.52	$74.78
4	65.6	$1.52	$99.71
5	82	$1.52	$124.64
6	98.4	$1.52	$149.57
7	114.8	$1.52	$174.50
8	131.2	$1.52	$199.42
9	147.6	$1.52	$224.35
10	164	$1.52	$249.28

Future Plans

- Perform a tow test on the cage model
  - Results from this test will conclude the drag forces acting on the model as it is put through a wave a current simulation
- Collaboration with local mussel farmers and other fishermen
- Present design at the Ropeless Consortium in October of 2024
- Build and deploy developed prototype

References and Acknowledgements

This work was made possible with the help of Louis Gitelman and Longhuan Zhu of UNH, Dr. Daniel Linden of NOAA, NEAq Aquaculture Programs Manager Matthew Thompson, NEAq Biologists Heather Pettis and Amy Knowlton, and NEAq Species Distribution Expert Dr. Laura Ganley

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