

Macrofaunal and macroalgal biodiversity on oyster reefs restored with novel non-plastic materials



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Oyster Reef Restoration



Plastic shell bag



Plastic oyster mat

Alternative Restoration Materials

Research to date:



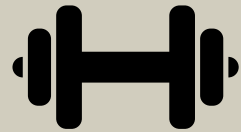
BESE® oyster mat*



Cement-jute volcanoes

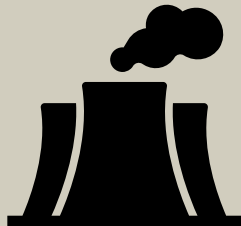


Metal gabion



Durability

- Does material last long enough to restore the reef?



Nutrient leaching + pollution

- Is material safe for the environment?

How does material type affect...



Macrofaunal communities?



Oyster recruitment?



Biofouling?

Experimental Materials

- Naltex®
- Polyethylene (PE)
- Control
- **Shell bag**



Plastic mesh

- Natrx®
- Spun basalt fiber
- **Shell bag**



Basalt mesh

- BESE®
- Biodegradable biopolymer
- **Shell bag**



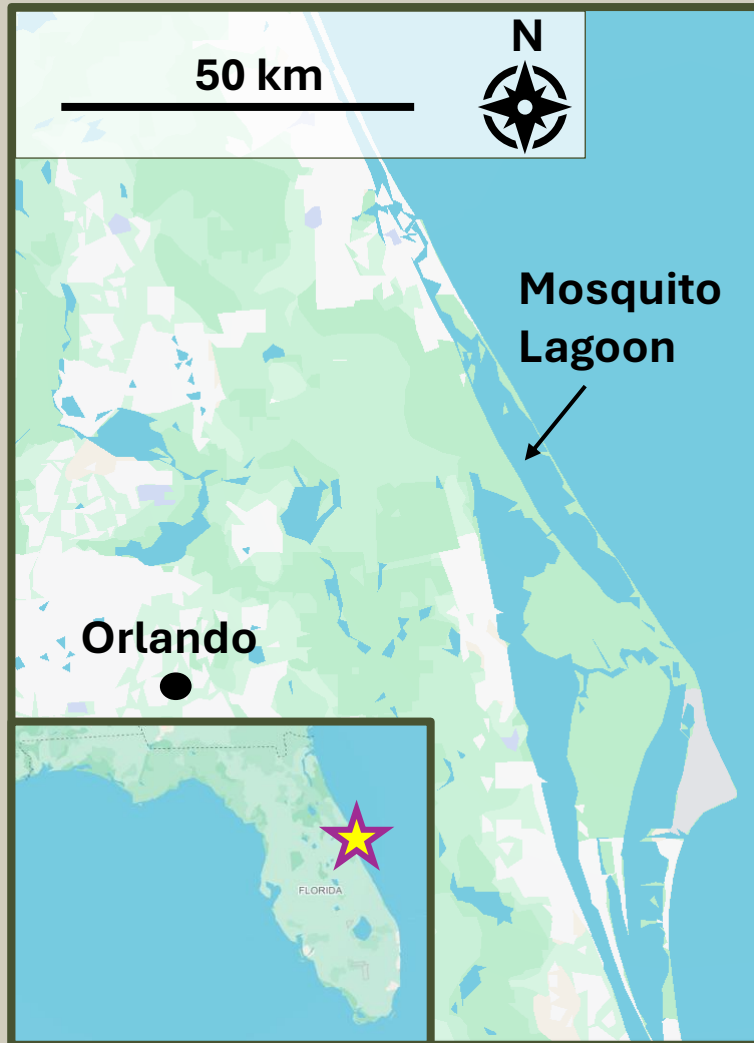
BESE® mesh

- Volunteer-made
- Cement and jute fiber
- Two rings = one shell bag
- **Cement structure**



Cement-jute rings

Field Study Location



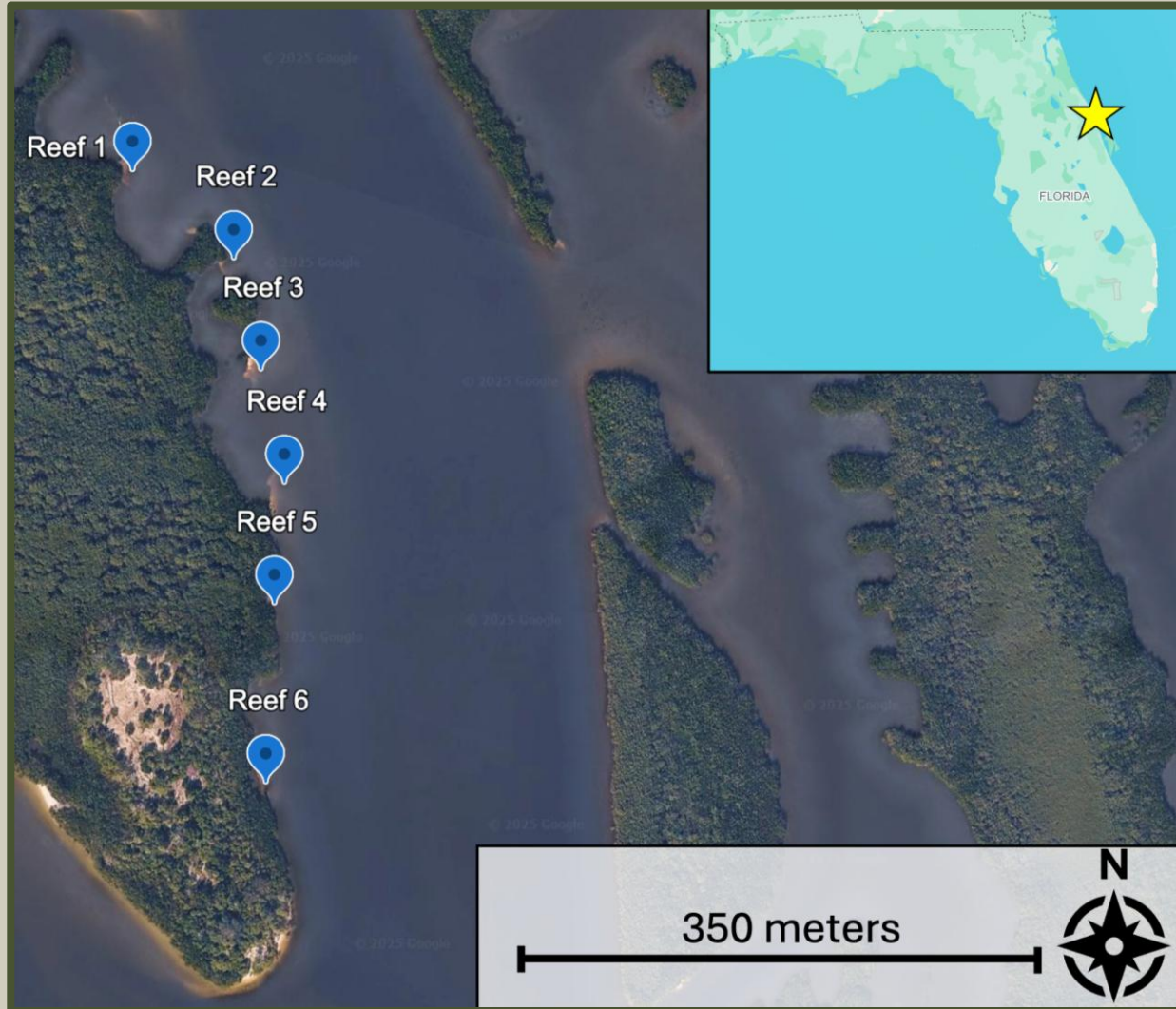
Mosquito Lagoon (ML)

- Subtropical, microtidal estuary
- Annual water temperatures 10 °C to 33 °C¹
- Salinity from 22.6 to 45.3 psu¹
- High wake energy
- Intertidal oyster reefs



¹Phlips et al., 2015, *Estuaries and Coasts*

Methods - Reef Restoration



May 2025

- Six reefs restored in ML
- All experimental units deployed as breakwaters
- $n = 10$ restoration units of each material treatment at each reef
- Monitored for two years

Monitoring - Macrofauna and Algae

Monitored one unit / treatment / reef quarterly:

- Units randomly selected
- No repeated measures

Macrofauna

- Identify to lowest possible taxonomic unit
- Record abundance for all groups

Biofouling

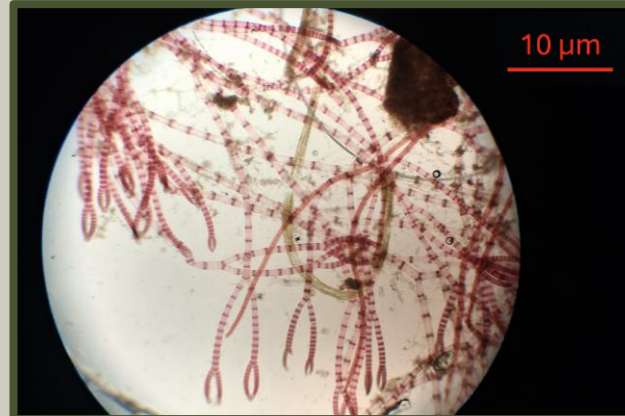
- Percent cover of algae on exterior of units



Plastic unit collected for sampling



Eastern oyster - *Crassostrea virginica*



Red alga - *Ceramium* sp.

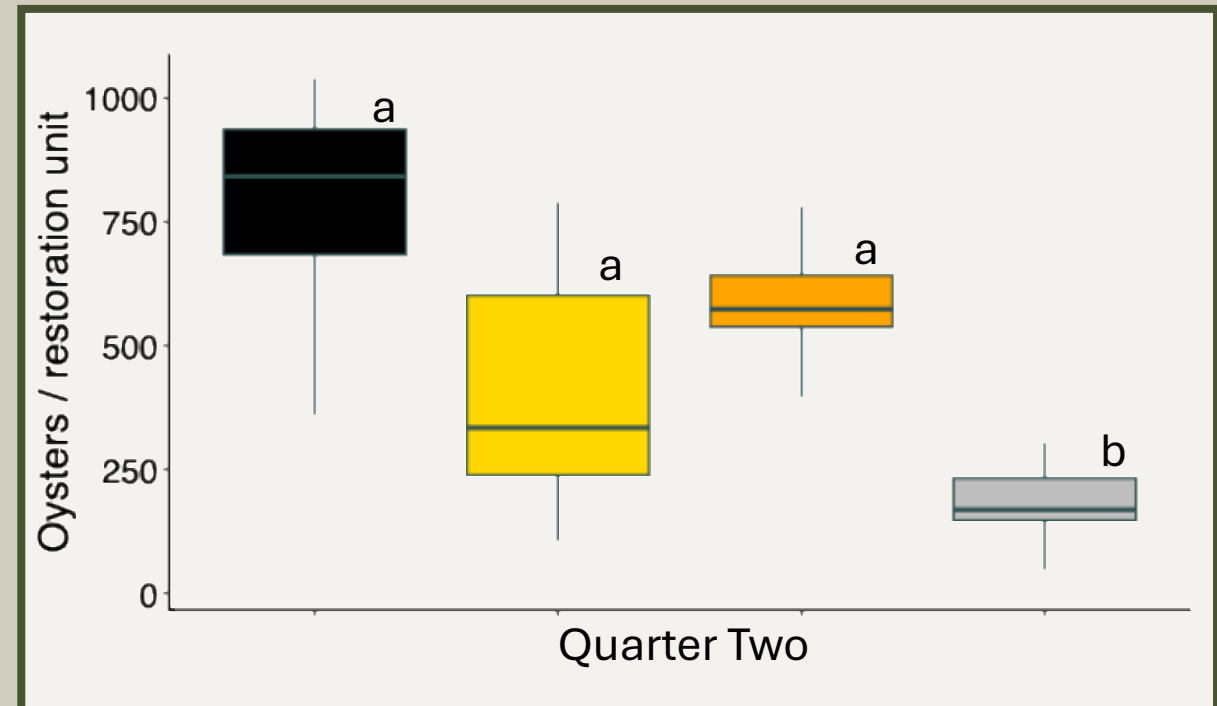
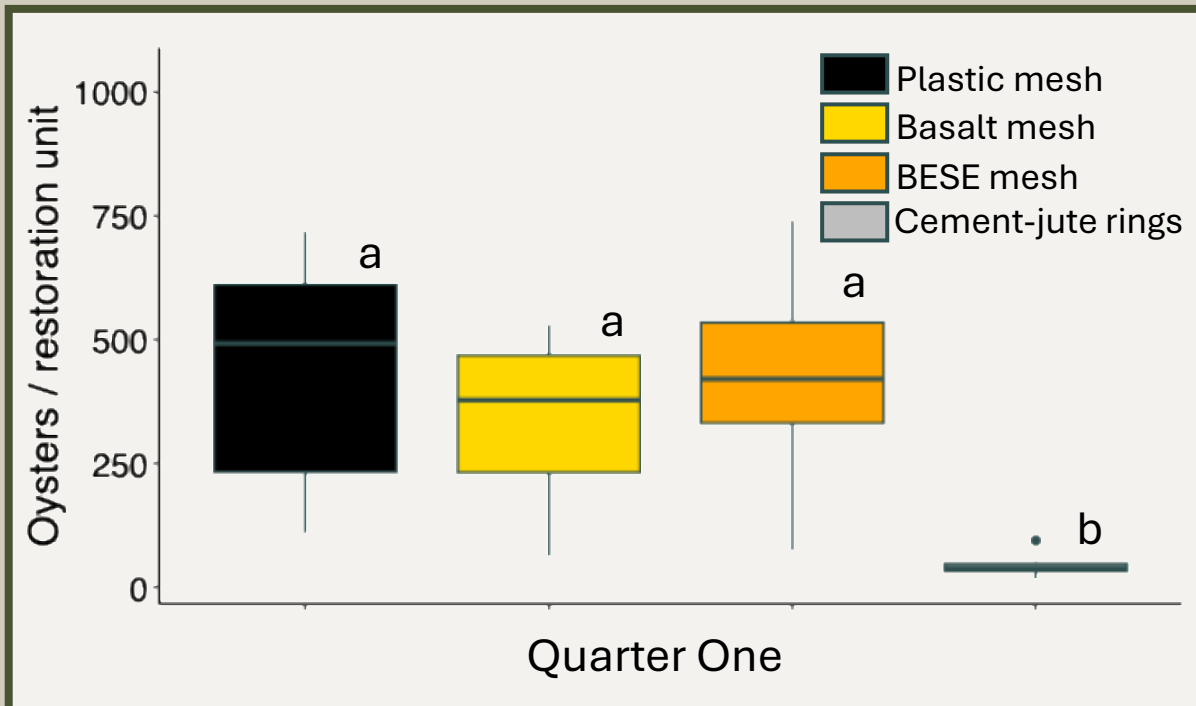


Mud crab - Family Panopeidae

Results - Oyster Settlement

Shell bag treatments have higher settlement than cement-jute rings ($p < 0.05$)

Overall settlement increased from quarter one to quarter two ($p < 0.0001$)



Analysis: Negative binomial GLMM: Abundance ~ Material + (1 | Reef). Quarters analyzed separately.

Results - Macrofaunal Abundance

39,966 total organisms

10 phyla



Eastern grass shrimp - *Palaemon paludosus*



Pleated Tunicate - *Styela plicata*



Snapping shrimp - *Alpheus sp.*



Brittle star and mud crab



Florida blenny - *Chasmodes saburrae*



Scorched mussel - *Brachidontes exustus*



Charru mussel - *Mytella strigata*



Dark Shore Crab - *Pachygrapsus gracilis*



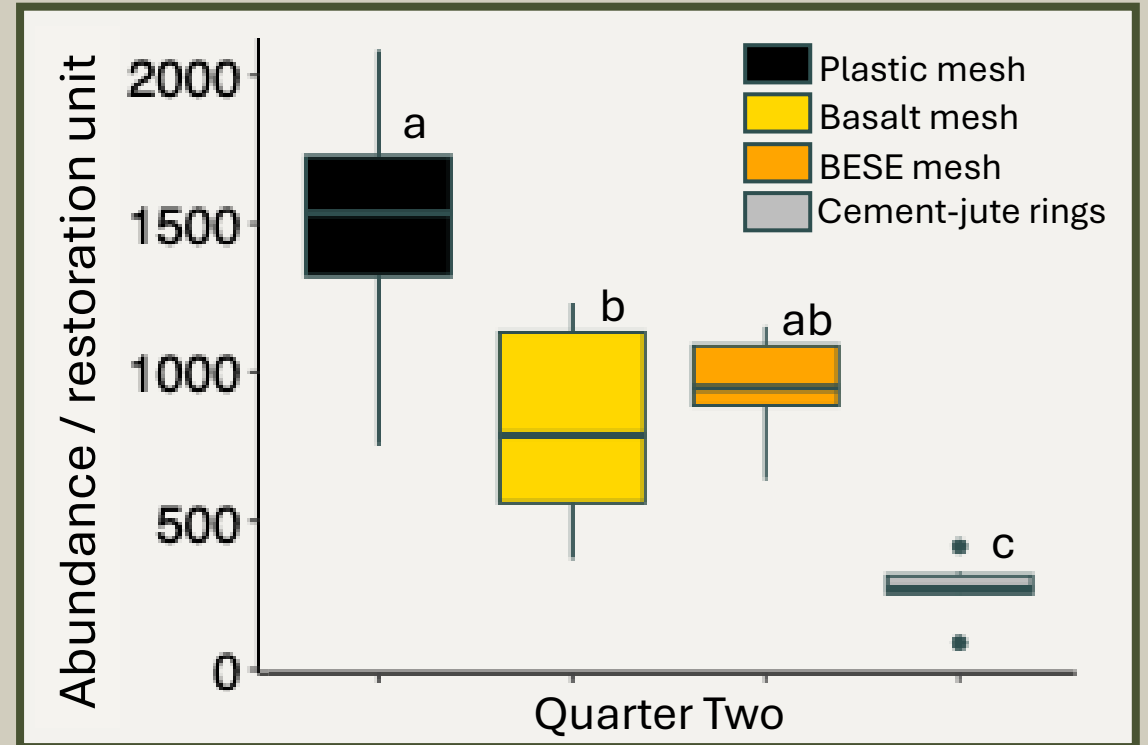
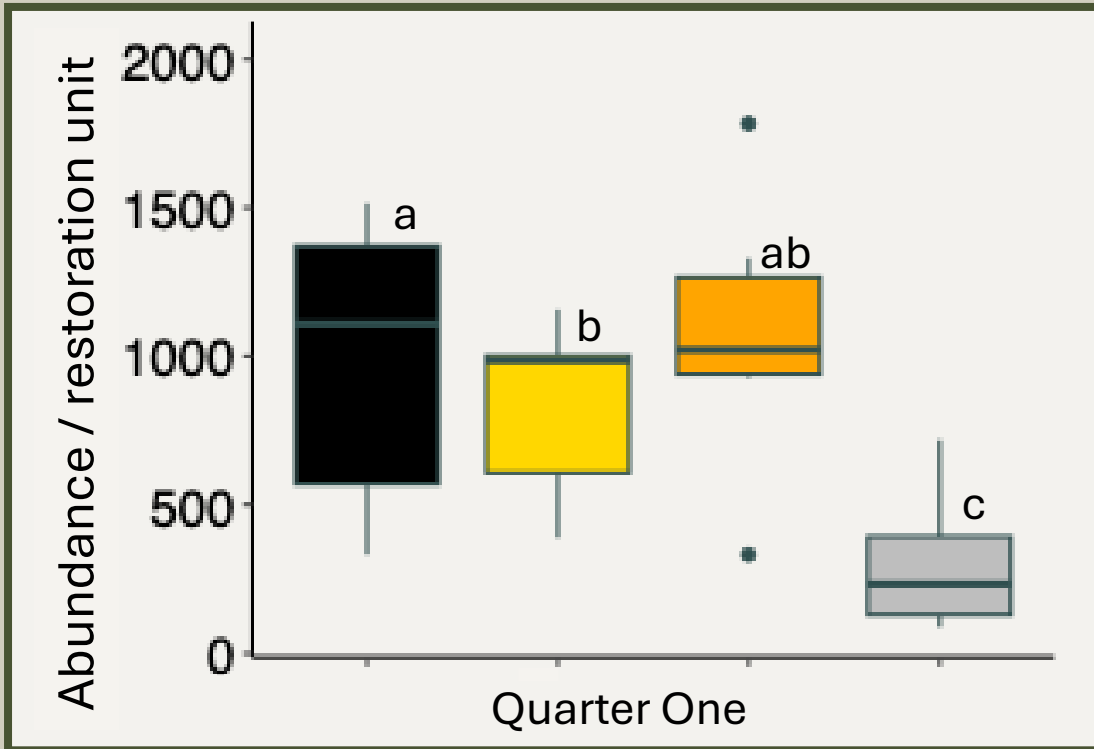
Mangrove Tree Oyster - *Isognomon alatus*

Results - Macrofaunal Abundance

39,966 total organisms

10 phyla

Shell bag treatments have higher macrofaunal abundance than cement-jute rings ($p < 0.05$)



Analysis: Negative binomial GLMM: Abundance ~ Material + (1 | Reef). Quarters analyzed separately.

Results - Species Richness and Diversity

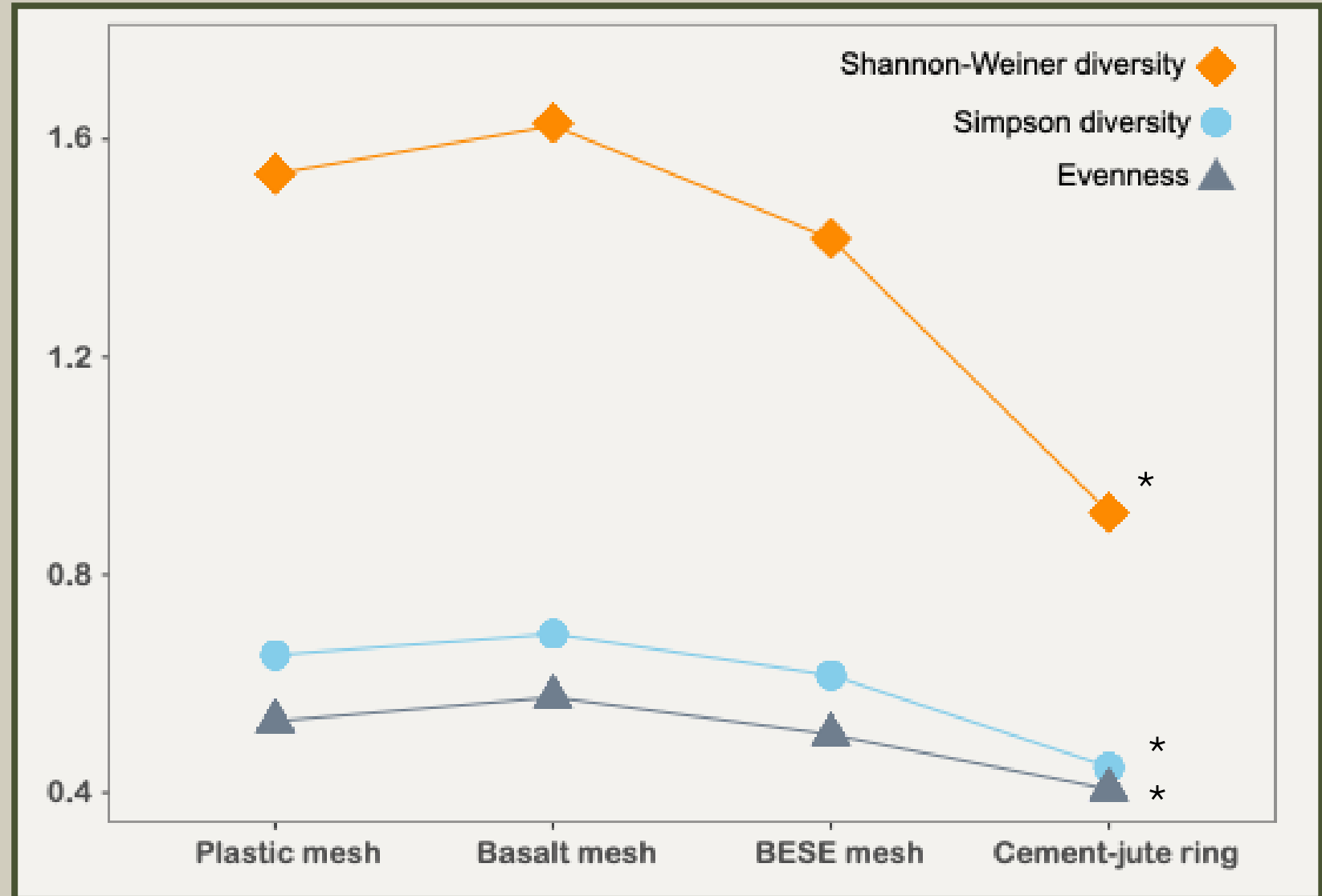
Diversity indices

Shannon-Weiner diversity

Simpson diversity

Evenness

Shell bags consistently score higher in all diversity indices ($p < 0.05$)



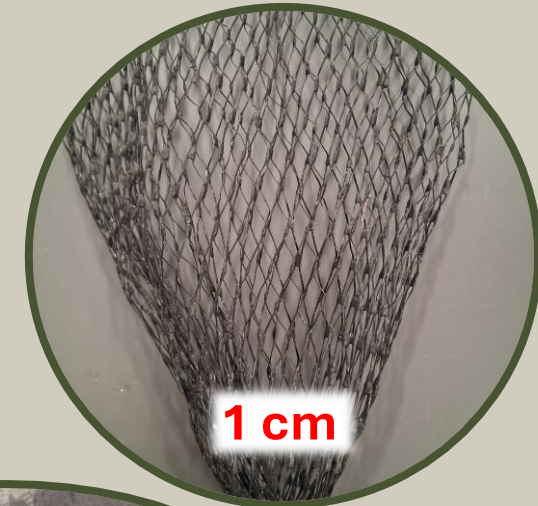
Analyses: Gamma and ordered beta regression GLMs: index ~ Material

Results - Macrofaunal Communities

High surface area due to many loose shells

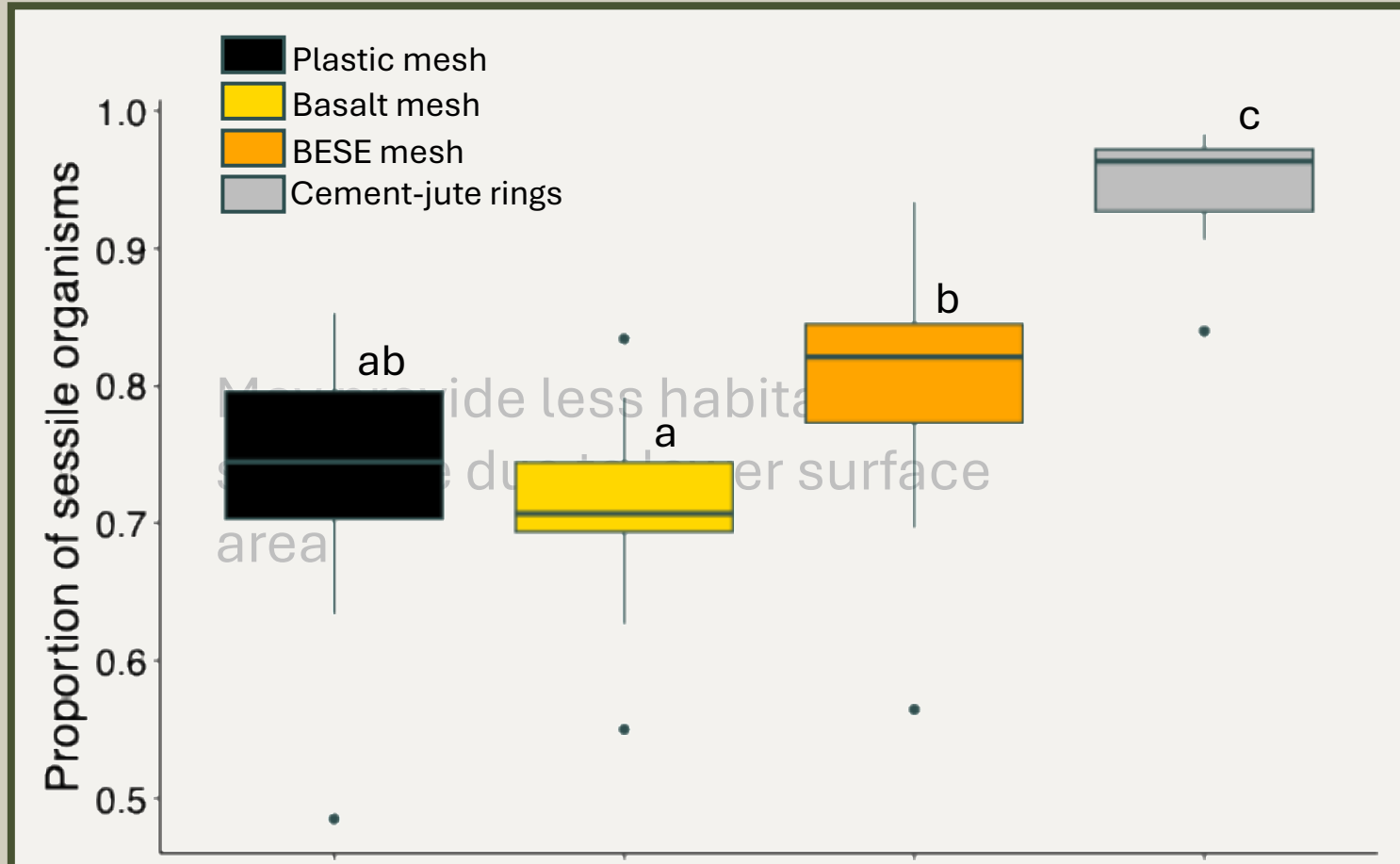
Differences between materials:

- Mesh size
- Rigidity of material



Shell bag units have consistently high biodiversity

Results - Macrofaunal Communities



Analysis: Ordered beta regression GLM: Proportion ~ Material.

Quarters analyzed together.

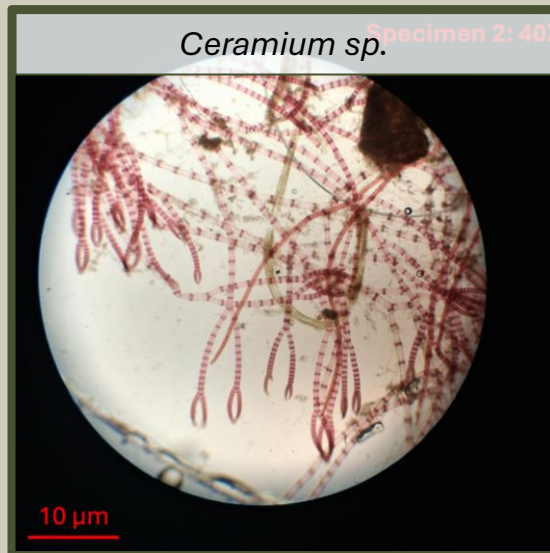
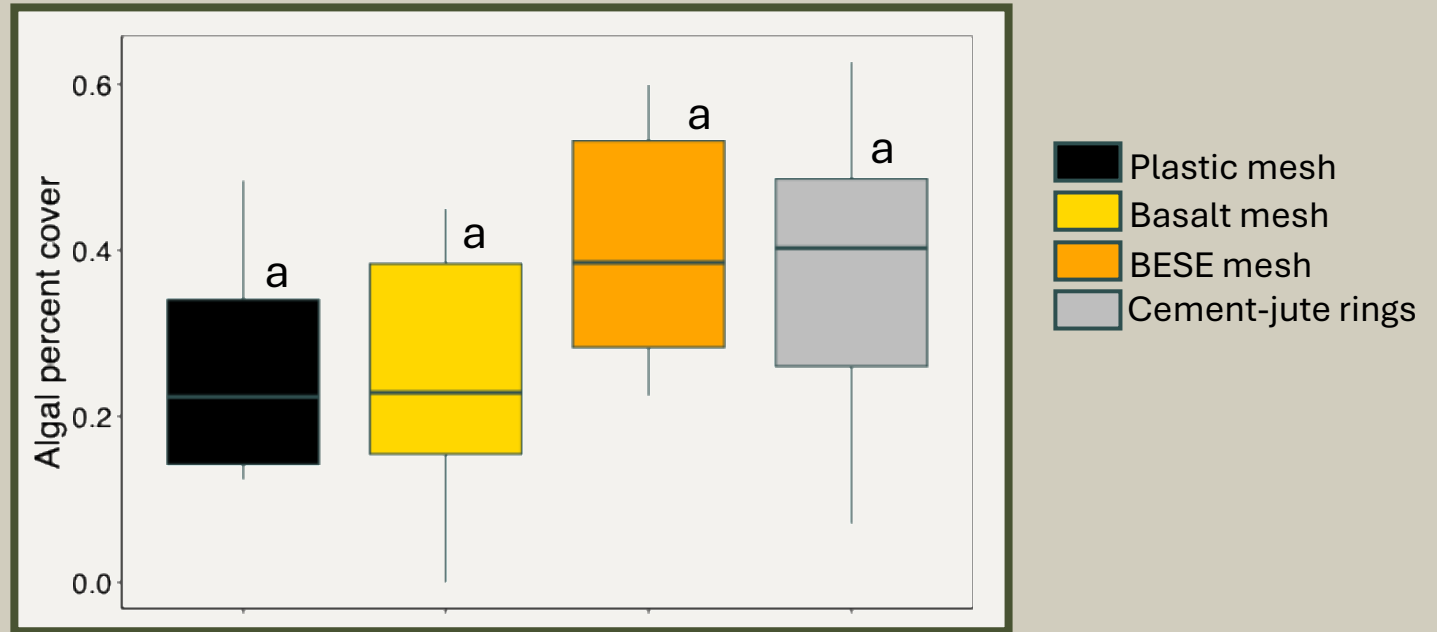


Macrofaunal communities present, but less abundant and diverse than in shell bag units

Results - Algal Percent Cover

- Algae recorded starting December 2025
- Algal coverage ranges from 0% to 60%
- No impact of material on algal coverage ($p > 0.05$)

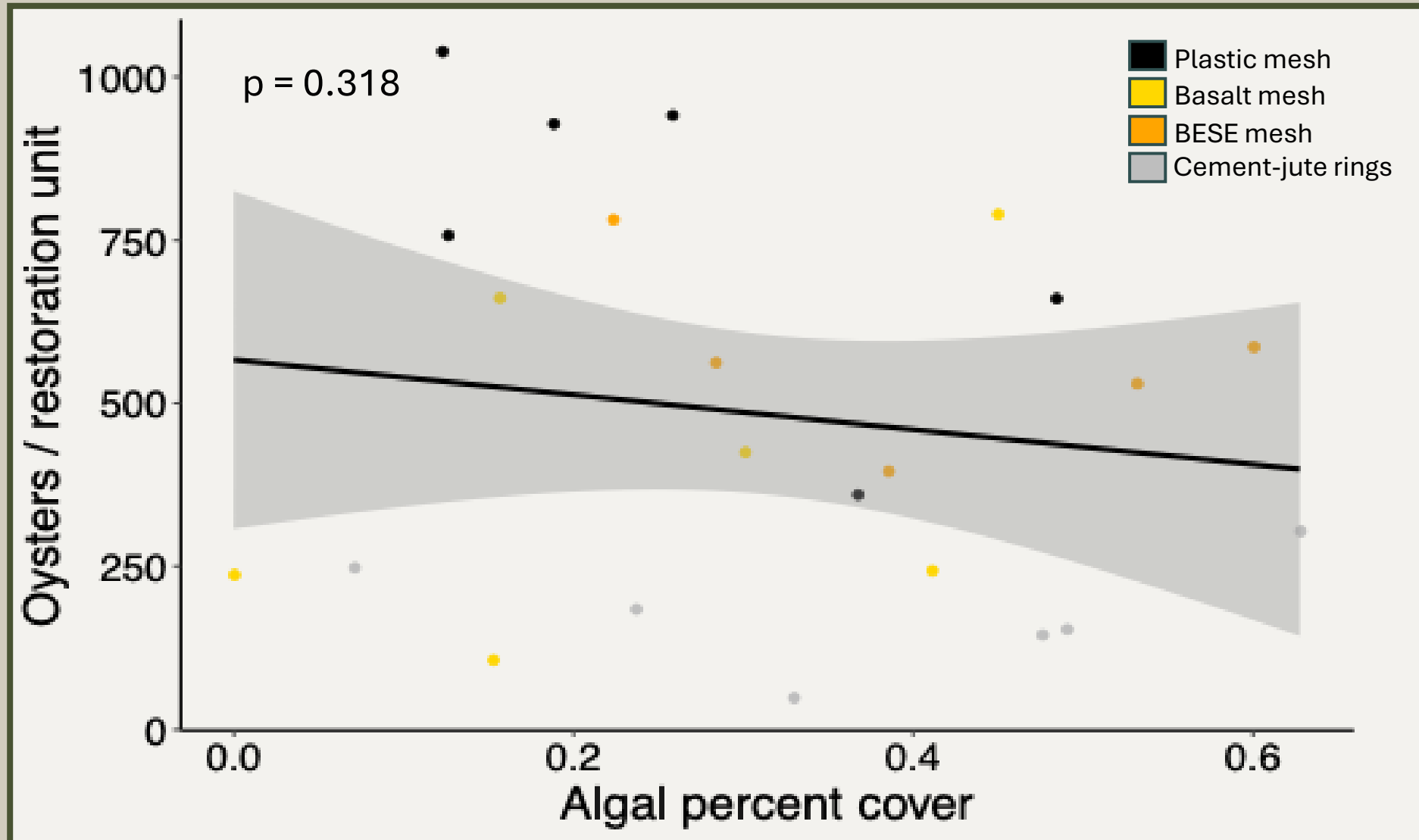
Analysis: Ordered beta regression GLM: % cover ~ Material.



Commonly observed taxa

- Filamentous red algae (including *Ceramium sp.* and *Herposiphonia sp.*)
- *Ulva spp.*
- *Rosenvingea sanctae-crucis*

Results - Algal Percent Cover



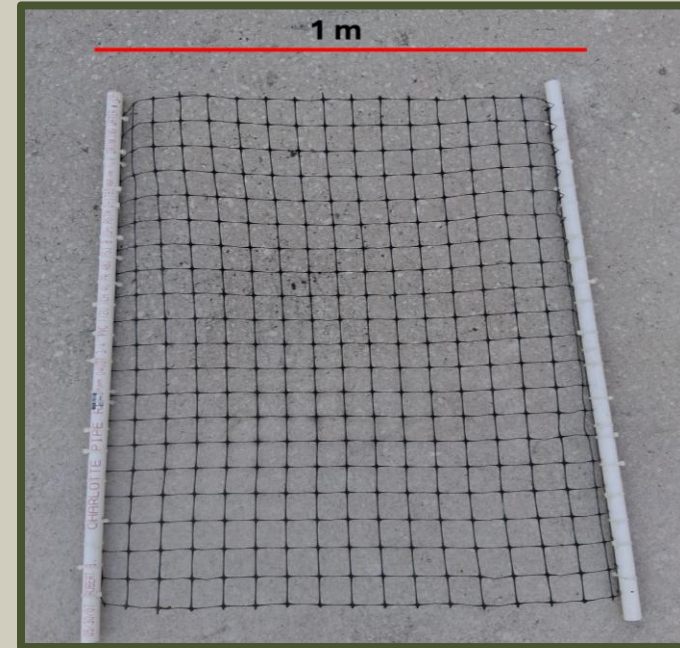
Analysis: Negative binomial GLMM: Abundance \sim % cover + (1 | Material)

Material Durability

Percent cover of damage

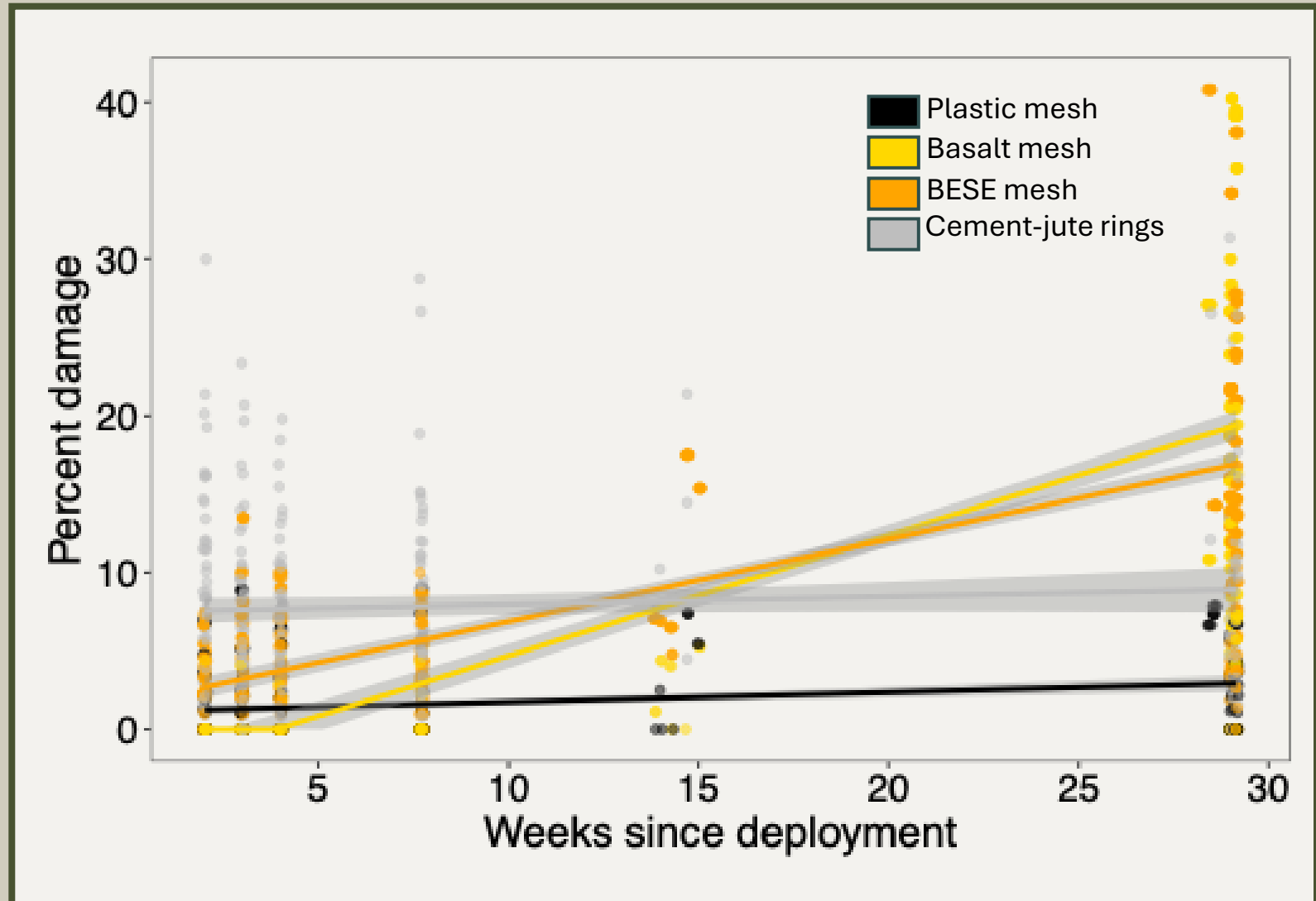
- Measured with flexible gridded quadrat
- Ring damage = loose or exposed jute fiber
- Shell bag damage = tears in mesh

$$\% \text{ damage} = \frac{\# \text{ damaged squares}}{\text{total \# squares}} \times 100$$







Material Durability

- Significant increase in damage over time for shell bag treatments ($p < 0.001$)
- Steep increase in damage for basalt and BESE mesh
- Cement-jute rings start off with some damage, but show no change over time ($p = 0.122$)



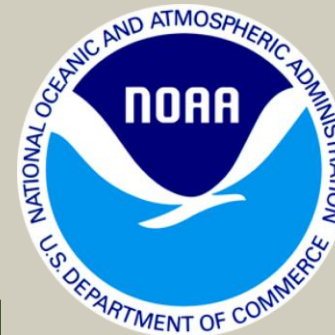
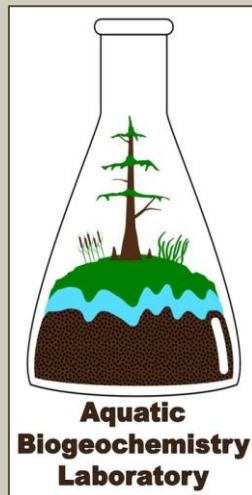
Analysis: Ordered beta regression GLMM: Damaged area ~ Material + Time + (1 | Reef)

Conclusions

	Oysters	Macrofauna	Biofouling	Durability	Cost/unit
 Plastic mesh	↑	↑	—	↑	\$1
 Basalt mesh	↑	↑	—	↓	\$30
 BESE® mesh	↑	↑	—	↓	\$1.14
 Cement-jute rings	↓	↓	—	↑	\$7.02

Acknowledgements

- Collaborators
- Restoration partners and volunteers
- NOAA Marine Debris Challenge
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- Monitoring crew





Questions?

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