Summer dredging effects on estuarine zooplankton near Cape Fear, North Carolina

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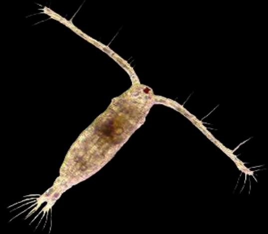


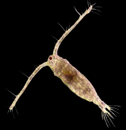



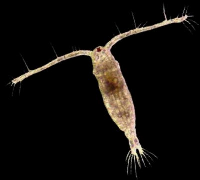

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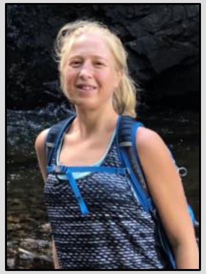

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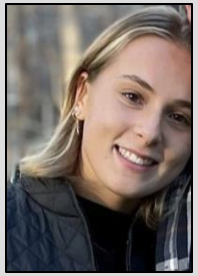
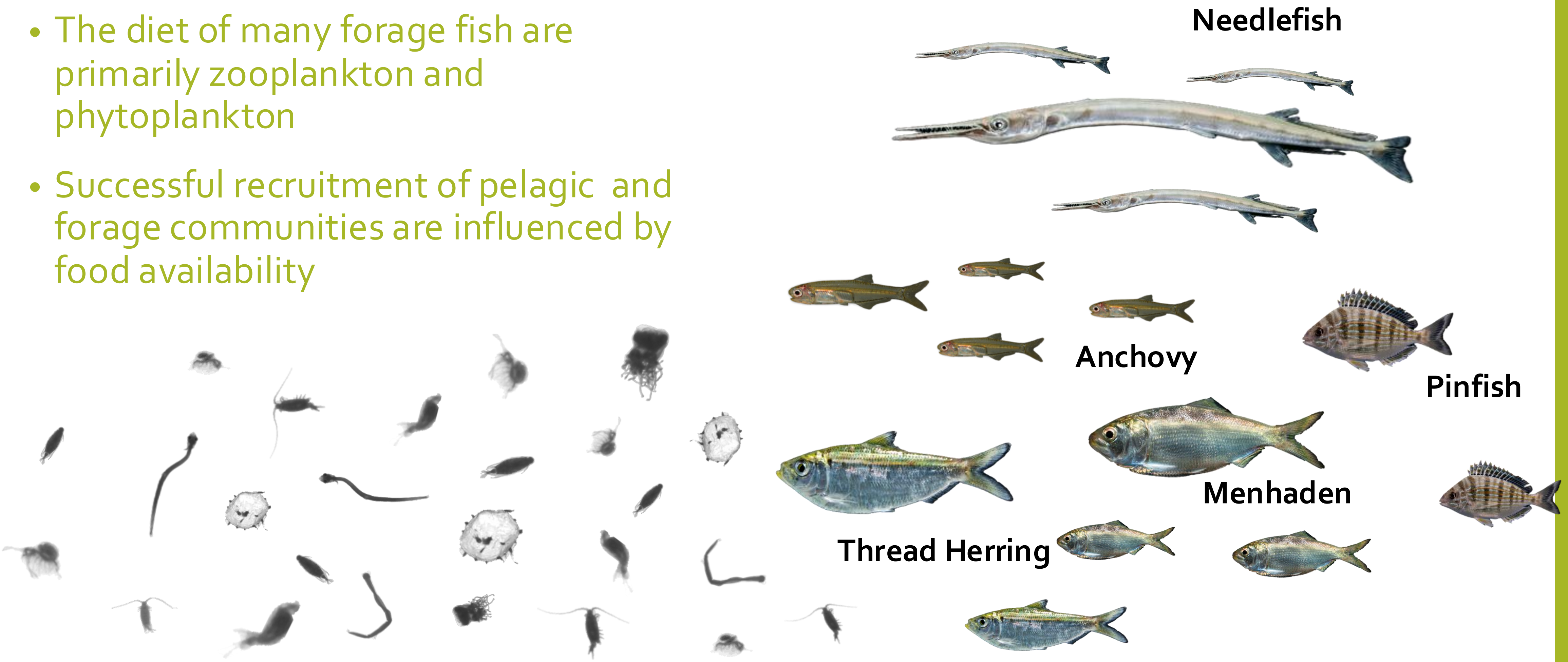


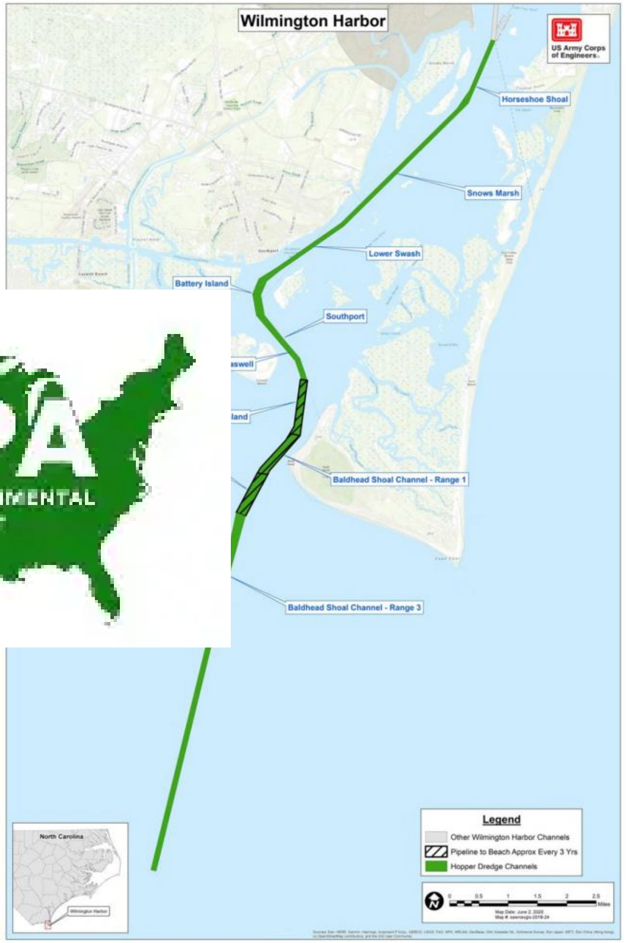
What do zooplankton have to do with "Navigating changes in small pelagic fish and forage communities?"

- The diet of many forage fish are primarily zooplankton and phytoplankton
- Successful recruitment of pelagic and forage communities are influenced by food availability



Hopper Dredging in North Carolina

Photo: Army Corps of Engineers, coastalre

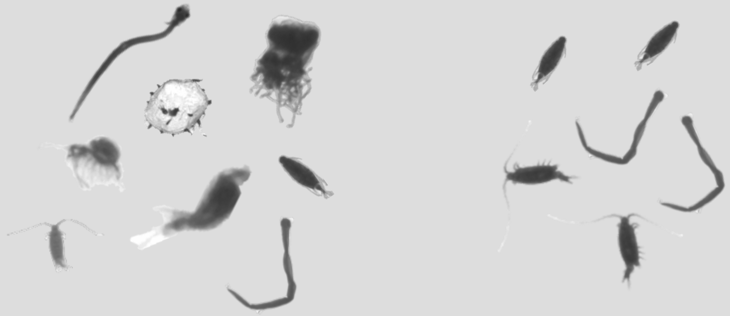


- Hopper Dredging – suctions sediment up and sprays it at disposal sites
- It can only occur during the **environmental window** (Dec 1- April 1) to reduce ecosystem damage from turbidity, entrainment, and low dissolved oxygen
- In 2020, the US Army Corps of Engineers (USACE) proposed to eliminate the environmental window
  - allow for flexibility in project timelines
  - save taxpayer money over time
- National Environmental Protection Act (NEPA) - NEPA requires federal agencies to assess the environmental effects of their proposed actions **prior** to making decisions.

Research Questions

1. How may dredging affect the diversity of zooplankton?

Hypothesis:
Dredging reduces the **diversity** of zooplankton assemblages.



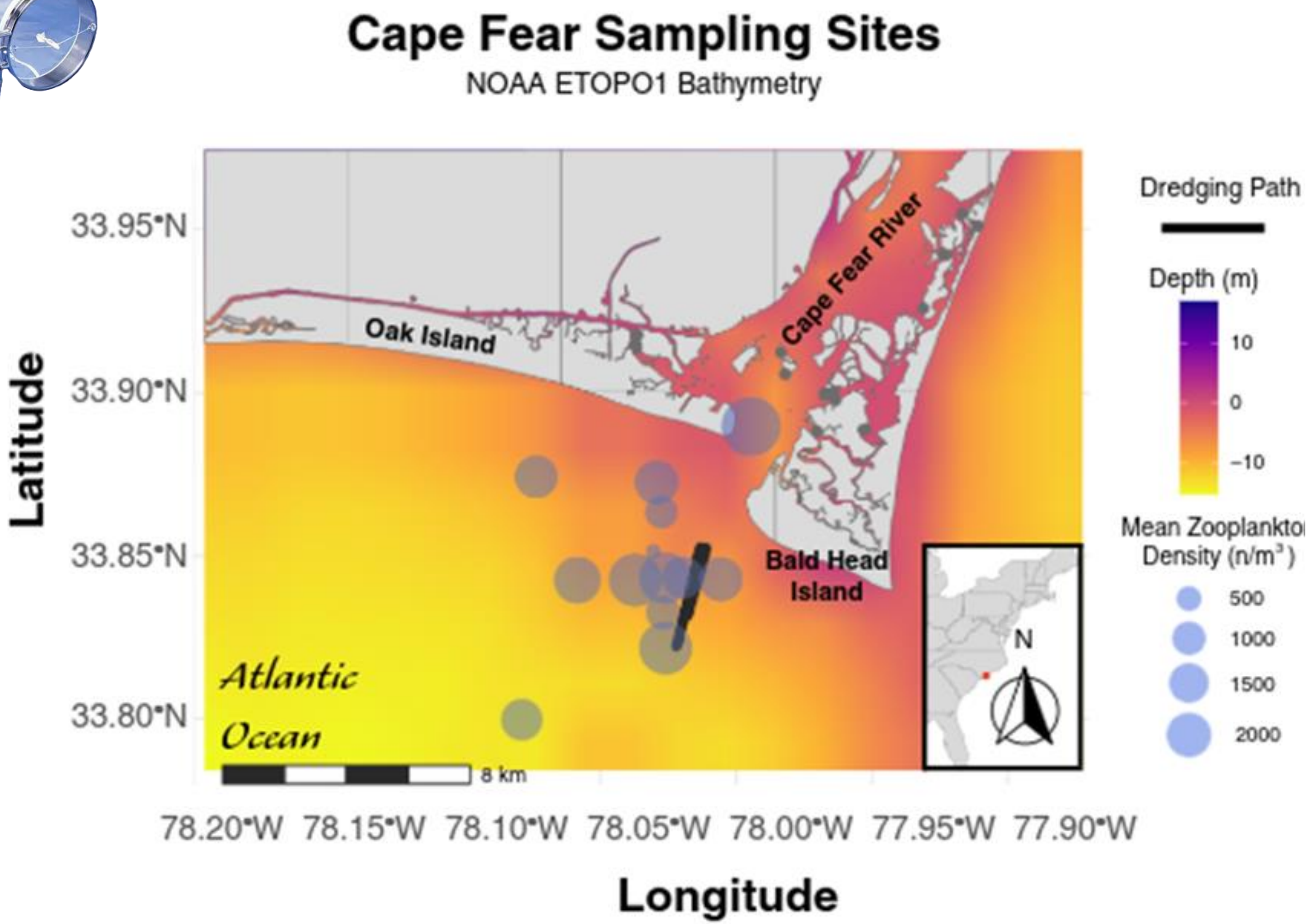
2. How may dredging affect the density of zooplankton?

Hypothesis:
Dredging reduces the **density** of zooplankton assemblages.

Methods : Collection

- Start at sunset
- 60-cm diameter bongo net (**335-µm mesh**) with flowmeter
- Mid-water tow
- Target speed: 1.5 knots
- Tow time: 10 minutes
- One YSI cast per station (15 stations)

Period	Date (2021)
Before	May 11 -13
During	June 14-17
After	July 10, 12-14



Dates of dredging: May 24-June 27, 2021

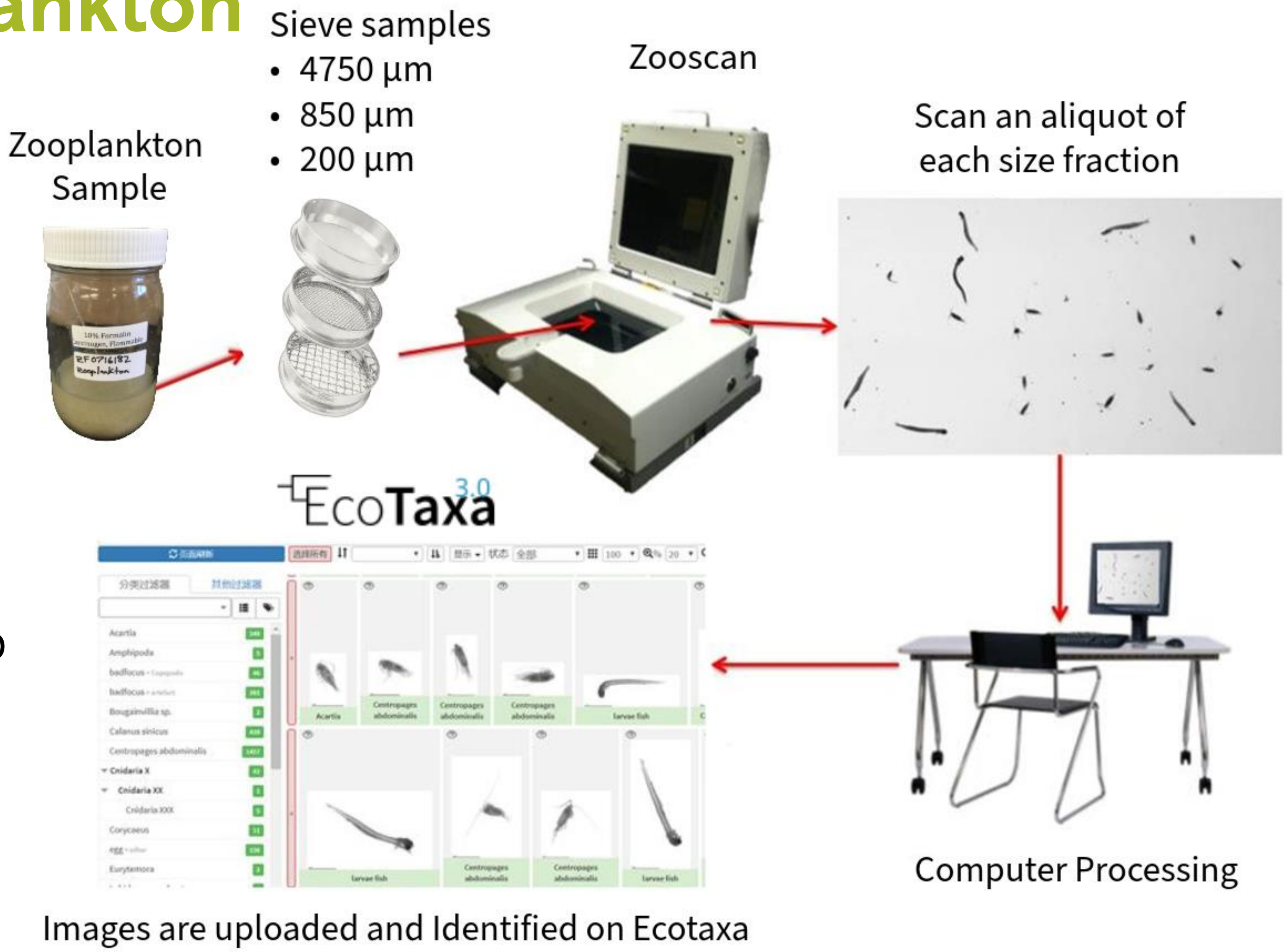
Methods: Zooplankton Identification

Pros:

- More plankton & biological matter are analyzed in less time
- Over **60,000** images were included in this analysis

Cons:

- Limited by pixel and single 2-D view
- Low taxonomic resolution for identification →Limits diversity interpretation



Environmental Effects vs Dredging Effects

Environmental Effects

- PCA Component Analysis:
  - Salinity
  - Dissolved Oxygen (DO)
  - Temperature
  - Day of Year (doy)
  - Chlorophyll a (chl a)
- Stepwise Multiple Linear Regression
- 1. Response Variable ~ PC1
- 2. Response Variable ~ PC1 + PC2
- Compare models using AICc, report significant predictor in best model

Dredging Effects

- Multiple Linear Regression - ANCOVA
- Response Variable ~ Period + Distance + Period:Distance

(from dredging activity)

Response Variables

Diversity* :

- Pielou's Evenness
- Taxa Richness
- Shannon Weiner Index

* Plankton not identified to species, identified to lowest possible taxonomic level

Density:

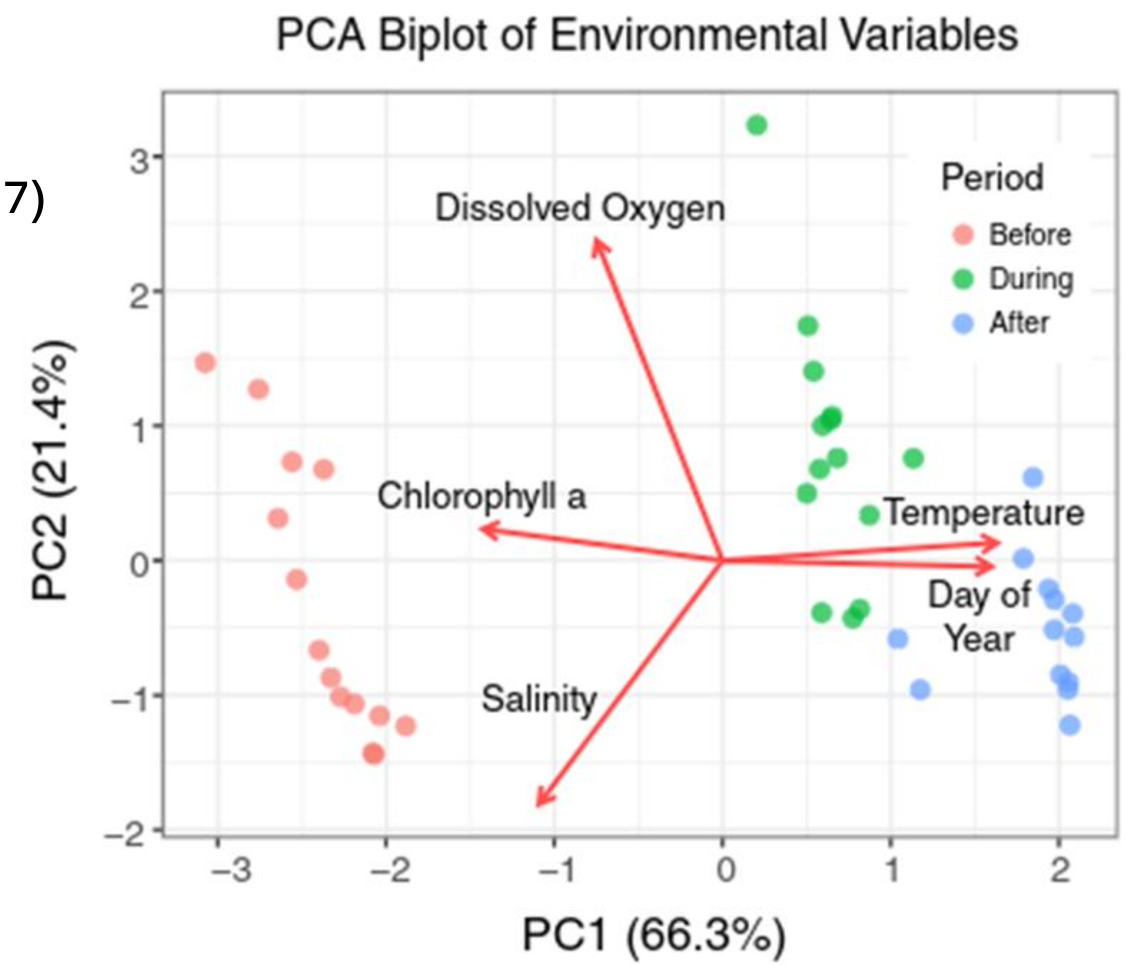
- Total zooplankton density
- Total detritus density
- Individual taxonomic group density**

** Selected based on abundance in dataset and relevance to fish diet

PCA Results

- Higher Dissolved Oxygen (2.37)
- Lower salinity (-1.81)

- Lower Dissolved Oxygen
- Higher salinity



- Cooler temperature
- Earlier day of year
- Higher chlorophyll
- Higher salinity

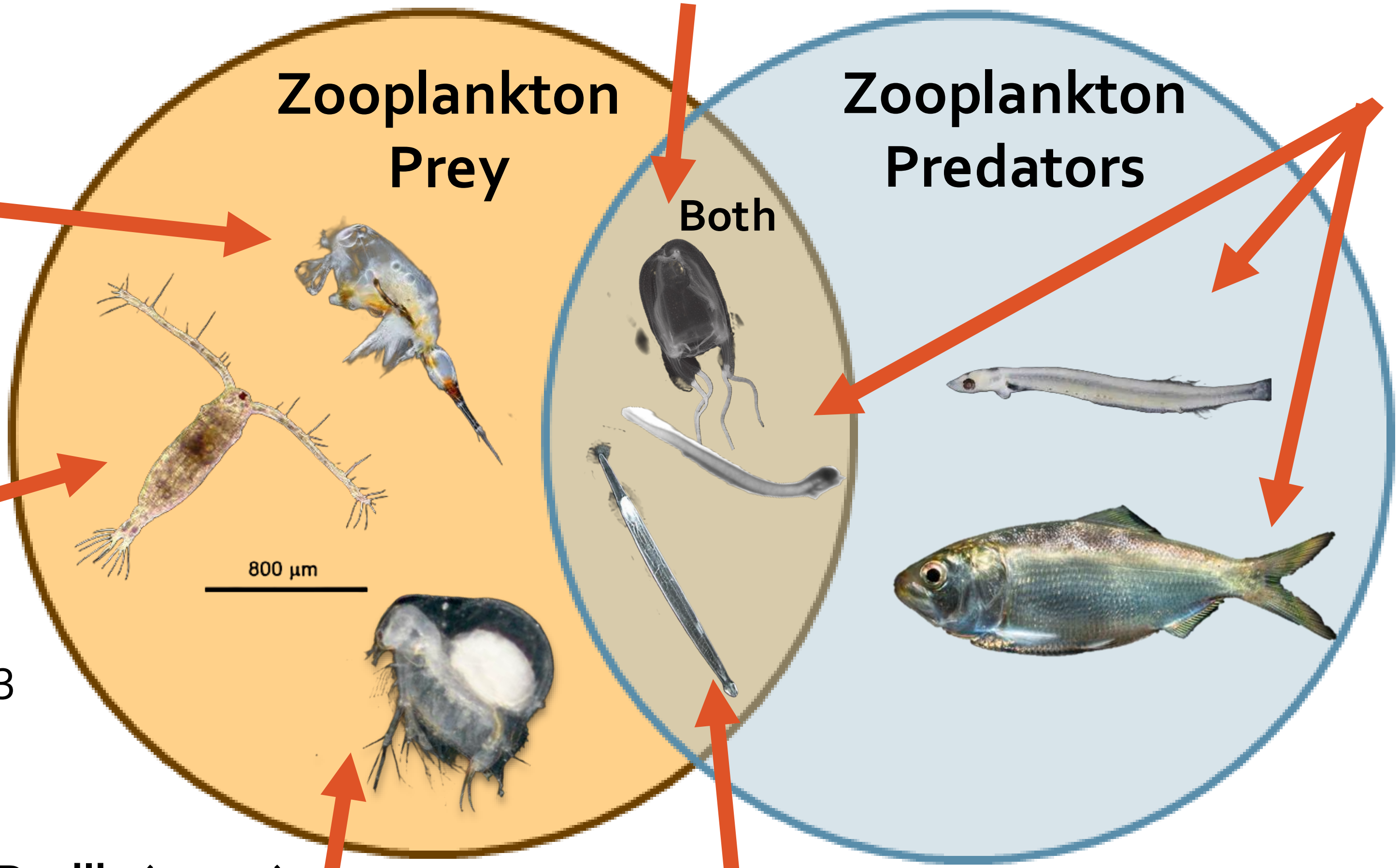
- Warmer temperatures (1.63)
- Higher day of year (1.59)
- Lower chlorophyll a (-1.42)
- Lower salinity (-1.09)

Taxonomic Groups

Meduszoa (sub-phylum):
- Consume larval fish and eggs Schiariti, A. *et al.* (2018)
- Prey for fish

Cyclopoida (order):
- Ambush feeders
- Small, high in lipids
- Dayras et al 2023

Calanoida (order):
- Filter feeders
- Thayer et al. 1974, Sanchez-Ramirez 2003 Jackson et al. 2016



Actinopterygii (class):
- Predators (late stage larvae, juveniles, and adults)
- Small larvae can be consumed by larger zooplankton

Penilia (genus):
- Filter feeders
- Sanchez-Ramirez 2003

Chaetognatha (phylum):
- Carnivorous predator of fish larvae and zooplankton
- Terazaki 2000

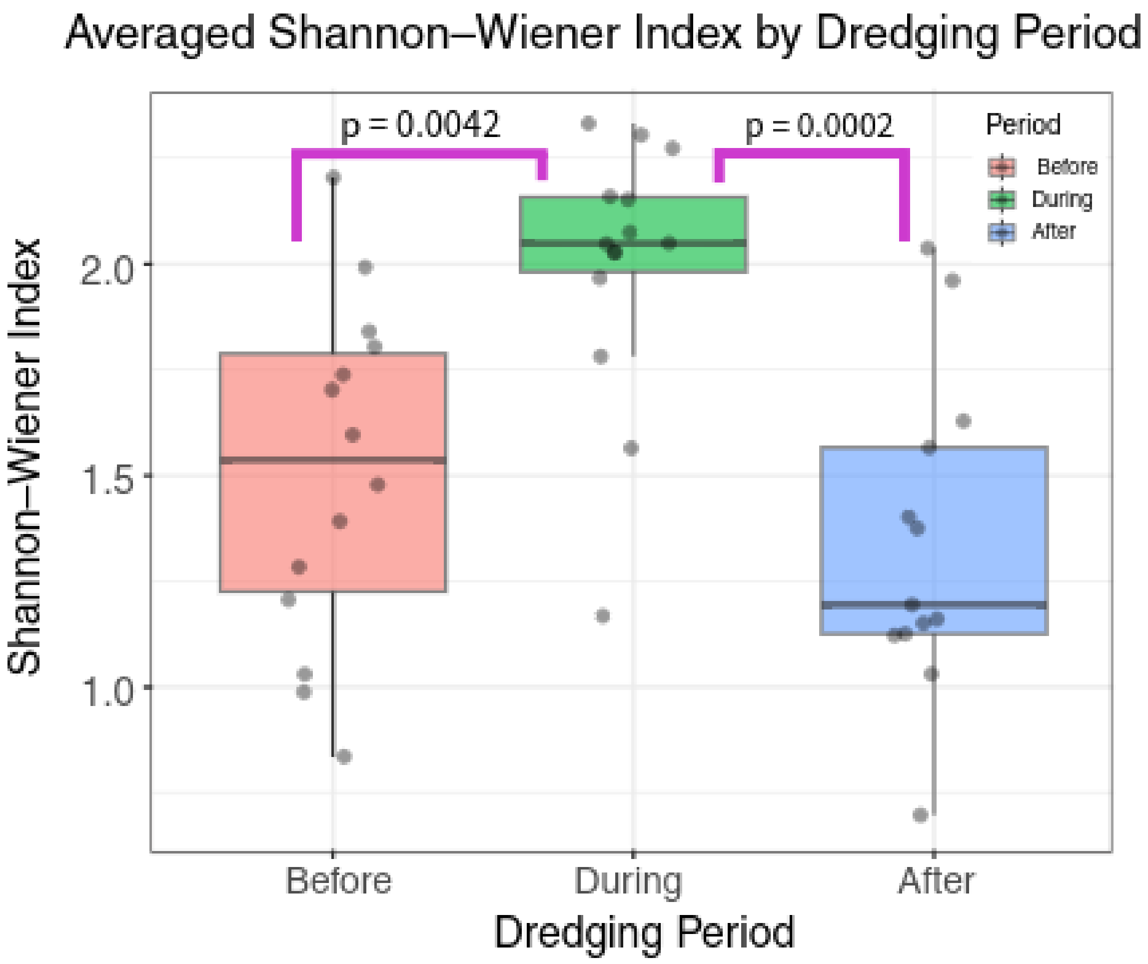
Results: Diversity – Shannon Weiner

Shannon Weiner ~ **Period** + Distance + Period:Distance

($p<0.05$)

Terms highlighted in green are significant

Shannon Weiner Index was higher during dredging than both before and after

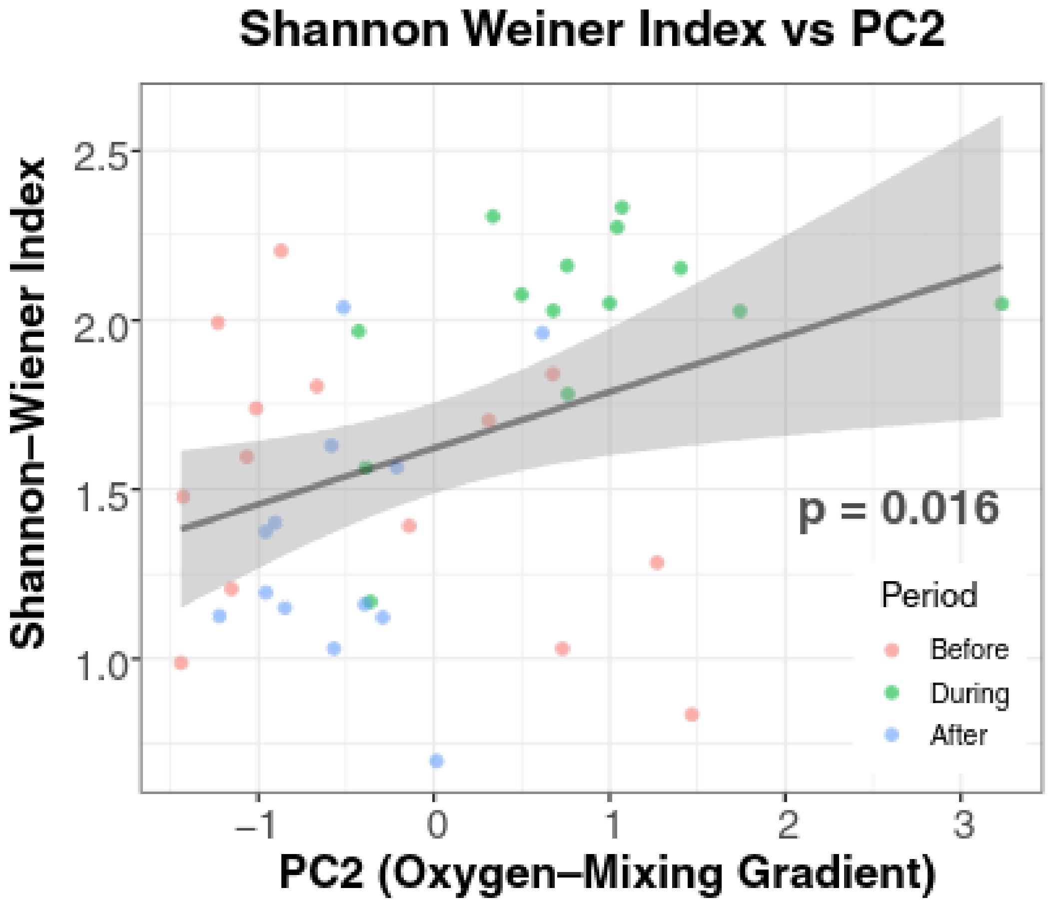


Results: Diversity – Shannon Weiner

Environmental Linear Regression Models		
Model	**AICc**	**P-value**
PC1	57.25	
PC1 + PC2	**53.37**	**0.016**

Shannon Weiner Index increases with PC2

- Higher Dissolved Oxygen (2.37)
- Lower salinity (-1.81)

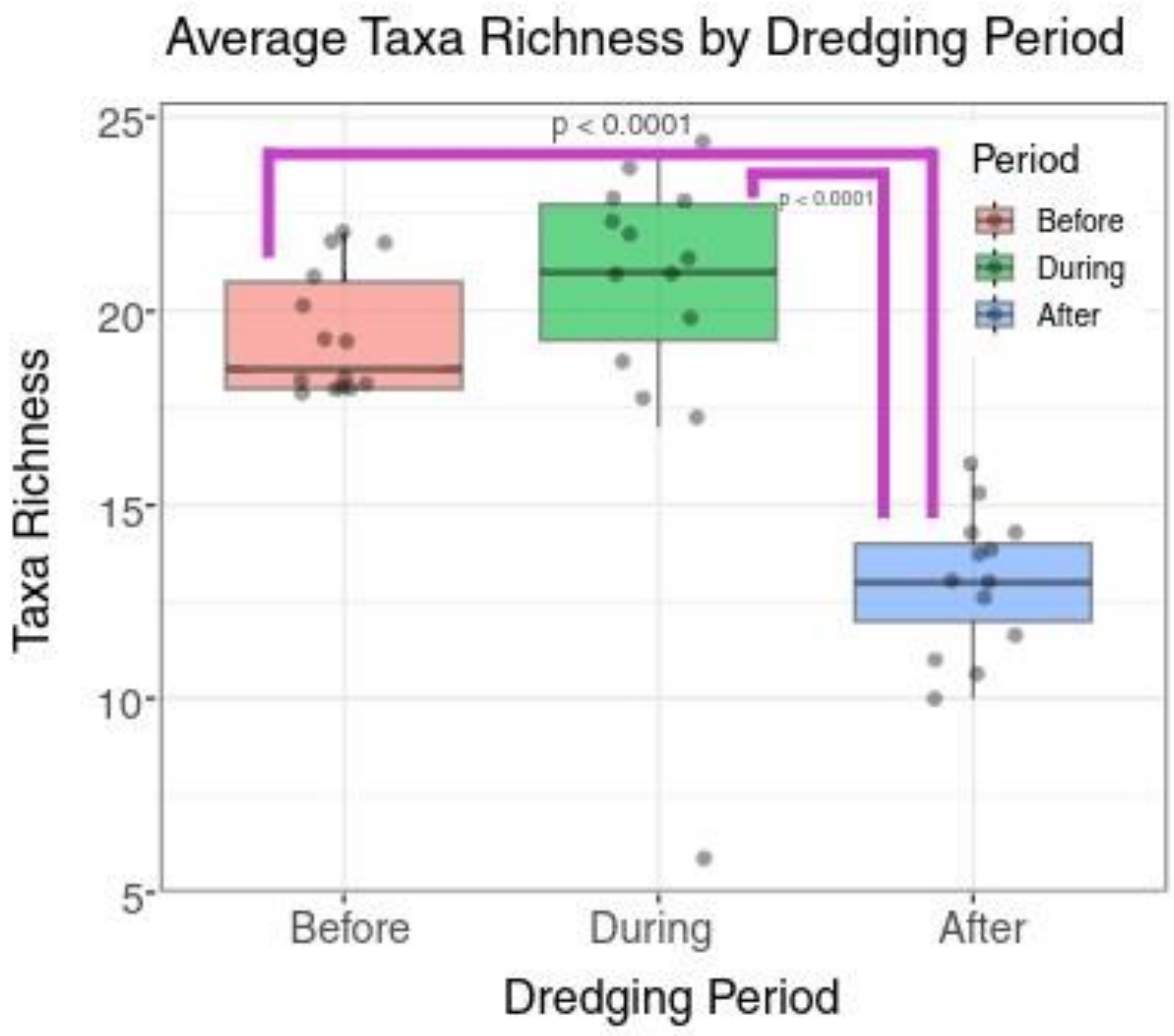


Results: Taxa Richness

Taxa Richness ~ **Period** + Distance + Period:Distance

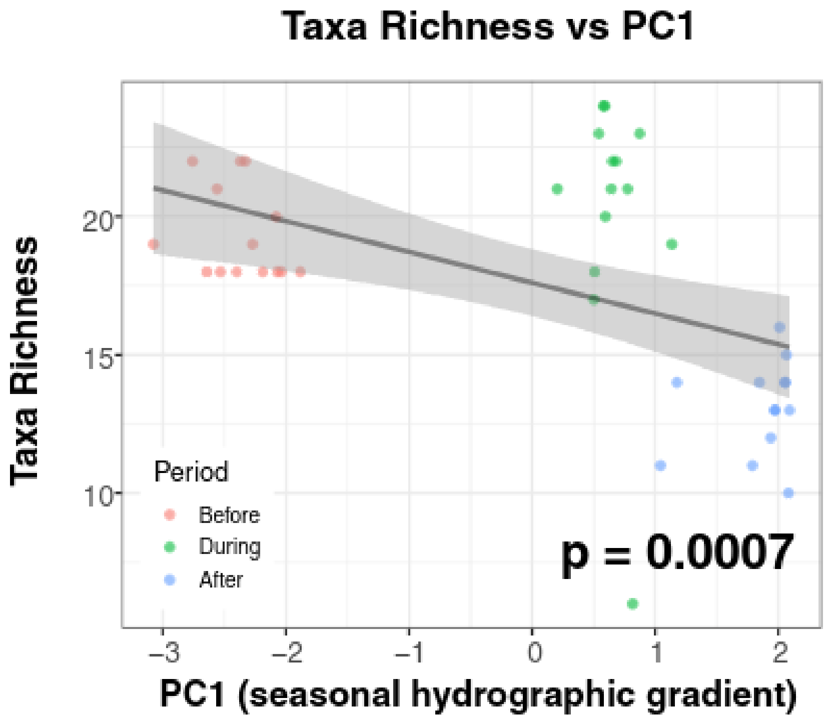
$p < 0.00001$

- Richness was higher **during** dredging than **after**
- Richness was lower **after** dredging than **before** dredging



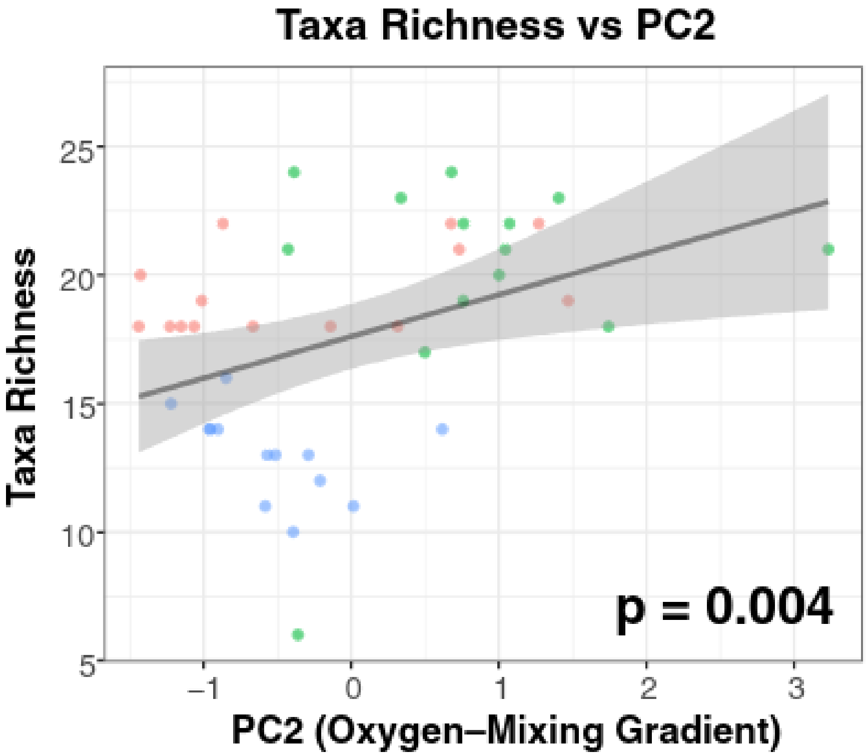
Results: Taxa Richness

Environmental Linear Regression Models	
Model	**AICc**
PC1	231.14
PC1 + PC2	224.63



Richness decreases as PC1 increases

- Warmer temperatures (1.63)
- Higher day of year (1.59)
- Lower chlorophyll a (-1.42)
- Lower salinity (-1.09)

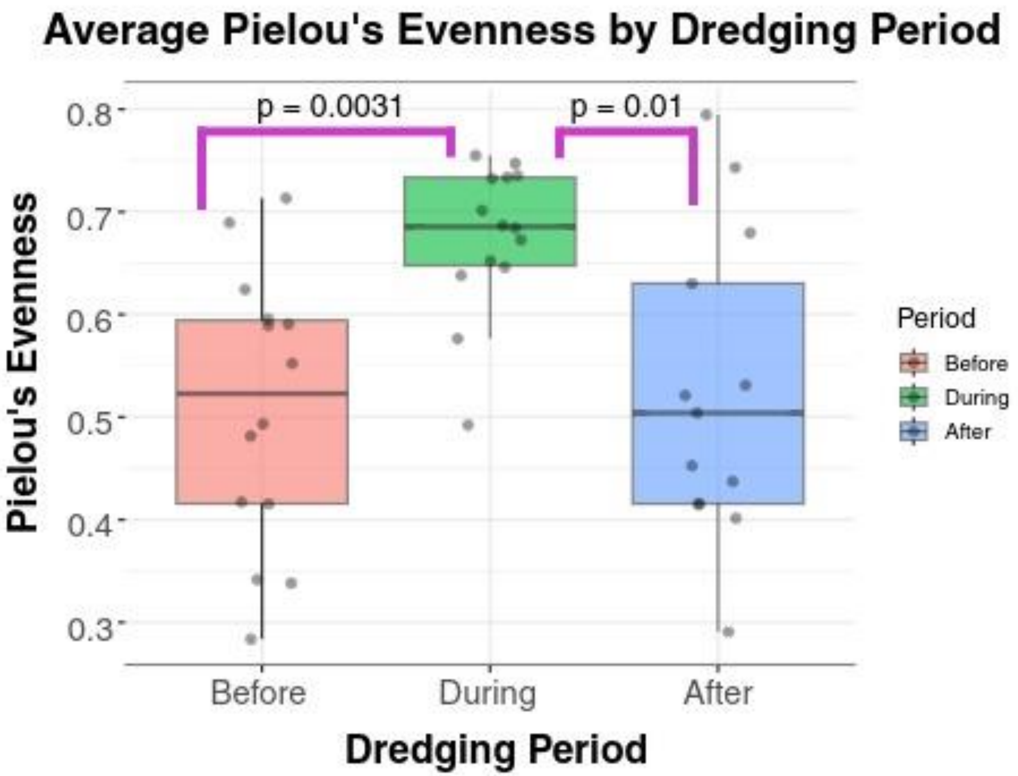


Richness increases as PC2 increases

- Higher Dissolved Oxygen (2.37)
- Lower salinity (-1.81)

Results: Diversity – Pielou's Evenness

Pielou's Evenness ~ **Period** + Distance + Period:Distance
p <0.001



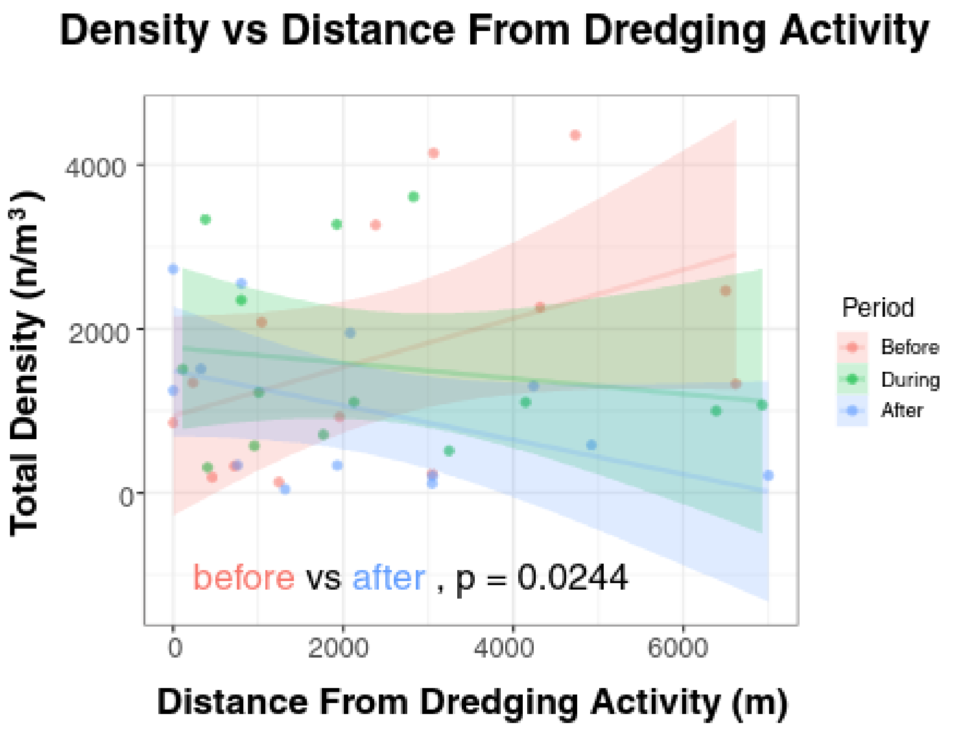
Environmental Linear Regression Models		
Model	**AICc**	**P-value**
PC1	-39.89	
PC1 + PC2	-40.91	P = 0.074

- Evenness was higher during dredging than both before and after
- No environmental PCAs were significant ($p<0.05$)

Results: Total Zooplankton Density

Density~ Period + Distance + **Period:Distance**

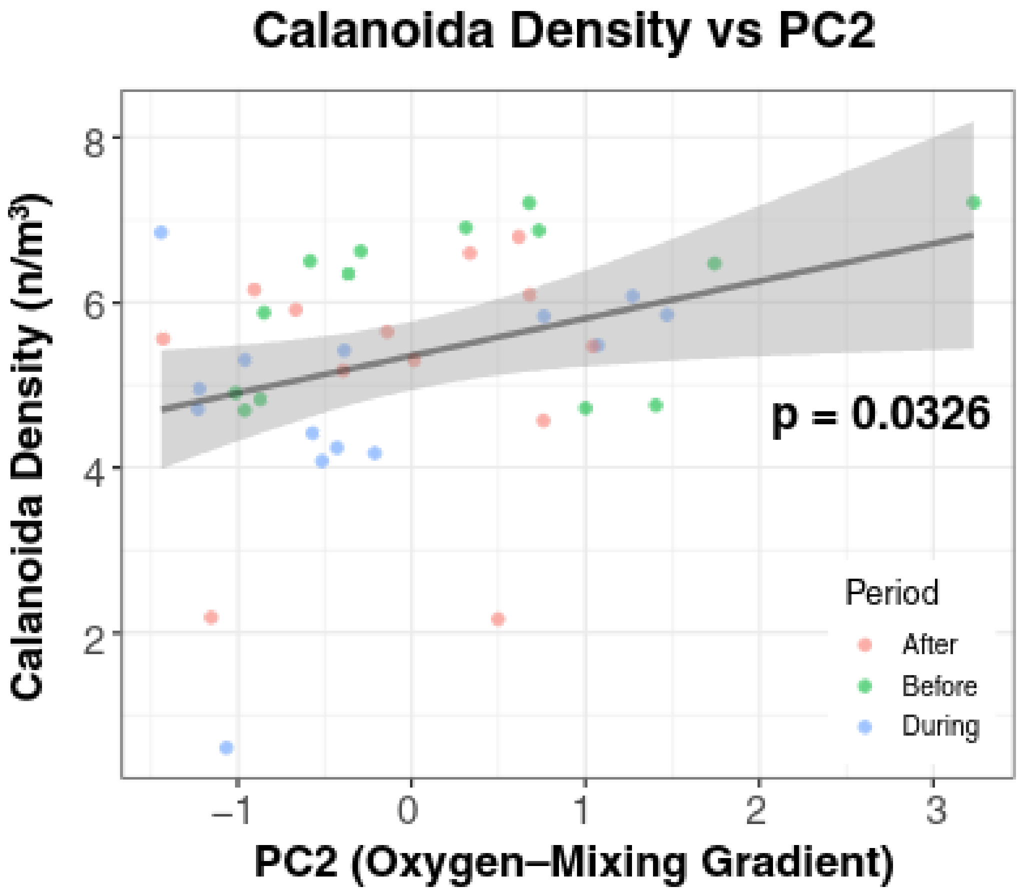
ANCOVA: p = 0.07
T-test (slope of before vs after), p = 0.0244



- Higher densities were observed closer to the dredging sites after dredging
  - Spatial effects may exist in the environment, but dredging may not have a strong **negative spatial footprint**
- Environmental PCs were not significant

Environmental Linear Regression Models	
Model	**AICc**
PC1	**130.69**
PC1 + PC2	131.29

Results: Calanoida Density



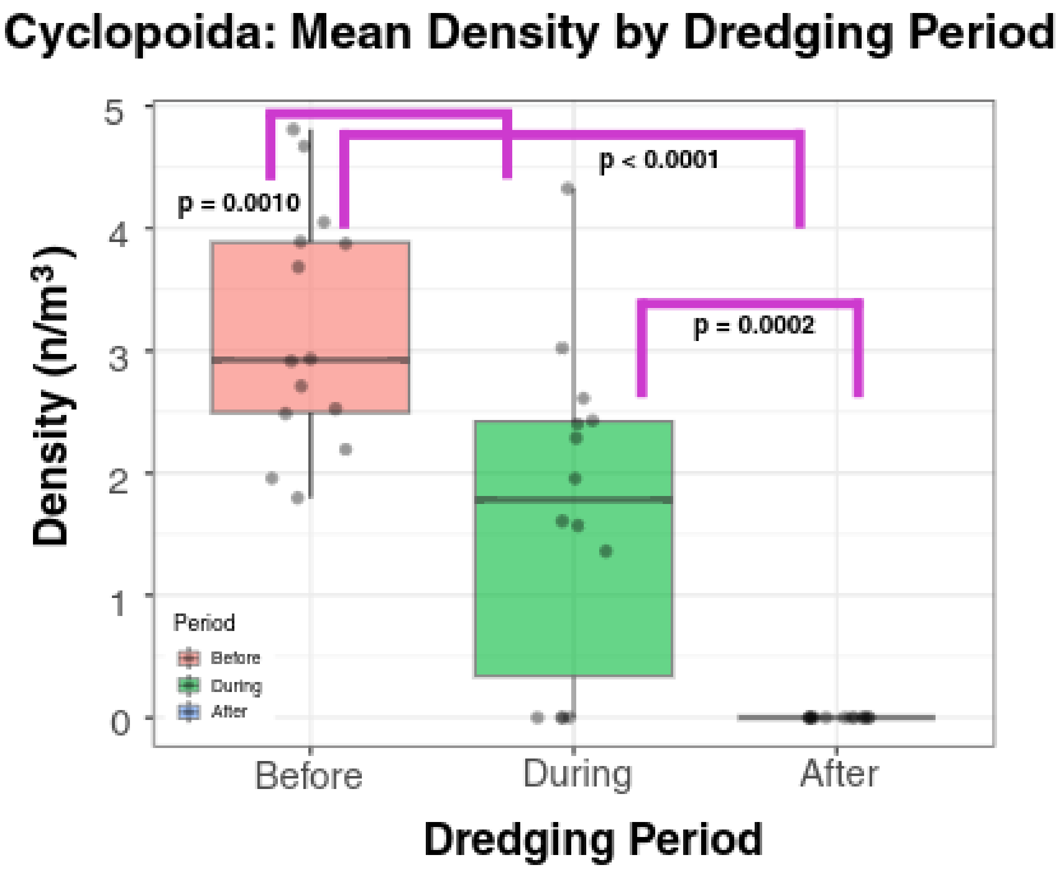
- **No Dredging Effects**: Density ~ Period + Distance + Period:Distance
- Calanoida density is positively correlated to PC2
  - Higher Dissolved Oxygen (2.37)
  - Lower salinity (-1.81)

Environmental Linear Regression Models	
Model	**AICc**
PC1	148.49
PC1 + PC2	**145.96**

Results: Cyclopoida Density

Density ~ **Period** + Distance + Period:Distance

$p < 0.0001$



- Density was **lower after** dredging compared to **before and during**
- Density was **lower during** dredging than **before** dredging
- Densities are typically highest in the summer (Thayer et al. 1974 &Fulton 1984)
- Environmental PCs were not significant

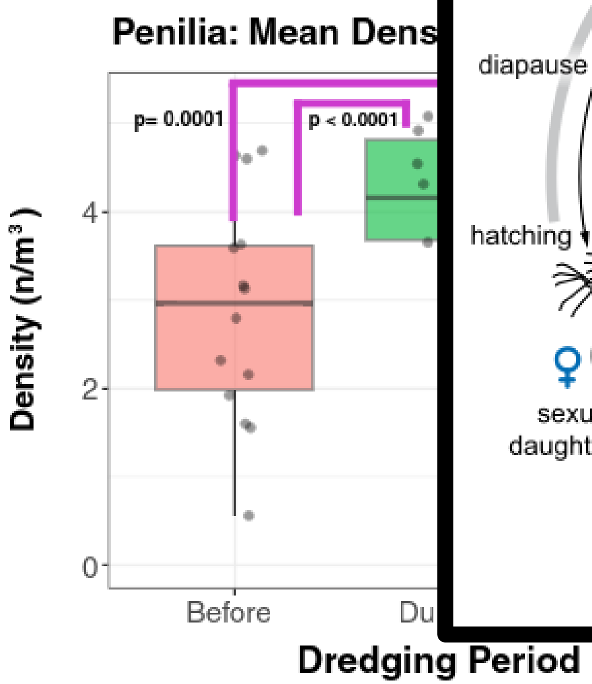
Environmental Linear Regression Models	
Model	**AICc**
PC1	160.14
PC1 + PC2	160.38

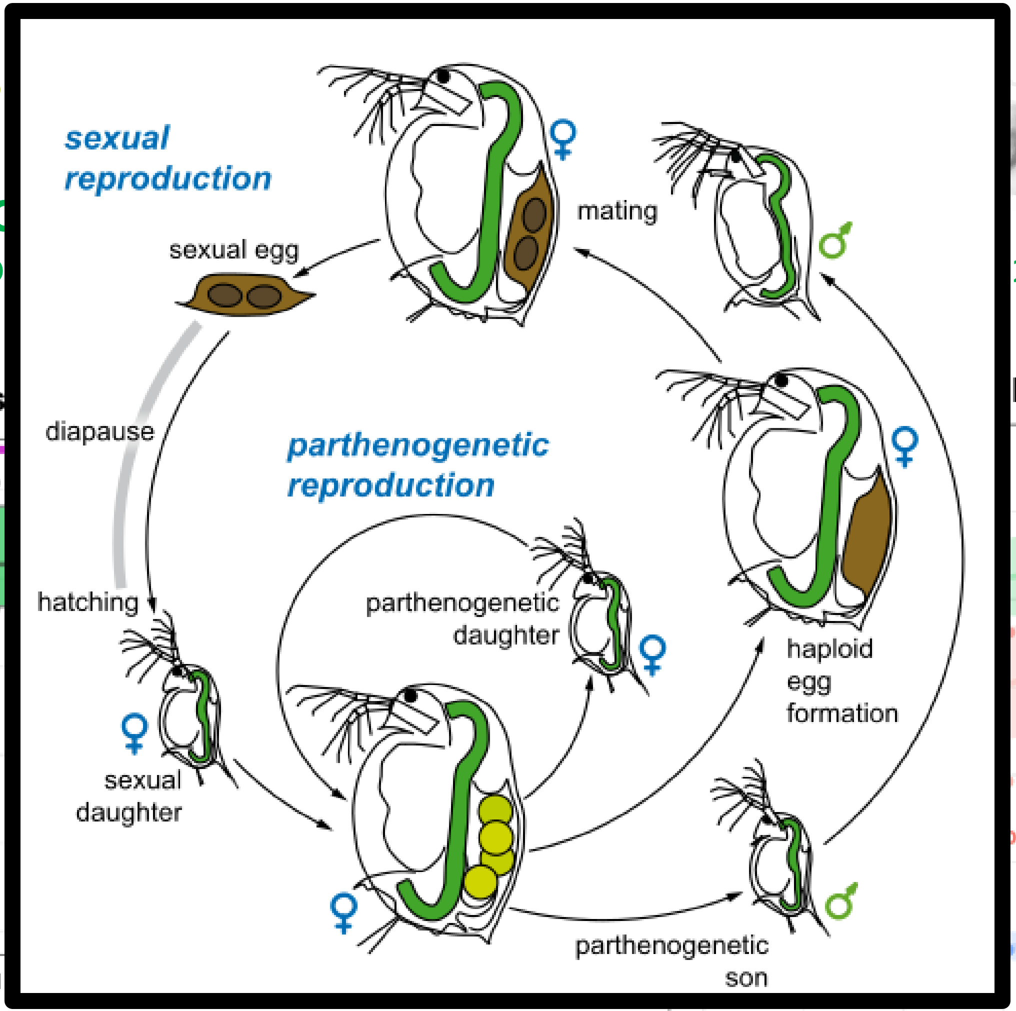
Results

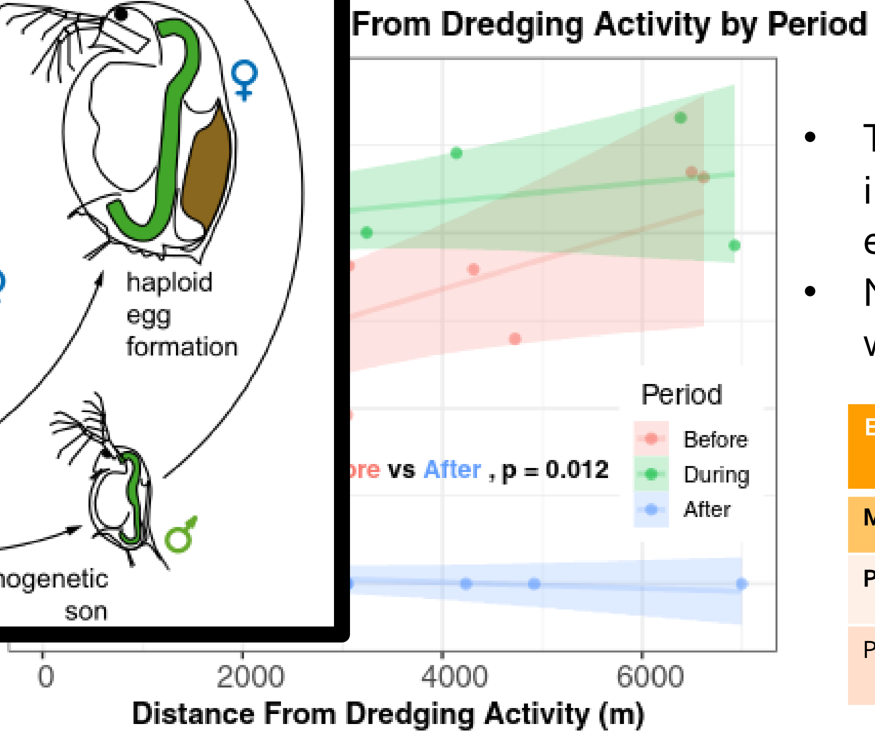
Density ~ **Peri**

p <0.00

2 (T-test , Before vs After slopes)







- Density **during** dredging is **higher** than **both before and after** dredging
- Density **after** dredging is **lower** than before dredging.

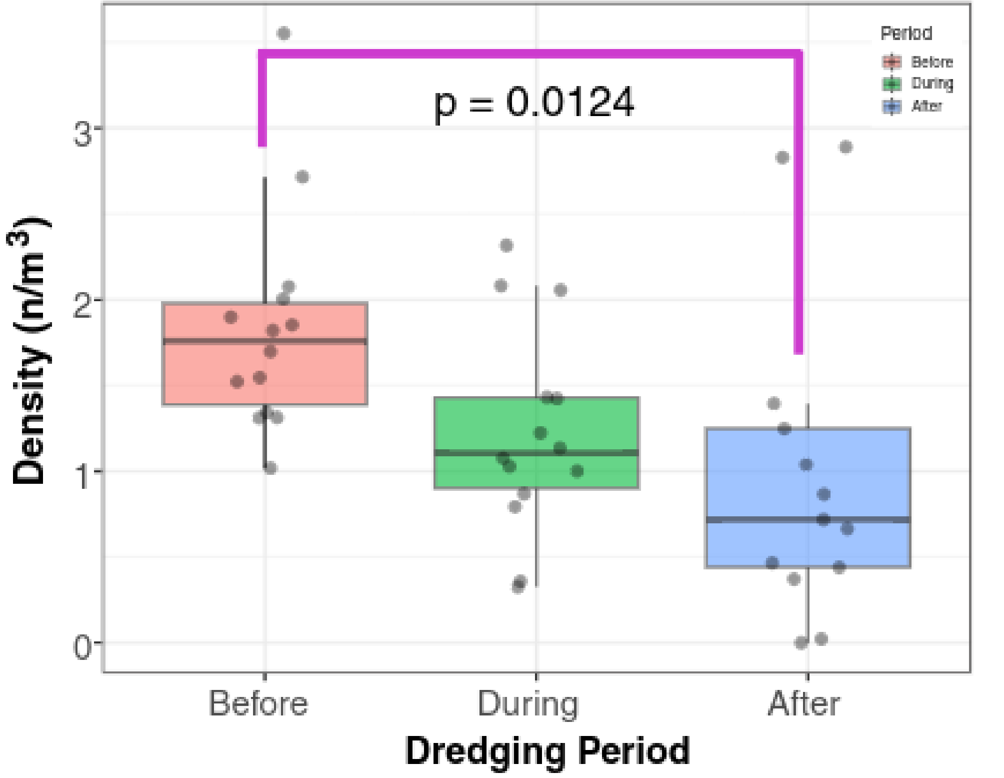
- Before dredging, densities were higher in areas farther away from the dredging channel

- Typically, most abundant in late summer in NC estuaries (Sutcliffe 1950)
- No environmental PCs were significant

Environmental Linear Regression Models	
Model	**AICc**
PC1	**175.08**
PC1 + PC2	177.53

Results: Actinopterygii Density

Density ~ **Period** + Distance + Period:Distance
p = 0.0126



- Decline in density over time (density before is higher than after dredging)
  - No immediate recovery after dredging
- No environmental PCs were significant

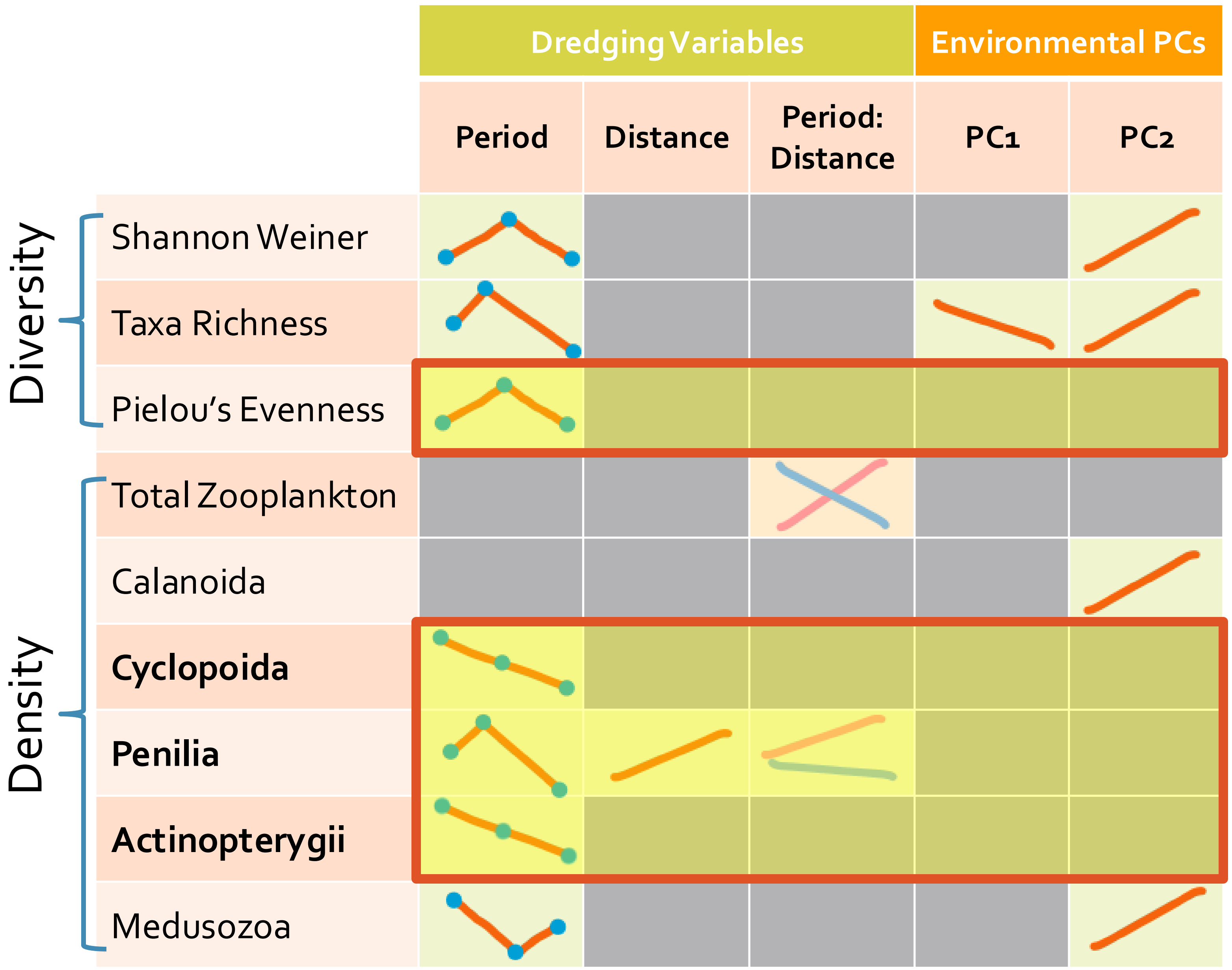
Environmental Linear Regression Models	
Model	**AICc**
PC1	**103.66**
PC1 + PC2	105.49

Conclusions

- **Diversity**: Not reduced by dredging; driven by environmental factors
  - **Evenness:** Temporary peaks during dredging (environmental influence)

- **Density Responses**: Taxon-specific, may be shaped by:
  - Reproductive strategies
  - Feeding mode
  - Water column position
  - Lifecycle length

- **Spatial Footprint:** No negative density effect from dredging across sites
  - **Local Peaks:** High densities near channel may be from turbulence and altered hydrology

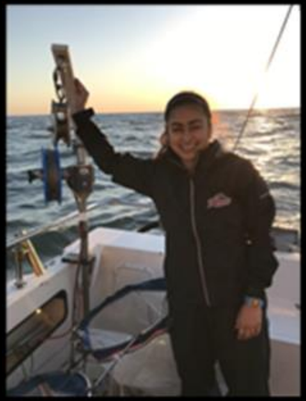


Next Steps:

- Increasing taxonomic resolution through microscopy and sub-sampling
- Taxon-specific in-situ experiments to isolate dredging effects
- Include wind vectors in environmental PCA
- Compare zooplankton responses to Beaufort Inlet data
- Variance partitioning:
  - Use a partial redundancy analysis to look at environmental versus dredging effects

Questions?

Thank you!



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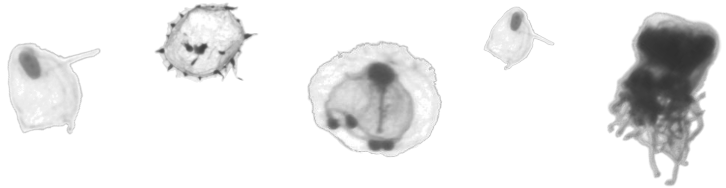
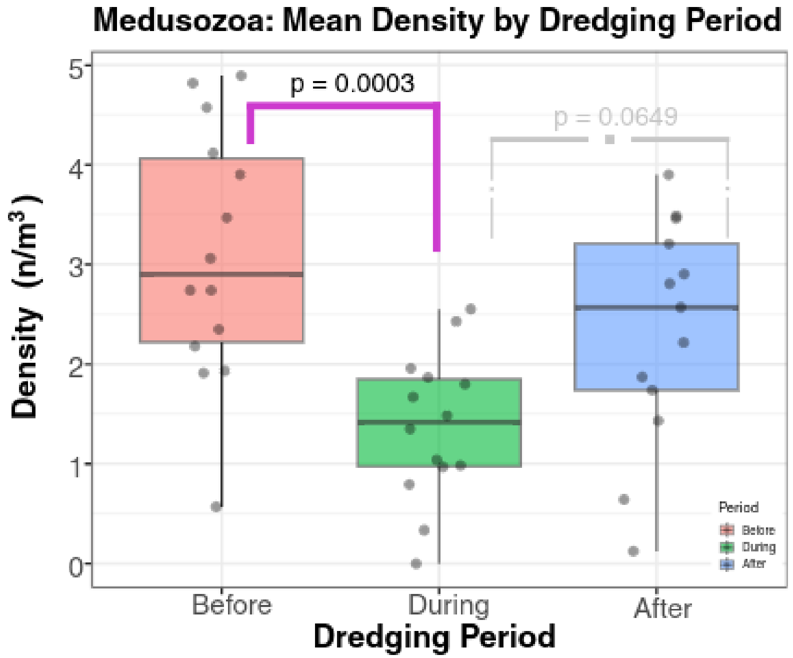
Results: Medusozoa Density



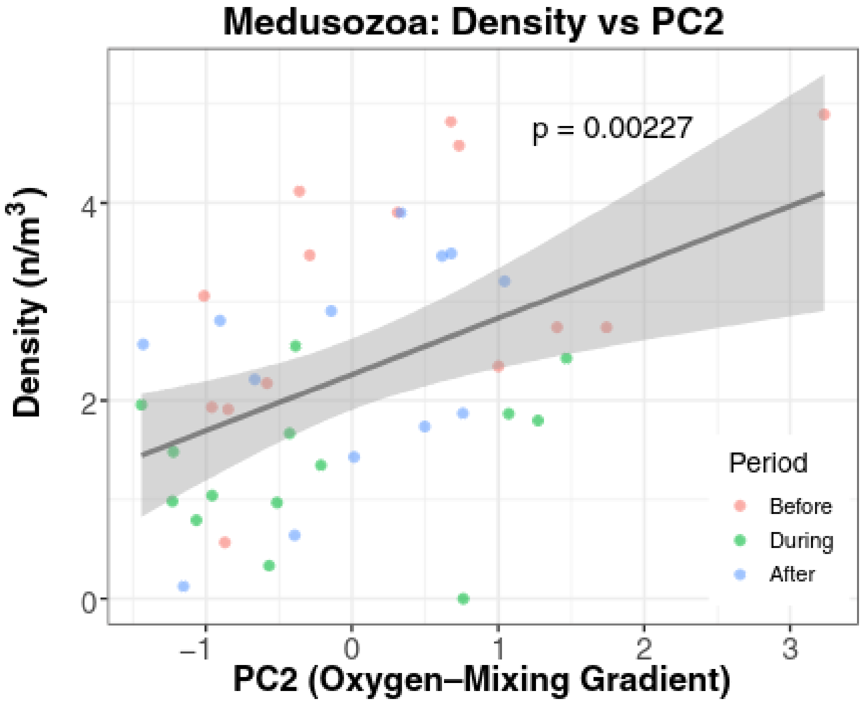
Density ~ Period + Distance + Period:Distance

p = 0.0004



Environmental Linear Regression Models

Model	AICc
PC1	140.37
PC1 + PC2	**132.64**



Pielou's Evenness vs PC2