ALGAE-REDUCING ECOSYSTEM SERVICES OF A NATIVE BIVALVE IN AN URBAN ESTUARY

ALLY KIDO

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UMBC

IMET

ICARE
Ecology • Engineering • Social Science • Policy

OUTLINE

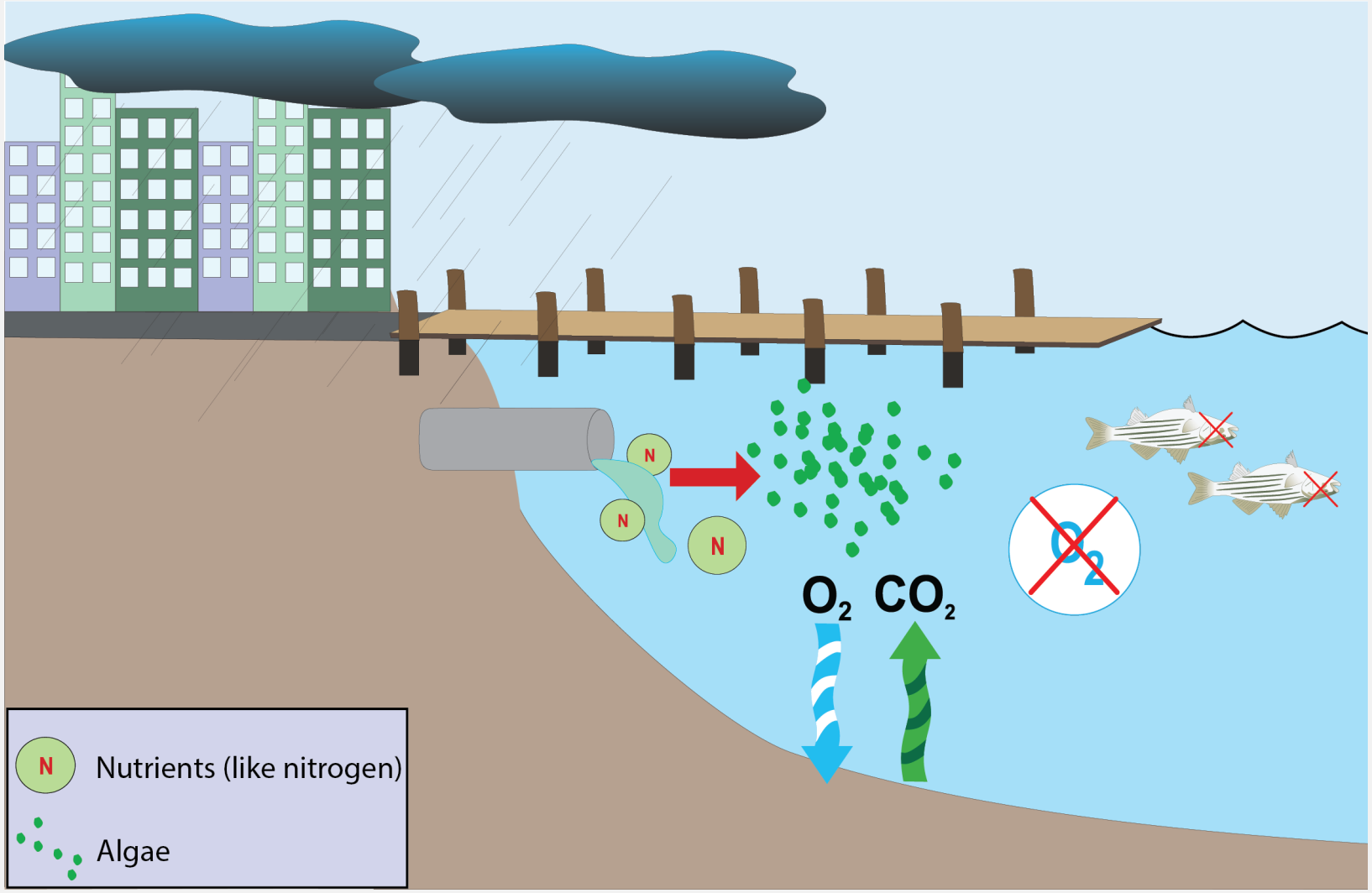
- Background
- Study System
- Research Aims
- Experiments and Results
- Conclusions and Future Directions


Marshalls
SEAFOOD
BARNES & NOBLE

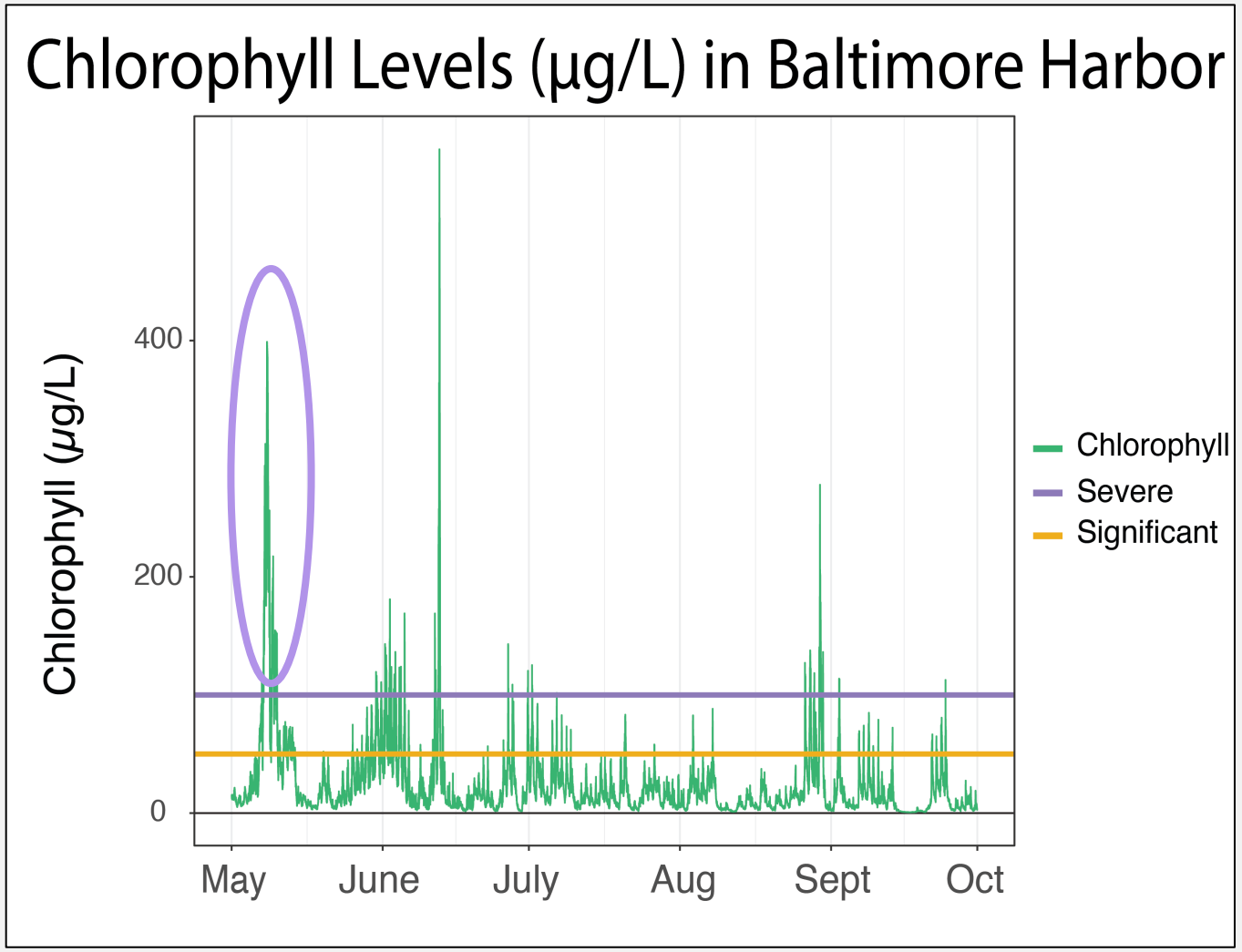
WHY ARE EXCESS NUTRIENTS BAD?

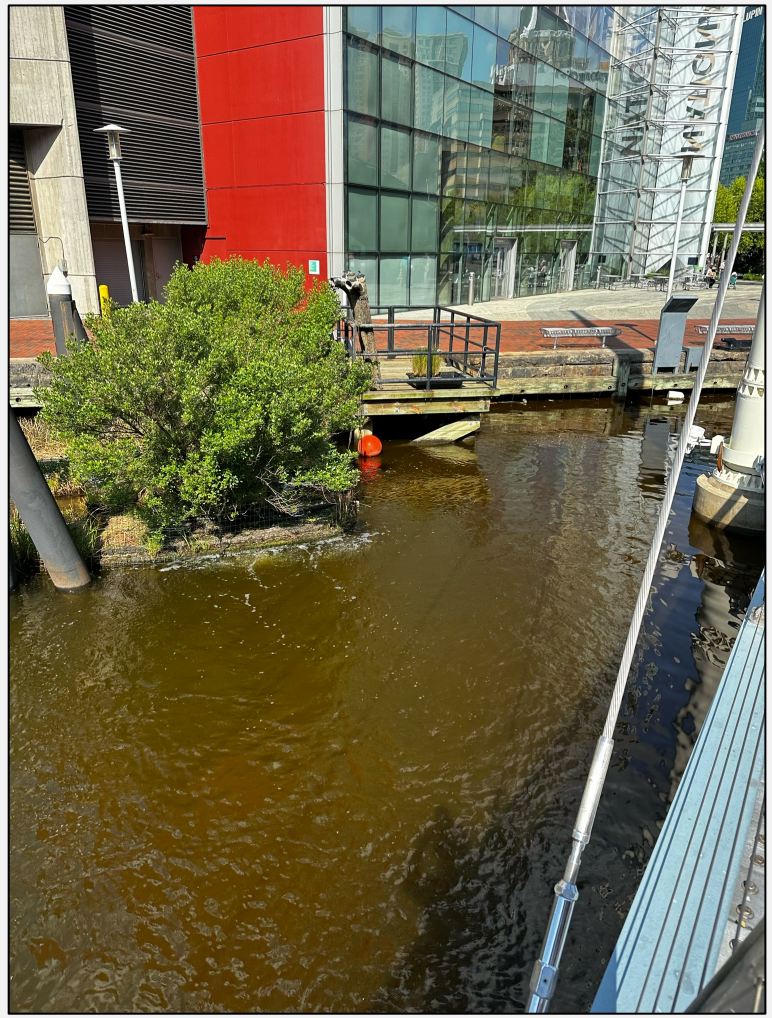
Algae Blooms

- Reduces oxygen
- Creates hypoxic and anoxic zones
- Not good for other animals in the water



ALGAE BLOOMS ARE FREQUENT IN BALTIMORE HARBOR

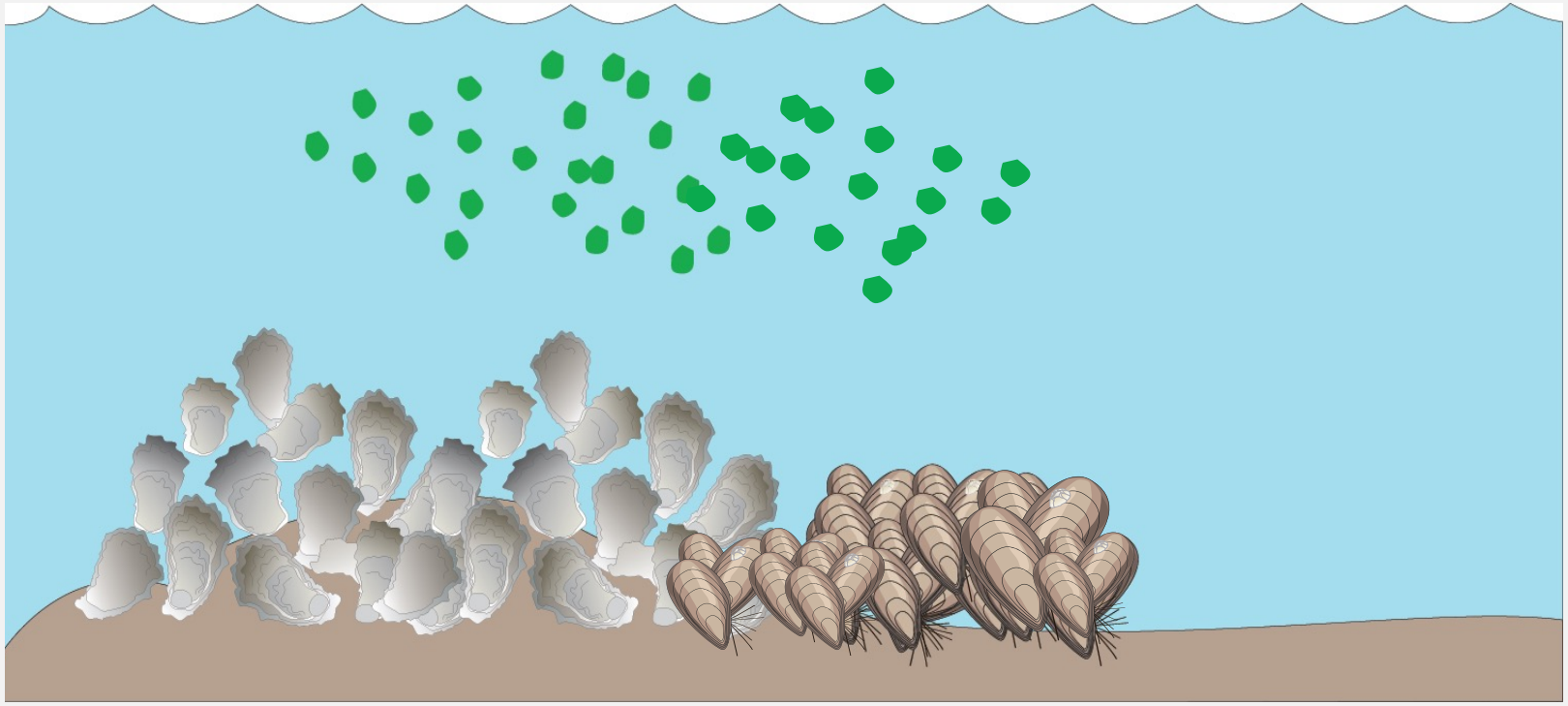




WAYS TO REDUCE ALGAE IN THE WATER

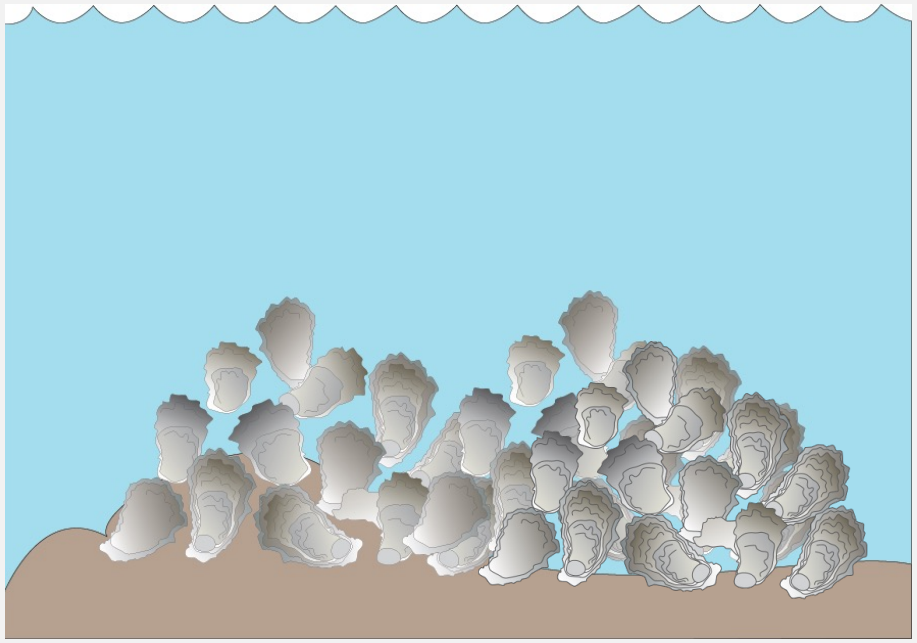
HOW CAN BIVALVES CLEAR THE WATER?

- Bivalves are filter feeders
- Sort through particles and use nutrients for growth
- Unused particles are returned as:
  - Feces/Pseudofeces
  - Dissolved nutrients
- This is an ecosystem service provided by the bivalve



OYSTER NUTRIENT CREDIT TRADING

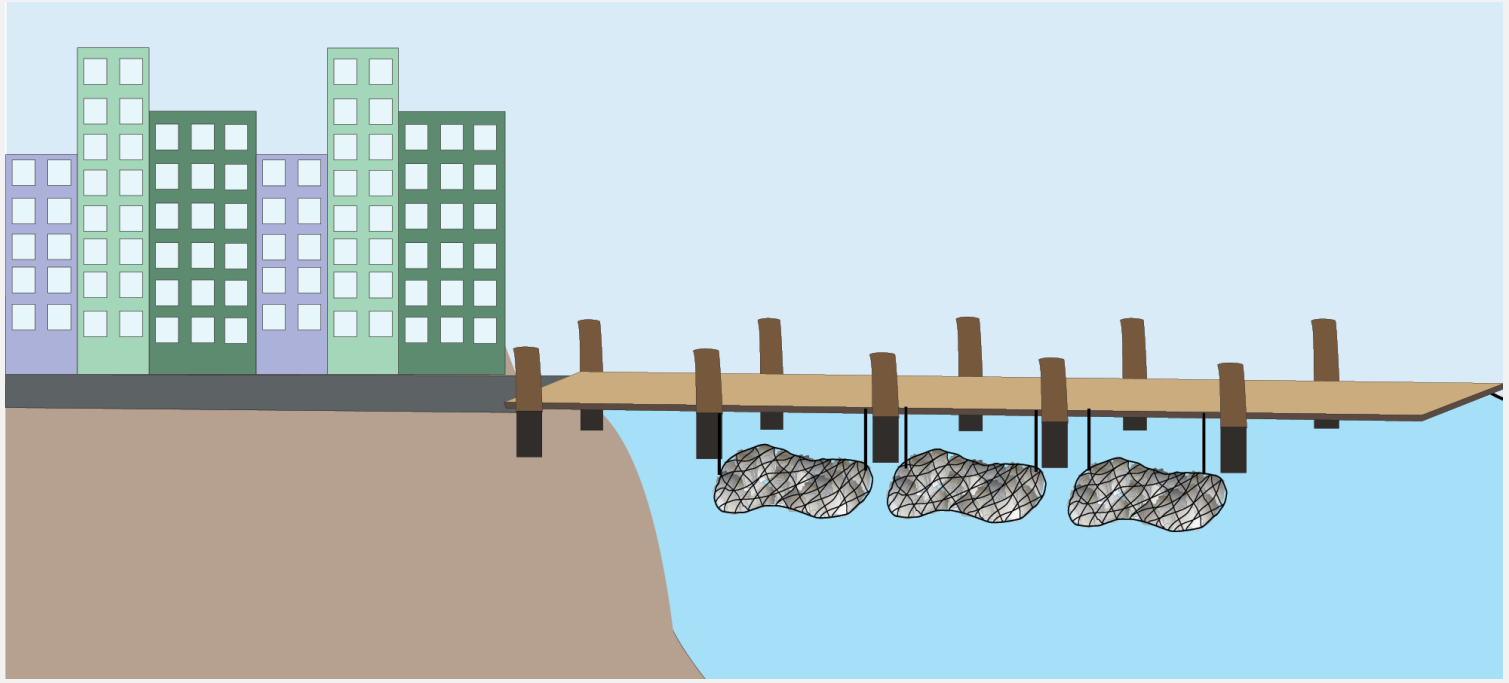
Oyster Growers



Nutrient Market

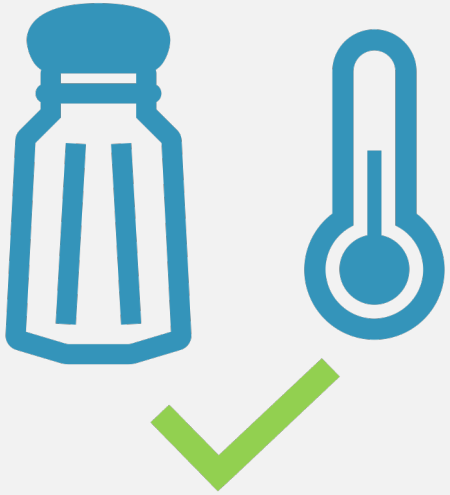
Groups that need to reduce nutrient input

DO OYSTERS GROW IN BALTIMORE HARBOR?



- Oyster gardening does occur, but oysters are moved to restoration sites
- No natural oyster populations
- Bacteria contamination
- Low salinity water

DARK FALSE MUSSEL (*MYTILOPSIS LEUCOPHAEATA)*



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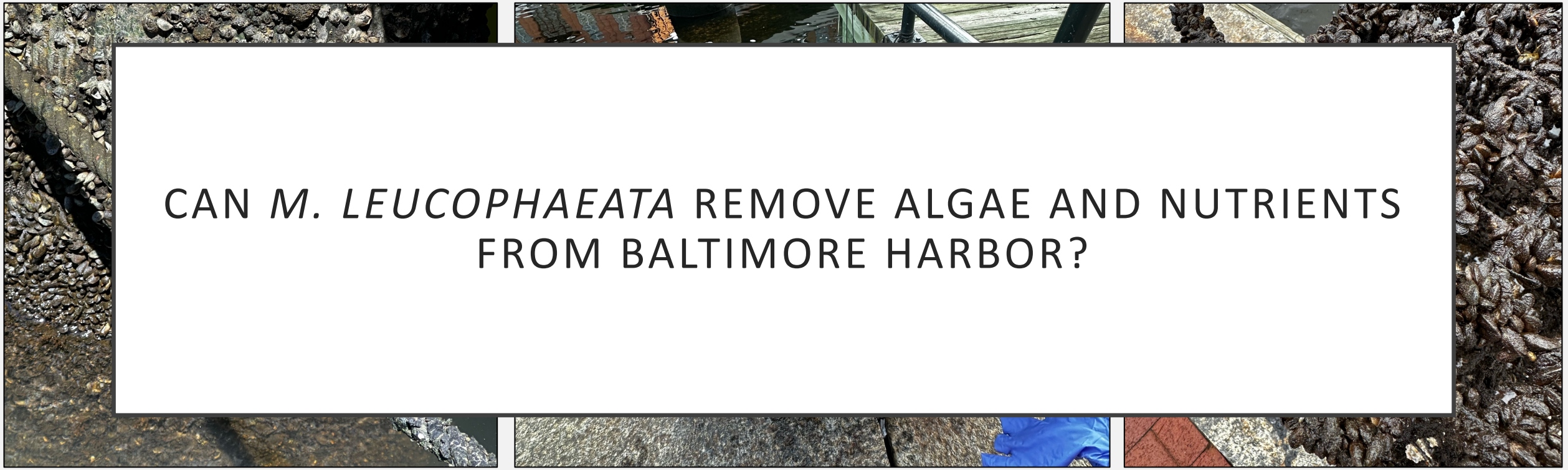

CAN *M. LEUCOPHAEATA* REMOVE ALGAE AND NUTRIENTS FROM BALTIMORE HARBOR?

RESEARCH AIMS

1. Determine if *M. leucophaeata* can reduce cultured algae

2. Examine the effect of water temperature on clearance rate

3. Examine the effect of water salinity on clearance rate

4. Determine if *M. leucophaeata* can reduce natural algae blooms

METHODS

- In vitro chlorophyll (IVCH)
- Algae counts
- Carbon and nitrogen analysis
- Extracted total chlorophyll

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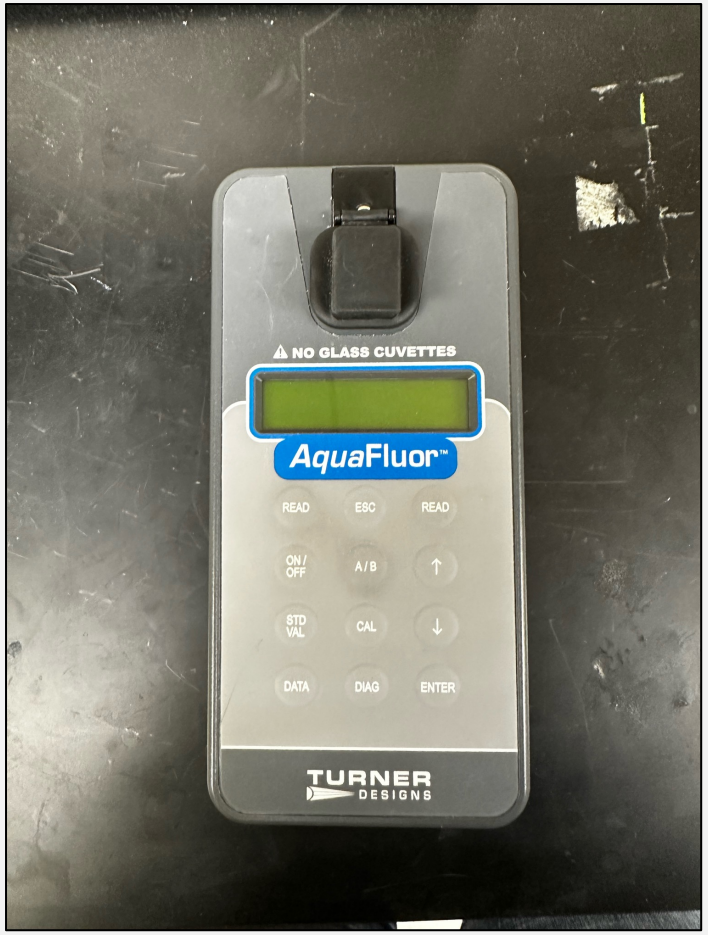

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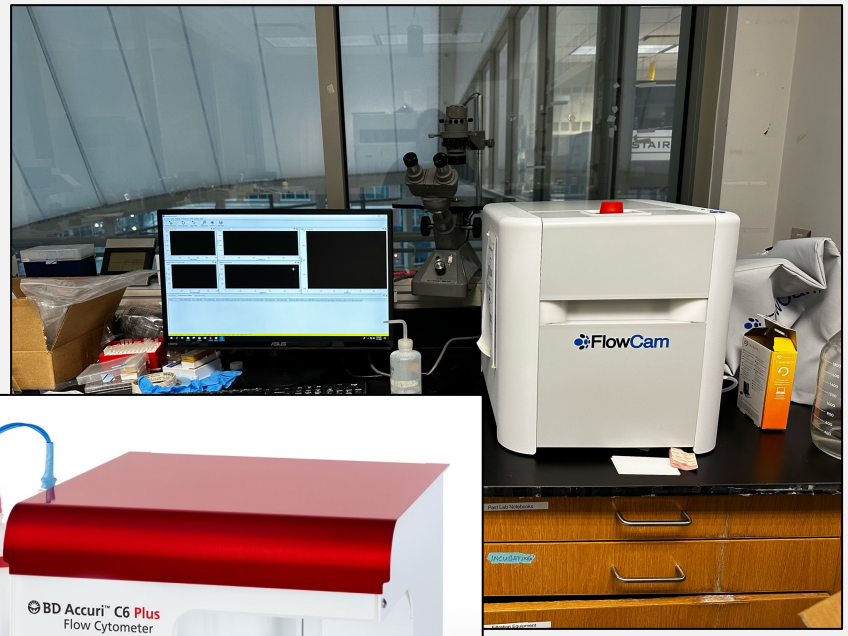
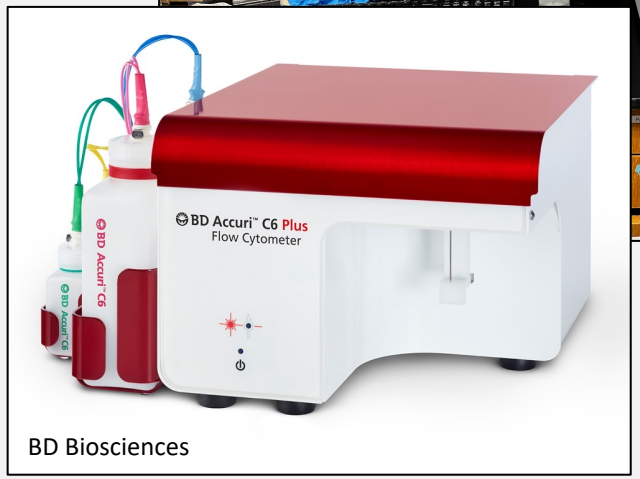
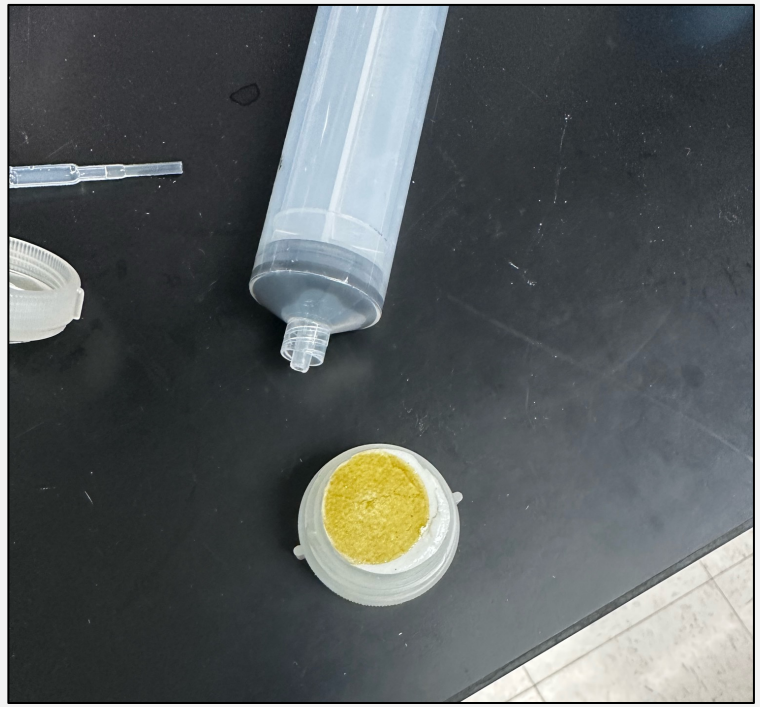




BD Biosciences

METHODS

- In vitro chlorophyll (IVCH)
- Algae counts
- Carbon and nitrogen analysis
- Extracted total chlorophyll (fluorometer)



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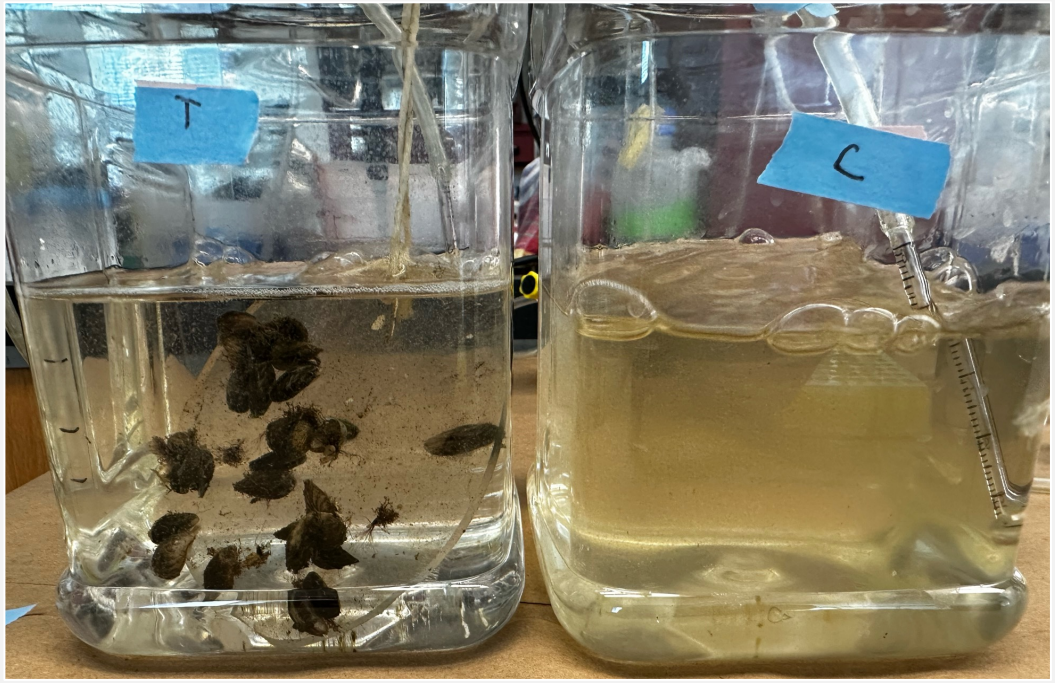
AIM 1 METHODS – ALGAE SPECIES

- 1000 ml of water
- ~20 mussels per container
- 2 algae species:
  - *Isochrysis*
  - *Chaetoceros*
- Water collections: 0, 2, 4, 6, and 22.5 hours

Isochrysis *Chaetoceros*

TYPES OF SAMPLES COLLECTED

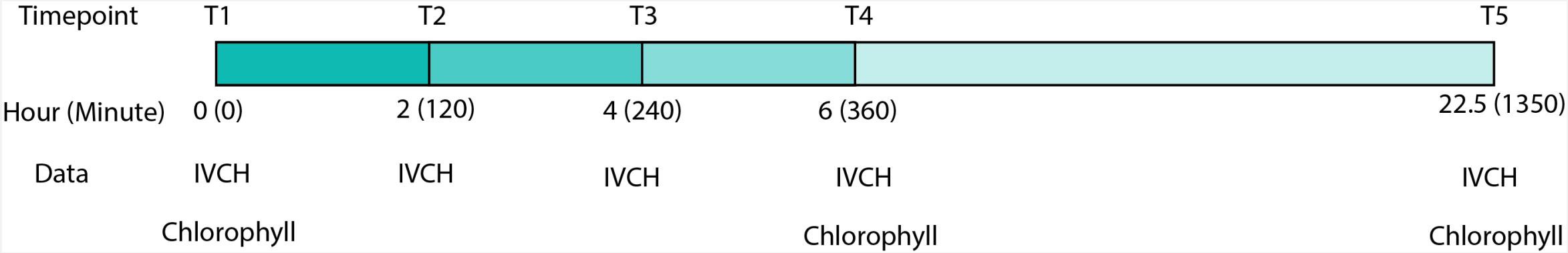


Mussel Treatment

No-Mussel Treatment

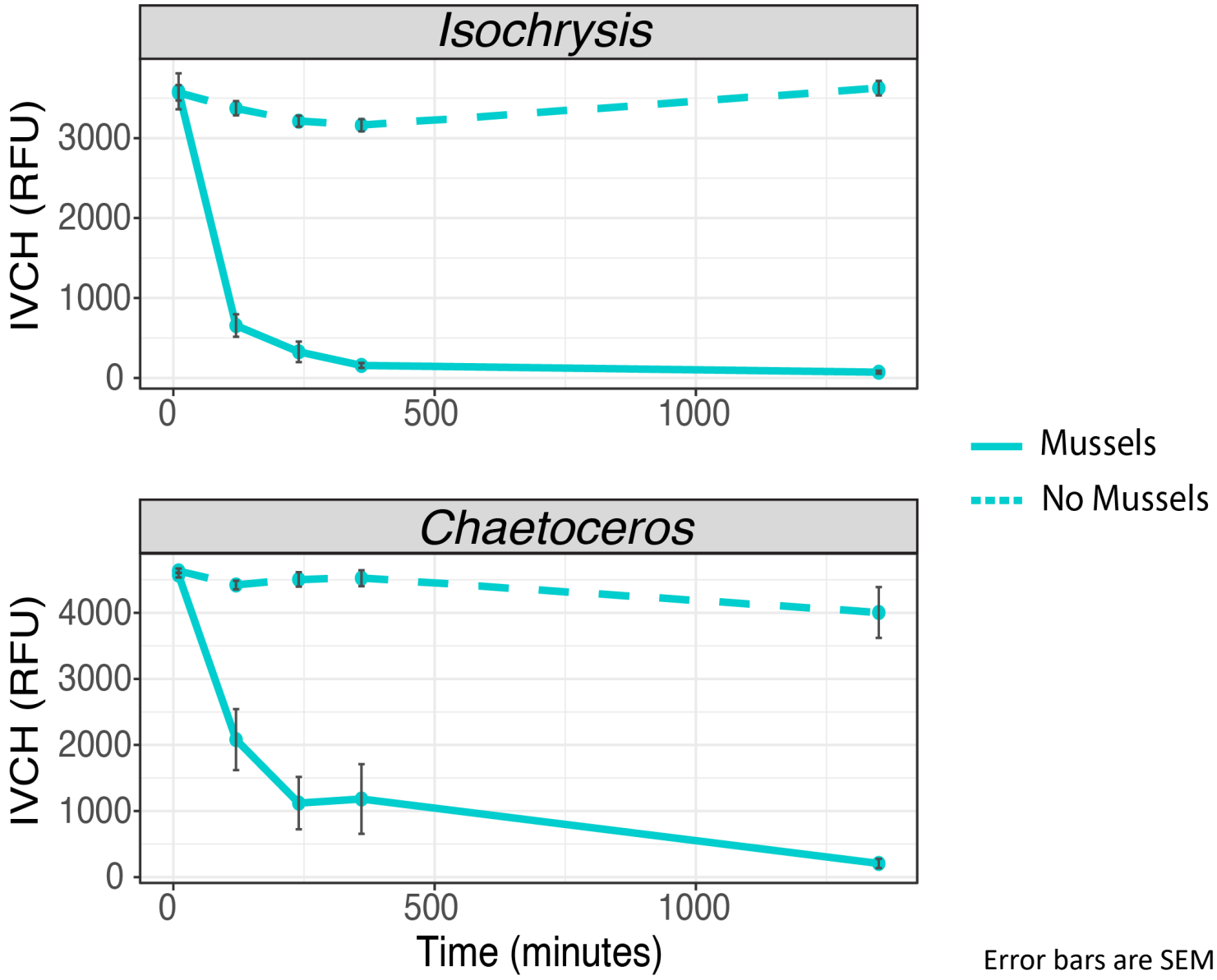
- In vitro chlorophyll (IVCH)
- Chlorophyll extractions

COLLECTION TIMELINE



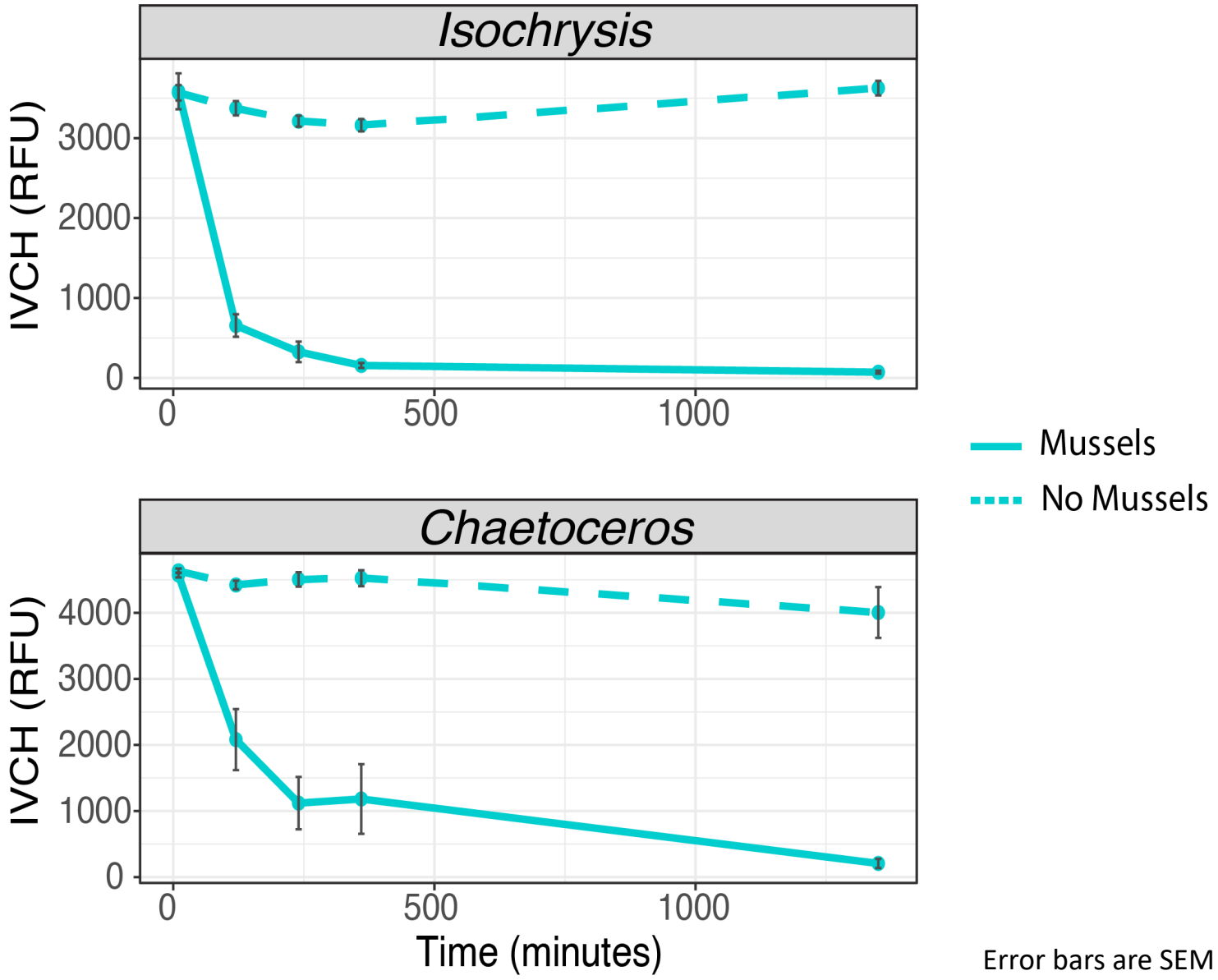
MUSSELS CAN REDUCE CULTURED ALGAE IVCH LEVELS

Effect of Treatment:
Isochrysis – **p < 0.001**
Chaetoceros – **p < 0.001**



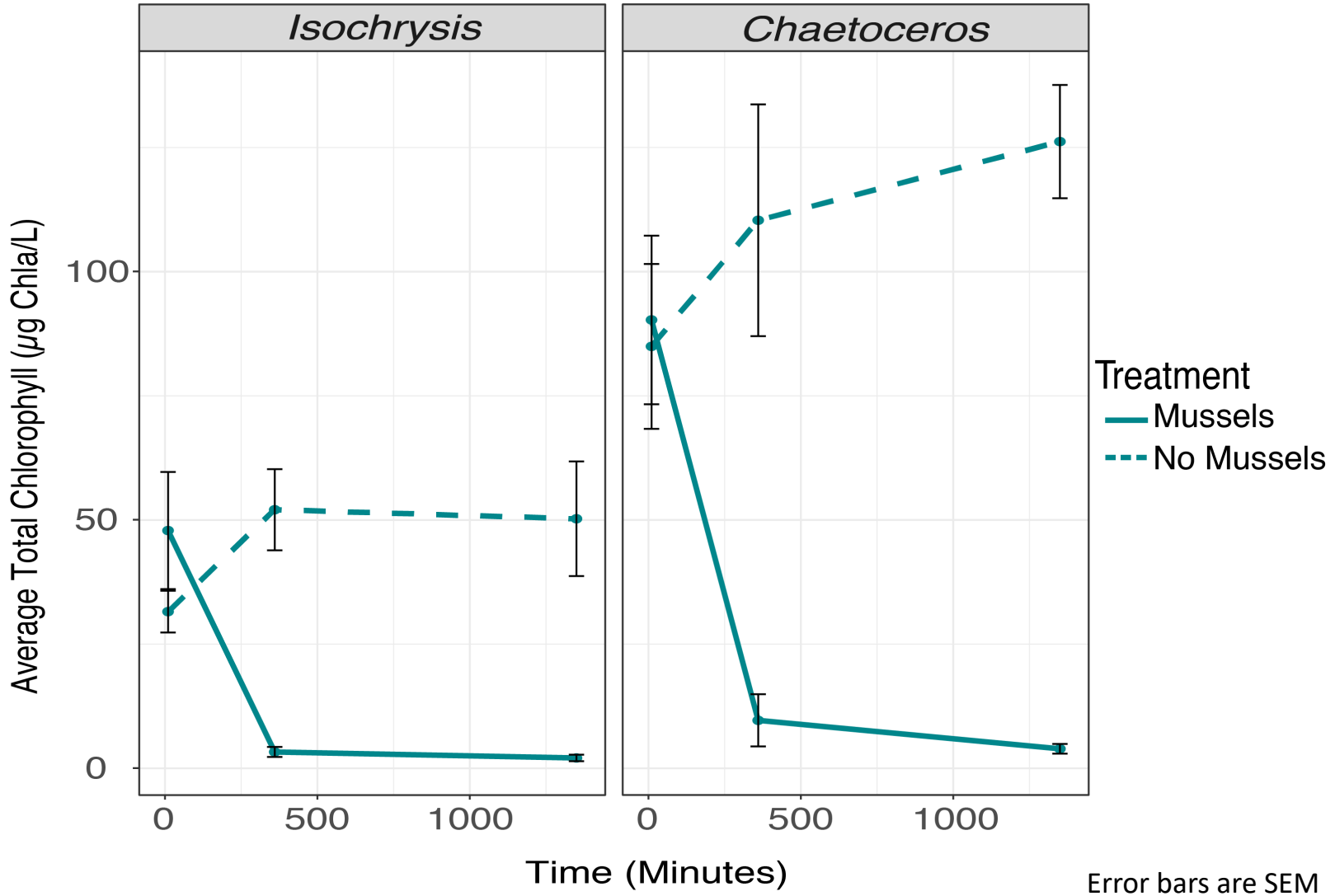
MUSSELS CAN REDUCE CULTURED ALGAE IVCH LEVELS

Effect of Time	Iso.	Chaet.
Mussels	**p < 0.001**	**p < 0.001**
No Mussels	**p < 0.001**	0.088



MUSSELS CAN REDUCE EXTRACTED CHLOROPHYLL

Effect of Treatment:
Isochrysis – **p = 0.011**
Chaetoceros – **p = 0.002**



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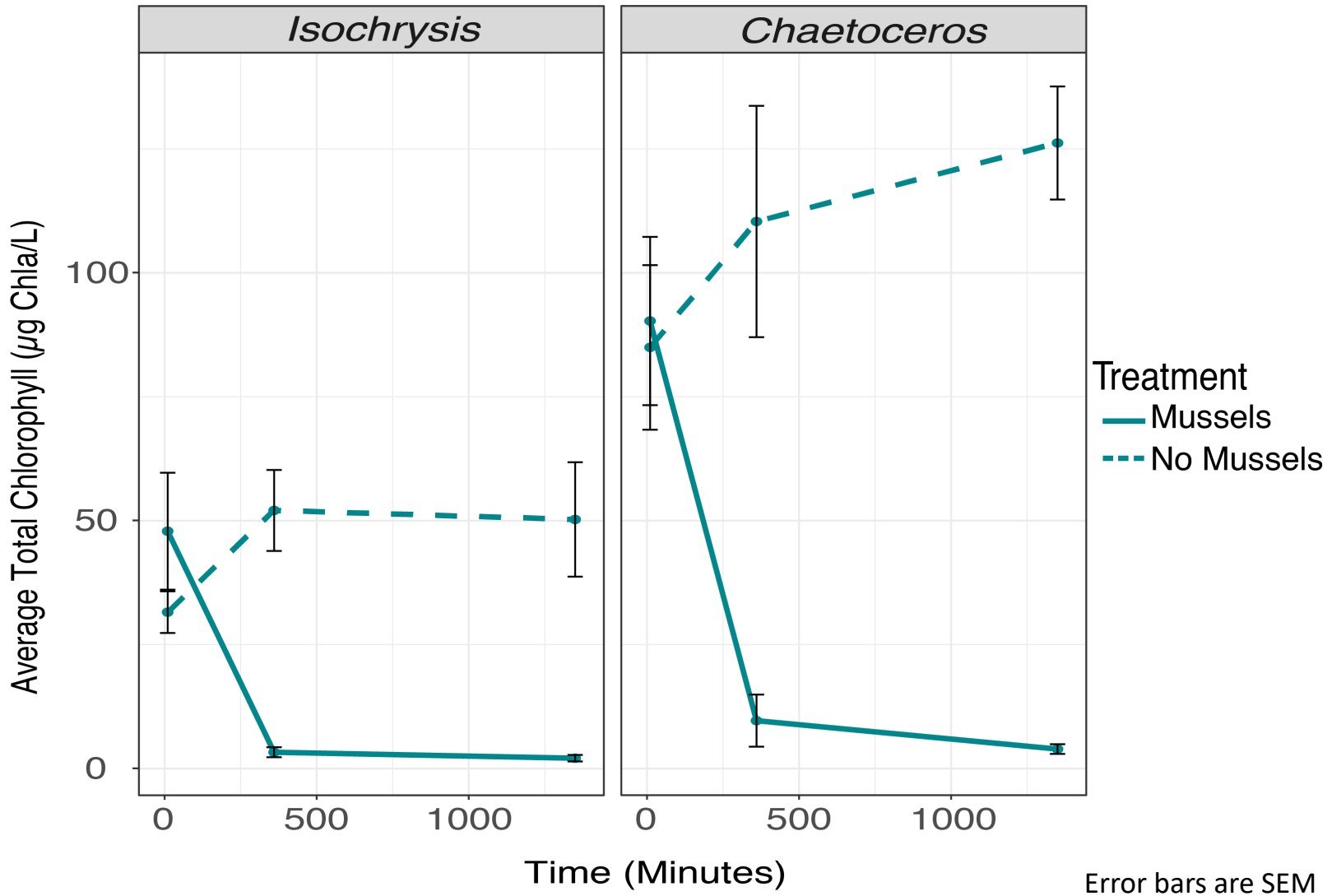
MUSSELS CAN REDUCE EXTRACTED CHLOROPHYLL

Effect of Time	Iso.	Chaet.
Mussels	**0.039**	**0.001**
No Mussels	0.717	0.135



CONCLUSIONS AIM 1

- Mussels can reduce cultured algae
- Time has a significant effect on chlorophyll (IVCH and extracted) levels

RESEARCH AIMS

1. Determine if *M. leucophaeata* can reduce cultured algae

2. Examine the effect of water temperature on clearance rate

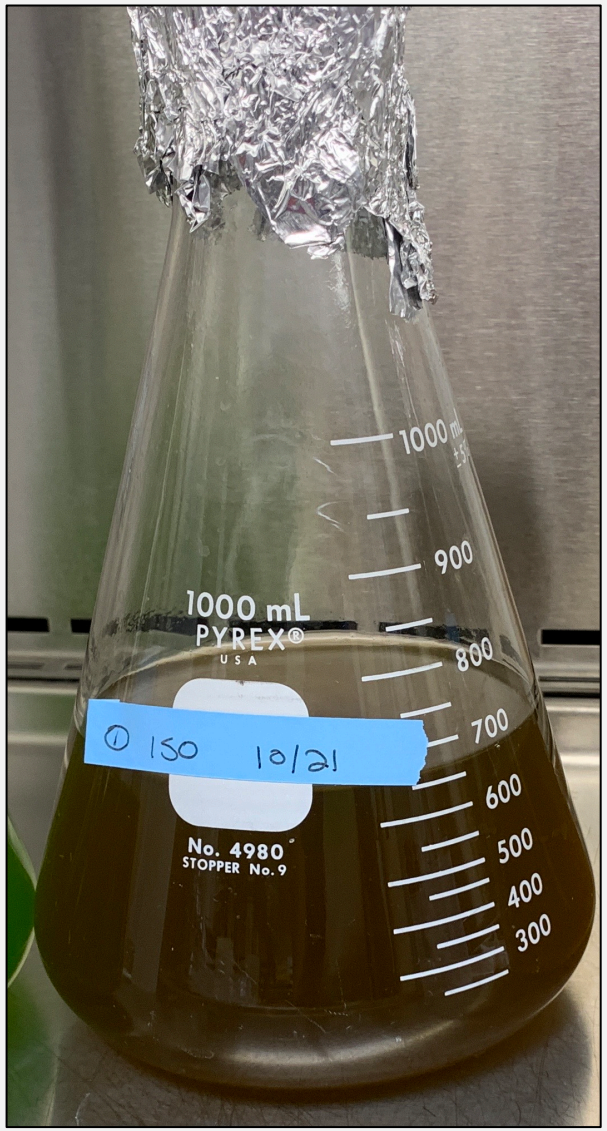
3. Examine the effect of water salinity on clearance rate

4. Determine if *M. leucophaeata* can reduce natural algae blooms

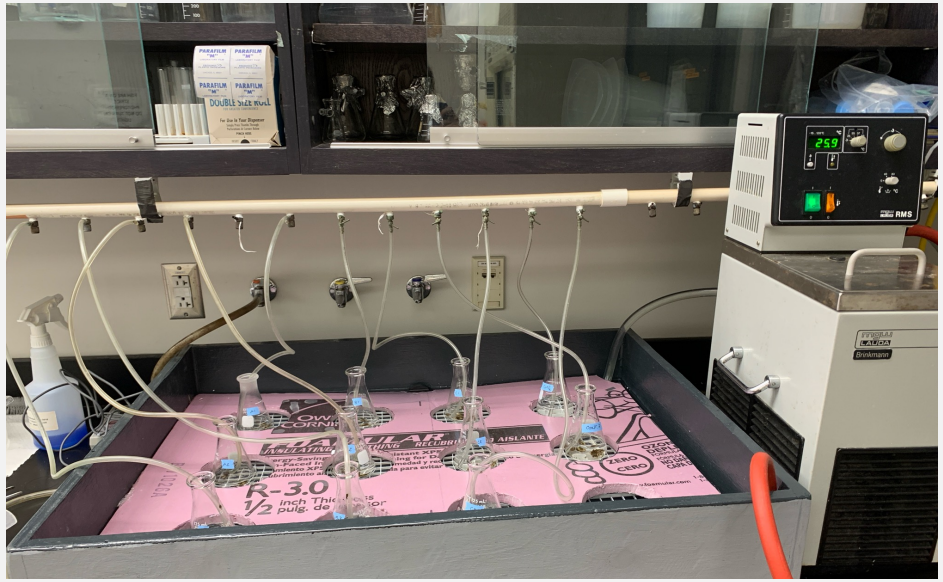
AIM 2 METHODS - TEMPERATURE

- 500 or 800 ml of water
- ~10 mussels per container
- Temperatures: 10, 20, and 30˚C
- Water collections: 0, 2, 4,and 6 hours

Noah Mansfield

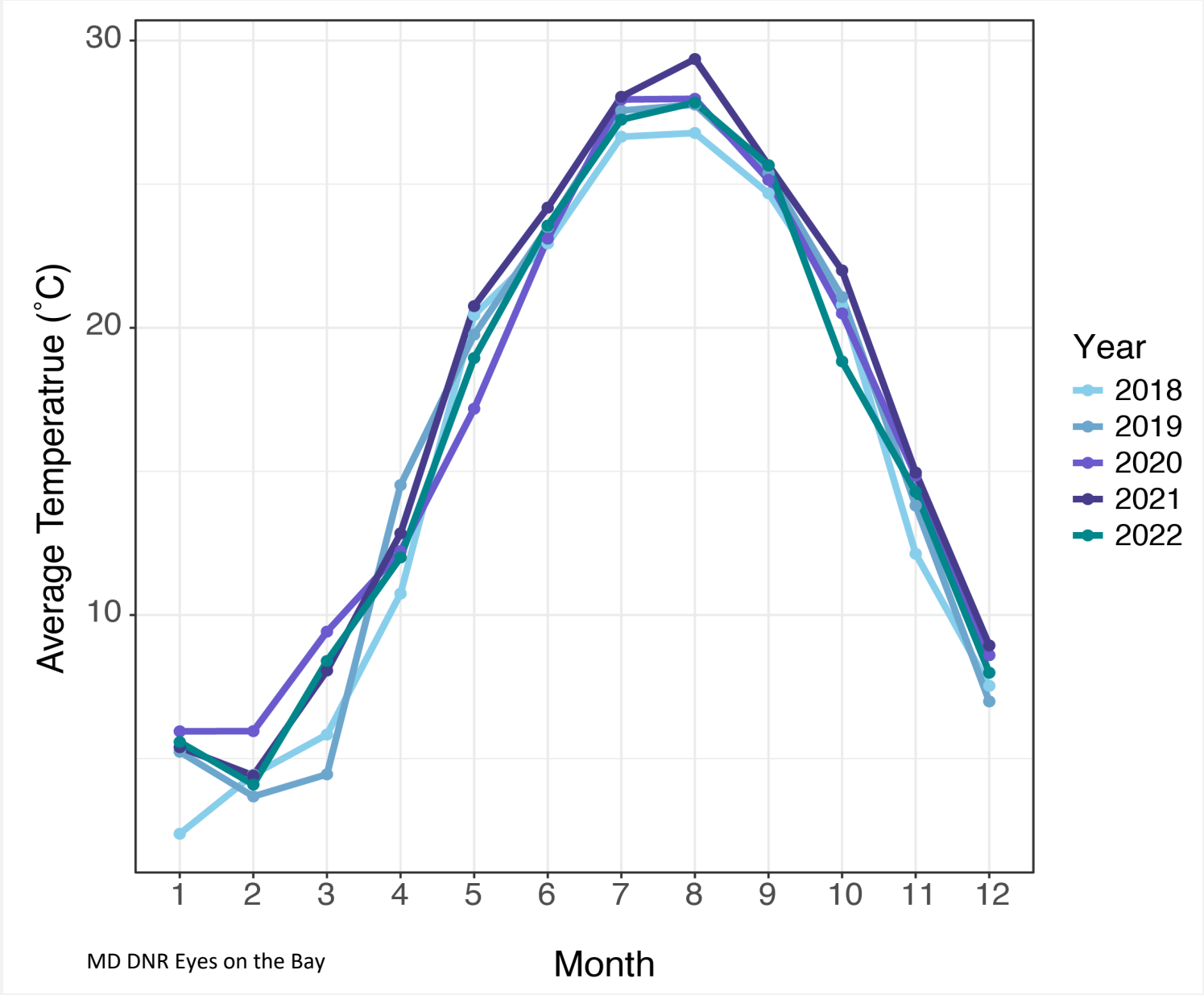


Isochrysis algae culture



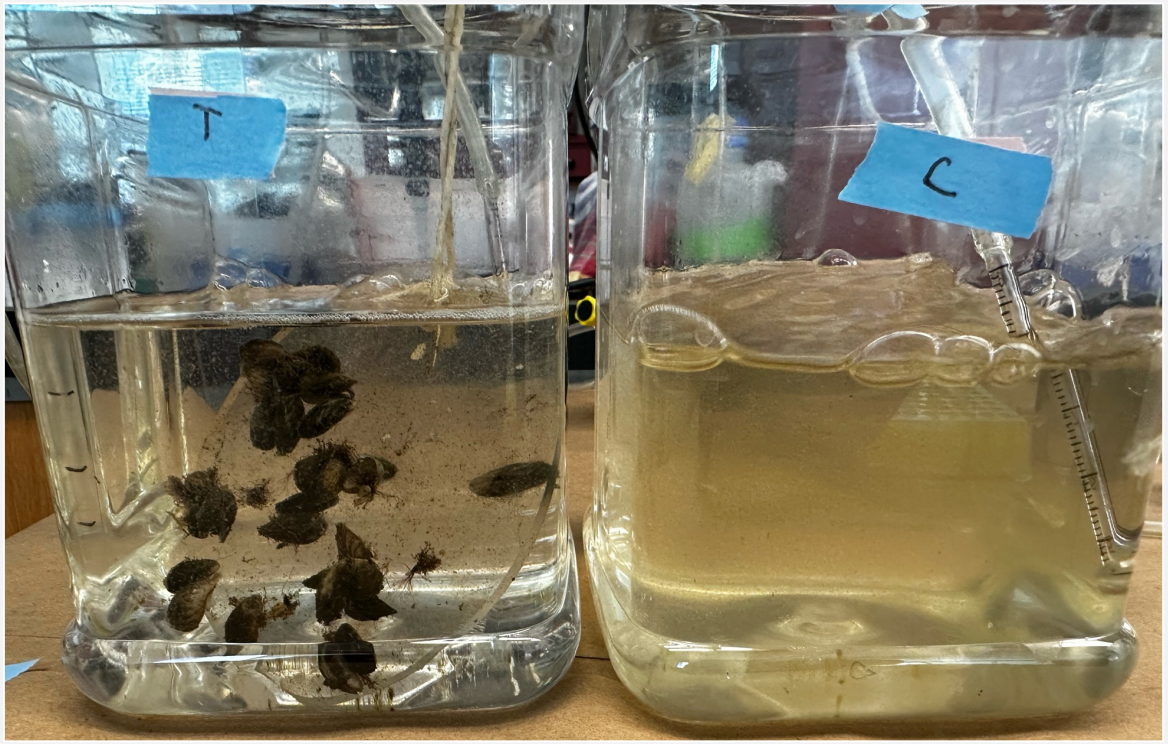
Example set up using water baths to alter temperature

WATER TEMPERATURES IN BALTIMORE HARBOR



MD DNR Eyes on the Bay

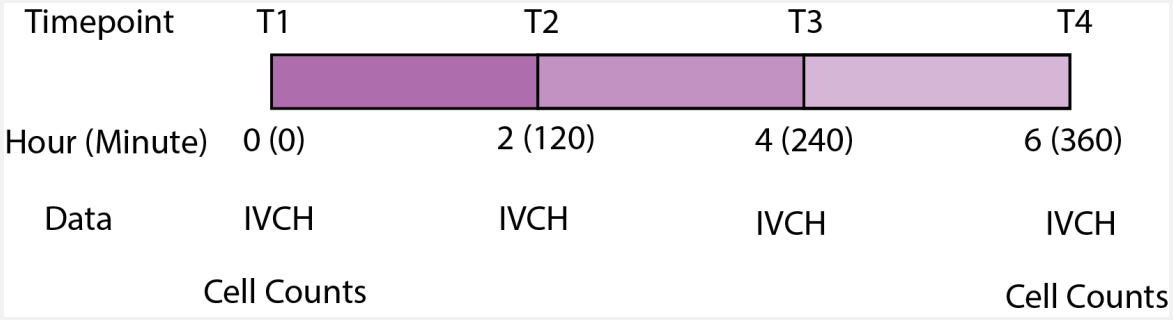
TYPES OF SAMPLES COLLECTED



Mussel Treatment

No-Mussel Treatment

- In vitro chlorophyll (IVCH)
- Algae counts



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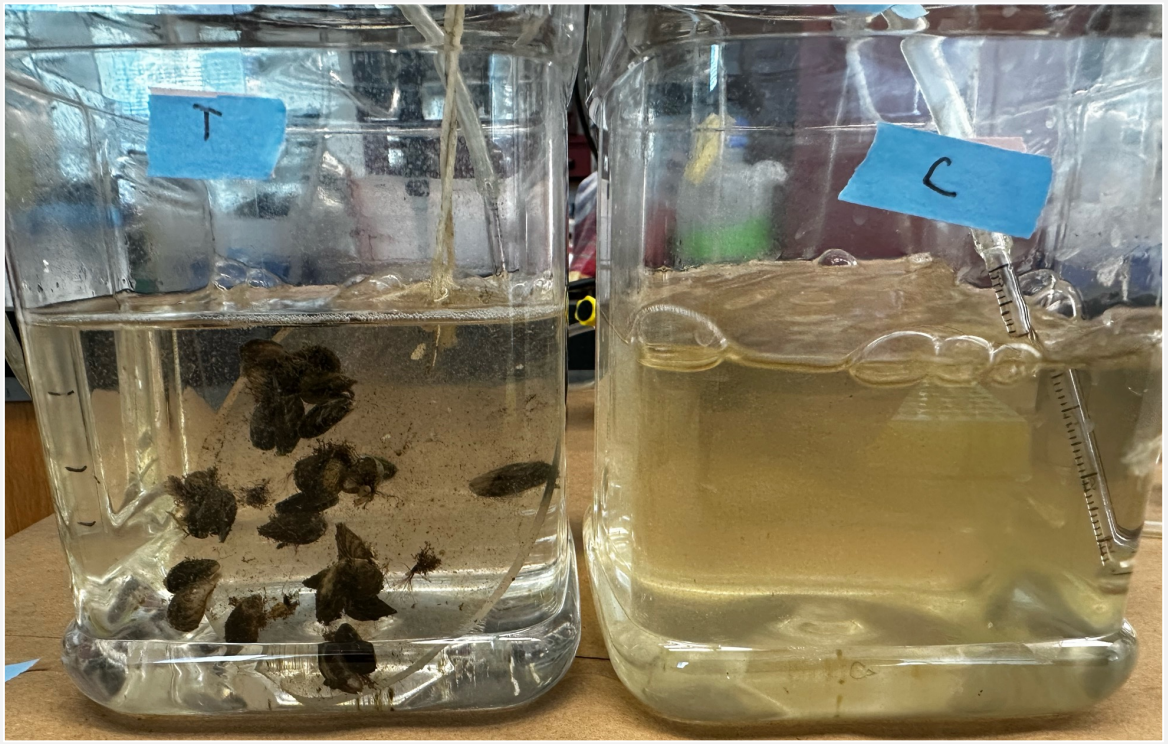


Mussel Treatment

No-Mussel Treatment

- In vitro chlorophyll (IVCH)
- Algae counts

Timepoint	T1	T2	T3	T4
Hour (Minute)	0 (0)	2 (120)	4 (240)	6 (360)
Data	IVCH	IVCH	IVCH	IVCH
	Cell Counts			Cell Counts

CLEARANCE RATE EQUATION

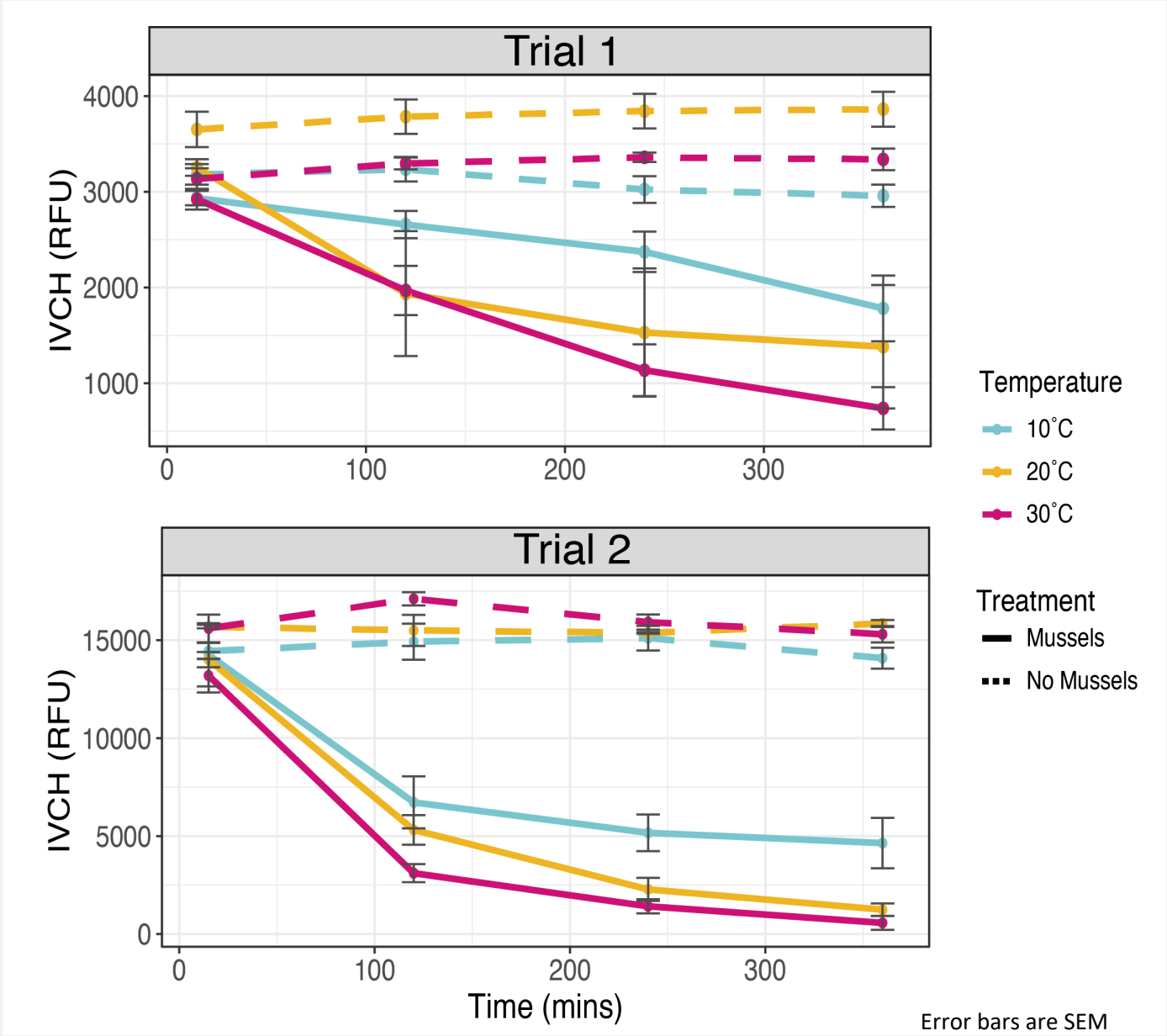
$$R_C = \frac{V}{nt}\left\{\ln\left(\frac{C_0}{C_t}\right) - \ln\left(\frac{C_{0'}}{C_{t'}}\right)\right\}$$

R_C	=	Clearance Rate	C_0	=	Concentration of treatment at start
V	=	Volume (liters)	C_t	=	Concentration of treatment at end
n	=	Number of mussels	$C_{0'}$	=	Concentration of control at start
t	=	Time (hours)	$C_{t'}$	=	Concentration of control at end

Jacobs et al., 2015

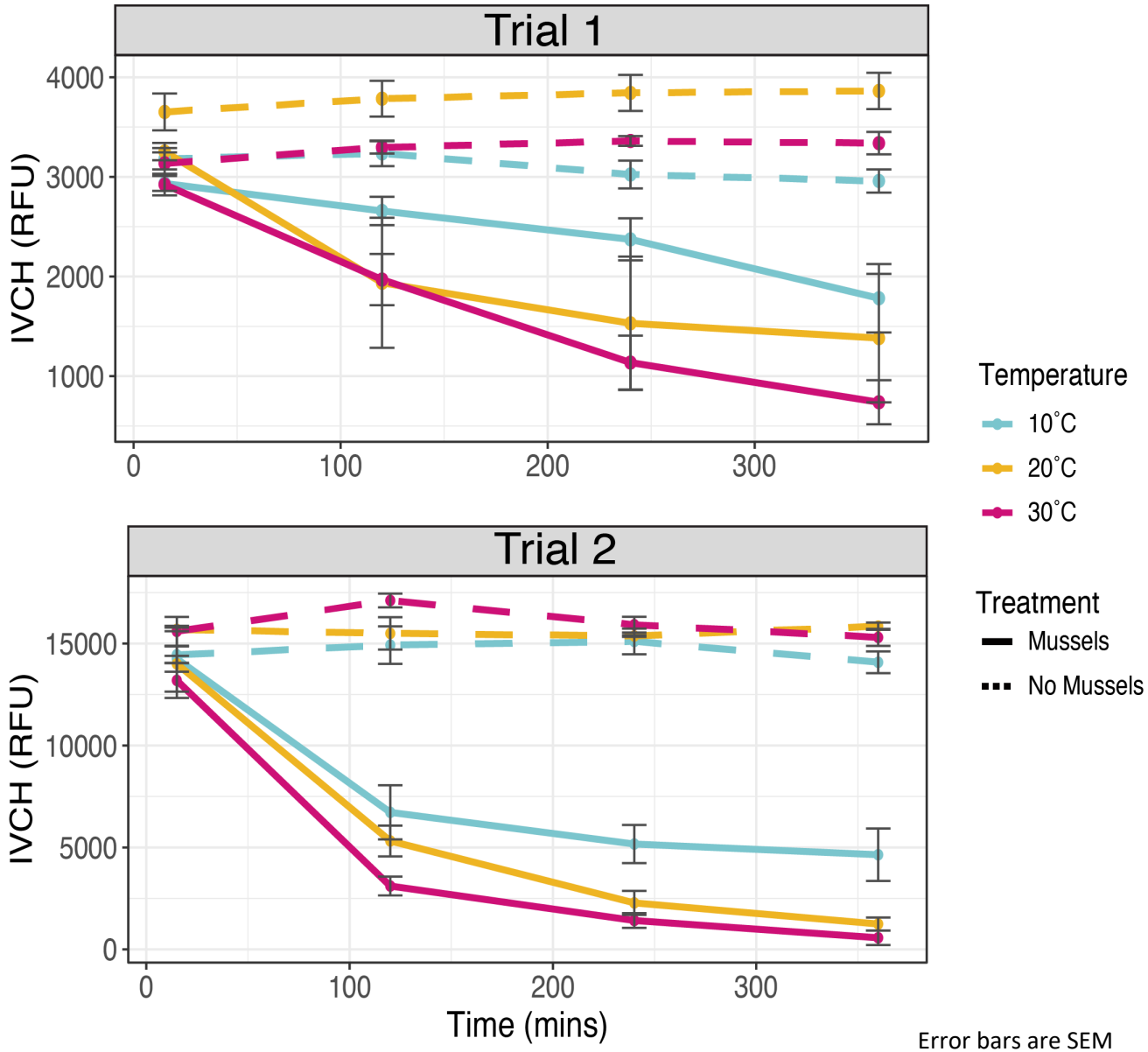
AT ALL TEMPERATURES TESTED, MUSSELS REDUCE IVCH LEVELS

	Effect of Treatment
Trial 1	**p < 0.001**
Trial 2	**p < 0.001**



AT ALL TEMPERATURES TESTED, MUSSELS REDUCE IVCH LEVELS

Effect of Time	Trial 1	Trial 2
Mussels	**p < 0.001**	**p < 0.001**
No Mussels	0.348	0.06



MUSSELS HAVE LOWER IVCH-BASED CLEARANCE RATES AT LOWER TEMPERATURES

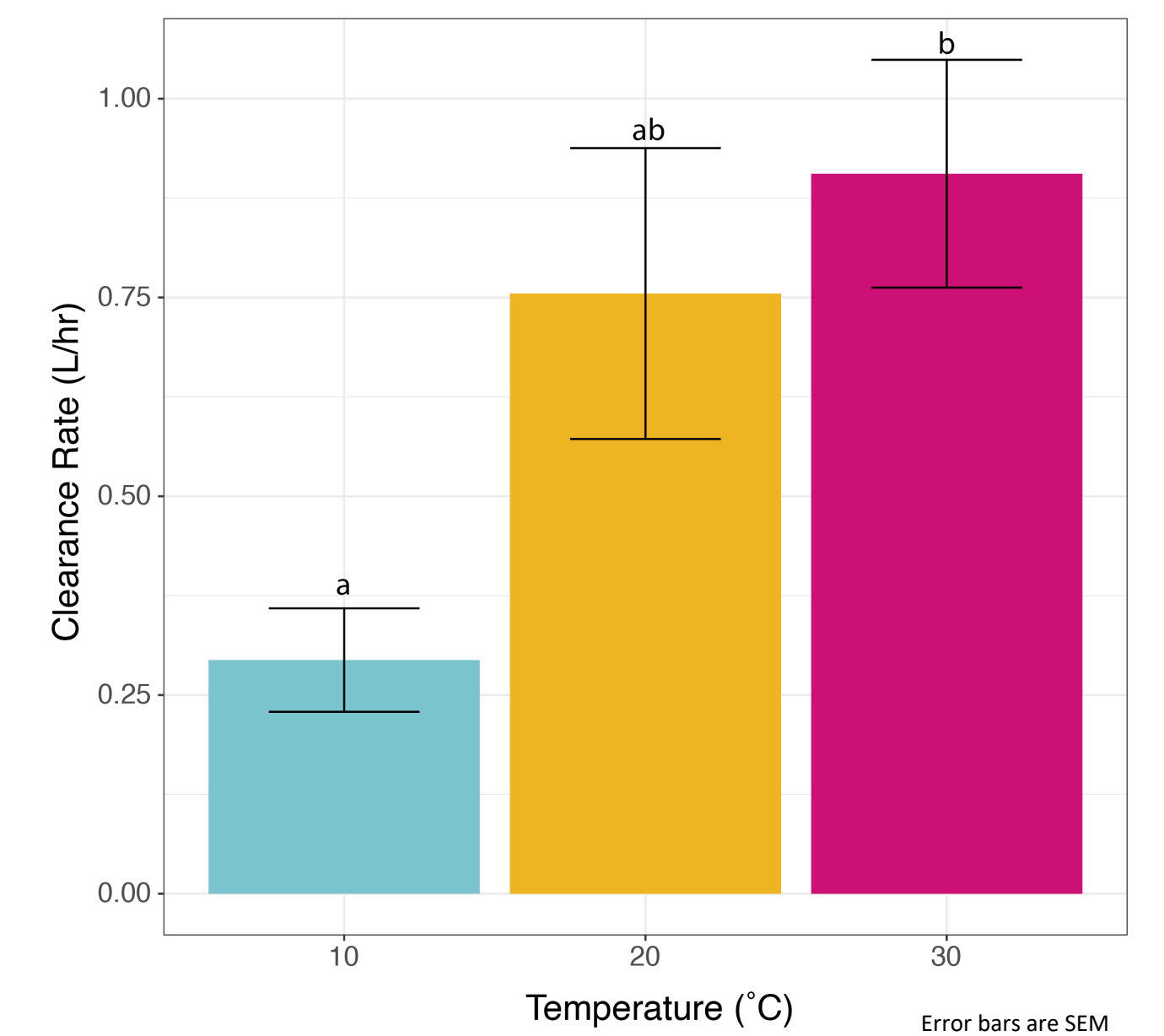
<u>One way ANOVA</u>: p = 0.014

<u>Pairwise Comparisons:</u>

10˚C – 20˚C: 0.079

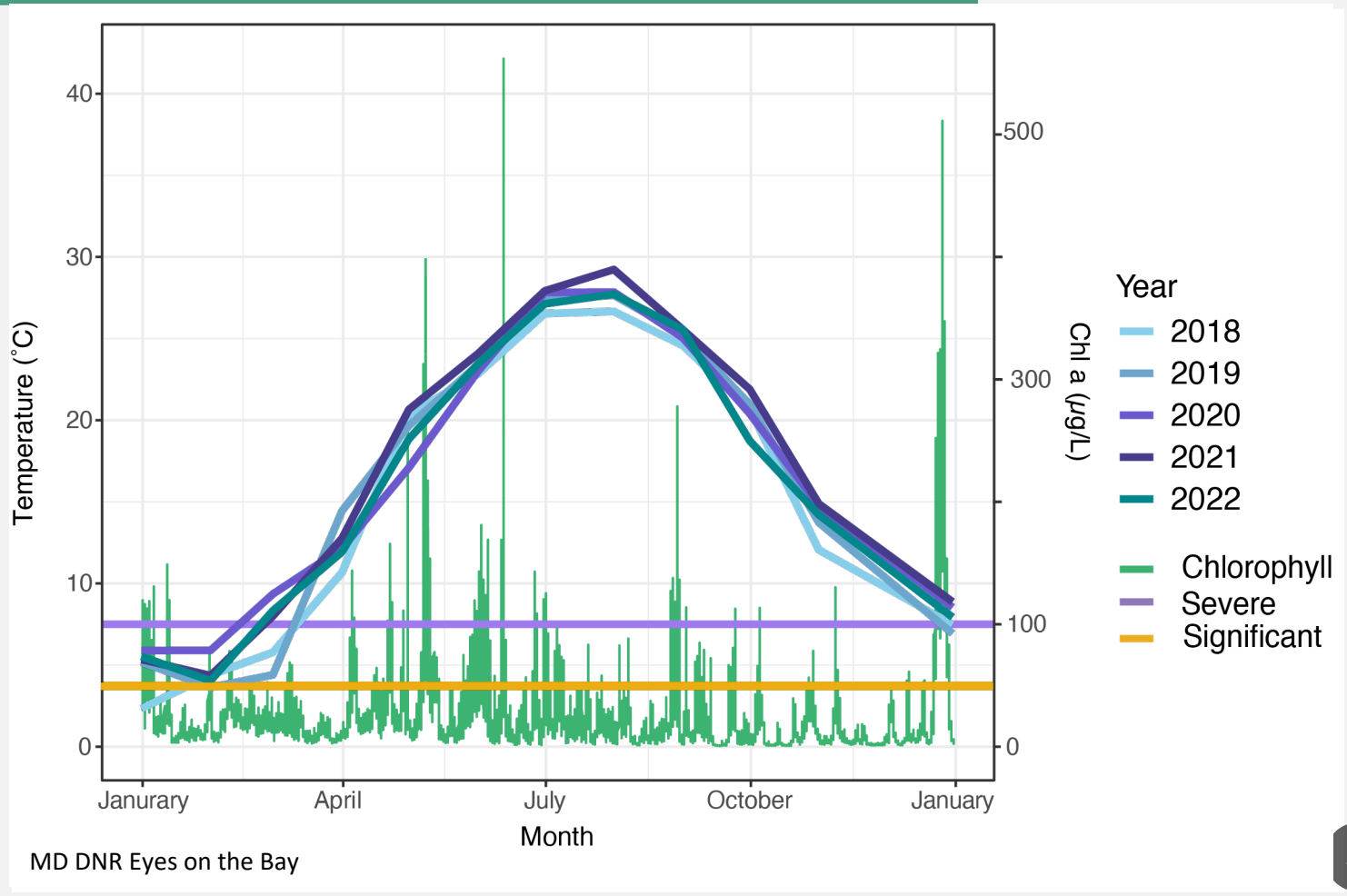
10˚C – 30˚C: 0.014

20˚C – 30˚C: 0.728



CONCLUSIONS AIM 2

- Mussels have a lower clearance rate at lower temperatures
- At all temperatures, the mussels were able to reduce the IVCH levels



MD DNR Eyes on the Bay

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1. Determine if *M. leucophaeata* can reduce cultured algae

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4. Determine if *M. leucophaeata* can reduce natural algae blooms

AIM 3 METHODS - SALINITY

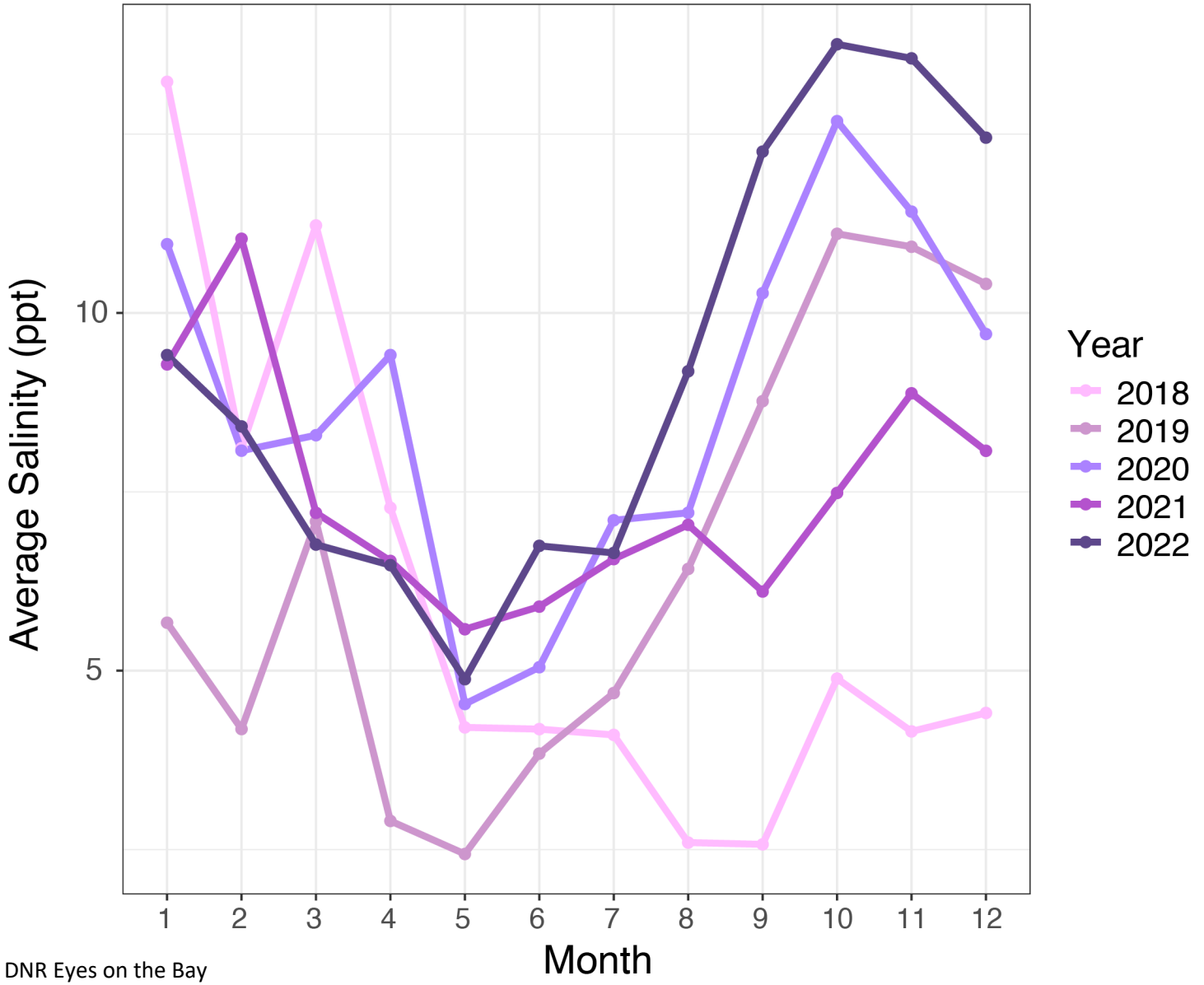
- 500 or 800 ml of water
- ~10 mussels per container
- Salinities: 5, 10, and 15 ppt
- Water collections: 0, 2, 4,and 6 hours

Noah Mansfield

0 Hours

6 Hours

SALINITIES IN BALTIMORE HARBOR



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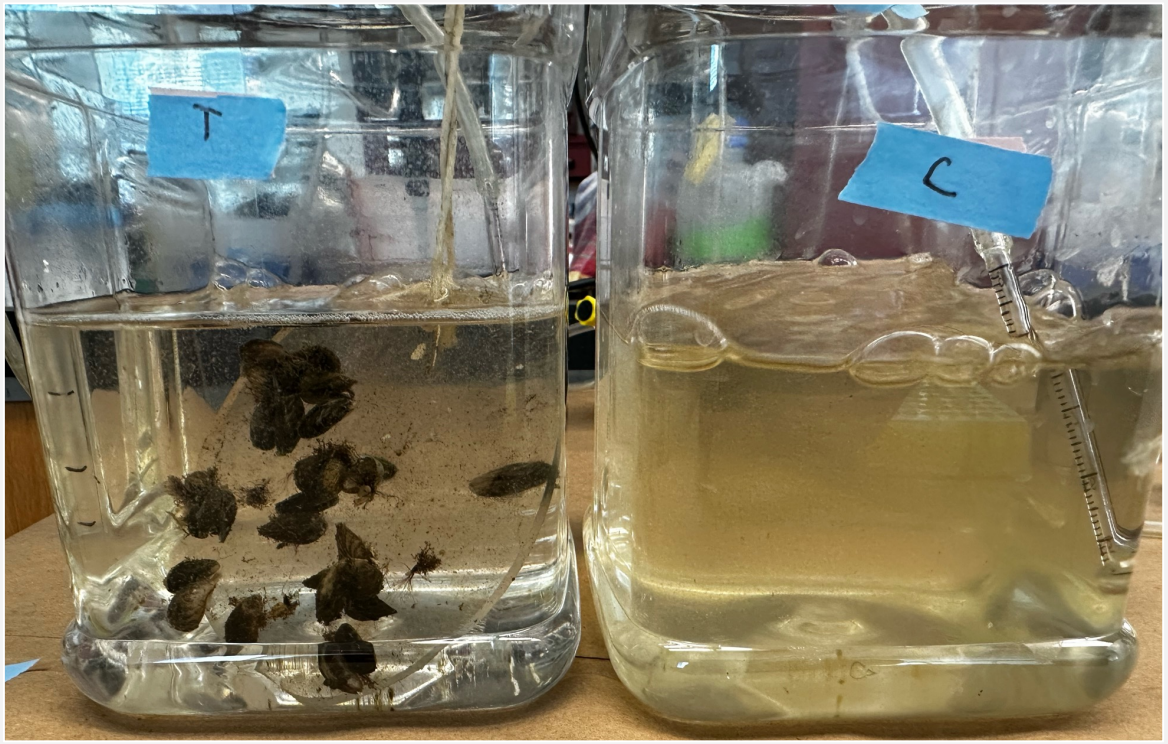

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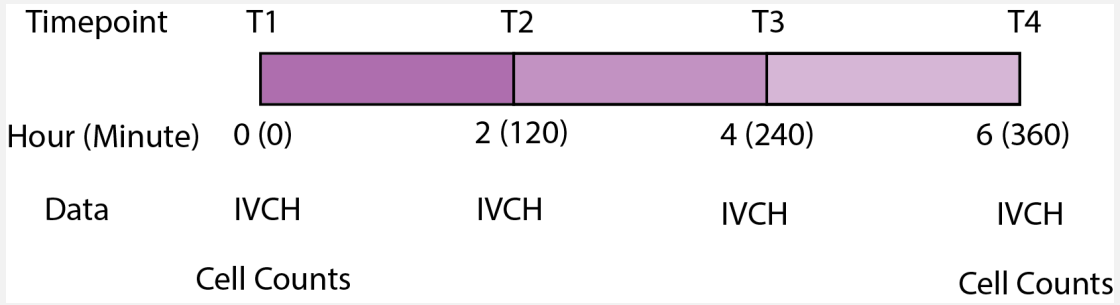
No-Mussel Treatment

- In vitro chlorophyll (IVCH)
- Algae counts



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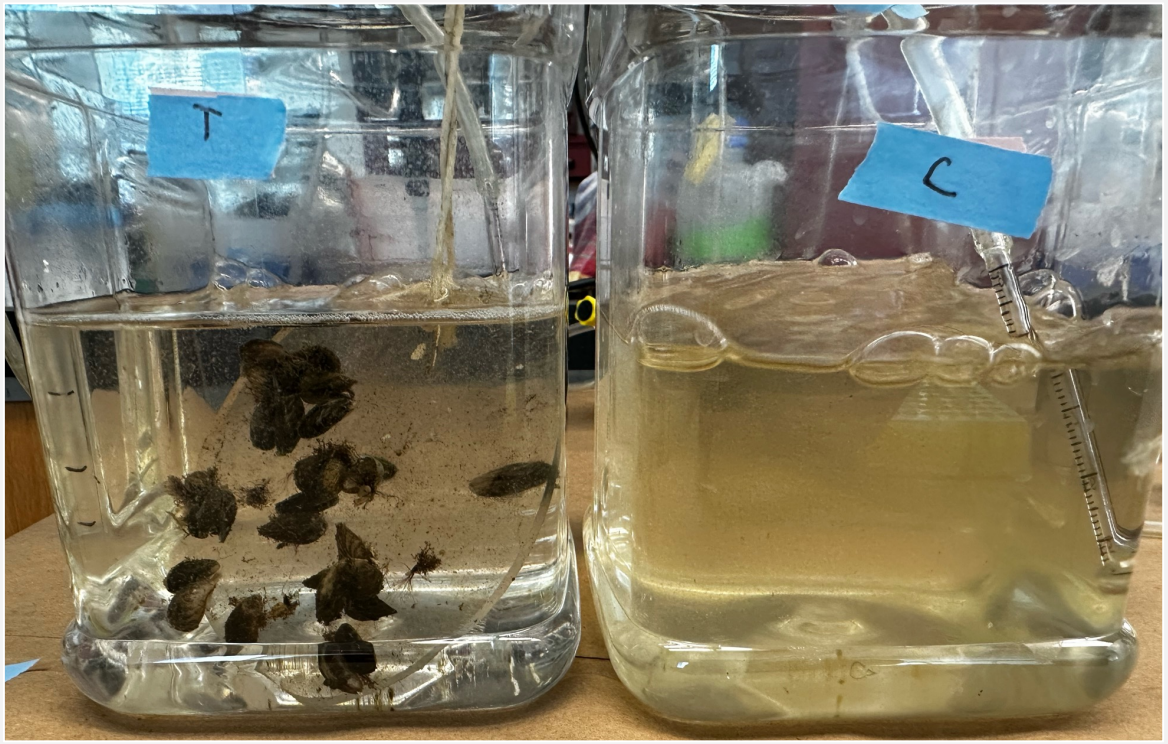

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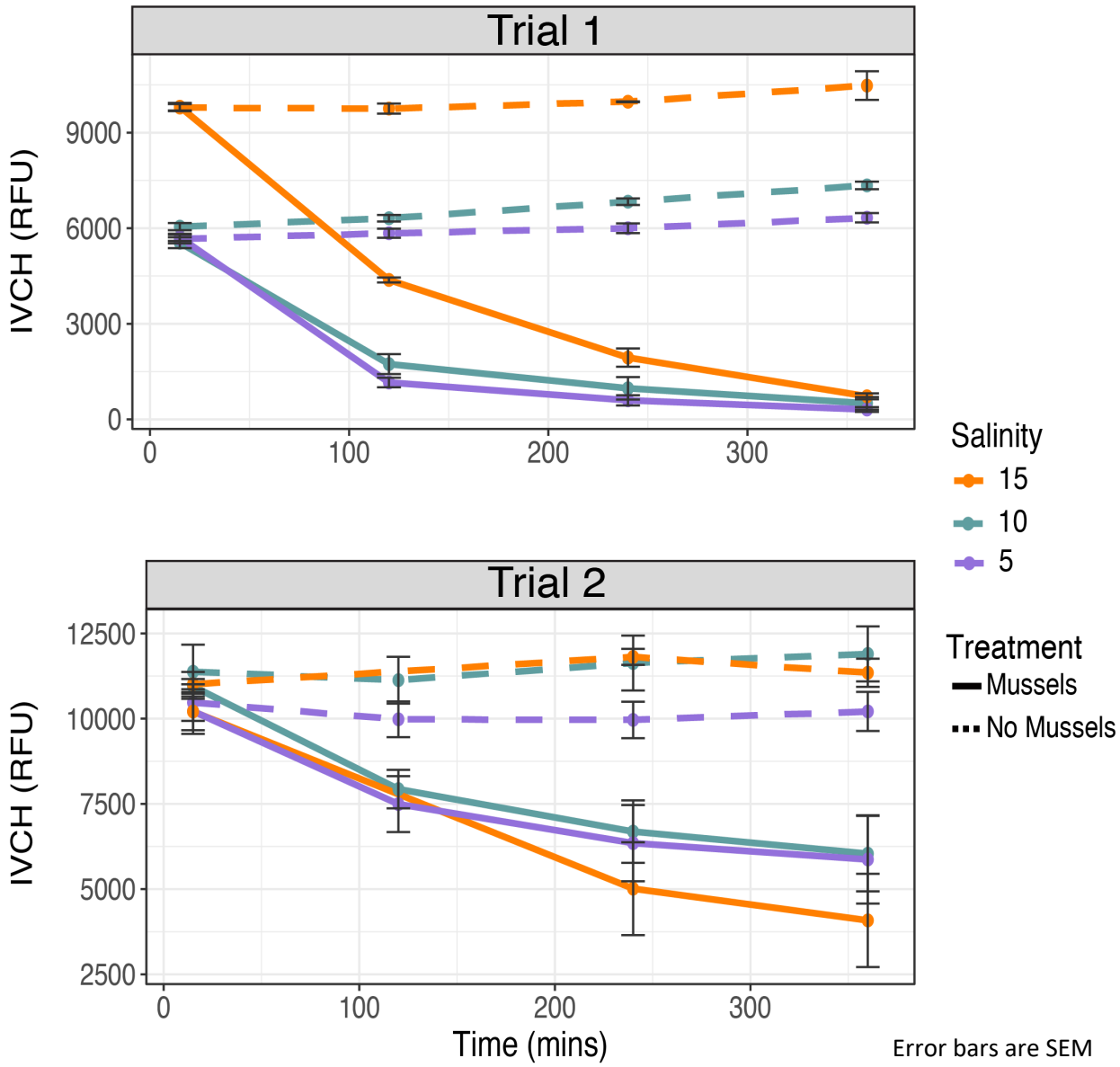
Jacobs et al., 2015

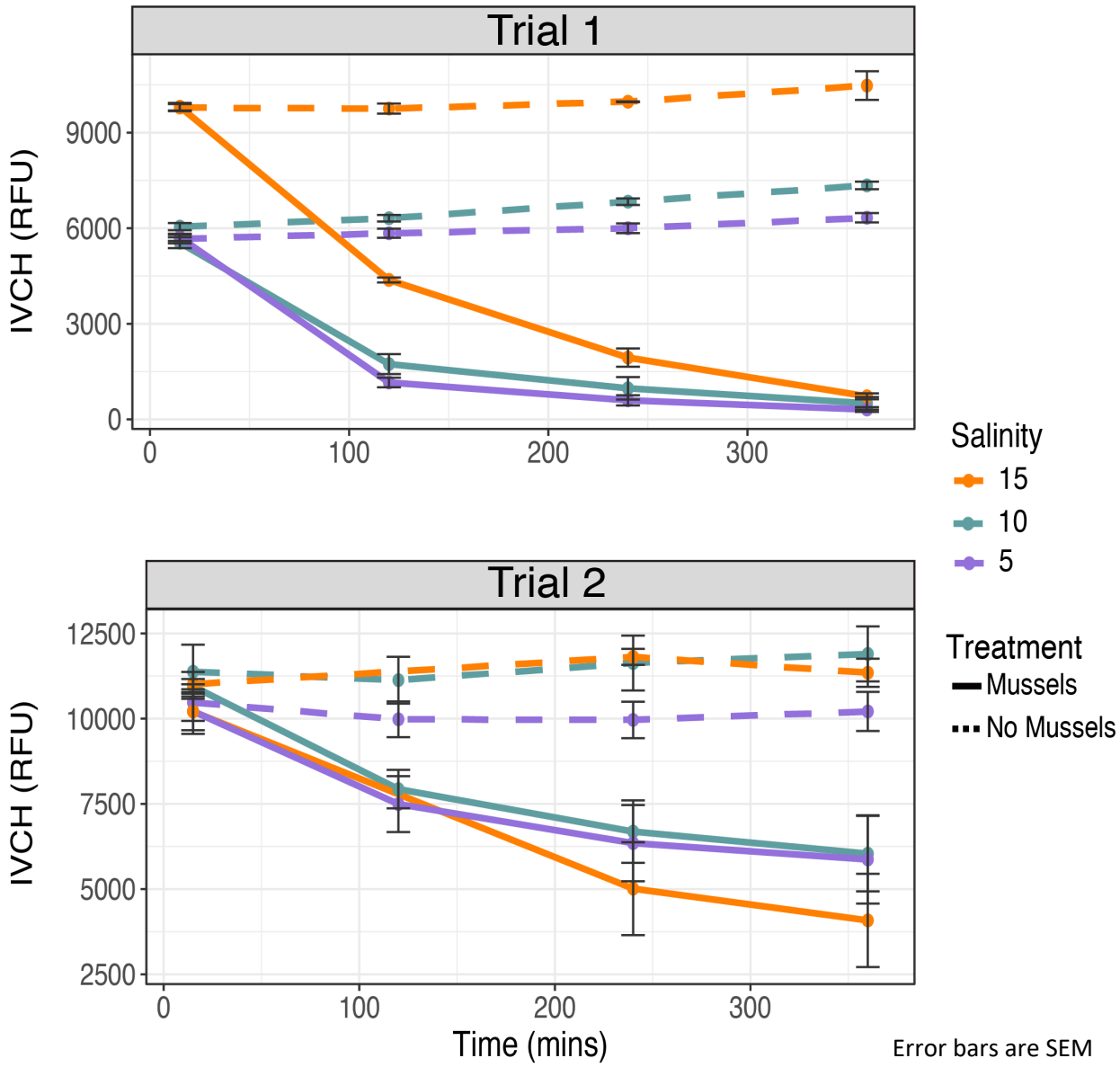
AT ALL SALINITIES TESTED, MUSSELS REDUCE IVCH LEVELS

	Effect of Treatment
Trial 1	**p < 0.001**
Trial 2	**p < 0.001**



AT ALL SALINITIES TESTED, MUSSELS REDUCE IVCH LEVELS

Effect of Time	Trial 1	Trial 2
Mussels	**p < 0.001**	**p < 0.001**
No Mussels	**p < 0.001**	0.43



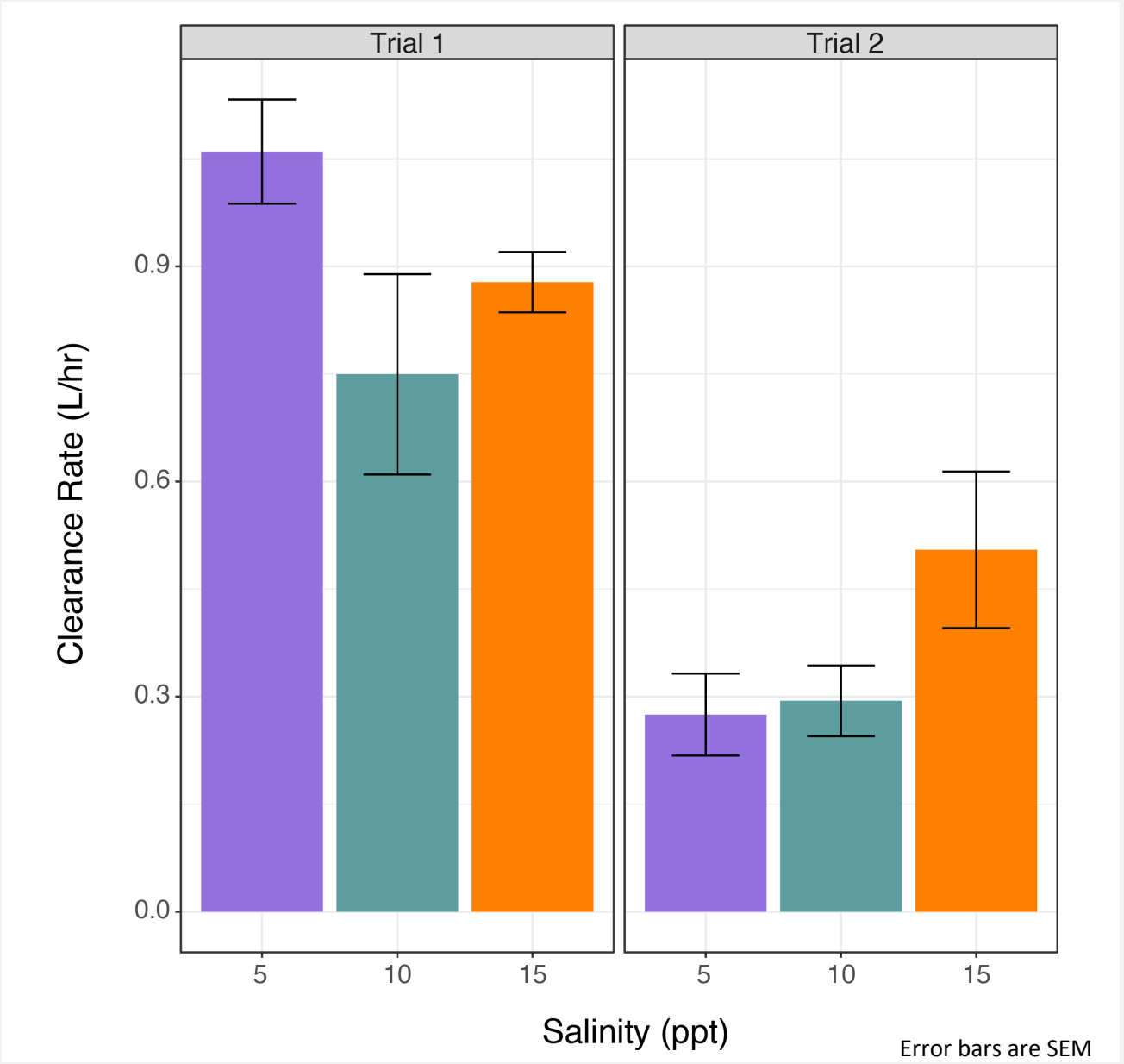
SALINITY DOES NOT AFFECT CLEARANCE RATES IN MUSSELS

One-Way ANOVA:

Trial 1 – p = 0.162

Trial 2 – p = 0.116

Pairwise comparisons	Trial 1	Trial 2
5-10	0.141	0.983
5-15	0.455	0.140
10-15	0.621	0.182



CONCLUSIONS AIM 3

- Salinity does not affect clearance rates of mussels
- Mussels are still able to reduce the IVCH levels
- Still more environmental variables to consider:
  - DO
  - pH
- Stage of mussels

RESEARCH AIMS

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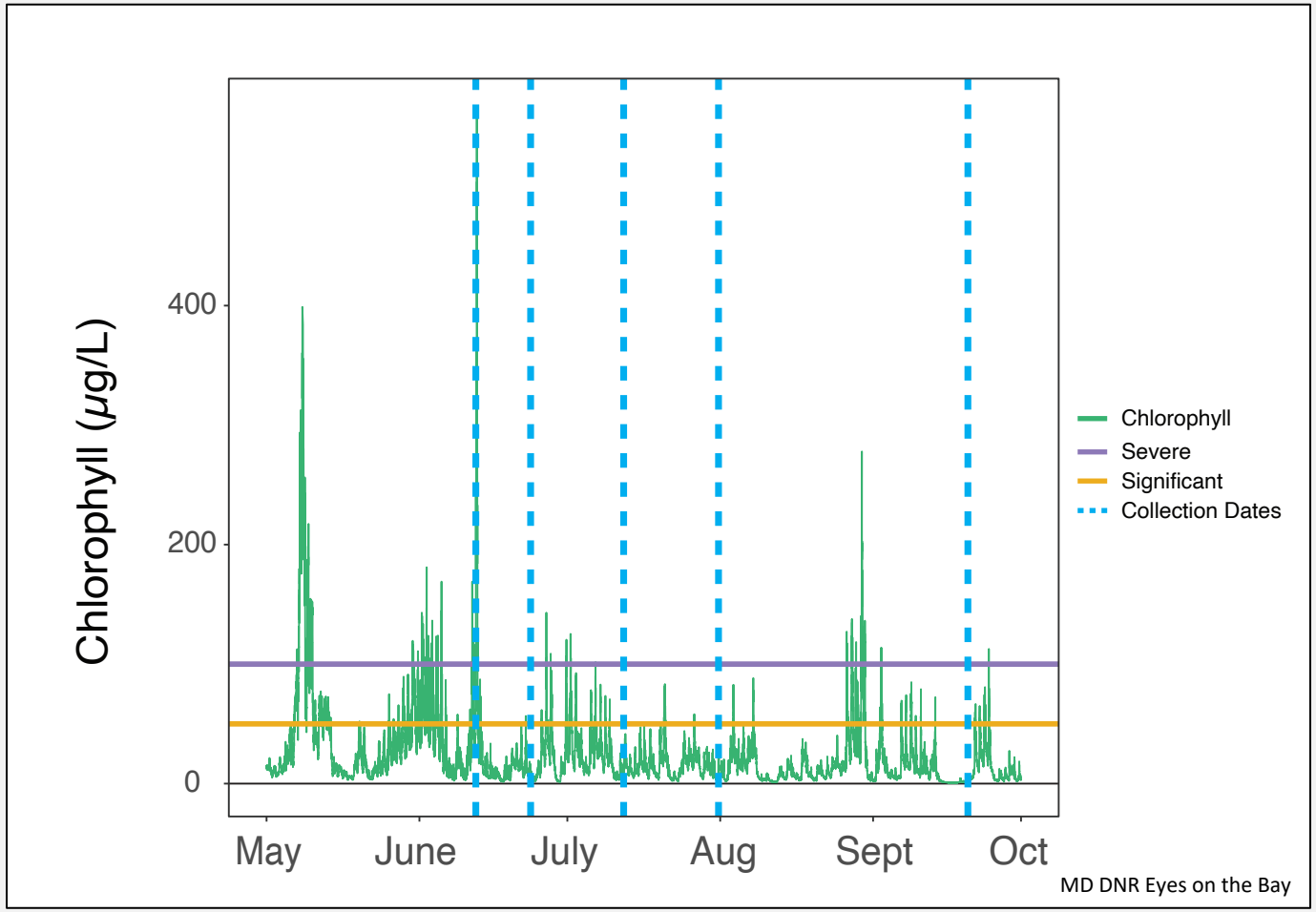
AIM 4 METHODS – NATURAL ALGAE BLOOMS

- 1,500 ml of algae bloom water
- ~20 mussels per container
- Water collections: 0, 2, 4, 6, and 24 hours
- June - September

ALGAE BLOOM COLLECTION DATES



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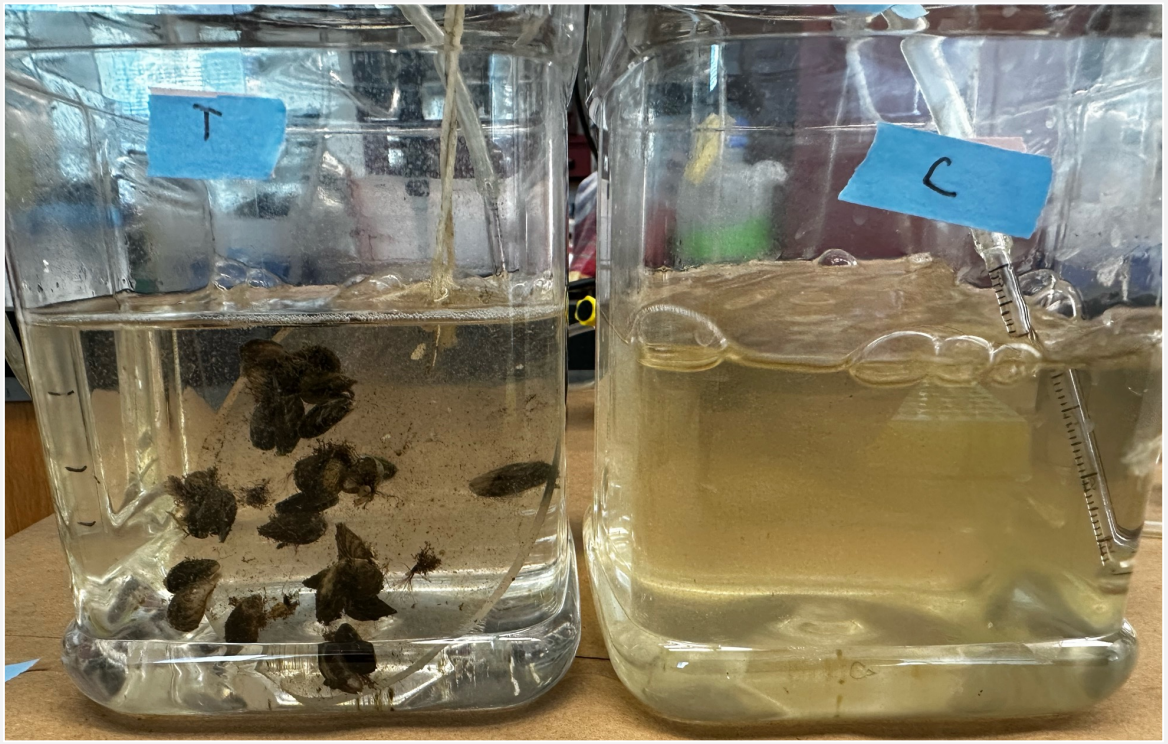

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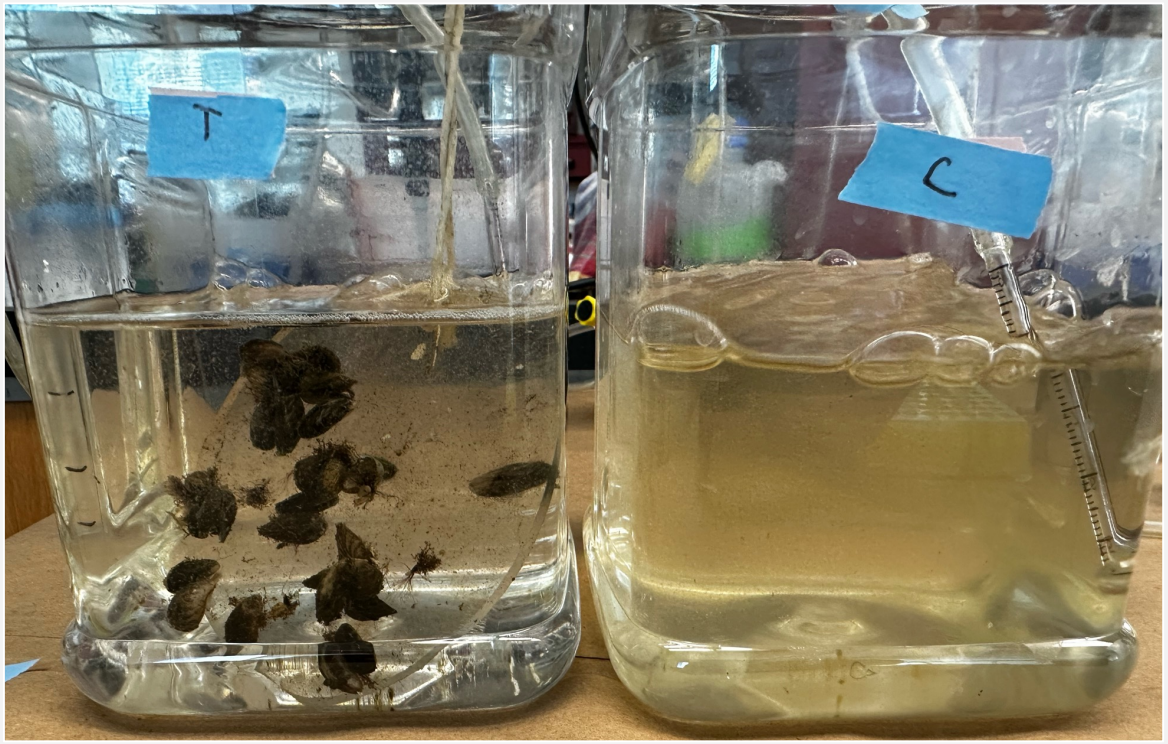

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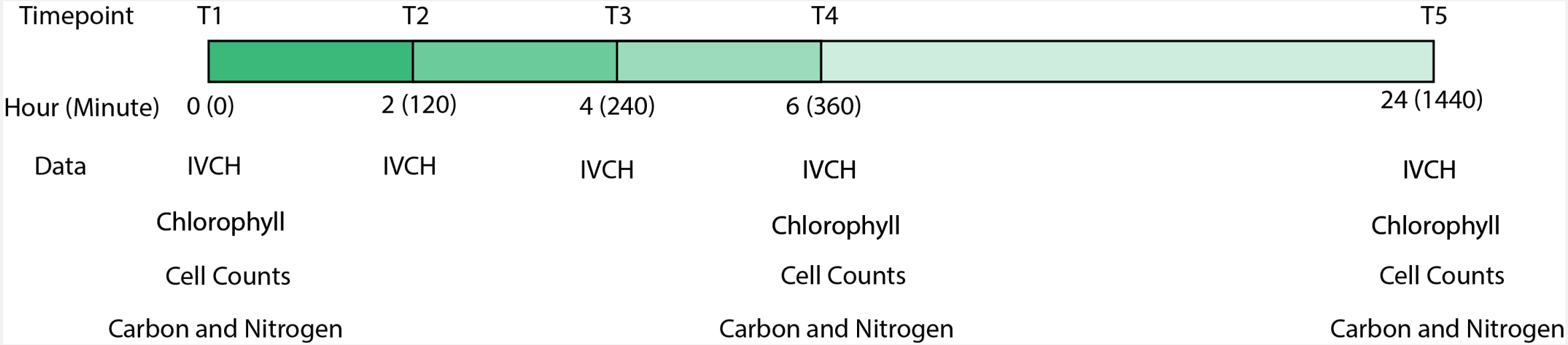
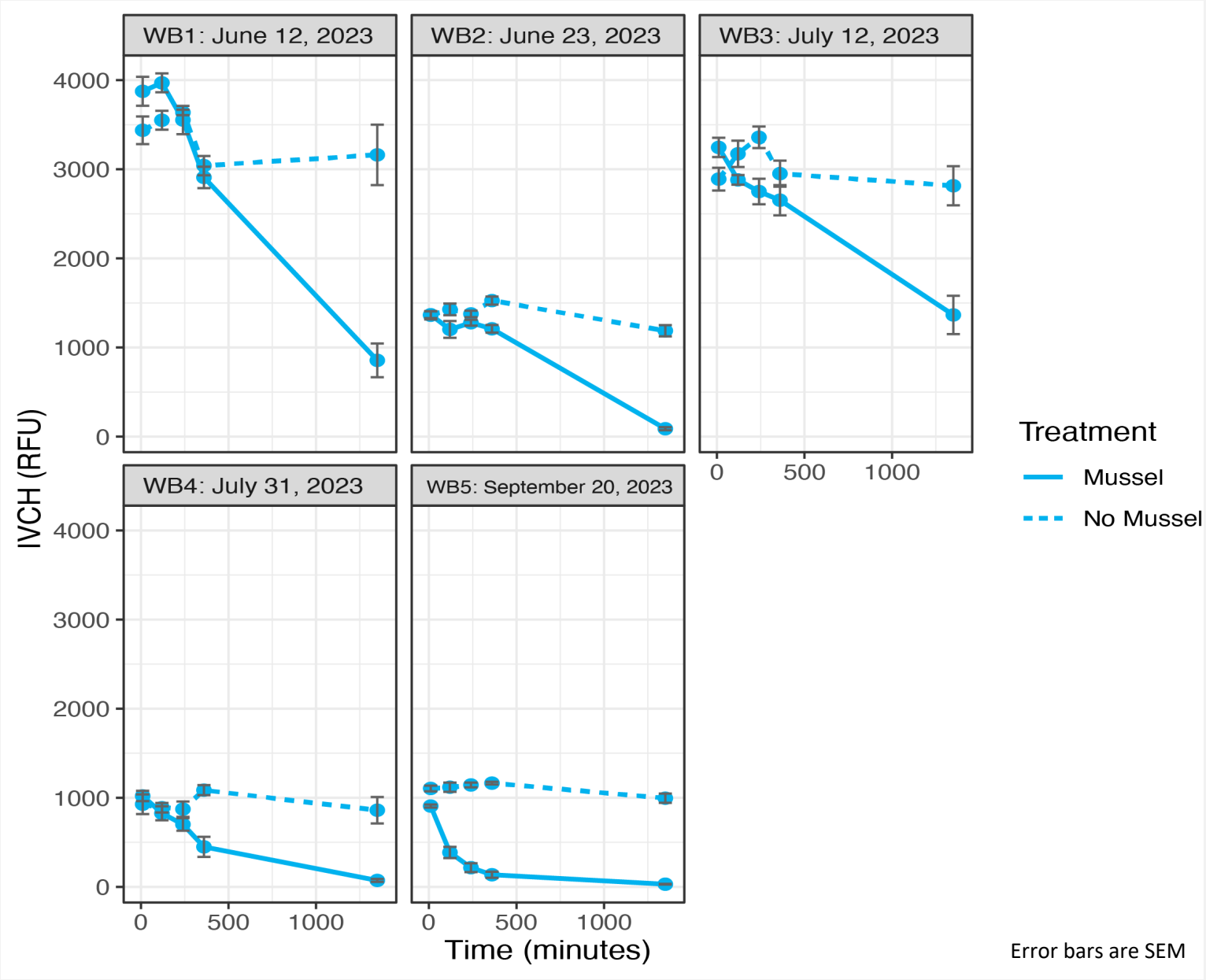
COLLECTION TIMELINE



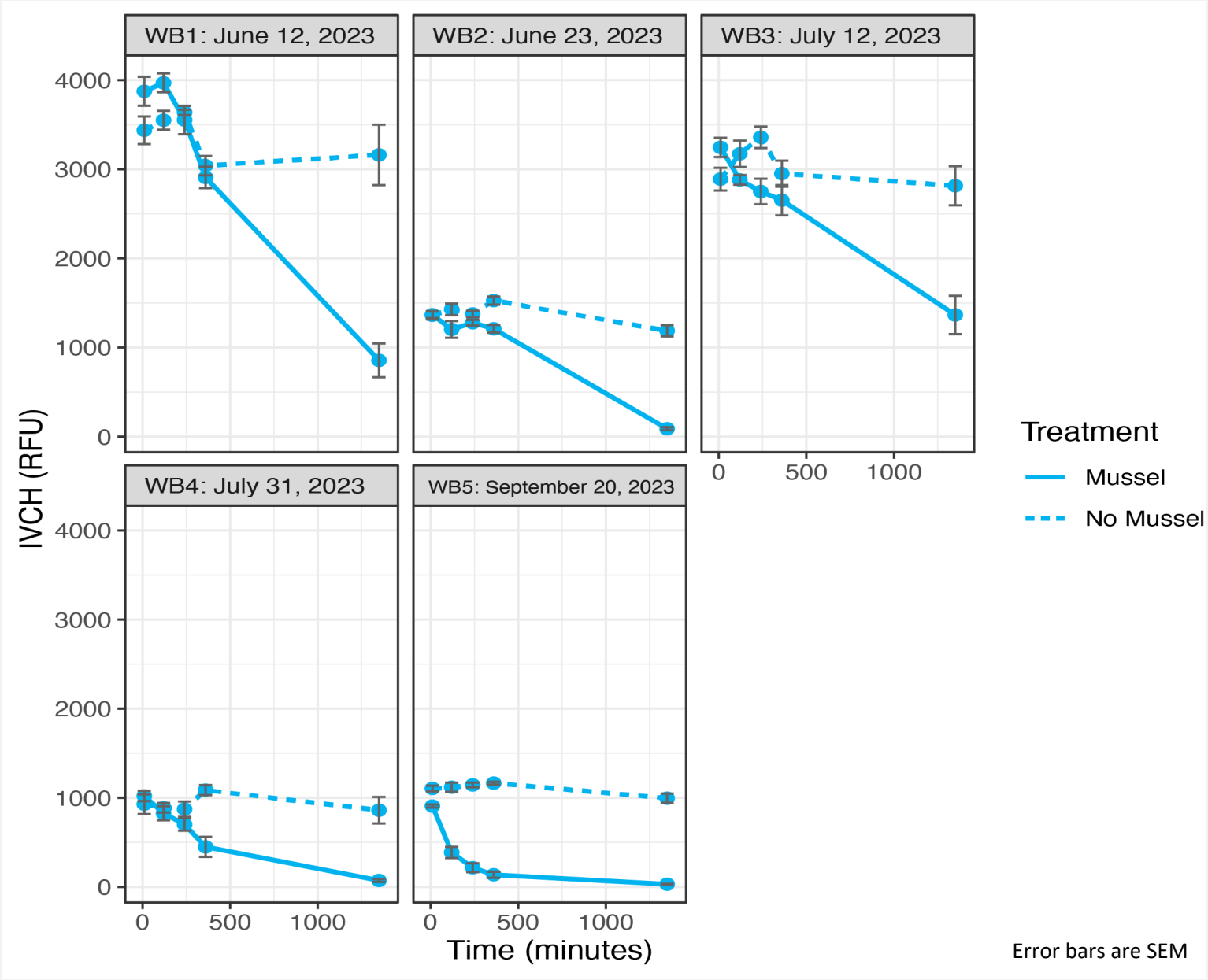
MUSSELS REDUCE IN VITRO CHLOROPHYLL (IVCH)

Effect of Treatment:
WB1 – 0.877
WB2 – **0.001**
WB3 – **0.013**
WB4 – **0.006**
WB5 – **p < 0.001**



MUSSELS REDUCE IN VITRO CHLOROPHYLL (IVCH)

Effect of Time	Mussel	No Mussel
WB1	**p < 0.001**	0.297
WB2	**0.011**	**p < 0.001**
WB3	**p < 0.001**	0.148
WB4	**p < 0.001**	0.25
WB5	**p < 0.001**	0.071



OYSTER NUTRIENT CREDIT TRADING

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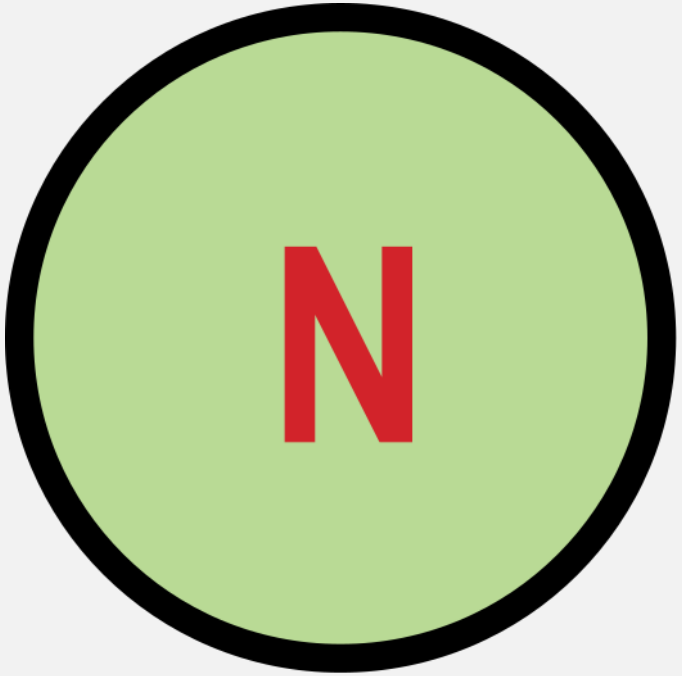
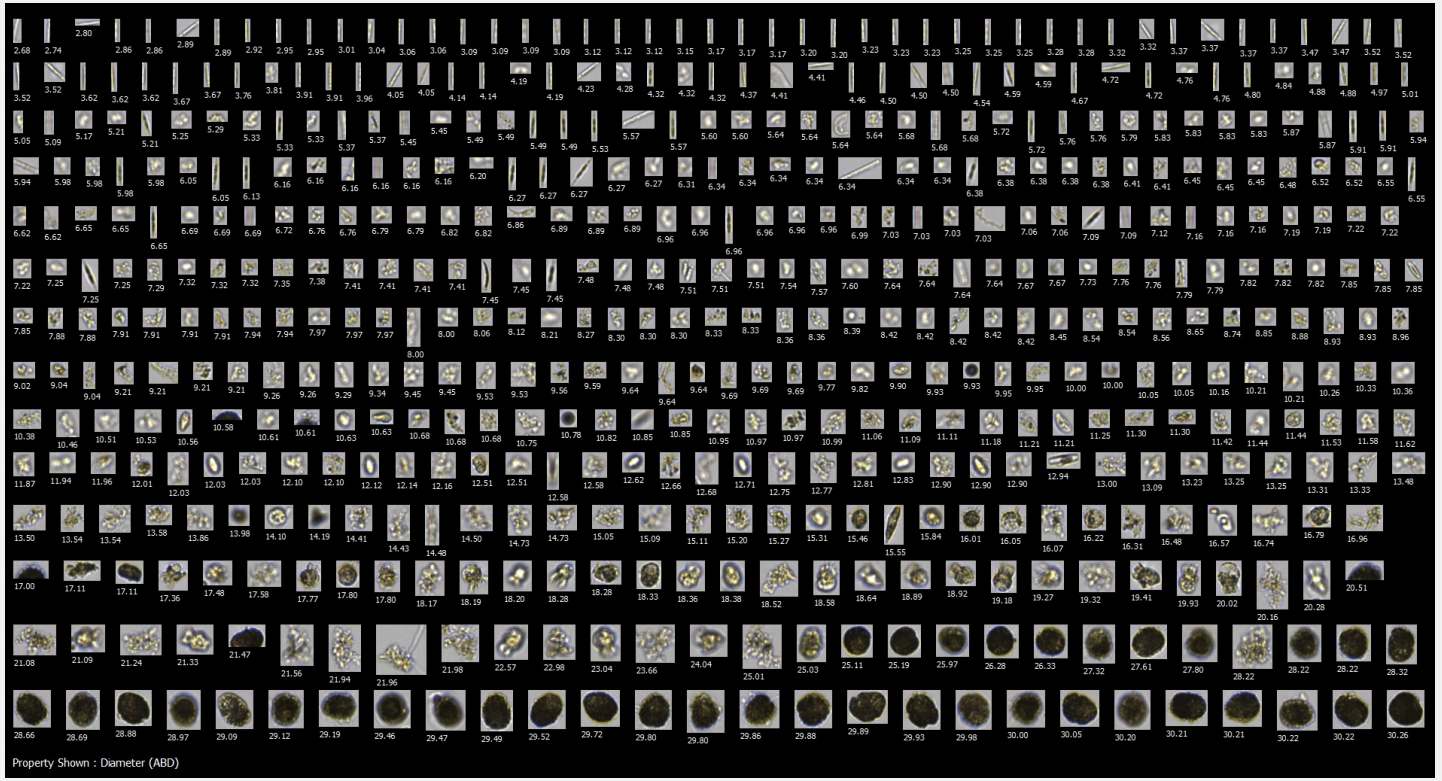


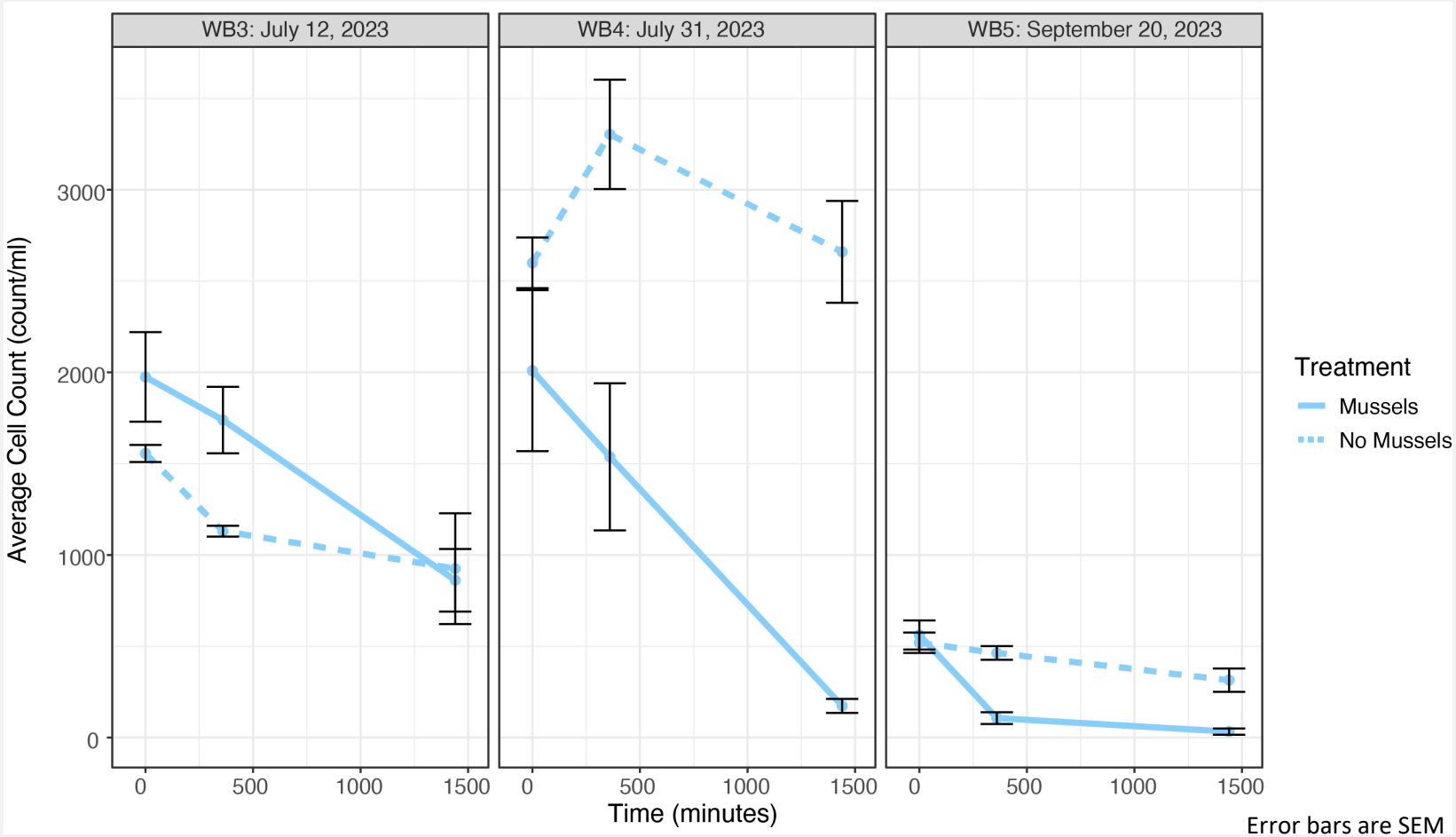
FLOWCAM IMAGES SHOW VARIATION IN ALGAE SPECIES

- Three experiments:
  - WB3 – July 12, 2023
  - WB4 – July 31, 2023
  - WB5 – September 20, 2023



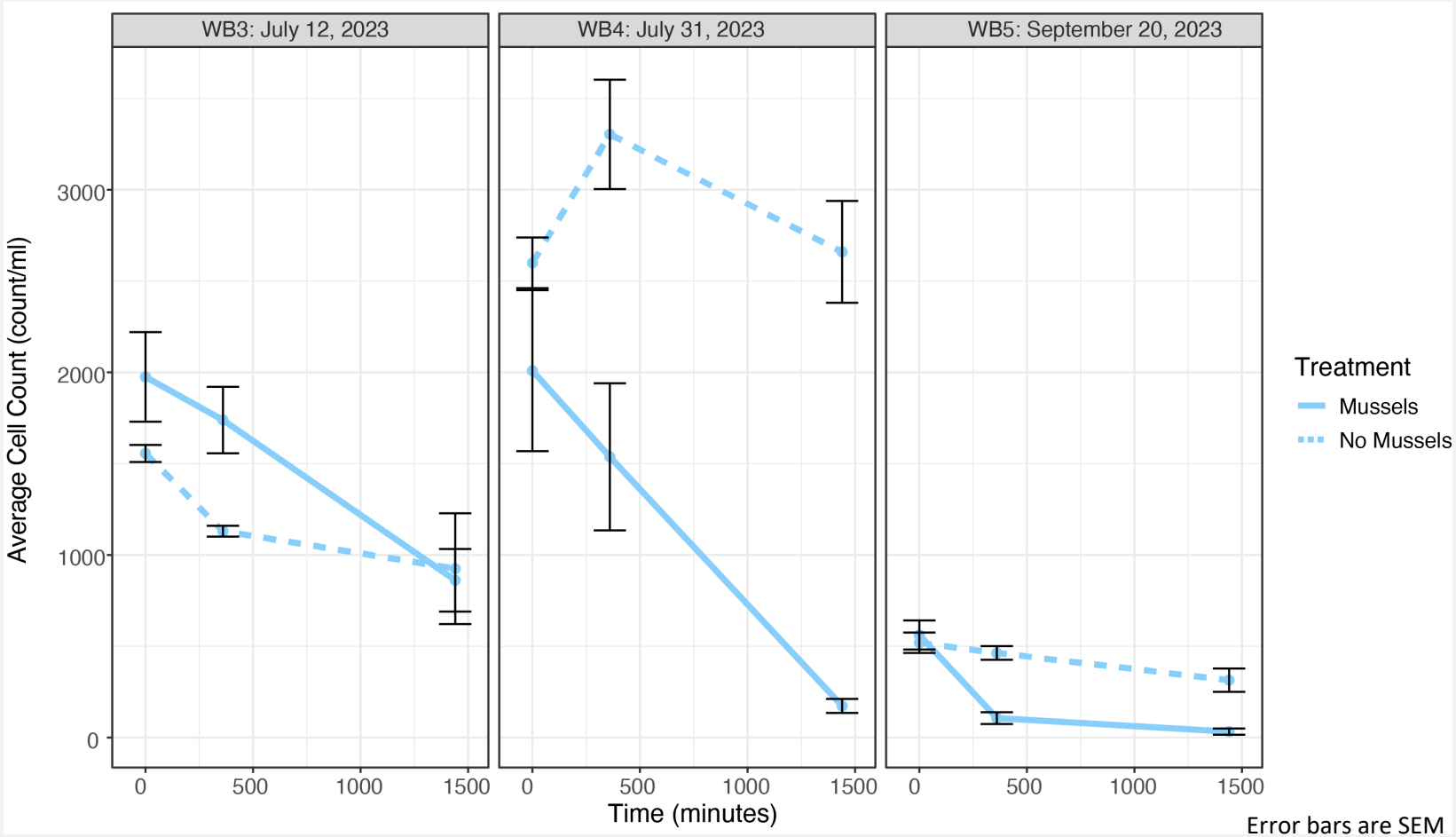
MUSSELS REDUCE CELL COUNTS

Effect of Treatment:
WB3 – 0.152
WB4 – **p < 0.001**
WB5 – **0.042**

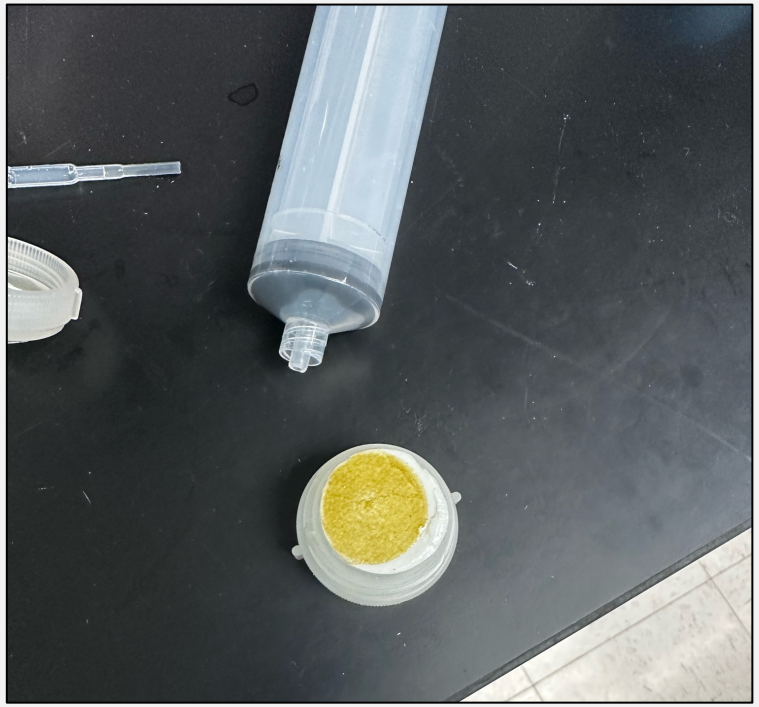


MUSSELS REDUCE CELL COUNTS

Effect of Time	Mussel	No Mussel
WB3	**0.036**	0.111
WB4	**0.039**	**0.039**
WB5	**0.039**	0.368



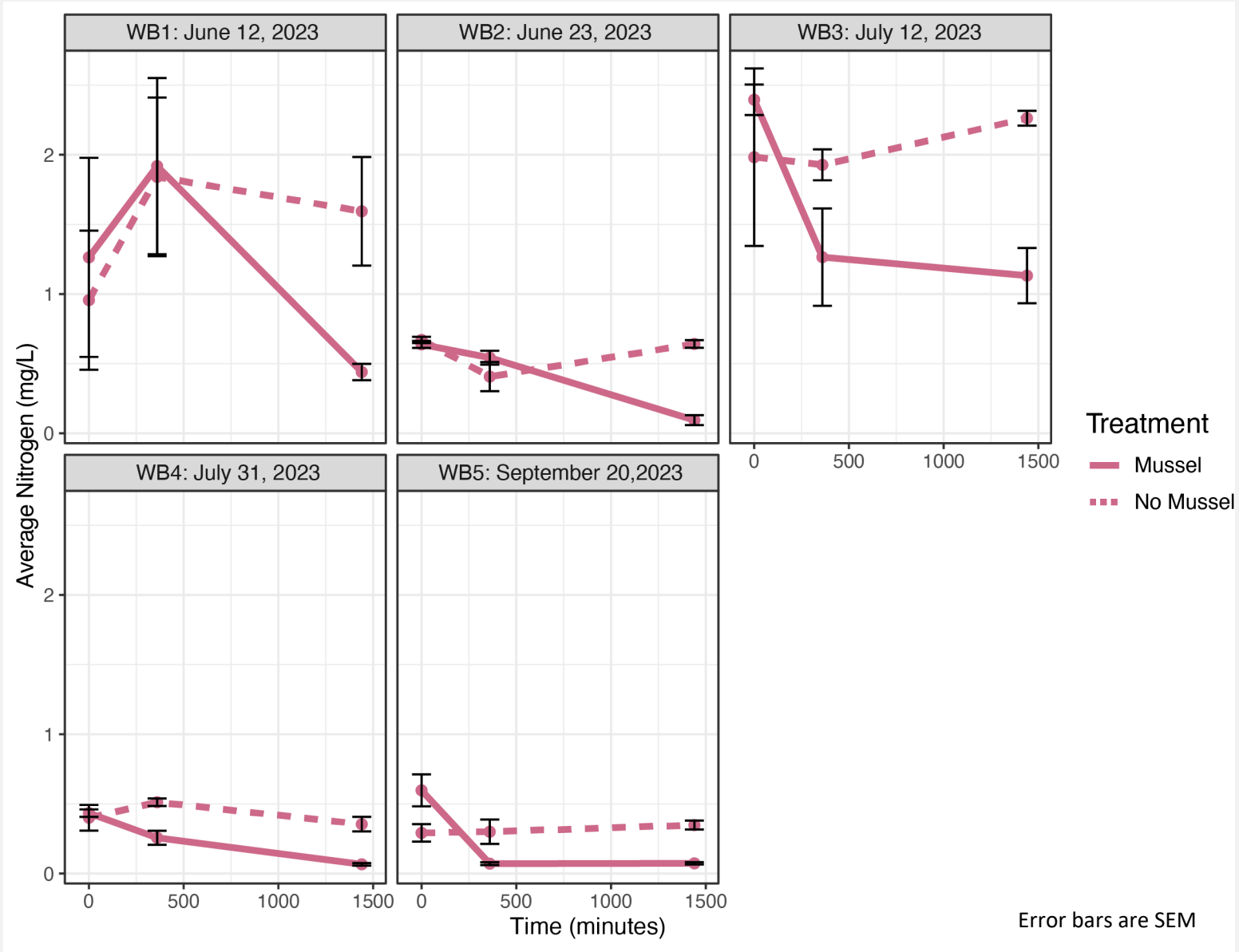
NITROGEN



- Nitrogen analysis from particulate matter
- Samples sent to Nutrient Analytical Services Laboratory

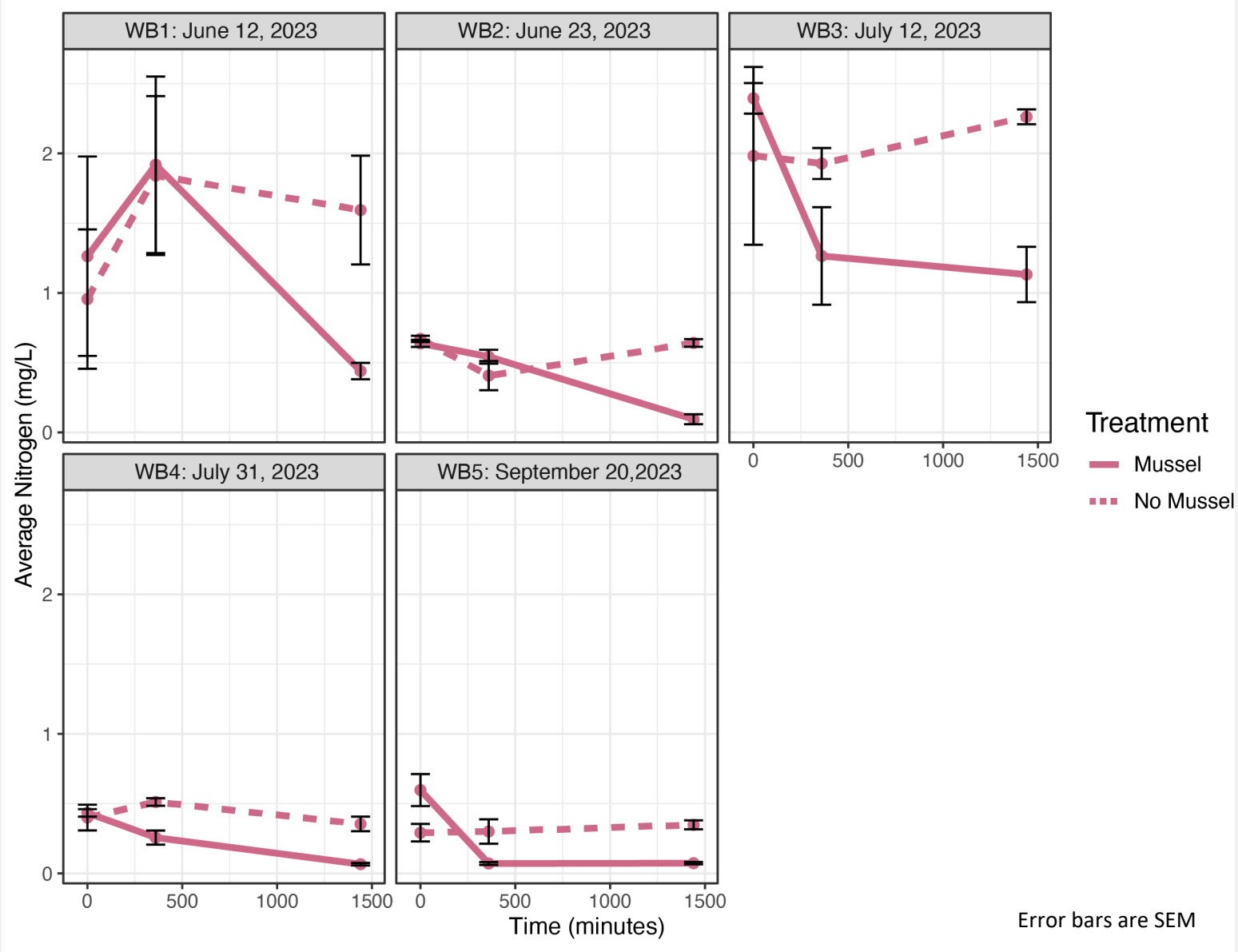
MUSSELS REDUCE NITROGEN CONCENTRATIONS

Effect of Treatment:
WB1 – p = 0.686
WB2 – **p = 0.005**
WB3 – p = 0.129
WB4 – **p = 0.012**
WB5 – p = 0.254



MUSSELS REDUCE NITROGEN CONCENTRATIONS

Effect of Time	Mussel	No Mussel
WB1	0.472	0.091
WB2	**p < 0.001**	**0.033**
WB3	**0.006**	0.683
WB4	**0.014**	0.105
WB5	**p < 0.001**	0.808

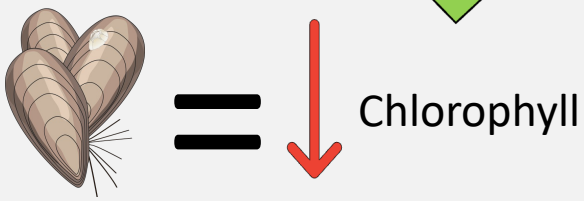


CONCLUSIONS AIM 4

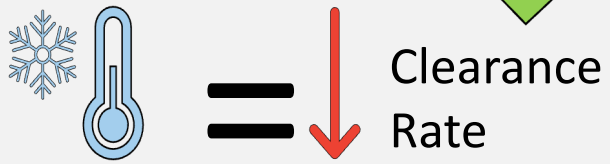
- Mussels reduce IVCH levels of wild algae blooms
- Mussels can reduce nitrogen
- Numerous variables to consider:
  - Mussel stage
  - Algae bloom composition
  - Other filter feeders

SUMMARY OF RESULTS

1. Determine if *M. leucophaeata* can reduce cultured algae

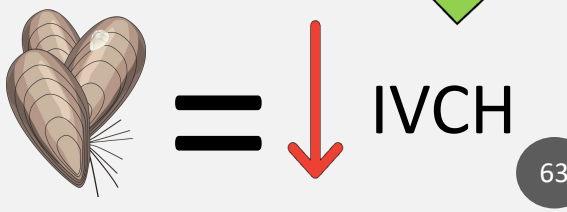


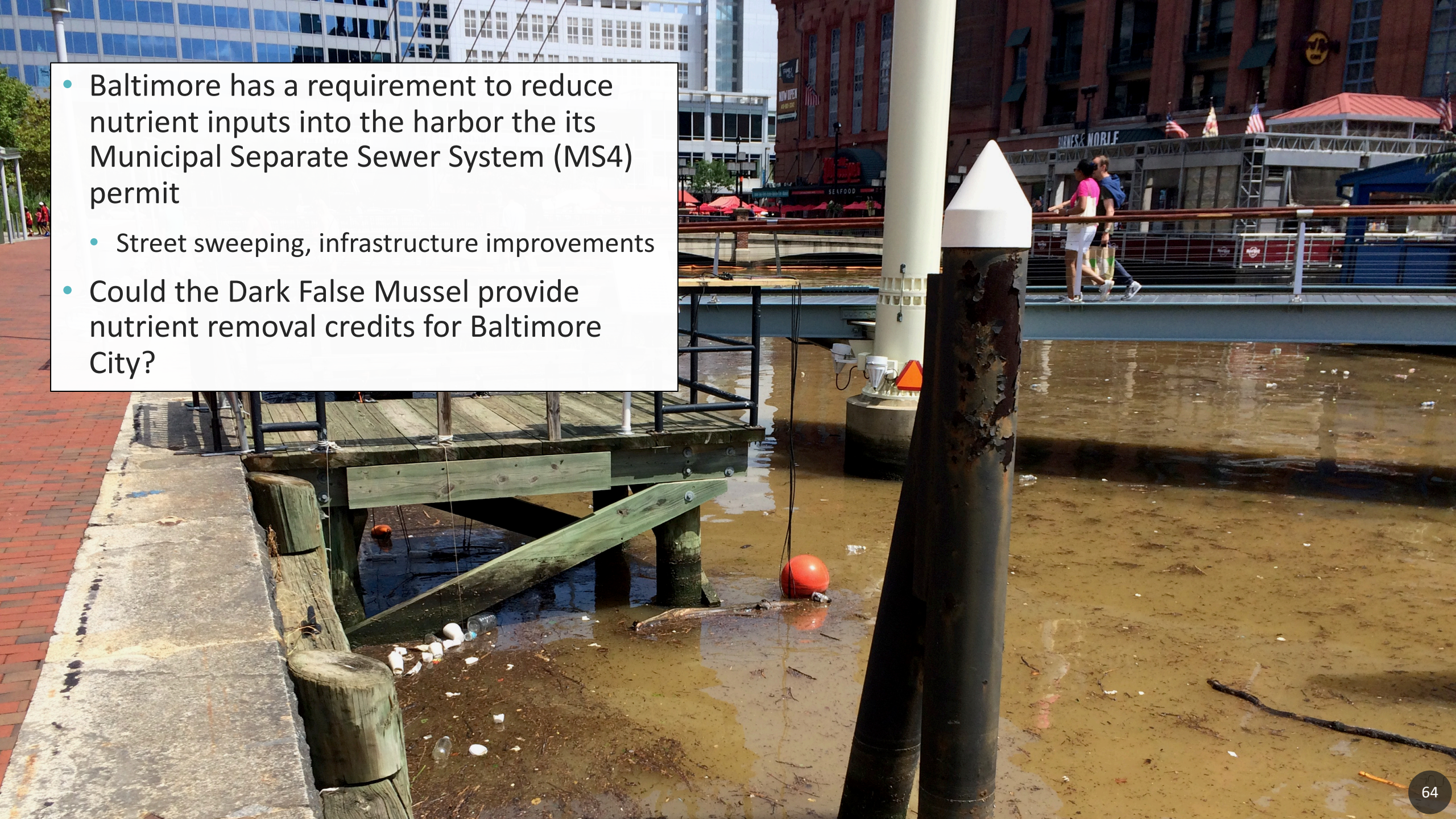
2. Examine the effect of water temperature on clearance rate



3. Examine the effect of water salinity on clearance rate

4. Determine if *M. leucophaeata* can reduce natural algae blooms





- Baltimore has a requirement to reduce nutrient inputs into the harbor the its Municipal Separate Sewer System (MS4) permit
  - Street sweeping, infrastructure improvements
- Could the Dark False Mussel provide nutrient removal credits for Baltimore City?

OYSTER NUTRIENT CREDIT TRADING

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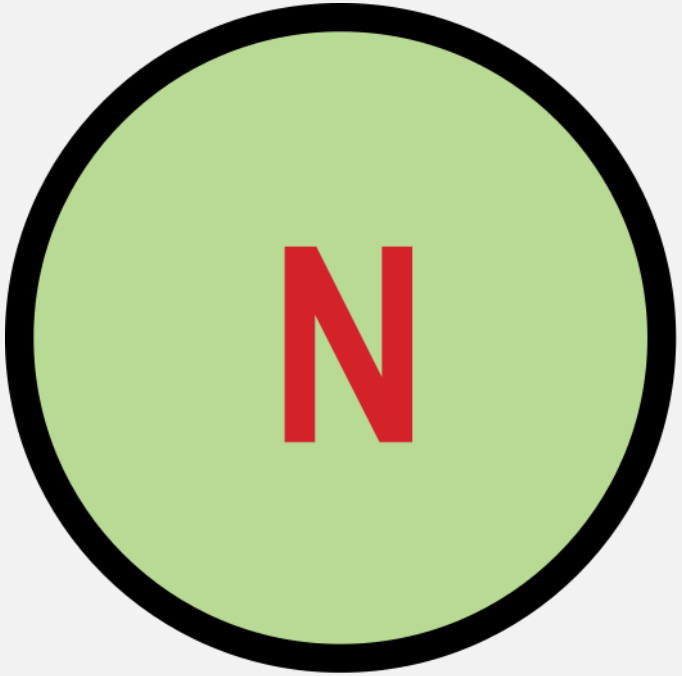
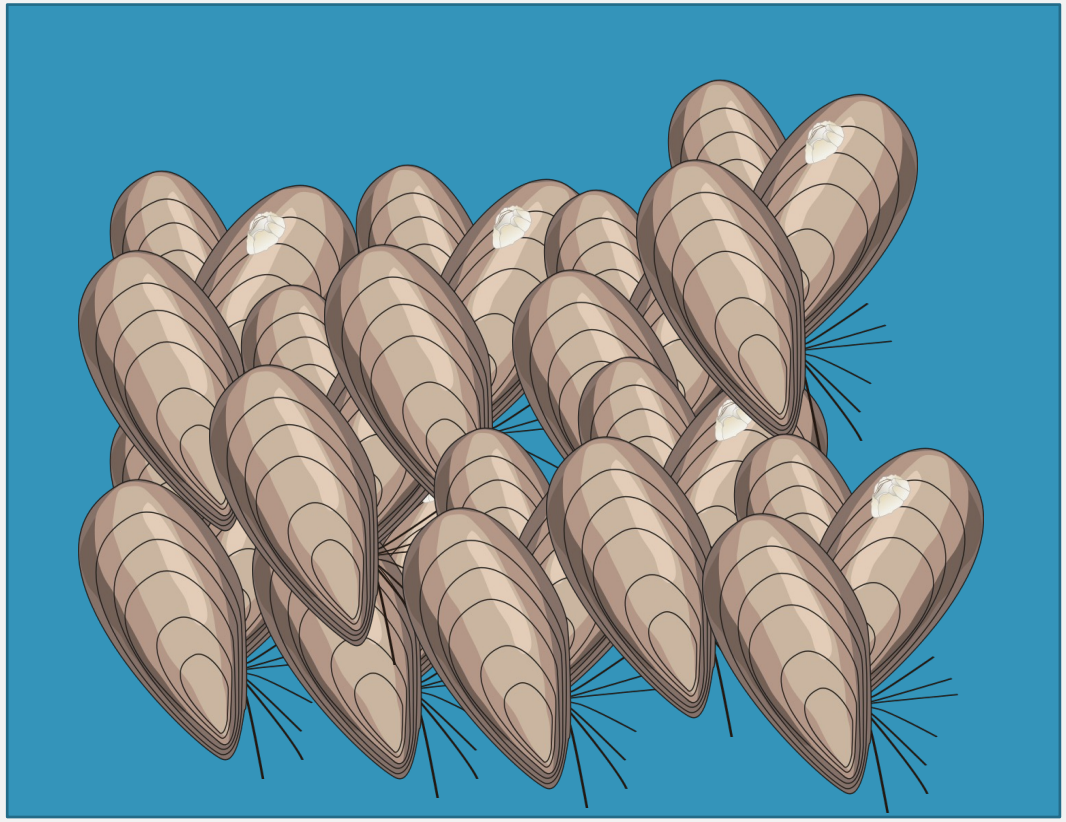


$190/ lb of Nitrogen

MUSSEL NUTRIENT CREDITS?



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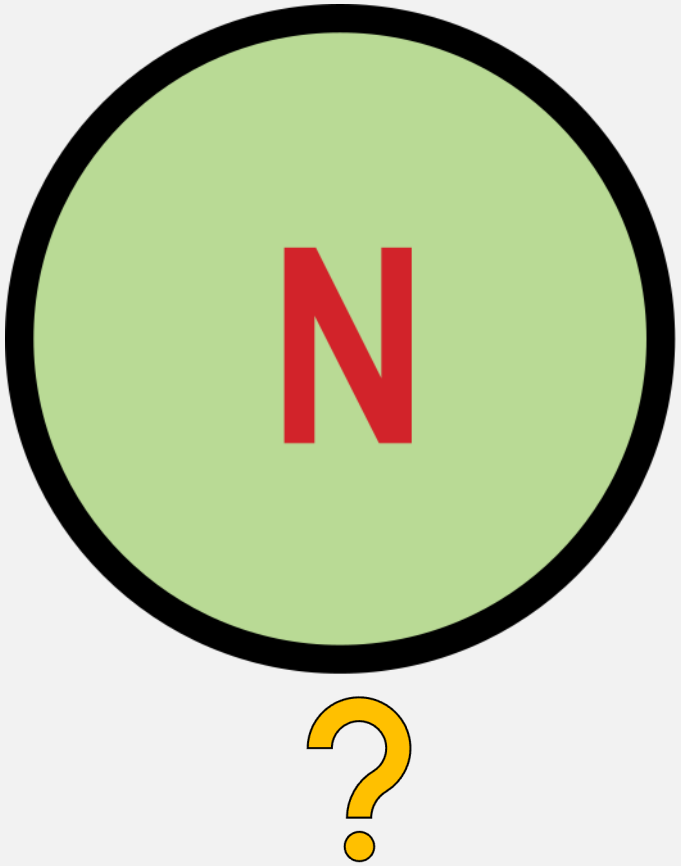
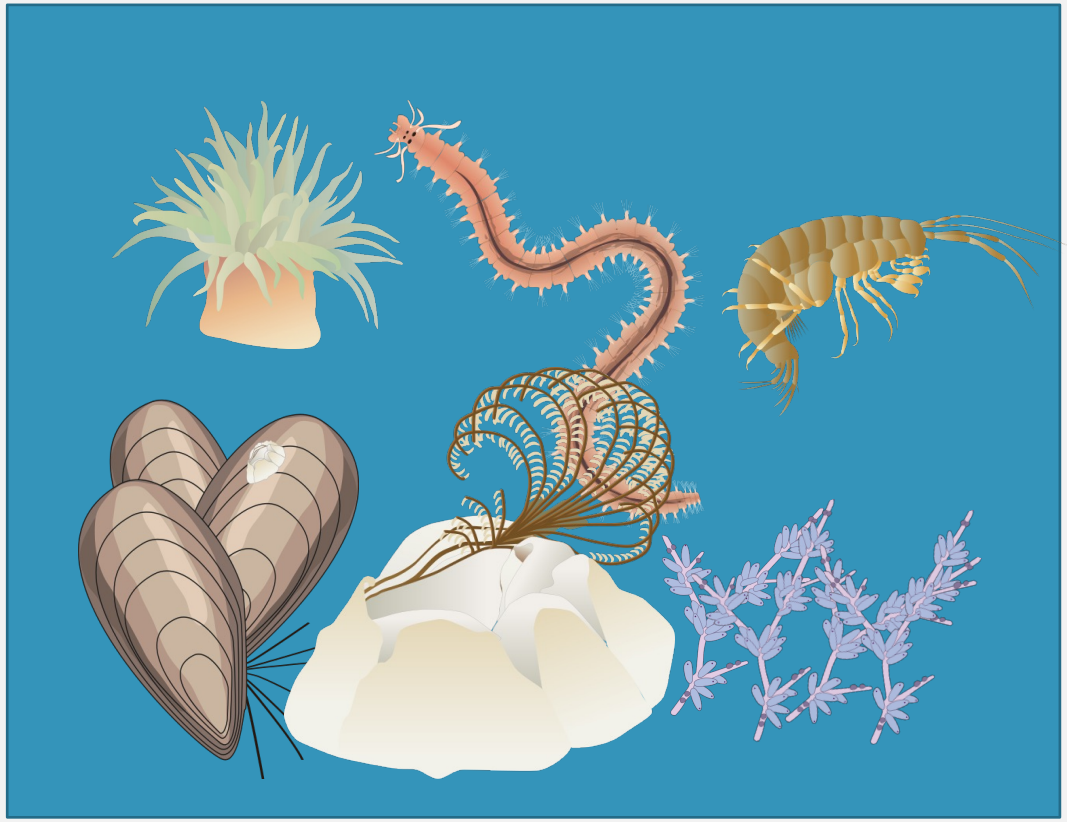


BIOFOULING NUTRIENT CREDITS?



Biofouling community

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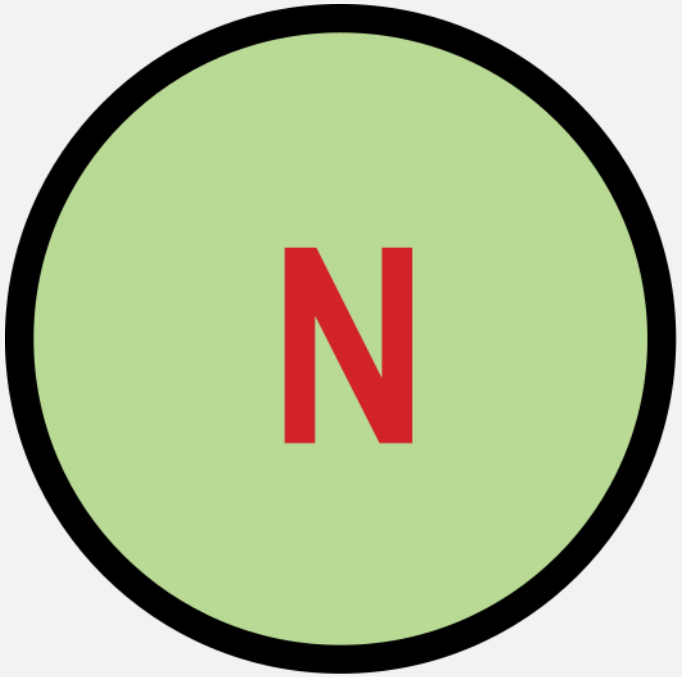

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FUTURE DIRECTIONS

- More filter feeders to examine
- Other environmental factors to investigate:
  - Algae bloom composition
  - Stage and age of mussels
- Other ecosystem services to consider
- Create a model for total nutrients removed by this ecosystem service

CONCLUSIONS

- Mussels can reduce both lab grown and wild algae blooms
- Provides a promising alternative to oysters and a way to remove nutrients from Baltimore Harbor
- Future work should focus on the biofouling community and understanding other ecosystem services that the growing structures may provide

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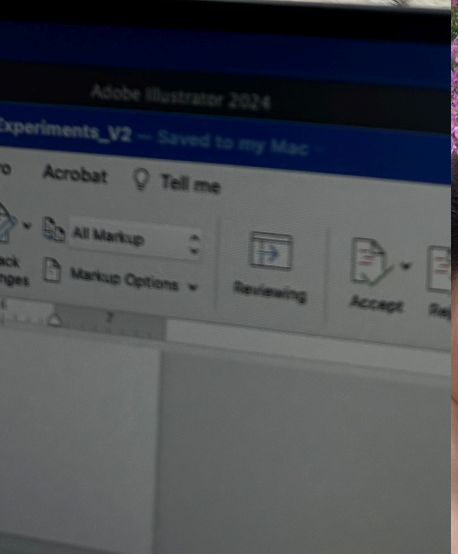
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Questions?