Effects of ocean acidification and nutrient additions on invasive amphipod herbivory of eelgrass in San Francisco Bay

Amy Yoger[1] & Katharyn Boyer[1]

[1] Estuary & Ocean Science Center, San Francisco State University

Introduction

- **Seagrass habitats** provide many ecosystem services but are declining globally largely due to anthropogenic stressors. Global climate stressors, such as **ocean acidification**, can interact with local environmental conditions, including **nitrogen pollution**, making large-scale **combined stressor effects** on seagrass ecosystems hard to predict.[1]
- Seagrasses provide habitat for epifaunal grazers which are valued for their consumption of epiphytic algae that grows on the seagrass leaves. In **San Francisco Bay**, the **invasive amphipod, *Ampithoe valida*, exhibits novel behavior by grazing on both epiphytic algae *and* eelgrass tissue**. However, the size at which they begin consuming eelgrass and how this behavior changes under combined stressors is unknown.[2]
- I conducted **two experiments to explore how *A. valida* size and exposure to ocean acidification and nutrient pollution influence their consumption of eelgrass, information helpful for effective eelgrass conservation and restoration in San Francisco Bay.**

Questions & Hypotheses

SIZE CLASS EXPERIMENT: How does *A. valida* size influence their herbivory on eelgrass, including younger and older eelgrass leaves, and epiphytic algae in San Francisco Bay?

H1: Larger *A. valida* will consume more eelgrass tissue compared to smaller *A. valida,* as larger individuals exhibit greater capacity to ingest plant tissue.

H2: All sizes of *A. valida* will consume more epiphyte than eelgrass tissue, as epiphytes possess fewer structural defenses, making them more palatable.[3]

STRESSOR EXPERIMENT: What are the effects of ocean acidification and nutrients additions on *A. valida* herbivory of eelgrass in San Francisco Bay?

H1: *A. valida* will consume more tissue from eelgrass grown in higher nutrient conditions due to increased nutritional quality via higher nitrogen content and lower C:N ratios.[4]

H2: *A. valida* exposed to reduced pH conditions will consume more eelgrass tissue, as seen in previous Boyer lab experiments.

Study Area: San Francisco Bay Estuary

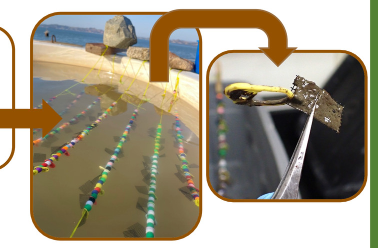
Map of relevant locations. All experiments were conducted at the **Estuary & Ocean Science (EOS) Center**. Eelgrass was collected at **Point Molate**.

Methods: General Feeding Assays

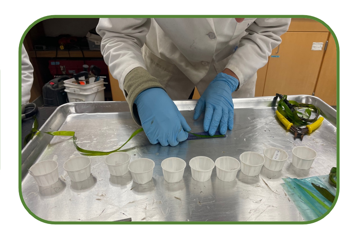
1. **No Choice**: amphipods given one food option
2. **Choice**: amphipods given three food options

Collect eelgrass from field; **grow epiphytes** in tanks

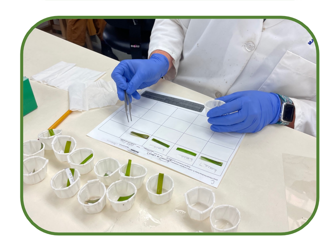
1 **Dry/weigh epiphytes** pre and post assay



2 **Cut eelgrass** segments from each treatment

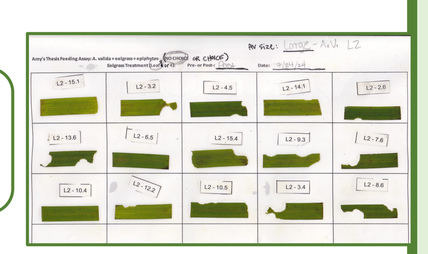


3 **Scan eelgrass** segments for pre-assay area



4 **Feed segments to** *A. valida* in assay container (n=15 per treatment)

5 **End assay and scan eelgrass** for post-assay area

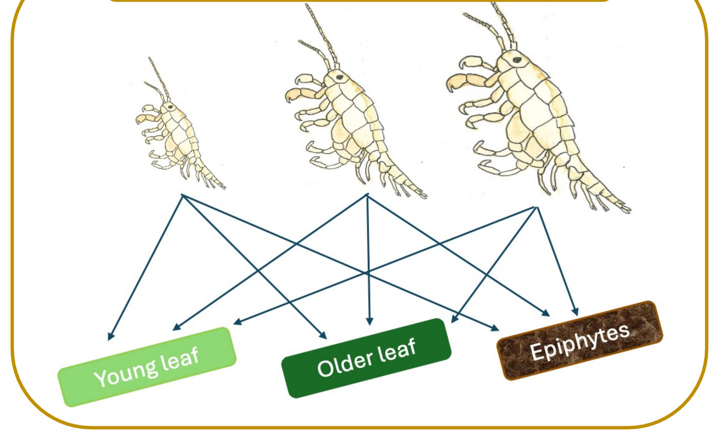


6 **Whole shoot processing** to obtain plant metrics across treatments

7 **Plant sample processing** for tissue composition (C:N and Fiber)

Methods: Size Class Experiment

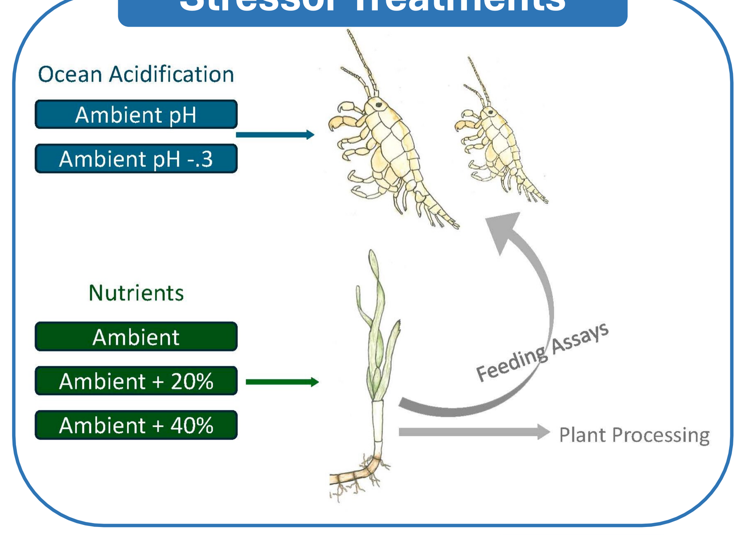
Size Class Treatments



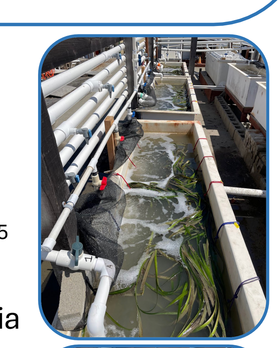
1. **Collect eelgrass** in field **and grow epiphytes**
2. **Treatments:**
   a. **A. valida Sizes:**
      - small (2-4.9mm)
      - medium (5-7.9mm)
      - large (8-11mm)
   b. **Food Options:**
      - Young leaf (leaf 2)
      - Old leaf (leaf 4)
      - Epiphytes
3. **Feeding Assays**

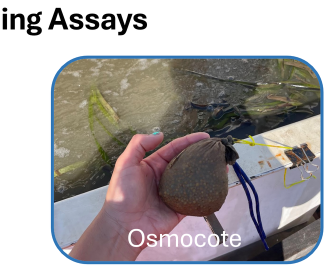
Methods: Stressor Experiment

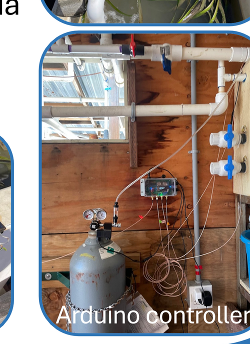
Stressor Treatments



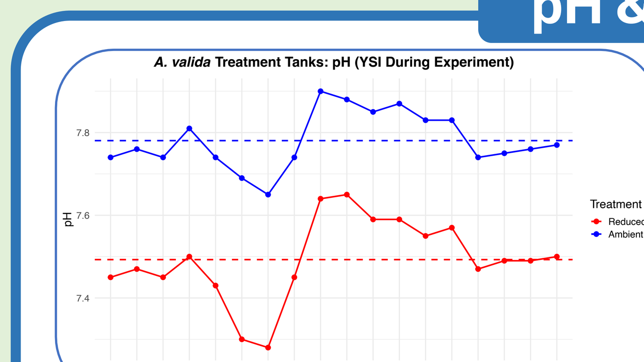
1. **Collect eelgrass & plant** in mesocosm tanks
2. **Initiate treatments** (grow plants for 30 days):
   - **pH**: via Arduino controller[5]
   - **Nutrients** (nitrate, phosphate, ammonium) via Osmocote packets
3. **Feeding Assays**



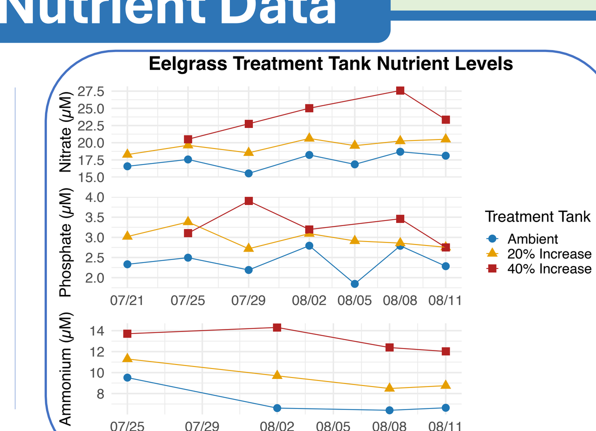




pH & Nutrient Data

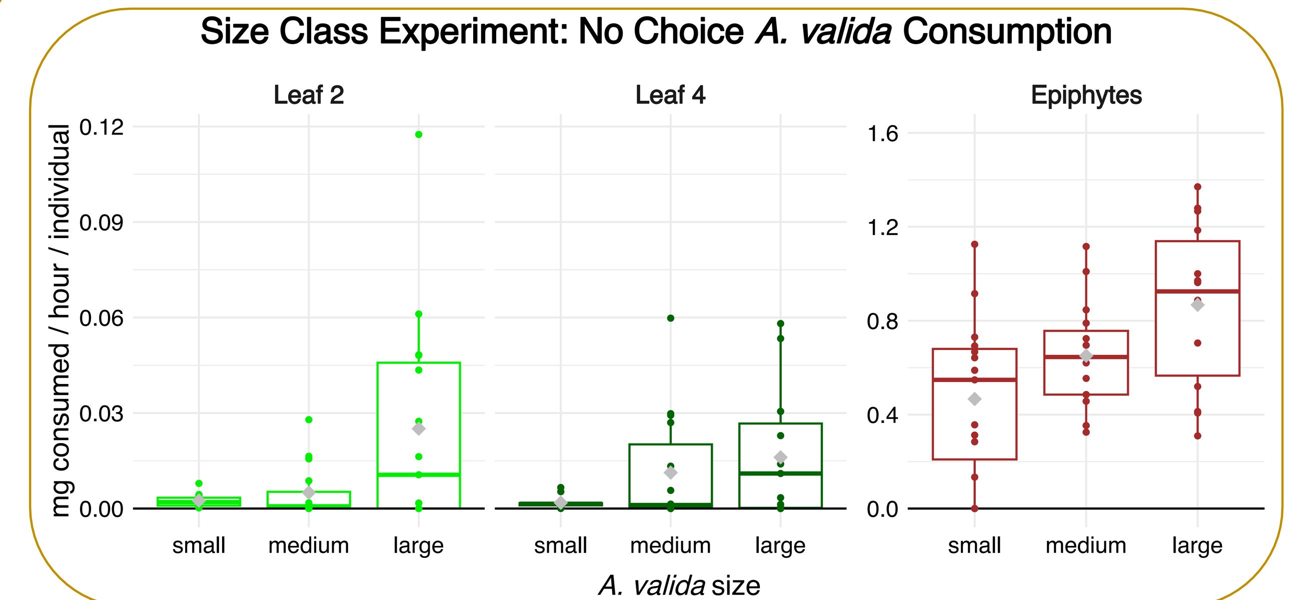


- **The Arduino controller maintained an average 0.3 pH difference** between invertebrate treatment tanks throughout the experiment.



- **The Osmocote fertilizer packets increased nitrate, phosphate and ammonium levels** in the eelgrass nutrient treatments over the three-week period.

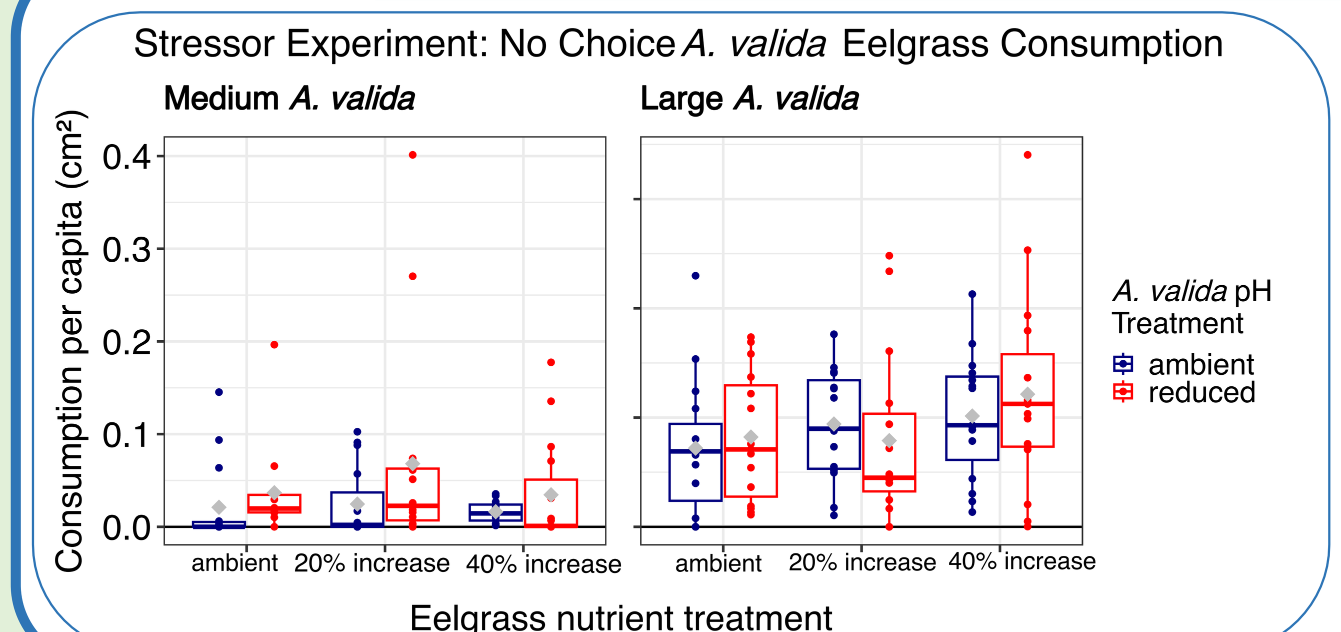
Results: Size Class Experiment Feeding Assays



Takeaways

- **Food type strongly influenced *A. valida* consumption** ($F_{(2, 130)} = 147.6$, $p < 0.001$).
  - Consumption was significantly higher on epiphytes than either eelgrass leaf type, with no significant difference between Leaf 2 and Leaf 4 (Tukey HSD).
- ***A. valida* size strongly influenced consumption** ($F_{(2, 130)} = 7.04$, $p = 0.001$).
  - Small individuals ate very little or no eelgrass tissue, suggesting that dense blooms of juvenile *A. valida* in the Bay may have limited direct impact on eelgrass beds.
- **These results support our hypotheses.**

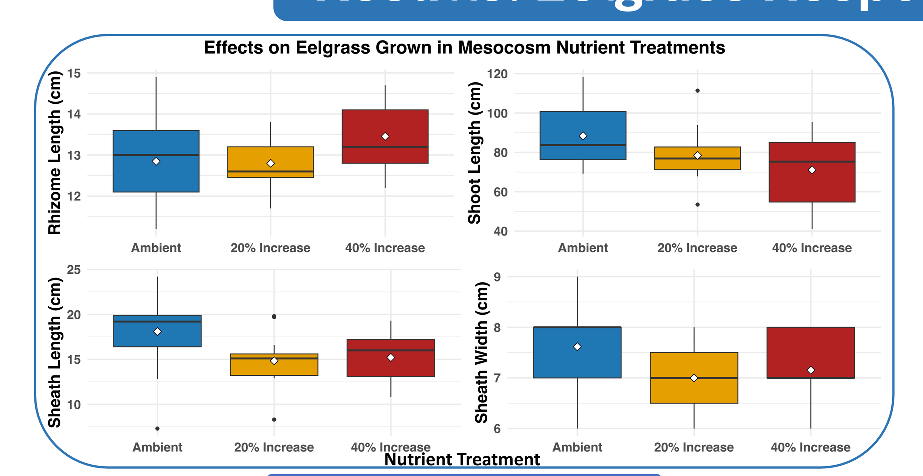
Results: Stressor Experiment Feeding Assays



Takeaways

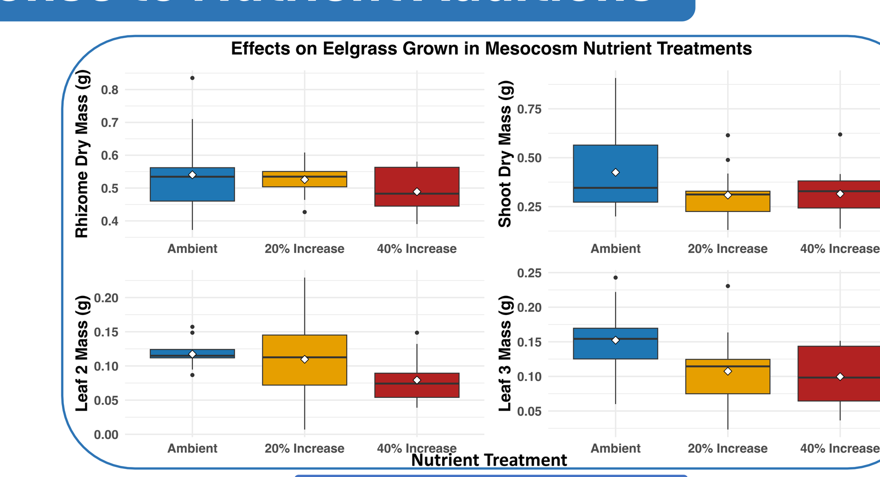
- **Reduced pH conditions tended to increase *A. valida* consumption** (GLM, LR $\chi^2_1 = 2.93$, $p = 0.088$) **by 55% on average.**
  - **Medium *A. valida* consumed significantly more eelgrass under reduced pH than ambient pH (ratio = 0.58, $p < .001$, Tukey HSD).** Large *A. valida* **showed a similar trend (ratio = 0.77, $p = 0.08$, Tukey HSD).**
- **Eelgrass nutrient treatments had no significant effect on *A. valida* consumption** despite changes to the eelgrass (see below)

Results: Eelgrass Response to Nutrient Additions



Summary of Eelgrass Response

Response Variable	DF (num,den)	Test Statistic	p-value (overall treatment)	p (20% vs ambient)	p (40% vs ambient)	Direction of effect
Rhizome Length (cm)	2, 38	F= 2.32	0.112	0.890	*0.085*	Slight ↑ at 40% (*trend*)
Total Shoot Length (cm)	2, 38	F= 3.98	**0.027**	0.103	**0.008**	↓ with nutrients (S at 40%)
Sheath Length (cm)	2, 38	F= 3.93	**0.028**	**0.013**	**0.031**	↓ with nutrients (S)
Sheath Width (mm)	2, 38	F= 2.55	*0.091*	**0.034**	0.120	↓ with nutrients (S at 20%)

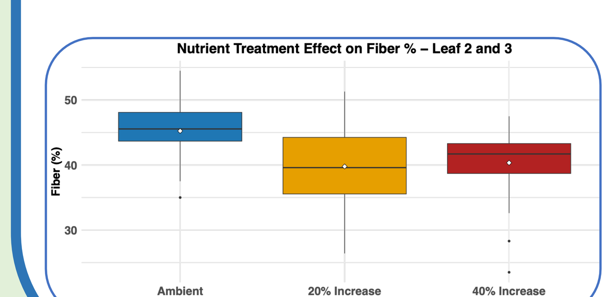


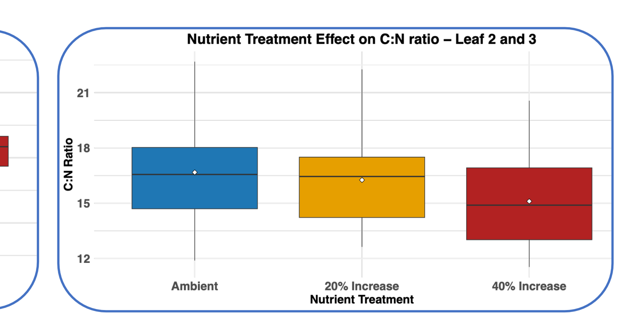
Summary of Eelgrass Response

Response Variable	DF (num,den)	Test Statistic	p-value (overall treatment)	p (20% vs ambient)	p (40% vs ambient)	Direction of effect
Rhizome Dry Mass (g)	2, 37	ΔD = .069	0.280	0.668	0.130	↓ with nutrients (NS)
Shoot Dry Mass (g)	2, 37	ΔD = .840	0.112	*0.067*	*0.097*	↓ with nutrients (*trend*)
Leaf 2 Dry Mass (g)	2, 38	F= 3.52	**0.039**	0.610	**0.017**	↓ with nutrients (S at 40%)
Leaf 3 Dry Mass (g)	2, 38	F= 4.48	**0.018**	**0.020**	**0.009**	↓ with nutrients (S)

Takeaway: Eelgrass Growth

- **Increased nutrients had a significant negative effect on eelgrass shoot length, sheath length, and leaf mass.**





Takeaways: Eelgrass Nutrient Contents

- **Fiber decreased with increased nutrient** ($F_{(2,43)} = 7.63$, $p = .001$).
- **Nitrogen content tended to increase** with the 40% treatment ($p = 0.05$), but the overall effect of nutrient treatment was not significant.
- **Carbon content** was not significantly affected.
- **C:N Ratios** tended to decrease with nutrient enrichment, though this effect was not statistically significant.

Conclusions

- **There is a threshold in *A. valida* size before it consumes eelgrass;** small *A. valida* may benefit eelgrass through epiphyte consumption only.
- As ocean acidification advances (pH lowers), ***A. valida* large enough to consume eelgrass leaf tissue may increase the magnitude of their damage to eelgrass beds (especially intermediate sizes).** Thus, this global change has implications for long-term success of eelgrass in San Francisco Bay.
- Increased nutrients had no effect on *A. valida* consumption of eelgrass; however, **diminished physical characteristics of eelgrass (length, biomass, fiber content) suggest a need to control nutrient inputs to San Francisco Bay.**

Next Steps

- Analyze **Choice Assay** data
- ***A. valida* Field Component**: Epifauna were collected from eelgrass beds in SF Bay (summer–fall 2024) to compare field sizes of *A. valida* with experimental individuals, with identification and measurements currently underway.

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Scan me!