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Effects of Anthropogenic Nutrient Introduction on Macroalgal Carbon Uptake in the Intertidal Zone

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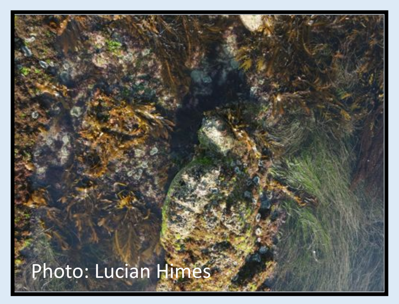
Introduction



- The intertidal is an important diverse coastal ecosystem
- Macroalgae are the foundation species of the intertidal
- Macroalgae are sensitive to environmental change
  - Particularly nutrients: nitrogen & phosphorus
- Main consequence of human development on coasts is eutrophication (nutrient enrichment)
  - Occurs via stream flow, storm drainage, submarine groundwater discharge (SGD)
    - 77.8% of total nitrogen input to Newport Bay comes from point sources (Domagalski & Saleh, 2015)
    - (Mclaughlin, 2021): In Southern California, 92% of terrestrial N flux is wastewater effluent, most of which is discharged directly into coastal waters
      - Nutrient loading from urban areas increased coastal nutrients 7 fold in some instances

- **Purpose**: To understand the effects of human activities on adjacent macroalgal communities
- **Goal**: Understand how anthropogenic based nutrients are influencing the foundation species of the intertidal.
  - Using macroalgal carbon uptake as a metric for productivity
- **Gap in current knowledge:** No existing *in situ* measurements of macroalgal carbon uptake in temperate Southern California coastal waters

Hypothesis: Terrestrial inputs laden with nutrients will increase the productivity rates of all species of intertidal algae.

Methods: Field Work

Site Selection

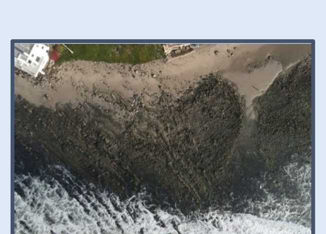
- Latigo Point (Malibu, California)
  - Biodiverse macroalgae, stream input, local SGD, storm drainage runoff
- Focus on 4 core macroalgal species

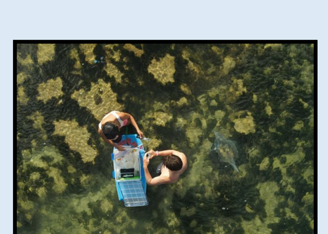
1. *Ulva* sp.
2. *Prionitis lanceolata*
3. *Egregia menziesii*
4. *Coralline* sp.

Field & Laboratory Methods

Use of benthic chambers as an in situ environment to evaluate carbon uptake

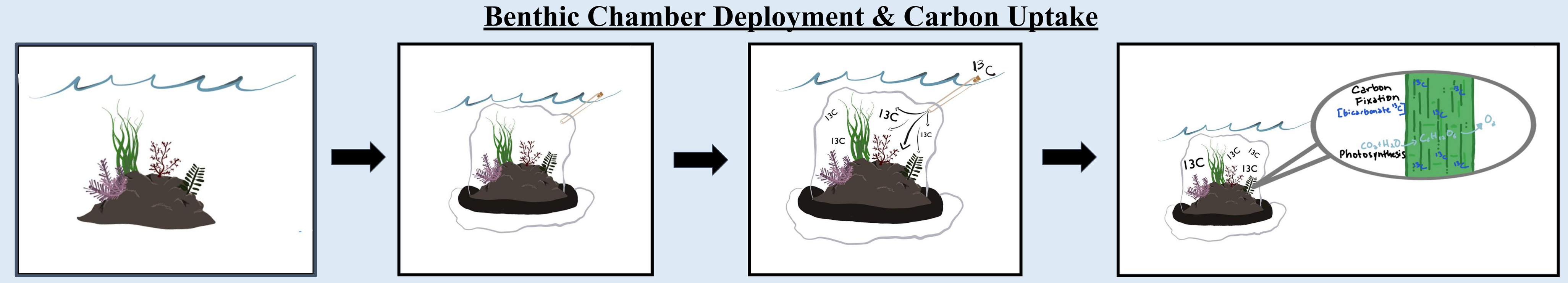
1. Collect samples of "pre" algal tissue, water nutrients, and ambient DIC
2. Inject 13C into the closed system
3. 1 hour elapses & carbon uptake occurs
4. Collect enriched "post" samples of nutrients and DIC from the chamber
5. Remove benthic chamber and collect enriched algal tissue
6. Offshore nutrient sample is take as a control for nutrients,
7. Measurements for salinity, PAR, and temperature are taken from within and outside the benthic chambers to ensure a consistent environment.





Methods Continued: Experimental Design & Analysis

Benthic Chamber Deployment & Carbon Uptake



Analytical methods

Sample Analysis

- **Nutrient samples:** Analyzed at Scripps Institute of Oceanography
- **13C samples**: Analyzed at the University of California at Berkeley Stable Isotope Lab
- Atomic % of 13C and carbon uptake values for macroalgae are calculated
- Environmental measurements are compared and plotted as a time series

Data Analysis

- Use of R to organize, graph, and statistically analyze data
  - Anova & Kruskal Wallis test performed to calculate differences between intertidal nutrients and offshore control, and carbon uptake for each species
  - Linear regression performed between nutrient availability and carbon uptake

Results

Results indicate that there is a significant difference between *Ulva sp.* and *J. macmillanii* carbon uptake at the intertidal site (Figure 1: p = 0.001). SGD and stream input are the principal sources of N & P (Figure 2). Offshore nutrient comparison (Figure 2) shows no significant difference in intertidal vs. offshore N (p = 0.98), suggesting chronic N enrichment of the intertidal and a shift from N-based nutrient limitation to P-based nutrient limitation. Intertidal P concentrations are significantly higher in the intertidal than the offshore control (p = 0.02) As such, data *suggests* a trend between heightened P in the intertidal and increased uptake among certain species. No significant relationship is described likely due to limited sample size.

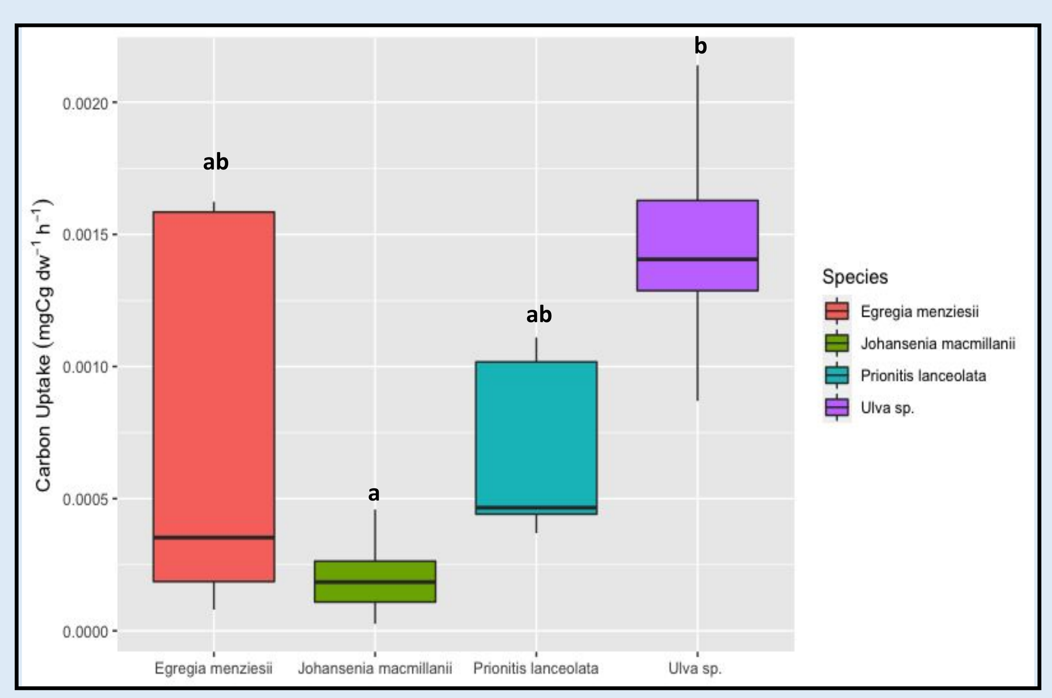


Figure 1: Boxplot of carbon uptake for each core species across all experiments. Groups "a" and "b" are significantly different (p = 0.001) using Anova and Tukey Post-Hoc.

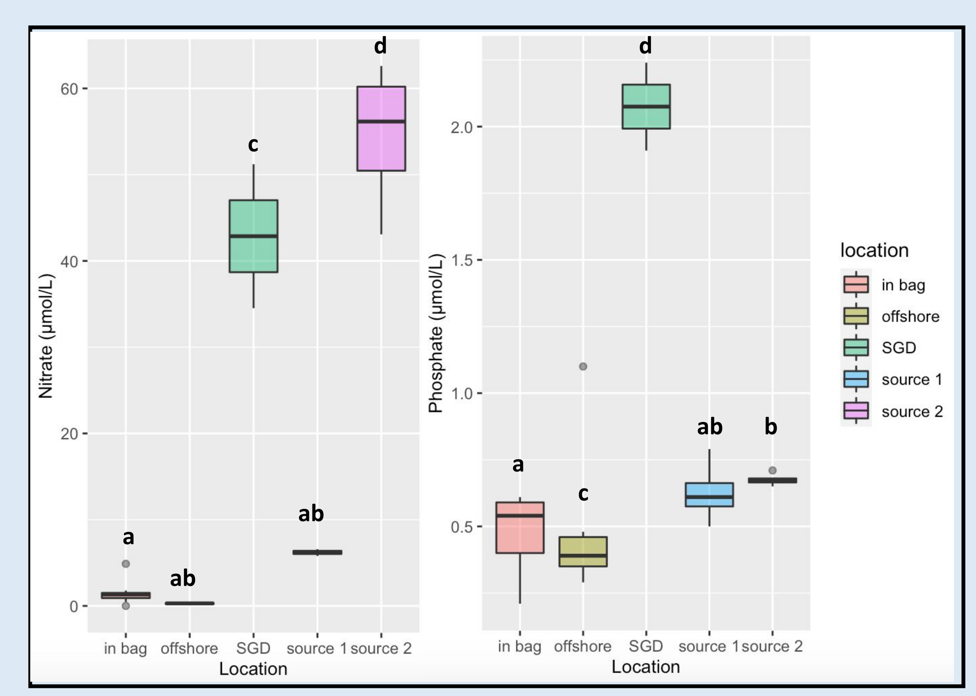


Figure 2: Boxplot of nutrient concentrations at each input source for N and P. Significant difference in P in offshore (control) and intertidal (p = 0.02), but no significant difference for N (p = 0.98).

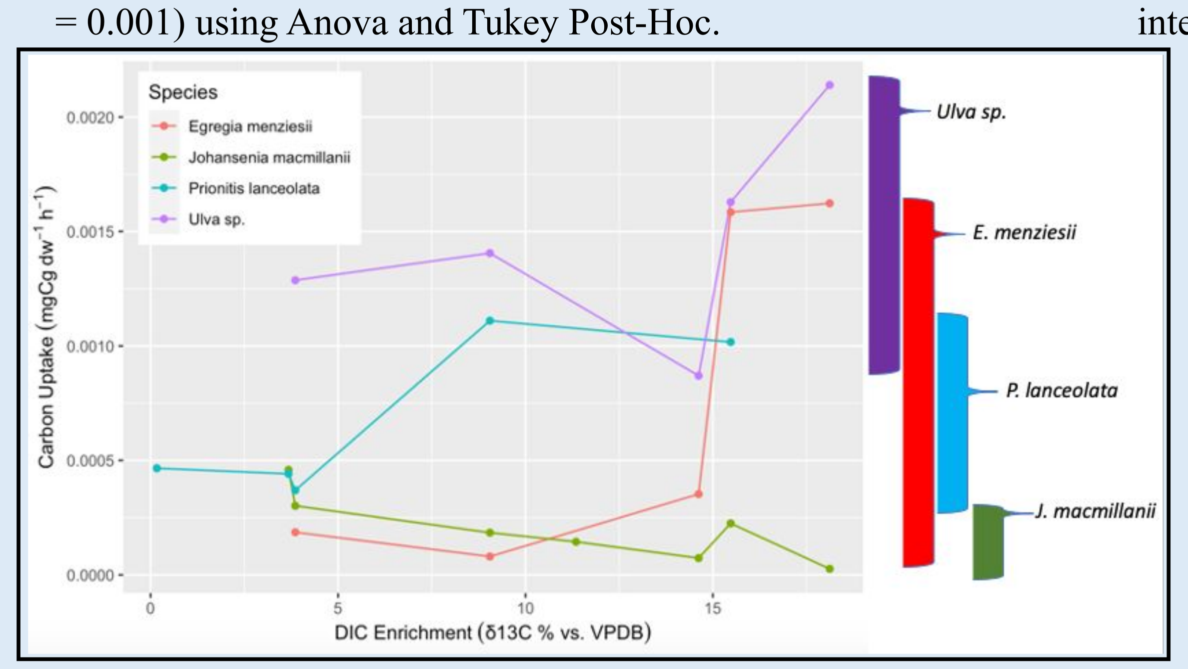


Figure 3: Line graph showing the range of species-specific uptake with varying DIC enrichment. Labeled bars on the right indicate the lower and upper limits of uptake for each species.

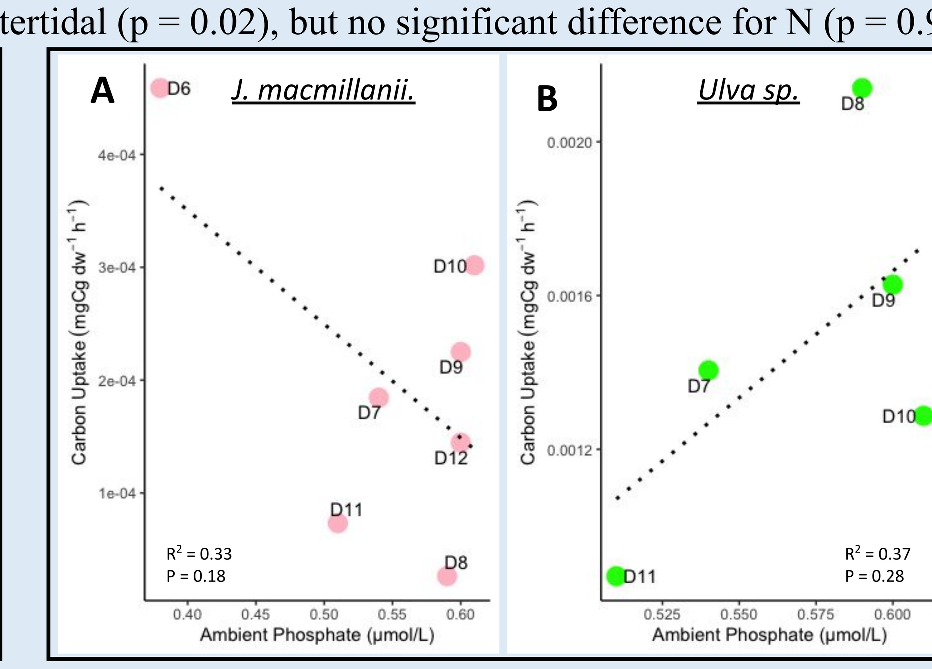


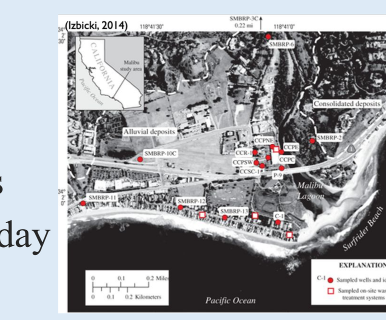
Figure 4: Scatterplots showing uptake of *J. macmillanii* (A) and *Ulva sp.* (B) against ambient phosphate levels.

Discussion

Overview

- Sources are a significant input of nutrients to the intertidal site
  - Sources of nutrients suggest they are anthropogenic in origin
- These nutrients are significantly enriching the water column
- Chronic N-based eutrophication has likely pushed the system towards P limitation
  - Heightened proportion of nitrogen to phosphorus is typical of effluent wastewater (Slomp & Van Capellen, 2004)
- Higher uptake rates for the opportunistic *Ulva sp.* than the slow growing *J. macmillanii* suggest a trend between P concentrations and uptake.

Implications



- Wastewater treatment in Malibu
  - Unsewered land, most use septic systems
  - Only 8% of systems designed to limit nutrients
  - Groundwater circulation with coast ~ 1050m^3/day
- SGD facilitates nutrient loading and potentially structures macroalgal communities through P introduction
- Productivity at Latigo is highly variable

Conclusion

- First study of carbon uptake of southern California macroalgae in situ.
- Cornerstone species *Ulva sp.* and *J. macmillanii* have distinct C-uptake rates.
  - Although these rates are not significantly associated with nutrient availability, preliminary data suggests that anthropogenic over enrichment of the intertidal with N has elevated P to a more influential role in coastal primary productivity. Trends of species-specific uptake suggest a correlation between higher uptake of *Ulva sp.* and lower uptake of *J. macmillanii* with P levels, although sample size is likely too small to define a significant relationship.
    - P enrichment trends and significant differences in species-specific uptake can potentially predict shifts in community structure
  - If more data confirms this hypothesis, human activity is having a significant impact on primary productivity and macroalgae community structure at Latigo Point.

References

1. Cornwall, C.E., Revill, A.T., Hurd, C.L., 2015. High prevalence of diffusive uptake of CO2 by macroalgae in a temperate subtidal ecosystem. Photosynthesis Res. 124(2), 181-190.
2. Harrer, S.L., Reed, D.C., Holbrook, S.J., Miller, R.J., 2013. Patterns and controls of the dynamics of net primary production by understory macroalgal assemblages in giant kelp forests. J. Phycol. 49(2), 248-257.
3. Littler, M.M., Arnold, K.E., 1982. PRIMARY PRODUCTIVITY OF MARINE MACROALGAL FUNCTIONAL‐FORM GROUPS FROM SOUTHWESTERN NORTH AMERICA 1. J. Phycol. 18(3), 307-311.
4. Perini, V., Bracken, M.E., 2014. Nitrogen availability limits phosphorus uptake in an intertidal macroalga. Oecologia 175(2), 667-676.
5. Slomp, C.P., Van Cappellen, P., 2004. Nutrient inputs to the coastal ocean through submarine groundwater discharge: controls and potential impact. Journal of Hydrology 295(1), 64-86. doi: https://doi.org/10.1016/j.jhydrol.2004.02.018.

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