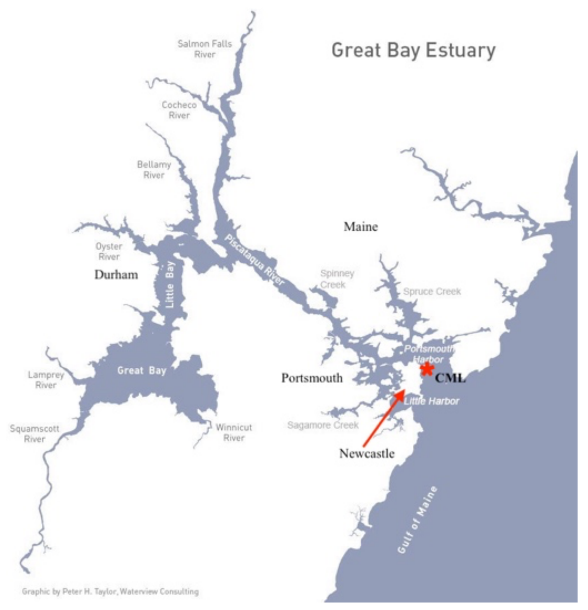
The Effects of Increasing Ocean Acidification on *Mytilus edulis* in the Gulf of Maine

Charlotte Grippo, Maddalena Glass, Dr. Stephen Jones
Department of Natural Resources, University of New Hampshire

BACKGROUND

- ***Mytilus edulis* is a keystone species in the GoM**
  - Mollusks, like *M. edulis,* are critically important to both the marine environment and the economy. In coastal Gulf of Maine ecosystems, *M. edulis* acts as a keystone species by providing food and habitat for many other organisms as well as playing a vital role in removing pollutants from the water through filter feeding[4].



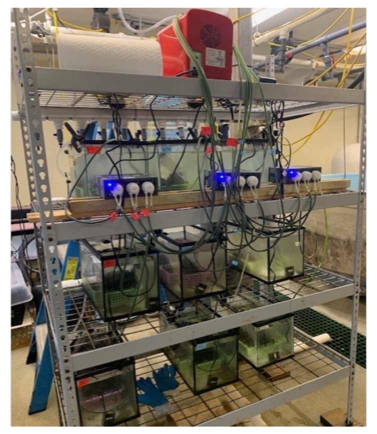
- **Shellfish aquaculture is valuable to this region**
  - New England has a rich history of shellfish aquaculture, dating back to 1900s when it became a focal point in the US seafood industry. The industry of shellfish aquaculture in NE is worth $50 million and has increased in popularity over the last decade, possibly due to lower costs than finfish aquaculture[1]. This escalated reliance on regional shellfish aquaculture calls for the need of comprehensive assessments of the current and future risks associated with a wide range of anthropogenic impacts brought on by global climate change.

- **Ocean Acidification in the GoM is projected to exceed critical thresholds by 2050**
  - One of the most troublesome stressors for marine organisms is the process of ocean acidification (OA). The oceans absorb 25% of atmospheric CO_2 emissions and 90% of the excess heat from these emissions, making marine organisms much more vulnerable to the stressors associated with global climate change than their terrestrial counterparts[8]. Ocean acidification is the process by which atmospheric CO_2 is absorbed by the oceans and results in higher inorganic carbon concentrations, subsequently lowering oceanic pH levels. This slow process is threatening the fundamental chemical balance of open ocean and coastal waters and will undoubtedly have consequences for marine organisms. OA is primarily driven by global anthropogenic carbon emissions, however recent studies have found that local factors such as river runoff with low alkalinity, excessive nutrients, and the upwelling of deep ocean waters can exacerbate localized coastal and ocean acidification[6].
  - OA is quantified by looking at the availability of calcium carbonate ($CaCO_3$) in the water. The naturally occurring chemical reaction which produces $CaCO_3$ in the water is altered under acidified conditions and loses equilibrium as the concentration of available carbonate ions decreases. Scientists quantify OA by looking at aragonite saturations, which result from the ratio of $CaCO_3$ to carbonate in the water. Aragonite saturation decreases because of OA, and researchers working to predict future projections of OA in the GoM have determined a critical threshold value of aragonite saturation at 1.5, by which the region is expected to drop below by 2050[5].

- **OA alters oceanic chemistry and affects *Mytilus edulis* physiology**
  - The availability of $CaCO_3$ in the water is essential to bivalve survival as they require this compound to create and maintain their external shells.
  - In this experiment, *M. edulis* in aquaria were exposed to in-vitro treatments of increased CO_2 levels that decreased pH levels, to assess the response of *M. edulis* to ocean acidification in terms of overall lengthwise growth, metals uptake, and shell strength to inform how the aquaculture industry can expect these organisms to fare with future predictions in oceanic chemistry.

METHODS

Control (C, ambient pH)	Treatment 1 (T1, -0.25 pH)	Treatment 2 (T2, -0.5pH)
C-1	1-T1	1-T2
C-2	2-T1	2-T2
C-3	3-T1	3-T2



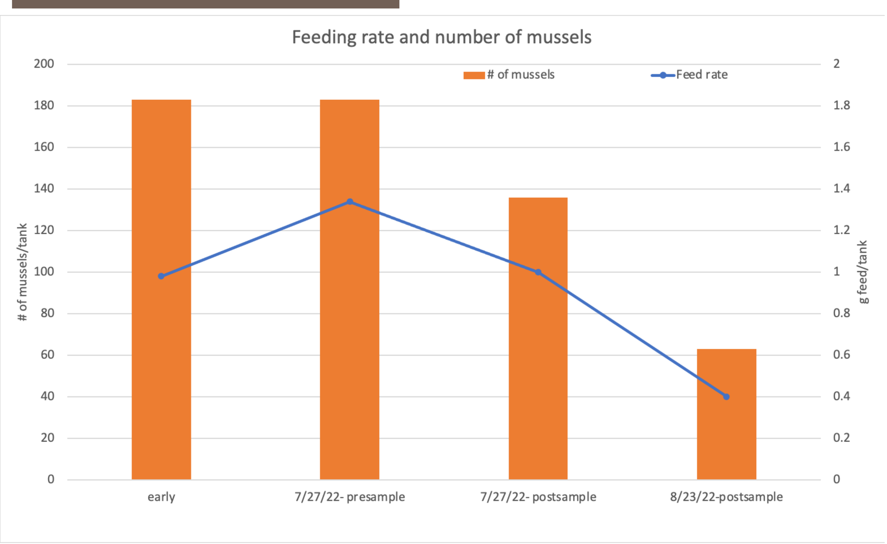
- Experiment set up at UNH's flow-through Coastal Marine Lab in Newcastle, NH from May - September 2022 spanning 84 days (see map in Background section)
- Auto-dosing peristaltic pumps used to dispense feed in 4-hour intervals, 6 times per day
- Mussel lengths were measured biweekly, and mortalities were counted and removed
- 3 treatment types, performed in triplicate as seen above

HYPOTHESIS

Mytilus edulis exposed to increased levels of ocean acidification will experience reduced overall lengthwise growth rates as compared to the control group of *Mytilus edulis* at ambient pH levels.

RESULTS

Feeding Rate:

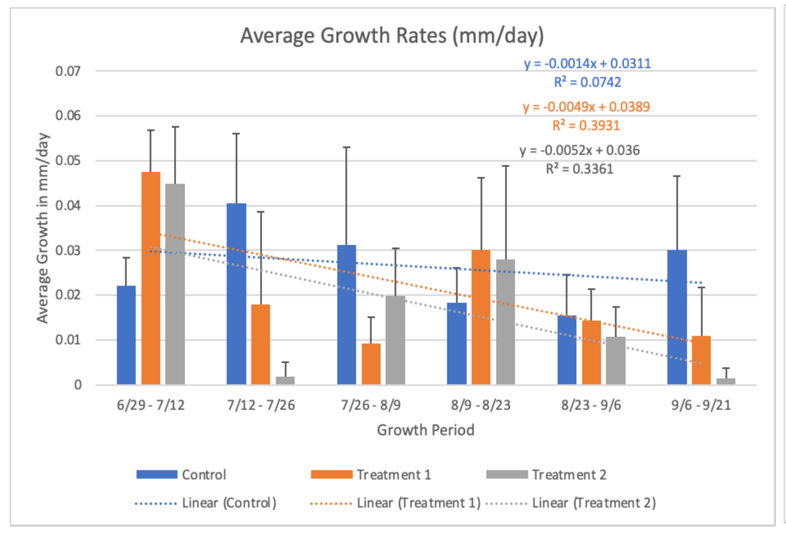


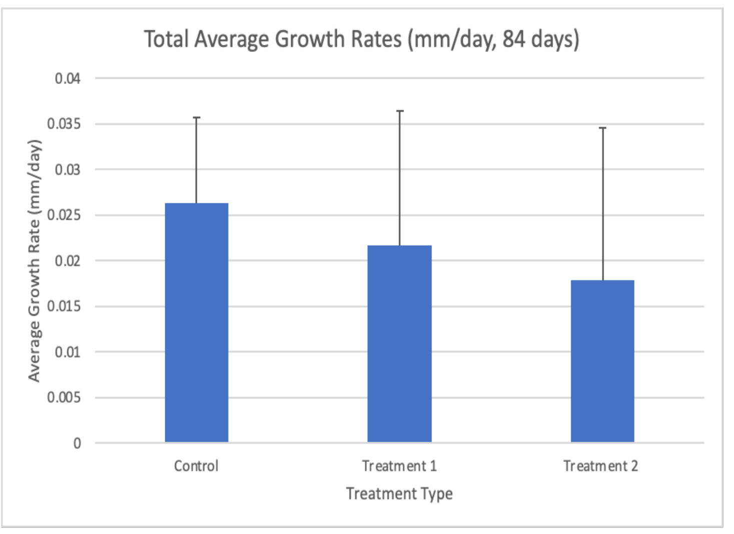
Feeding rate was calculated based on the biomass present in each tank. Individual mussels were fed at a rate of 2% of their biomass.

There was an increase in lengthwise growth noted after the acclimation period, which prompted an increase in feeding rate to accommodate the growing mussels.

As mussels were removed for metals sampling, the biomass present in the tanks decreased, therefore the feeding rate also decreased.

Growth Rates:



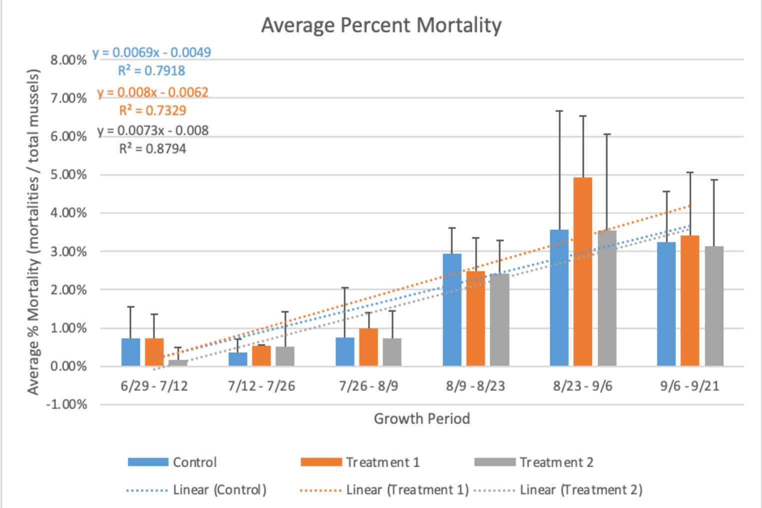


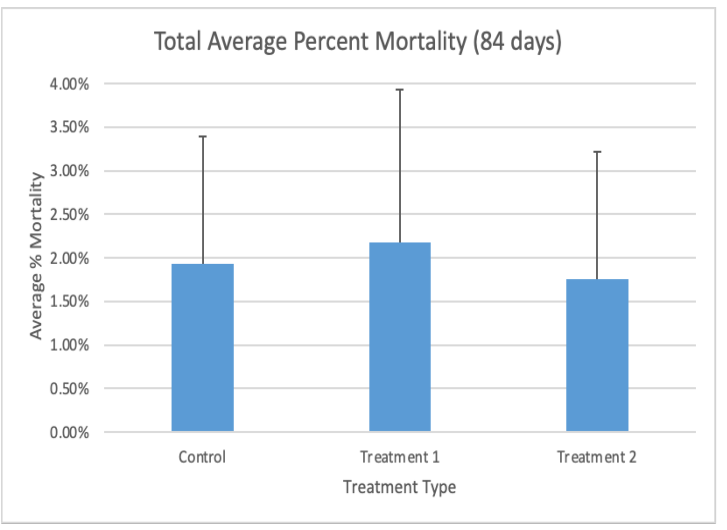
Average growth rates across total 84 days:

- 0.026 mm/day – Control tanks
- 0.022 mm/day – T1 tanks
- 0.018 mm/day – T2 tanks

- Average growth rates for all three treatment types decreased over time
- Control tanks showed least decrease in growth rates over time
- T1 and T2 tanks showed greater decreases in growth rates over time, with T2 tanks showing the greatest decline in growth rate

Percent Mortality:



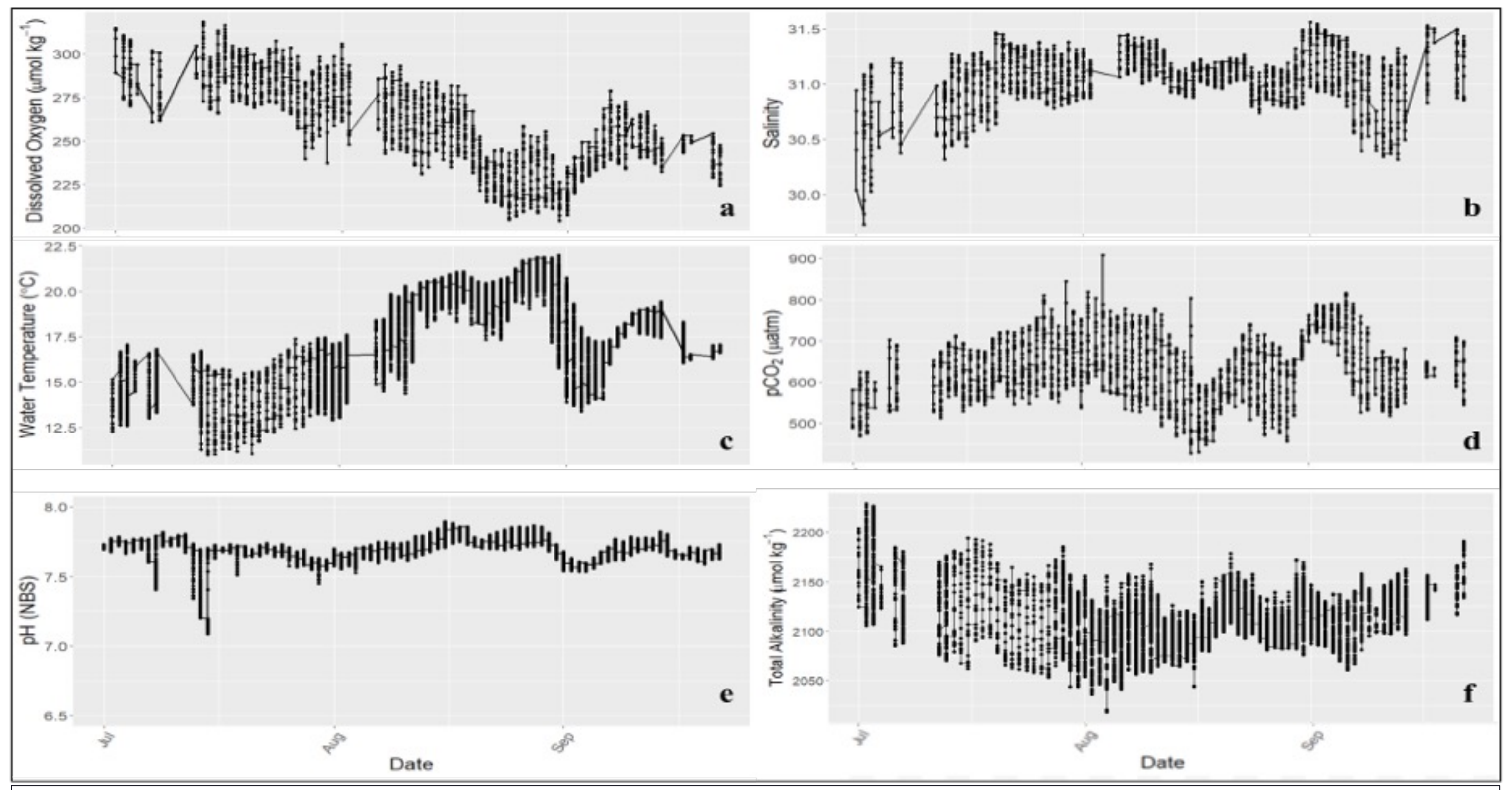


Average percent mortality across total 84 days:

- 2.18% – T1 tanks
- 1.94% – Control tanks
- 1.76% – T2 tanks

- These values are not significantly different; percent mortality is considered essentially the same across treatment types
- Average percent mortality for all three treatment types increased over time
- Mortalities attributed to captivity in high-density aquaria

RESULTS



Water quality conditions in the ambient water flowing into the experimental aquaria during the study were: (a) DO, (b) salinity, (c) temperature, (d) pCO_2, (e) pH, (f) total alkalinity.

Ambient water conditions, especially temperature, pH, and pCO_2 can influence mussel growth. A relationship can be seen between dissolved oxygen and temperature; DO decreased in August as seawater temperatures increased because warmer water can hold less oxygen. Salinity fluctuated within a range which is common in an estuarine system. The pCO_2 levels were consistent throughout the summer and then became more variable in August and September. pH remains fairly constant, although there was a slight drop in September. Alkalinity varied throughout the summer and is dependent on pCO_2, DO, and temperature. A tidal cycle can also be seen here in the ranges of values within a single date.

DISCUSSION

The decrease of 0.5 pH units below ambient levels that *M. edulis* endured in T2 tanks did cause their overall lengthwise growth to decline compared to *M. edulis* in the Control and T1 tanks.

With each 0.25 pH decrease, the growth rate declined at 0.004 mm/day. This reflects the hypothesis of the study team, that increased levels of ocean acidification causes declined growth rates of *M. edulis.*

Ocean acidification levels were determined to have no significant impact on percent mortality of *M. edulis*, which suggests that these mussels can survive under increased OA conditions even when their growth physiology and metabolism are negatively affected.

Overall lengthwise growth rates of *M. edulis* are directly affected by continuous exposure to increased amounts of ocean acidification.

The byproducts of anthropogenic fossil fuel consumption and coastal development are placing direct pressure on bivalves by contributing to global climate change[2,3]. Although bivalves, in general, have relatively strong defenses against climate change, they can only be resilient to a certain extent[7]. This study should be repeated to gather more data about how OA affects the *M. edulis* growth in the GoM, as the region is expected to experience aragonite saturation values below the acceptable threshold by 2050[5]. Understanding this is crucial, as *M. edulis* are vital to both ecosystem health and economic prosperity.

ACKNOWLEDGMENTS

Maddie and Charlotte would like to thank the Coastal Marine Lab staff for the use of their facilities, especially Michael Doherty for immense help in mussel collection, their advisor Dr. Stephen Jones for his support and mentorship, as well as NH Sea Grant and the NOAA Ocean Acidification Program for funding their research.

REFERENCES

[1] Barnes, N. (2015). Massachusetts Shellfish Aquaculture Economic Impact Study
[2] FAO. (2021). *FAO Yearbook of Fishery and Aquaculture Statistics*.
[3] Lapointe, G. (2013). Northeast Regional Ocean Council White Paper: Overview of the Aquaculture Sector in New England.
[4] Metcalfe, C. (2019). *'The disappearance of Mytilus edulis in the Gulf of Maine'*. Gulf Of Maine Institute.
[5] Siedlecki, S., et al. (2021). Projecting ocean acidification impacts for the Gulf of Maine to 2050: New tools and expectations. *Elementa: Science of the Anthropocene*, *9*(1).
[6] Strong, A. (2021). *Ocean and Coastal Acidification in Maine*. Senator George J. Mitchell Center for Sustainability Solutions - The University of Maine.
[7] Thomsen, J., et al. (2010). Calcifying invertebrates succeed in a naturally CO2-rich coastal habitat but are threatened by high levels of future acidification. *Biogeosciences*, *7*(11), 3879-3891.
[8] United Nations. (2023). *The ocean – the world's greatest ally against climate change*. United Nations.