The Influence of Warming, Acidification, and Nutrients on the Health of Gulf of Maine Intertidal Communities
Katherine Bacall, 2020

It has been well documented that the Gulf of Maine is undergoing intense changes in water chemistry due to climate change[1]. Ocean acidification is one of the primary negative effects of climate change and results in a lowering of the ocean's pH by increasing the amount of carbon dioxide (CO_2) present[2]. This increase in CO_2 negatively impacts marine creatures, especially calcifying, or shelling-building organisms, as the change in water chemistry impacts the strength and durability of their protective hard structures[3]. One important shelled organism in the Gulf of Maine is the blue mussel (*Mytilus edulis*). Mussels are a vital economic industry for Maine[1] thus it is important to understand how climate change may affect them and the ecosystem in which they live.

Past research has illustrated that ocean acidification alone can impact the hatching rates and shell growth of blue mussels[4], however, there is a lack of research regarding how multiple other stressors that come as a result of climate change may also impact blue mussels. Furthermore, the effects of the interaction between these stressors have yet to be examined.

This project investigated how multiple stressors of climate change - ocean acidification, warming, and changes in nutrient levels may be impacting blue mussels (*Mytilus edulis*). However, mussels do not live in isolation, so to determine how these stressors might influence species interactions we examined the influence of these stressors on a three-level food web including the carnivorous dog whelk, *Nucella lapillus*, their main prey, blue mussels, *Mytilus edulis*, and phytoplankton which filtering mussels consume. This gave a more holistic view of how these stressors were impacting not only the mussels but the larger system that they live within. We studied how these stressors - changes in pH, temperature, and nutrient level, altered the growth and behavior of these species and, consequently, the way they interact with each other.

This was a large-scale project which involved several different methods and techniques which resulted in a considerable amount of data collection. For example, at the beginning and end of the experiment, each animal's length and weight were measured to examine how the different conditions impacted the shell and tissue growth of the animals. Additional forms of data collected included water samples which were used to analyze water chemistry parameters, oxygen consumption rates and feces production rates which provided proxies for the metabolic rates of the organisms, as well as chlorophyll assessments which provided information about the concentration of phytoplankton and provided a proxy for mussel filtering rates. I participated in the collection of all data for this experiment.

However, the focus of my research as a component of this larger project concentrated on the behavioral response of mussels and snails to changing ocean conditions. In order to investigate how pH, temperature, and nutrients influenced the feeding behavior of both predator and prey, I did bi-weekly behavioral assays. These assays involved recording the feeding, reproductive, and anti-predator behavior of all the animals before and after a simulated low tide. I determined if the mussels were feeding through careful observation of the release of their valve and the presence of their filter feeding apparatus. I determined if the snails were feeding by observation of their attachment to mussel prey and the extension of their hole drilling proboscis. Recording the number of mussels and snails feeding through time allowed me to determine how the experimental conditions impacted feeding behavior and thus affected the interaction between these species. I additionally recorded mortality of mussels and snails throughout the experiment allowing me to examine if the different conditions influenced the survival of each species. This yielded some findings that, although preliminary, do show intriguing trends. For example, with mussel mortality, in conditions with no added nutrients mean mussel death was elevated in high-temperature conditions and reduced in low-temperature treatments regardless of pH level (Fig 1). In conditions with added nutrients, mussels in low pH had similar mortality as in the no nutrient condition; high temperature results in a higher mean death rate than low temperature. However, with added nutrients, there was a large increase in the mean total death under ambient pH conditions and warming. Overall, this would suggest that mussel death rates are most dramatically impacted by temperature, although high-temperatures coupled with added nutrients and ambient pH had the highest mortality (Fig 1). This data can give insights into how climate change might impact mussel predation which can have larger implications for the ecosystem in which they live.

This experiment generated and continues to produce a sizeable amount of data and provides opportunities for future avenues of examination, thus not all the findings can be included in this report. I plan to continue working with and analyzing this data through the upcoming school year and I am hopeful that I will continue to find intriguing results.

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Figure 1

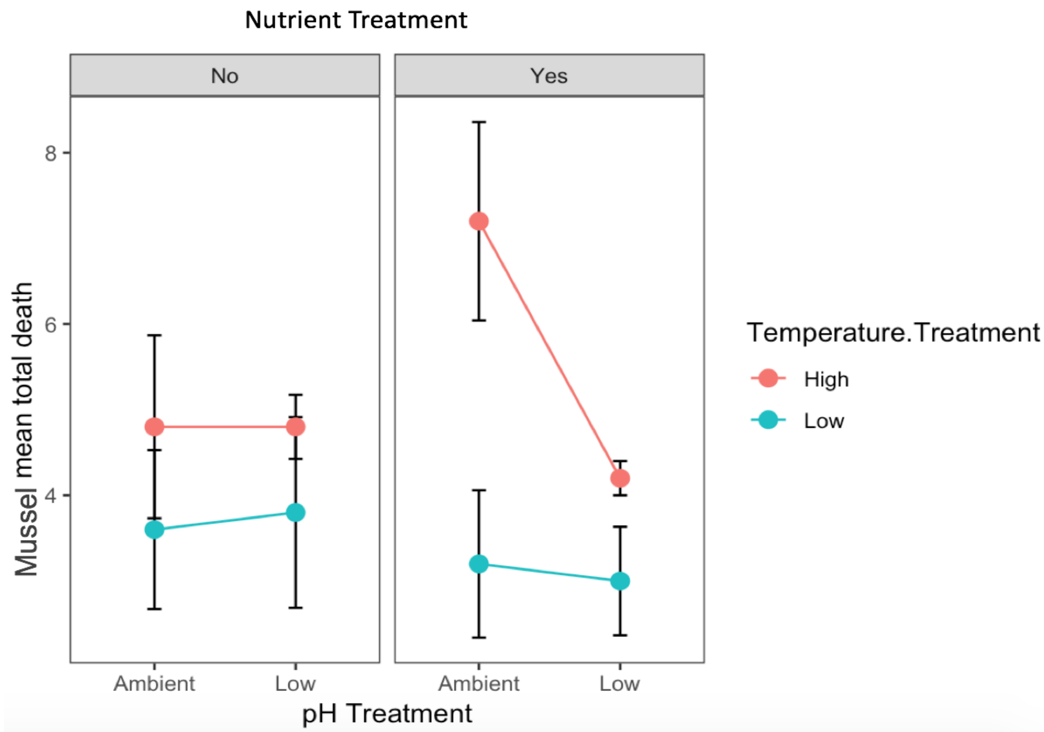

Figure 1. Mean mortality of mussels due to predation from snails across eight condition variations. Conditions varied by pH, temperature and nutrient levels. Across pH and nutrient variations, temperature produced the largest effect wherein warmer temperature conditions resulted in higher mean death rate. The highest mortality rate was produced by coupling high-temperatures with added nutrients and ambient pH.

Resources

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