DIFFERENCES IN TEMPERATURE TOLERANCE BETWEEN ADULT AND JUVENILLE *C. MAENAS* POPULATIONS ALONG THE PACIFIC COAST

By Alex Farrell

Mentor: Dr. M. Christina Vasquez

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Abstract

Carcinus maenas is an invasive species of crabs that originates from Northern Europe and the Mediterranean Sea. However, over the last three decades this species has proliferated along the North American west coast. *Carcinus maenas* has been called an "ecosystem engineer" (Klassen, 2007, p.1) due to its ability to completely transform whatever habitat it lives in. It preys on a wide variety of aquatic animals and is highly resistant to changes in salinity and temperature. Scientists speculate its resistance to temperature change is one of the primary reasons for the rapid population growth of this species (Tepolt, 2014, p. 1129). This paper proposes a summer research project to investigate the temperature tolerances of various *Carcinus maenas* populations along the Pacific coast from Morrow Bay, California up to Puget Sound, Washington. The purpose of this research project will be to collect more information about the physiology of *Carcinus maenas* as well as its metabolic response to changes in temperature in order to help better predict future spread of the species as well as monitor current *Carcinus maenas* populations.

Introduction

Carcinus maenas, or more commonly known as European green crabs, originated in Northern Europe and the Mediterranean Sea (Jamieson, 1998, p.1590). In the 18th century the crabs were transported from northern Europe to the U.S. East coast via the ballasts of merchant ships (Jamieson, 1998, p.1590). Since their initial introduction, there have been two more separate introductions on the east coast and a third on the west coast in San Francisco Bay in 1989 (Tepolt, 2014, p.1130). With each introduction of *C. maenas,* native ecosystems have seen radical transformations and a decline in biodiversity (Klassen, 2007, p.35). Some of the most significantly reduced species are mussels, juvenile dungeons crabs and oysters (Washington Department, 2003). This is significant because not only does *C. maenas* have massive impacts on an ecosystem's biodiversity, but they also have incredible economic consequences for commercial fishermen (Klassen, 2007 p.40). The annual economic losses along the Pacific coast due to green crab predation are estimated to be between $42 and $109 million dollars (Khiari, 2018, p.2). This is an enormous sum of money and puts great stress on coastal economies. This is why it is essential to closely monitor populations of this species in efforts to minimize their ecological and economic impacts.

Furthermore, cornerstone adaptations that make this invasive species unique and successful compared to native counterparts (i.e., hermit crabs, shore crabs, and juvenile dungeons crab [Colnar, 2007, p.126]), are its ability to adapt to a broad range of thermal and salinity conditions (Tepolt, 2014, p.1129). It can survive freezing temperatures and also withstand incredibly hot temperatures near 100°F (Tepolt, 2014 p.1134). This high thermal tolerance is one of the primary reasons why European green crabs have not only survived in North America but also continue to thrive and spread.

A recent study by Tepolt and Somero (2014) suggests that adult European green crabs have a cold tolerance well below 0°C as well as a heat tolerance between 33.7°C and 37.3°C (Tepolt, 2014, p.1132). This wide thermal tolerance, therefore, makes it difficult to control the adult crab population. Additionally, although the average temperature at which heart function collapses is usually between 33.7 and 37.3°C, there was one outlier population in California which had a tolerance level of 29.7°C (Tepolt, 2014, p.1131). These results suggest that the Northern and Central California populations of *C. maenas* could potentially be much more sensitive to heat than the rest of the green crabs surveyed in the study. This increased sensitivity shown by Californian *C. maenas* will be the focus of my research.

For my research, I propose collecting ten adult and ten juvenile European green crabs from each of five key locations along the West Coast: Morro Bay, the most southern location reporting *C. maenas* populations (Grosholz, 2000, p.1207); San Francisco Bay, the location where European green crabs were first introduced to the west coast (Grosholz, 2000, p.1207); Seadrift Lagoon, CA, a region highly populated with *C. maenas* as well as the location where Dr. Tepolt collected her samples (Tepolt, 2014, p.1130); Coos Bay, OR, a *C. maenas* stronghold (Yamada, 2017, p. 2); and Puget Sound, WA, which is one of the northern most locations for *C. maenas* in the United States (Jamieson, 1998, p.1587). The results from each of these locations will be compared to existing literature to update and verify tolerance differences between adult and juvenile *C. maenas* along the Pacific coast as well as identify any new differences in tolerance. Further investigation into *C. maenas* temperature tolerances is valuable for making future predictions as to which habitats *C. maenas* may expand into next. In addition, this information may be used to identify populations requiring continual monitoring to minimize further species expansion.

Methods

My research project will take place over a 10-week period. I will collect at least 10 adult crabs, with carapace length of 40 mm or greater, and 10 juvenile crabs with carapace length of 30 mm or less, from each location using standard rectangular "Ketcham" crab traps (Young, 2017, p.556-558). Gravid females (females bearing eggs) will be removed from the sample group to ensure that tolerance differences do not occur due to a variance in hormones. The traps will be allowed to soak in the water for up to three days or until a sufficient sample size has been collected. Temperature and salinity measurements will also be collected twice a day at 8am and 2pm to see if there are significant changes in salinity throughout the day and during high and low tide.

Once the samples are collected, the crabs will be brought back to the lab and stored in temperature-controlled seawater tanks that mirror the temperature and salinity levels the crabs were originally collected from. Crabs will be fed mussels *ad libitum* until experimentation time. The testing and analysis will occur over one week at each location and will begin by first acclimating the adult and juvenile crabs in a LOLIGO ® Respirometer at 15°C and 30 ppt salinity for two hours. Next, over a 60 min period the temperature will rise 6°C and then plateau at 21°C for another hour. During the hour of stable temperature conditions, data on O_2 consumption will be measured by the computer in the respirometer. This trend will continue for another 6 hours with the final temperature reaching 39°C. The experiment in total will occur over a 10-hour period and will be performed first for all 10 adult crabs. On the second day the experiment will be repeated for the 10 juvenile crabs. Figure 1 illustrates this process. Once the experiment is concluded the crabs will be collected and sacrificed by freezer as this is the most

humane way to discard of crabs that may still be alive after heating. I will repeat this collection and analysis routine for each of the proposed locations (Morro Bay CA, San Francisco Bay CA,

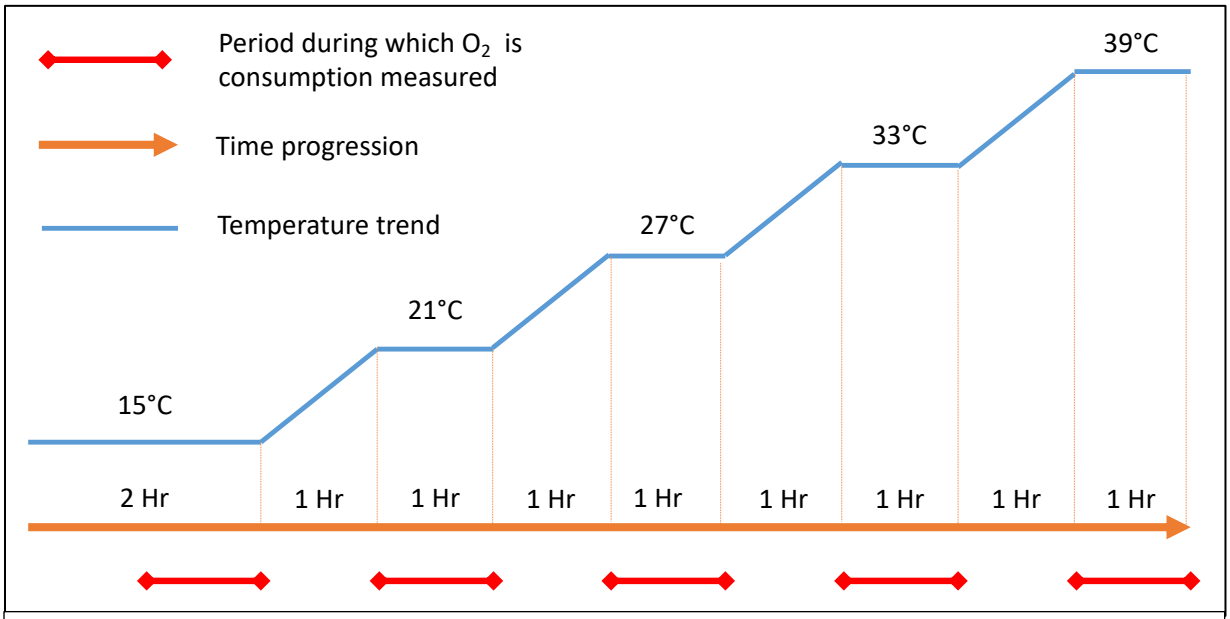

Fig. 1. This figure illustrates the rising heat trend in the experiment as well as the length of time the experiment takes place over and the period when oxygen consumption is measured

Seadrift Lagoon CA, Coos Bay OR, and Puget Sound WA).

Expected Results

Once these data points are collected, possible results include but are not limited to significant difference in temperature tolerance between California populations of *C. maenus* and their more northern counter parts in Oregon and Washington. Also expected are svariances between adult and juvenile temperature tolerances. Additionally, if there are variances in temperature tolerances between juvenile crabs in California and in Washington this could suggest a genetic predisposition to different tolerance levels. With the guidance of my mentor Dr. M. Christina Vasquez, I will then compose these findings into a scientific paper. Ultimately the goal would be to publish my research into a journal like the "Journal of Animal Ecology" or "Aquatic Conservation: Marine and Freshwater Ecosystems" or "The Biological Bulletin.

Conclusion

In closing, *Carcinus maenas* is an incredibly invasive species of crab that has the potential to permanently alter the Pacific coast. From its destruction of native ecosystems to the economic losses in commercial fishing, it is essential to continue the research and understand *C. maenas's* physiology in order to determine the best way to minimize their proliferation. Through the use of respirometry and increasing water temperature I will examine just how resistant various West Coast populations of *C. maenas* are to environmental temperature stress. This study will provide an inclusive and detailed picture of *C. maenas* populations along the entire West Coast of the United States.

Timeline

I will begin my research project on Sunday May 12th and it will continue to June 16th. I will first travel to Cal Poly's Center for Costal Marine Science in Morro Bay and check into the residential dorms on Sunday May 12th and become acclimated with the facilities on Sunday afternoon. From there, I will collect crab samples in traps from Monday May 13th to Wednesday May 15th. They will then be transferred into a temperature-controlled seawater tank on Wednesday afternoon and remain there until Thursday morning, May 16th. On Thursday ten adult *C. Maenus* crabs will be run through the experiment described above in methods will run for 10 hours. The next day on Friday May 17th the same experiment will be repeated this time using the ten juvenile crabs. Once the two-day experiment concludes, the remaining Saturday and Sunday (May 18th and May 19th) will be dedicated to data analysis and shadowing permanent researchers at the lab learning more about their fields of research. On Sunday afternoon I will leave Cal Poly and drive to San Francisco Bay and check into San Francisco State University's Estuary and Ocean Science Center.

The same weeklong process that occurred in Morro Bay will then also happen at San Francisco State University, however I will remain at SFSU's EOS Center for two weeks instead of one because San Francisco Bay and Seadrift Lagoon are located an hour away from the EOS Center. I will again repeat experiments and shadow faculty in a similar fashion as at Cal Poly. However, during the third week of my research, instead of shadowing SFSU faculty again on Saturday June 1st, I will drive to Stanford's Hopkins Marine Station in Monterey and shadow faculty there to discuss graduate school and internship opportunities. On Saturday evening I will drive back to San Francisco where I will check out on the next morning Sunday June 2nd.

Next, I will travel from San Francisco to the Oregon Institute of Marine Biology. I will repeat my sample collection procedures, testing, and analysis at OIMB from Sunday, June 2nd to Sunday June 9th. Finally, I will conclude my summer research by traveling to University of Washington's Friday Harbor Laboratories. Here I will again repeat my collection process and experiment from Sunday June 9th to Sunday June 16th.

By the end of the summer on August 26th, I will have an exhibition of my research ready to present for the LMU Undergraduate Research Symposium as well as have a working draft of my paper which I will continue to refine with Dr. M. Christina Vasquez to hopefully publish in a scientific journal.

References

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Budget

ITEM	DESCRIPTION	COST
2 Ketcham Green Crab Traps	Standard traps used by other researchers to collect green crabs	$57.00
Lab Fees	$120@ OIMB; $265 @ UW; ~$250 @ SFSU* & Cal Poly*	$1135.00
10 tanks of gas	Two tanks of gas per week for a car with a 16-gallon tank (California average ~ $3.694 per gallon)	$591.04
Weekly Room & Board	$100 ~ per week for OIMB; $131 per week at UW; ~$120 per week SFSU* & Cal Poly*	$591.00
Meal Plans	$371 @ OIMB; $279 @ UW; ~ $325 SFSU* & Cal Poly*	$1625.00
Unforeseen Expenses	Tax, unexpected lab or facility cleaning fees, extra gas	$500
Total		$4,499.04

* Estimates of these location expenses are based off average prices for other west coast marine biology labs. SFSU and Cal Poly would not supply cost estimate without the submission of an actual summer admission application.