Behavior and Interspecific Resource Usage of *Cancer Borealis*, *Libinia emarginata*, and *Carcinus maenas* in a Controlled Environment.

By: Ben Martino & Andrew Petlock

Abstract

New England shores are home to many endemic and non-native crabs that reside in the rocky intertidal zones of the water. The species that our experiment focused on were *Cancer. Borealis*, *Libinia emarginata*, and *Carcinus maenas*, and the driving force of the experiment was to see how these species interacted with each other when brought together in a confined space and competing for similar resources. We ran five trials each for the interspecific competition interactions of each species, resulting in fifteen total trials, and measured which of them utilized the energy resource (in this case, periwinkles) first after some time was given to acclimate. The results suggest that there must be some other form of competition in which *C. maenas* triumphs because of how successful it has been here in New England. One possibility is simply these three crabs occupy different niches and thus do not compete with each other directly, rather there is a form of exploitative competition happening in the intertidal area. We believe that our results are significant in the sense that the results did not coincide with our hypothesis, and that maybe future experiments can be conducted with the data from out lab in mind.

Introduction

Different types of crabs have made their way to the shores of New England, moving into the same space that native crabs have lived in for generations. Invasive species can have a

substantial impact on the ecosystem that they live in, and they can directly and indirectly affect the other members of the food web. Invasive species are non-indigenous species (e.g., plants or animals) that adversely affect the habitats they invade economically, environmentally or ecologically (RI CRMC Invasive Species 2017). The introduction of alien species into the state of Rhode Island is not new. European settlers intentionally introduced numerous non-native plants and animals upon their arrival in the New World, like sheep and cows. Unintentional introductions also occurred early in the settlement process (National Invasive Species Information Center 2017). Rocks used as ship's ballast that were discarded in New England's coastal waters are a likely vector for the introduction of European marine species, like *Littorina littorea,* that dominates a decent amount of rocky beaches in Rhode Island today (RI CRMC Invasive Species 2017). Over 20 invasive species have been found in Rhode Island (RI CRMC Invasive Species 2017), including *Hemigrapsus sanguineus*, *Membranipora sp*., *Codium fragile, Grateloupia turuturu,* and numerous species of shellfish pathogens and sea squirts (RI CRMC Invasive Species 2017).

Competition is most typically considered the interaction of individuals that vie for a common resource that is in limited supply, but more generally can be defined as the direct or indirect interaction of organisms that leads to a change in fitness when the organisms share the same resource (Lang 2013). The outcome usually has negative effects on the weaker competitors.

When an individual directly alters the resource-attaining behavior of other individuals, the interaction is considered interference competition (Lang 2013). Exploitation competition occurs when individuals interact indirectly as they compete for common resources, like territory, prey or

food (Lang 2013). Simply put, the use of the resource by one individual will decrease the amount available for other individuals. Whether by interference or exploitation, over time a superior competitor can eliminate an inferior one from the area, resulting in competitive exclusion (Lang 2013).

C. borealis is a marine crab that lives in waters along the east coast of North America from Newfoundland to Florida (Donahue 2009). They possess a rounded, rough-edged carapace with small light spots, and robust claws with dark brown-black tips. Habitat preferences for *C. borealis* range from rocky substrate in Rhode Island and the Gulf of Maine to silt and clay substrate on the continental slope (Donahue 2009). According to stomach content analysis on individuals from the Gulf of Maine, the diet of *C. borealis* consists of mussels, arthropods, snails, and some algal species (Donahue 2009).

L. emarginata occurs from Nova Scotia to the Florida Keys and through the Gulf of Mexico (Martinez 2003). It lives at depths of up to 49 m, with exceptional records of up to 120 m. It is roughly triangular in outline and very heavily calcified carapace and a large leg span (Martinez 2003). The whole crab is khaki, and the carapace is covered in spines and tubercles. Just like other decorator crabs, often clothes itself in debris and small invertebrates. *L. emarginata* lives on various substrates (Martinez 2003). Adults are sluggish and not aggressive, and younger crabs are frequently covered with sponges and hydroids. Despite its small size, in comparison to other predatory crabs, *L. emarginata* feeds on large sea stars like *Asterias forbesi* (Martinez 2003). Unusually for crabs, *L. emarginata* preferentially walks forwards, rather than sideways, although they are also capable of sidelong movement (Martinez 2003).

C. maenas is a widespread invasive species, listed among the 100 world's worst alien invasive species (Grosholz 1996). It is native to the north-east Atlantic Ocean and Baltic Sea, but has inhabited similar habitats in Australia, South Africa, South America and both Atlantic and Pacific coasts of North America. It grows to a carapace width of 90 millimetres, and feeds on a variety of molluscs, worms and small crustaceans (Grosholz 1996). Its successful dispersion has occurred via a variety of mechanisms, such as on ships' hulls, packing materials, and bivalves moved for aquaculture (Grosholz 1996).

The main goal of the experiment is to see how competitive *C. maenas* is relative to its native counterparts (*C. Borealis* and *L. emarginata*), along with seeing if they are a risk to endemic species and a threat to biodiversity. Our prediction for this experiment is that *C. maenas* will be more aggressive when competing with *C. Borealis* and *L. emarginata*, and *C. Borealis* and *L. emarginata* will be more defensive when confronted by *C. maenas* and are both fighting for food or shelter. We believe this because invasive species attempt to force themselves into an already established food web, and must compete with native species for food. Since the food web has been established for many years prior to a new predator coming in, the native crabs will not be sure how to react and will be more defensive until they find a strategy to deal with the invaders.

Materials/Methods

On April 14th 2017, we went to the Narrows Bridge salt marsh in Narragansett, RI, to collect crab specimens. We spent an hour before and after the low tide (which was 4:06 pm (0.1 ft)) on the mudflat and channel sections of the marsh searching for crabs. After searching, we

found one *C. Borealis* (Jonah Crab), three *L. emarginata* (Common Spider Crab), and five *C. maenas* (European Green Crab). We placed these species in a gallon bucket filled with seawater, and brought them back to the lab, where we placed them in two 10 gallon aquariums. One tank had the *C. Borealis* and *C. maenas,* while the other one housed the *L. emarginata* individuals. We then acclimated the crabs to the aquariums over the course of three days.

On April 17th, 2017, we ran the trials. We set up a third 10 gallon aquarium with fresh seawater and *Littorina littorea* (Common Periwinkle) individuals we had collected the day of from to the University of Rhode Island's Graduate School of Oceanography dock in Narragansett, RI, in a four gallon carboy. We did this so the water used in the trial tank would not have the familiar scents of the other crabs, rather new odors from the ocean. To get the crabs to be active, we placed an incentive periwinkle carcass in the middle of the tank (we boiled the snails so they would come out of their shells). We placed a mesh divider diagonally across the tank, placing one species of crab in one corner, and the other one in the opposite corner (see Figure 1). We then acclimated the crabs for three minutes to account for the shock of them being moved between aquariums. After this, we removed the divider and let the crabs approach each other over the course of a 10 minute interval, recording observations that we noticed. At the end of the 10 minutes, we removed the crabs. We repeated the trial steps five times for each crab combination: *C. Borealis* vs. *C. maenas*, *L. emarginata* vs. *C. maenas*, *C. Borealis* vs. *L. emarginata.*

On April 26th, 2017, we cleaned up the experiment. We placed the crabs back into the gallon bucket, and returned them to the ocean at the University of Rhode Island's Graduate

School of Oceanography dock in Narragansett, RI. We then rinsed out the two 10 gallon aquariums and stored them.

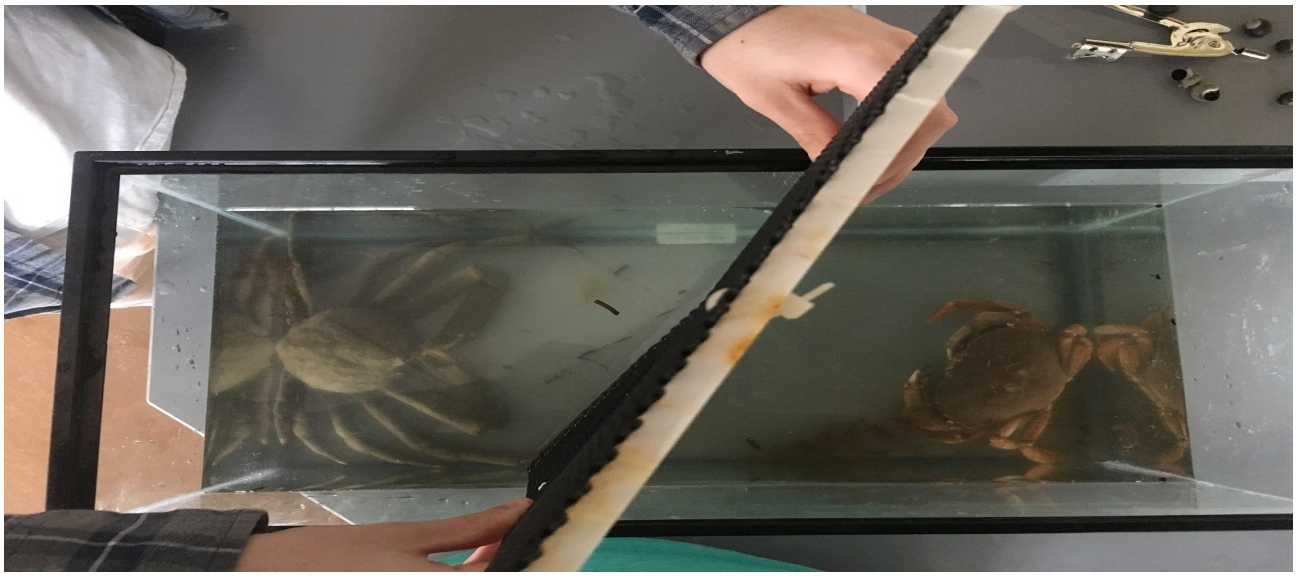

Figure 1. Crab trial aquarium set up. We placed a mesh divider diagonally in the tank, preventing the crab species being used in the trial from moving before the acclimation period was over.

Results

Figure 2. *L. emarginata* & *C. Borealis.* Here *L. emarginata* (left) is seen mingling with *C. Borealis* (right). Both crabs started on opposite ends of the tank, scuttling towards the center. Both *L. emarginata* and *C. Borealis* were hostile towards each other when scavenging for food.

Figure 3. *C. Borealis* & *C. maenas.* Here *C. maenas* (right) is seen getting comfortably close to the *C. Borealis* (left). *C. Borealis* started the trial on that side of the tank, while *C. maenas* came all the way across the tank, past the food, just to scout out the other organism in the tank. *C. maenas* was extremely active in our trials.

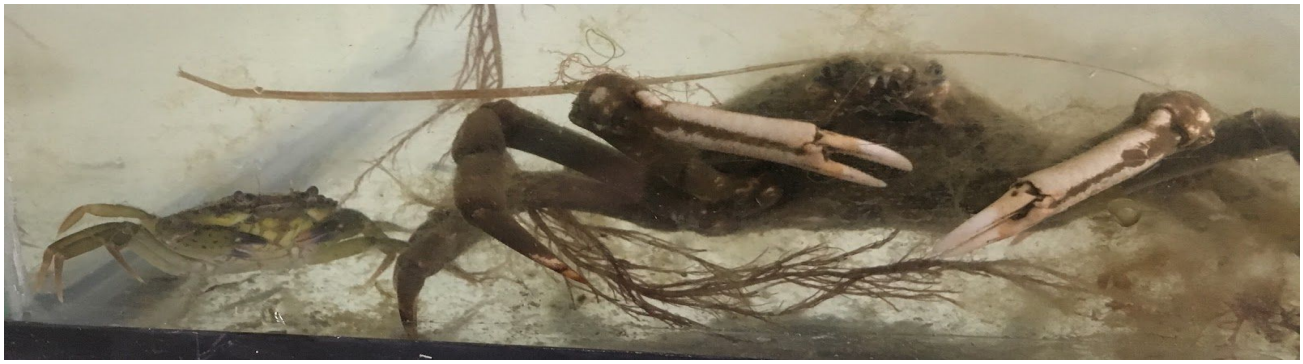

Figure 4. *C. maenas* & *L. emarginata.* Similar to the previous figure, *C. maenas* (left) is found mingling with *L. emarginata* (right). Although it is not shown in the figure, *C. maenas* tended to use its tank-mate as shelter by climbing on top of the back of its shell, and sometimes even crawling underneath of the crab.

Table 1. *C. Borealis* and *L. emarginata* trials. Shown below are the results of the competition between *C. Borealis* and *L. emarginata.* We developed a one to three rating system to quantify our observations. One represented the crab being shy, not going for food right away, and not forcing other crab away. Two represented the crab going for food, but not forcing the other crab away. Three represented the crab going for food, and aggressively forcing other crab away.

	C. Borealis	*L. emarginata*
Trial #1	2	2
Trial #2	2	1
Trial #3	2	2
Trial #4	2	1

Trial #5	2	3

Table 2. *C. Borealis* & *C. maenas* trials. Shown below are the results of the competition between *C. Borealis* and *C. maenas.* We developed a one to three rating system to quantify our observations. One represented the crab being shy, not going for food right away, and not forcing other crab away. Two represented the crab going for food, but not forcing the other crab away. Three represented the crab going for food, and aggressively forcing other crab away.

	C. Borealis	*C. maenas*
Trial #1	1	1
Trial #2	1	1
Trial #3	2	1
Trial #4	1	1
Trial #5	2	1

Table 3. *L. emarginata* & *C. maenas* trials.
Shown below are the results of the competition between *L. emarginata* and *C. maenas.* We developed a one to three rating system to quantify our observations. One represented the crab being shy, not going for food right away, and not forcing other crab away. Two represented the crab going for food, but not forcing the other crab away. Three represented the crab going for food, and aggressively forcing other crab away.

	L. emarginata	*C. maenas*
Trial #1	2	1
Trial #2	2	1
Trial #3	2	1

Trial #4	2	1
Trial #5	2	1

To say the least, our results did not match the expectations of our initial hypothesis. We expected the endemic crabs to be more passive relative to acquiring the necessity of food/energy and for the invasive crab, we predicted it to be faster at adapting to its environment and to secure energy resources faster. In just about all of our trials, *C. maenas* did not acknowledge the periwinkles that were placed in the middle of the tank, and instead, it was actively moving on the perimeter of the tank and many times coming very close to the other crab. This can be seen in both Figure 3 and Figure 4, where *C. maenas* does not mind getting up close and personal. Although *C. maenas* was given a 1 for all of its trials, this does not mean that the crab was not active. This was simply a measure of who utilized their resources after becoming acclimated to a new environment, and we were surprised to find that the endemic species found their food first. It is important to note however that there was a large size discrepancy between *C. maenas* and the other species, with *C. maenas* being about one-fourth the size of the other crabs.

With the trials relating to *C. Borealis* and *L. emarginata*, these were interesting because the crabs were close in size, and the tank was barely big enough to hold the both of them with some room to spare. In all but one trial, *C. Borealis* was usually the first to make its move, and eventually eat the periwinkle. The only trial where *C. Borealis* was bullied around was when we paired it up with the biggest specimen of *L. emarginata* we had, which was slightly bigger than it. This is interesting to note because all of our trials have the bigger crab obtaining the food first,

whereas the smaller crab would not have the food as their top priority. This can certainly be a possible source of error in our experiment, but we did gather useful information about *C. maenas*, in how even though it is much smaller than its competitors, it is not afraid to come close to them, which is unlike the behavior of many terrestrial animals such as lizards, who calculate precisely how close they can get to a predator, or how close a predator can get to them, while still having enough time / energy to escape that situation.

The most uneventful set of trials happened between *C. Borealis* and *C. maenas*, as many of the trials resulted in neither of the crabs obtaining the food. The reason may be that these crabs did not have enough time to acclimate to the cold water, as they were taken from relatively warm water to cold seawater in the tank. Also, the tank we provided was relatively small, and it gave the crabs almost no room to move. Ideally, the tank should should been large enough for small rocks to be used as shelter, and for the crabs to move freely and not confined by barriers. The glass of the tank should try to be only one way, so that the crabs are not intimidated by eager scientists observing them up close.

In conclusion, we are satisfied with our results with the tools available to us and the timeframe we were given to work on the experiment. These results suggest that there must be some other form of competition in which *C. maenas* triumphs because of how successful it has been here in New England. One possibility is simply these three crabs occupy different niches and thus do not compete with each other directly, rather there is a form of exploitative competition happening in the intertidal area.

Discussion

C. maenas was more passive when competing with *C. Borealis* and *L. emarginata*, and *C. Borealis* and *L. emarginata* were more aggressive when confronted by *C. maenas* while acquiring food. These results supported our null hypothesis that endemic crabs would be more aggressive when feeding than invasive crab species.

These results appear to make sense since they are very similar to some studies that have been carried out in the past. According to a study done in Canada, the lobster *Homarus americanus*, an endemic crustacean to the Northwest Atlantic spent proportionally more time feeding than *C. maenas* (Williams 2009). This seems to be what is expected because *H. americanus* is more familiar with the environment and the various food resources, since it has been living off Canada longer than *C. maenas,* giving *H. americanus* a competitive advantage over *C. maenas.* According to another study done in Washington State, United States, the crab *Cancer magister*, an endemic crustacean to the Pacific Northwest, spent more time feeding than *C. maenas,* along with making *C. maenas* retreat from the food (McDonald 2000). This also makes sense because *C. magister* is more familiar with the environment and the various food resources, since it has been living off Washington State longer than *C. maenas,* giving *Cancer magister* a competitive advantage over *C. maenas.* This relates to our findings, since *C. Borealis* and *L. emarginata* from Narragansett Bay went to the food item before *C. maenas,* along with

forcing *C. maenas* to retreat from the food item when the endemic crab scared it off through show of force.

Reflecting on the experiment that was performed, there were many procedures in our lab experiment that we could have done differently in order to obtain more conclusive and concise data and to become better scientists as a whole. The first method that comes to mind is when we were out collecting our test subjects. Some of us had zero experience with looking for crabs in the water, and we seemed to collect every living organism we could get our hands on. Looking back, although the process of collecting was extremely fun and memorable, we should not have collected crabs of different sizes and we should have stuck to our game plan of finding the specie we were focusing on in the first place. In our experiment, there were great size discrepancies between the different species of crabs; *C. maenas* on average were much smaller than the *C. Borealis* and *L. emarginata*, with the *C. maenas* being not even a quarter the size of the opposing crabs in almost all trials. If we were to run a similar experiment, we would be more committed to finding the crab that we chose to study, and afterwards, find crabs of similar sizes so the results would not be so one-sided.

Next issue to be improved upon for next time would be a better plan for conducting our experiment. At first, we planned on creating a system to measure the activity of the crabs when we started our experiment, but that never took off until we had done all of our trials of the different crabs in the tank together. We attempted to be consistent with having the same food available to all the crabs, same trial time, and same acclimation times for all crabs, but during the experiment, we were fixated on how the crabs were interacting and were too busy taking video instead of recording notes in our journals and creating a qualitative or quantitative way of

measuring the crabs. If we want to be professional scientists, we must be more disciplined as to not get carried away with procedures that were not part of the plan, like deciding to do different interspecific interactions that were not supporting our main goal of invasives versus endemics.

One question we would certainly want to know for a similar experiment would be is if crabs of the same size would provide more meaningful data. *C. maenas* were miniscule compared to the other crabs, and in almost all of our trials, we found that the bigger crab was the first to utilize the food and would bully the other crab first. Also, using the crab we were initially interested in testing for (*Hemigrapsus sanguineus*) would be a game changer for the experiment. Another factor that would be interesting to do, but may be much more costly with funds and also energy, would be performing the experiment out in the field rather than bringing the crabs to the lab. Having scuba or snorkeling experience would be useful in this situation, and we certainly would need to plan exactly where we need to go to do this experiment, even going beforehand to scope out the area.

References

Donahue, Megan J. , Allison Nichols, Carlos A. Santamaria, Paloma E. League-Pike, Cory J. Krediet, Kestrel O. Perez & Myra J. Shulman. "Predation risk, prey abundance, and the vertical distribution of three brachyuran crabs on Gulf of Maine shores". *Journal of Crustacean Biology*. 2009. 29 (4): 523–531.

Grosholz, E. D.; G. M. Ruiz. "Predicting the impact of introduced marine species: Lessons from the multiple invasions of the European green crab *Carcinus maenas*". *Biological Conservation*. 1996. 78 (1–2): 59–66.

Lang, Jennifer M., and M. Eric Benbow. "Species Interactions and Competition." *Nature News*. Nature Publishing Group, 2013. Web. 24 Apr. 2017.

Martinez, Andrew J. & Candace Storm Martinez. "Arthropods". *Marine Life of the North Atlantic: Canada to New England*. Aqua Quest Publications. 2003. pp. 144–175.

McDonald, Sean, Gregory C. Jensen, and David A. Armstrong. "The Competitive and Predatory Impacts of the Nonindigenous Crab Carcinus Maenas on Benthic Phase Dungeness Crab Cancer Magister." Journal Of Experimental Marine Biology and Ecology, 23 Nov. 2000. Web. 2017.

National Invasive Species Information Center. "About NISIC - What Is an Invasive Species? "*National Invasive Species Information Center*. Web. 10 Apr. 2017.

"RI CRMC Invasive Species." *RI Coastal Resources Management Council*. Web. 10 Apr. 2017.

Williams, P. J. , C. MacSween & M. Rossong. Competition between invasive green crab (Carcinus maenas) and American lobster (Homarus americanus), New Zealand Journal of Marine and Freshwater Research. 2009. 43:1, 29-33.