The predation of mudflat burrowing shrimp by native Oregon crabs Red rock crab (*Cancer productus*) and Dungeness crab (*Cancer magister*) versus an invasive crab European green crab (*Carcius maenas*)

Sean Trobaugh

Department of Integrative Biology

Oregon State University

Abstract

Yaquina Bay, Oregon, has been introduced to a few The invasive species in Yaquina Bay, Oregon can have a huge effect on the native species and local ecosystem. European green crab (*Carcius maenas*) is an invasive species. The European green crab can be found on the mudflats competing with the native crabs, including Red rock crab (*Cancer productus*) and Dungeness crab (*Cancer magister*), for food. Possible prey includes mudflat burrowing shrimp, the Ghost shrimp, (*Neotrypaea californiensis*) and the Mud shrimp, (*Upogebia pugettensis*). Thus study examines native crab (primarily Red rock) and European green crab predation on mudflat burrowing shrimp with controlled laboratory predation experiments: putting shrimp in sediment, then adding crab after an allotted burrowing time. My hypothesis is that Red rock is able to eat more shrimp than the European green crab because of the mobility of the Red rock claws. Both invasive and native crabs preyed upon the shrimp, however, the native crabs are doing statically significant greater (p-value =.001) at getting this food source then the invasive crab. The European green crab is not out competing the Red rock and Dungeness.

Introduction

Yaquina Bay, Oregon is a drowned river mouth estuary (Lewis and Henkel 2016) with tidal flats covering 60% of the whole area ($15km^2$) of this shallow tidal basin. Humans have had a strong impact on the native ecosystem in this region, including invertedly introducing invasive species that are affecting the native species here on the West Coast.

Dungeness crab (*Cancer magister*) and Red rock crab (*Cancer productus*) are native crab species in Oregon. European green crab (*Carcius maenas*) is an invasive species that came to the California coast in 1980's (Cohen et al. 1995) and is spreading up the West Coast to British Columbia. They have shown to be a good invader and have a steady population off the Oregon coast (Yamada, pers. comm.). Both native crab species and the invasive European green crab can be found in the Yaquina Bay mudflats and possibly competing for burrowing mudflat shrimp as prey.

In estuarine benthic communities burrowing shrimp are important ecosystem engineers (Dumbauld et al. 2014). Ghost shrimp (*Neotrypaea californiensis*), Mud shrimp (*Upogebia pugettensis*) are two common species in Oregon. The Ghost shrimp and Mud shrimp are a hard-shell animal that lives on the mud flats (Feldman et al. 1997; Chapman and Cater 2014). The Mud shrimp is already in danger from one invasive species *Orthione griffensis*, a parasitic isopod that has lead to declining Mud shrimp populations.The juveniles of both shrimp are important prey to juveniles sculpins (Armstrong et al. 1995). Adults shrimp may be important prey for crabs, but no prior studies have examined this. The European green crab has been known to dig in the mud (Schratzberger and Warwick 1999). Crabs are known for being omnivores and scavengers, however, crabs can be specialists and generalists when it comes to hard-shell prey (Yamada et al. 1998). Therefore, European green crabs could predate on burrowing mudflat shrimp, such as Mud and Ghost shrimp, but no studies have previously examined this. Having an invasive crab predator on the Mud and Ghost shrimps could influence the native estuary ecosystem. The objectives of this study are to examine the predatory behavior of the invasive European green crab versus two native crabs, the Red rock crab, and Dungeness crab. The prey for the study will be the burrowing shrimp of Yaquina Bay mudflats (Mud shrimp and Ghost shrimp). These mudflat shrimp are not, a potential, but previously unknown, to be preyed upon by these three crab species. Therefore, my research question is: are these crabs able to capture the burrowing shrimp species, and if so, is one hunting them better than the others?

Based on initial observation, my first hypothesis is that the Red rock crab will have a better predation rate than the other two crabs because this crab has more mobility of its claws. Furthermore, based on the findings of Yamada et al. (2010), my second hypothesis is that the Green crab will do better than Dungeness at predation of shrimp because Green crab having more crushing power than the Dungeness My third hypothesis is that the larger sized shrimp will be less preyed upon than the smaller size because of their ability to burrow deeper and evade predation.

I test these hypotheses by doing in lab experiments, with the three crab species (European green, Red rock, and Dungeness crab) as predators and the two shrimp species (Ghost and Mud shrimp) as prey. I will be considering the size of both crab and shrimp as well as the species of crab.

Methods

Mud and Ghost shrimp, as well as sediment, were collected from Yaquina Bay mudflats adjacent to Hatfield Marine Science Center (HMSC), Newport, OR, on 5/26/17-6/1/17. I used a shrimp gun, shovel and buckets to obtain the shrimp and sediment. I collected all shrimp that were found regardless of size. The size of each shrimp was measured from the tip of the tail to the eyes in centimeters. Square collapsible crab traps, with no escape holes, were deployed at the HMSC pump house dock as well as the mudflats to catch the crab. Originally, I hoped to collect nine crabs from all three species in the size range of five to fifteen centimeters, however, five European green crabs, ten Red rock, and one Dungeness crab were obtained. The crabs were measured from the furthest point on the left of the carapace to the right furthest point.

A preliminary test was performed to confirm that the European green crab would eat the shrimp. Three shrimp were put into a tank with two European green crabs with no sediment. Following preliminary experiments, I performed four control tests. I put eight inches of sediment in six buckets. Four buckets got five shrimp each. I added sea water to the buckets and left them for twenty-four hours. After that period, I carefully dug up the shrimp with a trowel and my hands to see if they survived in this environment. Then I recorded survival: dead shrimp were indicated by a one and live shrimp by a zero.

After the controls, I started the treatments. The original six buckets were used, but the crabs did not survive during the experiment due to the lack of running water. Because space to get the buckets into running water was not available, I switched to four small rectangular boxes, with holes punched in the lids. I put only one inch of sediment to allow space for the crab. These were all put into a holding tank with running water and the water level was well above the lids. Five shrimp were placed in each box and were allowed to burrow for four hours. I then put one crab in each box with the shrimp and allowed twenty-four hours for the crab to eat. I found that all the shrimp had been eaten and the crab had too much free space between it and the top of the lid. I added another inch of sediment to each box and reduced the experiment time down to twelve hours. This was run for the rest of the trials.

I compared the three species by plotting proportion of shrimp eaten by each species. Because I could not statistically compare Dungeness, I lumped Dungeness and red rock and did a Chi-square test comparing native and invasive crabs and their predation rates. A Chi-squared test is an attempt to reject the null hypothesis by seeing if the actual data is significantly different than what the calculated theoretical data would be if there were no difference between experimental groups. In addition, a two-tailed t-test was used to analyze the size distribution of the eaten shrimp compared to the ones that survived. For analysis of crab size on predation, all crabs species were binned together by size using 3-centimeter increments (5.5-8.5, 8.5-11.5, 11.5-14.5; Figure 1). I then did a Chi-squared test on the predation rate of crabs based on size bin. All analyses were done in Excel.

Results

For the preliminary test, I found that the European green crab ate the burrowing shrimp. Two out of three shrimp were eaten by two European green crabs in the 15 minutes of exposure to them.

I found that the average size of the crabs (European green, Red rock, and Dungeness crabs) used in the study was 9.40 centimeters (Figure 1). The average size of the shrimp (Ghost and Mud shrimp) used in this study was 4.04 centimeters (Figure 2).

My experiments showed that the average size of shrimp individuals that were preyed upon was 4.10 cm ± 0.16 cm standard error and the average size of shrimp individuals that survived was 4.00 cm ± 0.14 cm standard error (Figure 3). There was no significant difference in the size of shrimp that were eaten compared to those that survived (two-sided t-test, p-value = 0.68).

Both native crabs (Red rock and Dungeness) ate more than the invasive crab (Figure 4). The Chi-square test of the theoretical and actual datasets had a significant result (p-value =0.001) comparing the two native crabs(Red rock and Dungeness crab) to the invasive crab (European green crab; Figure 5 a and b).

The middle size crabs (8.5-11.5) were found to eat the most shrimp (Figure 6 a and b). The Chi-square test of the theoretical and actual datasets gave a significant result (p-value =.001).

Discussion

I found that there was a significant difference in predation on shrimp between crabs of different sizes (Figure 5) and native versus invasive crabs (Figure 6). I did not find that there was any statistical difference between the size of shrimp eaten and the size of shrimp that survived (Figure 3).

I reject my first null hypothesis that the crab species would all have an equal predation rate on the shrimp. Unequal numbers of crab prevented me from comparing species separately, but I was able to compare native versus invasive crabs. The p-value for the native vs invasive showed that native crab species (Red rock and Dungeness) are feeding on the shrimp at a higher rate than the invasive European green crab. This finding is interesting given that European green crab can have a higher feeding rate than the native crab species, depending on the food source (Yamada et al. 2010).

The second hypothesis could not be tested for native versus invasive crab species due to only catching one Dungeness crab in my target size range. Based on the fact that native species appeared to have higher feeding rates, I would speculate that the Dungeness would actually do better than the European green crab which goes against my second hypothesis. Therefore, the European green crabs greater crushing power is not a factor in shrimp predation (Yamada et al. 2010).

Rejection of the third null hypothesis is not possible. The null states that the size of the shrimp will not determine who is preyed upon. I found no statistical difference between the average size of the size of eaten shrimp and shrimp that survived. This could be because small crabs do not see these size of shrimp as prey and larger crabs do not see enough food there worth the time.

Overall the crab species (European green, Red rock, and Dungeness) there was a statistically significant difference between the crab sizes and their predation rate, so I reject the second null hypothesis that feeding rate is not related to crab size. The middle crabs (8.5-11.5) were found to have the greater predation rate on the Ghost and Mud shrimp. This is showing that the shrimp size used in this study are preyed upon by a certain size range of crab.

However, there was some experimental bias in this study due to the fact that there were only two inches for the shrimp to burrow in. With that, I adjusted the time to try and give the shrimp adequate time to burrow and shortened the time so the crab could not gorge themselves on the shrimp. There was some issues of the lids staying on the boxes a few times which could have led to loss of a shrimp in the box. As well as a chance for small shrimp to be able to get out the holes in the lids.

The European green crab is not out competing the Red rock and Dungeness for Ghost and Mud shrimp as a food source. There is a burrowing crustacean (*Corophium volutator)* that lives in the natural area of the European green crab but it does not use it as a major food source (Pihl 1985). Meaning that the European green crab's don't know to dig down to get to the Ghost and Mud shrimp. This could change over time as the European green crab is more used to the Ghost and Mud shrimp and how to find them. This might be a good thing to monitor as time goes on for the management of European green crab.

I would like to do this study over a longer time frame so I can catch enough crab need to actually fully compare European green, Red rock, and Dungeness crabs to each other on predation of Ghost and Mud shrimp with a less bias experiment. I would also like to more fully look at what different crabs sizes eat different size shrimp.

References

Cohen, A.N., J.T. Carlton, and M.C. Fountain. 1995. Introduction, dispersal and potential impacts of the green crab *Carcinus maenas* in San Francisco Bay, California. Marine Biology **122**: 225−237

Feldman, K. L., D. A. Armstrong, D. B. Eggleston, and B. R. Dumbauld. 1997. Effects of substrate selection and post settlement survival on recruitment success of the thalassinidean shrimp *Neotrypaea californiensis* to intertidal shell and mud habitats. Marine Ecology Progress Series **150**:121-136

Yamada, S. B., and E. G. Boulding. 1998. Claw morphology, prey size selection and foraging efficiency in generalist and specialist shell-breaking crabs. Experimental Marine Biology and Ecology **200**:191-211

Yamada S. B., T. M. Davidson, S. Fisher. 2010. Claw morphology and feeding rates of introduced European Green Crabs (*Carcinus maenas* L, 1758) and native Dungeness Crabs (*Cancer magister* Dana, 1852). Journal of Shellfish Research **29**:471-477

Armstrong, J.L., D. A. Armstrong, S. B. Mathews. 1995. Food-habits of estuarine Staghorn sculpin, *Leptocottus armatus*, with focus on consumption of juvenile Dungeness crab, *Cancer magister*. Fishery Bulletin **93**:456-470

Dumbauld, B. R., D. M. Mercer, M. Camara. 2014. Isolation and characterization of novel microsatellite loci in two species of burrowing shrimp, *Neotrypaea californiensis* and *Upogebia pugettensis.* Conservation Genetics Resources **6**:353-356

Chapman, J. W., C. S. Carter. 2014. A rapid intertidal megafauna survey method applied to *Upogebia pugettensis*, and its introduced parasite, *Orthione griffensis.* Journal of Crustacean Biology **34**:349-356

Schratzberger, M., R. W. Warwick. 1999. Impact of predation and sediment disturbance by *Carcinus maenas* (L.) on free-living nematode community structure. Journal of Experimental Marine Biology and Ecology **235**:255-271

Lewis, N. S., S. K. Henkel. 2016. Characterization of ecosystem structure within transplanted and natural Eelgrass (*Zostera marina*) beds. Northwest Science **90**:355-375

Pihl, L. 1985. Food selection and consumption of mobile epibenthic fauna in shallow marine areas. Marine Ecology-Progress Series **22**:169-179

Figure 1

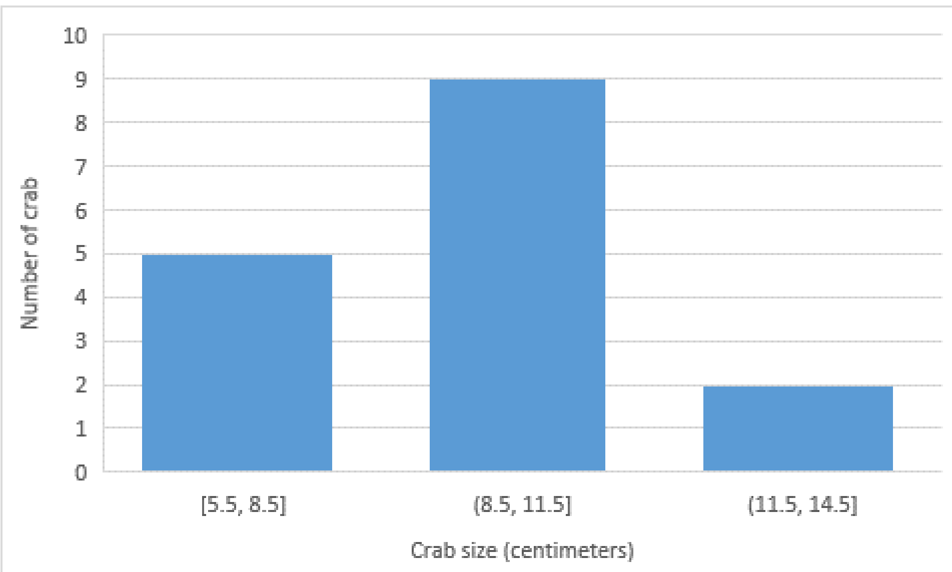


Figure 1: The size frequency of European green, Red rock and Dungeness crab in the study measured from the furthest left point on their carapace to the furthest right point (centimeters).

Figure 2

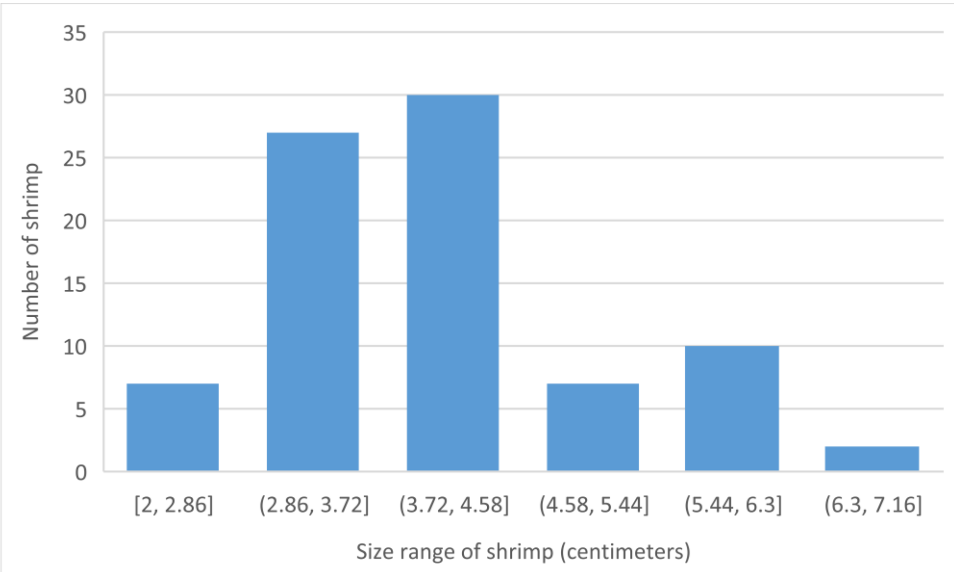


Figure 2: The size frequency of Ghost and Mud shrimp in the study measured as the size from the tip of the tail to the eyes (centimeters).

Figure 3

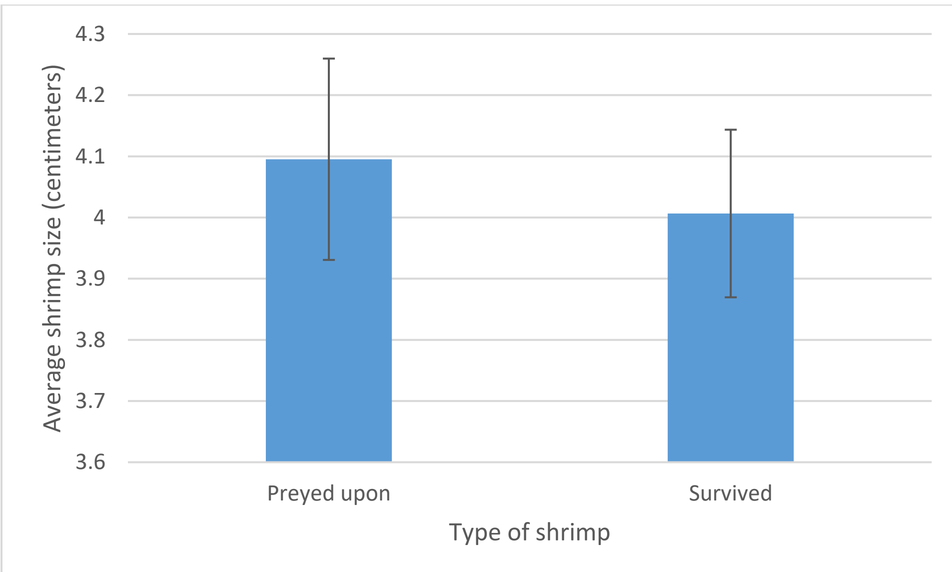


Figure 3: The average size (centimeters) ± SE of shrimp that were preyed upon or not preyed upon (survived). T-test results of comparisons between sizes of shrimp preyed upon versus not preyed upon were not significant (p-value = 0.68).

Figure 4

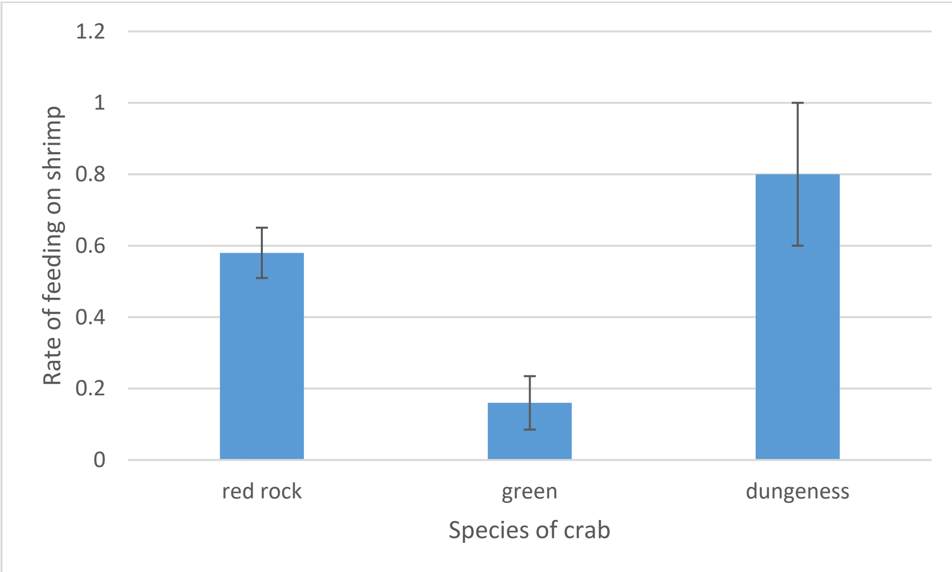
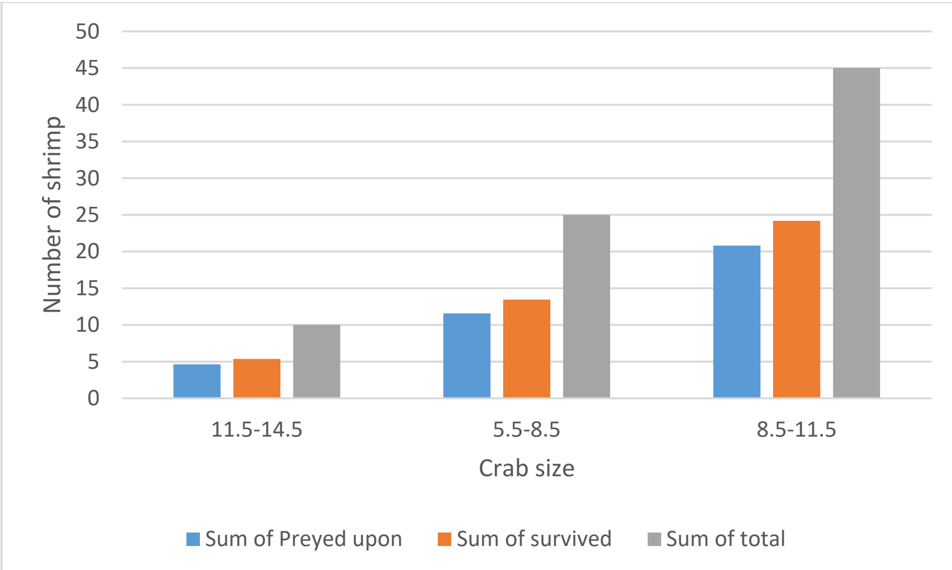


Figure 4: European green, Red rock and Dungeness crabs rate of feeding on shrimp, in proportions, compared to each other.

Figure 5

a.



b.

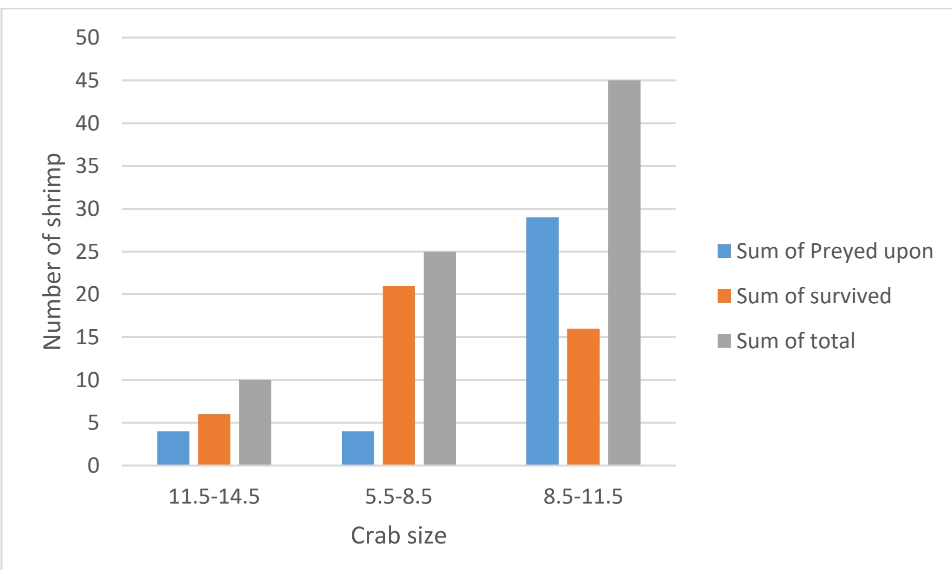
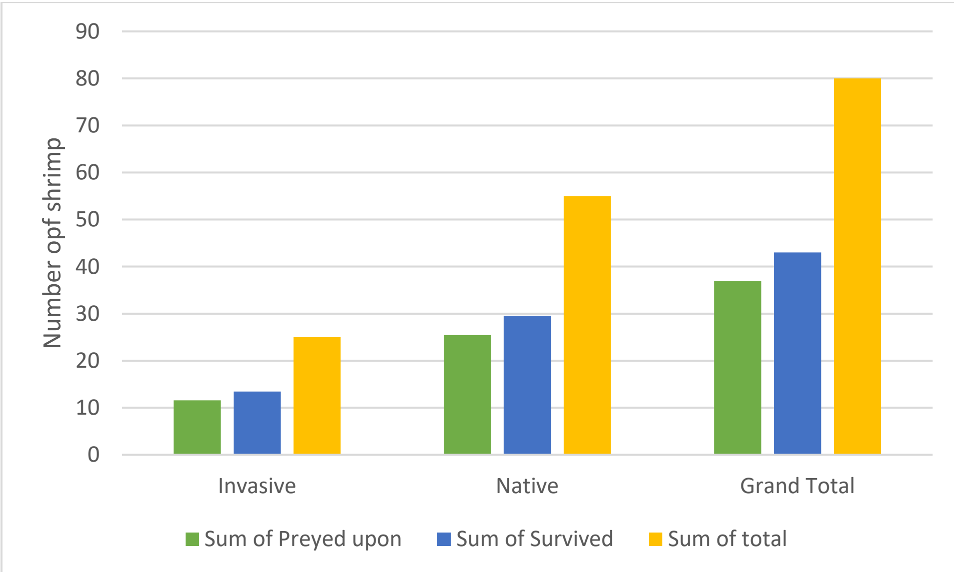


Figure 5: The a) theoretical and b) actual number of burrowing shrimp preyed upon, survived, and the total for each crab predator size bin. A chi-square analysis of the theoretical data to actual dataset showed a significant difference of p-value = 0.001.

Figure 6

a.



b.

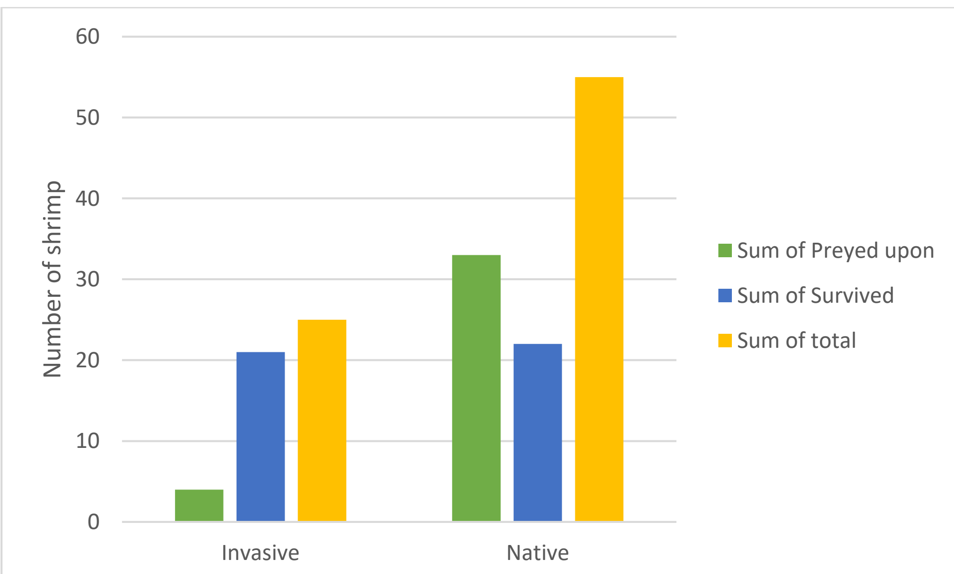


Figure 6: The a) theoretical and b) actual number of burrowing shrimp preyed upon, survived, and the total for crab predators that are either invasive (European green crab) or native (Red rock and Dungeness crab). A chi-square analysis of the theoretical data to actual dataset showed a significant difference of p-value = 0.001.