A DEMOGRAPHIC STUDY ON THE INVASIVE ASPECTS OF THE ASIAN SHORE CRAB (*HEMIGRAPSUS SANGUNEUS)* ALONG THE NEW ENGLAND COAST

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Abstract This study investigates several competitive advantages of the Asian Shore Crab *Hemigrapsus sanguineus* along the New England Coast. When haphazardly collected, there were more *H. sanguineus* compared to the Green Crab, *Carcinus Maenas*; significantly more *H. sanguineus* female crabs than any other category (*H. sanguineus* male, *C. Maenas* female, *C. Maenas* male). Reproducing multiple times per season could be an advantage for the invasive *H. sanguineus*, and may be one of the many reasons *H. sanguineus* is displacing the already invasive *C. Maenas*. The number of limbs lost upon collection time by the size (mm) of the crab was significant in *H. sanguineus*, however was not significant in *C. Maenas*. This exemplifies that autotomy was more prevalent and effective in increasing survival rate in the larger *H. sanguineus* than the *C. Maenas*. An analysis of population distribution for both *H. sanguineus* and *C. Maenas* revealed that *C. Maenas* had a greater number of age groups (4) than *H. sanguineus* (3) had, suggesting that although the number of *H. sanguineus* present at Nahant Beach, MA were greater, *C. Maenas* seemed to have been there longer.

Key Words: *Asian Shore Crab (H. sanguineus), Displacement, Invasive Species*

Introduction

The Asian Shore Crab, *H. sanguineus,* was first introduced to the New England coast in 1988, from Japan where it is indigenous. Species native to the New England coast as well as invasive species such as the Green Crab, *C. maenas*, may be displaced by *H. sanguineus,* due to direct and indirect competition for food and shelter such as rocks, shells, and vegetation (Armstrong et al. 2002). Due to the strong invasive advantages of *H. sanguineus*: a longer reproductive period (greater numbers), broadcasting, and effective autotomy (selective loss of limbs) in larger crabs, significantly more *H. sanguineus* will be found along the Rocky Intertidal zone of New England (Nahant Beach) than *C. maenas*. This creates an interest to study *H. sanguineus'* invasive advantages and techniques.

H. sanguineus typically have dark red spots on their chelipads (front claws), and dark bands on their hind legs. They have a square shaped shell body (carapace) with three spines on either side. Colors range from green, purple, orange, brown, dark-brown, and red. They are omnivores, feeding mainly on macroalagae, juvenile fish, and small invertebrates. Since this species has such a broad diet, they compete with larger crabs like the Blue Crab and Rock Crab, Lobster and the previously mentioned, Green Crab. Studies show that *H. sanguineus* numbers are steadily rising as native crab populations are declining (Glover et al. 2007).

An advantage *H. sanguineus* has over *C. maenas* is that their reproductive season is twice as long as that of the *C. maenas*. Female *H. sanguineus* crab breeds from May-September, where as the *C. maenas* only breeds during the months July-September. Females can produce 3-4 clutches, with 50,000 eggs per clutch each breeding season. The larvae are suspended in the water column for one month before developing into juvenile crabs. *H. sanguineus* are broadcast spawners, which allows their larvae to be transported over great distances, allowing for a more rapid spread to new niches. There are three stages of life before adulthood is reached: zoeae (larval), megalops and the juvenile stage. While zoeae, they are small (<1 mm) and shrimp like, allowing them to travel inconspicuously throughout habitats of the intertidal zone. Also, the interaction between physical and chemical cues plays a role in the spread of the *H. sanguineus* species, and contributes to its rapid colonization of the New England coast (Schwalm et. al 1998).

H. sanguineus crabs have recently been invading the already invasive *C. maenas* New England habitat. Competition exists between the two crabs for the same niche (mid-low intertidal zone). Both crab species, like most crab species, are able to autotomize their limbs when under threat. An “automiser” muscles is attached to the side of the coax (body side), where in-between the two lies the fracture plane (the site of detachment), and when the muscle is stimulated, it contracts and raises the limb to “detach” without causing further damage to the connection site. It is a highly effective escape mechanism, as a predator takes hold of a limb the crab will autotomise and escape (Southworth et. al 2005).

Typical of most crabs, *H. sanguineus* have eight hind legs and two chelipeds. Chelipeds are more likely to be lost in times of stress. Losing a cheliped does not necessarily hinder the crabs feeding habits and instead of eating less, the crab tends to eat at a slower rate (Southworth et. al 2005). The larger the crab, the more likely it is to be missing several limbs. In a process known as regeneration, limbs are able to grow back. Regeneration, autotomy and a lengthy reproduction cycle are true advantages to survival.

Materials and Methods

This study was conducted at Nahant Beach, Massachusetts (42.25 ˚N, 70.94˚W). Crabs of both species were hand collected during low tide, from the mid to low intertidal zones once during the month of September and once during the month of October, in 2012. Two 2 quart buckets were used to collect and transport crabs, and two 5-gallon buckets were used to sort and measure captured crabs. Latex gloves were used to safely handle the crabs. Electronic calipers were used to measure the length (anterior-posterior) and width (left to right) of crab carapace and measurements were recorded manually. An iPhone 4S was used to capture all images.

Crabs were collected from within tide pools and under rocks near tide pools. They were then sorted by species into the larger buckets, where they were measured, their limbs were counted, and their sex was determined. Sampling was biased, as smaller crabs are more difficult to see and capture. Crabs whose width was less than 10mm were noted and counted, however they were excluded from the statistical analysis since there limb count was too difficult to be accurate (Fig. 5).

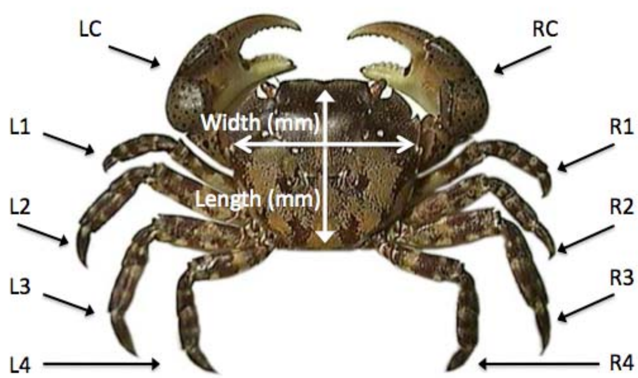


Fig.1. To the right is the diagram used to score the number of missing limbs in collected crabs. This is a photo of a *H. sanguineus* with all ten limbs intact, and the area of width and length measured on the carapace is indicated

Fig. 2. Large bucket containing over 40 crabs of both species waiting to be sorted and measured. Arrows indicated 2 *C. maenas* among a sea of *H. sanguineus* crabs collected at Nahant Beach, MA October 2012.

Fig. 3. The largest male *H. sanguineus* measured at Nahant Beach, MA during October 2012. Color: purple, length 29.35mm, width 33.34mm, missing limb L3.

Results & Discussion

Most *H. sanguineus* were found at the higher mid-intertidal region, under rocks and within shallow tide pools (0.076 meters deep). Most *C. maenas* crabs were found in the lower mid-intertidal region (0.3-0.6 meters deep) in open water and upon rocks. This could suggest displacement in that *H. sanguineus* were pushing *C. maenas* towards the lower zones of the intertidal zone, possible displacement.

In a statistical test of size (excluding crabs <10mm), *H. sanguineus* showed a tri-nominal distribution of all age classes (mean, 17.718; standard error mean, 0.604). When crabs less than 10mm were factored into the distribution, bin size started from 10mm, and increased in increments of 1.25 mm, up until 35mm. There was a total of 21 bins (translating to 21 “age groups”) however there were 3 peaks (where numbers within that age class were the majority) at carapace size of: <10mm, 15-16.25mm and 26-27.25mm (Fig. 4). This suggests that age plays an important role in the survival and reproduction of *H. sanguineus,* with numbers at age and size of 16.25mm, being the largest of the population whole. A distribution of 30 total *C. maenas* population (excluding crabs <10mm; mean,19.17; standard error mean, 1.60) produced 4 age classes within the population (Cole 2013). The difference in abundance, 3 age-classes within *H. sanguineus,* and 4 age-classes *C. maenas* could suggest that *C. maenas* have been around longer, and therefore were able to establish an older (4^{th}) age group within the population, that the relatively recently introduced *H. sanguineus* lacks.

Through a distribution of sex ratio, majority of females were found to be 15-17.5mm (mean, 16.455; standard error mean, 0.376), and the majority of males were found to be 17.5-20mm (mean, 18.97; standard error mean, 0.831). Overall, *H. sanguineus* males grew to be larger than females, and had a wider range of size distribution (Fig. 5).

Female *H. sanguineus* were significantly more abundant than male *H. sanguineus,* and there were significantly more males than females in the *C. maenas* population (stat=X; p<0.0001; Fig.6). The large number of females in a crab population may increase the chances of species growth and invasion.

The bivariate fit of limbs lost by width of crab was also significant (P<.0001) for the *H. sanguineus* (Fig. 7). The larger the crab (both male and female), the greater number of limbs lost. This significance demonstrates the importance of autotomy in crab survival, but also suggests other importance's, such as age correlating to survival rate. The larger crabs indeed have fewer limbs than the smaller crabs, but are surviving. Assuming that the lost limbs were due to autotomy, and not loss due to other factors like genetic mutations or disease related causes. In a test of distribution of limb loss numbers (0-5 limbs loss) and highest mean size was 22.20mm, with 3 limbs loss (Fig. 8).

The contingency analysis of limbs lost (yes/no) by species was not significant for either *H. sanguineus* or Green crabs (P<.08). The contingency analysis of sex by limbs lost was not significant in a total of 155 crabs including both species (P<.05). The contingency analysis of sex by limbs lost in 130 *H. sanguineus* was not significant (P<.331). There was no size difference between the species, as the one-way analysis of width by species was not significant (P<.874) as well as the one-way analysis of length (mm) by species (P<.661).

By studying various factors *H. sanguineus* characteristics, we can examine the importance of their seemingly expanding distribution along the New England Coast, and ultimately learn the direct and indirect impacts they have on native and non-native species within the intertidal zone. An extension of this demographic study can help with the process of tracking spatial and/or temporal changes with the *H. sanguineus* population, and determine the rate at which they seem to be migrating.

Future studies could further investigate species distribution along the New England coast by use of tagging methods. Tracking the spread of both *H. sanguineus* and *C. maenas* from the southern to more northern states could reveal of there is a preference of niche for either species. Mapping of both crabs current habitats, and their habitats over a spread of time would allow us to track their migration patterns. It would also be interesting to investigate the rate of autotomy as opposed to loss of limbs by other causes (stresses, physical trauma, etc).

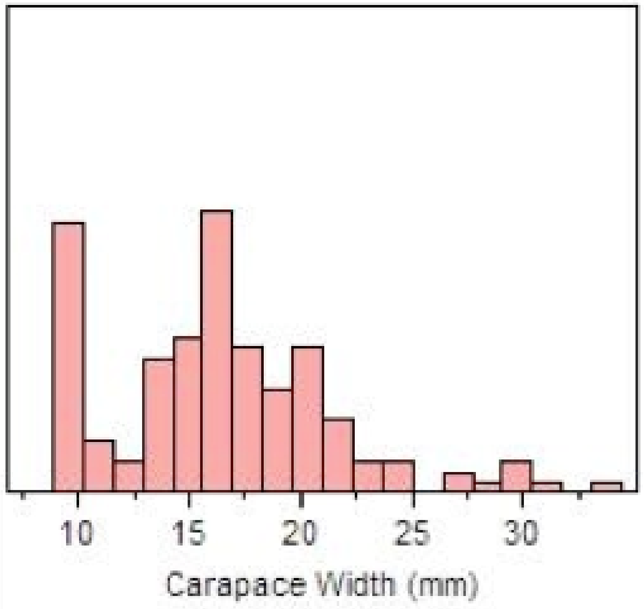


Fig. 4. A tri-nominal distribution of both sex, age and size classes of *H. sanguineus.*150 individuals total. Bins range from crabs under 10mm-35mm. Collected at Nahant Beach, MA, Fall 2012.

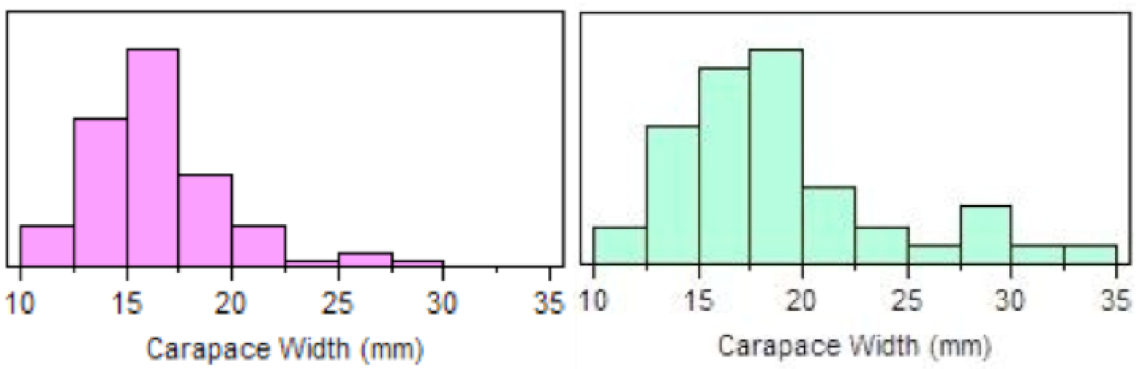


Fig.5. Size distributions by sex for *H. sanguineus:* 81 females (left) and 42 males (right).

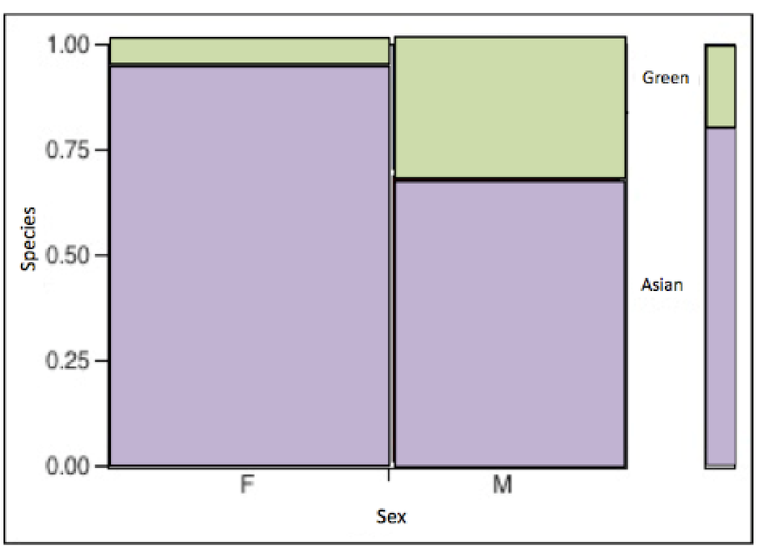


Fig. 6. A mosaic plot modeling the significance in sex abundance for both *H. sanguineus* and *C. maenas* populations. There is a reproductive benefit in having more female than males in a population, which may be one of the contributing factors of *H. sanguineus* being more invasive.

Fig. 7. The bivariate fit of limbs lost by width of crab was significant (P<.0001) for *H. sanguineus* (both male and female). An increase in width (mm) of the crab and the number of limbs lost is displayed in the 150 crabs analyzed.

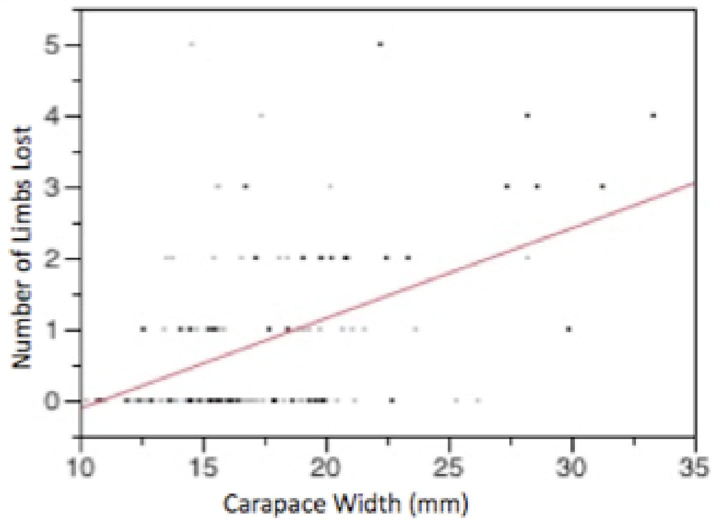
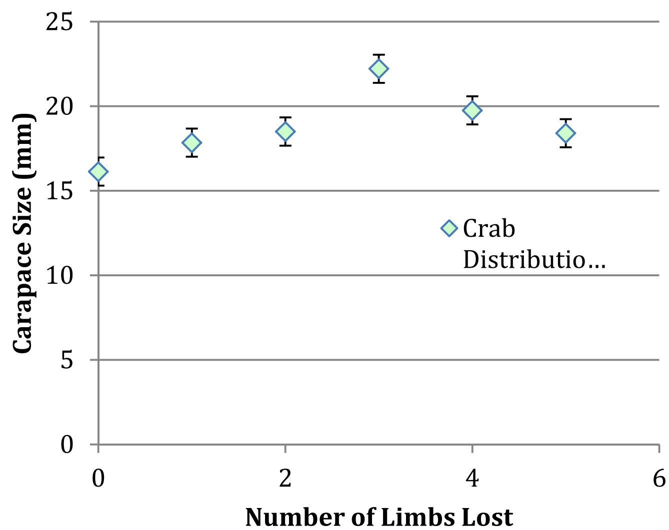


Fig. 8. Mixed gender groupings of *H. sanguineus* gave rise to 6 distinguished classes of carapace size (mm) in relation to the number of limbs lost.



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