Undergraduate Review

Volume 7 | Article 25

2011

The Invasive Asian Shore Crab, a Dominant Species on Southeastern Massachusetts Beaches: A Cause for Concern

Kimberly Westgate

The Invasive Asian Shore Crab, a Dominant Species on Southeastern Massachusetts Beaches: A Cause for Concern

KIMBERLY WESTGATE

Kimberly is a senior ecological biology major with a minor in chemistry. She wrote this paper for Dr. Jonathan Roling's Marine Biology course. She would like to thank Dr. Roling for his encouragement and guidance. Kimberly plans on attending graduate school for environmental biology in the near future.

The non-native Asian shore is becoming a dominant species in southeastern Massachusetts beaches. A study was conducted to test whether environmental conditions across beaches in southeastern Massachusetts had an effect on the crab species inhabiting those areas. Although this was the main focus, it was found that the invasive Asian shore crab has had an ecological impact on the native crab populations. Six southeastern Massachusetts beaches (Scituate Beach, Plymouth Beach, Mass Trust Estuary, Ellisville Harbor, Gooseberry Island, and Sandwich Marsh) were visited and crab species were counted in measured sites, generally two sites pe r beach. Crab species found were the Asian shore crab (Hemigrapsus sanguineus)*, green crab* (Carcinus maenas)*, Acadian hermit crab* (Pagurus acadianis)*, long-clawed hermit crab* (Pagurus longicarpus)*, white-fingered mud crab* (Rhithropanopeus harrisii)*, black-fingered mud crab* (Eurypanopues depressus)*, and lady crab* (Ovalipes ocellatus)*. After all data were collected, percentages of each crab species in each site were determined, as well as diversity. The majority of the crabs were the invasive Asian shore crab, making up 78.3% of the total caught. There was not any trend in crab species abundance with beaches of similar environmental factors including temperature, salinity, dissolved oxygen, tides, and type of habitat. However, it was apparent that the Asian shore crab has become a dominate species in southeastern Massachusetts. If the Asian shore crab continues to dominate beaches and cause declines in populations of other species, they might cause the local extinction of those species.*

Introduction

Invasive species are organisms that have been accidentally or purposefully introduced to an area outside that of their origin. Exotic species can come from another continent, another part of the country, or just from another watershed (NISIC, 2011). Organisms evolve with other species that moderate their population growth. When an organism is taken out of its original environment and placed in another environment without regulation, an exponential increase in the invasive species can displace indigenous species, causing dramatic ecological shifts (Mooney, 2001).

The green crab (*Carcinus maenas*), though not a native species, was once common in the rocky intertidal habitats of southern New England and has recently declined in abundance coincident with the invasion of the Asian shore crab (Lohrer, 2002). Over a four-year period in the late 1990s there was a significant decline (from 2 crabs per meter squared to less than 0.001 crabs per meter squared) in green crab density and a sharp increase (from

3 crabs per meter squared to greater than 80 crabs per meter squared) in Asian shore crab density at three sites in southern New England (Lohrer, 2002). There were many more Asian shore crabs than green crabs found at each site. The Asian shore crab and the green crab, interact aggressively with one another in competition over food and shelter. Research shows that the Asian shore crab, once introduced into the area, became a stronger competitor than the green crab, that had been introduced to the region earlier (Nelson, 2005).

Zonation is the division of an ecosystem into distinctive zones that provide different niches (habitats). Zonation is more gradual on muddy and sandy shores, whereas along the rocky intertidal zone the competition between species for food is much greater (Peterson, 1991). Factors such as sediment size and elevation contribute to zonation because different sediment types are suitable for different species. The most noteworthy contrast in community organization between rocky and soft shores lies in the importance of interspecific competition. Environmental factors, such as stresses from exposure, desiccation, and temperature change, can determine where species are found within an intertidal zone. If able to withstand these stresses, those species can avoid being forced to local extinction. The high intertidal barnacles *Balanus* and *Chthamalus* are a good example of this. At lower tide heights, *Balanus* out competes *Chthamalus*, whereas at higher tide heights, *Balanus* is unable to survive. Therefore, *Balanus'* low tide height limit is established by *Chthamalus* and its high tide limit is determined by the tide line. Likewise, *Chthamalus* has a low tide height limit set by competition with *Balanus* and a high tide height limit established by the tide line (Connell, 1961).

This study focused on species abundance and diversity of crabs at six beaches in southeastern Massachusetts. Crab species found at the six beaches were analyzed with factors such as the amount of human activity, terrain conditions and site size to determine if these conditions have an effect on the amount and type of crab in that area. Environmental factors are expected to be similar at each of the beaches visited. As a result, it is hypothesized that there will be one dominant species of crab at all of the six beaches.

Materials and Methods

The study was conducted on Wednesday afternoons between 1:00 and 3:00 pm over a six-week period, with one beach sampled per week. The following beaches were traveled to and studied from September 15, 2010 to October 20, 2010: Scituate Beach (sites 1 and 2), Plymouth Beach (sites 3 and 4), Mass Trust Estuary (sites 5 and 6), Ellisville Harbor (site 7), Gooseberry Island (sites 8 and 9), and Sandwich Marsh (sites 10 and 11) (Figure 1). Two sites with different habitat types from each beach were studied, with the exception of Ellisville Harbor. It should be noted that all sites were along or near the shore within 0.5 m of water depth.

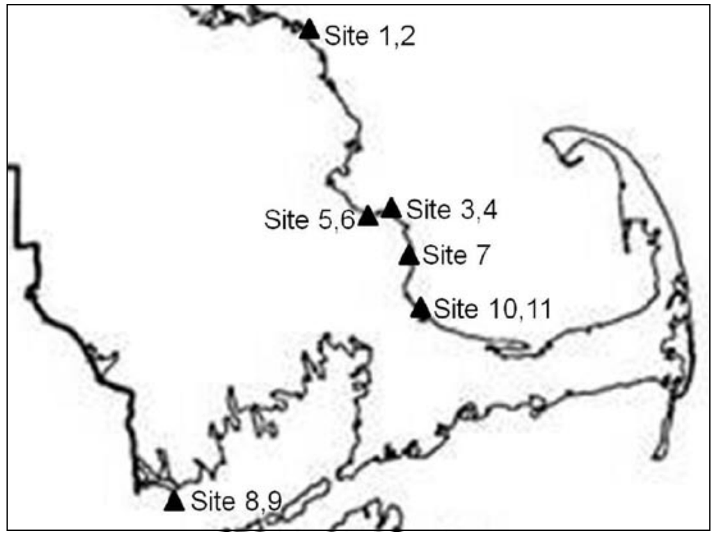

Figure 1: Sites visited across Southern Massachusetts. The field study was done to see if there is a correlation between crab species and environment type. At each site, the date, location, sea activity, tide, weather conditions, air and water temperature, salinity, DO, and air pressure were measured. Crabs were then searched for, collected, and identified in the marked area and then released. Sites 1 and 2 were visited on 9/15/10 at Scituate Beach. Sites 3 and 4 were visited on 9/22/10 at Plymouth Long Beach. Sites 5 and 6 were visited on 9/29/10 at Massachusetts Trust Estuary. Site 7 was visited on 10/6/10 at Ellisville State Harbor. Sites 8 and 9 were visited on 10/13/10 at Gooseberry Island. Sites 10 and 11 were visited on 10/20/10 at Sandwich Beach.

Scituate Beach site 1 was on top of large rocks, away from the shore; site 2 was located to the right of site one, on rocks in direct contact with open-ocean. Site 3 at Plymouth Beach was located near rough ocean water and on large rocks with pools beneath them; site 4 was on the other side, with calmer water, was less rocky, and there was grass and mud. Site 5 in Mass Trust Estuary had a mixture of fresh and salt water, site 6 had small rocks and was in direct contact with rough open-ocean water. There was only one site for Ellisville Harbor, site 7; it was located near open-ocean with medium sized rocks. Site 8 at Gooseberry Island was located near open-ocean with lots of seashells and rocks; site 9 was located on the other side with choppy water and larger rocks. Finally, site 10 in Sandwich Marsh was located on the edges of the salt marsh, where it was grassy and muddy; site 11 was located on rocks near the open-ocean with tidal pools.

Table 1: Table of Environmental Factors for Each of The Sites Visited.

				Environmental Factors							
Site #	Area (m^2)	DO %	Salinity (PPT)	Landscape	Beach	Date	Tide	Wind	Air Temp. (°C)	H2O Temp. (°C)	GPS
1	196	106.1	32	Open shore	Scituate	9/15/2010	Waxing	NM	18	16.7	41°11′21.14″ N 70°43′05.00″ W
2	140	106.1	32	Rocks and tidal pools							
3	343	103.1	30	Large rocks	Plymouth	9/22/2010	Waning	NE 12MPH	28.6	18.8	41°56′49.43″ N 70°37′40.12″ W
4	147	103.1	30	Grassy beach							
5	540	121.5	22	Estuary	Mass Trust	9/29/2010	Waxing	W 8MPH	23	24	41°56′26.93″ N 70°32′05.56″ W
6	257.25	114.5	28	Open shore							
7	122.5	95.7	35	Rocky beach	Ellisville	10/6/2010	Waning	NE 14MPH	NM	16.1	41°53′38.43″ N 70°32′09.42″ W
8	367.5	106.3	33	Rocks and pebbles	Gooseberry Island	10/13/2010	Waxing	NM	22	17.5	41°35′42.14″ N 70°27′57.78″ W
9	367.5	106.3	33	Larger rocks							
10	176.4	99.2	29.5	Marsh	Sandwich Marsh	10/20/2010	Waning	NM	18	14.3	41°45′50.89″ N 70°29′05.14″ W
11	264.6	101.6	30	Open shore							

NM – not measured at site

First, the date, location, sea activity, tide, and general weather were recorded (Table 1). Also, general observations were made at each site, including presence of dead organisms/shells on shore, presence of people/houses in the area, sediment type (rocky vs. sandy), and other physical parameters, including air and water temperature (°C), salinity (PPT), and dissolved oxygen (mg/L). Two different readings were taken for salinity and dissolved oxygen for the Mass Trust sites and for the Sandwich Marsh sites because the two sites were so different from each other. Researchers searched for crabs in the measured sites, and individuals were placed into buckets to be identified. The crabs were then identified based on the field guide, *Atlantic Seashore; A Field Guide to Sponges, Jellyfish, Sea Urchins, and More*, and were then released (Gosner, 1978).

Results

Out of the 714 total crabs found, 559 (78.3%) were the Asian shore crab (*Hemigrapsus sanguineus*). 7 out of the 11 sites were inhabited by this species. Of these 7 sites, the average percentage of Asian shore crabs found was 83.7%. Sites that had higher percentages of Asian shore crabs also had higher Simpson's diversity index, meaning less diversity. Sites 1, 4, and 11 had Simpson's diversity indexes above 0.9 and had Asian shore crab percentages above 90%. The most diverse site, site 5, had only 30% Asian shore crabs and a Simpson's diversity index of 0.302.

Six other crab species were observed during this study: the green crab (*Carcinus maenas*), Acadian hermit crab (*Pagurus acadianis*), long-clawed hermit crab (*Pagurus longicarpus*), white-fingered mud crab (*Rhithropanopeus harrisii*), black-fingered mud crab (*Eurypanopues depressus*), and lady crab (*Ovalipes ocellatus*). Out of all the other crab species found the Asian shore and the green crab are the only invasive crab species (Table 2). The green crab, however, made up only 2.24% of the total crabs found.

Table of Crab Counts and Totals for all Six Beaches

Site Number	Asian Shore	Green	Long-clawed	Arcadian	Rock	Lady	White-fingered	Black-fingered	Total # of crab species	Total # of Crabs
1	30	0	1	0	0	0	0	0	2	31
2	0	2	86	14	1	0	0	0	4	103
3	11	1	0	0	2	0	0	0	3	13
4	107	0	0	0	1	0	0	0	2	108
5	13	0	11	18	0	1	1	0	5	44
6	5	0	0	0	0	0	1	0	2	5
7	342	0	0	0	0	0	0	0	1	342
8	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0
10	0	12	0	0	0	0	0	2	2	14
11	51	1	0	0	0	0	0	0	2	52
Total:	**559**	**16**	**98**	**32**	**4**	**1**	**2**	**2**		**714**
% Total	**78.3%**	**2.24%**	**13.7%**	**4.48%**	**0.560%**	**0.140%**	**0.280%**	**0.280%**		**100%**

Table 2: Crab species and abundance found at six Southeastern Massachusetts beaches from September 2010 to October 2010.

Ellisville Harbor had the largest crab count with 342 crabs (Figure 2). No living crabs were found at either site at Gooseberry Island. Sites that had high percentages of Asian shore crabs (above 90%) had higher Simpson's diversity indexes, and sites with no Asian shore crabs had lower Simpson diversity indexes (less than 0.740). The Simpson's index of diversity is used to measure how diverse a population is. The closer the Simpson's diversity value to 1 that the site has, the less diversity that site has. The lower the value, the more diverse is at the site. So sites with fewer percentages of Asian shore crabs had higher diversity (Table 3).

All environmental factors previously mentioned were recorded. Most beaches had large to medium sized rocks and had rough open water. The water temperature was the warmest at site 5 (24°C), but most of the other sites had water temperatures between 14.3-18.8°C. Most sites also had a salinity reading between 28-33 PPT, though site 5 had a lower salinity at 22 PPT.

Discussion

The hypothesis that common environmental factors in beach environments will yield the same crab species has been rejected based on the data collected during this study. Most beaches had approximately the same salinity, dissolved oxygen, and water temperature, but not all sites had the same number of species or amount of crabs. Sites with higher dissolved oxygen and warmer water temperature had higher diversity, but most sites had a Simpson's diversity index of more than 0.6 (meaning they were less diverse). Based on these results, it cannot be concluded that similar environmental factors will yield the same crab species at different sites.

Though the hypothesis of this research was rejected, there was one important finding. The Asian shore crab is known to be an aggressive invasive species and findings from this study have shown that 559 out of 714 (78.3%) crabs captured at six different southeastern Massachusetts beaches were Asian shore crab. In an 8 year study recording the population of crab species in the Long Island Sound Estuary, the Asian shore crab population had spiked and was most likely a contributing factor in a decline of about 90% of the green crab and mud crab populations (Main, 2007). The Asian shore crab is such a strong competitor because its diet consists of invertebrates and seaweed, its broad temperature and salinity tolerance, and can produce several large broods per year (up to 60,000 eggs over a 3 year lifespan) (Main, 2007).

Taking this into consideration with the results from this study, the expanding Asian shore crab populations in southeastern Massachusetts may be a factor in the small populations of other crab species. Since the Asian shore crab is such a strong invasive

Crab Population Percentages for Each Site Visited

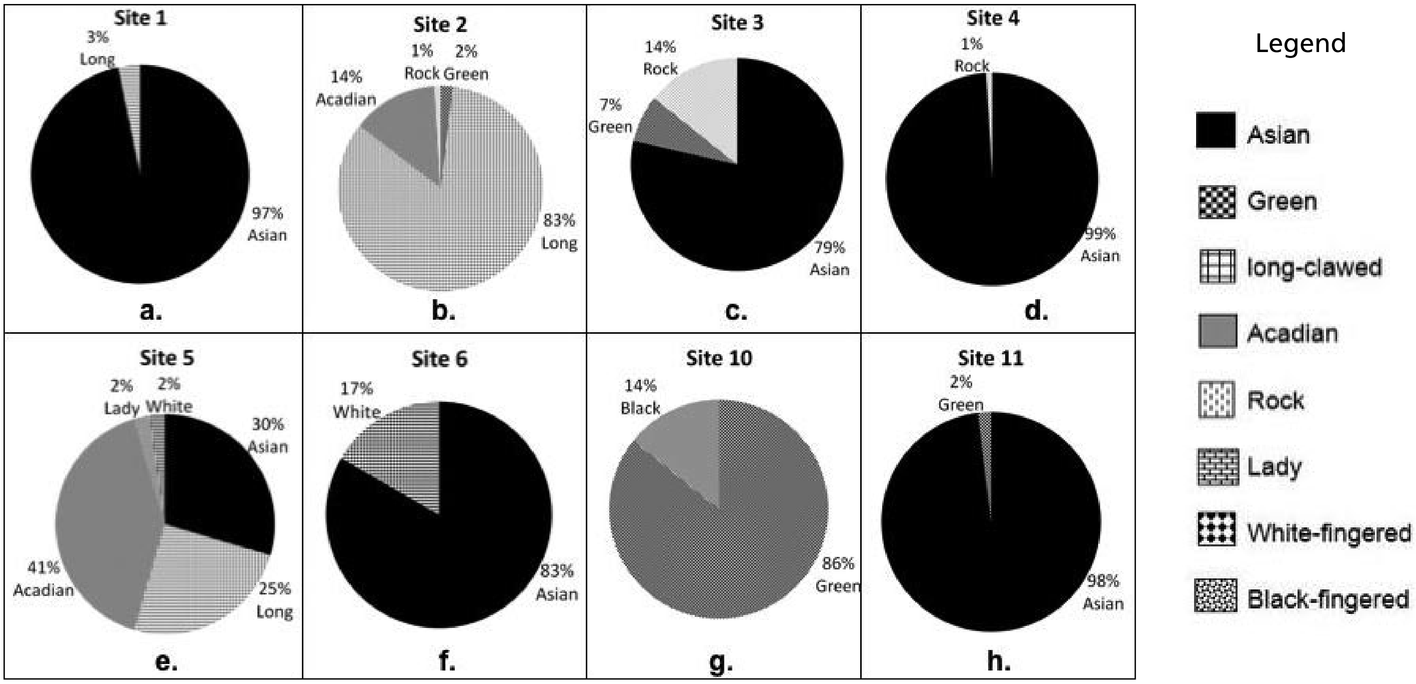

Figure 2a-h: Different crab population percentages for each site visited. Ellisville State Harbor and Massachusetts Trust Estuary were excluded because at Ellisville State Harbor all crabs counted were the same species, Asian shore crab, and at Gooseberry Island no crabs were counted.

The Dominance of Individuals Among Species (Simpson's Index of Diversity)

Site Number	Simpson's Index	Rank
1	0.935	6
2	0.713	4
3	0.615	2
4	0.981	8
5	0.302	1
6	0.667	3
7	1.000	9
8	NC	NC
9	NC	NC
10	0.736	5
11	0.962	7

Table 3: Simpson's index of diversity for each site of each of the six beaches. Gooseberry Island is excluded because no crab species were found during the time research was conducted. The higher the index value is to 1, the less diversity is shown in that sample. The lower the number, the higher the diversity in that sample. Sites are ranked from most diverse (1) to least diverse (9).

competitor with a large habitat range and diet, they would be able to thrive in many different areas and compete with different types of crab species for shelter and food. Eventually, the Asian shore crab might become the most dominate species in all of the southeastern Massachusetts beaches and bring other crab species into local extinction.

All six beaches not only had different crab species but also had different population sizes. Scituate Beach (sites 1 and 2) had two different sites that were very close together and had similar conditions. Site 2 was directly in contact with the open-ocean which can deliver more nutrients to that area than to site 1, located on rocks away from the surf. This means that site 2 would be more suitable for organisms to live because of the constant delivery of new nutrients. Their Simpson's index of diversity were 0.935 (site 1) and 0.713 (site 2), which further suggests that site 1 has lower diversity than site 2 and that site 2 is a better habitat for organisms to survive in.

For Plymouth Beach, the two sites (sites 3 and 4) were very different. Site 3 was rocky and was against the open-ocean. Site 4 was grassy and calm. The crabs in site 3 were found under rocks and in pools, that would provide shelter from predation. Though more crabs were found in site 4, the diversity was higher at site 3, supported by the Simpson's index of diversity of 0.615 (site 3) and 0.981 (site 4). Since site 4 was open and had few places for organisms to hide from predation, less species inhabited that area.

For the Mass Trust sites (sites 5 and 6) were two completely different habitats. Site 5 was an estuary during mid to high tide. There was high species diversity, as seen by the Simpson index of 0.302. Five crab species were found, the most out of any of the other sites. Site 6, on the other hand, had two crab species and only a total of six crabs. Since site 5 had the lowest salinity and highest dissolved oxygen of all the sites, this could be a contributing factor of its high diversity. Oxygen is supplied to the estuary water through photosynthesis of the sea-grass, making it an ideal habitat for not only crabs but a large number of other aerobic organisms. A mixture of both salt and fresh water could provide different habitats for different crab species. The water was also much warmer than all the other sites, and warmer water yields a greater biological capacity.

Site 7 at Ellisville Harbor had the largest count for Asian shore crabs of all the sites with a diversity index of 1.000. There was no diversity at the site since only Asian shore crabs were collected. The salinity at site 7 was the highest out of all the sites, but the Asian shore crab is known for its tolerance of salinity ranges (Ahl, 1999). This might account for the large numbers found at this site. The Asian shore crab is an aggressive invasive species that might have became so dominant in that area that few other species of crabs can be supported there (Main, 2007). Since only one species was found in a large abundance, it might be concluded that Ellisville is a stressed environment.

No living crabs were found at Gooseberry Island (sites 8 and 9). Both sites were rocky, but each was located on a different side of the island. Numerous sea shells were found along the beach at site one. There were only small rocks, and none seemed to retain any moisture. On these sites, as well, there were numerous starfish found, both dead and alive. The Northern sea star (*Asterias vulgaris*) is found in shallow water and preys on the mussel (*Mytilus edulis*) and other organisms that are similar to that size (Gaymer, 2001). Starfish are voracious eaters who can eat entire shellfish beds or coral reefs (Kraynak, 2009). Since the green crab and Asian shore generally prey on the same organisms (mussels, clams, snails) the abundance of starfish could be causing the lack of crabs in that area because there are not enough food sources (Bourdeau, 2003). It is also important to note that large crab claws and shells did wash up on shore, suggesting that larger crabs are deeper in the water. However, using established protocols, no sampling could be taken from deeper water.

The last area visited was Sandwich Marsh (sites 10 and 11). Site 10 was along the edge of the marsh. The salinity was a little lower than most other sites visited. Green crabs were collected as were two black-fingered mud crabs. While researchers were collecting data, a fisherman was collecting traps from in the marsh water and pulled out hundreds of green crabs. So even though 12 green crabs were found on shore, there were plenty more in the water. Site 11, near open ocean, had a higher amount of Asian shore crabs and only one green crab. Both sites had low diversity, and richness. It seems that the closer to the open ocean, the more Asian shore crabs are present. This could be a serious problem for the green crab; they might be limited to only the marsh because large numbers of the invasive Asian shore crabs are already inhabiting the areas that the green crab would occupy. When green crabs were first introduced to North America, they faced little competition for space under rocks in the mid to high intertidal zone since no native species were using that space. After the introduction of the Asian shore crab, competition for those areas increased. Interactions of aggressive crabs, such as the Asian shore crab, can greatly affect habitat usage and distribution of the green crab (Grosholz, 2009).

The introduction of non-native species can have ramifications that can impact indigenous species. Invasive species introduced to new environments can efficiently displace or can even cause the local extinction of native species. It is important to regulate the introduction of non-native species into new environments and to be aware of the possible consequences.

Acknowledgements
The authors would like to thank the Adrian Tinsley Program for the coursework grant that funded this research, Dr. Jonathan Roling for providing transportation and guidance, and Brian Esquilin for participating in the capturing and identification of the crab species.

Literature Cited

Ahl, R.S., and S. P. Moss."Status of the nonindigenous crab, *Hemigrapsus sanguineus*, at Greenwich Point, Connecticut." *Northeastern Naturalist* 6 (1999): 221–224.

Bourdeau, Paul E. "Predation by the Nonindigenous Asian shore crab *Hemigrapsus sanguineus* on Macroalgae and Mollusks." *Northeastern Naturalist* 10.3 (2003): 319-334.

Connell, J. H. "The influence of interspecific competition and other factors on the distribution of the barnacle Chthamalus stellatus." *Ecology* 42 (1961):710-723.

Gaymer, Carlos, 2001. Distribution and Feeding Ecology of the seastars *Leptasterias polaris* and *Aesterias vulgaris*. Journal of the

Marine Biological Association of the UK, 81, pp. 827-843.

Gosner, Kenneth. *Atlantic Seashore; A Field Guide to Sponges, Jellyfish, Sea Urchins, and More*. New York: Library of Congress Cataloging-in-Publication Data, 1978.

Grosholz, E.D. "European green crabs (Carcinus maenas) in the northeastern Pacific: genetic evidence for high population connectivity and current-mediated expansion from a single introduced source population." *Diversity & Distributions* 15, no. 6 (November 2009): 997-1009.

Kraynak, C., 2009. The destructive feeding habits of starfish: When ecosystems are devastated by overabundant sea stars. Suite 101. http://www.suite101.com/content/the-destructive-feeding-habits-of-starfish-a161502#ixzz13y3BoJIC.

Lohrer, A., Whitlatch, R. "Interactions among aliens: Apparent replacement of one exotic species by another". *Biological Sciences and Living Resources* 83 (2002) 719-732.

Main, Jeff. "Eight-year Record of Hemigrapsus sanguineus (Asian Shore Crab) Invasion in Western Long Island Sound Estuary." *Northeastern Naturalist* 14.2 (2007): 207-224.

Mooney, H.A. "The evolutionary impact of invasive species." *The National Academy of Sciences* 98 (May 2001): 5446-5451.

National Invasive Species Information Center (NISIC), 2011. What is an Invasive Species? U.S.

Department of Agriculture National Agricultural Library. http://www.invasivespeciesinfo.gov/whatis.shtml.

Nelson, Randy J., (2005). *Biology of Aggression.* USA: Oxford Press University.