Predicting the effects of climate change on *Hemigrapsus sanguineus* populations in intertidal cobble beaches

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ABSTRACT

In only 25 years, the Asian shore crab, *Hemigrapsus sanguineus*, has invaded and become established along the eastern US coast. It has likely displaced previously established species and greatly impacted local food webs. Unfortunately, environmental factors that affect the distribution and density of this invasive species are not fully understood. In this study, we identify environmental and substrate factors that affect *H. sanguineus* density and use the results to infer the potential response of this species to future changes in climate. We analyzed water quality, weather, crab density, and substrate data collected from 2008 to 2012 at four sites around Prudence Island, RI. A generalized additive model (GAM) with Gaussian distribution errors was used to explore nonlinear relationships between *H. sanguineus* density and abiotic and substrate data. We determined the amount of percent deviance explained, as well as variables' relative influence (percentage of the contribution to the deviance reduction). One-Way ANOVA was also used to test for significant differences in substrate characteristics among sites. The GAM fits explained 76% of the deviance in the model. The three variables that contributed the most to the percentage explanation of the deviance were year (43%), site (15%) and cobble (13%); the least influential (<1%) were gravel, shell, and PAR. Our results showed that sites with significantly higher amounts of cobble and significantly lower salinities had significantly higher crab densities (ANOVA, P<0.001). Our analysis of these long-term datasets provided valuable insights into the ecology of *H. sanguineus*. According to predicted climate change scenarios of higher temperatures and more precipitation (hence lower salinities) in RI, we might expect that invasive species like *H. sanguineus* will be more prevalent as the climate changes, as long as the proper habitat is available.

INTRODUCTION

At the Narragansett Bay National Estuarine Research Reserve (NBNERR) on Prudence Island, high-resolution long-term water quality and weather data have been collected since 1995 as part of the National Estuarine Research Reserve's System-Wide Monitoring Program (SWMP).

Originally, the SWMP was designed to track short-term variability and long-term changes in estuarine water quality through the collection of a broad suite of water and weather parameters. Later, the SWMP was augmented to include coastal and estuarine habitat mapping and biological monitoring (e.g., emergent wetlands, submersed aquatic vegetation, estuarine fauna, etc.).

As part of SWMP biological monitoring, we have been monitoring the Asian shore crab, *Hemigrapsus sanguineus* (De Haan 1853), since 2006.

Map of Prudence Island showing the water quality, weather and biomonitoring stations as part of SWMP.

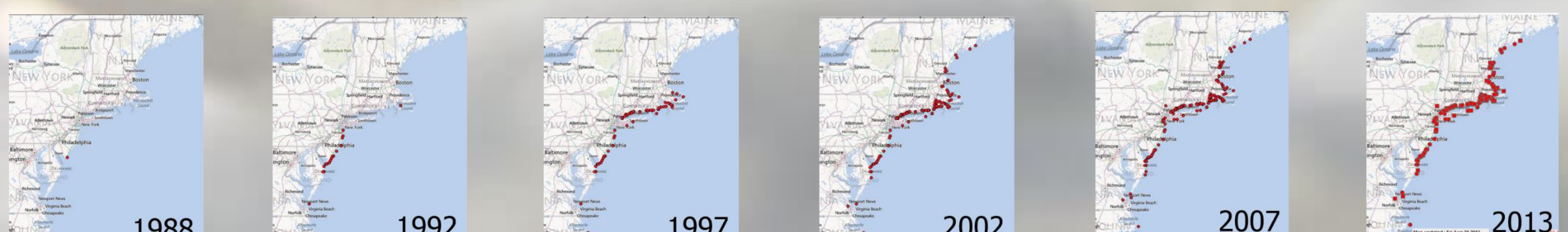
The Asian shore crab, *Hemigrapsus sanguineus*

Hemigrapsus sanguineus Facts

- Invasive, opportunistic, omnivorous species.
- First discovered in a rocky intertidal zone in NJ in 1988; quickly established breeding populations and colonized an extensive part of the east coast of the US (see time series below).
- Females can produce up to 50,000 eggs 3 to 4 times from May to September.
- Larvae are part of the plankton for nearly a month, increasing the chances of reaching new areas.
- May significantly affect native fish, shellfish, crabs, and other commercially important species by competing for food and habitat.

The Asian shore crab has been long recognized as an invasive species in Narragansett Bay. It now comprises over 98% of all crabs in unconsolidated cobble beaches in Narragansett Bay (Rohr and Raposa unpubl. data). However, the ecological impacts of this invasion are not well-understood; the NBNERR initiated its Asian shore crab monitoring program in part to help address this need.

Our goal is to demonstrate how combining long-term abiotic and biological datasets can help us better understand the ecology of the Asian shore crab. More specifically, we analyzed SWMP water quality and weather data together with data from the Reserve's Asian shore crab monitoring program to identify factors that significantly affect Asian shore crab density.



Time series data obtained from the USGS Non-indigenous aquatic species resource website http://nas.er.usgs.gov (may not accurately reflect actual species spread).

METHODS

Study Sites

Prudence Island: Bear Point, Potter Cove, Nag Creek, T-Wharf (Please see the map in the Introduction section).

Time Frame

- All data were collected from 2008 to 2012.
- Monthly sampling from June to October

Data

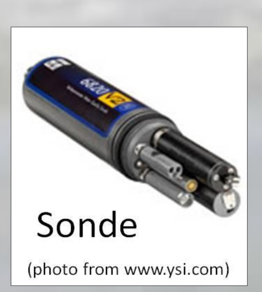
- To determine crab density a 1-m^2 quadrat was used (N=3 per site).

Researchers counting crabs and other invertebrates.

- The Point Intercept Method was used to classify substrate components as Boulder, Cobble, Gravel, Pebble, Sand, and Shell.

Researchers used a subdivided 1-m^2 quadrat to determine substrate components.

- Water quality parameters were collected with YSI 6600 sondes.
- Parameters included: Temperature, Salinity, Dissolved Oxygen, pH, Chlorophyll.



- Meteorological parameters were obtained from the Narragansett Bay NERR weather station on Prudence Island.
- Parameters included: Total Precipitation and Total Photosynthetic Active Radiation (PAR).

Water quality and weather parameters were averaged by using data collected one hour before and one hour after the time of crab sampling.

Statistical Analysis

- All data were natural log transformed.
- We used a generalized additive model (GAM) with Gaussian distribution errors to explore non-linear relationships between *H. sanguineus* density and environmental and habitat (substrate) data.
- Percent deviance explained (pseudo-R^2), as well as variables' relative influence (percentage of the contribution to the deviance reduction) were calculated in the model.
- A series of One-Way ANOVA tests were used to test for significant differences in substrate, abiotic characteristics, and crab density among years and sites.

RESULTS

General Additive Model

- GAM fits explain 76% of the deviance in *H. sanguineus* density in the model.
- The three variables that contributed the most to the percentage explanation of the deviance were year (43%), site (15%) and cobble (13%); the least influential (<1%) were gravel, shell, and PAR.

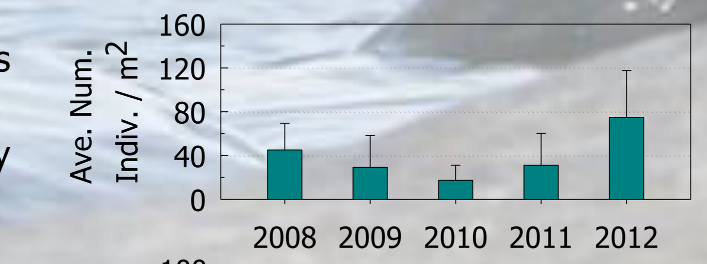
- GAM results showed two environmental and three habitat parameters were significantly influencing *H. sanguineus* density around Prudence Island (P<0.0001, Table 1) .

Table 1. GAM results for environmental and substrate parameters included in the model.

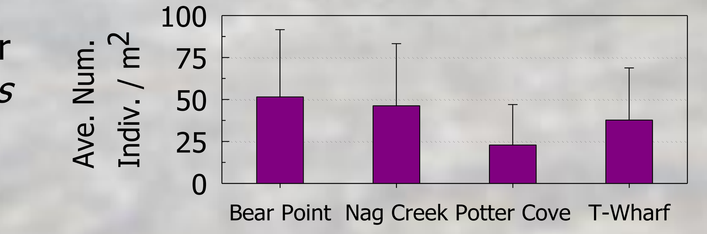
	Edf	Ref.df	F	P-value
Cobble	1.40	1.64	18.07	$1.04E^{-06}$
Salinity	1.93	1.99	10.79	$3.15E^{-05}$
T Precip.	1.55	1.80	7.41	0.0014
Boulder	1.00	1.00	8.70	0.0035
Sand	1.86	1.97	3.08	0.0481

Hemigrapsus sanguineus Population Density

- Across years, the highest density of *H. sanguineus* was observed during 2012 (One-Way ANOVA, P<0.001).
- The lowest density observed was during 2010 (One-Way ANOVA, P<0.001).

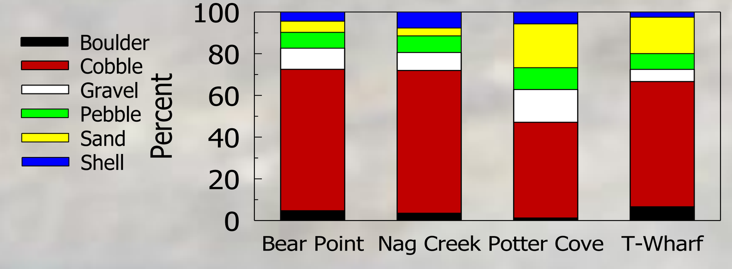


- Potter Cove has significantly lower densities while Bear Point has significantly higher densities of *H. sanguineus* than the other sites (One-Way ANOVA, P<0.001).



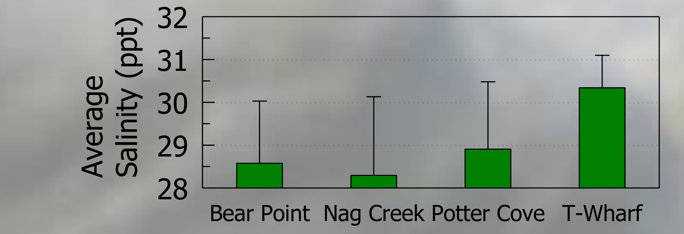
Substrate Characteristics

- Across sites and years, cobble was the dominant substrate.
- Potter Cove had significantly lower percent cobble than the other sites (One-Way ANOVA, P<0.001).



Salinity

- Salinity was significantly lower at Bear Point and Nag Creek than at the other sites (One-Way ANOVA, P<0.001)



DISCUSSION

Our results show that sites with large amounts of cobble and low salinities support significantly higher *H. sanguineus* densities around Prudence Island. Although previous studies have found that habitats with high components of cobble and boulder are important habitat requirements for *H. sanguineus* (Lohrer et al. 2000a), environmental parameters such as salinity has been considered in a more qualitative way (Lohrer et al. 2000b, Rohr 2012). According to predicted climate change scenarios (Frumhoff et al. 2007) of higher temperatures and increases in precipitation for Rhode Island (hence lower salinities in the Bay), we might expect that invasive species like *H. sanguineus* to be more prevalent as the climate changes, as long as the proper cobble habitat is available.

ACKNOWLEDGEMENTS

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