Keeping up with sea-level rise: the indirect role of crustacean ecosystem engineers, *Uca pugnax* and *Sesarma reticulatum*, in salt marsh accretion

Introduction

Salt marsh loss due to accelerated sea-level rise is a major concern in regions where rates of sea-level rise are higher than the global average, like the Atlantic coast of North America. Here, sea-level rise is 3-4 times greater than the global average (Sallenger et al. 2012). Salt marshes are among the most productive ecosystems in the world (Morris and Mehndelsson 2002) and provide important ecosystem services such as storm protection, carbon storage, food production, and tourism (Barbier et al. 2011). Salt marsh persistence in the face of sea-level rise relies on landward migration and vertical accretion. For vertical accretion, current ecogeomorphic models stress the importance of sediment trapping by marsh grass (i.e. smooth cordgrass *Spartina alterniflora*) and the contribution of organic matter via belowground production. While both above and belowground processes are required for accretion, sediment trapping and deposition by aboveground stems is predicted to be more important when considering accelerated sea level rise (Kirwan & Megonigal 2013). Thus changes in aboveground biomass should result in changes in sediment trapping and in turn vertical accretion. Previous ecogeomorphic models consider how inundation and hydroperiod influences vertical accretion (Fagherazzi et al. 2013); however, these models do not consider the indirect effect that animals have on accretion through interactions that affect plant production. Animals can influence salt marsh plant production (Bertness 1985, Hughes et al. 2014) via ecological interactions such as facilitation and herbivory. However, no tests of how these interactions influence sediment trapping and therefore vertical accretion have been conducted. Therefore, the overarching **goal of my research is to determine the indirect effects of animals on vertical accretion, through their effects on plant production.**

Ecosystem engineers are organisms that modify habitats and change resource availability through their activities. In salt marshes, the marsh fiddler crab, *Uca pugnax* and the purple marsh crab, *Sesarma reticulatum* co-occur in the same tidal zone (Grimes et al. 1989, Johnson, 2014, Sepile 1979) and have well-studied direct effects on salt marsh physical structure via their burrowing activities (Bertness 1985). Their indirect effects on ecosystem structure, however, are not well understood. In terms of aboveground biomass, *U. pugnax* is a facilitator species that increases *S. alterniflora* biomass via nutrient regeneration and biodeposits (Bertness 1985, Hughes et al. 2014). By increasing *S. alterniflora* biomass, *U. pugmax* may indirectly facilitate sediment trapping and ultimately marsh accretion rates.

In contrast, *S. reticulatum* reduces *S. alterniflora* production through herbivory (Coverdale et al. 2012) *S. reticulatum*, could therefore decrease accretion rates. *S. alterniflora* die-offs due to *S. reticulatum* overabundance have occurred in New England salt marshes (Holdredge et al. 2009). Given the large geographic distribution of *S. reticulatum* (Seiple 1979), these events should be widespread in Atlantic salt marshes, but they are not. Thus, the negative effects of *S. reticulatum* may be offset by positive effects of other species such as *U. pugnax*. Belowground processes are also affected by burrowing activity of both species of crustaceans, through increased decomposition rates, decrease in belowground biomass, and changes in sediment strength. I hypothesize the non-trophic interactions between *U. pugnax* and *S. alterniflora* will result in increased sediment accretion, while trophic interactions between *S. reticulatum* and *S. alterniflora* will decrease sediment accretion.

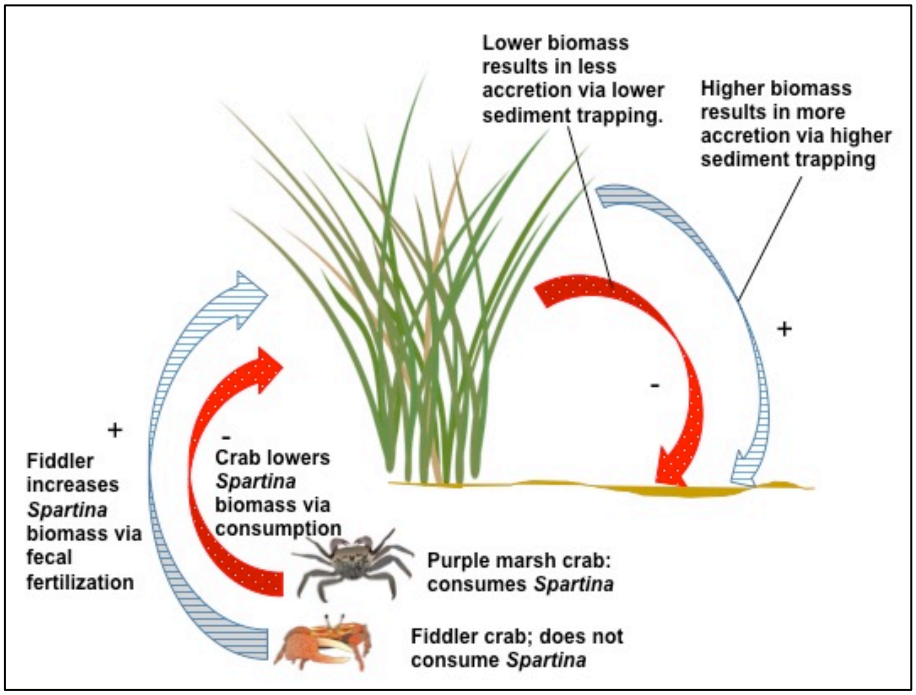

Figure 1: Predicted indirect effects of functionally different crabs on marsh geomorphology.

Proposed Research

Objective 1: Determine how a gradient of *Uca pugnax* and *Sesarma reticulatum* densities affect sediment accretion in salt marshes through their contrasting effects on cordgrass production.
Objective 2: Test the individual and combined effects of *U. pugnax* and *S. reticulatum* on sediment accretion via changes in cordgrass production, using experimental field manipulations.

For this study, I will use aboveground sediment deposition as a proxy for measuring marsh accretion, acknowledging that 1) both aboveground and belowground processes are necessary for accretion and 2) that increased accretion does not necessarily equate to elevation gain because it does not account for other factors such as subsidence. Sediment deposition is still a useful measurement because my research objective is to understand the indirect effect ecosystem engineers on physical processes via changes in plant production.

To accomplish my research objectives, I will conduct my experiments in salt marshes in the following estuaries: Chesapeake Bay, Delaware Bay, North Inlet, and Narragansett Bay. Using these different marshes allows the analysis of sites with different levels of sediment supply but similar species composition. In each estuary, I will conduct both field surveys and manipulative experiments.

Field Surveys (Objective 1):

At each site, I will examine the relationship between field densities of *U. pugnax* and *S. reticulatum* and sediment trapping ability using a regression approach. In twenty haphazardly tossed quadrats I will enumerate *U. pugnax* and *S. reticulatum* densities along with *S. alterniflora* biomass and stem density, and sediment deposition. Because these crabs co-occur in the same tidal zone, the goal is to identify areas with varying proportions of each crab to examine sediment trapping as a test of accretion potential. This work will be done during May-August 2016.

Manipulative experiment (Objective 2):

I will deploy an experimental field manipulation testing the individual and combined effects of these two crab species on *S. alterniflora* production and sediment trapping capability. I will conduct a fully factorial experiment with the following four levels: *U. pugnax* only, *S. reticulatum* only, *U. pugnax* and *S. reticulatum*, and no crabs. Crabs will be caged in *S. alterniflora* in the three surveyed marshes (n=8 per marsh) from May to August 2016. Densities of crabs in this manipulation will be scaled using data from the previous survey, so that I can determine the effects of ambient densities. In August, sediment deposition within the cage will be measured using sedimentation plates. Cages will be removed just before the deploying plates, because the cage inhibits sedimentation within the plot. After sedimentation has been measured, plant biomass will also be measured through aboveground and belowground harvest. I hypothesize that the *U. pugnax* treatment will increase *S. alterniflora* biomass and thus increase sedimentation, while the *S. reticulatum* treatment will decrease *S. alterniflora* and decrease sedimentation. I hypothesize that the *U.pugnax* and *S. reticulatum* treatment will result in an overall increase in plant biomass and an increase in sediment trapping due to the combined effects of these species. I further hypothesize that when combined, the stimulation of aboveground production by *U. pugnax* will ameliorate the negative impacts of *S. reticulatum* herbivory, thus increasing marsh accretion.

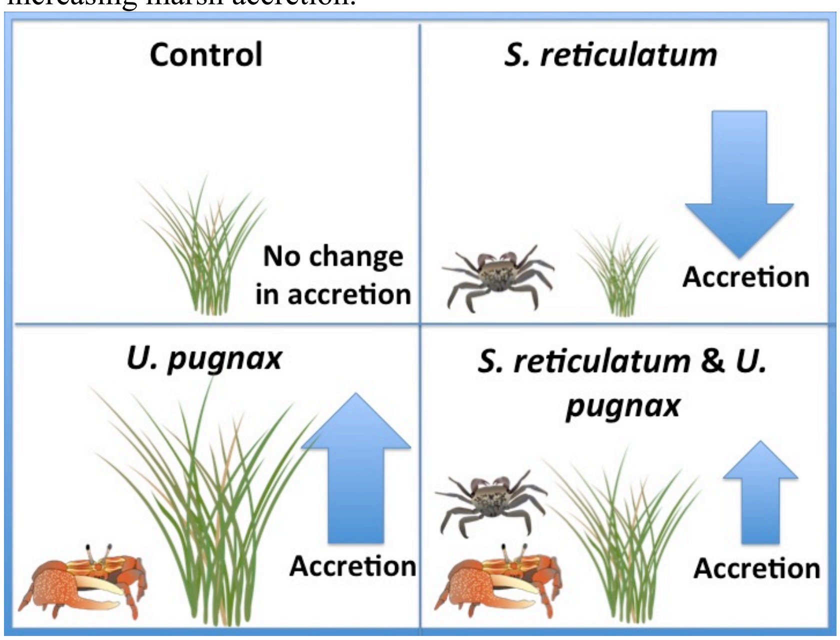

Figure 2: Treatments and expected results in field manipulations. *Uca pugnax* will increase *Spartina alterniflora* biomass, while *Sesarma reticulatum* will decrease *S. alterniflora* biomass. When combined, *U. pugnax* will ameliorate the stresses of *S. reticulatum*, increasing S. alterniflora biomass. *Spartina alterniflora* sizes are proportional to response. Arrows are proportional to accretion response.

Benefit to Coastal Wetlands

This research will improve our understanding of how coastal wetlands are responding to climate change. Determining the net effect of these two species with contrasting impacts improves our understanding about the indirect role of animals in vertical accretion of salt marshes, which could useful for managers. The results of this research could be integrated into management plans to aid marsh accretion along the Atlantic coast in the face of accelerated sea-level rise. Additionally as global temperature continues to rise, many species ranges are extending poleward. For instance, *U. pugnax* now ranges as far north as New Hampshire (Johnson 2014). The movement of this species into systems it did not previously inhabit makes it even more important to understand the effects of these crabs on the ability of salt marshes to maintain elevation. My research will produce a better understanding of the ability of salt marshes to persist as an ecosystem in light of accelerated sea-level rise.

Budget

Travel ($1700): Traveling to all the field sites will be approximately 2,000 miles worth of travel. A VIMS vehicle will be utilized for traveling to field sites ($0.85/mile), thus costing $1700.
Vessels ($2000): Completion of field work will require the use of a VIMS vessel, for which rates are $100/day. A vessel will be needed for twenty days. Trailer rental ($20/day) will cost $400.
Materials and Supplies ($900): This portion of funds will be used to purchase equipment for the completion of field work and processing of samples in the laboratory. Supplies include: PVC, plexiglass sedimentation plates, garden shears, a vacuum pump, digital calipers, 90 mm fiberglass filters, 25 mm fiberglass filters, re-sealable bags, rubber bands, and bottles for water sample collection.

Broader Impact

To share my results with the scientific community, I will publish the results in a peer-reviewed scientific journal such as, *Estuaries and Coasts*. I will also present the results of this research at the regional conference for the Atlantic Estuarine Research Society and the national conference for the Coastal and Estuarine Research Federation.

To share this research with a larger audience, I will create two lesson plans, integrating hands-on demonstrations using data generated from this proposal and group learning. I will teach these lessons at a local high school, Chesapeake Bay Governor's School for Marine and Environmental Science (CBGS). After delivering these lessons and receiving feedback from both the outreach mentor and classroom teacher, I will modify the lessons, making them more usable by other local secondary teachers. I will engage students at CBGS in current research through field trips. The Chesapeake Bay Governor's School conducts field trips where students experience field ecology and scientific sampling methods. I will attend one field trip to a wetlands ecosystem, answering students' questions about coastal ecosystems and the effects of global changes such as sea-level rise. I will also demonstrate the results of my research in the field with students through hands on experience.

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