RESEARCH PLAN- ANDREW BRINTON

Title

Marsh Restoration: Ribbed Mussels (*Geukenisa demissa*) as a Revival Mechanism to Rebuild the Coastal Salt Marshes of Long Island, New York

Category

Earth and Environmental Sciences

a. RATIONALE: Include a brief synopsis of the background that supports your research problem and explain why this research is important and if applicable, explain any societal impact of your research.

Storm surges as a result of extreme weather such as Superstorm Sandy, which struck Long Island on October 29, 2012, tear apart coastal communities. While the physical damage to homes and businesses may be repairable, many people face lasting trauma, including financial instability, mental anguish, and physical ailments caused by high levels of stress. Therefore, all possible remedies to reduce the damage caused by storm surge must be explored.

Storm surge damage can be lessened — or even prevented — in a number of significant ways. This study will focus on a natural barrier against storm surges: salt marshes. Specifically, *Geukensia demissa,* or ribbed mussels, have been shown to have a symbiotic relationship with salt marsh grasses, particularly cord grasses such as *Spartina alterniflora* and *Spartina patens.* The grasses provide a safe location for the mussels to tether to, and the marshes are a prime location of ocean water flow, which allows the mussels to grow via filter-feeding and breeding. In return, the mussels provide nutrients for the grasses in the form of feces and pseudofeces, which are rich in organic nitrates, sulfates, and ammonium-based molecules. Through the process of filter-feeding, they also excrete silicates, which become suspended in the surrounding water, and eventually accumulate to form new sediment that allows the marsh to expand, both vertically and horizontally, thus increasing this natural barrier against storm surge. While this relationship has been established in controlled environments, there have been few, if any, extensive investigations as to how this relationship can be used to naturally restore marshlands.

Salt marshes and salt flats along the coast are dense havens of wildlife, and support over 2,000 species. In addition to serving as the home of hundreds of thousands of creatures, coastal marshes contain a variety of plant life, including cord grasses, which dominate the wetlands. Along the coastal marshes of Long Island, New York, the two most prevalent species are *Spartina alterniflora* and *Spartina patens.* These grasses hold together the otherwise loose sediment that makes up the soil with their salt-resistant root structures. Their high tolerance for salt, tall height, and resilient root structure allow them to act as a "mother species" for salt marsh communities, housing many bird nests, crustacean eggs, and bivalve breeding grounds.

In recent decades, salt marshes have degraded at an alarming rate. Among the reasons is salt marsh submergence, or the covering of the marshland with saltwater as a result of rising sea levels caused by anthropogenic climate change. The rate of marsh decline has been tracked in the past, but the past two decades of marsh data are all but missing from general records. The majority of studies conclude: The salt marshes surrounding Long Island have been reduced in size, both vertically and horizontally, because of submergence.

Based on preliminary research, the marshes surrounding Long Island can be restored to their area prior to the 1960's. Few methods of restoration have been attempted — and all have been through human-made means, including bulwarks, reservations, and storm surge walls along the coast. While these may be effective methods of preserving the mainland beyond the wetlands, the marshes continue their steady decline. Without a means of restoration, they will eventually be destroyed, and the threat of storm surge to the mainland will increase dramatically. This study aims to prove that ribbed mussels can serve as an effective means of restoring the wetlands, thus creating a natural barrier against storm surge and further marsh degradation.

b. RESEARCH QUESTION(S), HYPOTHESIS(ES), ENGINEERING GOAL(S), EXPECTED OUTCOMES: How is this based on the rationale described above?

The primary objective of this study is to analyze the relationship between Geukensia demissa and the marsh grasses surrounding Long Island. Specifically, the analysis will include the cord grass *Spartina alterniflora* and *Spartina patens*.

This study will aim to answer the following questions:

1- Can Geukensia demissa be used to restore marshlands? If so, how?

2- Is an increased mussel density significantly correlated to larger marshland, measured vertically and horizontally?

3- What is the current rate of marsh decline due to submergence? What is the expected rate of decline in the coming decades?

4- If mussels significantly restore marsh size, can the rate of restoration outpace the rate of submergence?

c. Describe the following in detail: • Procedures: Detail all procedures and experimental design including methods for data collection. Describe only your project. Do not include work done by mentor or others. • Risk and Safety: Identify any potential risks and safety precautions needed. • Data Analysis: Describe the procedures you will use to analyze the data/results.

Experimental Design: The study will be conducted each during a period of time that encompasses both high and low tides to ensure mussel visibility at all points during the study. Photographs of marsh leveling will be taken to measure cross-sectional views of the marsh. Study sites to be included in the study are Waterfront Park, Norman J. Levy Preserve, Cow Meadow Park, and Merrick Bay (tentative). These sites were chosen based on scouting expeditions conducted prior to experimentation, and observations of mussel presence/absence, spartina presence/absence, and mudflat erosion presence. Marsh area will be recorded via pictures from two Gopro cameras, each attached to a remote controlled drone. Each week an aerial photo will be taken of each site to develop an observable change in marsh area over the four month study period.

Risk and Safety: Outdoor safety procedures will be followed to ensure healthy levels of hydration, eliminate risk of sunburn, and to not acquire any physical injuries. Waders will be purchased alongside life vests to ensure safe travel in and out of the marshes.

Data Analysis: The computer language "R" will be used in the program "RStudio" to perform statistical analysis to correlate mussel presence or absence with marsh area and height according to Kendall and Pearson correlation tests.

d. BIBLIOGRAPHY: List major references (e.g. science journal articles, books, internet sites) from your literature review. If you plan to use vertebrate animals, one of these references must be an animal care reference.

1. Bilkovic, D. M., Mitchell M. M., Isdell, R. E., Schliep, M., Smyth, A. R., 2017. "Mutualism between ribbed mussels and cordgrass enhances salt marsh nitrogen removal". *Ecosphere* 8(4):e01795. doi: 10.1002/ecs2.1795

2. Bowman, J., 1990. "The greenhouse effect". *Land Use Policy* Volume 7, Issue 2, April 1990, Pages 101-108 doi: 10.1016/0264-8377(90)90002-G

3. Brandon, C.M., et al., 2014. "How Unique was Hurricane Sandy? Sedimentary Reconstructions of Extreme Flooding from New York Harbor" *Scientific Reports* 2014/12/08/online, Volume 4;7366 10.1038/srep07366

4. Chaisson, B., 2018. "What We Know (and Don't Know) About Sea Level Rise". *Center for Climate and Life, Lamont-Doherty Earth Observatory, Columbia University Earth Institute*

5. Church, J.A., et al., 2016. "Anthropogenic forcing dominates global mean sea-level rise since 1970". *Nature Climate Change* Volume 6, pages 701–705 (2016) doi: 10.1038/nclimate2991

6. Cochran, J. K., et al., 2018. "Health and Resilience of Salt Marshes in Jamaica Bay, NY". *Natural Resource Report, Geochemical and Dynamical Perspectives* NPS/NCBN/NRR—1643

7. Colle, B.A., et al., 2008. "New York City's Vulnerability to Coastal Flooding". *American Meteorological Society* doi: 10.1175/2007BAMS2401.1

8. Dahl, T.A., 1990. "Wetlands Loss Since the Revolution". *National Wetlands Inventory Newsletter,* Volume 12, No. 6, Environmental Law Institute, Washington, D.C.

9. Davis, J. L., et al., 2015. “Living Shorelines: Coastal Resilience with a Blue Carbon Benefit”. *PLoS One* 10(11):e0142595 doi: 10.1371/journal.pone.0142595

10. Environmental Protection Agency, Report on the Environment, undated Internet publication from EPA.gov. “Greenhouse Gases: What are the trends in greenhouse gas emissions and concentrations and their impacts on human health and the environment?”

11. Flavell, C. and Lu, D., 2019. “Rising Seas Will Erase More Cities by 2050, New Research Shows”. *The New York Times*

12. Gedan, K.B, Bertness, M. D., 2010. “How will warming affect the salt marsh foundation species *Spartina patens* and its ecological role?”. *Oecologia, Community Ecology* (2010) doi: 10.1007/s00442-010-1661-x

13. Gedan, K. B., et al., 2008. “Centuries of Human-Driven Change in Salt Marsh Ecosystems”. *Annual Review of Marine Science* doi: 10.1146/annurev.marine.010908.163930

14. Jain, P.C., 2003. “Greenhouse effect and climate change: scientific basis and overview”. *Renewable energy* doi: 10.1016/0960-1481(93)90108-S

15. Jones, N., 2017. “Breaking Records: How the World Passed a Carbon Threshold and Why It Matters”. *Yale360, published by the Yale School of Forestry & Environmental Studies*

16. Kreeger, D., Moody, J., Padeletti, A., Whalen, L., December 2017. “Constructing Bio-based Living Shorelines to Stem Erosion of Salt Marshes in New Jersey: Final Report for the New Jersey Department of Environmental Protection”. *Partnership for the Delaware Estuary — A National Estuary Program*

17. Kroeze, C., 1992. “Nitrous oxide and global warming”. *Science of The Total Environment Volume 143,* Issues 2–3, 15 April 1994, Pages 193-209 doi:10.1016/0048-9697(94)90457-X

18. Lacy, H.S., DeVito, A., De Nivo, A. C., 2013. “Geotechnical Aspects of Three Storm Surge Barrier Sites to Protect New York City from Flooding”. *Storm Surge Barriers to Protect New York City, ascelibrary.org by Columbia University*

19. Moody, J. A., 2012. “The relationship between the ribbed mussel (Geukensia demissa) and salt marsh shoreline erosion” *Masters thesis submitted to the Graduate School at Rutgers, the State University of New Jersey* doi:10.7282/T3TT4PW8

20. Moore, G.W.K., Holdsworth, G., Alverson, K., 2002. “Climate change in the North Pacific region over the past three centuries”. *Nature* (2002) Nov 28;420(6914):401-3. doi: 10.1038/nature01229

21. Nataly, N., 2018. “Freeport officials, hoping to construct floodgates here, tour Massachusetts project”. *Freeport Herald-Leader*

22. Nataly, N., 2019. “’Waiting for 2030 is unacceptable’: Residents angry — study offers no flooding solutions”. *Freeport Herald-Leader*

23. Porter, Elka T., Lawrence P. Sanford, and Steven E. Suttles. 2000. “Gypsum Dissolution Is Not Universal Integrator of ‘Water Motion’”. *Limnology and Oceanography.* 54(1): 145-158.

24. Solomon, S., Plattner, G. K., Knutti, R., & Friedlingstein, P., 2009. Irreversible climate change due to carbon dioxide emissions. *Proceedings of the National Academy of Sciences of the United States of America*, *106*(6), 1704–1709. doi:10.1073/pnas.0812721106

25. South Shore Estuary Reserve Council, 2016. “Long Island South Shore Estuary Reserve Eastern Bays Project: Nitrogen Loading, Sources, and Management Options” *Prepared for the New York State Office of Planning and Development*

26. Stedman, S. and Dahal, T.E., 2008. “Status and Trends of Wetlands in the Coastal Watersheds of the Eastern United States 1998 to 2004”. *National Oceanic and Atmospheric Administration, National Marine Fisheries Service, and the U.S. Department of the Interior, Fish and Wildlife Service*

27. Swanson, R.L., O'Connell, C., Wilson, R.E., 2013. "Storm Surge Barriers: Ecological and Special Concerns". *Storm Surge Barriers to Protect New York City: Against the Deluge* ISBN (print): 9780784412527ISBN (PDF): 9780784477007 doi: 10.1061/9780784412527

28. "Threats to Wetlands: What is the Status of Our Nation's Wetlands?" September 2001. *U.S. Environmental Protection Agency*

29. Town of Hempstead School District Boundaries Map, 1903

30. Town of Hempstead Water Quality Report 1975-2012, *Department of Conservation and Waterways entry*

31. Wallace, R. B., Baumann, H., Grear, J. S., Aller, R. C., Gobler, C. J., 2014. "Coastal ocean acidification: The other eutrophication problem" *Estuary, Coastal and Shelf Science* Volume 148, 5 July 2014, Pages 1-13 doi: 10.1016/j.ecss.2014.05.027

32. "What Are Coastal Wetlands?" *Science and Climate Defined*, undated Internet publication from the University of California at Davis

33. Yokoyama, 2004. "Estimation of the assimilative capacity of fish-farm environments based on current velocity measured by plaster balls." *Aquaculture* 240; 233-247.

ADDENDUM

Sections Added

- Procedure was modified to include quadrat measurements to measure ribbed mussel density. The 25cm by 25cm grid was constructed using PVC pipe, lawn mower wire, and waterproof tape. No additional safety precautions were needed.

- Procedure was modified to include linear transect measurements along the marsh edge. This endeavor involves the physical trekking of marshes. No official safety protocols exist for such a task; however, proper gear including waist-high waders, water, life vests, headlamps, walking poles, sungear, and head-and-neck covering hats were used to ensure safety. Each step taken had to be tested using the walking pole to see if the marsh would give in, the sand was too soft, or the mud was too deep to walk through. Such safety procedures were followed with the Boy Scouts of America hiking and safety procedures.

- Procedure was modified to include mass-transfer meters to measure wave energy along the linear distance of each transect. Safety procedures were added during the production of the meters, which occurred in a sediment laboratory at Hofstra University. The creation of the meters involved plaster-of-Paris, a potential carcinogen if inhaled in the form of raw dust. As such, the Uniondale fire chief was contacted to ensure proper breathing masks were used. Other lab gear including a full-body lab coat, goggles, hairnets, and gloves were provided by Dr. Emma C. Farmer of Hofstra University. Dr. Farmer supervised the student researcher during the creation of the meters.

- Historical analysis was added for comparison purposes and to analyze general trends. All maps were gathered from publicly available sources including Google Earth and the Town of Hempstead Archives.

Sections Removed

- Drones and their use, by any means, were not included in the study.

- Gopros were not used for photography at any point during the study.

- Marsh height was not a factor that was used in analysis. Attempts were made but ultimately proved futile due to the time-consuming and cumbersome nature of measuring such a factor, which ended up posing a safety risk at points.