Gabby Giacomangeli
June 21, 2017

Inundation of Coastal Freshwater Lagoons by Rising Seas: Impacts and Management strategies

1. INTRODUCTION

Back Bay National Wildlife Refuge is located in Southeastern Virginia, in the southern most rural section of Virginia Beach. Surrounding the refuge is residential and agricultural development, and the area north of Back Bay is urbanized. Fortunately, Back Bay has acquired a total of 9035 acres, allowing the bay and the surrounding ecosystems to remain protected from development (U. S. Fish and Wildlife Service, 2010).

Back Bay NWR is a system composed of water, barrier island sand dunes, and wetland marsh. The ecosystems that make up Back Bay NWR are freshwater forested wetlands, freshwater shrub wetlands, freshwater emergent wetland, and brackish/transitional marsh. The refuge's barrier islands feature more ecosystems such as large sand dunes, maritime forests, fresh water marshes, ponds, and ocean beach (U. S. Fish and Wildlife Service, 2010). The refuge was established to protect and conserve waterfowl that use the Back Bay watershed during migration. Management of the refuge includes ten oligohaline impoundments. These impoundments are man-made, managed wetlands that support freshwater wetlands where submerged aquatic vegetation (SAV) is abundant. This provides food and shelter for the migrating waterfowl as well as other water bird species.

The land surrounding Back Bay is generally flat, and this can cause the surrounding agriculture to become flooded during high wind tides. Though there is agricultural development around the bay, the overall groundwater quality is good, due to small increase in nitrate levels (U. S. Fish and Wildlife Service, 2010).

Research shows that over the last hundred years, Back Bay has experienced many transitions between systems of a freshwater regime and brackish/saltwater marsh (Virginia Institute of Marine Science, 1989). There are still large populations of cord grass and black needle brush (both estuarine species), presumed to be from the influence of a brackish/saltwater marsh. Up until the 1930s, Back Bay would experience overwash events that would keep the bay a saltwater marsh. The Civilian Conservation Corps constructed and stabilized sand dune formations during the 1930s to prevent any overwash from occurring. These new dunes protected the bay from the ocean water and allowed the formation of a brackish marsh that evolved into the existing oligohaline (salinity of <5 ppt) wetlands of Back Bay (Virginia Institute of Marine Science, 1989). Up until 1962, Back Bay remained a freshwater regime. A storm caused complete overwashes of the dunes, causing the salinity in the bay to rise and transition back into a brackish marsh. In 1964, pumping began in the Bay to keep it a saltwater/brackish system. The pumping transitioned the Bay back to 3.5 ppt. Freshwater systems dominated again until 1978 when pumping was continued, and the water was once again brackish. By 1985, pumping was terminated by the City of Virginia Beach, which allowed to bay to return to a freshwater regime (Virginia Institute of Marine Science, 1989).

For my internship at Back Bay NWR, I will be researching the impacts of inundation on coastal freshwater lagoons, and will determine possible management strategies in response to these impacts. To determine these management strategies, I plan to research the current dominant species of SAV in Back Bay, and how these plant communities keep the bay a dominantly freshwater system. I will also research how the bay has transitioned from saltwater to freshwater over these past decades to help me determine the outcomes of complete inundation of the freshwater system.

2. HAZARDS RESULTING FROM SALTWATER INTRUSION

Inundation is one of the main hazards that this system is exposed to. The barrier spit is what protects the freshwater system from being inundated by ocean water. A hazardous form of inundation is wind driven inundation (Lagomasino et al 2013). Back Bay is 80 miles north of the nearest ocean inlet, and because of this it experiences no lunar tidal action. Instead, the bay experiences “wind tides” that determine the Bay water levels. Any wind driven inundation can determine the salinity levels of Back Bay’s water (Virginia Institute of Marine Science, 1989). The low-lying topography makes the refuge more susceptible to this type of inundation. Storms are another hazard that can cause the bay to flood. In 1962, the area experienced the Ash Wednesday Storm that caused overwash of the dunes and increased the salinity of the bay, causing it to transition from freshwater to brackish (Virginia Institute of Marine Science, 1989). Any of these hazards can cause the salinity in the bay to rise.

Another hazard the Back Bay would encounter from inundation would be changes in sediment. A study was done that determined the relationship between short term sediment movement and long term accumulation based on topography, inundation depth, and inundation duration (Lagomasino et al 2013). The study determined that elevation did not influence the amount of sediment deposited or accumulated and the short-term sea level rise can have direct effects on changes in sediment accumulation to marshes in wind driven estuarine systems (Lagomasino et al 2013).

The coastal freshwater ecosystems are protected from the ocean water by the barrier island spit and the beach dunes. Though these dunes have been restored and protected, they have experienced an overwash regime before, as well as erosion. In an overwash regime the sand and sediment is typically transported away from the beach, and causes the barrier island to slowly migrate landward. When Back Bay previously experienced this from the Ash Wednesday Storm, the freshwater system experienced an influx of salt water (Sallenger Jr., 2000).

3. FRESHWATER ECOSYSTEM VULNERABILITIES TO SALTWATER INTRUSION

If the coastal freshwater systems within Back Bay NWR experience inundation, then the system could be vulnerable to a loss of habitat, a decrease in biodiversity, the destruction of the dune system, and migration of plant communities. The low-lying topography of Back Bay is what makes the bay so vulnerable to inundation. Flooding in the bay would cause seedlings to experience difficulty in germination and production along shorelines. This would cause the plant communities to migrate in land, and the bay would become more vulnerable to transition from fresh water to brackish since the plant composition will have changed.

The inundation of the system could cause the barrier islands and their sand dunes to experience an inundation regime. This would mean that the sand and sediment of the dunes would be completely inundated, and this would result in irreversible damage of the surrounding ecosystems (Sallenger Jr., 2000). Not only do the sand dunes face overwash and erosion, but according to a news article, the shoreline of the bay had been eroding at a rate of 1.3 to 1.67 feet per year between 2001 and 2013 (Smith, 2017).

4. POSSIBLE SEA-LEVEL RISE IMPACTS ON BACK BAY NATIONAL WILDLIFE REFUGE

According to a SLAMM analysis, much of Back Bay’s freshwater systems will transition due to sea level rise. The data shows that, initially, inland freshwater marshes have an acreage of 732, and that by 2100, the acreage will have decreased to 268. This is a 36% decrease in inland freshwater marshes. This model also shows that, by 2100, the percentage of brackish marsh will have decreased from 20.63% to 2.91%. Even more alarming data shows that estuarine open water will increase by at least 48% by 2100. This means that in 2100, estuarine open water will make up 76.95% of the Back Bay NWR. To increase the land/water ratio, the Back Bay NWR would have to acquire more land to compensate to the loss of land caused by sea level rise. For the internship, I would like to determine other possible scenarios and compare them to this SLAMM analysis.

Back Bay National Wildlife Refuge, SLAMM Analysis Data

SLAMM Code	Initial Acreage	2050 Acreage	2100 Acreage	Initial Percent	2050 Percent	2100 Percent
Developed Dry Land	2.42	2.78	2.50	0.01	0.02	0.02
Undeveloped Dry Land	1957.43	1184.77	585.29	12.04	7.29	3.60
Swamp	410.90	124.27	24.76	2.53	0.76	0.15
Cypress Swamp	128.47	127.05	124.90	0.79	0.78	0.77
Inland Freshwater Marsh	731.74	615.69	267.93	4.50	3.79	1.65
Tidal Freshwater Marsh	1.56	1.56	0.67	0.01	0.01	0.00
Transitional Saltmarsh	845.64	395.49	179.15	5.20	2.43	1.10
Saltmarsh	1840.14	1878.45	1185.17	11.32	11.55	7.29
Estuarine Beach	178.39	294.54	212.72	1.10	1.81	1.31
Tidal Flats	0.00	806.99	334.75	0.00	4.96	2.06
Ocean Beach	101.22	48.45	27.19	0.62	0.30	0.17
Inland Open Water	327.17	59.25	56.84	2.01	0.36	0.35
Estuarine Open Water	6108.97	8833.75	12511.55	37.57	54.33	76.95
Open Ocean	15.12	93.15	247.75	0.09	0.57	1.52
Brackish Marsh	3354.88	1703.36	472.53	20.63	10.48	2.91
Tidal Swamp	255.82	90.32	26.14	1.57	0.56	0.16
Total	**16259.85**	**16259.85**	**16259.85**	**100.00**	**100.00**	**100.00**

*Table 1: Changes in ecosystem acreage as a result sea level rise in Back Bay NWR. (*U. S. Fish and Wildlife Service, 2010)

5. DECISION MAKING FOR SEA LEVEL RISE ADAPTATION AT BACK BAY

Who is relevant for decisions on adaptation and what is impacting their decision making? Multiple government agencies will be a part of the decision making processes. These agencies and departments include the Fish & Wildlife Service, the Virginia Department of Conservation and Recreation, the Division of State parks, the Virginia Department of Game and Inland

Fisheries, and the City of Virginia Beach Department of Parks and Recreation. Wildlife Biologists and bird enthusiasts are also relevant, as the professionals come to Back Bay frequently.

The population that lives in the surrounding areas will also be relevant in the decision making process. The Friends of Back Bay, a membership organization, obtained $24 million of funds from the Land and Water Conservation Fund to acquire land and increase the size of the refuge.

6. OPTIONS TO ADAPT TO SEA LEVEL RISE AT BACK BAY

Research suggests that the brackish marsh plants are more adaptable to transition of freshwater than the freshwater plants are to the transition of brackish conditions, which would explain why there is a dominance of brackish plant species (Virginia Institute of Marine Science, 1989). If Back Bay is going to experience total inundation from sea level rise, then one short term option for the refuge would be to allow the bay to transition back to mainly a brackish/saltwater system, like how pumping water into the bay had caused the system to transition. This would allow the plant communities to adapt more easily. One long term option would be to look at possible future scenarios where the fresh water system could move inland if total inundation of the bay were to occur.

During my internship, I would do more research about the current dominant plant species and how they would be able to adapt to an increase in salinity from inundation.

7. RECOMMENDATIONS

The management of Back Bay NWR should continue to restore the shoreline of the bay so that the shoreline will remain more stable and less susceptible to erosion. A recent project to restore the eroding shoreline required 1,870 tons of stone and 1,616 cubic yards of sand to be brought in to reinforce the shore and provide a base for plants such as groundsel tree, southern bayberry, salt meadow cordgrass and northern wild rice that would also help stabilize the shoreline. This project is expected to protect the site from erosion for 30 to 50 years (Smith, 2017). Shorelines around the bay should be surveyed to determine if any project is required to further protect it from erosion. Another recommendation would be to restore the surrounding sand dunes like they were back in the 1930's. This would keep the area from experiencing an overwash regime and keep the freshwater system from experiencing sudden inundation and therefore a sudden increase in salinity. This would only work short term, as future SLR projections might be too high for the dunes to withstand. The area should be surveyed to determine where a possible sight would be to slowly allow salt water intrusion from the ocean, such as a low lying to determine how sediments and plant communities would be impacted.

References

U. S. Fish and Wildlife Service. “Back Bay National Wildlife Refuge [Electronic Resource] Final Draft Comprehensive Conservation Plan and Environmental Assessment.” Virginia Beach, VA. U.S. Fish and Wildlife Service, Northeast Region, 2010.

Silberhorn, GM., Priest, WI., Dewing, S. 1989. “City of Virginia Beach Marsh Inventory.” Gloucestor Point, VA. Virginia Institute of Marine Science

Smith, Darryl. “Back Bay National Wildlife Refuge tackles erosion with sand, stone and grasses.” The Virginian Pilot, 2017.

Lagomasino, D., Corbett, D. R., & Walsh, J. P. “Influence of wind-driven inundation and coastal geomorphology on sedimentation in two micro tidal marshes, Pamlico river estuary, NC.” *Estuaries and Coasts*, vol. 36, no. 6, 2013, pp. 1165-1180.

Sallenger, Asbury H. Jr. “Storm Impact Scale for Barrier Islands.” *Journal of Coastal Research*, vol. 16, no. 3, 2000, pp. 890–895. *JSTOR* , www.jstor.org/stable/4300099