Gabriela Giacomangeli

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

1. INTRODUCTION

Back Bay National Wildlife Refuge (NWR) is 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 open 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, freshwater 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. Back Bay is wind-tidal oligohaline marsh and hardly experiences increases in salinity. The bay is separated from the ocean only by a narrow barrier spit.

The bay is an integral part of the refuge system. Waterfowl rely on the freshwater habitat of the bay and it is in the bay where multiple species of submerged aquatic vegetation (SAV) are found. Small invertebrate lives within the SAV beds and this is what the waterfowl feed on. It is thought that a poor SAV habitat is considered not suitable for the migrating waterfowl. SAV species that are found in Back Bay are sago pondweed, wild celery, widgeon grass, redhead grass, and milfoil (Morton and Kane, 1994). Eurasian milfoil is an invasive species that has become a dominant species in the bay (Morton and Kane, 1994).

Management of the refuge includes ten freshwater impoundments. These impoundments are man-made, managed wetlands that are used as a habitat for wintering waterfowl. This provides food and shelter for the migrating waterfowl as well as other water bird species, especially when Back Bay is not providing a desirable habitat for waterfowl. The impoundments are an important part of refuge management and the water in the bay is what supplies the freshwater for these impoundments.

This report discusses and analyzes the hazards and vulnerabilities the ecosystems of Back Bay NWR and the Back Bay freshwater system may face under various plausible sea level rise scenarios. Analysis of the threats and foresights have aided the development of options and recommendations to facilitate the adaptation of these systems to salt water intrusion.

2. HAZARDS RESULTING FROM SALTWATER INTRUSION

Like many coastal freshwater ecosystems, Back Bay faces threats from the possibility of sea level rise. 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, but there is a possibility that the barrier spit could be breached. If this were to occur then Back Bay could experience saltwater intrusion (SWI). Fortunately, in the 1930s, the dunes were built up on the beach and are able to protect the impoundments, so it is unlikely that the dunes in Back Bay NWR would experience overwash, but a breach could occur in a different area of the barrier spit. Over the last 50 years, Back Bay has experienced some sudden changes in salinity as well as different occurrences where SAV populations declined (Morton and Kane, 1994). The increase of salinity could affect SAV populations, but changes in salinity over the past years did not necessarily correlate with trends of SAV populations (Morton and Kane, 1994). It is possible that salinity could change the nutrient composition within the bay, which in turn would affect SAV growth. A solid SAV population is important for the bay because migrating waterfowl rely on the SAVs for food and habitats. Figure 1 shows that there were two instances where a decline in percent frequency of SAV populations correlated with a decline in total waterfowl (dabbling ducks, swans, geese, and feeding ducks) in Back Bay (Settle and Schwab, 1991). It was during 1966-67 that the bay experienced the domination of Eurasian Milfoil, and invasive SAV. It was also during this time that the bay was recovering from SWI caused by the Ash Wednesday Storm that occurred in 1962. It is possible that the recovery of native SAVs from SWI that was caused by the storm was stunted by the Eurasian Milfoil because the milfoil could outcompete native vegetation (Morton and Kane, 1994).

Another hazard resulting from SWI would be the inability to manage the freshwater impoundments. Moist-soil management is complicated and is dependent on the water levels of the bay, the wind direction and tides, and the weather. Therefore, a lot must be considered when deciding whether to drain or fill an impoundment. Water is pumped from the bay into the impoundments, and if the bay is no longer freshwater, then the plant composition and habitats within the impoundments could change. In the summer, the impoundments are usually drawn down to expose mudflats, which is a suitable habitat for the shorebird populations. In the winter, they are filled so that wintering waterfowl can use the impoundments for feeding in case the bay is undesirable. If the bay were to transition to a mostly brackish/saltwater ecosystem, then the shorebirds would probably be the dominant bird species found within the refuge, as they would be able to feed both on the beach shore and within the impoundments that would have also transitioned from freshwater to saltwater. The bottom of the impoundments would become desolate as freshwater grasses would no longer be able to grow (Fredrickson and Taylor, 1982). This would affect the amount of invertebrate available for waterfowl to feed on.

Water quality degradation is another hazard that will impact Back Bay because of sea level rise. Flooding in the bay would make it difficult for SAV to grow. SAVs do not benefit in deeper waters or in water with high turbidity, as they need sunlight to grow. High turbidity levels do not allow water to penetrate to the bottom of the bay, where SAV beds grow and the result is reduced germination of SAVs. Flooding will also prevent management from being able to drain the impoundments, since higher water levels would make it difficult to drain. This would also be detrimental to any moist-soil plants that are in their germination or early seedling periods (Fredrickson and Taylor, 1982). But it is hard to predict whether SWI will improve or degrade water quality both in the bay and the impoundments.

3. FRESHWATER ECOSYSTEM VULNERABILITIES TO SALTWATER INTRUSION

Inundation of saltwater into the bay would cause water levels to rise, and this is turn would cause more wave, wind, and tidal action in the bay. This is not a positive effect for SAVs, as they like slow and still moving water (Dennison et al., 1993). SAVs can grow in deeper waters, if the water turbidity is low. Robel (1961) carried out a study to observe the relationship between water depth, turbidity, and the growth of the sago pondweed in Utah . Researchers

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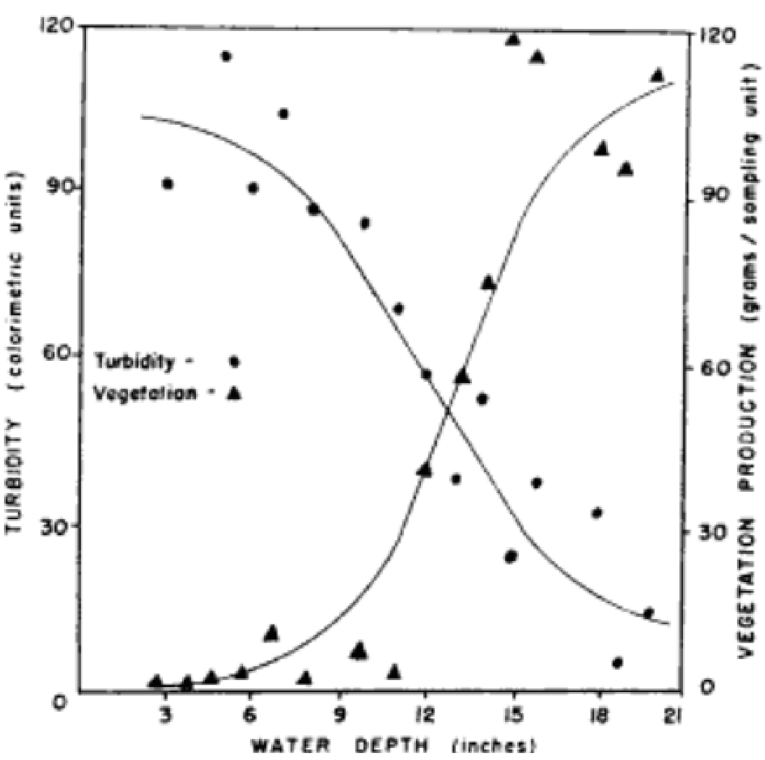


Figure 1. Relationship between water depth, turbidity, and vegetation production (Robel, 1961).

If the bay's water depth increased and the bay also experienced an increase in turbidity, then light would be unable to reach the SAVs at certain depths, causing less light availability. If SAV's were unable to grow due to water quality degradation and decrease in water clarity, then there would be no roots from aquatic vegetation to stabilize the bottom sediments (Baker and Sterling, 2006). Greater wind action and wave action would cause suspension of unstabilized bottom sediments. This means the water turbidity would increase even more. These factors would create an environment with poor water quality for SAVs. If SAV beds crashed in the bay, the result would be an increase in erosion along shorelines as there would be no roots to stabilize the shore, further contributing to turbidity levels (Baker and Sterling, 2006). There could be benefits resulting from increased salinity. In 1964, a program was initiated to maintain salinity at 10% seawater to promote sediment flocculation (Morton and Kane 1994). The hope was that the increase in salinity would improve water clarity and therefore improve water quality for SAV beds. If salinity levels increased to a certain amount that SAV species could tolerate, and water turbidity decreased from the presence of salt ions, then SAV populations could increase.

Inundation of salt water into the bay would make the impoundments vulnerable to experience flooding from the west. If water levels in the bay got high enough and the water had already transitioned from freshwater to saltwater, then the impoundments would experience SWI from the rising water levels. Another impact would be that freshwater plant species that grow in the impoundments, and germinate in the mudflats and shorelines of the impoundments, would be negatively affected by SWI since they cannot tolerate the salinity (Fredrickson and Taylor, 1982). This would mean that the freshwater habitats that the impoundments and the bay provide for migratory waterfowl would disappear. There are multiple migratory waterfowl species that prefer the freshwater bay and impoundments for habitats. Two dabbling duck species, the American Black Duck and the American Widgeon, as well as the Tundra Swan, rely on SAVs. These migratory waterfowl species feed on the aquatic vegetation as well as the invertebrate that inhabit the SAV beds (Settle and Schwab, 1991). Figure 2 shows a direct relationship between

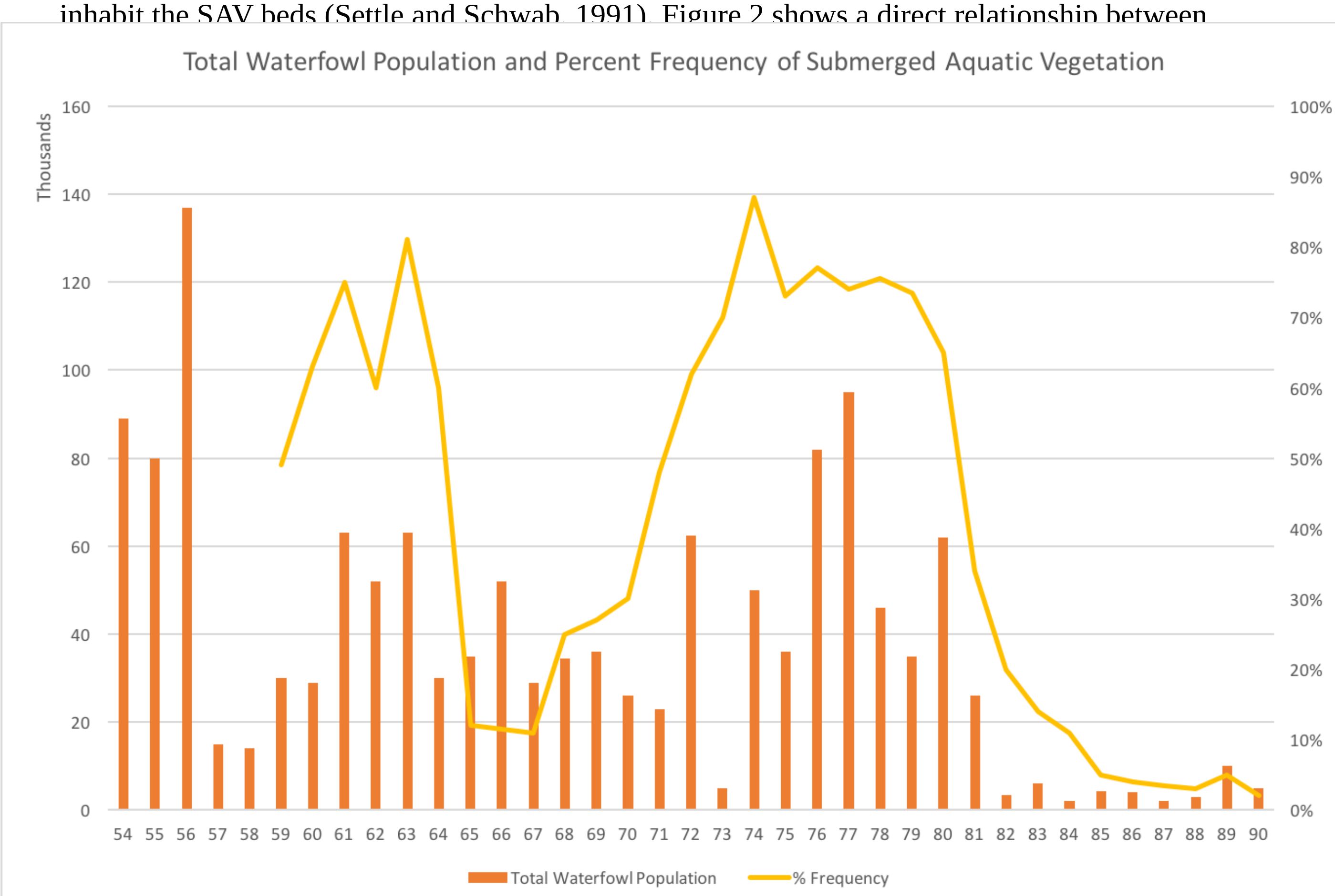
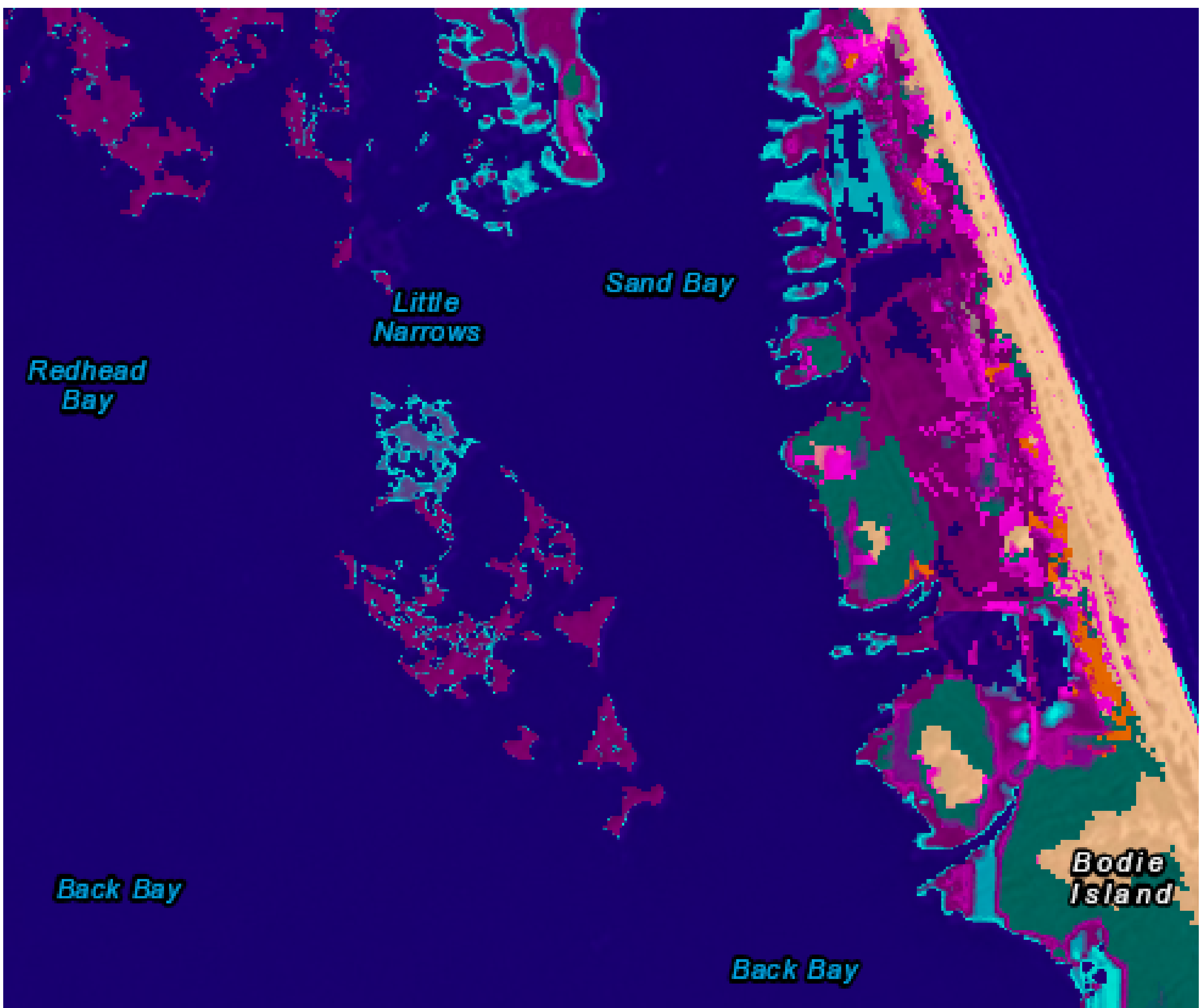
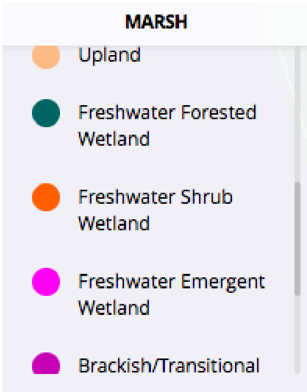


Figure 2. Waterfowl trends in Back Bay from 1954-1990 show a direct relationship between SAV abundance and waterfowl populations. When SAV populations were low, the total waterfowl population at Back Bay was also low (Settle and Schwab, 1991).




MARSH
Upland
Freshwater Forested Wetland
Freshwater Shrub Wetland
Freshwater Emergent Wetland
Brackish/Transitional

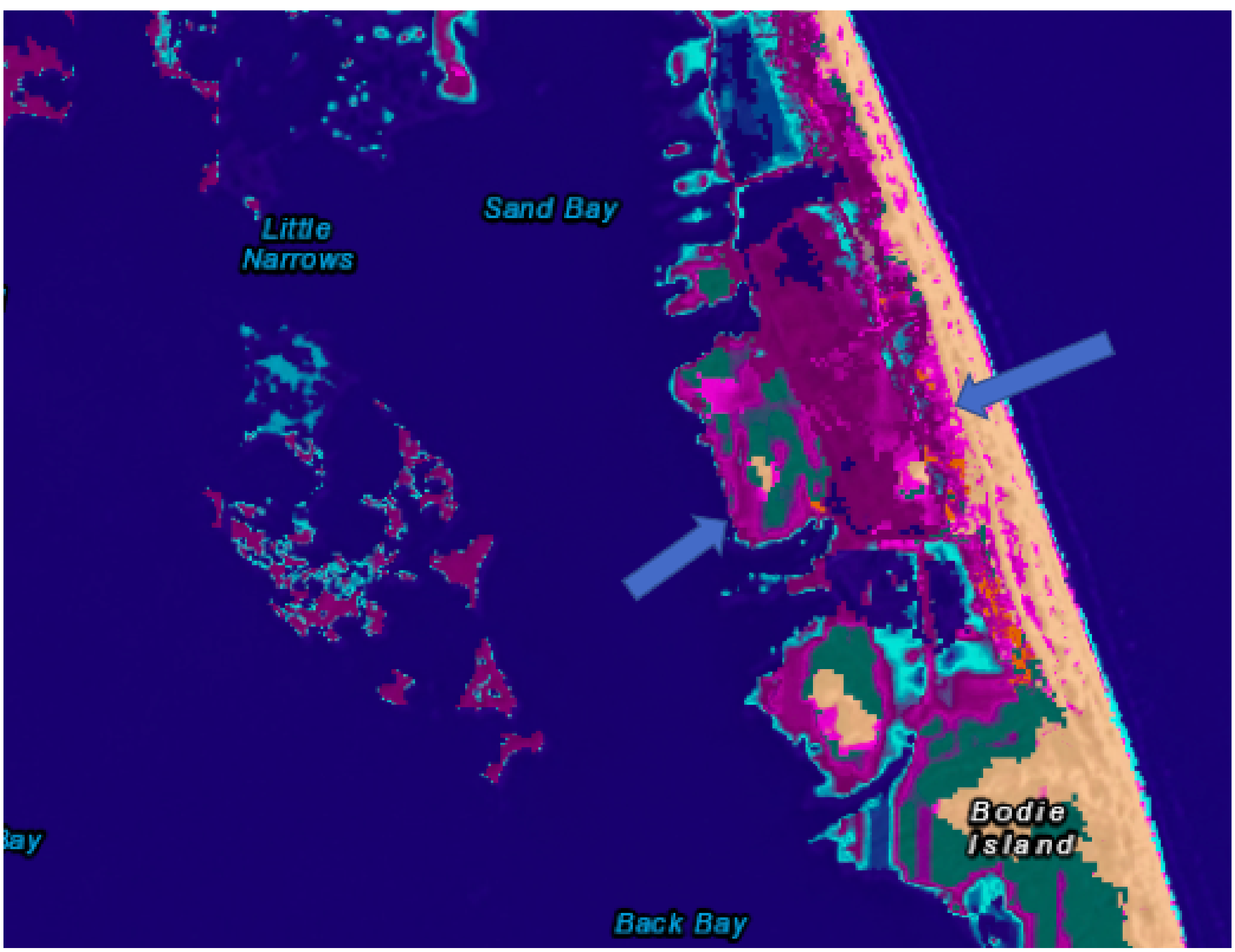

Little Narrows
Sand Bay
Bodie Island
Back Bay

Photo 2. Projected marsh migration at 0.8 m sea level rise (NOAA)

NOAA projections show that at 0.5 m of sea level rise (SLR) some freshwater emergent areas (such as the impoundments) would still have remained freshwater emergent. It is at 0.8 m where most of the freshwater emergent area has transitioned to a brackish/transitional marsh. These projections also show that at 0.8 m SLR, that the freshwater forested upland and upland area to the west of the impoundments shifts to a freshwater emergent marsh. This means that there is still a possibility that some of the different marshes and habitats in Back Bay NWR could shift to a favorable habitat for migrating waterfowl.

Back Bay NWR would experience a shift in species diversity in the refuge from SLR. If the bay transitioned to a saltwater marsh and the SAV beds crashed, and migrating waterfowl no longer came to the refuge due to the increase in salinity, then the refuge could experience an increase in shorebird populations.

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 (U. S. Fish and Wildlife Service 2010). Wildlife Biologists and bird enthusiasts are also relevant, as the professionals come to Back Bay frequently. Ducks Unlimited works closely with management at Back Bay to conserve wetland for duck species.

The North Carolina Department of Environmental and Natural Resources, Albemarle-Pamlico National Estuarine Program, Division of Marine Fisheries, North Carolina Fish & Wildlife Department, Elizabeth City State University and East Carolina University are all agencies and groups have been involved in inventorying, understanding SAV, and how to better manage the SAV populations and resources (U. S. Fish and Wildlife Service, 2010).

Habitat Goals and Objectives in the Habitat Management plan, Objective 4d, states that a goal by the end of 2015 was to increase the number of multi-agency partnerships aimed at providing additional water quality, vegetation, wildlife use, and habitat management data together with other environmental conditions of Back Bay (U. S. Fish and Wildlife Service, 2014).

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

If there is a breach, the bay would become a lunar tidal, not wind tidal, water body and could no longer rely on winds to fill impoundments. This would cause management at Back Bay to rely solely on rainwater to fill the impoundments.

Management at Back Bay could allow the bay to transition if the area experienced a breach from the ocean. If this were to occur, management could allow the impoundments to also transition, and just begin to manage saltwater impoundments. This would completely change the plant composition within the impoundments, and freshwater habitat availability for waterfowl will have disappeared. One option could be to keep one large impoundment flooded continuously (never allow it to drain) with rainwater to keep a freshwater habitat option available for waterfowl, and to allow native SAV species to grow in this impoundment.

7. RECOMMENDATIONS

Currently, management at Back Bay is trying to get the pump located by the C storage impoundment to pump water both ways from the C storage impoundment and bay. If the bay were to transition to a saltwater system, and management wanted to keep the impoundments freshwater, this two way pump would not be needed, but for the time being, a two-way pump would be helpful in filling and draining the impoundments more easily, especially during seasons where the area experiences changes in weather (wind direction and strength, rainfall, storms, etc.). This two-way pump could also help in the future. If a freshwater impoundment is flooded with rainwater and the bay's salinity is rising, then the impoundment could be drained quickly with this pump and the bay would experience a freshwater input. As mentioned before, SAVs population crashes in the past could have been a result of the inability to adapt to sudden salinity changes. Using the impoundments to try and keep the bay at a certain salinity so that the aquatic vegetation does not experience such sudden environmental changes, especially in places located close to the impoundments, could be a recommendation.

Management should obtain recent data to determine trends in salinity, SAV frequency, and water turbidity in Back Bay to see if there are any new correlations or relationships between data sets. If sea level rise follows the higher NOAA projections then management should start to allow slow transition of salt water and allow slow SWI. This would allow the system to adapt. In the future, if the bay experiences a breach of saltwater, perhaps allow Lake Tecumseh to open back into Back Bay to allow the northern part of the bay to remain at a lower salinity/oligohaline system, while the bay towards Currituck sound would have a higher salinity. The impoundments should be kept freshwater for plant composition and waterfowl populations. Water control structures should be maintained so that they can combat flooding. The goal for management is to be able to drain impoundments to expose mudflats. It is still possible that nor'easter storms and winds cause freshwater inputs. If this region continues to experience constant, or even more rainfall and storms that cause more freshwater inputs, then management should not worry about the bay experiencing a sudden and fast increase in salinity from SWI.

8. FUTURE RESEARCH

Chincoteague NWR had been contacted, but we did not receive any preliminary data from them. Back Bay NWR management should reach out to Chincoteague, or any other locations that have experienced salt water intrusion, to see what has happened there and if it can be applied to what Back Bay is experiencing or may experience. What was the water quality, turbidity, salinity, in the bay during SAV irruptions? (Morton and Kane, 1994). This could help determine what conditions SAVs grow best in within the bay. Salinity would change nutrient and sediment dynamics within the bay, how exactly would it affect oxygen levels, pH, nitrates? And how would that affect plant/species composition in Back Bay?

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