MIGRATION OF COASTAL ECOSYSTEMS AND SECRETIVE MARSH BIRDS IN THE BACK BAY NATIONAL WILDLIFE REFUGE

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Contents:

Abstract

This report serves the purpose of delineating the phenology of the ecosystems that presently exist in the Back Bay National Wildlife Refuge (NWR) and discerning where they will most likely migrate in the face of rising sea-levels over the next century and how this will affect several species of waterfowl and herons of interest to the Back Bay NWR. In this report, I will use system knowledge to answer the following questions:

- What are the primary ecosystems of Back Bay?
- What bird species of interest utilize this habitat, how, and when do they use it?
- Which ecosystems will decline as sea-level rises and how will this affect the previously mentioned species?
- Where will these ecosystems migrate to?
- What pieces of land should USFWS seek to purchase in order to secure their ability to continue managing and protecting the species they are the stewards of. (Goal Knowledge)

In my report, I have studied the currently existing ecosystem phenotypes within the Back Bay NWR and compartmentalized their individual responses to sea-level rise within the refuge as a whole as well as a focus on the impoundment system located on the eastern coast of the lagoon due to the important role it plays in helping managing ecosystems to support a wide variety of plant life and migratory birds. The ecosystems of prime interest included brackish marshes and freshwater marshes. It is necessary to analyze specific regions and habitats under the lens of sea-level rise because their response to sea-level rise is almost never representative of the whole and can occur at their own specialized rate (Lentz et al, 2015). After studying Back Bay's migrating ecosystems under varying degrees of sea-level rise using a geo-planning tool released by NOAA I discovered trends perpetuated by sea-level rise such as a sharp decline in freshwater forested wetland and an increase in total area of freshwater wetland habitat as it migrated inland. However, the projected trend of an increase in freshwater wetland reaches its peak at about 1.1 m of sea-level rise and after which it begins to decline as it is overtaken by brackish wetland which in turn becomes turned into open water. After delineating these changes in the phenology of the ecosystems of Back Bay I outlined territory on a map of the refuge and its surrounding areas of locations that brackish and freshwater wetland would most likely migrate to and thus provide habitat to the migratory birds within the currently existing Back Bay NWR. I have also created profiles of necessary habitat, feeding pattern, and nesting patterns of the King Rail, American Bittern, Least Bittern, and American Black Duck which reside in the Back Bay NWR and are species of interest in order to properly understand what kind of ecosystems they depend on. After reaching an understanding of the projected change that is most likely to occur in the Back Bay lagoon I created a recommendation for which areas will be of interest to the U.S. Fish & Wildlife Service for purchase in the near future to help facilitate their continued management activity in the lagoon.

1 INTRODUCTION

The Back Bay NWR was established in 1938 and manages 9,000 acres in the southeastern portion Virginia. As a constituent refuge of the U.S. Fish & Wildlife Service its purpose is to preserve the integrity of the wildlife it has been charged with stewarding. Specifically, the Back Bay NWR exists around the Back Bay lagoon and barrier island system for the sake of managing a wide assortment of waterfowl, shorebirds, and wading birds. A great number of these migratory birds including songbirds stop in the refuge during their northern migration from South America and stay for the summer to breed and nest. During the autumn and winter months the refuge will see a vast number of waterfowl and shorebirds congregate in the refuge as storms offshores bring more uncommon species to the refuge. The refuge is integral in providing local and migratory species of migratory birds with habitat, food, and safety from hunting and other threats. However, the ecosystems these species depend on is not necessarily restricted to the actual location of the refuge itself. As sea-level rise is projected to increase over the next century prominent and storm surges increase in strength and number it stands to reason that the coastal ecosystems that are of vital importance to sustaining the myriad of migratory bird species will migrate in response to these outside pressures (Sweet et al, 2017).

2 HAZARDS POSED TO COASTAL ECOSYSTEMS

Rising sea-level poses an immense threat to the integrity of ecosystems and species which exist on the coast. The hazards perpetuated by sea-level rise and storm surges include inundation of coastal habitat, salinification, erosion, overwash, and accretion of sediment (Larson, 2010). Inundation threatens the barrier islands and ecosystems along the coastline by altering the favorable conditions they presently exist under which allows them to reproduce and prosper. It is these hazards which serve as the fundamental forces behind coastal ecosystem migration due to the fact that locally existing plant species can only tolerate a specific range of sea-level height as well as salinity. Land subsidence, which is the process by which the land sinks further into the Earth, compounds the effects of sea-level rise and increases the speed at which it impacts the coast. Erosion also exasperates the effects of sea-level by making the coastline more vulnerable to wave action and making overwash a greater issue. Overwash is caused by wave activity on the coast and when bolstered by storm surges sends waves over the dunes and depending on the severity and displace sediment kilometers away from its origin and facilitate the migration of the coastal ecosystem. Sea-level rise and storms are both hazards derivative of climate change which can directly impact the speed and degree of ecosystem decline and migration.

3 VULNERABILITIES OF COASTAL ECOSYSTEMS AND SECRETIVE MARSH BIRDS

Every habitat in Back Bay NWR is susceptible to the hazards of sea-level rise due to the low-lying topography of the area with minimal elevation deviation. Each ecosystem's phenotype depends on a relatively stable water level to continue existing in its current state. Plant species and many non-human animal species have a very limited range of tolerance for sea-level and salinity. Storm surges, breaches in the barrier islands, and just general sea-level rise can threaten the integrity of Back Bay's ecosystems and thus trigger a migration. Dunes and beaches are especially vulnerable to overwash and wave action when effected by sea-level rise and erosion. However, despite the fact that beaches and dunes have the natural ability to repair themselves over time when impacted by storm surges this process takes weeks to months and can be overtaxed by stronger storms and increased sea-level rise (Steffen et al, 2014). Aside from sea-level rise it is also possible that hazards induced by climate change such as a shift in the temperature profile in the region, increased precipitation, drought, or snap freezes could alter the conditions that in the past were appropriate and convenient for migratory bird species but may no longer be in the future. The nesting and breeding habits of all bird species of interest in Back Bay NWR are also contingent upon a specific habitat type and temperature profile so If conditions are not appropriate for plant life then they will most likely decline and when the habitat is no longer a feasible place of refuge for the bird species they will seek habitat farther away that is more conducive to their needs and may very well abandon the region as a refuge. Several species of heron such as the King Rail, Least Bittern, and American Bittern reside in the Back Bay NWR year-round but specifically rely on the refuge for breeding in the summer and safe habitat for nesting and feeding (The Cornell Lab of Ornithology, 2015). The King Rail in particular requires freshwater or brackish marshes for its habitat with tall grass or reeds to use as cover and cannot thrive in an ecosystem with exceptional sea-level rise. King Rails feed primarily at low tide and thus require a proper habitat that provides it with plant coverage and shallow water that only covers its beak. This vulnerability is not unilateral among all species in Back Bay however as the Least Bittern has a proclivity to hunt for food in deeper water by utilizing reed stalks as ladders to prevent it from going below the water level (The Cornell Lab of Ornithology, 2015). Thus, the response from these marsh birds to sea-level rise may not be seen at the same time but rather a decline in the American bittern and King Rail could be observed before the Least Bittern due to this adaptation to higher sea-level. The American Black Duck primarily visits the refuge in the winter and utilizes freshwater wetland for its habitat. They also have the ability to nest in saltmarshes as well but depend on the refuge for safety from hunting and other types of disturbances.

4 FORESIGHT INTO MIGRATION OF COASTAL ECOSYSTEMS

The global mean sea-level has risen by about 24 centimeters since 1880 and the rate at which it is occurring is outpacing any other observed period of time in the last 2,800 years (Sweet et al, 2017). Given the trends reflected in the data collected from scientists and institutions like NOAA it is appearing more likely that Back Bay NWR will observe a change in its ecosystems Global mean sea-level rise is of course an impact of climate change however in this report I will singularly address the migration of the coastal ecosystems of Back Bay through the lens of sea-level rise. I acknowledge and recognize that Back Bay will be impacted by more facets of climate change than just sea-level rise thus when taking my recommendations into consideration understand these estimations of where the ecosystems in the lagoon will appear are found only utilizing data that considers sea-level rise. It is highly recommended that Back Bay NWR considers purchasing land and territory in tandem with other governmental agencies and groups in order to continue managing and monitoring the species Back Bay NWR has been stewarding as their ecosystems migrate further inland due to sea-level rise.

Figures 1 to 10 show delineation of the various ecosystems in Back Bay NWR for increasingly larger sea level rise scenarios. I will use the following map legend to define and describe the changes I observed in the projection maps of the lagoon and its ecosystems:

Ecosystem Phenology of current Back Bay lagoon and refuge (2017) ★=Decline ☆=Growth

Brackish/Transitional Marsh (purple)
Freshwater Forested Wetland (green)
Freshwater Emergent Wetland(pink)
Upland (beige)

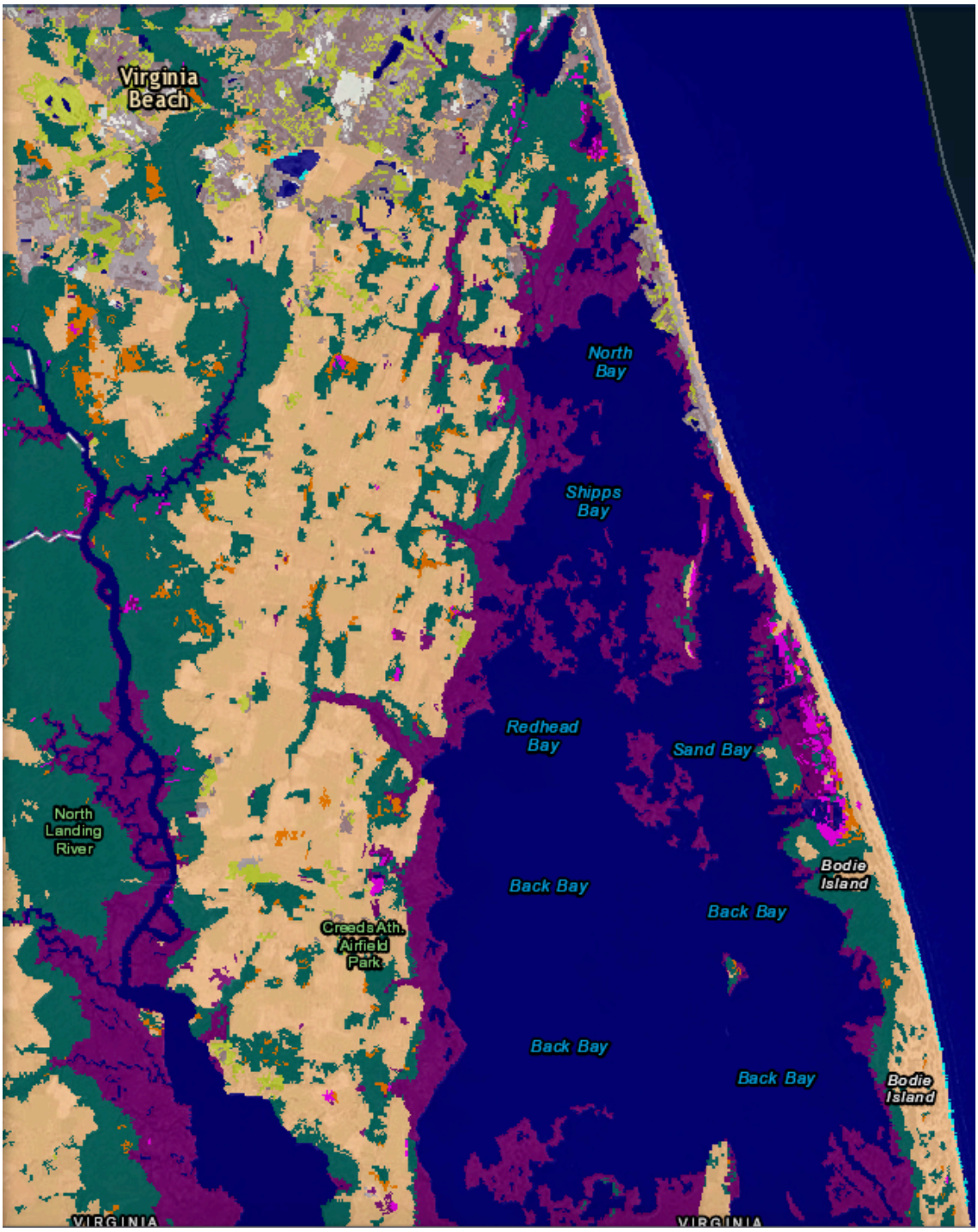

Figure 1: Current map of Back Bay NWR and surrounding areas. Figure generated with NOAA's Sea-Level Rise Viewer Tool.

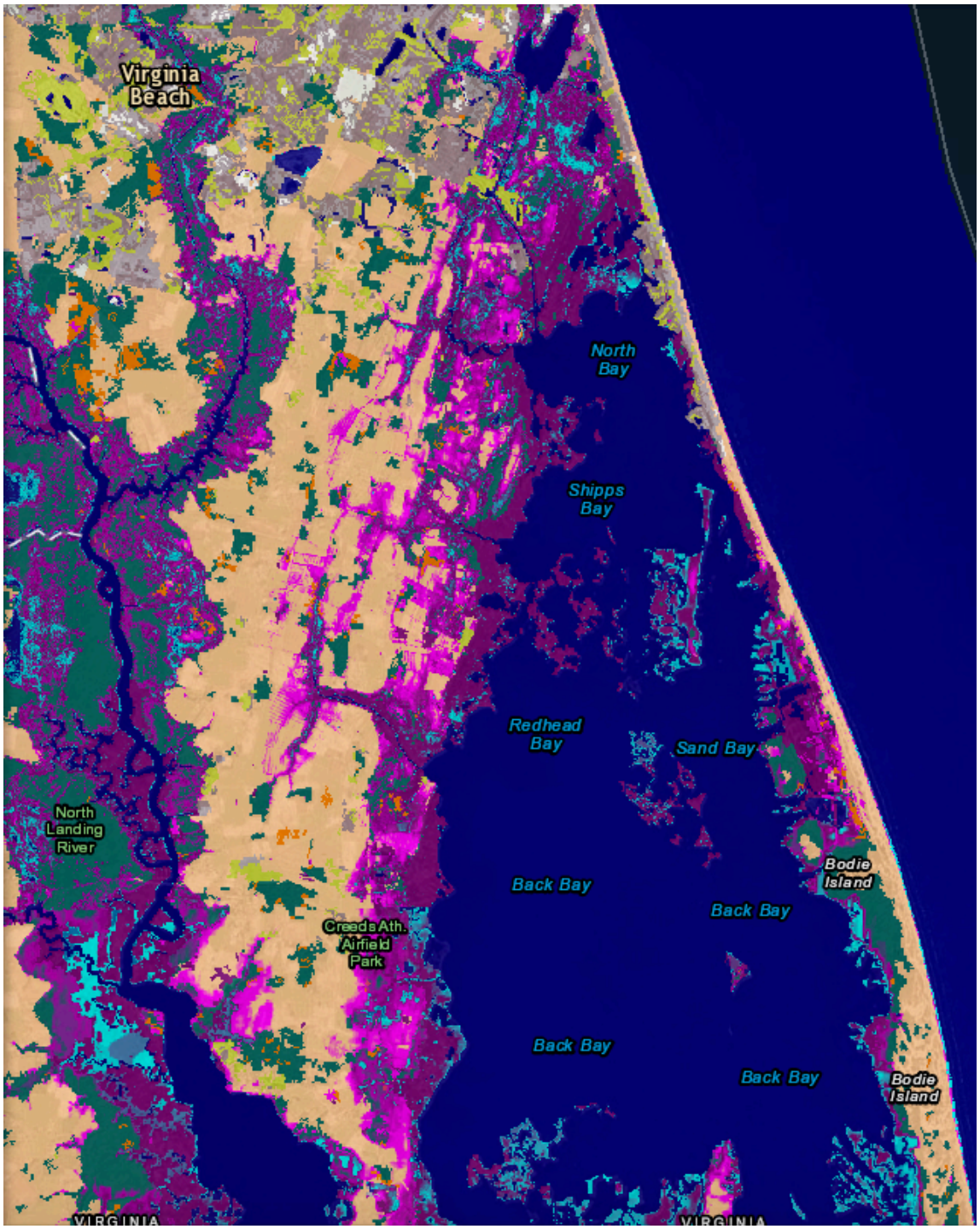

Figure 2: Back Bay NWR under 0.5 m of sea-level rise. Note the substantial increase in freshwater marshes appearing on the western coast of the lagoon. This trend suggests that as sea-level rise occurs many shorebirds and waterfowl could potentially see an increase in population as their preferred habitat actually expands and thrives.

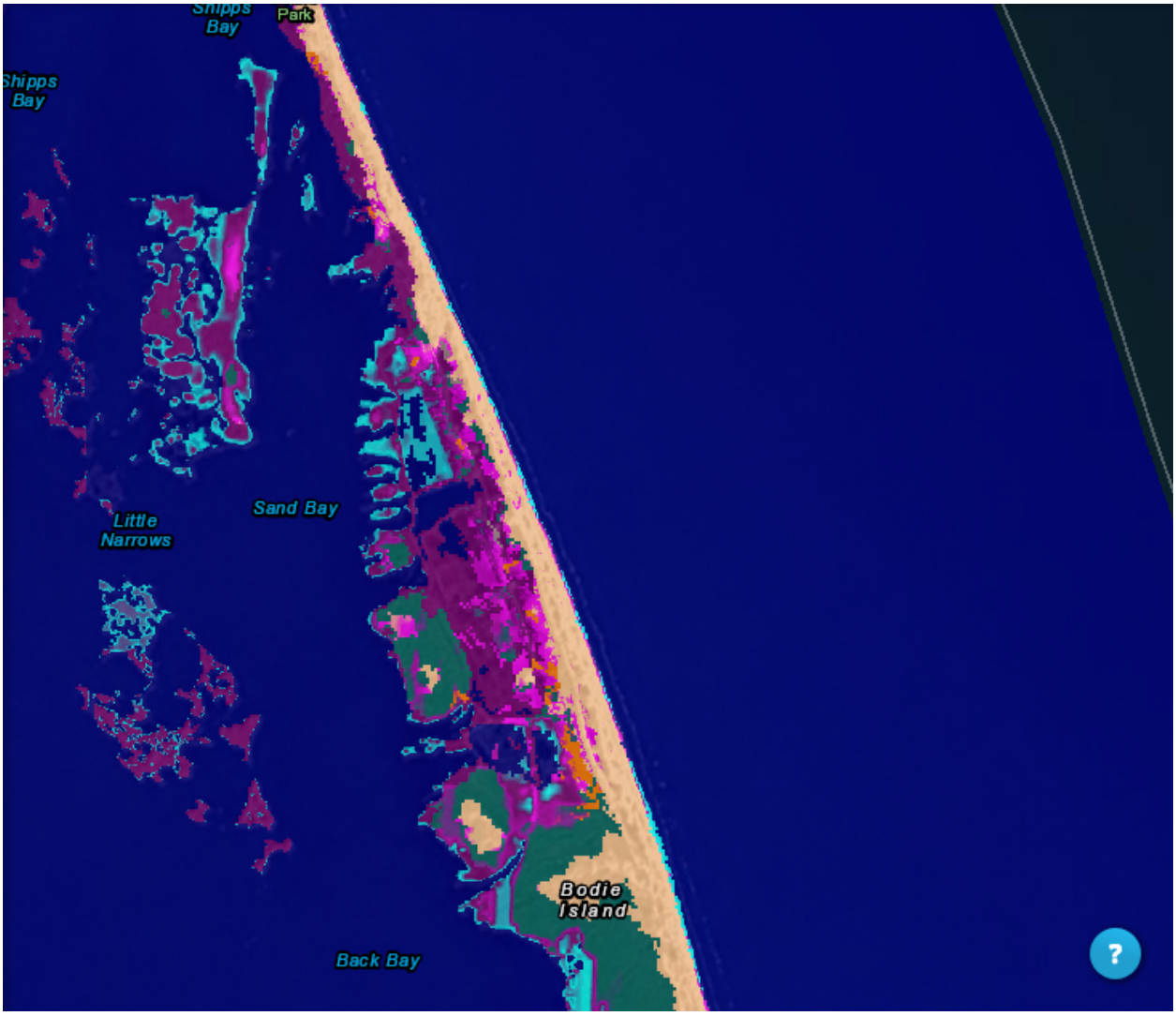

Figure 3: Back Bay NWR impoundment system under 0.5 m of sea-level rise.

Ecosystem Phenology of Back Bay lagoon under 0.5 m

★Brackish/Transitional Marsh

- Brackish marshes will experience the most severe decline in overall volume in the lagoon itself and most visibly in the islands below Shipps Bay, Sand Bay, and Back Bay. Brackish marshes will begin to migrate slowly inland accompanied by the freshwater emergent wetland habitat.

★Freshwater Forested Wetland

- Area above North Bay will experience an intrusion of unconsolidated shore as previously brackish marshland becomes inundated and migrates north replacing upland. Freshwater Forested Wetland will experience the most drastic loss most likely on the western coast of the lagoon with less severe projected loss of the ecosystems on the east coast of Sand Bay and Back Bay along south on Bodie Island.

Freshwater Emergent Wetland

- Freshwater Emergent wetland depicts the fastest and farthest projected rate of migration. Freshwater emergent wetland is beginning to encroach and replace the upland and freshwater forested habitats on the western coast of the lagoon. However, it is declining prominently on the refuge impoundments.

Ecosystem Phenology of Back Bay Impoundments under 0.5m

☆Brackish/Transitional Marsh

- After .5 m of sea-level rise we are seeing the majority of brackish marshland quickly begin receding and becoming replaced with unconsolidated shore primarily around C Pool and C Storage. The transitional marshes could migrate as far back as the upland and be in much closer proximity to the ocean. However, brackish marsh migration along B Pool and A Pool at this point will be limited. The maritime forest beyond B Pool will experience a decline in freshwater forested wetland as brackish marshland

Freshwater Emergent Wetland

- The freshwater emergent wetland behind the transitional marsh located in C Pool and C Storage will most likely be replaced with the migrating transitional marsh before giving way to unconsolidated shoreline as well. The freshwater emergent wetland will first decline in total volume before signs of migration towards the coastline become apparent. The freshwater emergent wetland occupying J Pool and H Pool will show signs of migration closer to the coast of the ocean at this point. An increase of freshwater emergent wetland within the maritime forest ecosystem off of A Pool is also likely to occur.

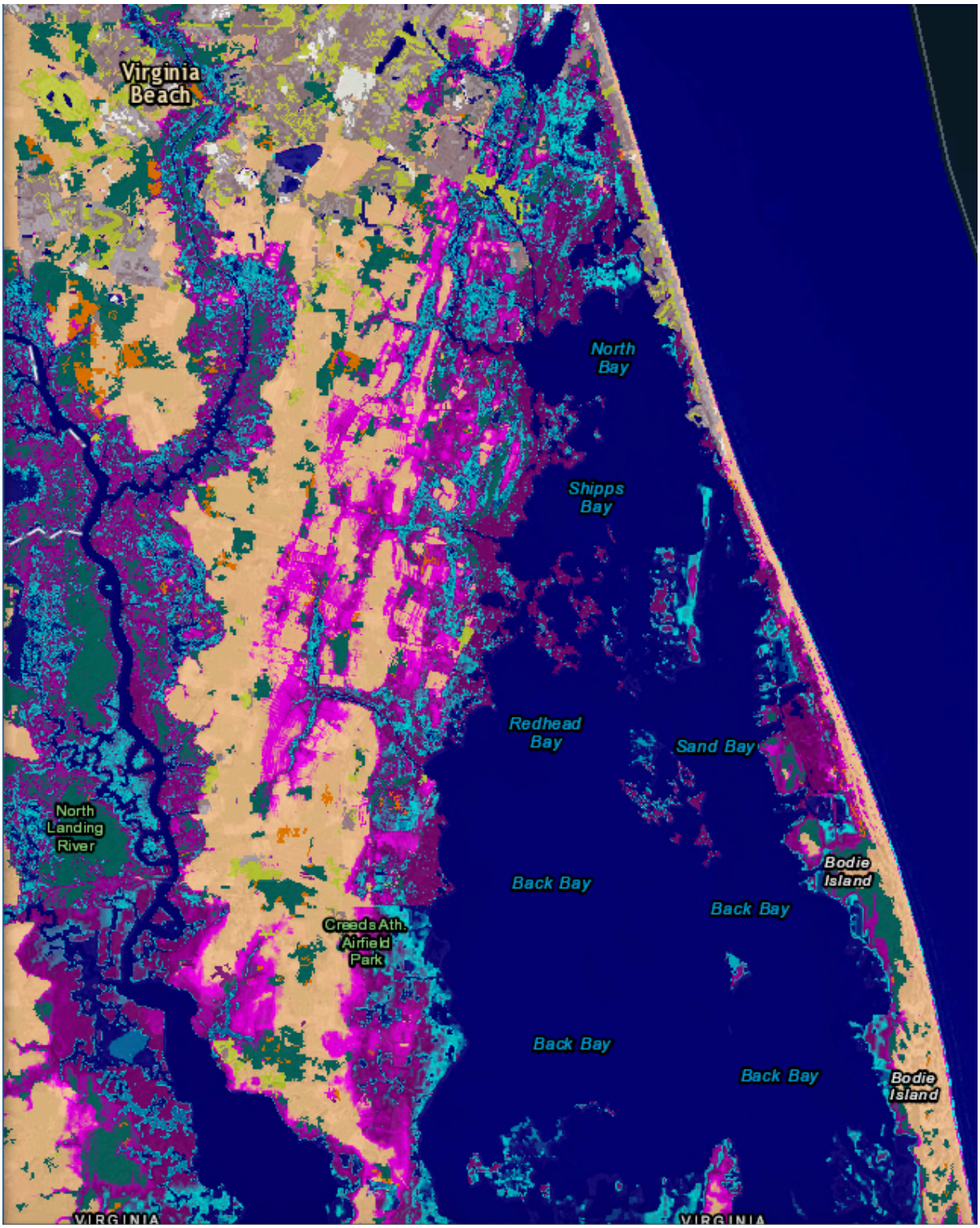

Figure 4: Back Bay NWR under 0.8 m of sea-level rise.

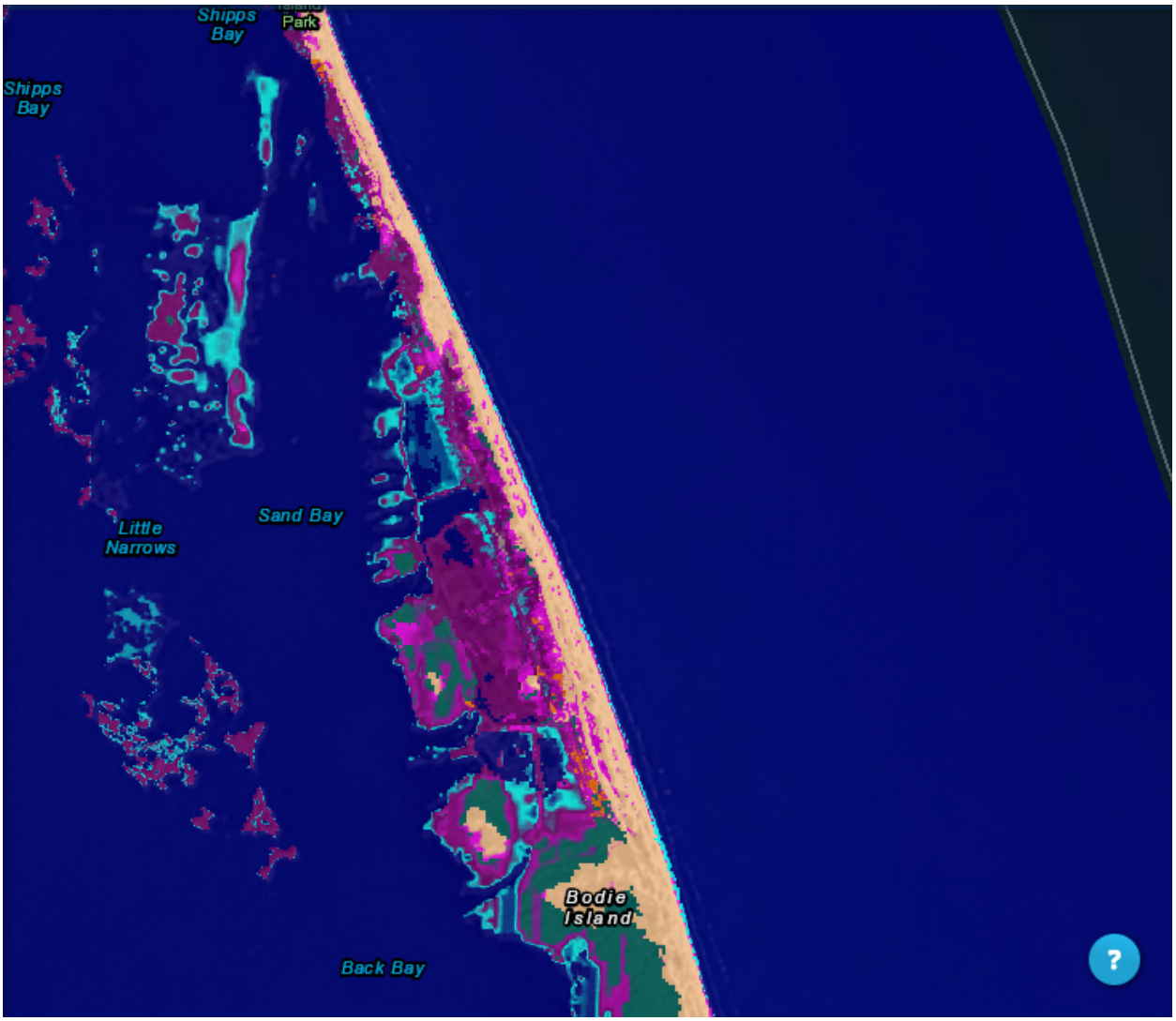

Figure 5: Back Bay impoundment system under 0.8 m of sea-level rise.

Ecosystem Phenology of Back Bay lagoon under 0.8 m

★Brackish/Transitional Marsh

- Sharp decline of total brackish marsh volume in lagoon.

★Freshwater Forested Wetland

- After 0.8 m of sea-level rise the maritime forests present on the coasts of the lagoon and on its barrier islands has become exceedingly fragmented and nearly non-existent. Bodie Island still possesses the highest volume of freshwater forested wetland at this point.

☆Freshwater Emergent Wetland

- Further migration of the freshwater emergent wetland ecosystem on the western coast of the lagoon Especially on the coast behind Great Cove and Redhead Bay. Further decline on the coast as the ecosystem gives way to the unconsolidated shore.

Ecosystem Phenology of Back Bay impoundments under 0.8 m

☆Brackish/Transitional Marsh

- Mild migration of brackish ecosystem behind A Pool's maritime forest as it encroaches upon the small patches of upland located there. Brackish marsh migrates and covers area previously occupied by freshwater wetland in B Pool.

★Freshwater Emergent Wetland

- Freshwater emergent wetland continues to migrate in disjoint patches along Sand Bridge upland stretch.

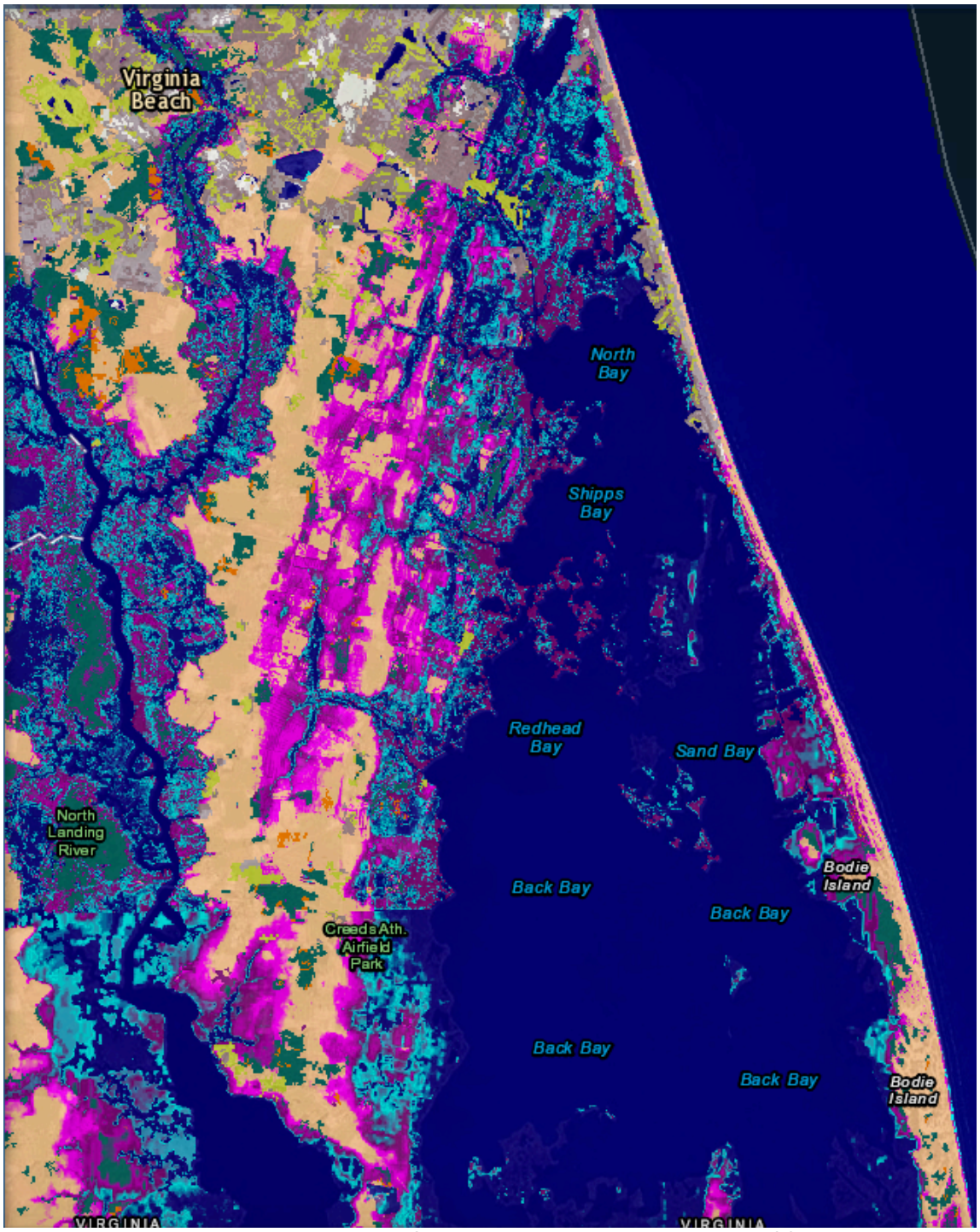

Figure 6: Back Bay NWR under 1.1 m of sea-level rise. Total increase of freshwater emergent wetland has reached its peak of migration.

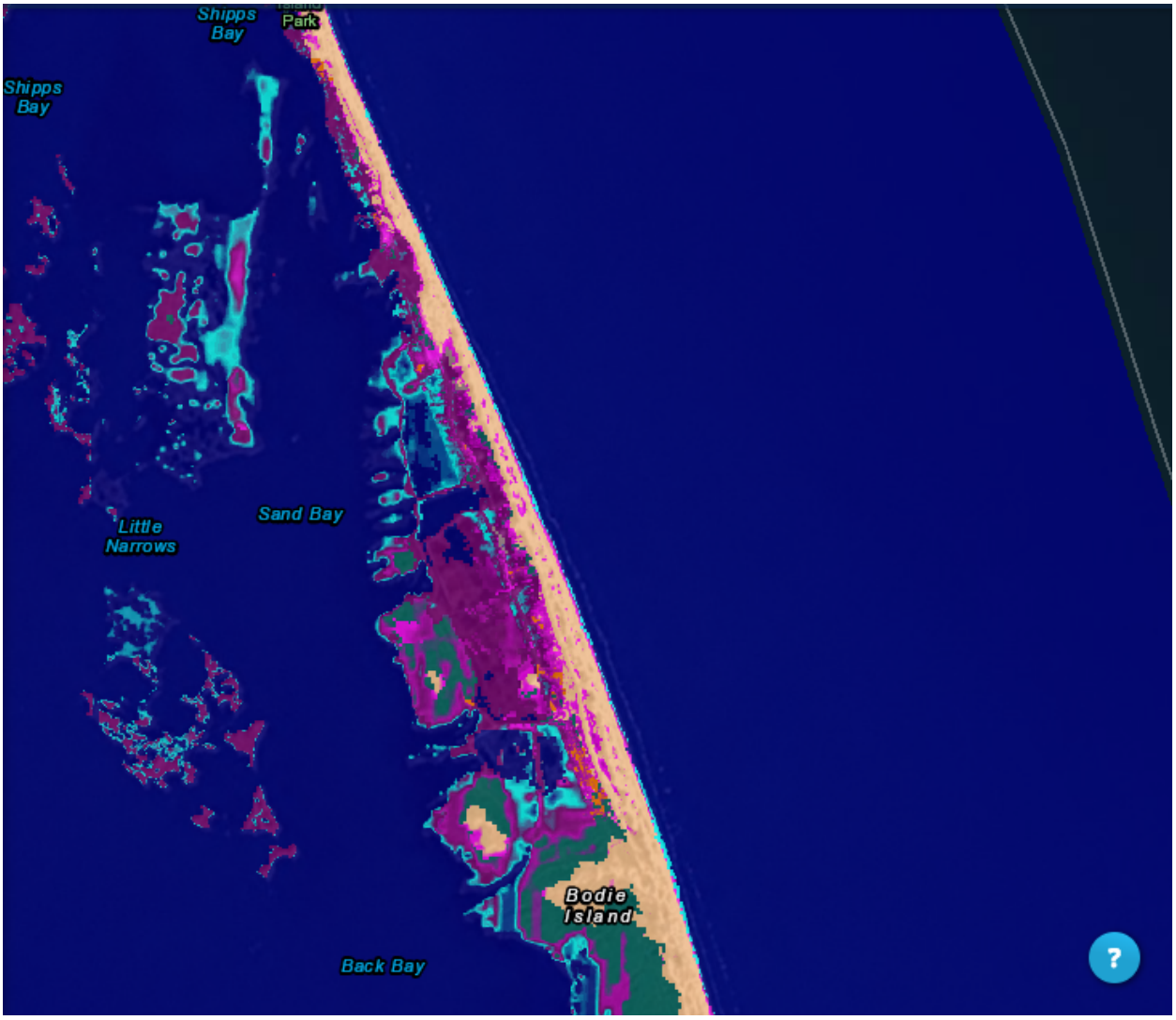

Figure 7: Back Bay impoundment system under 1.1 m of sea-level rise.

Ecosystem Phenology of Back Bay lagoon under 1.1 m

★Brackish/Transitional Marsh

- Brackish marsh habitats continue to become more fragmented and disjointed as sea-level rises and creates more unconsolidated shore appear on the western coast of the lagoon. Previously freshwater wetland begins to transition to brackish marsh in the middle of the burgeoning peninsula on the western coast of the bay.

★Freshwater Forested Wetland

- The freshwater forested wetland portions of the coastal regions of the lagoon continue to show the least physical migration as they continue to diminish in overall volume unilaterally across the bay.

☆Freshwater Emergent Wetland

- Freshwater marshes are showing the most net migration and growth within the developing peninsula and I suspect will be the prime site for the majority of ecosystem migration within the bay as it becomes a barrier island.

Ecosystem Phenology of Back Bay NWR under 1.1 m

★Brackish/Transitional Marsh

- The brackish wetland that dominates B Pool and A Pool has now begun to decline much faster and open water begins to appear in the middle of these impoundments. G Pool, H Pool, and J Pool become dominated by brackish marsh as the freshwater marsh area declines.

★Freshwater Emergent Wetland

- The vestigial maritime forest located next to A Pool that transitioned into freshwater emergent wetland is now becoming fragmented by open water and freshwater marshes continue to develop into larger but still unconnected disjointed patches on Sand Bridge.

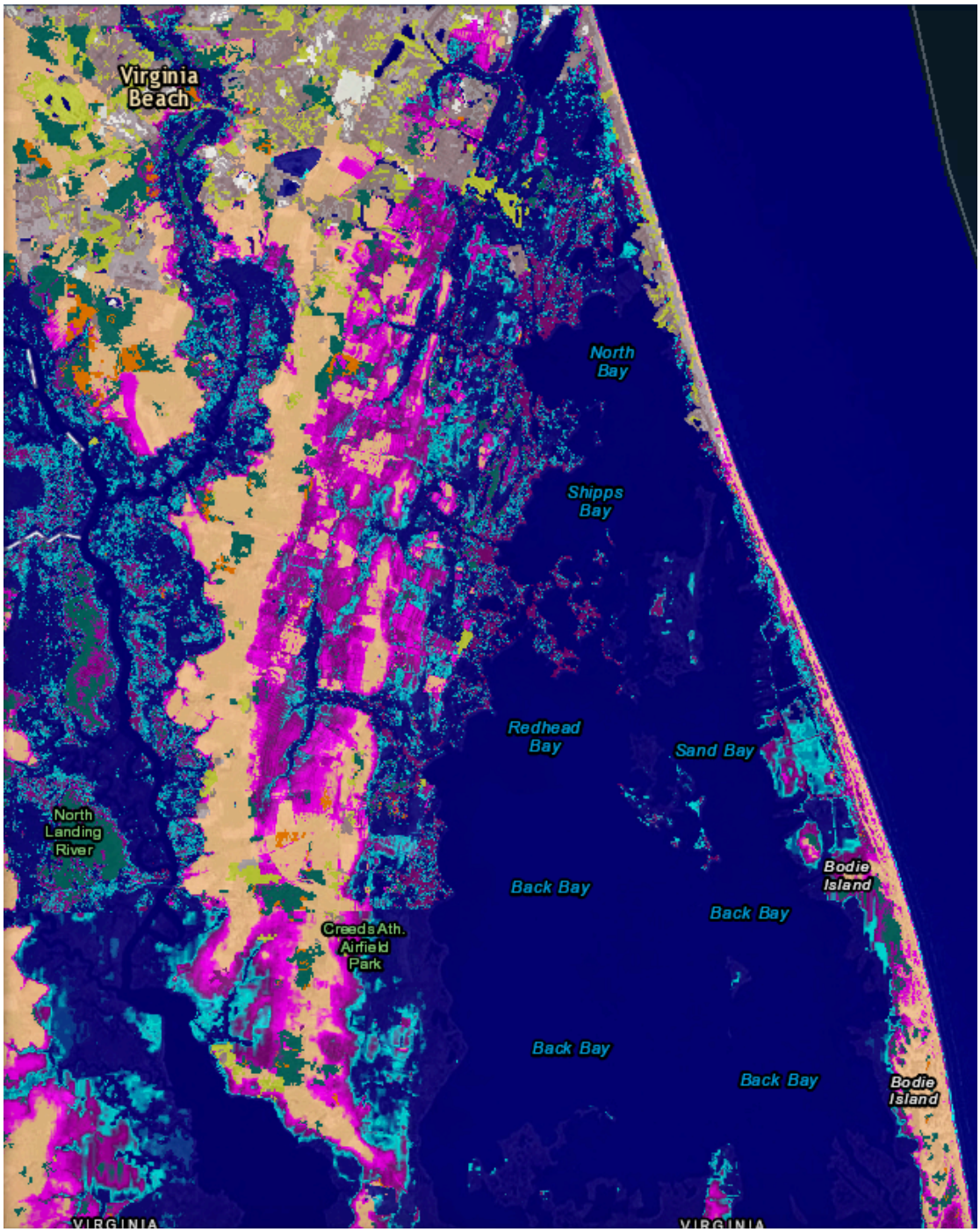

Figure 8: Back Bay NWR under 1.4 m of sea-level rise.

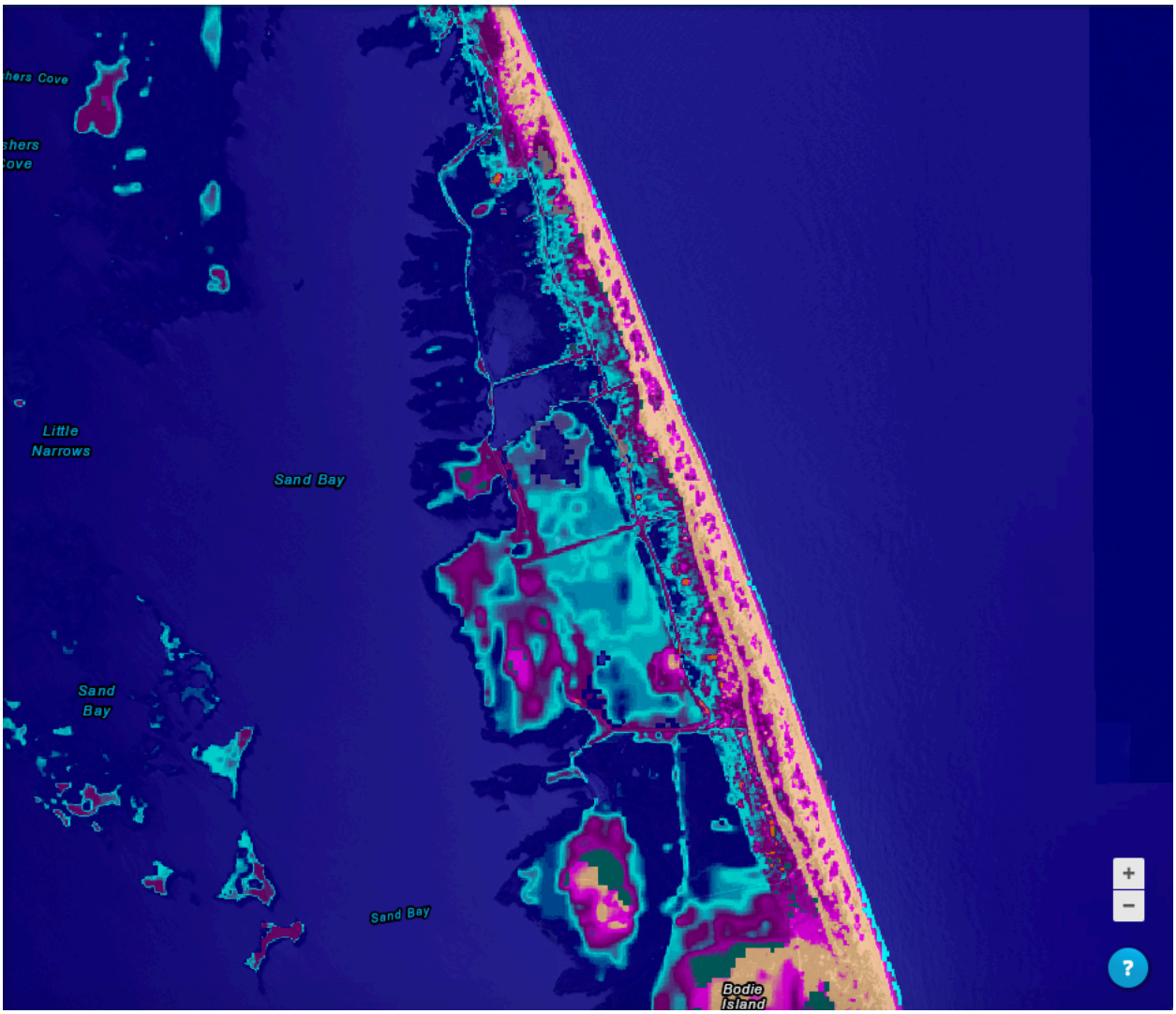

Figure 9: Back Bay impoundment system under 1.4 m of sea-level rise.

Ecosystem Phenology of Back Bay lagoon under 1.4 m

☆Brackish/Transitional Marsh

- The majority of the freshwater marsh area on the peninsula in the lagoon is beginning to transition to brackish marsh

★Freshwater Forested Wetland

- What's left of the maritime forests in the lagoon continue to diminish at a gradual pace and exist as fragmented pieces of their former selves.

★Freshwater Emergent Wetland

- The total area of freshwater marshes has since reached its peak and has now either stopped migrating or begun to be overtaken by transitional marshes.

Ecosystem Phenology of Back Bay NWR under 1.4 m

- ★Brackish/Transitional Marsh
  - The impoundments are now mostly vacant of any ecosystem except for open water as inundation has dominated every impoundment and left only vestigial disconnected patches of brackish marsh that has now declined greatly.
- ★Freshwater Emergent Wetland
  - Freshwater marshes now primarily exist as small pools along Sand Bridge now that the impoundments are irreversibly inundated.

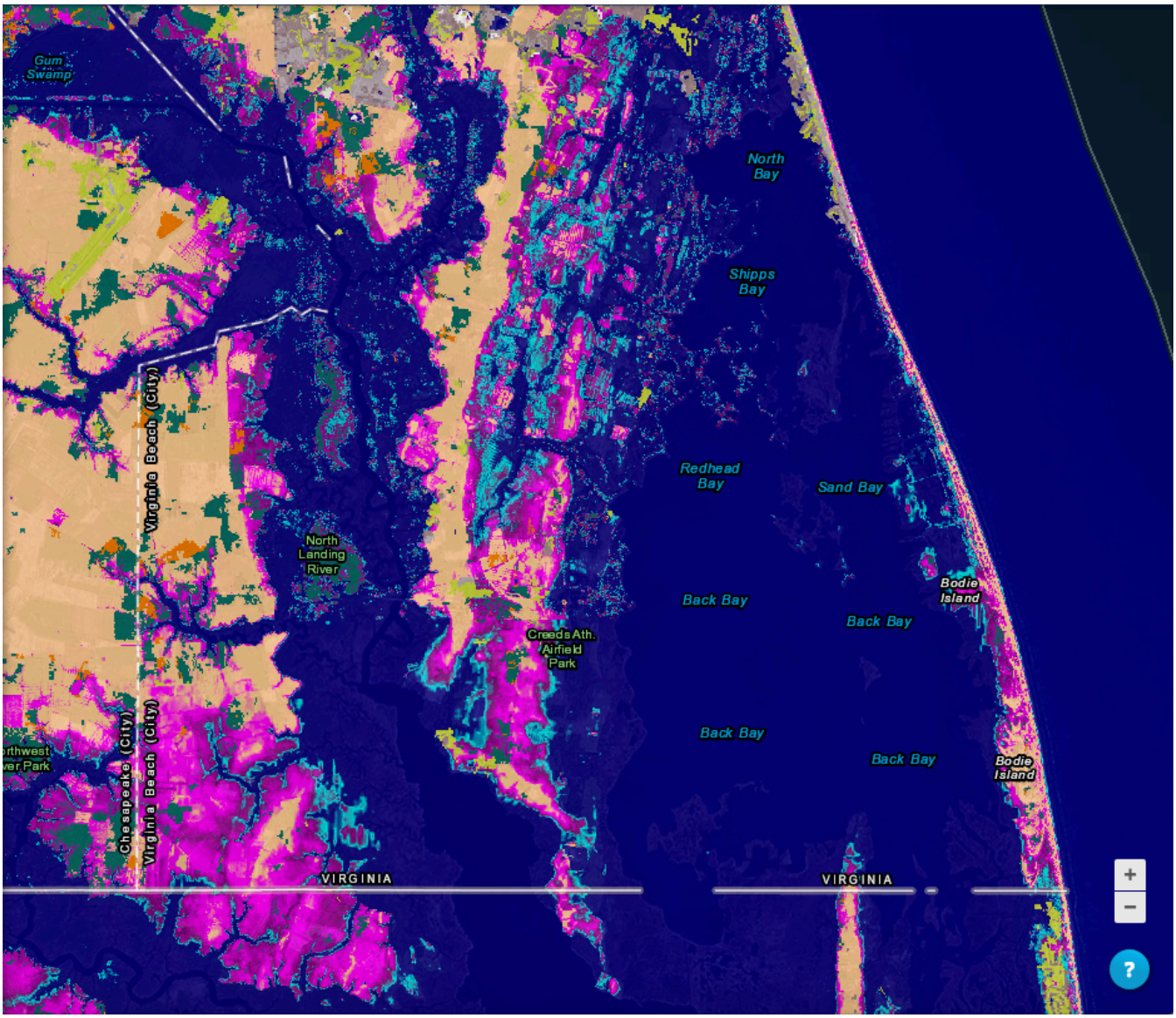

Figure 10: Back Bay NWR under 1.8 m of sea-level rise.

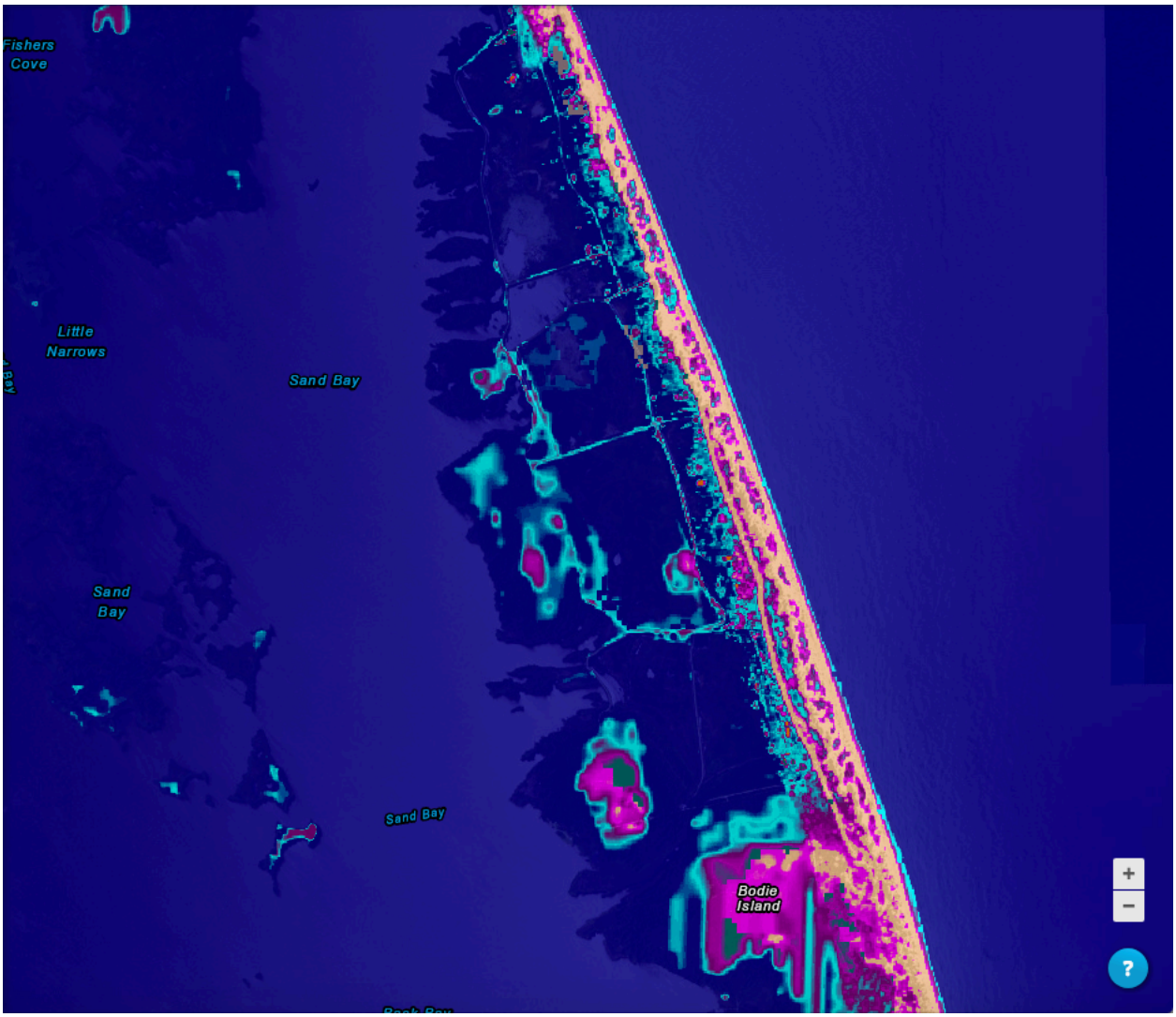

Figure 11: Back Bay impoundment system under 1.8 m of sea-level rise.

Ecosystem Phenology of Back Bay lagoon under 1.8m

★Brackish/Transitional Marsh

- The total area of brackish marshes now exists on the fringes of the freshwater marshland now dominating the emerging barrier island on western side of the lagoon.

★Freshwater Forested Wetland

- Freshwater marshes suffer the least overall decline however are encroached upon by transitional marshes and the open water.

★Freshwater Emergent Wetland

- The total area of maritime forests has become nearly nonexistent in the bay and in its barrier islands at this point and show no sign of successfully migrating.

Ecosystem Phenology of Back Bay NWR under 1.8 m

★Brackish/Transitional Marsh

- Now virtually gone from the original impoundment location save for a few remnant islands the brackish marsh area has now mostly exists close to the Sand Bridge on Bodie Island.

★Freshwater Emergent Wetland

- The freshwater marshes now exist in very small disjoint pools on Sand Bridge that appear to be slowly breaking up the linear upland area which will most likely result in a complete breach of the open ocean into the lagoon.

The projection mapping tool created by NOAA that was utilized to create these maps only projects as high as 1.8 m however it should be noted this is nowhere near the highest projection of sea-level rise for the era. NOAA has projected that sea-level could rise by as much as 2.5 m by the end of the century and with this projection comes several implicit changes to the current Back Bay NWR.

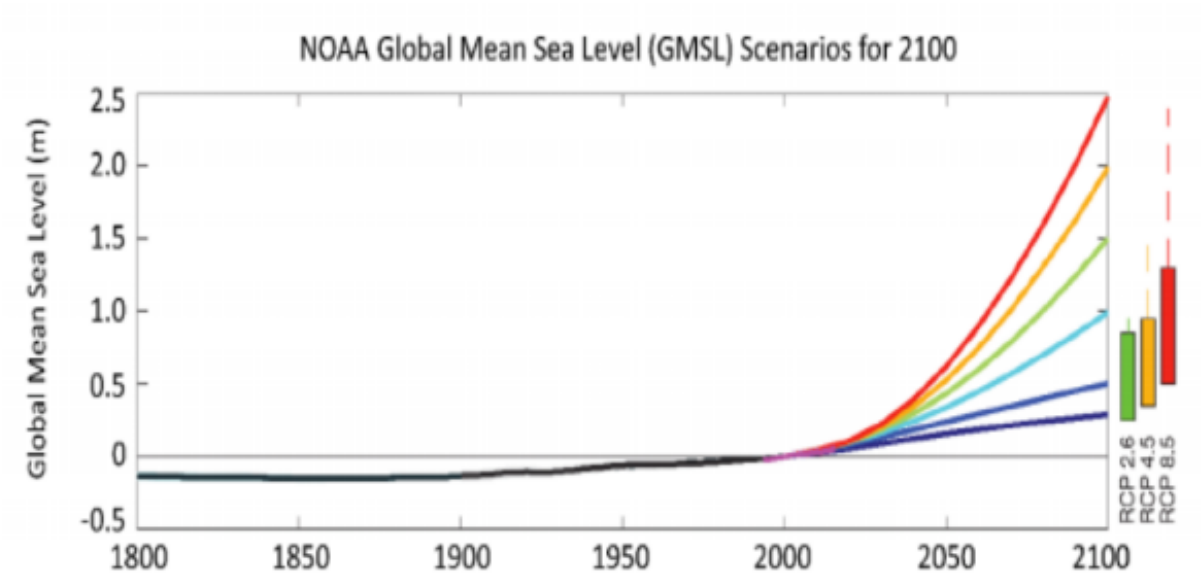

Figure 11: GMSL projections by NOAA (Sweet et al, 2017).

Although mapping has not been done for these upper bound projections it is safe to imagine that the trends seen in the previous projections will continue and we will see even more severe inundation of these higher projects come to fruition. It is also important to recognize that as time progresses it is seeming more likely that these higher projections will occur. Thus, when making decisions that will impact the ecosystems it is important that the upper bound projections be considered especially for areas like the Back Bay which are very much at risk of inundation and ecosystem migration.

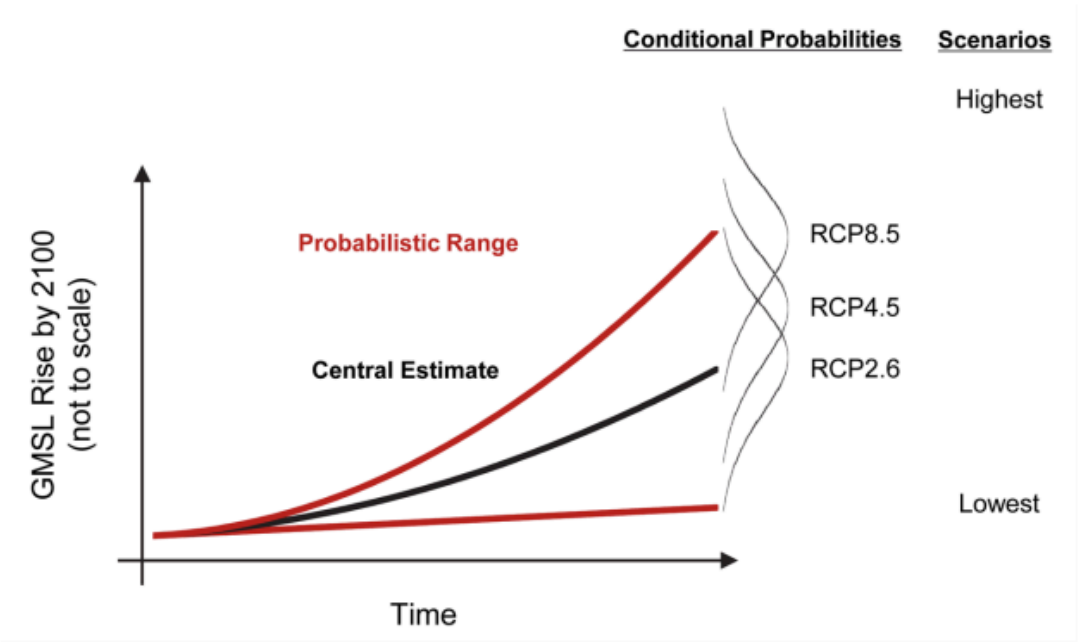

Figure 2. Schematic showing the intersection of scenario approaches with emission-dependent (conditional) probabilistic projections of sea level rise under the climate modeling community's Representative Concentration Pathways (RCP) (van Vuuren et al., 2011).

Figure 12: Projected likelihood and probability of sea-level rise as time progresses (Sweet et al, 2017).

5 STAKEHOLDERS INVOLVED IN DECISION MAKING

As the staff and personnel at Back Bay NWR continue to act as stewards for the local ecosystem and their constituent species it will be necessary to collaborate and act in tandem with other organizations and governmental agencies in order to facilitate the procurement of land and resources necessary for the survival of species that depend on migrating ecosystems. These governmental and non-governmental agencies and groups include the U.S. Fish & Wildlife Service, the U.S. Army Corps of Engineers, the Virginia state government, the Virginia Beach local government, and the Virginia Department of Agriculture and Consumer Services among others. Once the desired areas of purchase are known between these organizations they can discern which specific agencies can and should purchase which lands.

6 OPTIONS FOR BACK BAY NWR MANAGEMENT

As sea-level rise continues to perpetuate the migration of coastal ecosystems we are posed with not a question of whether the location and nature of the ecosystems located in the lagoon will move but whether or not the refuge should move with them. If the Back Bay NWR does not seek to procure more land and areas where the currently existing ecosystems are projected to move then we can use imagination to envision how this will impact the lives of the species that the NWR currently oversees. If we consider the current highest projection of sea-level rise over the next century which is an increase of 2.5 m we can see from NOAA's sea-level rise viewer that the portion of the Back Bay refuge dedicated to impoundment systems will dramatically shrink and lose much of its ecosystem variation and total volume before 1 m of increase is seen (NOAA). Whether due to storm surges or local sea-level rise increase we can see that the impoundments will most likely sometime in its future see a dramatic increase in water intrusion and begin to lose much of its maritime forests and see a sharp increase in total brackish marsh area. By the time a sea-level rise of 2 m has occurred in the impoundment region of the refuge it seems most likely that it will not be feasible to continue managing this part of the refuge as only Sand Bridge will most likely survive the inundation with emerging transitional marshes appearing parallel to the upland further south along the coast. With these ecosystems declining in the impoundment region we can expect that the species that reside in these impoundments seasonally or year-round will either adapt and find habitat in other locations or decline in number. From the projection mapping done by NOAA's sea-level rise viewer we can see that the total area of brackish and freshwater marshes will most likely increase significantly across the lagoon as a whole and along its western coast as sea-level increases. The stretch of land west of the Back Bay lagoon and east of North Landing River will most likely over the course of the century experience severe flooding on both sides which will turn it into a burgeoning barrier island that will become the host for the majority of the

brackish and freshwater marshes in the area. I therefore propose that the various species which currently reside in the Back Bay NWR which include the King Rail, American Black Duck, Least Bittern and American Bittern will most likely migrate to this area in the coming years to this area transform into productive habitat. If the Back Bay NWR or an affiliate organization does not procure these lands for the purpose of providing refuge to these waterfowl and herons then it is very likely that the current refuge will find themselves losing diversity in their species as they either decline or migrate elsewhere.

7 RECOMMENDATIONS FOR BACK BAY NWR MANAGEMENT

After researching and studying the process by which barrier islands respond to sea-level rise I am confident that the ecosystems and marsh birds residing in the Back Bay NWR will migrate inland as sea-level rise and storm surges continue to impact and change the geometry of the region. The majority of currently existing ecosystems will almost certainly decline to near non-existence aside from freshwater wetland when considering the highest projections of sea-level rise in the Back Bay lagoon. After studying the life history of several species of interest to the Back Bay NWR in tandem with varying projections of sea-level rise for the Back Bay lagoon and its surrounding barrier islands I have created the map showing in Figure 13, which delineates land that the U.S. Fish & Wildlife Service should seek to procure through purchase or lease in order to facilitate the continued management of the species under its stewardship.

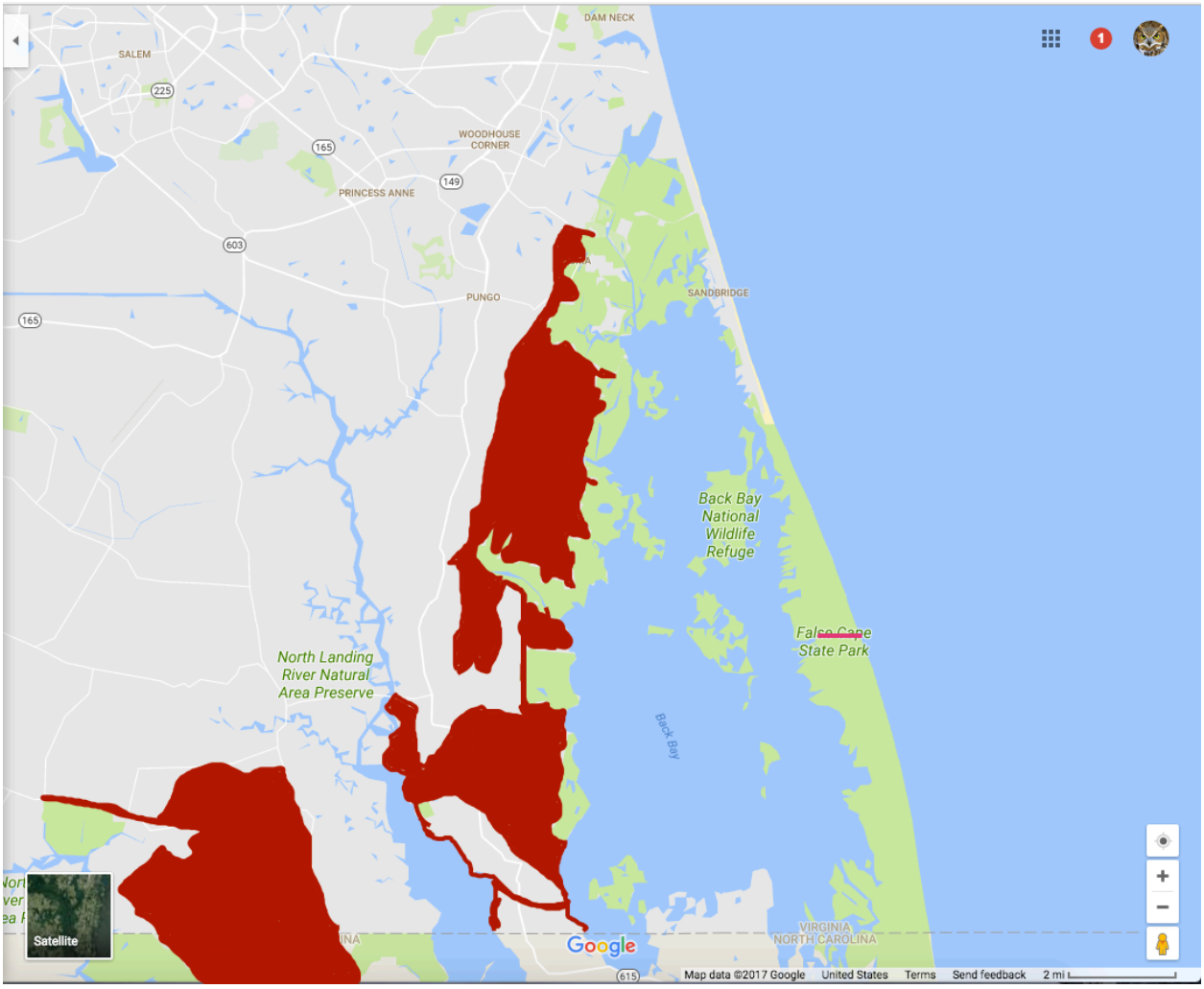

Figure 13: Map of the current Back Bay NWR with the lands of interest to the USFWS for the purpose of purchasing outlined in red. The vertical pink line on the east of the refuge denotes the boundary between the Back Bay NWR and False Cape State Park. Figure generated with Google Maps tool.

The areas outlined in red are the areas that are projected to be dominated by freshwater and brackish wetland area according to the trends of ecosystem migration estimated by NOAA's Sea-Level Rise Viewer. Purchasing this land early on via authority of the U.S Fish & Wildlife Service granted by the Migratory Bird Conservation Act which is overseen by the Migratory Bird Conservation Commission and through the North American Wetlands Conservation Act would help facilitate the continued management of the species and ecosystems currently within the jurisdiction of the Back Bay NWR. The ecosystems currently in the Back Bay NWR and specifically its impoundment system are projected to migrate primarily in the areas outlined in red and thus will most likely become the preferred habitat of migratory birds that visit the refuge and rely on the refuge for safe habitat, breeding and food procurement such as the American Black Duck, King Rail, American Bittern, and Least Bittern.

8 APPENDIX

This report operates under the assumption that sea-level rise will indeed instigate a migration of the coastal ecosystems present in Back Bay. However, this paper predominantly focuses on sea-level rise as the driving force behind this migration. I suspect that other facets of climate change such as a shift in the temperature profile of the region, increased precipitation, heat waves, and snap freezes will induce changes to the phenology of the ecosystems in Back Bay NWR as they migrate and I urge anyone reading this report that is studying the refuge to begin conducting a study of the refuge's vulnerability to hazards induced by climate change. This report should serve as a starting point for discerning a more holistic vision of the refuge's potential future under sea-level rise and climate change. The science and predictive modeling used to construct this report is sound but is not complete. I strongly urge future interns working at the Back Bay NWR to explore other possible ways that Back Bay's ecosystems and migratory bird populations could be affected by climate change. Possible changes could be an increased speed by which ecosystems migrate, a diminishing of certain ecosystems, or a loss of the presence of one or more migratory marsh birds due to a change in regional climate or loss of habitat.

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