COASTAL HABITAT PROTECTION PLAN

2021 AMENDMENT

Executive Summary

To be completed

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TABLE OF CONTENTS

LIST OF TABLES

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LIST OF FIGURES

1. INTRODUCTION

1.1 Purpose

North Carolina contains the largest estuarine system of any single Atlantic coast state, with numerous estuarine rivers, creeks, sounds, inlets, and ocean bays creating a diverse system of over 2.9 million acres and 412,000 miles of shoreline (Figures 1.1-1.2). Located at the convergence of the Mid-Atlantic and South Atlantic biogeographical provinces, NC supports a mix of northern and southern fish species. This combination of species richness, extensive coastal waters (estuarine and marine waters), and the diversity and abundance of coastal habitats makes NC's coastal fisheries among the most productive in the US.

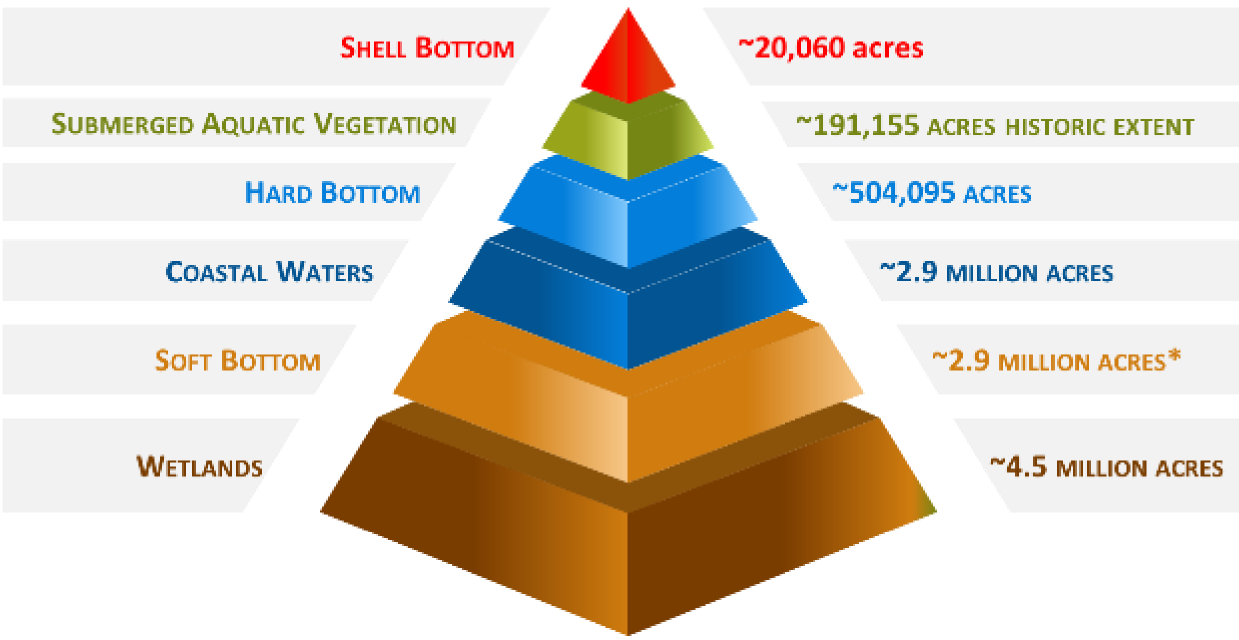

Figure 1.1. The coastal habitats of North Carolina are the foundation for healthy fisheries. *Soft Bottom habitat is an over estimation due to overlapping regions of the data used for analysis.

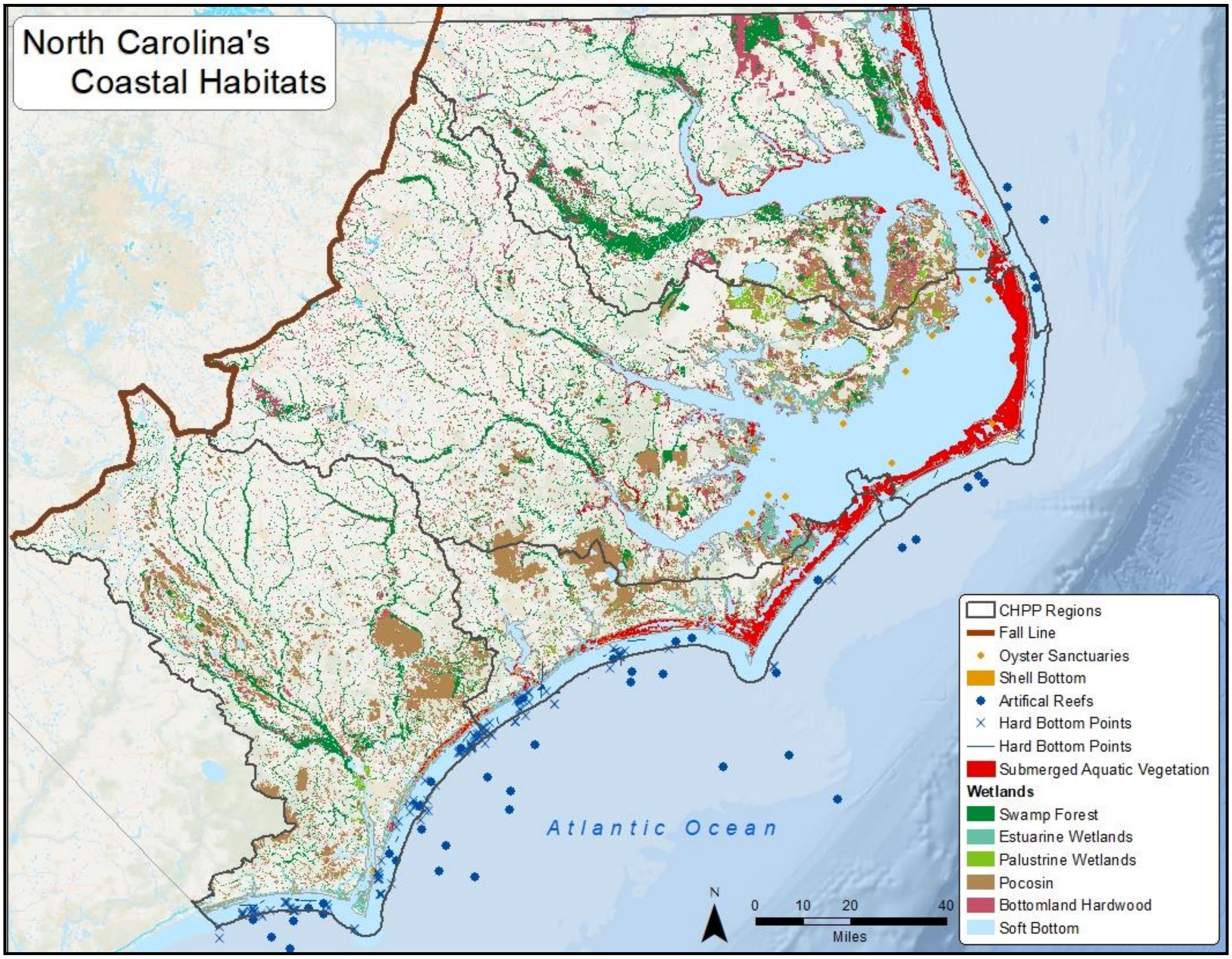

Figure 1.2. North Carolina's coastal habitats within the Coastal Habitat Protection Plan regions.

The need for a coastwide habitat plan(s) originated in the 1990s when fish populations, habitat, and water quality concerns were becoming increasingly more evident. Addressing habitat and water quality degradation was recognized by resource managers, fishermen, the public, and the legislature as a critical component for improving and sustaining fish stocks, as well as the coastal ecosystem. Developing Coastal Habitat Protection Plans (CHPPs) were required in the Fisheries Reform Act of 1997(FRA; G.S. 143B-279.8).

The legislative goal of the CHPP is *"…the long-term enhancement of coastal fisheries associated with coastal habitats."* The law specifies that the CHPP identify threats and recommend management actions to protect and restore coastal habitats critical to NC's coastal fishery resources. The plans must be adopted by the NC Coastal Resources (CRC), the NC Environmental Management (EMC), and the NC Marine Fisheries (MFC) commissions, to ensure consistency among commissions, as well as their supporting NC Department of Environmental Quality (DEQ) agencies. The FRA clearly required that recommendations of the management plans be implemented. The passage of the FRA and the initiation of the CHPP implementation process demonstrated the public's desire and political will to better manage NC's fisheries and coastal habitats.

1.2 Authority for management and protection of public trust resources

The Public Trust Doctrine provides the overarching authority for the state to manage public trust resources. The doctrine states that "public trust lands, waters, and living resources in a state are held by the state in trust for the benefit of all the people, and establishes the right of the public to fully enjoy public trust lands, waters, and living resources for a wide variety of recognized public uses." Public trust resources include the waters to the upstream extent of navigation, including navigation by small recreational boats, such as canoes or kayaks; submerged lands beneath the waters up to the normal high tide line (or normal water level in areas not subject to lunar tides); and the habitat and fisheries resources within those waters. Public trust rights include navigation, commerce, fishing, swimming, and hunting. State authority generally applies within the boundaries of NC, extending from internal creeks, rivers, and lakes downstream through coastal sounds, into the Atlantic Ocean for three nautical miles (nm) from the ocean shoreline. The DEQ and the NC Wildlife Resources Commission (WRC) have stewardship over NC's public trust resources (G.S. 113-131) and G.S. 113-132 specifically gives MFC jurisdiction over the conservation of marine and estuarine resources. Authority is provided in G.S. 143B-279.8 for DEQ to develop CHPPs and requires the associated environmental commissions to implement recommendations from the plans.

While the MFC manages fishing practices in coastal waters through rules implemented by the NC Division of Marine Fisheries (DMF), several agencies manage activities affecting coastal habitats and fisheries resources. The EMC has authority over activities affecting water quality, such as point and nonpoint discharges, wastewater, alteration of wetlands, and stormwater. The EMC's rules are implemented by different DEQ agencies, including the NC Division of Water Resources (DWR), the NC Division of Air Quality (DAQ), and the NC Division of Energy, Mineral, and Land Resources (DEMLR). The DEMLR administers rules adopted by multiple regulatory commissions, including the EMC, Sedimentation Control Commission (SCC), and the Mining and Energy Commission. The CRC enacts rules to manage development within and adjacent to public trust and estuarine waters, coastal marshes, and the ocean hazard area. The NC Division of Coastal Management (DCM) implements rules adopted by the CRC. The WRC, while not a participant in the CHPP process, has a direct role in the management of migratory coastal fisheries and habitats through the designation of Primary Nursery Areas (PNAs) and Anadromous Fish Spawning Areas (AFSAs) in inland waters, the review of development permits, monitoring and management of habitat, and the regulation of fishing in inland waters. There are many other state, federal, and interstate programs that directly or indirectly influence coastal fisheries resources and habitats in NC.

1.3 Coastal Habitat Protection Plan Process

The CHPP Steering Committee (CSC), which consists of two members from each environmental commission, recommends priority issues to address, provides policy oversight, reviews draft recommended actions, and serves as liaisons back to their respective regulatory commissions. They also meet to discuss cross-cutting habitat and water quality issues and solutions and receive updates on CHPP implementation progress. Increased communication across commissions benefits environmental management. The MFC, CRC, and EMC must review and approve the plans and adopted the first CHPP in 2004 with revisions in 2010 and 2016.

Chapter 1. Introduction

The CHPP is a DEQ document that requires all the DEQ divisions with authority over coastal habitat and water quality management to assist with drafting the plans. A CHPP Development Team, consisting of staff from the associated DEQ divisions is responsible for drafting the plans, participating at CSC meetings, and assisting with the implementation of recommended actions. The DEQ divisions that must participate are DMF, DCM, DWR, DEMLR, and the NC Division of Mitigation Services (DMS). Additionally, staff in the Forest Service and Soil and Water District, within the NC Department of Agriculture and Consumer Services (DA&CS) participate. Because the plans are developed with guidance from multiple agencies and commissions, recommended actions require broad support to be successful.

Similar to previous years, the CHPP includes four overarching goals for the protection of coastal habitats in NC (recommendations under these goals were reviewed and modified by the CSC):

1. Improve effectiveness of existing rules and programs protecting coastal habitats.
2. Identify and delineate strategic coastal habitats.
3. Enhance coastal habitat and protect it from physical impacts.
4. Enhance and protect water quality.

For the original CHPP and first update, recommendations were included in a single document, and bi-annual implementation plans were developed with specific actions to accomplish the plans recommendations. The CSC approved the implementation plans and met quarterly to discuss progress.

In an attempt to improve outreach, the CHPP structure was reorganized in 2016. Beginning with the 2016 revision, the Plan was organized into two documents: the CHPP Source Document (ecosystem data) and the CHPP Summary Document, also referred to as the CHPPlet. The Source Document provides the science and data to support recommended actions and information on the ecological value, needs, and status of each coastal habitat and anthropogenic threats is summarized. The Source Document includes issue papers on selected priority issues from 2016 including restoring oyster reef habitat, encouraging use of living shorelines, reducing sedimentation impacts in estuarine creeks, and developing metrics on habitat trends and management effectiveness. The issue papers include specific recommended actions that replace the need for a separate implementation plan. The CHPPlet provides succinct information in a public-friendly format on past implementation progress, priority issues, and the recommended actions to be taken by the CRC, EMC, MFC, DEQ and its divisions.

To further streamline the CHPP process in 2021, rather than update the entire Source Document, the CSC decided to create an amendment to the 2016 CHPP Source Document and chose five priority issues to focus on (2021 CHPP Amendment). The literature in the Source Document continues to serve as supporting information for proposed coastal habitat protection and restoration efforts. Additional supportive science is included in each issue paper.

Although progress has been made to implement CHPP recommendations, water quality has generally shown a declining trend with concerns about degrading submerged aquatic vegetation (SAV), shell bottom, and wetlands. Many of the stressors to the structured habitats originate from declining water quality. Consequently, most of the selected priority issues in the 2021 CHPP Amendment includes elements of improving water quality and the recommendations will not only improve the coastal ecosystem, but strengthen community and ecosystem resilience.

The five priority issue papers in the 2021 CHPP Amendment include:

1. Submerged Aquatic Vegetation protection and restoration through water quality improvements

2. Wetland protection and restoration through Nature-based Solutions
3. Environmental rule compliance to protect coastal habitats
4. Wastewater infrastructure solutions for water quality improvement
5. Coastal habitat mapping and monitoring to assess status and trends

Although new priority issues were selected for the 2021 CHPP Amendment, the 2016 issues remain a continuing priority. Progress on oyster restoration will continue, and CHPP Team members will continue to participate on the Oyster Steering Committee (OSC) to ensure actions of the CHPP and NC Oyster Blueprint are implemented. The NC Coastal Federation (NCCF) serves as the lead organization for the OSC and NC Oyster Blueprint. The OSC, comprised of multiple state and federal organizations, nongovernmental organizations (NGOs), and researchers, work together to develop and implement recommendations for the NC Oyster Blueprint on five-year intervals. The OSC meets regularly to discuss progress on oyster restoration, which includes oyster enhancement, actions related to water quality, and living shorelines that can benefit oysters. Progress on living shorelines will continue through recommended actions in **Chapter 5 Wetland Protection and Restoration through Nature-based Solutions**, as well as the Living Shoreline Steering Committee and NC Oyster Blueprint. Degradation of water quality occurred over many years from multiple causes. Therefore, improving coastal habitats and water quality conditions will take time. Faced with continuing coastal development, the CHPP recommended actions are meant as a starting point for continuing strategic actions to restore NC's coastal habitats, and in doing so, increase coastal resiliency.

1.1.1. Coastal Habitat Status and Trends Summary

To achieve the legislative goal of the CHPP, ***"…the long-term enhancement of coastal fisheries associated with coastal habitats."*** the status and trends of the six coastal habitats must be monitored over time to assess quantifiable long-term changes. This information can then be used to educate the public on the condition of the coastal habitats, to inform protection and restoration decisions, and evaluate and adapt management actions and strategies. The following are general summaries of the status and trends of the six coastal habitats based on the best available data. For additional information, see **Chapter 8. Coastal Habitat Mapping and Monitoring to Assess Status and Trends**.

Water Column

The water column is the medium through which all aquatic habitats and the organisms that use them are connected, making it one of the most important habitats.[1] Water quality describes the condition of waters based on selected physical, chemical, and biological characteristics, usually with respect to its suitability for a particular purpose such as drinking, recreation, or supporting aquatic life. Fish species and other organisms, such as SAVs and oyster that also provide fish habitat, exhibit water quality threshold tolerances. Conditions of the water column that are outside the threshold tolerance are considered impaired, polluted, or otherwise not supporting aquatic life. Basic parameters of water impairment include: pH, temperature, dissolved oxygen (DO), turbidity, bacteria, and chlorophyll *a*. Additional parameters impacting water quality include nutrients, such as nitrogen and phosphorous. However, currently there are no nutrient standards used to assess for water quality impairment. Excessive nutrient-rich sediment from land-based activities can exacerbate eutrophication, decreasing DO and water clarity and increasing toxic contamination. Therefore, flow and movement of water play a vital role in distributing pollutants and degraded waters to other habitats and waterbodies.

An assessment of the Southeast Coastal Region (NC to FL) found less than 25 percent of the area in good condition based on the water quality index.[2] The assessment of water quality in NC, known as the Integrated Report (IR), indicates the general condition of NC's waters and identifies waters that are not meeting water quality standards where sufficient data exists.[3] The 2018 IR listed 15,889 acres (34 percent) and 482 miles (12 percent) of freshwater and 618,300 (20 percent) of saltwater in the CHPP regions as impaired. Across the NC coast, there are general trends of increasing nutrients entering the rivers and sounds. The four basins carrying the supplemental classification of Nutrient Sensitive Waters (NSW), the Chowan, Tar-Pamlico, Neuse, and New rivers saw improvements during the initial classification implementation, but continuing and emerging issues still need to be addressed. Overall, decreasing nutrients will improve water quality which would decrease the amount and severity of fish kills, algal blooms, and recreational swimming closures, and potentially increase the acres of open shellfish growing areas.

Shell Bottom

The eastern oyster (*Crassostrea virginica*) occupies a unique position in the estuaries of NC because it: 1) colonizes estuarine bottom creating a productive habitat that has ecosystem benefits, and 2) the animal itself is harvested as a food item which has economic benefits. Shell bottom in NC has seen dramatic changes since colonial times when oyster reefs were so extensive along the coast they were a hazard to navigation.[4] Due to the combined effects of habitat destruction, overfishing, disease, and deteriorated water quality, oyster populations have experienced tremendous declines world-wide, particularly within subtidal oyster reefs that occur along the Mid-Atlantic coastline of the United States.[5, 6, 7, 8] It has been estimated that 85 percent of oysters have been lost globally.[9]

Since the 2016 CHPP, mapping of shell bottom (12 ft depth) has been completed in all of NC's coastal waters. A total of 22,060 acres of subtidal and intertidal shellfish were mapped between 1990 and 2019. Most of NC's shell bottom resource can be found in the southern CHPP regions. The White Oak River basin (CHPP Region 3) is dominated by subtidal oysters while the Cape Fear River basin (CHPP Region 4) is dominated by intertidal oysters. In recent years, mariculture (marine aquaculture) landings from private/leased bottom have increased substantially, surpassing wild harvest landings for the first time in 2017 and continuing through 2020. However, even with several DMF monitoring programs, there are insufficient data to conduct a traditional stock assessment for the oysters in NC.[10] Therefore, population size and rate of removals from the wild oyster population are not known.

To combat the generally declining trends of shellfish, shellfish habitat restoration efforts have been occurring throughout NC's estuarine waterbodies for over half a century. The primary purpose of DMF's Cultch Planting Program is to enhance the oyster fishery by planting oyster shell and other materials for natural recruitment which provides temporary habitat value as well as fishery benefits. The goal of the Oyster Sanctuary Program is to create protected oyster habitat that provides broodstock to enhance larval output for wild oyster reefs, leading to a naturally sustainable oyster population. Both programs are housed in DMF's Habitat and Enhancement (HE) Section. These efforts also increase the co-benefits of the ecosystem services oysters provide, including water filtration and shoreline protection against waves and storms. As of 2020, DMF constructed 15 oyster sanctuaries in the Pamlico Sound, totaling 396 permitted acres, and annually deploys several thousand bushels of cultch material strategically throughout the estuaries of NC. Since standard record keeping began in 1980, DMF's HE Section has planted over 12 million bushels of cultch material.

Submerged Aquatic Vegetation

Currently, NC is steward to one of the most productive and biodiverse SAV resources on the Atlantic seaboard.[1, 11, 12, 13, 14, 15] There are two distinctive groups of SAV ecosystems in NC distributed according to estuarine salinity. One group, referred to as low salinity SAV or underwater grasses, thrives in fresh and low salinity riverine waters (≤10 parts per thousand; ppt). The second group, referred to high salinity SAV or seagrass, occurs in moderate to high (>10 ppt) salinity estuarine waters of the bays, sounds, and tidal creeks. Collectively, they are referred to as SAV. When SAV beds are subjected to anthropogenic impacts (i.e., physical damage, water quality degradation), large-scale losses may occur. Natural stressors, such as storm damage and climate change can also impact SAV, with the latter an increasing concern for SAV survival due to predicted temperature, salinity, and wave energy changes. Globally, SAV abundance is declining at rates similar to the rainforest and coral reefs.[16, 17, 18]

In NC, various mapping and monitoring projects have been conducted by universities and state and federal agencies since the 1980s. Each of these mapping events produced shape files of SAV presence, that when compiled together, make up the historically known presence and suitable habitat of SAV along NC's coast (commonly referred to as the SAV mosaic), suggesting a historic extent of approximately 191,155 acres of SAV in the public trust waters of coastal NC. However, the extent of SAV loss has not been well quantified in NC. Anecdotal reports indicate SAV beds may be reduced by as much as 50 percent, especially on the mainland side of the coastal sounds.[1, 19] Based on the most recent hydroacoustic surveys of SAV extent in the Neuse, Pamlico and Albemarle rivers sub-estuaries, there has been an estimated 33 percent decline from the historical extent of low salinity SAV.[20, 21] Declines in the extent of high salinity SAV from Roanoke Island to Bogue Inlet have also been reported with the southern zone, where there is more development and higher population densities, declining by over 10 percent at a rate of 1.7 percent loss per year.[22] For more information, see **Chapter 4 Submerged Aquatic Vegetation Protection and Restoration Through Water Quality Improvements**.

Wetlands

For the purposes of this paper, coastal wetlands include two broad classes: palustrine and estuarine.[23] Palustrine wetlands include all non-tidal wetlands, as well as any tidal wetlands where ocean-derived salinities are less than 0.5 ppt. Wetlands with ocean-derived salinities greater than 0.5 ppt are categorized as estuarine wetlands.

Wetland resources in the United States have declined considerably (>50 percent) since the colonial period.[24] It is estimated nearly half of NC's 11 million historical acres of wetlands were lost (physically or functional) between pre-colonial times and the 1980s.[25] The loss of NC's coastal wetlands continues into the 21st century. Approximately 40 percent of total documented coastal wetland losses occurred between 1950 and 2000 with approximately 95 percent of NC's wetland resources in the state's Coastal Plain.[26] According to the most recent National Oceanic and Atmospheric Administration's (NOAA) Coastal Change Analysis Program (C-CAP) data, NC has 4.35 million acres of palustrine wetlands, of which 71 percent are forested wetlands, 23 percent are scrub/shrub wetlands, and 6 percent are emergent wetlands, as well as 235,425 acres of estuarine wetlands, of which 97 percent are emergent wetlands.[27]

While the value of coastal wetlands is well documented, and rules are in place to protect them, permitted and unpermitted impacts continue. The DWR reported 17,984 acres of wetland impacts were permitted statewide through issuing 401 certifications (12,386).[28] The areas with the most impacted acres can be found in some of the coastal counties. The DWR permit data for the 20 coastal counties indicate that in the 1990s, most impacts were attributable to water dependent structures (marinas, docks, bulkheads), followed by dredging. From 2000 to 2010, there was a large increase in mining impacts and since 2010, most impacts were associated with transportation. For additional information, see **Chapter 5. Wetland Protection and Restoration through Nature-Based Solutions** and **Chapter 6. Environmental Rule Compliance to Protect Coastal Habitats.**

Hard Bottom

Oceanic hard bottom is the primary structured habitat for offshore marine organisms on the continental shelf of NC.[29, 30] These exposed structures function as foundation for sessile invertebrates and algae, refuge for free moving benthic invertebrates and vertebrates, as well as juvenile, bait, and economically important fishes.[31, 32] Hard bottom in NC is limited to specific areas of the continental shelf with 90 percent of existing hard bottom occurring south of Cape Hatteras. Although limited information exists on the distribution of hard bottom off the NC coast, there is no regular monitoring in place to evaluate the status and trends of hard bottom habitat in state territorial waters.[33, 34, 35, 36] It has also been reported that live bottom reef comprises a larger area of the South Atlantic Bight.[37]

Anecdotal information from fishermen and residents in coastal NC suggests that many nearshore hard bottom sites in the mid-twentieth century are now covered by sand, reducing the abundance of fish in these areas. The observed declines in species abundance and richness lead researchers to conclude that the conflict between beach nourishment and hard bottom productivity is a serious conflict that will only worsen.[29, 38]

As of 2020, DMF's Artificial Reef Program manages 63 artificial reefs including 22 estuarine reefs, 15 of which serve as oyster sanctuaries, and 43 offshore reefs (13 in state waters (≤3 nm) and 30 in federal waters (3-200 nm)) with the goal of supporting and functioning similarly to nearby natural reefs while providing user access opportunities. Although the purpose of the artificial reefs is to enhance fishing, they have been shown to support a similar community as natural reefs on multiple metrics.[39, 40] The artificial reefs also provide habitat for top predators and fishes at the edges of their distribution ranges.[41, 42]

Soft Bottom

Marine sediments constitute one of the largest habitat types on earth, covering roughly 80 percent of the ocean bottom with tidal flats occupying over 31 million acres.[43, 44] Environmental characteristics, such as grain size, salinity, DO, depth, and flow conditions affect the condition of the habitat and the organisms using it. The characteristic common to all soft bottom is the mobility of unconsolidated sediment.[45] Soft bottom is in a constant state of flux, as other habitats expand or contract. The loss of more structured habitat, such as SAV, wetlands, and shell bottom, leads to gains in soft bottom habitat. Gains in new soft bottom habitat may not be as beneficial as mature soft bottom habitat. It is estimated that approximately 16 percent of tidal flats were lost between 1984 and 2016 due to coastal development, lack of sediment transport, increased erosion, and sea level rise (SLR).[44]

In NC, soft bottom covers approximately 90 percent of the estuaries and coastal rivers.[46] As expected, the most extensive amounts of soft bottom can be found in CHPP regions 1 and 2, which include the vast open waters of the Albemarle and Pamlico sound systems.[47, 48, 49, 50] The deep soft bottom (>6 ft) is dominant with at least more than twice the amount of shallow soft bottom (≤6 ft) in every region. No targeted mapping efforts exist for soft bottom and bathymetry data are out dated. Therefore, it is not possible to quantify how the extent of soft bottom habitat has changed through time.

The condition and quality of soft bottom habitat can affect species abundance and diversity of the benthic community and could be considered a more important factor for soft bottom than extent. Sediments in soft bottom habitat can accumulate both chemical and microbial contaminants, potentially impacting benthic organisms and the community structure. The US Environmental Protection Agency (EPA) National Coastal Condition Assessment (NCCA) is the only regular monitoring source of soft bottom in NC. In 2010, the biological quality of 77 percent of the waters in the Southeast Coastal Region was rated as good based on the benthic index, 65 percent was rated good based on the sediment quality index, and 81 percent was rated as good based on sediment toxicity.[10] The contaminants that most often exceed the lowest observed adverse effect level (LOAEL) thresholds were selenium, mercury, arsenic, and (in rare instances) total DDTs.

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Photo Credit: Nolen Vinay

2. IMPLEMENTATION PROGRESS ON PRIORITY HABITAT ISSUES (2016-2021)

2.1 Background

Since the approval of the 2016 Coastal Habitat Protection Plan (CHPP), implementation has focused on four identified priority issues:[1]

1. Restoring oyster reef habitat.
2. Encouraging use of living shorelines.
3. Reducing sedimentation impacts in estuarine creeks.
4. Developing metrics on habitat trends and management effectiveness.

The primary divisions responsible for implementing CHPP recommended actions are the NC Department of Environmental Quality's (DEQ) Division of Marine Fisheries (DMF), NC Division of Coastal Management (DCM), NC Division of Water Resources (DWR), and NC Division of Energy, Minerals, and Land Resources (DEMLR). Progress on these actions to address priorities are summarized below.

2.2 Oyster Reef Habitat Restoration

The 2016 CHPP included Oyster Reef Habitat Restoration as a priority habitat issue.[1] The participating DEQ divisions and partners made substantial progress towards achieving and implementing the 2016 recommended actions. Progress was strengthened by DMF partnering with others on the NC Oyster Steering Committee (OSC). The OSC consists of a diverse group of state and federal agencies, including DMF, as well as researchers, nongovernmental organizations (NGOs), and shellfish lease growers with the common goal of restoring and protecting oyster habitat through multiple strategies. The NC Coastal Federation (NCCF) serves as the lead organization for the OSC and production of the Oyster Restoration and Protection Plan: A Blueprint for Action, that is updated on five-year cycles. The 2015-2020 Oyster Blueprint summarizes work being done in NC related to oysters, and builds on progress accomplished through the 1995 Blue Ribbon Advisory Council for Oysters and the CHPP. Many of the goals in the Oyster Blueprint closely align to recommendations and implementation actions of the CHPP, including creating additional acreage of oyster sanctuaries, planting cultch for sustainable harvest, protecting and improving water quality in priority shellfish growing areas, and documenting oyster population status and trends.[2] Through collaboration with partners, particularly the OSC, and support from the NC General Assembly, progress on oyster restoration has made been significant advances over the past five years.

The 2016 CHPP recommended actions were presented for three categories: Cultch Planting, Oyster Sanctuaries, and Hatchery and Oyster Seed Production.

2.2.1 Cultch Planting

The 2016 CHPP recommended actions for cultch planting were:[1]

1. Increase spending limit per bushel of shell to compete with other states.
2. Develop a cooperative public/private, self-sustaining shell recycling program by providing financial incentives in exchange for recycled shell.
3. Work with the shellfish industry to institute an "oyster use fee" to help support the Cultch Planting Program.
4. Identify alternative substrates for larval settlement in intertidal and subtidal oyster reefs, including a cost-benefit analysis.

5. Establish long-term monitoring program to support future decision-making.
6. Utilize new siting tools and monitoring protocols to maximize oyster reef success.

Since 2016, several actions have been taken to advance the success of cultch planting. In early 2019, DMFs' special delegation for the purchase and transport of oyster shell was increased to account for inflation of transportation costs. New state purchasing procedures were implemented in 2021 providing DMF greater flexibility for purchasing and transporting oyster shell to account for market fluctuations. In 2018, due to lack of appropriated funding, DMF formally terminated the Oyster Shell Recycling Program. However, the NCCF has continued recycling across the state. Recycled shell used for DMF cultch planting is either donated or available for purchase under the shell delegation. No progress has been made toward establishing incentives or funding mechanisms such as oyster use fees (tax on sale of oysters with revenue allocated for cultch planting) to acquire shell for the program. As described in the 2016 CHPP, DMF recently reallocated a position to establish the new Cultch Planting Program biologist which focuses on providing scientific support to the cultch planting decision-making process including: identifying alternative substrates for larval settlement in intertidal and subtidal oyster reefs, establishing a long-term monitoring program and using new siting tools and monitoring protocols to maximize reef success. Of note, the newly redefined Coastal Recreational Fishing License Fund (CRFL) Request for Proposal (RFP) process has afforded the Cultch Planting Program an opportunity to request focused university research to inform decisions. Also, DMF recently repurposed another position to create a dedicated side-scan mapping role. This position is tasked with mapping hard bottom areas, with particular attention paid to cultch planting reefs, oyster sanctuaries, artificial reefs, and natural oyster reefs. Data will provide spatial context for public consumption, reference tools for other division programs (i.e., leases, CHPP).[3]

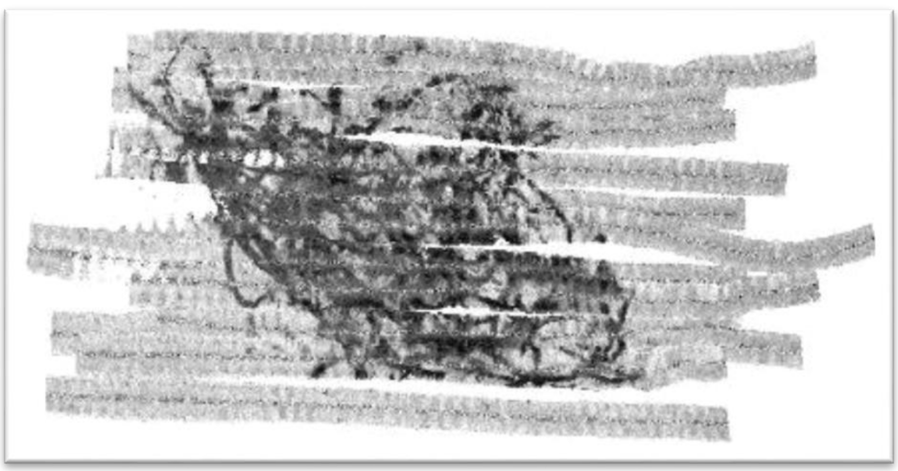

Figure 2.1. Backscatter imagery from a high-resolution survey conducted at a cultch planting site in Bonner Bay on 6/9/2016. The darker colors indicate hard bottom habitat created by the North Carolina Division of Marine Fisheries cultch planting vessel, RV Shell Point. The lighter colors indicate softer sand/mud bottom.

While not listed under any recommended actions, it is important to note the substantial accomplishments of DMF in pursuit of the cultch planting objective. Since 2016, staff have built a total of

261 acres of oyster habitat using 1,266,815 bushels of material, without assistance from marine contractors.

2.2.2 Oyster Sanctuaries

The 2016 CHPP recommended actions for oyster sanctuaries were:[1]

1. Identify alternative substrates for larval settlement in intertidal and subtidal oyster reefs, including a cost-benefit analysis.
2. Identify the size and number of oyster sanctuaries needed.
3. Develop oyster reefs that are resistant to poaching.
4. Utilize new siting tools to maximize oyster reef success.
5. Explore actions for in-situ sampling protocol to incorporate alternative construction materials.
6. Expand oyster sanctuary network to include intertidal oyster reefs in euhaline waters.

Since 2016, substantial progress has been made toward achieving and implementing the oyster sanctuary recommended action. Between 2016 and 2019, DMF protected approximately 80.7 acres of bottom, and with partners, developed approximately 51.2 acres of oyster habitat within that area. Two independent oyster sanctuaries were constructed, Little Creek Sanctuary (20.7 acres) and Swan Island Sanctuary (60 acres). The Swan Island project was the most notable accomplishment involving a public-private partnership with the NCCF and funding from both the NC General Assembly and the National Oceanic and Atmospheric Administration (NOAA). The initial project was completed in 2019 using a combined total of 80,600 tons of granite and marine limestone marl. However, additional funding was received that added 4,400 tons in 2020 and 6,600 tons in 2021 for a total of 91,600 tons of material deployed at the Swan Island Sanctuary.

Rigorous sampling of oyster sanctuaries, including Swan Island, resumed in 2019 after a short hiatus. Monitoring will provide size structure and population density information to inform recommendations for identifying alternative substrates for larval settlement in intertidal and subtidal reefs, identifying the size and number of sanctuaries needed, and new siting tools to maximize reef success. Presently, these data are undergoing analysis to compare 2019 results to historic data in published literature.[4] The primary objective of this analysis is to evaluate trends in population and size structure over a long time series and potentially develop predictive tools for future management. Preliminary results and analysis of the 2019 data are presented in Figures 2.2-2.4.

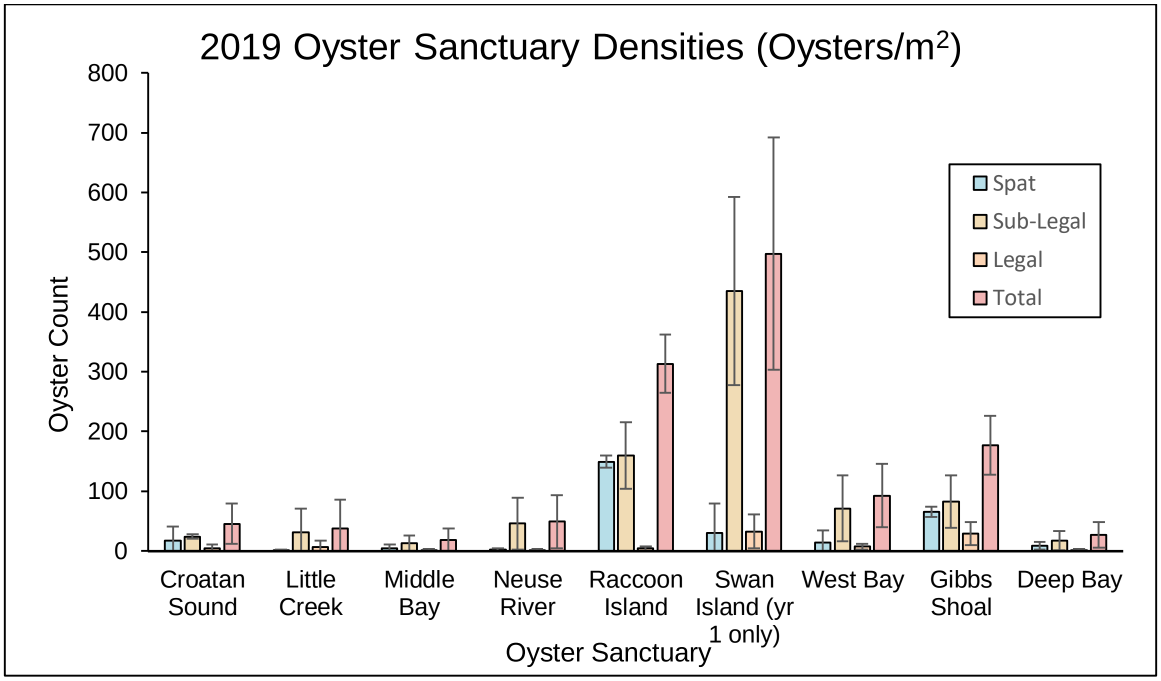

Figure 2.2. Population density data for 13 oyster sanctuary sites in Pamlico Sound. Size class densities (oysters/m2) are presented with error bars for each sanctuary, along with the total mean density at each. Only habitat material at Swan Island Oyster Sanctuary with ≥2 years in the water was sampled.

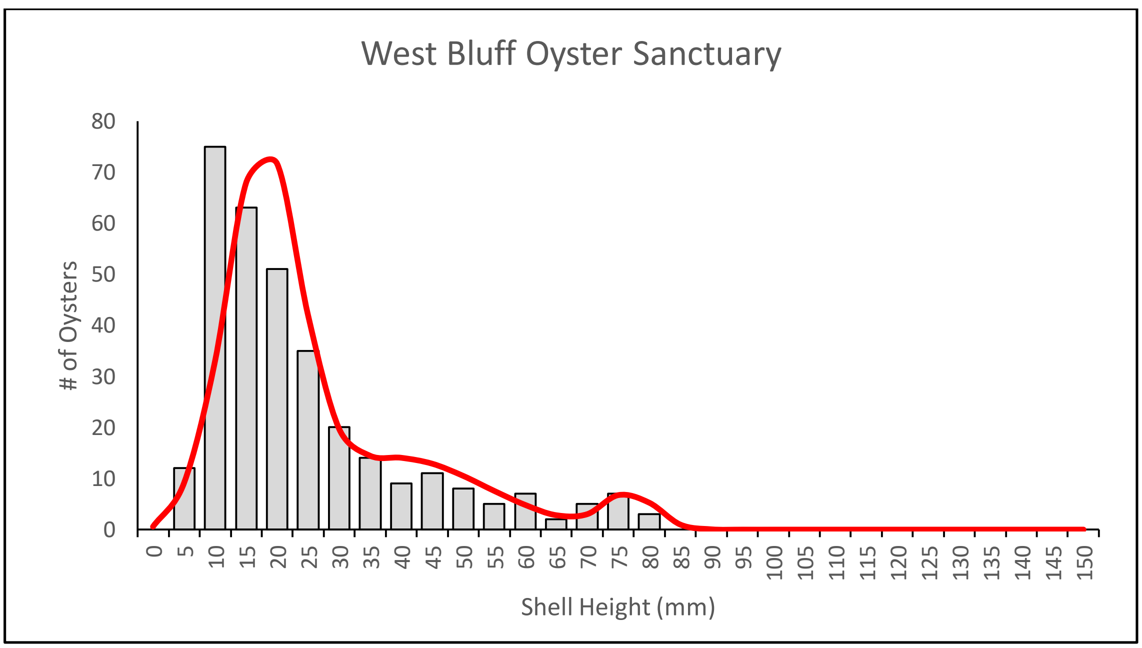

Figure 2.3. Length frequency data collected in 2019 at the West Bluff Oyster Sanctuary in Pamlico Sound. The red line indicates the findings of a cumulative modal analysis to identify individual cohorts.

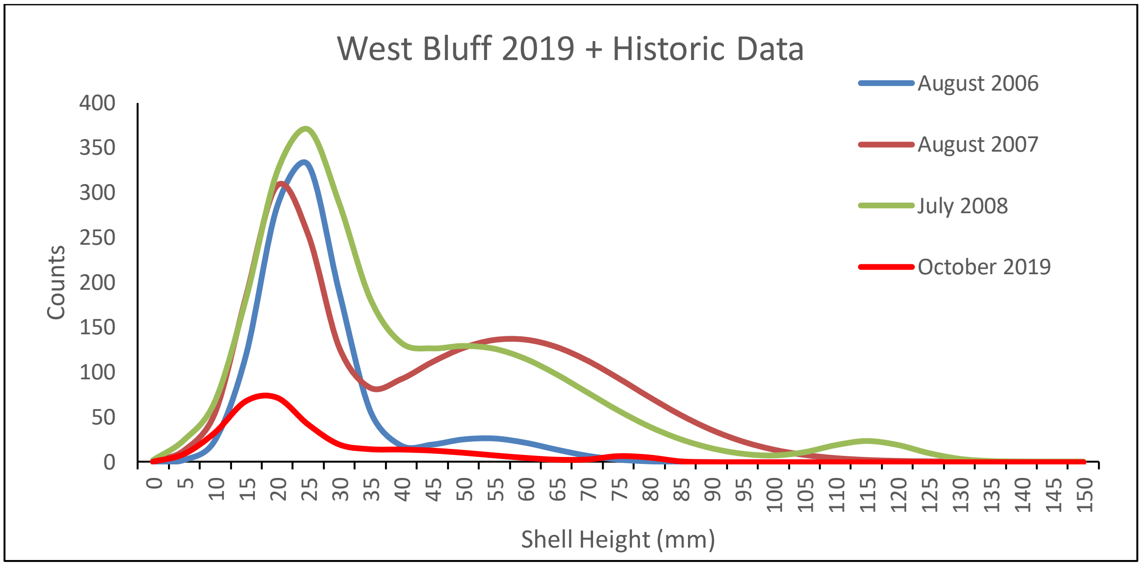

Figure 2.4. Comparison of length frequency data for West Bluff Oyster Sanctuary site in Pamlico Sound and historic data.[4]

2.2.3 Hatchery Oyster Seed Production

The 2016 CHPP recommended actions for hatchery oyster seed production were:[1]

1. Explore options for increasing funds to support University of North Carolina at Wilmington (UNC-W) oyster hatchery.
2. Identify regional genetic variability within NC.
3. Improve availability of seed oysters genetically suited to respective regions.

Since 2016, UNC-W has been making progress on the recommended actions for hatchery oyster seed production. Based on legislative reports provided by UNC-W, the university has successfully and progressively increased viable spawns and provided broodstock from multiple lines to commercial hatcheries and community colleges statewide. The Shellfish Research Hatchery Breeding Program was substantially compromised during Hurricane Florence, which identified a need for storm resilience through industry/community/academic partnerships. Funding has been budgeted for genetics and additional staff to presumably address recommended actions to identify regional genetic variability within NC and improve availability of seed oysters genetically suited to respective regions.

2.3 Encourage Use of Living Shorelines

The 2016 CHPP directs agencies to continue focusing efforts on encouraging living shorelines to protect property, restore shoreline habitat, and improve water quality.[1] Starting in 2018, a Living Shoreline Steering Committee (LSSC) was established through a partnership with Albemarle-Pamlico National Estuary Partnership (APNEP) and the NCCF. Member partners include DEQ staff from DMF, DWR, DCM and its NC Coastal Reserve and National Estuarine Research Reserve (NC Coastal Reserve) as well as research scientists from NOAA, UNC-W, UNC at Chapel Hill (UNC-CH), East Carolina University (ECU), Duke University and NC Sea Grant. Two NGOs, NCCF and The Nature Conservancy (TNC) are also members. The goals and objectives of the LSSC and the CHPP Living Shoreline Priority Issue Paper closely align.

Through the LSSC, there has been a dramatic increase in communication, collaboration and significant progress in advancing the recommended actions in the 2016 CHPP Living Shoreline priority habitat issue paper, including:

1. Continuing to educate the public and waterfront property owners regarding the benefits of living shorelines.
2. Promoting additional research and monitoring of living shorelines.
3. Continuing to simplify the federal and state permitting process for living shorelines.
4. Promoting the appropriate use of oyster shells to facilitate habitat enhancement and incorporation into living shorelines.

Much of the progress described in the following sections is associated with members of the LSSC and CHPP Team.

2.3.1 Permitting

The most notable accomplishment toward CHPP implementation is the simplification of permit requirements, specifically the changes to the General Permit (GP) for marsh sills. In 2017, DCM worked with a stakeholder group that included the U.S. Army Corps of Engineers (USACE), marine science community, DMF, DWR, NCCF, NC Sea Grant, and NOAA to determine how best to move forward with creating a more streamlined permitting process for marsh sills. For there to be an efficient streamlined general permit, all federal and state agency concerns must be addressed with permit conditions. In early 2017, DCM compiled all the comments and recommendations from the stakeholder group and drafted an amended general permit 15A NCAC 7H .2700. In 2018, the USACE used the draft amended GP .2700 as guidance in the development of a Regional General Permit (RGP) for marsh sills that would allow DCM to issue GPs for marsh sills without a case-by-case federal review prior to issuance.

On September 5, 2018, the USACE issued a public notice proposing to authorize a RGP for the construction, maintenance, and repair of marsh sills. The RGP for the construction and maintenance of marsh sills included all conditions that were agreed upon at the stakeholder meetings. On March 26, 2019, the USACE issued the RGP (RGP 20181536) that authorizes the construction, maintenance, and repair of marsh sills for shoreline stabilization.

The CRC adopted amendments to 15A NCAC 7H .2700 that were consistent with the USACE RGP and the temporary rule became effective on April 1, 2019 followed by the permanent rule which became effective on July 1, 2019. This GP does not require any coordination with state and federal agencies if the permit conditions are met; therefore, creating a streamlined GP process that is consistent with other Coastal Area Management Act (CAMA) general permits. Since the effective date of this general permit, there has been an increase in 15A NCAC 7H .2700 applications and to date there have been approximately 14 GPs issued for the construction of marsh sills.

Another permit related activity underway is exploring the possibility of living shorelines being constructed for mitigation credits. The NCCF is currently looking into the feasibility of this with environmental consulting companies. Similar crediting is being used in the Chesapeake Bay. Living shorelines are one type of shoreline Best Management Practice (BMP) that can be used for Total Maximum Daily Load or Limit (TMDL) or shoreline management BMP credits to reduce nutrients and sediment. Virginia offers a residential cost-share program (Virginia Conservation Assistance Program), an agricultural cost-share program, and low interest loans as incentives.

2.3.2 Education

Since 2017, the NC Coastal Reserve has conducted nine living shoreline training events throughout NC's coast to promote the use of living shorelines as a preferred erosion control method where appropriate. These training events were conducted in three coastal regions and attendees included real estate professionals, marine contractors, land use planners, landscape architects, property owners, and homeowner associations. Adapted from a Florida training, in 2021 due to COVID-19, the NC Coastal Reserve conducted a pilot virtual training that included a field session. They plan to have future in-person events. DCM regulatory staff and the NCCF presented at most of the NC Coastal Reserve workshops, providing valuable technical expertise. The workshops have been effective in increasing understanding of not only the benefits of living shorelines, but where and how to construct them. A contractor that attended training has independently built several living shorelines, a sign that the workshops are effective.

The NCCF has played a major role in encouraging property owners to consider living shorelines to stabilize their shorelines. They provided shoreline consultations to 55 waterfront property owners coast wide in 2019 alone. The NCCF also engaged with multiple homeowner associations, providing presentations and guidance on living shoreline implementation, as well as to town planners and during town meetings. By utilizing community volunteers to construct living shorelines, the value, applicability, and effectiveness of living shorelines reach large numbers of people from a diversity of backgrounds, including students, to church members, environmental groups, and private businesses.

2.3.3 Research

There are several research projects that are ongoing and include monitoring of salt marsh surface elevation tables (SET) and vegetation in natural marshes and nearby living shorelines in Carteret County. A study that surveyed coastal property owners after Hurricanes Irene (2011) and Arthur (2014) found that most homeowners believed that bulkheads were the most effective way to prevent erosion from hurricanes.[5] However, the study also showed that most hurricane damages were to bulkheads. Cost for repairs of these bulkheads were double the price and four times the cost of annual maintenance of natural or living shorelines. However, during the same timeframe, shoreline hardening increased by 3.5 percent from along the Outer Banks. Recent work demonstrated the resilience of living shorelines to hurricanes and that living shorelines had better resistance to erosion than bulkheads and natural marshes.[6] It was also found that no repairs were required during the two-year study period. Post Hurricane Florence monitoring of several living shorelines throughout the state showed minimal signs of damage to both rock and oyster sills. Some marsh shoreline erosion was observed but only an average loss of 14 percent of marsh vegetation, suggesting that marsh was protected and retained after the storm. What structural damage was observed was some displacement of oyster bags from the main sill.[7] There are several other studies that are completed or are close to completion that demonstrate: 1) that bulkheads reduce salt marsh extent, 2) how wave energy is attenuated by natural marshes, reducing erosion of uplands, and 3) how waves are transformed across living shorelines. A new online tool was developed by NOAA and TNC incorporating recent research and the relationship between salt marsh distribution, shoreline wave energy, and suitability for living shorelines.[8]

Several presentations were given at various scientific conferences. Beaufort, NC was also the site of Restore America's Estuaries' Third National Living Shoreline Technology Transfer Workshop in October 2019. The workshop, locally hosted by NCCF, was attended by approximately 250 professionals. Field trips showcased local living shorelines projects at Piver's Island, Carrot Island, Trinity Center, the NC Aquarium at Pine Knoll Shores and Hammocks Beach State Park's Jones Island.

Work on testing alternative construction materials has also been ongoing. A 185 ft. living shoreline was constructed in Bogue Sound at the NC Aquarium at Pine Knoll Shores using Sandbar Oyster Company's Oyster Catcher™ material. Oyster shell and rock gabions developed by the Tensar International Corporation and JLS Contracting Services, LLC, are being tested at Jones Island and at a shoreline along the Intracoastal Waterway in Swansboro. The NCCF is working with Green Recycling Solutions to develop a degradable alternative to the traditional plastic mesh bags. The company is in the process of developing a jute mesh bag that can be used to fill oyster shells. This will be tested for living shoreline construction. The use of their degradable erosion control sock may also be explored.

2.3.4 Living Shorelines with Oyster Habitat

Using oyster shell as substrate to create a living shoreline doubles the habitat benefits by enhancing wetland and oyster habitat. While oyster shell is limited in supply, other hard substrate can be used that oysters can recruit onto. Environmental conditions, primarily salinity, limits oyster habitat on all living shorelines. Therefore, living shorelines incorporating oysters represents a subset of all living shorelines. The 2021-2025 Oyster Blueprint includes a new goal to expand the use of living shorelines in areas that support oyster habitat and make them the most commonly used stabilization method in those areas.[9] Living shorelines located in areas that support oysters will provide benefits to oyster rehabilitation efforts by potentially providing another source for oyster larvae. They provide another opportunity to supplement oyster rehabilitation efforts and improve water quality. Living shorelines are one strategy to protect and restore wetlands, and in some cases oysters.

Being a Nature-based Solution, living shorelines remain a priority in the 2021 CHPP Amendment for the benefits they provide as fish habitat, wetland restoration, oyster restoration, water quality improvement, and enhancing coastal resilience (Figure 2.5). Recognition of the benefits of living shorelines has greatly increased in the past five years. To this point, the NC General Assembly in 2019 (Session Law 2019-251) allocated $2 million to the NC Department of Transportation (DOT) to construct living shorelines in areas close to vulnerable infrastructure. For additional information, see **Chapter 5. Wetland Protection and Restoration through Nature-Based Solutions**.

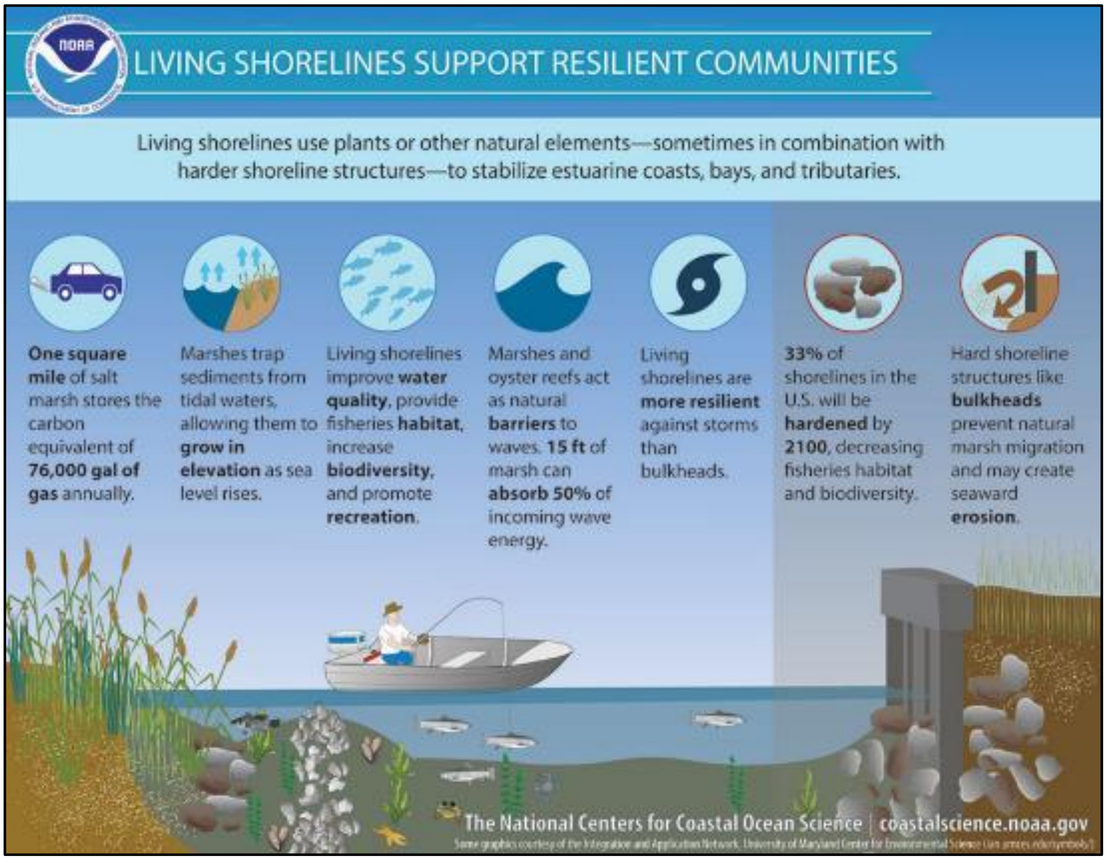

Figure 2.5. The ecosystem benefits of living shorelines for shoreline stabilization.

2.4 Sedimentation in Estuarine Creeks

Tidal creeks are the critical connection between the upper and lower estuary, but many have been overloaded by influx of sediment and pollutants.[10] Reducing sedimentation in tidal creeks was a priority issue in the 2016 CHPP due to concerns that sedimentation was causing upper creeks to fill in, reducing habitat availability for juvenile fish, smothering oyster reefs, and degrading water quality, particularly shellfish harvest waters. Review of literature concluded that the negative impacts of sedimentation are fairly well understood and a few studies were done in NC to look at sedimentation rates and sources. However, more assessments of tidal creeks across a continuum of anthropogenic disturbance were needed to determine prevalence of high sedimentation, major land use activities contributing to it, and the effects of sedimentation on nursery area function. The research and management actions included:

1. Determine magnitude and change in sedimentation rates and sources over time at sufficiently representative waterbodies and regions.
2. Determine the effect of sedimentation in the upper estuaries on primary and secondary productivity and juvenile nursery function.
3. Encourage research for innovative and effective sediment control methods in coastal areas.
4. Encourage expanded use of stormwater Best Management Practices (BMPs) and low impact development (LID) to reduce sediment loading into estuarine creeks.

5. Improve effectiveness of sediment and erosion control programs.

2.4.1 Research Actions

Two studies completed since 2015 examined sedimentation rates and sources in NC and both found that sedimentation rates in tidal creeks were exceeding local sea level rise (SLR). One study examined the relationship of land use, shoreline change, and sedimentation rates in three creeks in Onslow and Carteret counties.[11] Sediment composition and profiles indicated sediment in the upper creeks originated from land runoff and an increased flux of organic carbon and nitrogen over time. There was not a clear relationship between sedimentation, shoreline change, and land use. However, timing of the measured change in sediment accumulation rates in Oyster and Broad creeks coincided with periods of development and land use change in the surrounding areas.

Another study examined sedimentation rates and resulting impacts to fishery production in nursery areas.[12] This study, funded by the CRFL, began in 2016 and is in the final stages of completion. The first part of the study assessed the relationship of land use change and tidal creek infilling by calculating sedimentation rates from twelve tidal creeks in Carteret and New Hanover counties. Sedimentation rates were compared to changes in watershed land use from 1959 to 2010. Sedimentation rates experienced notable increases through time as developed land area increased and the sedimentation in all creeks was greater than the relative SLR rates. The results of the study indicated that land-use change, particularly increasing development, leads to higher sedimentation rates with the potential to drive infilling and shallowing of tidal creeks. However, it was noted that hydrological conditions influence whether sediment loads are deposited in the upper creeks or exported downstream to larger estuaries.

The second part of the study conducted extensive spring, summer, and fall nekton sampling in the same 12 creeks, from 2017 to 2019. Preliminary results indicated that for 11 of the tidal creeks, there appeared to be a negative relationship between sedimentation rate (integrated over the last 50 years) and catch rate of nekton (fish and decapod crustaceans).[13] The investigators continue to explore whether the mechanism for this negative relationship include changes in habitat amount (i.e., higher sedimentation = smaller creeks), changes in water quality (i.e., turbidity), and/or changes in benthic habitat quality (i.e. altered sediment characteristics and/or burial of biogenic habitat).

Another research action in the 2016 CHPP Living Shoreline priority habitat issue paper was the need for more research on innovative and effective sediment control measures in coastal areas.[1] Changes to coastal stormwater rules in 2016 made this even more critical than in the past. With less emphasis on built-upon limits and stormwater ponds, research on innovative and effective infiltration systems continued to be a high priority. Significant research has been conducted in the past five years, primarily through collaboration among North Carolina State University (NCSU), DEQ, and DOT. Research projects in coastal counties examined effectiveness of rain gardens, permeable pavement, stormwater wetlands and drainage improvements.

Through Section 319(h) of the Clean Water Act, the United States Environmental Protection Agency (EPA) provides states with funding to reduce nonpoint source pollution. North Carolina typically receives around $1 million for competitive funding of watershed restoration projects. Section 319 grant projects must be used to help restore waterbodies currently impaired by nonpoint source pollution in areas with approved watershed restoration plans. Since 2015, several projects have occurred in coastal watersheds. These ranged from drafting and implementing watershed restoration plans, to designing and constructing projects that reduce stormwater runoff, and establishing stormwater wetlands to improve water quality. Project descriptions are available on the DWR website.[14]

A major source of impervious surfaces in coastal NC is DOT roadways. Consequently, they have several programs to research and implement innovative techniques to reduce stormwater runoff. Although not within DEQ, the magnitude of their potential impact on sedimentation and progress they are making to minimize adverse impacts is worth noting. Through the DOT Research Program, the agency explores new and innovative technologies that may be suitable for use with the linear nature of most DOT activities. DOT actively funds university research to investigate and evaluate suitable methods for treating pollutants associated with DOT activities. Active research programs involving detailed analytical monitoring have been established to investigate and document the impacts of stormwater runoff from highways as well as the effectiveness of BMPs. This has included research on performance of dry swales, wet swales, permeable pavement, and bioswales. Research publications sponsored by the program are listed on their website.[15]

2.4.2 Management Actions

DEMLR Coastal Stormwater and Erosion and Sedimentation Control Programs

The Sedimentation Pollution Control Act (SPCA) addresses sedimentation impacts in surface waters. The law requires an erosion and sedimentation control plan for any land-disturbing activity if more than one acre is to be disturbed. The law is primarily implemented by the Sediment Control Commission (SCC) and two programs in DEMLR - Stormwater Program and Erosion and Sedimentation Control Program (E & S). The SCC and DEQ are charged with enforcement of the SPCA and educating the regulated community and general public about erosion and sedimentation control. Agriculture, forestry, mining, and emergency situations are exempted from the law. Coastal counties that are subject to National Pollutant Discharge Elimination System (NPDES) Phase II MS4 post-construction requirements (15A NCAC 02H .1016) such as Brunswick, New Hanover, Onslow, Pitt, and Wayne counties, must have their own stormwater programs. Additionally, some local municipalities have elected to implement their own stormwater and E & S programs.

The Coastal Stormwater Program has undergone several rule changes from its inception in the late 1980's. The rules of 1995 were updated in 2008 and again in 2017 due to legislation. In 2008, coastal stormwater rules were modified, reducing the percent impervious cover limits for low density development from 24 percent to 12 percent adjacent to Outstanding Resource Waters (ORW), SA waters, and areas with 0.5 mi and draining to SA waters. This change was based on research that showed fecal coliform bacteria increased directly with increasing runoff from impervious surface and shellfish harvest closures were continually increasing.[16] In 2016, legislation required the coastal stormwater rules to be modified. While impervious surface limits in SA-HQW and SA-ORW, and ORW remained at 12 percent, impervious surface limits in other coastal county waters returned to 24 percent.[17] A DEQ report on the existing coastal stormwater program stated that "any direct discharge of stormwater to a coastal water can compromise its quality" and that the solution for controlling fecal coliform contamination is incorporation of Stormwater Control Measures (SCMs) in developments to infiltrate stormwater onsite. Recommended SCMs includes but are not limited to infiltration systems (basins and aggregate-filled trenches designed to soak stormwater into the ground), permeable pavement, and disconnected impervious surface (i.e., direct rainwater from roofs and pavement to vegetated areas with gutters). Where high water tables make infiltration systems ineffective, wet ponds and stormwater wetlands are considered a more effective technique. Due to the revised rules, greater use of stormwater BMPs and low impact development are encouraged (Action #4).[18]

The latest stormwater rules have created new flexibility in the stormwater approach that reduces costs, while still protecting water quality. The flexibility and reduction in cost comes from reduction in size of some of the SCM's (i.e., wet pond's vegetative shelf reduced from 10 feet to 6 feet). More flexibility was given in the design of infiltration systems, disconnecting built-upon area, use of smaller SCMs, as well as use of other innovative systems. The new set of rules favors use of infiltration systems over the traditional "store and release" approach. It is important to mention that despite agency efforts to step away from the wet pond approach in stormwater treatment, a large percentage of developers and consultants continue proposing these systems. The stormwater permitting process is being streamlined by implementation of the new "Fast Track" permitting option by scanning of all stormwater files and switching to electronic permitting.

The financial support for the local and state programs to better manage sediment control measures from all land disturbing activities has stayed at about the same level. Several coastal municipalities and counties have their own Stormwater or E & S programs, or both, and are inspected annually. Examples include Goldsboro, Greenville, Pitt County, Nags Head, and Kill Devil Hills. Although Greenville was non-compliant in 2014-2015 and minor non-compliances were noted during annual inspections, the overall efficiency of local programs is high because non-compliances in the field can be monitored regularly (daily/weekly) until corrected. In contrast, the state programs have much higher number of projects per staff and cannot monitor as frequently.

While agricultural activities are exempt from the SPCA, farmers must address erosion and sedimentation control through other means such as reduced tillage, vegetative filter strips/buffers, cover crops and other conservation practices. Farmer education and BMP implementation is addressed by the NC Department of Agriculture and Consumer Services' Division of Soil and Water Conservation, and local Soil and Water Conservation Districts.

DOT Post Construction Stormwater and Best Management Practice (BMP) Retrofit Programs

DOT is required by its NPDES permit to implement a Post-Construction Stormwater Program (PCSP). The primary objective of the PCSP is to manage stormwater runoff from DOT projects by requiring structural and non-structural BMPs to protect water quality. The requirements described in the PCSP apply to DOT projects which increase built-upon area. DOT implements structural BMPs described in the BMP Toolbox and/or non-structural pollution minimization measures described both in the PCSP and the BMP Toolbox.[19]

The NPDES Retrofit Program designs and constructs BMPs retrofitted into existing DOT roadways and facilities. While effective SCMs for new construction minimizes water quality impacts, retrofitting is a means of potentially improving water quality. The program is required by the NPDES permit to implement a minimum of 70 retrofits over the course of the five-year NPDES permit term. In most cases, the stormwater discharge cannot be eliminated due to space constrictions, therefore the goal is to reduce the volume and increase the quality of the stormwater. Criteria for selecting retrofit projects include water quality improvement and the need for stormwater conveyance maintenance.

Collaboration with another organization, such as when a watershed restoration plan has already been developed, will increase project priority. Another role of the Retrofit Program is to test new BMPs or design criteria prior to inclusion in the BMP Toolbox. DOT maintains a geospatial inventory of its roadway system and stormwater outfall assets within priority watersheds. The outfall inventory is used to support the BMP Retrofit Program. There are over 20 different types of BMPs used for stormwater outfall retrofits (Figure 2.6).

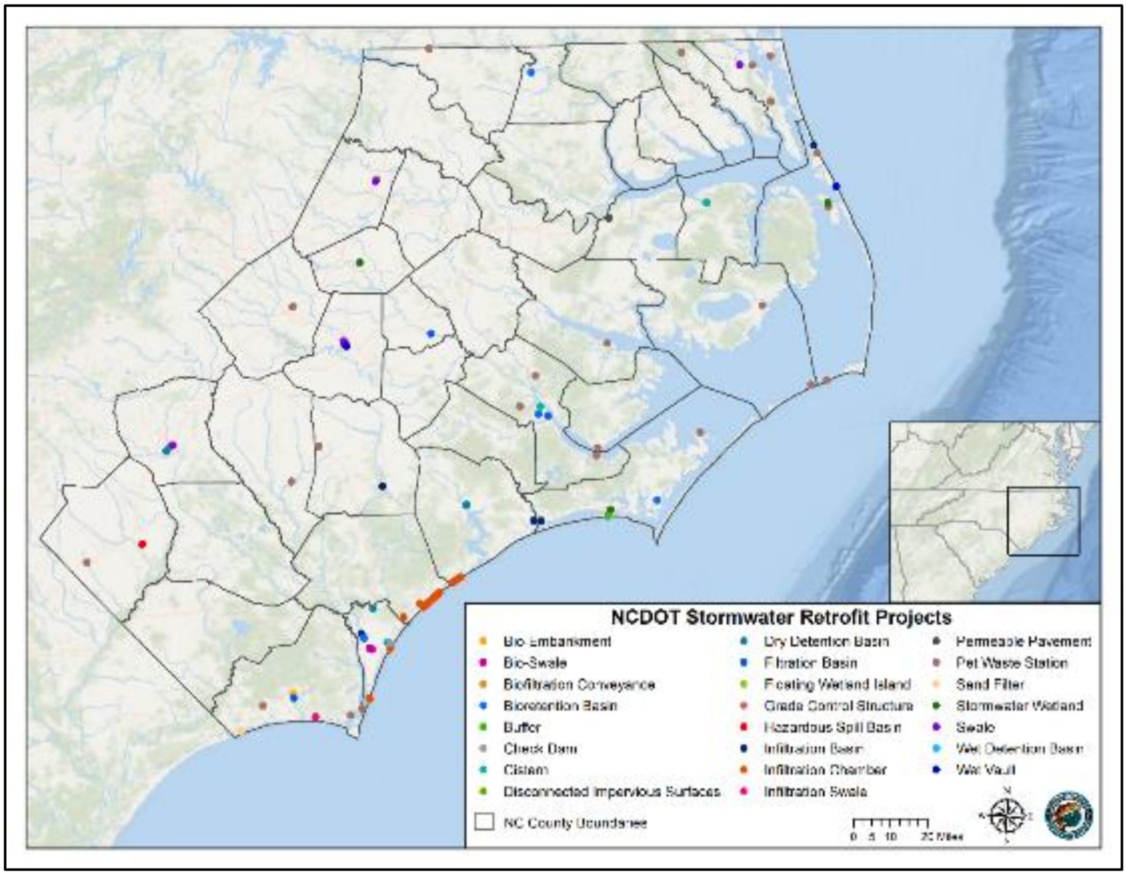

Figure 2.6. North Carolina Department of Transportation (DOT) stormwater retrofit projects completed from 2018 to 2019.[20]

2.4.3 Outreach

Outreach on sedimentation control occurs in several ways within DEMLR, starting at the Regional Office during daily interactions, inspections, and meetings with interested parties, as well as the DEQ website. A 319(h) grant provides funding for one Sediment Education Specialist, for the education and training program mandated by the Sedimentation Pollution Control Act. Outreach is used as a tool to encourage use and proper construction of SCMs in both the Stormwater and E & S programs.

Technical assistance is offered through the Sedimentation and Erosion Control Planning and Design Manual, the companion Field Manual and the Inspectors Guide, and annual workshops for design professionals and local government programs.[21] Another objective of the program is to provide education on erosion and sedimentation control to the general public. Technical expertise has been and will continue to be provided to education professionals to help implement sedimentation pollution awareness in public schools and colleges.

In 2019, two Erosion and Sedimentation Control Design Workshops were conducted for design professionals, with a total of 255 participants. A wide range of experts presented on common erosion and sedimentation issues and solutions based on innovative design and solid research. Additionally, an annual training workshop was conducted for local government staff with delegated local erosion and sediment control programs. Representatives from 45 of the 54 local governments participated in the workshop with a total of 102 participants. State representatives provided updates on the latest regulatory changes, various experts presented on related erosion and sedimentation control topics including planting native, beneficial fill, forestry inspections and research updates from NCSU's Erosion Field Lab. The workshop also provides an opportunity for local programs to connect, learn from each other, and share challenges, strategies, and successes of managing erosion and sediment throughout the state.

In 2019 the Sediment Education Specialist exhibited at and distributed educational materials at the NC Association of Soil and Water Conservation Districts annual meeting, two conferences, and made numerous school visits. One tool often brought to these education outreach events is the Enviroscape, a watershed model that is used to demonstrate point and non-point source pollution.

In 2020, approximately seven trainings were provided on stormwater inspection and maintenance certification; stormwater design and erosion and sediment control plans; stormwater installation; Minimum Design Criteria; rain garden and permeable pavement installation and maintenance.

Stormwater and Erosion Control programs limitations

While progress has been made by DEMLR in controlling sedimentation, more resources are needed to run these programs effectively. The current compliance programs are insufficient to address the large percentage of noncompliant sites and complaints, reducing program efficiency (see Compliance Issue Paper for more information). There is interest in the programs becoming more "user-friendly" for the developing community, yet the impact of sedimentation on the state's estuarine resources continues. In 2020, DEMLR is going through a program evaluation of the E & S, Post-Construction Program with the Stormwater Program to address legislative complaints. Resulting program changes that are implemented will likely affect both programs in a negative way since a goal is to reduce costs of running these programs. To the contrary, more resources are needed to improve compliance and monitoring capabilities of both local and state sediment control programs. Purchasing of new equipment to enhance the monitoring and appropriate training of program staff can be only achieved by increased funding.

2.5 Generating Metrics on Management Success and Habitat Trends

The 2016 CHPP included Generating Metrics on Management Success and Habitat Trends as a priority habitat issue.[1] The participating DEQ divisions have made substantial progress towards achieving and implementing the identified proposed management options. See **Chapter 8: Coastal Habitat Mapping and Monitoring to Assess Status and Trends** for more details on progress made. The 2016 options included:

1. Develop indicator metrics for monitoring the status and trends of each of the six habitat types

within North Carolina's coastal ecosystem (water column, shell bottom, SAV, wetlands, soft bottom, hard bottom).
2. Establish thresholds of habitat quality, quantity, or extent, similar to limit reference points (LRPs)or traffic lights, which would initiate pre-determined management actions.
3. Develop indicators for assessing fish utilization of strategic coastal habitats.
4. Develop performance criteria for measuring success of management decisions.
5. Include specific performance criteria in CHPP management actions where possible.

2.5.1 Submerged Aquatic Vegetation

Substantial progress has been made to establish SAV monitoring protocol and collect data. The APNEP published a revised coastwide map from the 2006-2008 SAV mapping cycle and a new map of the high-salinity zone of the Albemarle Pamlico estuary for the 2012-2014 mapping cycle.[22, 23] The DMF revised and finalized 2015 SAV mapping data for coastal waters south of Bogue Inlet.[24] The APNEP and DMF conducted a coastwide aerial survey in 2019, and re-surveyed in 2020 to improve image quality for interpretation. Funding for the 2019/2020 efforts was supplied by APNEP and DEQ. However, long-term funding to sustain this monitoring is still being sought. Using past SAV delineations and field sampling data collected by a partnership of agencies, APNEP produced a high-salinity SAV extent report and funded a study on the economic value of SAV.[25, 26] The APNEP also completed a monitoring plan for high and low salinity SAV, with input from APNEP's SAV Monitoring Team.[27] In 2021, using methodology set forth by this plan, tier one (aerial survey) and tier 2 (monitoring) data were collected in high salinity regions from Back sound to Bogue Inlet by APNEP and partners, and from Bogue Inlet to Mason Inlet buy DMF and UNC-W.

The APNEP established low salinity SAV sentinel sites for monitoring in Neuse (10) and Pamlico rivers (6), and Albemarle Sound (10), and work is being done to establish a site in Currituck Sound. The protocol used to monitor these sites was developed through CRFL grant funding and employs sonar methodology. These sites have been established and monitored over the last five years, although lack of funding prevented monitoring in 2021. Methods for sentinel site monitoring of the high-salinity zone SAV are being developed through a pilot project. The results will be used to establish a long-term high-salinity SAV monitoring protocol. For additional information, see **Chapters 4. Submerged Aquatic Vegetation Protection and Restoration through Water Quality Improvements** and **Chapter 8. Coastal Habitat Mapping and Monitoring to Assess Status and Trends**.

2.5.2 Shell bottom

Several CRFL funded research projects are examining the use of remote sensing technology, such as sonar and drones, to develop repeatable protocols for mapping and monitoring multiple coastal habitats including intertidal and subtidal oysters, SAV, and wetlands.

In 2019, DMF began a pilot study to explore the use of remote sensing technology, such as drones and sonar, as alternative means of mapping shell bottom. The Estuarine Bottom Habitat Mapping Program is using drones to map intertidal oysters and modifying parameters to establish sentinel sites for more frequent and rapid mapping and monitoring. These changes will greatly increase the efficacy of the Estuarine Bottom Habitat Mapping Program and allow more timely trend assessments of the intertidal oyster population. To enhance subtidal oyster habitat mapping, a vacant position in the Habitat and Enhancement section was repurposed to focus on using side scan sonar to map priority subtidal areas for the Oyster Sanctuary and Clutch Planting Programs with primary focus in Pamlico Sound. For additional information, see **Chapter 8. Coastal Habitat Mapping and Monitoring to Assess Status and Trends**.

2.5.3 Wetlands

Most of the progress in wetlands mapping and monitoring within DEQ has been undertaken by DWR. In 2016, DWR participated in the EPA's National Wetland Condition Assessment (NWCA). As part of this national wetland assessment, 21 wetland sites were surveyed (and two sites twice). The DWR is participating in the 2021 NWCA. In 2021, DWR will also begin sampling for an EPA grant called "The Assessment of Change in North Carolina Coastal Plain Wetlands". This assessment will be looking at new wetland sites as well as known sites surveyed five, 10, and 30 years ago. In addition, NCSU continued the long-term monitoring of a few sites previously monitored by DWR from 2014 through 2018/2019. The DWR is currently awaiting funds from the EPA to initiate a statewide wetland mapping project and a more accurate, publicly available wetland mapping tool for North Carolina.

In addition to the wetlands mapping and monitoring conducted by DWR, other agencies and academics have also contributed to improving wetland status. The DOT developed a LiDAR-based GIS wetland prediction model to update wetland mapping as part of a pilot project. DOT has been working with researchers at University of North Carolina at Charlotte (UNC-C) to automate the modeling process which has resulted in GIS tools that can rapidly predict wetland locations. Ultimately, DOT will use these tools to update wetland mapping across the state which will be accessible in the DOT ATLAS web-based applications. In Back and Bogue sounds, and parts of the Newport and New rivers, some site- specific monitoring has been conducted. Using remotely sensed imagery, rates of saltmarsh shoreline erosion and upland transgression with and without the presence of bulkheads were quantified over a 30-year period.[28] The 2021 CHPP priority habitat issue paper, Wetland Protection and Enhancement through Nature-Based Solutions, provides more detail on shoreline erosion, wetlands loss, and potential mitigating techniques. Other studies have used multiple metrics (i.e., elevation, accretion, sediment supply, SLR) to assess the vulnerability of salt marshes to SLR at National Estuarine Research Reserves (NERRs) across the country. In NC, Masonboro Island Reserve near Wilmington was assessed and found to have very low resilience to SLR.[29] For additional information, see **Chapter 3. Climate Change and Coastal Habitat Resiliency** and **Chapter 5. Wetland Protection and Restoration through Nature-Based Solutions**.

2.5.4 Strategic Habitat Areas

Since the 2016 CHPP, the nomination of Strategic Habitats Areas (SHAs) was completed for all four CHPP regions, with Region 4 (The Cape Fear River Basin) nominations being approved by the Marine Fisheries Commission at the May 2018 business meeting (NCDMF 2018).[30, 31, 32, 33] The same year, a CRFL grant provided funding to begin the validation of the fish use and habitat condition of the nominated SHAs. The first two years of the study focused on CHPP Region 3 (The White Oak River Basin). Multiple sampling gears are used to collect various fish and habitat metrics to compare fish abundance and diversity and habitat condition between SHA nominations and areas not nominated as SHAs. Sampling in CHPP Region 3 was completed in the fall of 2019 with a total of 252 sampling events (126 SHAs and 126 Non-SHAs). In the spring of 2020, the study expanded into CHPP Region 4 and analysis of the CHPP Region 3 data is underway. The expansion of the study into the larger waters of CHPP Region 1

(Albemarle Sound) and Region 2 (Pamlico Sound) is also being examined. The results of this study will be used to validate or modify the existing SHA nominations and provides a foundation for the ecological evaluation of management areas such as designated nursery and spawning areas.

The progress made towards establishing baseline habitat conditions through sentinel sites and long-term monitoring of coastal habitats, and the validation and verification of SHAs in all CHPP regions is the foundation for establishing management thresholds for coastal habitats. The quality, quantity, and extent of the coastal habitats in North Carolina must be identified before management thresholds can be applied. This was recognized by the CSC during the selection of priority habitat issues for this update. For additional information, see **Chapter 4. Submerged Aquatic Vegetation Protection and Restoration through Water Quality Improvements, Chapter 5. Wetland Protection and Restoration through Nature-Based Solutions,** and **Chapter 8. Coastal Habitat Mapping and Monitoring to Assess Status and Trends**.

2.6 Implementation Progress on Other Coastal Habitat Protection Plan Recommendations

In addition to the priority habitat issues, progress has occurred with other recommendations from the 2016 CHPP. One implementation action to aid in compliance with existing rules and permits (Recommendation 1.1) was to "cross train Marine Patrol officers to take note of and report violations of CRC and EMC rules and permits in coastal waters to appropriate agencies".[1] The DCM staff conducted training in 2019 to DMF's Marine Patrol staff in the Northern and Central districts and over 60 officers attended. Background on CAMA jurisdictional areas and rules was provided. They were shown how to look for unusual activity such as heavy equipment on the shoreline, projects that stand out like excessively longer pier than surrounding areas, fresh dirt piled on vegetation without a silt fence, new looking boatlifts or docks in very shallow primary nursery areas (PNAs), and bulkheads unusually far from the shoreline. The officers were receptive to assisting when out in the field and provided flights to assess potential violations periodically.

Considerable work continues to be done by DEQ regarding expanding outreach on fish habitat value, threats, and explanations of management measures (Recommendation 1.3). One implementation action was to provide educational information to school children (K-12) regarding biodiversity and value of estuaries. Towards this, APNEP has an ongoing Shad in the Classroom program. An education specialist position with DWR was filled in 2017. Through that, staff conduct live workshops and online modules. The primary programs are Project WET (reached 500-3780 students/ year 2017-2020); It's Our Water Online Module (reached 80-680 students per year from 2017 to 2020), and NC Stream Watch. Other smaller programs and school visits are also done. Project WET, NC Sea Grant, NC Water Resources Research Institute (WRRI), and NC Watershed Stewardship Network partnered to create a new PBS online program called Watershed Wisdom that includes interactive lessons/videos. The Soil and Water Conservation Districts continue with Envirothon training and competition, Resource Conservation workshops, school field days, and Poster and essay contests.

One implementation action to restore fish passage for migratory fishes through elimination or modification of stream obstructions (Recommendation 3.5b) was "the DEQ, through the DWR and Division of Mitigation Services (DMS) will pursue dam removal projects where appropriate".[1] Staff from DWR participate in the NC Aquatic Connectivity Team, a group of experts that manage dam removal projects within the state of North Carolina. American Rivers and Southeast Aquatic Resources

Partnership (SARP) provide technical support on barrier identification, inventory, and prioritizations. Several projects were completed 2018-2020 in the coastal draining river basins by DWR and DMS (Table 2.1). Additionally, Milburnie Dam on the Neuse River was removed by a restoration company for mitigation bank credits. The DEQ actively engaged with the USACE to encourage transfer of the Lock and Dams on the Cape Fear River to the Department. The outcome of that effort has not yet been determined.

Table 2.1. Barrier removals or modifications completed by North Carolina Divisions of Water Resources and Mitigation Services and partners in coastal river basins, 2018-2020.[34]

River Basin	Dam removal	Culvert, ditch, or pond modifications
Chowan	-	3
Neuse	4	5
Cape Fear	-	4
Lumber	-	2

Managing stormwater will not only reduce sediment loading as discussed earlier in the chapter, but also nutrient and bacteria loading. The revised stormwater rules, stormwater design manual, and minimum design criteria support Recommendations 4.5, "to improve strategies to reduce nonpoint pollution and minimize cumulative losses of fish habitat through voluntary actions, assistance, and incentives, including a) improved methods to reduce pollution from construction, agriculture, and forestry; and b) increased on-site infiltration of stormwater; and c) encouraging and providing incentives for implementation of Low Impact Development practices."[1] Additionally, the recently readopted Neuse and Tar-Pamlico nutrient stormwater rules require implementation of the Division's Stormwater Nitrogen And Phosphorus (SNAP) calculator for new development activity subject to those rules. The rules also require annual electronic reporting from local governments, which will include exported SNAP data from developments within their jurisdictions. Taken together, the rules provide the division data to maintain effective regulatory strategies for water quality (Recommendation 4.6).[1] The DWR, through the Nutrient Criteria Development Plan (NCDP), is evaluating existing nutrient-related criteria and will consider changes needed to support aquatic life in the Albemarle Sound region. For additional information, see **Chapter 4. Submerged Aquatic Vegetation Protection and Restoration through Water Quality Improvements**.

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3. CLIMATE CHANGE AND RESILIENCY

3.1 Introduction

Impacts from climate change including sea level rise (SLR) will affect all coastal habitats and species throughout NC. On October 29, 2018 in the wake of Hurricane Florence, NC's Governor Roy Cooper signed Executive Order 80 – NC's Commitment to Address Climate Change and Transition to a Clean Energy Economy (EO80) directing all cabinet agencies to integrate climate adaptation and resiliency planning into their policies, programs, and operations.[1] As part of this executive order, the Climate Change Interagency Council (Council) was created including members from all of the cabinet agencies. The Department of Environmental Quality (DEQ) was tasked to serve as the lead agency the with the Secretary of DEQ serving as Council chair.

Staff from all DEQ divisions were active on the Council and associated working groups. These working groups, along with staff from the National Oceanic and Atmospheric Administration (NOAA), National Centers for Environmental Information (NCEI), North Carolina State University's (NCSU) Institute for Climate Studies (NCICS), Duke University's Nicholas School of the Environment, and numerous other academics and stakeholders, developed a state-specific NC Climate Science Report (NCCSR), assessed hazards and risks associated with climate change, and compiled a Natural Working Lands (NWL) Report.[2, 3] These efforts were incorporated into the 2020 NC Risk Assessment and Resilience Plan (2020 Resilience Plan)[4] with strategies and recommendations to increase carbon sequestration and resiliency of coastal habitats and communities. The 2016 CHPP provided valuable information during this process and many of the goals and recommendations from the 2016 CHPP were aligned in the 2020 Resilience Plan and NWL Action Plan.[5] Likewise, aspects of the NCCSR, 2020 Resilience Plan, and the NWL Action Plan will be integrated into this CHPP update wherever possible.

3.2 Background

The foundation for addressing climate change related issues is the NCCSR, which is a scientific assessment of historical climate trends and potential future climate change specific to NC under increased greenhouse gas (GHG) concentrations.[2] For the NCCSR, statements about future changes refer to projections through the end of this century, and the following definitions apply:

Virtually Certain = 99-100% probability of outcome
Very Likely = 90-100% probability of outcome
Likely = 66-100% probability of outcome

The scientific understanding of the climate system strongly supports the conclusion that large changes in NC's climate, much larger than at any time in the state's history, are very likely by the end of this century under both the lower and higher GHG concentration scenarios.

North Carolina's annual average temperature has increased by about 1.0°F since 1895, somewhat less than the global average.[2] However, the most recent 10 years (2009-2018) represent the warmest 10-year period on record in NC, averaging about 0.6°F warmer than the warmest decade in the 20th century (1930-1939). Recently released data for 2019 indicate that it was the warmest year on record for NC. Although regional changes in temperature can vary from global changes, it is very likely that NC temperatures will also increase substantially in all seasons. It is also very likely that the number of warm and very warm nights will increase, and summer heat index values will increase due to increases in absolute humidity. Just as the number of hot and very hot days is likely to increase, the number of cold days will likely decrease. Along the northeastern coast of NC, SLR is occurring about twice as fast as along the southeastern coast, averaging 1.8 inches per decade since 1978 at Duck, NC, and 0.9 inches per decade since 1935 at Wilmington, NC (Figure 3.1). It is virtually certain that SLR along the NC coast will continue to increase due to expansion of ocean water from warming and melting of ice on land, such as the Greenland and Antarctic ice sheets.

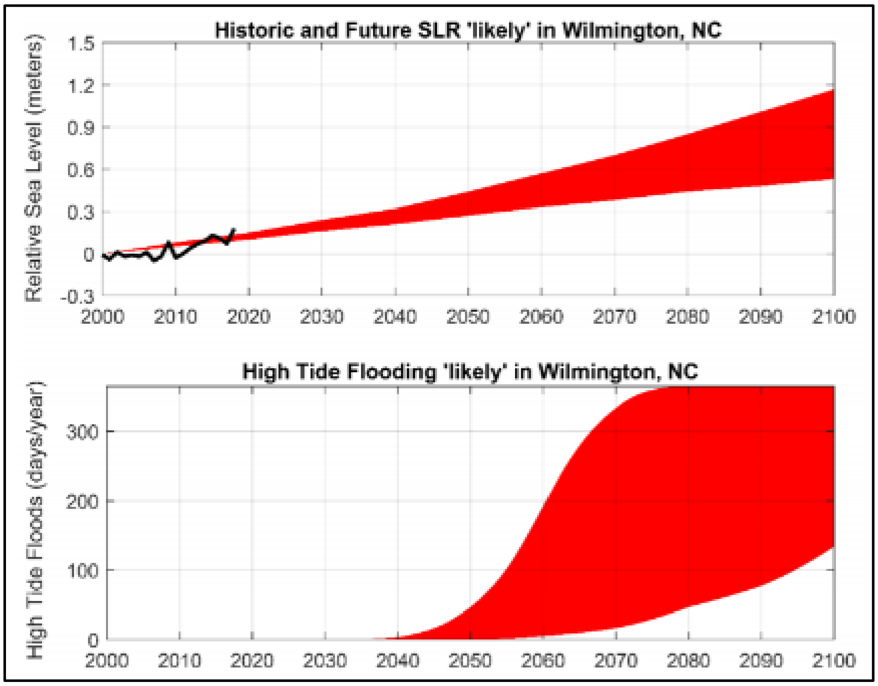

Figure 3.1. Historic and future relative sea level rise (SLR) and high tide flood events in Wilmington, NC.[2]

In NC, hurricanes have some of the most important impacts on the state, often catastrophic (storm surge, wind, and flooding damage), but sometimes environmentally beneficial (rainfall recharging soil moisture and groundwater aquifers). The intensity of the strongest hurricanes is likely to increase with warming temperature that could result in stronger hurricanes impacting NC.[2] Heavy precipitation accompanying hurricanes that pass near or over NC is very likely to increase, which would in turn increase the potential for freshwater flooding. These events could have major ramifications on the hydrology, carbon and nutrient loads, and habitat and water quality in the state. However, there is low confidence concerning future changes in the number of hurricanes making landfall in NC. Additionally, it is likely that the frequency of severe thunderstorms and the annual total precipitation in NC will increase. It is very likely that extreme precipitation frequency and intensity in NC will increase due to increases in atmospheric water vapor content. So, it is virtually certain that SLR and increasing intensity of coastal storms, especially hurricanes, will lead to increases in storm surge flooding in coastal NC. Additionally, changes to salinity, water temperatures, depth, and wave exposure are expected to affect habitat and fish distribution.

The repeated impacts and compounding losses from the effects of climate change, such as stronger hurricanes, more severe storms, SLR, and associated flooding events can be catastrophic not only to the coastal communities, but to the coastal habitats and the ecosystem services they support. While the risk and hazards associated with climate change and natural disasters cannot be eliminated, their affects can be lessened by increasing coastal resilience. Coastal resilience can be broken down into two parts that are intertwined: 1) community resiliency – the ability of a community to withstand, respond to, and recover from a disruption, and 2) ecosystem resiliency – the ability of the natural environment to withstand, respond to, and recover from a disruption, such as hurricanes, tropical storms, and flooding.[4] A resilient ecosystem is able to bounce back from disturbances over time while resistant ecosystems may withstand a disturbance or two but over time the ecosystem function is lost and unable to recover (Figure 3.2).

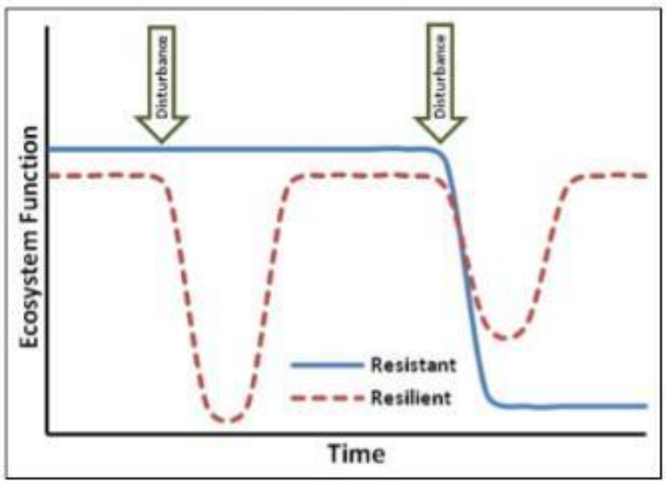

Figure 3.2. Illustration of the response of ecosystem function of resistant and resilient ecosystems after multiple disturbances.

3.3 Discussion

Coastal habitats contribute to the resilience and resistance of coastal communities and ecosystems by reducing coastal erosion and flooding by stabilizing sediment and attenuating waves (Figure 3.3a).[6, 7, 8] In NC, dunes are especially important for protecting the communities and habitats on the barrier islands, which are frequently exposed to waves and ocean overwash (Figure 3.3b). Other habitats like salt marsh and coastal forests also provide significant protection (Figure 3.3c).

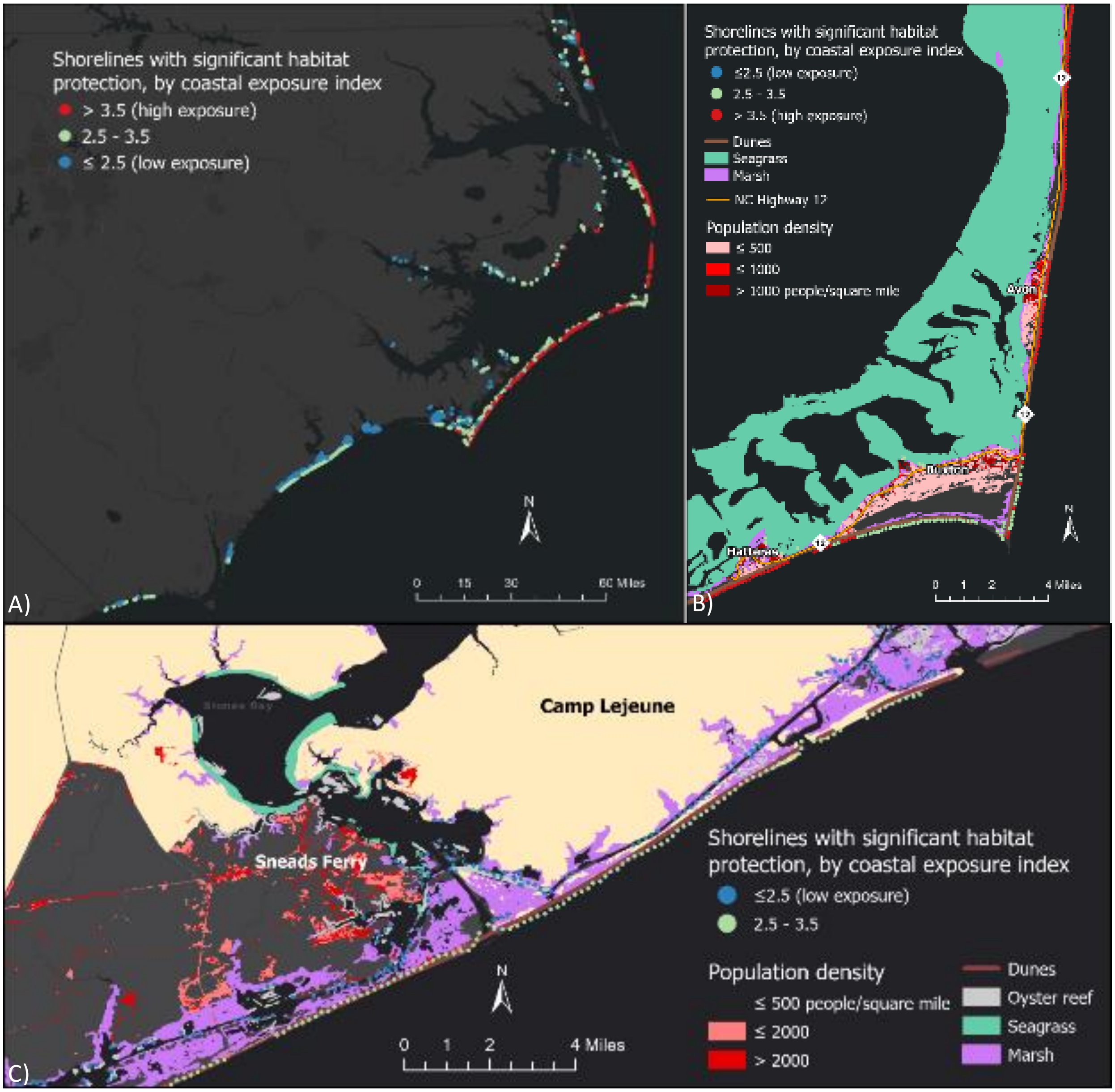

Figure 3.3. Shoreline protection by coastal habitats in North Carolina. (a) Sections of the North Carolina shoreline that benefit from significant protection by coastal habitats. Colors indicate how exposed the shoreline is to coastal hazards such as flooding and erosion. (b) Dunes protect the Outer Banks communities of Hatteras and Avon, in addition to North Carolina Highway 12, the only access route for residents and tourists. (c) Salt marsh and dunes protect Camp Lejeune and the town of Sneads Ferry. Maps adapted from an updated analysis originally conducted for the 2020 NC Risk and Resilience Plan.[4, 9]

Impacts from climate change including sea level rise (SLR) will affect all coastal habitats and species throughout NC. Therefore, actions should be taken to make them more resilient to these disturbances and ensure coastal habitats and their valuable ecosystem services continue to persist. Changes to environmental variables, such as increased water temperatures due to warmer air temperatures and salinity due to increased freshwater runoff or breached inlets from hurricanes, will impact the distribution, range, and abundance of coastal habitats and the species that use them for nursery, forage, spawning, and refuge. Impacts can be minimized and coastal resilience can be increased by conserving, protecting, and restoring coastal habitats that provide valuable ecosystem services and using natural and nature based infrastructure wherever possible.

Wetland loss due to SLR will likely outpace the rate of wetland migration inland in many areas, especially under higher rates of SLR (Figure 3.4). Currently, NC has about 220,000 acres of salt marsh. Much of this marsh is projected to be lost through drowning or erosion by the end of the century. Sea level rise will allow some marshes to migrate inland, partially offsetting the loss. In the lowest SLR scenario, there may be more marsh in 2100 than currently exists. However, the potential for marsh migration decreases at higher SLR elevations, resulting in greater net marsh loss.

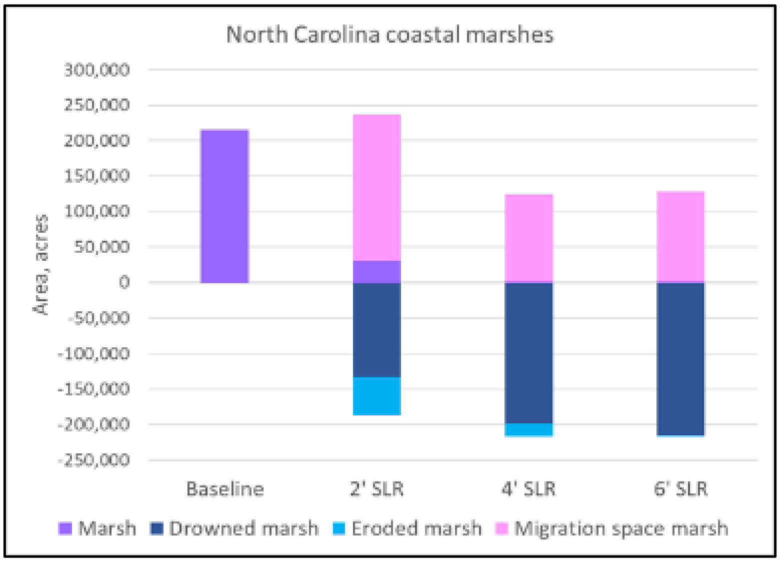

Figure 3.4. Projected coastal marsh area under three sea level rise (SLR) scenarios representing 2-6 feet of SLR by 2100, in comparison to current marsh extent. As SLR elevation increases, so does the area of marsh that is projected to drown due to SLR. North Carolina's low-lying coastal plain provides space for marsh migration under the lowest SLR scenario, but less space is available for migration under the higher scenarios. Data from an updated analysis originally conducted for the NC 2020 Risk and Resilience Plan.[4, 9]

Assessing when certain areas of coastal marshes are likely to be lost due to SLR can help prioritize conservation and restoration (Figure 3.5). For example, marshes that are very vulnerable to SLR (projected to drown by 2050) are likely to need extensive intervention, such as thin-layer sediment deposition, to survive and may be too risky for investing limited resources for restoration. Marshes projected to persist to the end of the century could be good candidates for conservation and management to ensure they remain as healthy as possible.

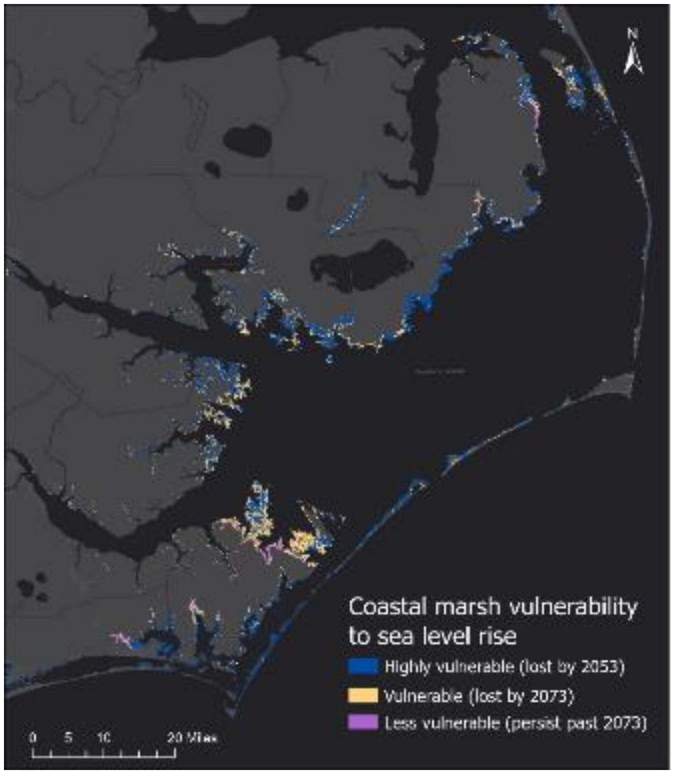

Figure 3.5. North Carolina coastal marshes' vulnerability to sea level rise (SLR). 134,000 acres (62 percent) of North Carolina's marshes are projected to drown by 2053 and 194,000 acres (90 percent) by 2073 under the scenario projecting four feet of SLR by 2100.

Loss of wetlands will result in habitat losses that will impact the species that use them and degrade water quality due to the reduction in buffering capacity of nutrient rich stormwater runoff. For additional information, see **Chapter 5. Wetland Protection and Restoration through Nature-Based Solutions**. Extreme precipitation events result in flooding which leads to high loads of organic matter and organic nitrogen and phosphorus, fueling phytoplankton production and resulting in algal blooms and associated hypoxia. Runoff from agricultural fields and urban development also add to the contamination of floodwaters into the watershed. These impacts to water quality could have major detrimental effects on coastal habitats in NC.

Coastal marshes not only provide essential habitat and protect shorelines, but also store large amounts of carbon in their sediments. North Carolina's coastal marshes are currently estimated to store about 64 million metric tons CO_2-e, equivalent to the state's gross GHG emission for five months.[10] These marshes are continuing to lock away approximately 200,000 metric tons CO_2-e each year. When marshes drown or erode, not only do we lose their ongoing carbon sequestration function, but a significant proportion of this carbon is also released to the atmosphere, contributing to GHG emissions. Marsh loss due to SLR may turn NC's coastal habitats from a carbon sink into a carbon source (Figure 3.6).

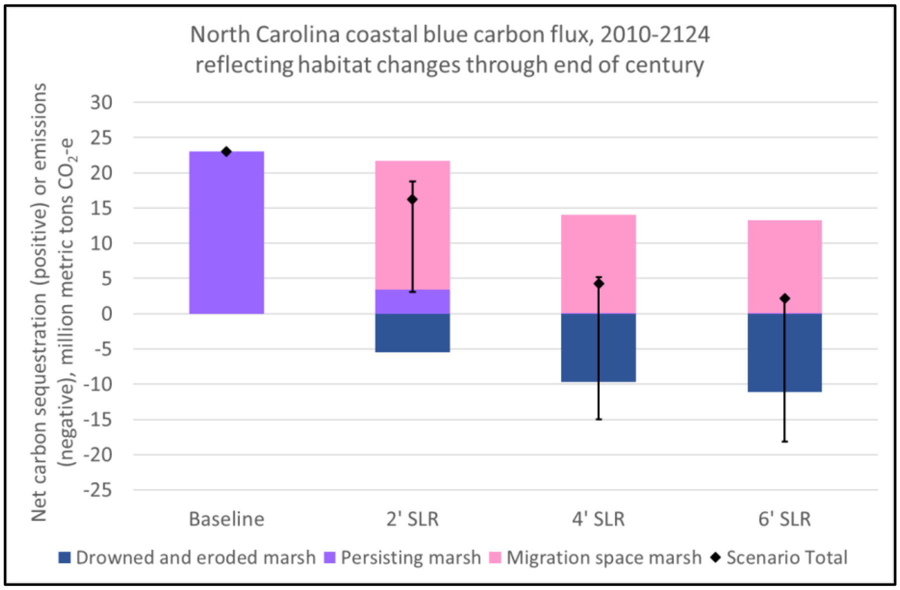

Figure 3.6. Projected net carbon flux from North Carolina marshes through 2124, reflecting marsh loss due to sea level rise (SLR) compared to a baseline scenario (no SLR). Positive values indicate carbon sequestration by marshes; negative values indicate carbon released from drowned or eroded marshes. The black diamond shows the net carbon flux (sequestration minus emissions) for the scenario. There is high uncertainty about how much stored carbon is released when marshes drown or erode. These results assume 25 percent loss; the error bars show the range in net carbon flux when that assumption is varied. Data from an updated analysis originally conducted for the 2020 Resilience Plan.[4, 9]

Submerged aquatic vegetation (SAV), also known as seagrass or underwater grass, is a critical coastal habitat for many important aquatic species, and is also highly responsive to degraded water quality including changes in salinity, water temperature, and water clarity, making SAV an ideal indicator species for water quality and climate change impacts. The expected changes to water conditions due to climate change are likely to result in varying distribution and reduced abundance of SAV. The impairment of water quality is one of the most widespread threats to SAV ecosystems, with global losses estimated at over 29 percent during the last century.[11] Along the Atlantic seaboard, SAV has already experienced significant declines directly or indirectly attributed to the stressors associated with degraded water quality. What distinguishes NC from other coastal seagrass systems on the Atlantic seaboard is the overlapping distribution of temperate and tropical seagrasses in the higher salinity waters: eel grass, *Zostera marina*, a temperate grass at the southernmost extent of its range, and shoal grass, *Halodule wrightii*, a tropical grass at the northern most extent of its range. It has been suggested that under the current emissions scenario, it is likely that eelgrass will be extirpated in NC and the Chesapeake Bay with the new southern range as far north as Long Island Sound by 2100.[12]

The effects of the climate-change-driven shift in distribution of SAV species will affect the aquatic organisms of the coast of NC that use the SAV as nursery areas, refuge from predation, and foraging for food. It has also been indicated that there is a potential for increased Harmful Algal Bloom (HAB) occurrence due to increased nutrient loading in the water and increasing water temperature attributed to changing climate.[13] In addition to causing detrimental impacts to water quality, fish, and habitats, particularly submerged aquatic vegetation (SAV) and shell bottom, HABs are unsightly, malodorous, and potentially hazardous to humans and pets if exposed to contaminated waters or consumed shellfish that have taken up the algae toxins. For additional information, see **Chapter 4. Submerged Aquatic Vegetation Protection and Restoration through Water Quality Improvements**.

Shell bottom, composed of living or dead shellfish serves as both an important commercial and recreational fishery resource and an essential coastal habitat. Shellfish species found in NC include the Eastern oyster (*Crassostrea virginica*), Northern quahog or clam (*Mercenaria mercenaria*), and bay scallop (*Argopecten irradians*). Increased precipitation from hurricanes and storm events coupled with wetlands loss will increase the amount of nutrient rich and polluted stormwater runoff entering the estuaries. This can lead to hypoxic (low oxygen) conditions, resulting in mass mortality of shellfish and finfish. Smaller storm events can result in the closure of shellfish growing areas and recreational swimming advisories, all of which have economic impacts to the resource and the use of the public trust waters of NC. As sea level continues to rise, intertidal oysters will become inundated and must adapt to the subtidal environment. Additionally, increased water temperatures could result in more occurrences of illness from naturally occurring *Vibrio* species from shellfish consumption, which is a significant public health issue and can also disrupt shellfish markets.[14] The acidification of ocean waters, a consequence of excess carbon dioxide in the atmosphere, will also cause oysters and other shellfish to be unable to grow their shells. The loss of shell bottom habitat will not only affect these important fisheries, but the marine organisms that rely on them for habitat. As shell bottom and other coastal habitats are lost or shift in distribution and abundance due to climate change and anthropogenic impacts, they will need to be mapped and monitored to assess these changes and habitat conditions to ensure they persist. For additional information, see **Chapter 8. Coastal Habitat Mapping and Monitoring to Assess Status and Trends**.

The predicted impacts of climate change will have direct impacts on the finfish and invertebrate populations off NC's coast. In recent years, it has been predicted that hundreds of finfish and invertebrate species will be forced to move northward by climate change.[15] The range of valuable fisheries species in NC, including black sea bass (*Centropristis striata*) and summer flounder (*Paralichthys dentatus*), have already been seen shifting northward while other species such as white shrimp (*Litopenaeus setiferus)* are having greater biomass following warm winters.[16] Other species, such as spot *(Leiostomus xanthurus*) are shifting their migration route to occur further offshore or deeper in the water column, affecting catchability.[17] Environmental changes are affecting how species use certain estuaries and habitat types, such as bull sharks (*Carcharhinus leucas*) using NC's estuary as a nursery area when it has historically only been used as foraging grounds for adults.[18] Some species like Cobia (*Rachycentron canadum*) may be able to withstand the environmental fluctuations due to climate change that occur in coastal habitats and the broad environmental conditions their prey items can tolerate.[19] Under some future climate change scenarios, spotted seatrout (*Cynoscion nebulosus*) have been shown to increase range due to increased habitat suitability. However, under the same scenarios, their prey species show significant decreases which could result in a food-limited population.[20]

In addition to shifts in coastal habitat availability and species distribution, economic impacts and regulatory issues due to impacts from climate change will need to be addressed. North Carolina already exhibits one of the greatest northward shifts in commercial fishing effort, with average vessel landings occurring 24km further north each year.[21] As finfish move north, the commercial fishermen follow, resulting in NC fishermen landing more finfish in NC ports that were caught outside of state waters. This can cause confounding regulatory issues when trying to determine the new or expanded ranges and distributions of the finfish species. The management of commercially and recreationally important finfish and shellfish species and the coastal habitat they call home is vital to ensuring the sustainability of these species.

Since its inception, the CHPP has focused on identifying threats and recommending management actions to protect and restore habitats critical to NC's coastal fishery resources. The 2016 CHPP included priority habitat issues focused on oyster restoration, living shorelines, sedimentation, and developing metrics to assess habitat trends along with implementation actions such as improving water quality by reducing stormwater runoff. These issues and actions are not only beneficial to the fishery habitats, but also increase coastal community and ecosystem resilience to climate change stressors. The CHPP has and will continue to highlight the importance of conserving, protecting, and restoring coastal habitats and the ecosystem services they provide, and will integrate climate adaptation and resiliency planning wherever possible. Recommendations and implementation actions from CHPP will continue to support and align with the 2020 Resilience Plan and NWL Action Plan.[2, 4] With more interest and urgency sparked by the storm events of the last several years and Governor Cooper's EO80, the CHPP will play an even more important role in ensuring the future of coastal fishery habitats for the benefit and resiliency of all North Carolinians.1

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Photo Credit: Chris Voss

4. SUBMERGED AQUATIC VEGETATION PROTECTION AND RESTORATION THROUGH WATER QUALITY IMPROVEMENTS

4.1 Issue

Protection and restoration of submerged aquatic vegetation (SAV) is critical for healthy fisheries in NC while providing additional valuable ecosystem functions and benefits that enhance coastal resiliency of aquatic life and coastal communities. Nationally, water quality, in particular water clarity, is recognized as one of the most significant factors limiting SAV distribution, abundance, survival, and expansion. Regionally, on the Atlantic seaboard of the US, large declines of SAV have been attributed to impaired water quality in neighboring estuaries both north (Chesapeake Bay) and south (Indian River Lagoon, FL) of NC. Environmental monitoring data indicate that water quality is also having an adverse impact on SAV in NC estuarine waters, especially in the lower salinity regions more directly impacted by numerous watersheds and coastal land use. Water quality impairment coupled with the expectation of sea level rise (SLR) and increasing water temperatures associated with climate change, will expose all NC SAV to multiple stressors that can limit their growth, reproduction, and distribution.

4.2 Background

Currently, NC is steward to one of the most productive and biodiverse SAV resources on the Atlantic seaboard, including the largest polyhaline and mesohaline seagrass meadows in the temperate western Atlantic.[1, 2, 3, 4, 5, 6] SAV habitat is the foundation for ecological services that directly benefit the coastal ecosystems of NC and neighboring states.[7, 8] These services include primary and secondary fisheries production, habitat for fish, wildlife and waterfowl, sediment and shoreline stabilization, wave energy attenuation, water purification, and carbon sequestration. Recently, it has been shown that SAV may reduce bacterial pathogens that can cause disease in humans and marine organisms.[9] All these services are important to ecosystem health and provide increased community and ecosystem resilience.[10] Resource valuation studies indicate that the monetary value of the ecosystem services provided makes SAV habitat protection and restoration a priority conservation and management issue. SAV contributes to coastal resilience and economic and cultural values from local coastal communities and residents statewide, to the millions of annual visitors to NC.[6, 11, 12, 13, 14, 15]

Through work funded by Albemarle-Pamlico National Estuary Partnership (APNEP), it has been reported that estimates of economic loss increase proportionately with declines in SAV in the Albemarle-Pamlico estuary.[16] Based on economic losses to commercial and recreational fisheries, residential property values, and carbon sequestration, they conservatively estimated an aggregate loss of $1,290 per acre over the next decade. It was found that a five percent decadal decline in SAV acreage would generate total economic loss of $8.6 million in 2019 dollars. If SAV acreage loss were to accelerate to 50 percent, the estimated total economic loss would be $88.7 million over a decade. In both cases, most of the loss comes from declines in carbon sequestration.

Submerged aquatic vegetation is important to many aquatic organisms at some point in their life cycle, with fish and invertebrates depending on SAV for refuge, spawning, nursery, foraging, and corridor needs.[1] Because of the seasonal abundance patterns of SAV, refuge and foraging habitat are provided almost year round for estuarine-dependent species.[17] Fish and invertebrate use of SAV differs spatially and temporally due to distribution ranges, time of recruitment, and life histories.[18, 19, 20] Table 4.1

provides a list of species that use SAV in NC.

Table 4.1. List of fish and invertebrates documented to use Submerged Aquatic Vegetation (SAV) in NC. Names in bold are species with relative abundances reported in literature as higher in SAV than other habitats. Note: lack of bolding does not imply non-selective use of the habitat, but lack of information.[1, 6, 21, 22, 23, 24, 25]

	Submerged Aquatic Vegetation (SAV) Functions				
Species	Refuge	Spawning	Nursery	Foraging	Corridor
River herring*	X		X	X	X
Striped bass				X	
Yellow perch		**X**			
American eel	X		X	X	X
Bay scallop	**X**	**X**	**X**	**X**	
Blue crab	**X**		**X**	**X**	**X**
Grass shrimp	**X**		**X**	**X**	
Hard clam	**X**		**X**	**X**	
Red drum	**X**		**X**	**X**	**X**
Spotted seatrout	**X**	**X**	**X**	**X**	**X**
Weakfish	X		X	X	X
Atlantic croaker	X		X	X	X
Atlantic menhaden	X		X	X	X
Brown shrimp	**X**		**X**	**X**	**X**
Southern flounder			X	X	
Spot	X		X	X	X
Striped mullet	X		X	X	X
White shrimp	X		X	X	X
Black sea bass	X		X	X	X
Bluefish			X	X	
Gag	X		X	X	X
Kingfish spp.	X		X	X	X
Pinfish	**X**		**X**	**X**	**X**
Pink shrimp	**X**		**X**	**X**	**X**
Smooth dogfish				**X**	
Spanish mackerel			X	X	
Summer flounder			X	X	

*Includes blueback herring and alewife

The Fisheries Reform Act of 1997 requires the DMF to prepare fishery management plans (FMP) for adoption by the NC Marine Fisheries Commission (MFC) for all commercially and recreationally significant species or fisheries that comprise state marine and estuarine resources. The goal of the plans is to ensure long-term viability of these fisheries. Fisheries habitat and water quality considerations are one of several requirements of these plans and are to be consistent with the CHPP. Several state FMPs list SAV and water quality management actions because of the importance of SAV and water quality to the different fisheries that are managed and prosecuted within the state. The Blue Crab Fishery Management Plan Amendment 3 is the latest plan with management actions that focus on water quality.[26] One action specifically tasks the CHPP Steering Committee to prioritize blue crab water quality impacts (Table 4.2). The Blue Crab FMP is one of several FMPs that have both SAV and water quality management actions that overlap with the CHPP issue of protection and restoration of SAV through water quality improvements (Table 4.2).

Table 4.2. North Carolina State Fishery Management Plans with submerged aquatic vegetation (SAV) and water quality management actions.

NC Fishery Management Plan	Habitat and Water Quality Management Actions
Bay Scallop Amendment 2 (2015)[27]	• Remap and monitor SAV coverage in NC to assess distribution and change over time • Restore coastal wetlands to compensate for previous losses and enhance water quality conditions for the bay scallop • Improve methods to reduce sediment and nutrient pollution from construction sites, agriculture, and forestry • Reduce impervious surfaces and increase on-site infiltration of stormwater through voluntary or regulatory measures • Aggressively reduce point and non-point nutrient and sediment loading in estuarine waters, to levels that will sustain SAV habitat, using regulatory and non-regulatory actions
Blue Crab Amendment 3 (2020)[26]	• Create a joint interagency work group • Task the CHPP steering committee to prioritize blue crab water quality impacts • Send letters to other state agencies sharing concerns about water quality and Best Management Practices • Invite other agencies to future Marine Fisheries Commission (MFC) meetings to present their efforts to address water quality
Estuarine Striped Bass Amendment 1 (2013)[28]	• Work with NC Wildlife Resources Commission (WRC), Division of Water Resources (DWR), and others to implement management measures that will enhance water quality in Strategic Habitat Areas (SHAs) used by striped bass • Division of Marine Fisheries (DMF) and WRC should work with DWR and other agencies to initiate efforts to determine and establish more stringent water quality standards in waters designated as Anadromous Fish Spawning Areas (AFSAs)
Kingfishes (2007)[29]	• Reduce nutrient and sediment loading in the Albemarle-Pamlico system, particularly the Neuse and Tar-Pamlico rivers, to levels that will support SAV, using regulatory and non-regulatory actions • Improve methods to reduce sediment and nutrient pollution from construction sites, agriculture, and forestry • Increase on-site infiltration of stormwater through voluntary or regulatory measures • Modify stormwater rules to more effectively reduce the volume and pollutant loading of stormwater runoff entering coastal waters
River Herring Amendment 2 (2015)[30]	• Work with other agencies to identify potential incentives for landowners for protection of riparian buffers in the management area • Develop, identify and clarify what critical habitat actions are needed to protect, enhance and restore habitats and water quality affecting river herring.
Southern Flounder Amendment 1 (2013)[31]	• Coordinate SAV mapping efforts such that statewide monitoring and trend analysis can be conducted most efficiently • Reduce point and non-point nutrient and sediment loading in estuarine waters, to levels that will sustain SAV, using relevant standards and regulatory/non-regulatory actions • Acquire updated and coast-wide data on bathymetry, sediment type, and pollutant concentrations • Increase coverage of waters assessed for aquatic life and increase coverage of continuous monitoring stations • Restore hydrology on lands used for silvaculture, agriculture, and urban development using Best Management Practices (BMPs)
Spotted Seatrout Revision (2014)[32]	• Continue mapping of SAV in NC to assess distribution and change over time • Aggressively reduce point and non-point nutrient and sediment loading in estuarine waters, to levels that will sustain SAV, using regulatory and non-regulatory actions

NC Fishery Management Plan	Habitat and Water Quality Management Actions
	• Work with National Oceanic and Atmospheric Administration (NOAA) and DWR to determine appropriate levels of total suspended solids (TSS), turbidity, chlorophyll a, and other water clarity parameters to achieve adequate water quality conditions for SAV growth, and model potential SAV habitat • Improve methods to reduce sediment and nutrient pollution from construction sites, agriculture, and forestry • Increase on-site infiltration of stormwater through voluntary or regulatory measures • Work with DWR and the NC Environmental Management Commission (EMC) to modify stormwater rules to more effectively reduce runoff volume and pollutant loading to coastal waters to levels that protect and enhance fish habitats vital to spotted seatrout • Reduce impervious surfaces associated with new development as much as possible and reduce the maximum amount of impervious surfaces allowed in the absence of engineered stormwater controls
Striped Mullet Amendment 1 (2015)[33]	• Develop and maintain accurate maps and documentation of wetlands, soft bottom, SAVs, and water column • Support research on the causes of hypoxia and anoxia and impacts on striped mullet populations in NC's estuarine waters

There are two distinct groups of SAV habitats in NC distributed according to estuarine salinity. One group thrives in fresh and low salinity riverine waters ($\leq$10 ppt), referred to as low salinity SAV. The second group occurs in moderate to high (>10 ppt) salinity estuarine waters of the bays, sounds, and tidal creeks, referred to as high salinity SAV or seagrasses. Collectively they are referred to as SAV. These groups are distinguished by different species composition and environmental requirements, and have characteristics similar to SAV communities found in many other estuaries in the US (Table 4.3).[34, 35]

Photo Credit: XXX

Table 4.3. Average environmental requirements at locations where SAV occurred in coastal North Carolina, 1988-1991.[1]

	Environmental parameter					
	Salinity (ppt)		Secchi depth m (ft)		Water depth m (ft)	
SAV species	Range	Average	Range	Average	Range	Average
HIGH SALINITY (<10-30 ppt)						
Eel grass (*Zostera marina*)	10 ≥ 36	26	0.3 - 2.0 (1.0 - 6.6)	1.0 (3.3)	0.4 - 1.7 (1.3 - 5.6)	1.2 (3.9)
Shoal grass (*Halodule wrightii*))	8 ≥ 36	25	0.4 - 2.0 (1.3 - 6.6)	1.0 (3.3)	0.1 - 2.1 (0.3 - 6.9)	0.8 (2.6)
Widgeon grass (*Ruppia maritima*)	0 - 36	15	0.2 - 1.8 (0.7 - 5.9)	0.7 (2.3)	0.1 - 2.5 (0.3 - 8.2)	0.8 (2.6)
FRESHWATER-LOW SALINITY (0-≥10 ppt)						
Redhead grass (*Potamogeton perfoliatus*)	0 - 20	1	0.4 - 1.4 (1.3 - 4.6)	0.9 (3.0)	0.4 - 2.4 (1.3 - 7.9)	0.9 (3.0)
Wild celery (*Vallisneria Americana)*	0 - 10	2	0.2 - 2.0 (0.7 - 6.6)	0.6 (2.0)	0.2 - 2.3 (0.7 - 7.6)	1.0 (3.3)
Eurasian watermilfoil (*Myriophyllum spicatum*)	0 - 10	2	0.2 - 1.4 (0.7 - 4.6)	0.6 (2.0)	0.5 - 2.4 (1.6 - 7.9)	1.1 (3.6)
Bushy pondweed (*Najas guadalupensis)*	0 - 10	1	0.2 - 2.0 (0.7 - 6.6)	0.7 (2.3)	0.5 - 1.7 (1.6 - 5.6)	1.0 (3.3)
Sago pondweed (*Stuckenia pectinate*)	0 - 9	2	0.2 - 0.4 (0.7 - 1.3)	0.3 (1.0)	0.6 - 0.9 (2.0 - 3.0)	0.8 (2.6)

North Carolina is unique among other coastal SAV ecosystems on the Atlantic seaboard because of overlapping distributions of temperate and tropical seagrasses in relatively higher salinity waters.[1, 36] Eel grass (*Zostera marina*) is a temperate species at the southern limit of its western Atlantic range in NC. In contrast, shoal grass (*Halodule wrightii*) is a tropical species that reaches its northernmost extent in NC. Widgeon grass (*Ruppia maritima*) has a wide salinity tolerance, but grows best in moderate salinity areas. The co-occurrence of these three SAV species in NC, results in high coverage of shallow bottom areas in NC's estuaries, both spatially and temporally.[4] In NC, perennial and annual meadows of eelgrass are common in shallow, protected estuarine waters in the winter and spring when temperatures are cooler. However, in the summer when water temperatures are above 20-25°C (68-77°F), shoal grass is more abundant while eelgrass survives where water temperatures are relatively cooler in deeper sub-tidal areas, especially locations with continuous water flow.[24]

SAV occurs in subtidal and intertidal areas of sheltered estuarine and riverine waters where there is unconsolidated sediment, adequate light reaching the bottom, and moderate to negligible current velocities or wave turbulence.[1, 4] The primary factors controlling SAV distribution are water depth, sediment composition, wave energy, and the penetration of light through the water column.[37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49]

Because SAVs are rooted in anaerobic sediments, they need to produce a large amount of oxygen to aerate the roots, and therefore have the highest light requirements of all aquatic plants.[6, 34] SAV can become stressed by eutrophication and other environmental conditions which impair water transparency and/or diminish the oxygen content of water and sediments. The plant's response to these factors makes them a sensitive bio-indicator of environmental health.[48, 49] Required light conditions can vary by species; low salinity grass species have slightly lower light requirements of >9 percent of surface incident light required at the leaf and >13 percent of surface incident light required through the surface compared to >15 percent and >22 percent, respectively, for species found in moderate to high salinity areas.[45, 50, 51]

High salinity SAV in coastal NC occurs on shallow back-barrier bars behind the Outer Banks (Pamlico, Core, Back, and Bogue sounds), and along the mainland shores.[6, 52] Estuarine high salinity SAV occurs at a smaller scale in protected coastal embayments, marsh channels and along the Intracoastal Waterway, south of Bogue Inlet to around Mason's Inlet in northern New Hanover County. It has been documented in the New River, Chadwick Bay, Topsail Sound, and along the edges of creeks and the Intracoastal Waterway as far south as northern New Hanover County. In the fresh and brackish water portions of NC estuaries, low salinity SAV is abundant in larger black water systems, but rare in small black water streams, due to tannic water, irregular flows, and shading from forested wetlands. SAV can be extensive in low-salinity back bays and lagoons, such as Albemarle and Currituck sounds, tributaries of the Pamlico and Neuse rivers, and in coastal lakes like Lake Mattamuskeet (not included in SAV coverage estimates).[53]

There have been various mapping projects over the last 40+ years by several universities, and state and federal agencies. The data sources, mapping years, methodology, and extent of each individual mapping event are described in Table 4.4. These individual mapping events compiled together make up the historically known presence and suitable habitat of SAV along NC's coast, and suggests a historic extent of approximately 191,155 acres of SAV in public trust waters (Table 4.5; Figures 4.1-4.9). Additional mapping and monitoring of fresh and brackish SAV have occurred with hydroacoustic surveys, and the establishment of sentinel sites in recent years in the Neuse and Pamlico rivers and Albemarle Sound.[54, 55, 56, 57] Coastwide aerial photography mapping of high salinity SAV occurred in 2019 and 2020 with funding from NC Department of Environmental Quality (DEQ) and APNEP. This imagery is currently being processed and will be incorporated into this SAV mosaic along with future efforts to better inform the known historic and current extent of SAV in NC.

Photo Credit: NOAA

Table 4.4. Data sources, mapping years, methodology, and extent of each individual SAV mapping event along the North Carolina Coast from 1981 to 2015.

Data Source	Mapping Year(s)	Methodology	Mapping Extent
Carraway & Priddy (1983)[2]	1981	Maps of SAV were created from aerial natural color photography accompanied by ground truth data for verification including location and density.	May 1981: Bogue and Core sounds
Ferguson & Wood (1994)[4]	1983, 1985, 1988, 1990, 1992	SAV was delineated and mapped from natural color aerial photography with a minimum mapping unit of 20m. Accompanying field inventories were conducted within study regions to verify SAV signatures and species distribution and composition.	1990: Currituck, Albemarle and Roanoke/Croatan Sounds 1991: Pamlico River Estuary, Neuse River Estuary, western Pamlico Sound and Albemarle Sound 1992: Pamlico River, Core and Bogue sounds and parts of eastern Pamlico Sound, western Pamlico Sound, Perquimans River
Division Water Quality (DWQ) 1998 (Now DWR)	1998	Maps from aerial photography	Neuse River and tributaries
Eastern Carolina University (ECU)	2002-2003, 2006	Maps from aerial photography	Albemarle and Currituck sounds
North Carolina State University (NCSU)[58]	2005	Aerial photography from July 2005 accompanied by ground truth data	Southern shore of Albemarle Sound including Bull Bay to northern Croatan Sound
Division Water Quality Rapid Response Team (Now DWR)[59, 60]	2005-2008	Maps from interpolated transect data. SAV was observed and collected using a garden rake from boat, traveling along the shoreline.	2005 & 2006 (June-September): major tributaries of Neuse and Pamlico Rivers 2007 (May-August): Neuse and Pamlico Rivers and tributaries
Marine Corps Air Station Cherry Point[61]	2007	Field survey's consisting of visual observations and underwater cameras and aerial survey analysis of hyperspectral imagery.	Mouth of the Neuse River near Point of Marsh.
Albemarle Pamlico National Estuarine Partnership (SAV Partners)[62, 63]	2006-2008	SAV was mapped along the coast of NC and northward into Back Bay, Virginia by manually digitizing visible SAV from remotely-sensed imagery.	This extent encompasses the coastal zone that lies within the APNEP regional boundary (Bogue Inlet north to Back Bay), as well as that which is outside of that boundary (Bogue Inlet south to Masonboro Inlet).
	2012-2013	SAV was mapped along the coast of NC by manually digitizing visible SAV from remotely-sensed imagery.	This extent encompasses the high-salinity coastal zone that lies within the APNEP regional boundary (Hwy. 64 Bridge of Roanoke Sound south to Bogue Inlet).
DEQ, DOT, & NOAA[64]	2015	SAV was mapped along the Southern coast of NC by manually digitizing visible SAV from remotely-sensed imagery.	This extent encompasses the high-salinity coastal zone of Onslow Bay that lies south of the APNEP regional boundary.

Table 4.5. The known historical extent of submerged aquatic vegetation (SAV) in North Carolina.

Salinity Zone	SAV Region #	SAV Region Name	Historic Extent* (ac)	Percent of Historical Extent* (%)
Low	1	Currituck and Back Bay	21,613	11.3
Low	2	Albemarle Sound	12,872	6.7
Low	3	Tar-Pamlico & Neuse rivers	4,581	2.4
High	4	Pamlico Sound	712	0.4
High	5	Roanoke Sound to Ocracoke Inlet	101,739	53.2
High	6	Core Sound	36,862	19.3
High	7	Bogue Sound	10,826	5.7
High	8	Bear Inlet to Snow's Cut	1,950	1.0
High/Low	9	Cape Fear River to SC line	0	0.0
Total			**191,155**	100.0

*SAV Mosaic 1981 to 2015 (as of 6/3/2020)

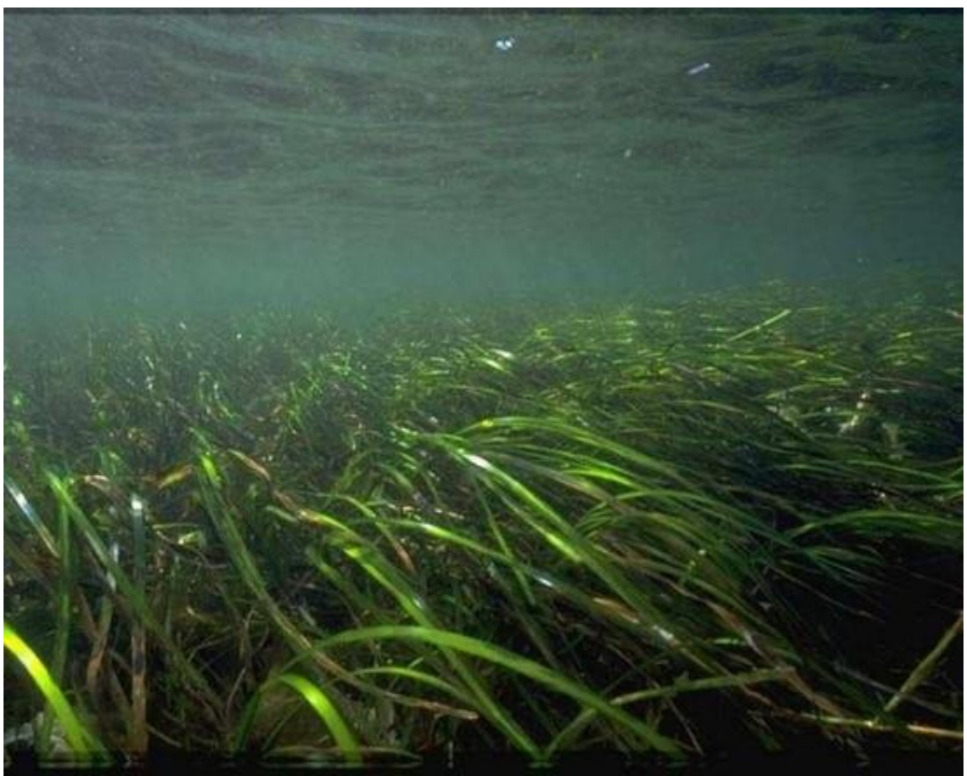

Photo Credit: Brian Conrad

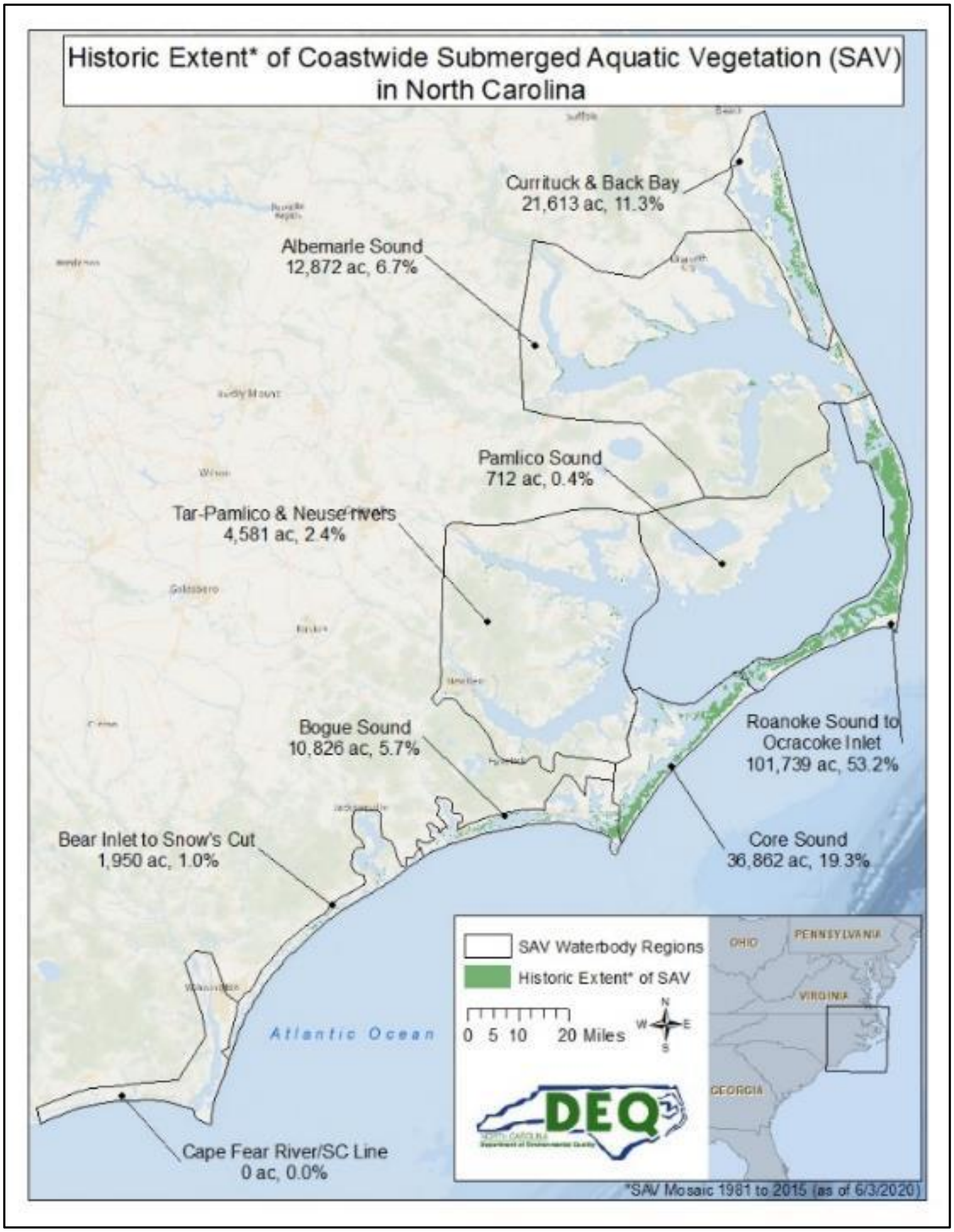

Figure 4.1. Known historic extent of submerged aquatic vegetation (SAV) in North Carolina, mapped from 1981 to 2015. Absence of SAV does not suggest actual absence, as surveys have not been conducted in all areas. Presence of SAV does not reflect current state, as data dates to 1981.

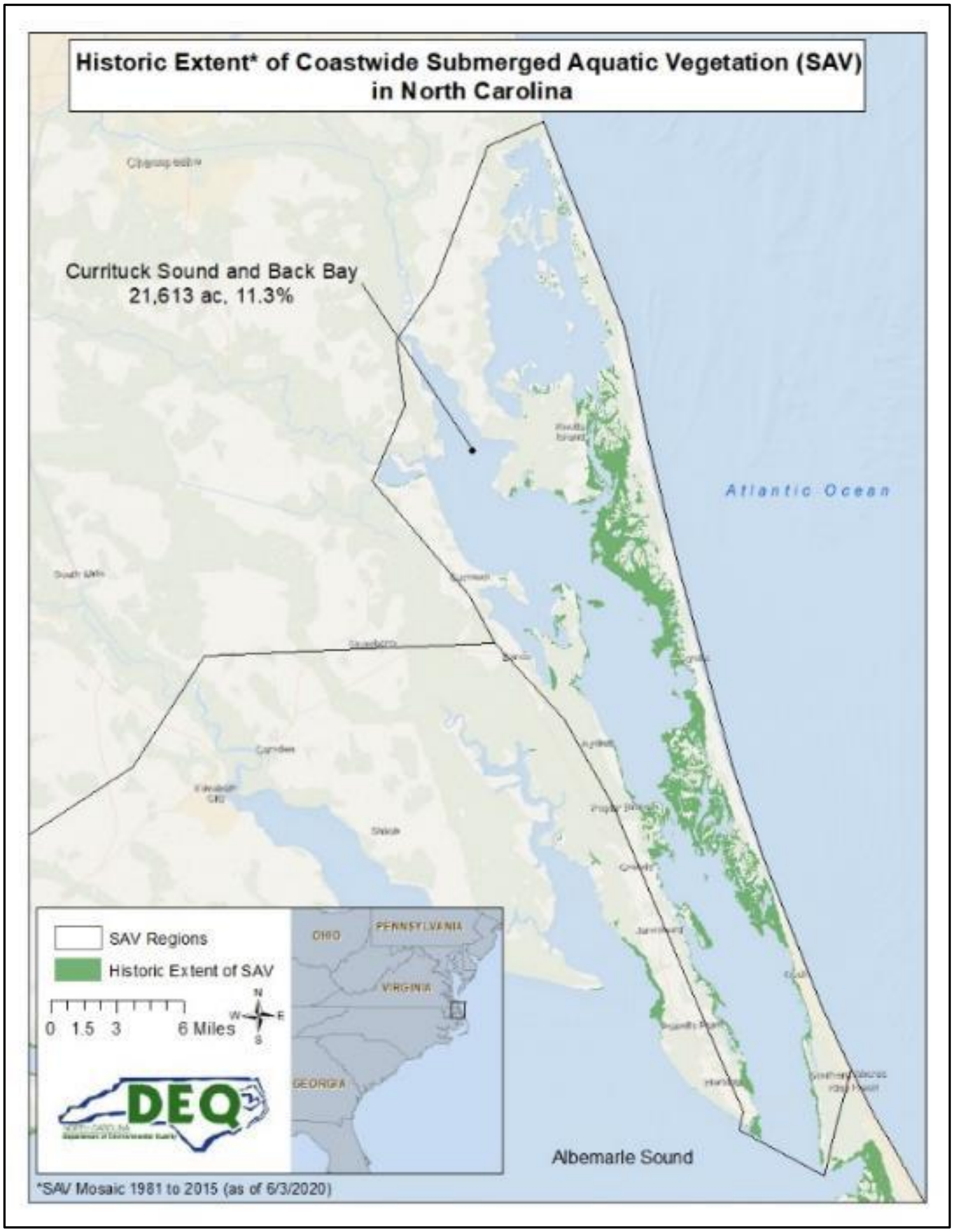

Figure 4.2. Known historic extent of submerged aquatic vegetation (SAV) in North Carolina, mapped from 1981 to 2015 in Currituck and Back Bay. Absence of SAV does not suggest actual absence, as surveys have not been conducted in all areas. Presence of SAV does not reflect current state, as data dates to 1981.

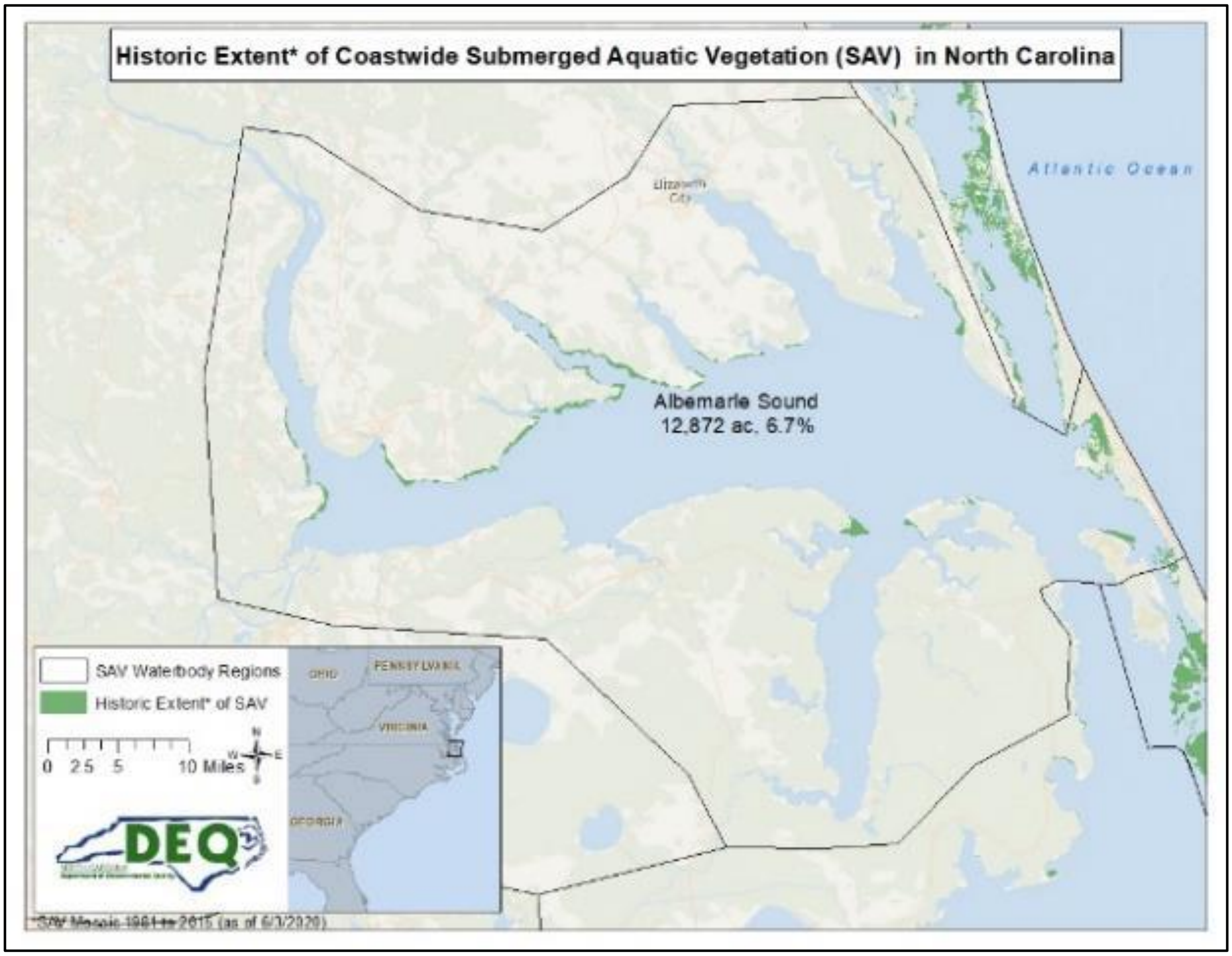

Figure 4.3. Known historic extent of submerged aquatic vegetation (SAV) in North Carolina, mapped from 1981 to 2015 in Albemarle Sound. Absence of SAV does not suggest actual absence, as surveys have not been conducted in all areas. Presence of SAV does not reflect current state, as data dates to 1981.

Photo Credit: John Carroll

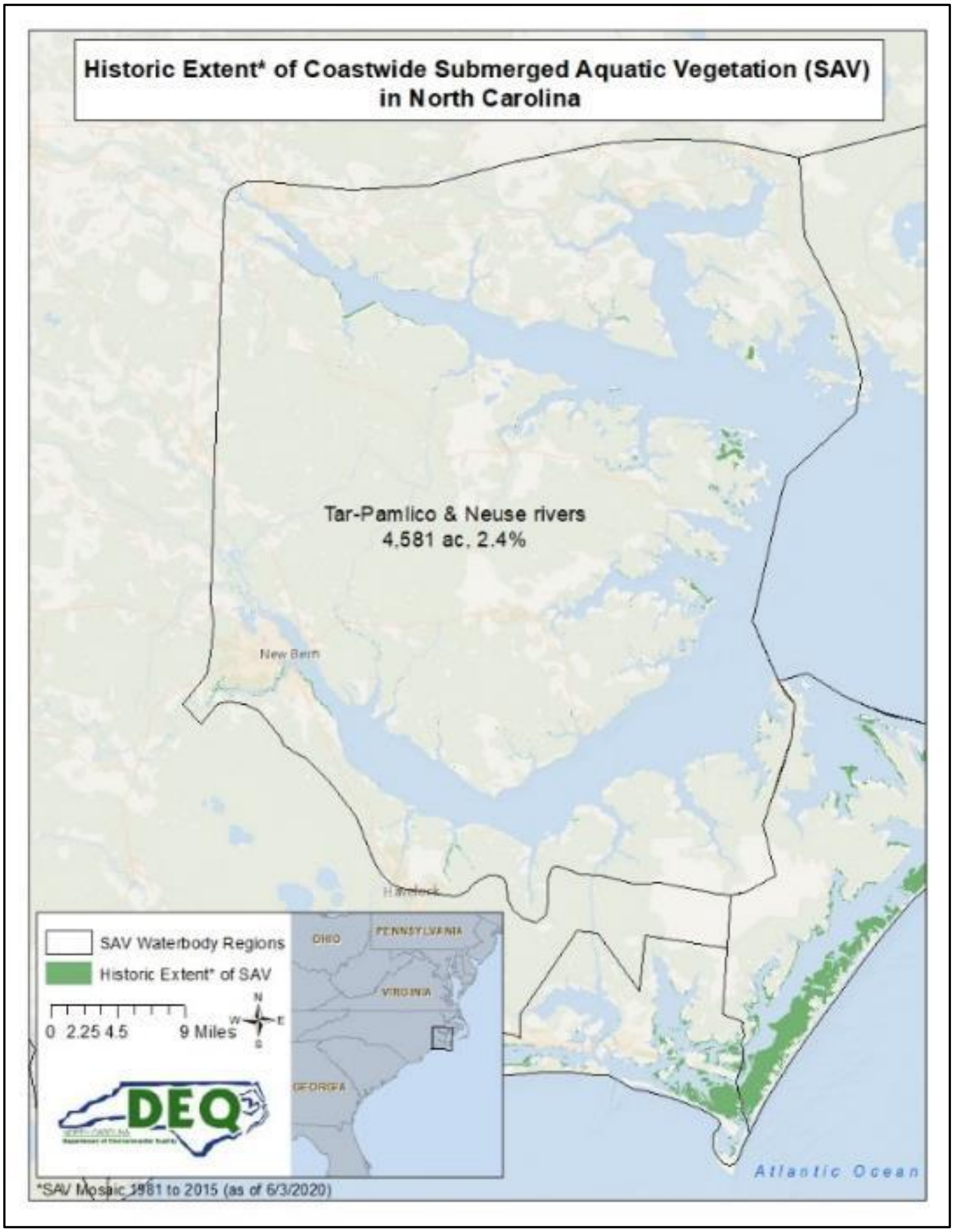

Figure 4.4. Known historic extent of submerged aquatic vegetation (SAV) in North Carolina, mapped from 1981 to 2015 in Tar-Pamlico and Neuse rivers. Absence of SAV does not suggest actual absence, as surveys have not been conducted in all areas. Presence of SAV does not reflect current state, as data dates to 1981.

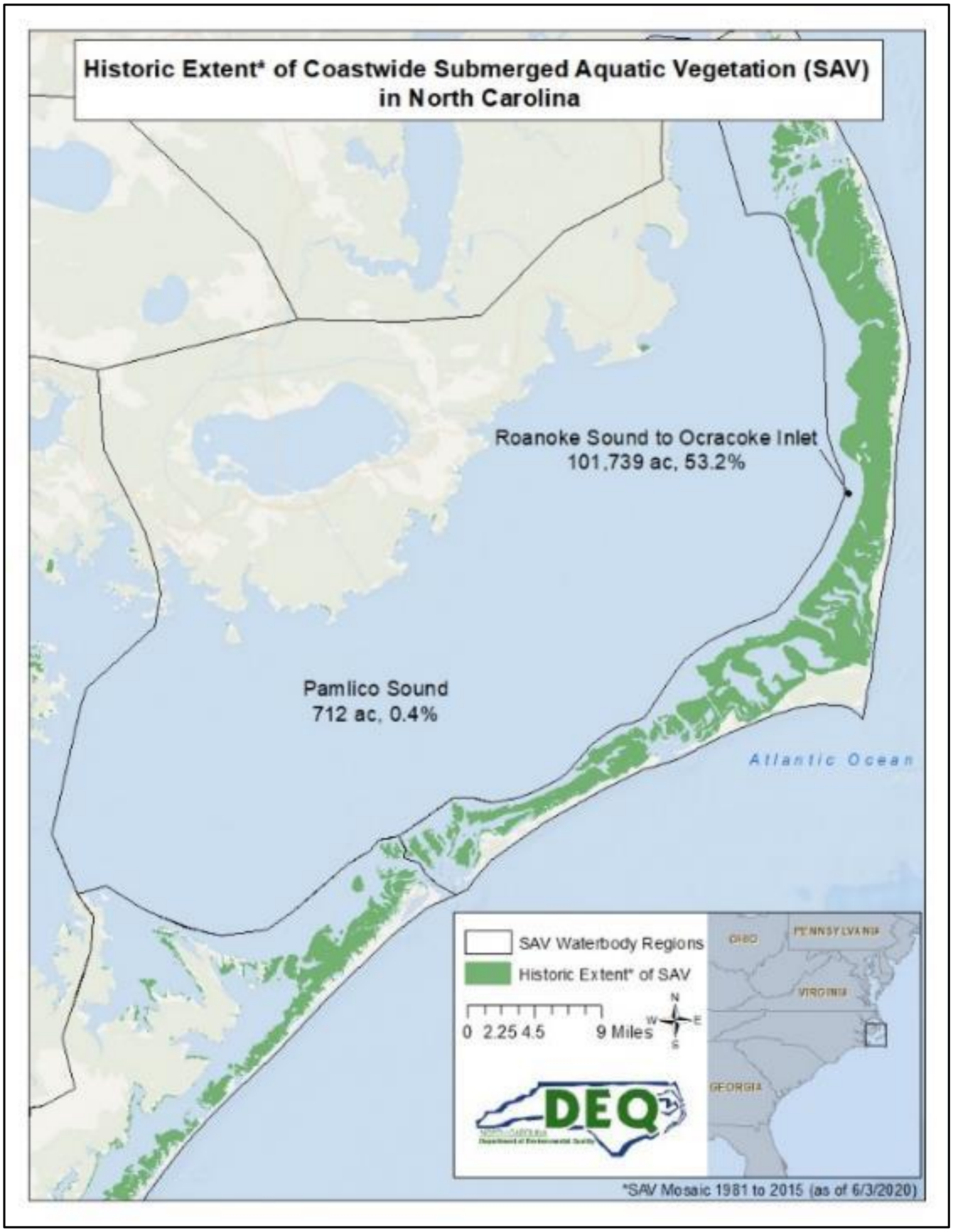

Figure 4.5. Known historic extent of submerged aquatic vegetation (SAV) in North Carolina, mapped from 1981 to 2015 in Pamlico Sound. Absence of SAV does not suggest actual absence, as surveys have not been conducted in all areas. Presence of SAV does not reflect current state, as data dates to 1981.

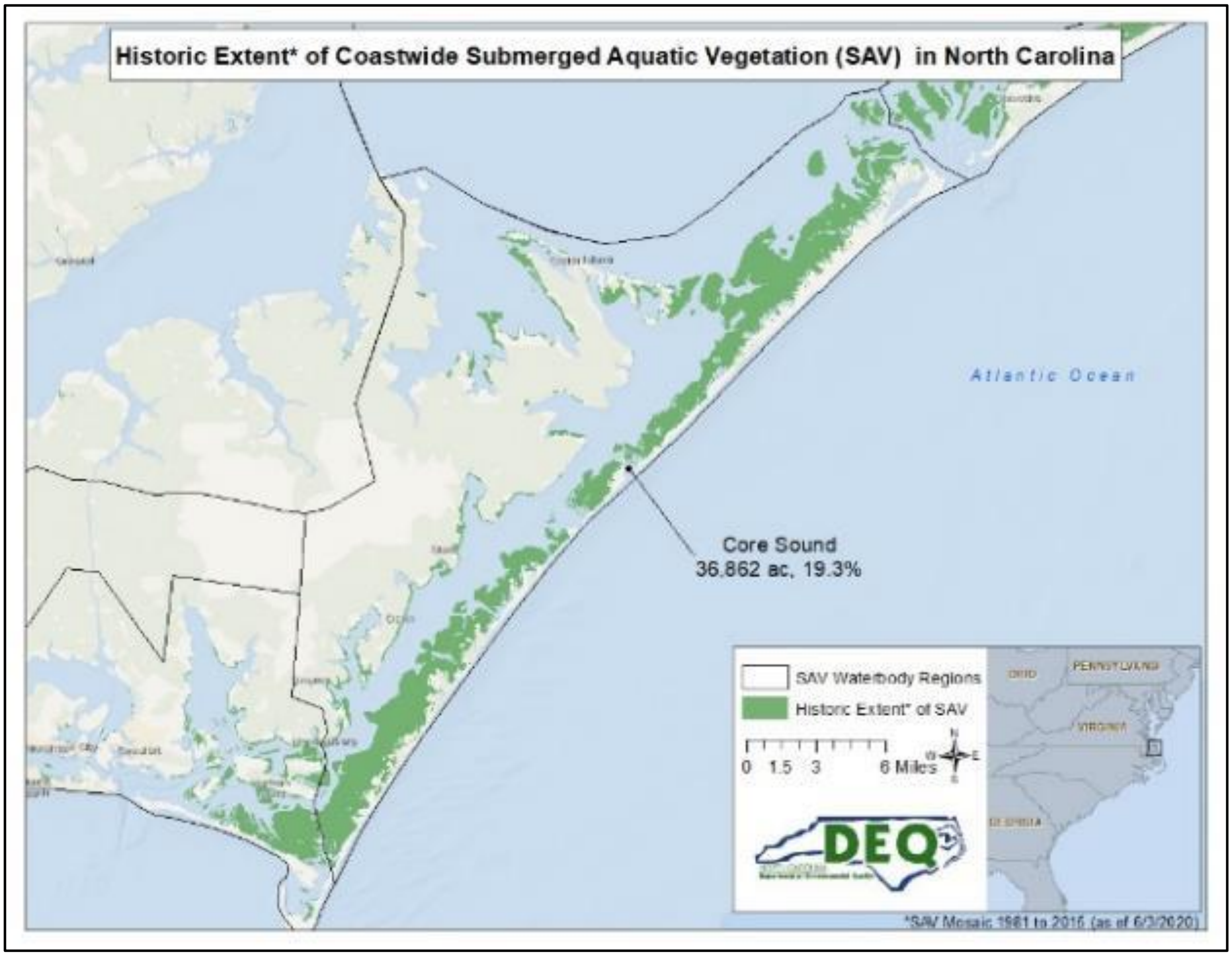

Figure 4.6. Known historic extent of submerged aquatic vegetation (SAV) in North Carolina, mapped from 1981 to 2015 in Core Sound. Absence of SAV does not suggest actual absence, as surveys have not been conducted in all areas. Presence of SAV does not reflect current state, as data dates to 1981.

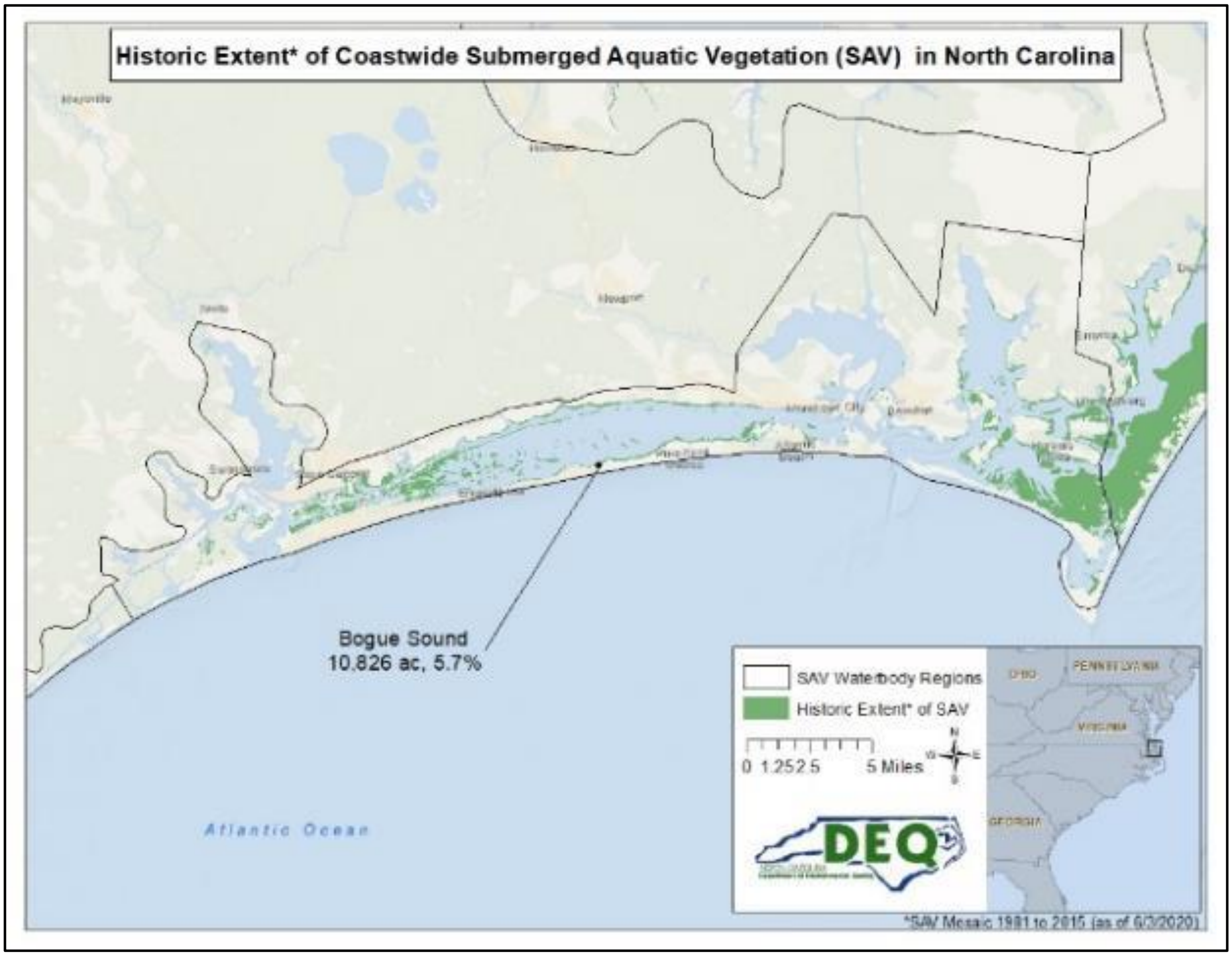

Figure 4.7. Known historic extent of submerged aquatic vegetation (SAV) in North Carolina, mapped from 1981 to 2015 in Bogue Sound. Absence of SAV does not suggest actual absence, as surveys have not been conducted in all areas. Presence of SAV does not reflect current state, as data dates to 1981.

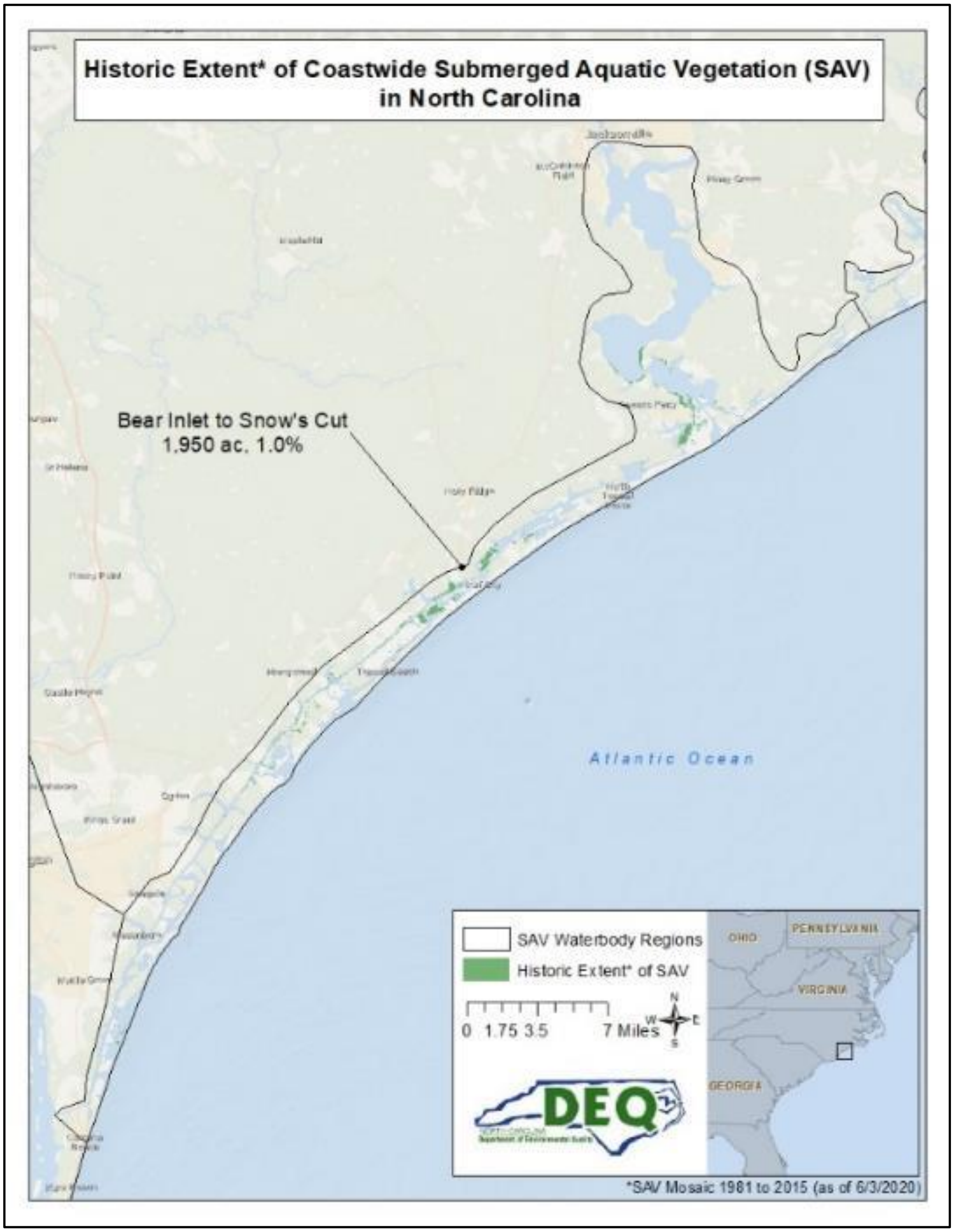

Figure 4.8. Known historic extent of submerged aquatic vegetation (SAV) in North Carolina, mapped from 1981 to 2015 in Bear Inlet to Snows Cut. Absence of SAV does not suggest actual absence, as surveys have not been conducted in all areas. Presence of SAV does not reflect current state, as data dates to 1981.

Figure 4.9. Known historic extent of submerged aquatic vegetation (SAV) in North Carolina, mapped from 1981 to 2015 in Cape Fear River to the South Carolina line. Absence of SAV does not suggest actual absence, as surveys have not been conducted in all areas. Presence of SAV does not reflect current state, as data dates to 1981.

Mapping and monitoring low salinity SAV is more difficult due to low water clarity compared to high salinity SAV areas of the estuary. Despite low water clarity and the limited availability of historical baseline data of low salinity SAV habitat, fluctuations in SAV abundance have been observed through hydroacoustic surveys and other sentinel site observations.[57, 65] Based on the most recent hydroacoustic surveys of linear SAV extent along the 1-meter isobath in the Neuse, Pamlico and Albemarle river sub-estuaries, there has been an estimated 33 percent decline from the historical extent of low salinity SAVs (Table 4.6). Although there is less known about low salinity SAV extent, there are

Table 4.6. Net Change from Historical to 2014-2017 Linear Extent (LE) along 1-meter isobaths line for low salinity SAV based on recent hydroacoustic surveys.[57, 65]

Estuary	Historical* SAV LE (m)	2014-2017 SAV LE (m)	No change in SAV from historical (m)	Change in SAV LE (gain)	Change in SAV LE (loss)	Percent change in SAV LE (loss)
Albemarle Sound	117,778	90,565	56,457	+34,108	-61,321	-23.10
Tar - Pamlico River	29,223	6,036	756	+5,280	-28,467	-79.33
Neuse River	10,512	9,519	2,821	+6,692	-7,685	-9.42
Total	157,513	106,120	60,034	+46,080	-97,473	-32.62

*From 1981-2015 SAV Mosaic

recurring themes. These include large fluctuations in abundance, changes in species composition, occurrence of non-native species in some waterbodies, high turbidity, extreme weather events, large amounts of precipitation, and fluctuations in salinity.[65]

The high salinity seagrasses appear to be in better condition than the low salinity SAVs. There is a good baseline of data on distribution and abundance for most of the high salinity SAV resource, along with a good understanding of species composition, persistence and resilience. However, little water quality data are collected and represents a crucial data gap.

The APNEP metric report: *Extent of Submerged Aquatic Vegetation, High-Salinity Estuarine Waters*, provides an analysis of SAV change based on spatial coverage detected from aircraft during two survey periods: 2006-2007 (Survey 1) and 2013 (Survey 2) (Table 4.7).[66] Survey 1 represents late spring aerial surveys of Bogue and Back Sounds and fall aerial surveys between Roanoke Island and Barden's Inlet. Survey 2 represents late spring aerial surveys between Roanoke Island and Bogue Inlet. For analysis purposes, these coastal areas are broken down into three geographic regions. The northern region is from the US Hwy 64 Bridge (Roanoke Island) to Hatteras Inlet; the central region is from Hatteras Inlet to Ophelia Inlet; and the southern region is from Barden's Inlet to Bogue Inlet.

All three regions showed declines in SAV acreage (Table 4.7).[66] However, the southern region, where there is more development and higher population densities, declined by over 10 percent (Table 4.8). The northern and central regions are less developed, receive less direct riverine input, and therefore had a lower estimated SAV acreage loss. No regions gained SAV based on this assessment despite the ability for SAV to grow at depths generally ≤ 2.0 meters, yet much of that available benthic habitat within this depth range was not occupied by SAV. An additional concern is the amount of continuous beds that were converted to patchy beds. The biggest component of the overall change in the northern region was the conversion of 15,327 acres (6,202.8 ha) of continuous seagrass in Survey 1 to patchy seagrass in

Survey 2.

Table 4.7. Net change in seagrass extent in North Carolina from Survey 1 (2006/2007) to Survey 2 (2013) in three regional zones 1) the "North Zone" from the U.S. Highway 64 Bridge at Roanoke Island to Hatteras Inlet, 2) the "Central Zone" from Hatteras Inlet to Ophelia Inlet and, 3) the "South Zone" from Barden's Inlet at Cape Lookout to Bogue Inlet and overall (acres, hectares in parentheses).[66]

Regional Zones	Survey 1	Survey 2	Change	% Change
North	70,861 (28,676)	66,445 (26,889)	-4,416 (-1,787)	-6.2
Central	24,132 (9,766)	23,477 (9,501)	-655 (-265)	-2.7
South	5,850 (2,367)	5,235 (2,119)	-615 (-249)	-10.5
Overall	100,843 (40,810)	95,157 (38,509)	-5,686 (-2,301)	-5.6

Table 4.8. From-to calculations for the net change in seagrass extent in the three North Carolina zones 1) the "North Zone" from the U.S. Highway 64 Bridge at Roanoke Island to Hatteras Inlet, 2) the "Central Zone" from Hatteras Inlet to Ophelia Inlet and, 3) the "South Zone" from Barden's Inlet at Cape Lookout to Bogue Inlet and overall (acres, hectares in parentheses).[66]

Conversion		Zone		
From	To	North	Central	South
No SAV	Patchy SAV	4,462 (1,810)	4,386 (1,775)	638 (258)
No SAV	Continuous SAV	203 (82)	150 (601)	60 (24)
Gain		4,665 (1,888)	4,537 (1,836)	698 (283)
Continuous	None	1,895 (766)	401 (162)	88.4 (36)
Patchy	None	7,009 (2,837)	4,782 (1,935)	1,218 (493)
Loss		8,904 (3,603)	5,184 (2,098)	1,306 (528)
Net Loss (Loss – Gain)		4,239 (1,715)	647 (262)	607 (246)
Total		70,861 (28,676)	24,132 (9,766)	5,850 (2,367)
% Change		-6.2	-2.7	-10.5
% Change yr-1		-1.1	-0.5	-1.7

A global assessment of 215 studies found that seagrasses around the world have been disappearing at a rate of 110 km^2 per year since 1980 with an overall global average rate of decline of 1.5 percent per year.[67] Although rates of decline within the northern and central regions of NC are lower than this global average, the higher rate of decline in Back and Bogue sounds (1.7 percent per year) is comparable.[66] Bogue and Back Sounds may be especially vulnerable to the impairment of water quality associated with shoreline development and other anthropogenic impacts (boat wakes, dredging, fishing gears, etc.).

4.2.1 Management of Submerged Aquatic Vegetation in North Carolina

There are several DEQ commissions that manage activities that can directly and indirectly affect SAV. The MFC has authority over regulations of fishing practices in coastal waters through the DMF. The NC Environmental Management Commission (EMC) has authority over activities that affect water quality and are implemented by the NC Division of Water Resources (DWR) and NC Division of Energy, Minerals, and Land Resources (DEMLR). The NC Coastal Resources Commission (CRC) has authority over development activities within and adjacent to the public trust and estuarine waters and coastal marshes which are implemented by the NC Division of Coastal Management (DCM). Although the NC Wildlife Resources Commission (WRC) is not a formal participant in the development of the CHPP, they oversee regulation of boating in coastal and inland waters and fishing in inland waters and are involved with the three commissions as it concerns SAV and other fisheries habitats. Additionally, the NC Department of Agriculture and Consumer Services (DA&CS) and NC Department of Transportation (DOT) oversee activities that effect water quality via runoff.

4.2.2 Policies and Plans

There are several state, federal, and interstate policies and plans that directly or indirectly influence SAV management, restoration, and protection in NC. Table 4.9 provides information on the four policies detailed below, with specific guidance as it pertains to monitoring, water quality, physical disturbance, land use and development, restoration, research, and education in NC. The MFC SAV Policy recognizes the importance of SAV to NC and calls for management guidelines to monitor and protect SAV.[68] The NC Department of Environmental and Natural Resources (DENR; now DEQ) Technical Guidance Document for the Protection of Submerged Aquatic Vegetation Habitat is a document created to ensure regulatory review bodies consider SAV during the permit review process.[69] The South Atlantic Fishery Management Council (SAFMC) Policy for Protection and Enhancement of Estuarine and Marine Submerged Aquatic Vegetation (SAV) Habitat encourages the South Atlantic states to assess the status and trends in SAV and consider establishing plans that integrate monitoring and research, planning, management, education, and enforcement to protect and revitalize SAV resources.[70] The Atlantic States Marine Fisheries Commission (ASMFC) Policy was developed to communicate the necessity of conservation of coastal SAV resources because of the importance of SAV habitat to managed fish species.[71]

Photo Credit: Jay Fleming/Getty Images

Table 4.9. Existing submerged aquatic vegetation (SAV) management policies from regulatory agencies affecting North Carolina.

	NC Marine Fisheries Commission[68]	NC Department of Environmental Quality[69]	South Atlantic Fishery Management Council[70]	Atlantic State Marine Fisheries Commission[71]
Assessment & Mapping	In order to delineate and assess the distribution and health of SAV habitat, SAV beds need to be mapped and monitored.	Definition of SAV habitat is expanded for mapping and monitoring purposes.	Develop and standardize imagery acquisition and resource mapping protocols, with regional modification as necessary to achieve effective results.[72] Develop and maintain a GIS database for essential habitat including SAV and use that information for	At a minimum, each member state should ensure the implementation of an SAV resource assessment and monitoring program which will provide a continuing quantitative evaluation of SAV distribution and abundance and the supporting
Water Quality	Minimize nutrient and sediment loading to coastal waters that support existing SAV to protect adequate water quality as defined by water-column clarity in standard measurement units.	Minimize nutrient and sediment loading to coastal waters that support existing SAV to protect adequate water quality as defined by water-column clarity in standard measurement units.	Evaluate water quality criteria needed to support SAV survival and growth and support policy making to manage quality and quantity of surface runoff. Review state water quality standards and rules to	Support and promote the development of water quality standards by the EPA and member states that can be implemented to protect SAV habitat (i.e., light attenuation, total suspended solids,
Fishing Gear Disturbance	All SAV needs to be protected from all bottom-disturbing fishing and recreational gear. Sufficient buffer zones surrounding SAV beds should also be protected from disturbance	Dredging directly alters the bottom to conditions unfavorable for SAV growth or recolonization and should be avoided in existing and suitable bottom that has supported SAV in the past.	Review and modification of state and federal rules to ensure protection of SAV from impacts such as dredging, propeller scarring, marina and pier construction, and bottom-	In partnership with NOAA Fisheries and USFWS, develop technical guidelines and standards to objectively evaluate fishing gear, propeller scarring, dredging, coastal construction, and
Docks & Piers		Piers and docking facilities can potentially impact SAV through construction impacts, shading, and indirect impacts from boat wakes and prop dredging. Floating docks block more sunlight due to the solid surface and lower position over the bottom and in shallow water may rest on	Encourage states to minimize impacts to SAV by developing design criteria for docks and piers which establish minimum height, maximum width and materials.	Encourage citizen involvement in impact reporting.
Protection from Development	Provide adequate safeguards to prevent direct (or indirect) impacts from development projects adjacent to or connected to SAV. Assess cumulative impacts of land use and development changes in the watershed affecting SAV to identify the potential	Field reps and permit reviewers should consider the potential impacts of proposed activities to SAV habitat on a case-by-case basis. Reviewers should consider the level of impact of the specific proposed activity on SAV habitat and the level of scientific documentation supporting	Development of economic analyses on the economic benefits of protecting and enhancing SAV habitat.	

	NC Marine Fisheries Commission[68]	NC Department of Environmental Quality[69]	South Atlantic Fishery Management Council[70]	Atlantic State Marine Fisheries Commission[71]
Habitat Restoration	Require compensatory mitigation where impacts are unavoidable. Initiate restoration programs to recoup and/or enhance lost SAV habitat.	Shoreline stabilization practices that result in increased wave energy regimes, turbidity, or sedimentation can potentially impact SAV habitat. Shoreline stabilization methods should utilize the method that would cause the least expected impact to SAV habitat if possible.	Investigate effective restoration techniques, including ecological function and cost/benefit. Development of SAV restoration guidelines for both high and low salinity SAV to accelerate successful, cost-effective SAV restoration.	Protection is preferred over restoration. Restoration programs should include establishment of habitat quality necessary for SAV prior to restoration. Restoration methods should incorporate scientifically based protocols. Restoration goals should consider potential and historical SAV spatial footprint.
Education & Outreach	Educate landowners adjacent to SAV, boaters, and other potential interested parties about the value of SAV as a habitat for many coastal fishes and invertebrates.		Design of education programs to heighten the public's awareness of the importance of SAV. An informed public will provide a firm foundation of support for protection and restoration efforts.	ASMFC and member states should promote and support public education and stewardship programs that will increase the public's knowledge of SAV, its importance as fish habitat, and commitment to SAV conservation.
Scientific Research			Research and document causes and effects of SAV losses, including cumulative impacts, watershed runoff, shoreline development, shading associated with pier and dock, development, invasive species, and extreme weather conditions (drought, tropical storms, algal blooms, etc.). Research potential effect of climate change on SAV habitat.	ASMFC and member states should promote and support those research projects which will improve our knowledge of SAV and its benefits as fish habitat.
Regulations & Enforcement Improvements		Specific guidance for permits.	The regulatory definition of SAV habitat is: shallow water habitat with appropriate sediment, depth, light penetration and wave energy, including areas without existing SAV. Review of existing regulations and enforcement to determine their effectiveness. Coordination with state resource and regulatory agencies to ensure that existing regulations are being enforced.	ASMFC members should propose improvements necessary in state regulation and management including conditions pertaining to harvesting shellfish or finfish in SAV beds by use of mechanical means and the placement and operations of aquaculture activities to protect existing SAV beds. Encourage state agencies or departments with jurisdiction over construction activities to propose improvements necessary in state regulation and management of SAV habitats based on the standards developed in the above actions.

In addition to the policies described above, there are also various NC plans that address the importance of monitoring, protecting, and restoring the state's SAV resources. They are summarized below:

NC Wildlife Resources Commission Wildlife Action Plan (WAP)

The Wildlife Action Plan (WAP) is a comprehensive planning tool used by the WRC to help conserve the state's fish and wildlife species and their habitats. This includes numerous recommendations for monitoring the state's SAV. The WRC received approval from the US Fish & Wildlife Service (USFWS) for the comprehensive revision of the WAP on March 30, 2016.[73]

Albemarle-Pamlico National Estuary Partnership (APNEP) Comprehensive Conservation and Management Plan (CCMP)

The APNEP CCMP was developed using the principles of ecosystem-based management (EBM) which includes consideration of human and natural systems, an adaptive management framework, and meaningful engagement with the region's citizens to find environmental management and policy solutions. Protection and restoration efforts to improve water quality and SAV are addressed with an emphasis on assessment and monitoring to facilitate adaptive management as more knowledge is gained in the system.[13]

APNEP Submerged Aquatic Vegetation Partners Plan

This document provides a framework to guide actions and efforts in protecting and restoring SAV habitat through coordinated research, monitoring, assessment and outreach activities. It also serves as a more detailed "step-down" document that can be used to implement conservation measures specific to SAV in support of the CHPP, the WAP, and the CCMP. The goals, objectives, and actions of this plan must utilize an ecosystem approach to maximize effectiveness and efficiency.[74]

North Carolina Aquatic Nuisance Species (NCANS) Management Plan

The purpose of the NCANS Management Plan is to improve the state's ability to address aquatic invasive and aquatic nuisance species with the goal of preventing and controlling their introduction, spread, and negative impacts. Within this plan, invasive aquatic plant species, which can have an impact on native brackish water and high salinity SAVs, are addressed.[75]

4.2.3 Impacts of Water Quality Impairment to Submerged Aquatic Vegetation

As noted earlier, SAV is especially sensitive to water quality impairment from nutrient and sediment pollution and has been considered a "coastal canary", serving as a valuable bio-indicator of the overall health of our coastal ecosystems.[48] Global losses of SAV are estimated to be at over 29 percent during the last century.[67] The impairment of water quality is one of the most widespread threats to SAV habitats. In the US, SAV along the Atlantic seaboard has experienced significant declines directly or indirectly attributed to the stressors associated with degraded water quality.[8, 76]

The majority of SAV loss can be attributed to large-scale eutrophication (nutrient enrichment) and suspended sediments, which reduces light penetration to the plants.[7, 34, 37, 38, 48, 77, 78, 79] Eutrophication and/or increased sediment loads impact light available for SAV by:

- Reducing water clarity with sediment or phytoplankton associated with algal blooms[8, 79]
- Increasing epiphyte and/or drift algae coverage[8, 80]

Chapter 4. Submerged Aquatic Vegetation Protection and Restoration Through Water Quality Improvement

Eutrophication of shallow estuaries can lead to proliferation of ephemeral macroalgae and filamentous green and brown algae and epiphytes that compete directly with SAV for nutrients and light.[81, 82, 83] Studies have found that macroalgal biomass is directly related to increased nutrient levels and that SAV loss is greater with increased macroalgae.[84, 85] Once macroalgal blooms die, they decompose rapidly, increasing nutrient levels in the water column, stimulating phytoplankton production, further reducing light, and decreasing dissolved oxygen (DO) in the water and sediments. These have all been important factors in the decline of SAV on the Atlantic seaboard.

Chlorophyll *a* is an indicator of phytoplankton production, where high concentrations in the estuary can indicate algal blooms that in turn decrease light penetration, thus impacting SAV growth. In Albemarle Sound there has been a subtantial increase in Chlorophyll *a* over time, which is associated with increasing reports of cyanobacteria blooms over the same time period. Concentrations have fluctuated over the last twenty years across the Albemarle-Pamlico estuarine systems. Additionally, remote sensing information corroborates a rapid increase in cyanobacteria biomass throughout the Albemarle Sound region.

Colored dissolved organic matter (CDOM) is primarily leached from decaying detritus and organic matter and gives water a brownish color. Light penetration is greatly reduced in waters with high CDOM concentrations. In general, CDOM concentrations are higher in fresh and oligohaline waters compared to polyhaline waters. In the Neuse River estuary, CDOM is increasing and may be linked to the salinity regime. As such, declines in water quality for this region could be harder to manage because they are not just directly related to nutrient enrichment.[65]

4.2.4 Case Studies of Water Quality Improvements that Benefit Submerged Aquatic Vegetation

Water quality impairment is a serious but manageable threat to SAV in NC. Water clarity for light penetration is necessary for SAV growth, and SAV survival is impacted by suspended sediments and nutrients. Coastal development expansion combined with increases in the intensity and severity of storm events, and rising sea levels, are resulting in runoff and associated increases in suspended sediments nutrient loading and more turbid waters. However, in Chesapeake Bay and Tampa Bay, improvements in water quality and resulting improved water clarity have in turn improved environmental conditions for SAV survival, growth, and propagation, allowing each system to reach targeted SAV acreage goals.

Chesapeake Bay

Loss of SAV in the shallow waters of the Chesapeake Bay from the early 1960s through the mid-1980s has been documented over time, resulting from nutrient over-enrichment and increased suspended sediment and the associated reduction of light availability to the plants.[51] Since the 1950s, the population grew around the bay, more than doubling from 8 million to over 18 million by 2020. Consequently, land development doubled and correspondingly impervious surfaces, fertilizer use (domestic and agricultural), and livestock production increased. These factors impacted water quality in the bay from nutrient enrichment and sediment loading. This, in turn, increased light attenuation (reduction) by suspended sediments, higher phytoplankton populations, and epiphytic fouling on SAV blades resulting in significant SAV population decreases.[8, 86, 87]

Early efforts were made to reduce point source nutrient loads, especially from wastewater treatment plants (WWTP). Examples include the Upper Patuxent River and Potomac River where WWTP upgrades to improve nitrogen and phosphorus removals were implemented in the late 1980s and early 1990s.[78] Both areas were devoid of SAV until these WWTPs were upgraded. SAV has since reappeared downstream of these plants and the reappearance has been linked to the reductions in wastewater nutrient discharges that reduced nutrient concentrations, algal biomass and light attenuation.[8, 78, 87]

Since establishment of the Chesapeake Bay Program partnership in 1983 with the signing of the first of four Chesapeake Bay watershed agreements, significant progress has been made in reducing nitrogen loads by over 60 percent and phosphorus loads by over 75 percent from hundreds of significant municipal and industrial wastewater dischargers across the six-state watershed. Atmospheric deposition of nitrogen to the bay's watershed and tidal waters has been reduced dramatically as a result of implementation of the Clean Air Act and regional efforts connecting clean air to a healthy Chesapeake Bay. Implementation of hundreds of Partnership approved conservation practices across millions of acres of agricultural cropland, hay land, pasture and livestock operations is making measurable improvements in the thousands of miles of streams and rivers flowing into Chesapeake Bay. Widespread implementation of stormwater management practices and systems are starting to show signs of holding the line against increased flows and pollutant loads within areas of increased land development and construction. Chesapeake Bay's SAV habitats have been responding in kind to these pollutant load reductions. From a low of 38,000 acres in 1984, annual baywide coordinated aerial and ground surveys mapped a high of 105,000 acres of SAV in 2017.

In response to the Chesapeake 2000 Agreement, the six watershed states (Delaware, Maryland, New York, Pennsylvania, Virginia, West Virginia) and the District of Columbia worked with the United States Environmental Protection Agency (EPA) and hundreds of partners and stakeholders to develop a set of Chesapeake Bay specific water quality criteria, designated uses and criteria attainment assessment methodologies.[51, 88] Agreement was reached on establishing the Program's overall strategy, including the following five designated uses for Chesapeake Bay's tidal waters:

- Migratory fish spawning and nursery habitat
- Open-water fish and shellfish habitat
- Deep-water seasonal fish and shellfish habitat
- Deep-channel seasonal refuge habitat
- Shallow-water bay grass habitat

Shallow-water grass habitat was defined as areas that supported underwater bay grasses in 0.5 m to 2.0 m depth. The designated use "protects underwater bay grasses and the many fish and crab species that depend on the vegetated shallow-water habitat provided by underwater grass beds".[88]

The *Chesapeake 2000 Agreement* also committed the signatories—state governors, DC mayor, EPA administrator, and chair of the Chesapeake Bay Commission—to adopting these criteria, designated uses and criteria attainment assessment methodologies into Delaware, Maryland, Virginia and the District of Columbia's state water quality standards regulations. These unprecedented adoptions of consistent state water quality standards across the shared multi-state body of water occurred simultaneously from 2004-2006.[89] For the protection of the shallow-water bay grass designated use, the three states and the District of Columbia adopted numerical water clarity criteria as well as numerical SAV restoration acreages into their respective states' water quality standards regulations.

Based on historical SAV acreage and abundance from the 1950s through 2000, the Chesapeake Bay

Program partners established an SAV restoration goal of 185,000 acres.[88, 90] An interim target to achieve 50 percent of the 185,000-acre restoration goal (92,500 acres) by 2017 was set and met in 2015. By 2017, there was over 100,000 acres in the bay, meeting the 50 percent interim goal. The baywide SAV restoration goal was broken down into acreages for each of the 106 Chesapeake Bay segments. It was these Bay segment-specific SAV restoration acreages which were promulgated into the respective states' water quality standards regulations.

In order to achieve these SAV restoration goals, water clarity criteria were developed by the Chesapeake Bay Program partners and published by the EPA on behalf of the partnership based on:

- Light requirements for underwater grasses
- Factors that contribute to light attenuation
- Epiphyte contribution to light attenuation on leaf surface
- Minimal requirements for light penetration through the water column and leaf surface.

Based on research, literature review and modeling, the minimal amount of light necessary for SAV is ≥22 percent light availability through the water column (PLW) for polyhaline and mesohaline species. For tidal fresh and oligohaline species, ≥13 percent light availability is necessary.[45, 51, 90]

In the Chesapeake Bay, linking biological responses of SAV to improved water quality management over time was possible through the availability of annual digital SAV maps based on aerial overflights with ground-based surveys for species distribution delineations conducted annually since 1984. These maps, along with extensive land cover and land use mapping, water quality data collected through a coordinated monitoring network within the Chesapeake Bay and across its watershed enabled monitoring of SAV abundances, which served as a response indicator of nutrient and sediment inputs into the bay. The positive feedback of increased light availability leading to increased SAV abundance led to lower suspended chlorophyll, particulates and turbidity, resulting in further increased water clarity.[87]

Tampa Bay

As with the Chesapeake Bay, Tampa Bay has also experienced environmental degradation by similar stressors as a result of urbanization and development.[79, 91, 92] Discharges of poorly treated wastewater into the bay, an abundance of small package plants and aging septic systems, stormwater runoff and industrial discharges all led to algal blooms that peaked in the 1970s in the upper reaches and expanded throughout the Bay. This resulted in approximately 44 percent loss of SAV between 1950 and 1990 in the bay due to increased light attenuation caused by algal blooms.

Because of these issues, citizens demanded that the government take action to restore Tampa Bay. In the early 1970s, an ambient water quality monitoring program was established and is still in place today. Municipal WWTPs were required to provide advanced water treatment in Tampa Bay, which reduced this source of nitrogen loading by 90 percent.[79, 91, 92] Stormwater regulations were also put in place by the State of Florida that reduced nitrogen loading from non-point sources.

During the 1990s, numerous agencies around the Tampa Bay area worked to adopt water quality management strategies that linked nitrogen loading management to SAV restoration and protection. With the formation of the Tampa Bay Estuary Program, nitrogen management became the focus in order to benefit SAV restoration through the Tampa Bay Nitrogen Management Consortium.[93, 94] Over fifty stakeholders, consisting of local, state, and federal partners began working with diverse private entities such as electric utilities, phosphate mining companies, and the shipping industry to reduce nitrogen loading in the bay. Through this Consortium, hundreds of projects were implemented by voluntary actions to collectively reduce or prevent nitrogen from entering the bay.

To improve and maintain water quality conditions in the face of growing populations around the bay, numeric targets were established for chlorophyll *a* concentration and light penetration levels based on light requirements of SAV.[45, 93, 94] Models were used to relate nitrogen loads to chlorophyll *a* concentrations within four bay segments. These models were then used to develop nitrogen loading targets necessary to restore SAV in each of the four bay segments. Over time, periodic evaluations of these targets have occurred using an adaptive management strategy through assessment of both seagrass coverage and water quality improvements. Based on the assessment, if targets are met, the Consortium continue to implement projects as planned and continue monitoring. If standards are not met, and based on the level of water quality conditions, some form of management action is required.[79, 91, 92]

As a result of the efforts made by the numerous partners within the Consortium and the Tampa Bay Estuary Program, Tampa Bay has experienced a decrease in nitrogen loading to approximately one third of estimated levels from the 1970s, even as populations around the Bay have increased.[94] This has resulted in decreases of chlorophyll *a* and increases in water clarity to the extent that seagrass coverage now exceeds the 1950s target estimates, reaching the SAV recovery goal of 38,000 acres by 2016. It should be recognized that the collaboration of numerous regulatory, non-regulatory, industry and municipalities are responsible for the overall water quality in the bay.[92, 95]

4.2.5 Nutrient Control in the Albemarle Sound/Chowan River

The Albemarle Sound and the Chowan River have experienced an increase in the number of algal blooms over the past several years. Based on sampling in Chowan River, a tributary of the Sound, organic nitrogen has increased over time. In Potecasi Creek, a tributary of the Chowan River, nutrient patterns shifted around 2002, with nitrate concentrations declining and total nitrogen increasing. The cause for this is unknown. In the Nottaway River, total nitrogen has increased similar to Potacasi Creek, but to a lesser extent. In the Blackwater River, there has been a decline in nitrogen over time, in contrast to what is occurring in Chowan River. There were initial thoughts that the increases were from Virginia, but data suggest this is a NC issue.[96] Other potential causes being examined are runoff from land use activities, particularly agriculture, and subsurface flow of nutrient enriched groundwater into the estuary. This could occur since all WWTPs in the Chowan River watershed utilize land application.

There were several algal blooms in the Chowan, Perquimans, and Pasquotank Rivers in 2019, with different toxins encountered, including microcystin. Concentrations were highly elevated in some blooms (Arrowhead Beach, Indian Creek, Leary Landing), requiring health advisories. In October of 2019, there were six reports of blooms near Elizabeth City. These blooms are starting to begin earlier in the year and are lasting longer.[96] The DWR is actively working to develop appropriate nutrient criteria for the waters of the state. The DWR's goal is to develop scientifically defensible criteria based primarily on the linkage between nutrient concentrations and protection of designated uses. The criteria for each waterbody will be coordinated with other waterbodies to ensure consistency across the state and protect downstream uses.

North Carolina's nutrient management strategies have historically been driven by concerns over algal blooms and fish kills, not SAV decline. Early nutrient reduction efforts included the implementation of a statewide chlorophyll *a* standard in 1978, a nutrient sensitive waters (NSW) classification in 1979, and a phosphorus detergent ban in 1988.[65] The NC Nutrient Criteria Development Plan (NCDP) outlines several steps to establish nutrient criteria within the state in two phases.[97, 98] This includes the creation of a Scientific Advisory Council (SAC) and the identification of three geographic areas within the state for development of nutrient criteria. The plan also establishes a process through which DWR will evaluate nutrients throughout NC. One of the three areas identified is the estuarine region of the Albemarle Sound.

Phase I nutrient criteria development for the Albemarle Sound was completed in 2016 where a nutrient workgroup was convened and met over a period of two years to develop nutrient criteria recommendations and research needs. Although no consensus was reached on nutrient criteria recommendations, research needs were identified and a report generated.[98] North Carolina is now in Phase II of the process and has convened a SAC to review research and nutrient criteria proposed in Phase I, assess the quality and relevance of nutrient data, identify data gaps and help develop a management approach for Albemarle Sound.[97] Management actions will be focused on wastewater, agriculture, riparian buffer protection, stormwater runoff from new and existing development, and nutrient trading. Criteria will be regulatory goals for the waterbodies and are aimed at protecting designated uses such as aquatic life, using SAV habitat as a biological endpoint.

4.2.6 Other Contributing Factors

Climate Change

As climate change continues, forecast scenarios predict that NC coastal waters will experience warming temperatures, rising sea levels, and increasing risk for storminess and coastal flooding.[10, 99, 100, 101] Coastal NC has had 36 tropical cyclones over the past two decades that, based on their duration, wind speed, precipitation, and geographic track, have had impacts on hydrodynamic flows and nutrient and carbon loading to the Pamlico Sound system. A review of these storms by Paerl et al. on the impacts to the Neuse River and to the Pamlico Sound demonstrates that major storms can double annual nitrogen and triple phosphorus loading and can be a significant source of CO_2 releases into the atmosphere from extreme winds.[99] Historic flooding also provides large inputs of carbon from the watershed disrupting the carbon balance and leading to sustained CO_2 releases into the atmosphere for months. Phytoplankton patterns were also influenced by the loading and flushing of nutrients based on the quantities of freshwater discharged. High freshwater discharges will flush maximum nutrient loads, but these flushing rates can also exceed phytoplankton growth rates and cause temporary reductions in phytoplankton biomass. However, as flushing rates tend to be moderate in the days to weeks following a storm, phytoplankton can take advantage of elevated nutrients delivered during the storm and form blooms.

The warming ocean waters contribute to storm intensity, increased precipitation, slowed storm movement, and therefore provide more opportunity for heavy precipitation over a particular area for a longer period of time.[99, 101] It has also been observed that tropical cyclone paths are shifting northward, making NC more susceptible to these events. Extreme precipitation events result in flooding and high loading of organic matter, including organic nitrogen and phosphorus. This in turn fuels phytoplankton production, resulting in algal blooms and associated hypoxia. Runoff from agricultural fields and urban development also add to the contamination of floodwaters. This leads to the consideration that there may be a regime shift in heavy precipitation and tropical cyclone flooding and associated ecosystem impacts.[100] NC has experienced very high precipitation since the late 1990s with increasingly high precipitation events, including those associated with tropical cyclones that could have major ramifications for hydrology, carbon, nutrients, habitat and water quality in NC. Regime shifts in salinity and sediment budgets can also be expected if storms create new inlets alter the hydrology of the barrier islands.

With a regime shift in storms due to rising temperatures, it can also be expected to see species distribution shifts within our SAV system. As mentioned earlier, two of the three species of high salinity SAV in NC are existing at the edges of their geographic distributions; the tropical shoal grass where NC is the northernmost range and eelgrass, a temperate grass where NC is the southernmost range. As the climate changes and the waters warm, this could alter the growth, abundance and distribution of eelgrass with the potential for the southern range to shift north. Based on models of the impacts of sea surface temperatures, sea surface salinity, and melting sea ice on eelgrass distribution under different carbon emission scenarios, it is projected that climate change could possibly result in extirpation of eelgrass in NC by the end of the 21st century.[102] If there are no changes to carbon emissions, this study suggests that eelgrass will be extirpated in NC and Chesapeake Bay with the new southern range as far north as Long Island Sound by 2100. However, it is important to note that this study used very few eelgrass occurrence records from NC to inform their species distribution model making it unclear how this may have impacted their findings and the potential relevance to NC's SAV community.

<u>Physical Disturbances</u>

Physical disturbances can impact SAV and the shallow bottom habitat that they occupy by damaging or removing the plant and by changing the depth contour so that light is unable to penetrate for photosynthesis. Physical disturbance can come from fishing gear, mariculture practices, navigational dredging and impacts from marina and dock siting.

Mobile bottom-disturbing fishing gear is towed or run by power, and includes bottom trawls, oyster and crab dredges, hydraulic clam dredges, clam trawls, and haul seines. Most commonly used in NC is the shrimp trawl, followed by oyster and clam dredges. A legislative report to the Moratorium Steering Committee compiled a list of gears used in NC and probable habitat impacts and listed trawls and dredges having the greatest potential for impacts.[103]

Shearing or cutting of SAV leaves, flowers, or seeds, and uprooting of the plant are most often caused by dragging or snagging by these mobile fishing gears.[104] Shearing of above ground biomass does not always result in SAV mortality, but productivity is reduced since energy is diverted to replace damaged tissue, and nursery and refuge functions are reduced in the absence of structure. Belowground effects, such as those from toothed dredges, heavy trawls, and boat propellers, may cause total loss of SAV, requiring months to years to recover, if recovery occurs at all. Excessive suspended sediments from bottom disturbing fishing gear and propeller wash can bury SAV and reduce water clarity, resulting in decreased SAV growth, productivity, and survival. Qualitatively, damage to eel grass meadows from unspecified shellfish harvest dredges was surpassed only by damage from propellers.[1]

Bottom disturbing gears can potentially affect primary productivity through the connection of bottom and water column processes. Nutrients released into the water can increase nitrogen and phosphorus levels, stimulating phytoplankton growth and enhancing secondary productivity of herbivorous zooplankton and larger prey.[105] Increased plankton growth can reduce bottom penetrating light and extend the effects of trawling beyond episodic increases in turbidity. Eventually, the remains of plankton and other organisms will settle, adding to the food available to benthic deposit feeders. However, if large amounts of organic matter are resuspended, the increase in plankton can reduce water oxygen levels, causing hypoxia and anoxia.[106, 107] By resuspending sediments, trawling can make inorganic and organic pollutants available in the water column.[108, 109] Such toxins can affect productivity and accumulate in organisms through food chain interactions.

Shellfish mariculture is a growing industry in NC with 278 leases in 2018.[110] With this growth comes the concerns of how shellfish mariculture may impact SAV through use of bottom disturbing gears and by mariculture practices. Mariculture practices that may have an adverse impact on SAV include the type of farming method used (bottom or off-bottom), extent of shading, density of SAV within and adjacent to the lease area, density of product and equipment within the lease, water depth and harvest/retrieval methods.[111]

However, shellfish mariculture of bivalves such as oysters may have positive impacts to SAV by providing filtration of nitrogen and phosphorus into its shells and tissue and consuming phytoplankton and organic matter, thus improving water quality and clarity. Oysters represent a bottom-up approach to improve water quality while providing fisheries habitat and an economic benefit. Several studies are underway in NC to assess the effects of mariculture on SAV and ecosystem services. As more information becomes available, the full impacts of oyster mariculture can be determined.[112]

Other physical disturbances that can impact SAV include navigational dredging, dock and marina siting, boat wakes and prop scarring by boats and personal watercraft, and shoreline stabilization. Channel dredging impact is the physical loss of SAV within the dredge footprint. Impacts extend beyond the dredge footprint from sloughing into the channel and coverage from sediment on nearby SAV. Impacts from marina construction to SAV come from pile jetting/driving, shoreline stabilization, excavation, installation of docks, wave attenuation, and construction of associated high ground facilities, etc. Lesser recognized impacts are indirect and come from associated boating activities. The impacts from individual docks are less than those from marinas, yet the number of such dock permits far exceeds those of marinas. If properly designed, individual piers may not pose significant threats to beds of SAV. Other impacts come from associated boating activities. Direct physical impacts from propeller scarring, vessel wakes, and mooring scars have been identified nationally as a major and growing source of SAV loss.[21, 113, 114]

Propeller scarring of SAV occurs when outboard vessels travel through water that is shallower than the draft of the boat. The propeller blade cuts leaves, roots, and stems, as well as creating a narrow trench, or scar, through the sediment.[113] Large holes may also be blown where boaters rapidly power off shallow bottom.[115] Mechanical disturbance to the sediment damages plant rhizomes, which reduces abundance and cover for extensive periods of time. Recovery of SAV can take from two to 10 years, depending on species and local conditions. In some cases, though, the habitat may never recover.[116, 117] Once started, SAV damage can increase beyond the initial footprint of the scar, due to scour, storms, or biological disturbance such as crab and ray burrowing.[118, 119] Where prop scarring is extensive and SAV beds destabilized, the ecological value of the habitat is reduced.[114, 120]

Shoreline stabilization can threaten SAV and SAV habitat. Vertical hard structures alter the bathymetry and hydrodynamics of the adjacent bottom, with potentially adverse effects on shallow SAV. Such structures can increase reflective wave energy, causing scouring at the toe of bulkheads, eroding adjacent shorelines, and deepening adjacent water, thus reducing or eliminating wetland vegetation and shallow subtidal habitat such as SAV.[121, 122, 123] Shoreline hardening may also prevent wetlands and shallow subtidal habitats from migrating as sea level rises, resulting in loss or conversion of habitat. Other types of shoreline stabilization, such as living shorelines, can result in covering SAV due to its larger footprint, though permitting requirements do not allow living shorelines in SAV in NC.

SAV Pathogens

The endophytic slime mold protist, *Labyrinthula zosterae,* has been identified as the causative agent of wasting disease in eel grass; however, the triggers of these pathogenic outbreaks remain unclear. Bockelmann et al. have found that traces of *L. zosterae* endophytes are omnipresent in contemporary grass beds.[124] *L. zosterae* are detectable as black lesions on grass blades, a result of necrosis, but may also be present on apparently green healthy tissue. Historic population losses of large vertebrate grazers may have, among other consequences, increased SAV vulnerability to infection by pathogens.[125] It was suspected, but never proven, that *Labryinthula* was the cause of the wasting disease event that devastated eelgrass populations throughout the North Atlantic between 1930 and 1933, dramatically disrupting estuarine systems.[17] Higher water temperatures apparently stressed the SAV, making them more susceptible to *Labryinthula.* Vergeer et al. later confirmed a decline in the microbial defenses of SAV with increasing temperature.[126] The primary factor enhancing microbial defenses was increasing light intensity, which is related to both water quality and self-shading.

Potential impacts in NC include reductions in fisheries resources, and large reductions in migratory waterfowl populations and loss of ecosystem services. Future research should focus on obtaining quantitative data on the prevalence and abundance of the wasting disease pathogen *L. zosterae* in eelgrass populations.

Chemical Control of Aquatic Nuisance Species

Aquatic nuisance species are non-native and invasive species that can cause detriment to the ecosystem. Many invasive SAV can be transported from one system to another on boats, trailers and other equipment. Aquatic nuisance SAV species form dense beds, making swimming, fishing, and boating difficult; clogging water intake systems for municipalities and industries; and impeding water flow in drainage canals. Dense beds of Eurasian watermilfoil (*Myriophyllum spicatum*) can cause the water column to become anoxic at night, stressing fish or causing them to leave the area.[127] Although watermilfoil and other nuisance SAVs provide some benefits to fish and crabs, such as refuge and sediment stabilization, and can be an important component in the low salinity/freshwater SAV community of northeastern NC, they can also negatively impact natural habitat by shading or out-competing native SAV species, which may have greater value to fish.[128]

Chemical herbicides are used to suppress aggressive nuisance vegetation and should be applied using an integrated management approach. Effects of herbicides are influenced by their toxic mode of action, their method of application and either target a specific species or provide a broad spectrum of control. Registered chemicals are used to control nuisance aquatic vegetation and are highly effective when following labelling. Application rates vary based on the system and environment, and efficacy of herbicides varies based on the herbicide and formulation and the specific species being treated. Rotation of herbicides is recommended because of a growing number of cases where aquatic plants are developing resistance.[129]

The DWR implements the Aquatic Weed Control Program (AWCP), which focuses primarily on non-native invasive species in freshwater lakes, ponds, and rivers. The AWCP responds to requests for assistance from local governments, public utilities, and other agencies, providing technical and financial assistance (50:50 cost share). There are growing concerns that the control of noxious aquatic weeds by herbicides may also impact native SAVs. Overall, broader coordination is needed to address and balance the impacts and patchwork treatments of noxious aquatic weeds such as hydrilla (*Hydrilla verticillata*), alligatorweed (*Alternanthera philoxeroides*), and Eurasian watermillfoil and the protection of native SAVs. Some DMF sampling has indicated that these noxious weeds, particularly Eurasian watermilfoil, provide nursery habitat for various fish species such as blue crab and river herring. There are other concerns of the public wanting native SAVs removed because of disruptions in boating traffic, recreation, and aesthetics. Outreach on the value of native SAV is needed to address this negative public perception.

4.3 Discussion

To have cleaner waters and resilient coastal habitats that support fisheries, it has become more important than ever to make the effort to attain a healthy condition that supports SAV recovery. As we experience increased coastal development and extreme rainfall and flooding associated with climate change, SAV can then be more resilient to natural perturbations that also drive the natural fluctuations of SAV populations and extent.

4.3.1 Reducing Nutrient Loads

Submerged aquatic vegetation sensitivity to nutrient concentrations occurring in NC's estuarine system makes it a valuable bio-indicator of eutrophication of our estuarine waters. Both the Tampa Bay experience and the Chesapeake Bay experience are examples of how the direct effects of nutrient and sediment enrichment of estuarine and coastal systems cause losses of SAV. In both cases, reductions in land-based sources of nutrients and sediment pollutant loads documented by scientists and managers directly lead to significant increases in SAV acreage, bed density and species diversity in both estuaries. The adoption of numerical SAV restoration goals by policy makers responsible for management of both of these systems led to actions which significantly reduced nutrient and sediment pollutant loads from land-based sources resulting in clearer and cleaner waters and restoration of SAV. While SAV distribution fluctuates naturally due to storms, temperature, salinity, and other factors, the long-term increase in SAV abundance and density in Chesapeake and Tampa bays was attributed to the improvement of water quality conditions from management changes.[130] Additionally, the improvements in water quality helped make the SAV habitat more resilient to the more frequent and intensive storms and weather patterns. Clean water is a necessity for estuarine health as well as human health. As we begin experiencing the impacts of climate change, it is even more important to establish cleaner and clearer water so that when weather conditions are less favorable for SAV and declines occur, recovery is faster. This will help ensure NC's estuarine ecosystem remains vital for healthy fisheries, coastal resilience, and overall value of these NC resources.

Clean Waters and SAV: Making the Connection Workshop

In March 2020, a technical workshop, *Clean Waters and SAV: Making the Connection*, was held and included over seventy federal, state, and local governments, academic institutions, and nonprofit organizations to discuss the scientific links between SAV health and water quality.[65] Strategies to improve water quality for the protection and restoration of SAV in NC coastal waters were discussed. Besides providing an opportunity for different participants to learn about the connection of water quality to SAV, it also provided information to inform this issue paper. Facilitated group discussions focused on identifying additional information needed to develop long-term SAV conservation and management strategies in NC. Through facilitated group discussions, informational needs for both high and low salinity SAV were listed and then prioritized by the workshop participants. Those needs were used to guide potential recommended actions for this issue paper.

4.3.2 Proposed Strategies

Following the successful examples of Chesapeake Bay and Tampa Bay and in support of the efforts of the NCDP, NC can consider the development of a five element strategy to improve water quality and restore and protect SAV. These elements include:

1) supporting efforts to improve water quality
2) protecting and restoring SAV
3) enhancing SAV research and monitoring
4) improving collaboration through citizen involvement, education and outreach
5) addressing other contributing factors such as physical disturbance and climate change.

Because of observed links between nutrients, light limitation and SAV abundance, reducing nutrients by improving water clarity is the key objective to increase SAV abundance.[78, 94]

Support Water Quality Improvement Efforts

Water quality improvements through the implementation of standards and best management practices must be supported by data. North Carolina has large amounts of basic water quality data for estuarine waters, particularly in the tributaries and along the barrier islands, but data gaps do exist, especially in open water areas of the sounds. While much of the available chlorophyll *a* and turbidity data come from DWR's Ambient Monitoring System, other state agencies like DMF also collect water quality parameters, such as secchi disk depth, during routine surveys. Another large data set comes from the Neuse River estuary Modeling and Monitoring Project (ModMon) and a state ferry-based monitoring system for Pamlico Sound (FerryMon). Both are led through the University of North Carolina at Chapel Hill – Institute of Marine Science (UNC-IMS).[65] However, another light attenuating factor that is only collected by ModMon at limited stations is CDOM. CDOM is linked to river discharge and salinity, but is not nutrient related and may make areas such as the Neuse and other coastal rivers more difficult to address in terms of nutrient management. All of these data sources and others should be evaluated, standardized, and expanded where possible to support existing and future water qualtiy management actions.

Current water quality improvement efforts include DWR's work toward a nutrient criteria plan for the Albemarle Sound and Chowan River. The DWR's goal is to develop a scientifically defensible criteria based primarily on the linkage between nutrient concentrations and the protection of designated uses. The NCDP SAC includes several SAV, water quality and nutrient cycling/primary production dynamics experts. The NCDP SAC and DWR are reviewing potiential endpoints and parameters such as DO, chlorophyll *a*, algal density and biovolume, light penetration, SAV, and aesthetics, etc. to be included in the criteria. Ongoing work on an optical model relating chlorophyll *a* to water clarity will also be used to help inform the NCDP SAC's decisions. Considering SAV when developing plans like this, and others, such as watershed plans, will help improve water quality by expanding areas suitable for the growth and reproduction of SAV.

<u>Protect and Restore SAV</u>

By consulting experts from Chesapeake and Tampa bays, NC can benefit from the lessons learned from their experiences, and NC can develop a similar process of protecting and restoring SAV.[65] Like both bay examples, establishing an SAV restoration goal and determining the light requirements for growth and reproduction for SAV across salinities will help narrow the management focus on water quality parameters such as chlorophyll *a* and nitrogen loading targets. This will require a multi-step and additive process to achieve the goals set forth and are descibed below. Figure 4.10 provides a conceptual framework of the process. Addressing suspended sediments can also aid water clarity. However, it was decided to focus on nutrients since they were thought to be having a greater influence on water clarity and SAV, and nonpoint runoff strategies for nutrient loading reductions will also reduce sediment loading.[131]

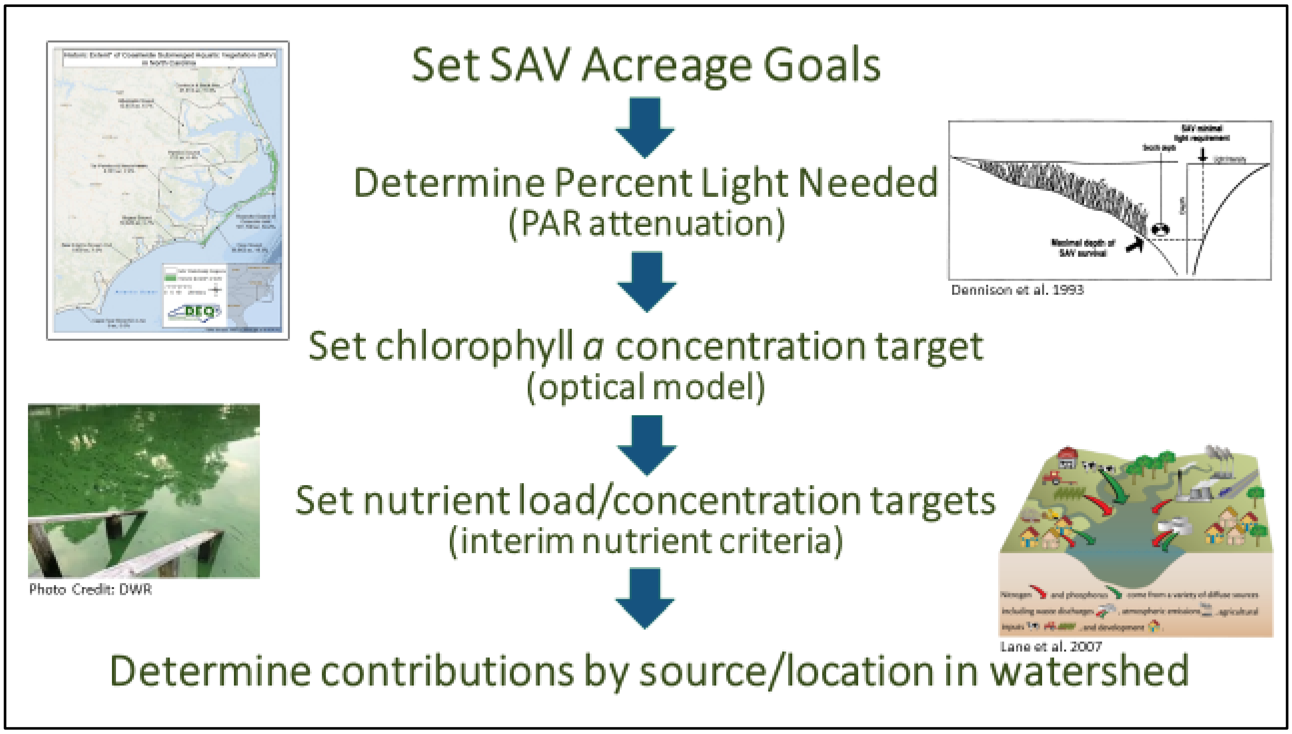

Figure 4.10. Conceptual framework depicting the steps to restore Submerged Aquatic Vegetation (SAV) through water quality improvements.

Adopt an interim SAV acreage goal

As previously discussed, multiple individual mapping events have been compiled to make up the historically known presence and known habitat suitable for SAV along NC's coast, suggesting a historic extent of approximately 191,155 acres of SAV in public trust waters in coastal NC (Table 4.5; Figure 4.1-4.9). This is currently the best known estimate of where SAV has persisted in the past, may currently persist, and will hopefully persist in the future. Therefore, the coastwide SAV protection and restoration goal is set as an interim goal of 191,155 acres. The NC coast and the known historic SAV extent is further divided into nine SAV regions to best represent regional variability of waterbodies, and are as follows: Currituck and Back Bay (Figure 4.1), Albemarle Sound (Figure 4.2), Tar-Pamlico and Neuse rivers (Figure 4.3), Pamlico Sound (Figure 4.4), Roanoke Sound to Ocracoke Inlet (Figure 4.5), Core Sound (Figure 4.6), Bogue Sound (Figure 4.7), Bear Inlet to Snow's Cut (Figure 4.8), Cape Fear River to SC line (Figure 4.9; Table 4.5). Setting regional goals allow for targeted actions that will aid in meeting the interim coastwide goal as each region is continually evaluated and refined and as new mapping data become available.

Adopt a light target of 22 percent for high salinity SAV and 13 percent for low salinity SAV to the deep edge of the SAV beds

Water clarity and light penetration are two major limiting factors to SAV growth that can be managed with appropriate interventions. Light attenuation by non-algal particulates, phytoplankton, and CDOM therefore influence SAV growth and depth of growth.[49, 91, 132] In order to protect and restore SAV, studies indicate that water clarity needs to be maintained to the depth where 22 percent of subsurface irradiance (incident light) is available for photosynthesis for high salinity SAV and 13 percent subsurface irradiance for low salinity SAV.[45, 50, 51]

Validate a bio-optical model to define interim chlorophyll a targets for SAV waterbody regions

With funding support from APNEP, UNC-IMS scientists have conducted a validation exercise for a bio-optical model that is intended for use to develop chlorophyll *a* and turbidity standards that are protective of NC's high salinity and low salinity SAV habitats.[49] Results from this model can then be used to estimate chlorophyll *a* concentrations necessary to maintain water clarity needed for seagrass growth as it relates to 22 percent incident light to a depth of 1.7 m for high salinity SAV and 13 percent incident light to a depth of 1.5 m for low salinity. These concentrations can then be used as light penetration targets.

The bio-optical model was initially developed by Gallegos for use in Chesapeake Bay. However, Biber et al. re-calibrated the model using waters from the North River in NC, for intended use throughout the Albemarle-Pamlico estuarine system.[39, 49] Optical characteristics of particles and phytoplankton of the North River may, or may not, be similar to those of other areas within the Albemarle-Pamlico estuarine system, and those differences may impact the ability of the model to accurately predict relationships between light attenuation and concentrations of chlorophyll *a*, turbidity, and CDOM that attenuate light. To assess the validity of the model outside of the area where it was calibrated, the validation exercise compared model predictions of light attenuation to measurements of light attenuation from waters throughout the Albemarle-Pamlico estuarine system.

Preliminary results from the validation exercise showed that the bio-optical model accurately predicted observed light attenuation in high salinity waters similar to those of the North River.[133] In the high salinity waters, turbidity rather than chlorophyll *a* was the main light attenuating substance in the water. For the high salinity locations which included Bogue Sound, Core Sound, Back Sound, and eastern

Pamlico Sound, a median chlorophyll *a* concentration of 10 µg/L would meet the 22 percent light target for SAV protection.

For low salinity waters of the Neuse River, Pamlico River, western Pamlico sound, and Albemarle and Currituck Sounds, the model underestimated light attenuation by approximately 50 percent. Estimates of target chlorophyll *a* concentrations required to meet the 13 percent light target for low salinity SAV would also be significantly underestimated, thus preventing the use of the current model to derive low salinity chlorophyll *a* targets. The bio-optical model will require recalibration for NC's low salinity estuarine waters before it can provide meaningful targets for chlorophyll *a* and turbidity for protection of NC's low salinity SAV habitats.[133] Through collaborative efforts from DEQ, APNEP, National Oceanic and Atmospheric Administration's (NOAA's) Beaufort Laboratory, and UNC-IMS, efforts to recalibrate the bio-optical model for low salinity estuarine waters are underway. Once the model is validated for high and low salinity, the model can be used to develop management scenarios for chlorophyll *a* reduction to meet water clarity targets that are supportive of SAV restoration goals. Scenarios can be used to develop GIS layers of areas where there will be sufficient light for SAV persistence and may be used to determine potential growing areas that will support SAV.

Assess existing North Carolina water quality standards for chlorophyll a supporting sufficient light penetration for SAV growth and reproduction

Target concentrations of chlorophyll *a* and turbidity identified by the bio-optical model should be compared and considered in relation to existing water quality standards for class C waters to determine whether the standards need revising to protect critical SAV habitats. Preliminary results from the model showed that a median annual chlorophyll *a* concentration of 10 µg/l would be protective of NC's high salinity SAV habitats; this value is lower than the current 40 µg/l standard for chlorophyll *a* in NC surface waters. However, a direct comparison to the standard is difficult because the current standard is not assessed at the median (50 percent quantile) chlorophyll *a* level, rather the current 40 µg /l standard is assessed at the 90 percent quantile. Using the statistical, probability distribution of chlorophyll *a* from estuaries throughout NC waters, a 10 µg /l median value corresponds to a 90 percent quantile of 26 µg/l, significantly less than the current 40 µg/l standard.[133] Comparisons of chlorophyll *a* concentrations to revised standards will help identify regions where nitrogen load reductions are necessary to protect SAV. Relationships between nutrient loading and chlorophyll *a* will need to be determined and will help manage sources of nutrient loads by SAV waterbody region and ultimately throughout coastal NC.

Enhance Submerged Aquatic Vegetation (SAV) Research and Monitoring

Understanding the distribution and health of SAV in NC is critical to understanding the dynamics of shifts in SAV species extent, distribution, and composition. As previoulsy described, mapping of SAV has occurred at irregular intervals over the last 40+ years by several different agencies and universities, across different extents, and with varying methodologies and resolutions. A comprehensive monitoring and assessment program for SAV should be developed using the best available technology. The use of the most comprehensive, highest resolution, and cost effective methods available should be explored and used. This program should be developed by a team of partners, and should include a full-scale, routine (occurring every five years or sooner), coast-wide assessment and monitoring program. Sentinel sites should be re-evaluated and expanded along the coast, with regular groundtruthing using standardized metrics (i.e. water quality, species composition, density, and condition).[10] This will allow managers to account for changes in SAV over time, giving the ability to evaluate the success of management actions and determine causative relationships between changes in SAV species extent, distribution, and composition. Through regular monitoring and assessment, protection of this habitat can be improved and targeted, benefiting the diversity and resiliency of the entire coastal ecosystem.

Improve Collaboration

Strong collaboration among scientists, managers, and the public is essential to achieve the goals and actions listed above. Regional collaboration among resource stakeholders was critical to success in both Chesapeake and Tampa bays.[94, 95] North Carolina should establish a similar collaborative process involving state agencies, local governments, academic institutions, NGOs and the public to monitor, assess, and adaptivly manage regional areas. Collaboration to develop and adopt management goals, and to engage in the decision making process on needed management actions, changes, and adjustmants leads to better public understanding and appreciation of the issues. This in turn helps to change public perception and behavior by engaging and informing stakeholders early in the process to play a role in implementation of management actions in their communities, such as voluntary citizen science monitoring programs.

Other Contributing Factors

Climate Change

As noted earlier, increases in extreme rainfall and flooding events associated with climate change will play a role in continued and future water quality degradation, which will result in further impacts to SAV.[10, 101, 99] Water quality impacts include increasing water temperatures, changes in salinities due to increased freshwater input and breaching inlets, hydrologic changes from extreme rainfall and flooding events, high loading of organic matter and organic nitrogen and phosphorus, and contaminants from agriculture and development runoff into the estuary. This in turn can fuel algal blooms and associated hypoxic events. This can be catastrophic to SAV, the other surrounding coastal habitats, and the marine organisms that use them.

It is also possible that the effects of climate change could create a shift in the distribution and metabolism of SAV species and will have impacts on marine organisms that use SAV for nursery areas, refuge, and food supply. These same impacts will also force hundreds of fish and invertebrate species to move northward.[134] A comprehensive, routine, coastwide assessment and monitoring program would also be benfical in determing the relationships between SAV species extent, distribution, and composition and the effect of climate change. This could be instrumental in determining ways to make the NC coastal community and ecosystem more resilient.

Physical Disturbance

It must also be recognized that physical disturbance from fishing gears, boating activities, aquaculture, and impacts from toxins and pathogens are also sources of SAV loss. SAV is offered some protections from physical disturbance under several state, federal, and interstate rules, policies and plans. Further protections and increased mitigation requirements for impacts to SAV and SAV habitat, such as restoration efforts, could be beneficial to the SAV ecosystem and add to its resiliency and the resiliency of the coastal community.

Fishing Gears

Through the authority of the MFC, DMF implements and enforces the use of fishing gears in coastal waters. Rules describe and define habitat areas such as SAV that are protected from bottom disturbing gears. For example, the SAV along the Outer Banks are closed to trawling, mechanical clam harvest and mechanical oyster harvest. Areas known as Primary Nursery Areas (PNAs), located in the upper most tributaries of our estuarine sounds and rivers, are also closed to trawling, long haul, swipe nets, and mechanical gear for clams and oysters. Secondary Nursery Areas (SNAs) are typically located adjacent and downstream of primary nursery areas and are closed to trawls.

Through the state FMP process, SAV habitat has been protected by establishing buffers and altering boundaries to further protect SAV. Changes in trawling boundaries have occurred in Pamlico Sound, western Bogue Sound and in New River to further protect SAV. The mechanical clam harvest line in New River was also altered to protect SAV, and now both the shrimp trawl lines and the mechanical harvest lines are the same in the area below the Highway 172 Bridge. Fishing gears, practices, and areas should be evaluated regularly to ensure there are no additional impacts to SAV.

Mariculture

The growth in the NC mariculture industry may have impacts to SAV. In 2018, 69 lease applications were submitted with 39 leases granted. An average of 28 lease applications was submitted per year in the previous six years, showing a measurable increase in interest in the industry.[135] Prior to 2015, DMF, in accordance with federal regulation, did not permit shellfish leases where SAV was present. This presented numerous challenges for state managers during the application review process in determining if the location of a proposed lease complies with federal regulation of causing no or acceptably low impact to SAV. To resolve this challenge, a working group of federal and state resource agency staff was created to develop guidance for acceptable amounts of SAV during the survey by water depth. Additionally, no bottom disturbing methods can be used to harvest shellfish from leases meeting the SAV criteria. These interim conditions were later adopted as part of the 2017 authorization of the US Army Corps of Engineers Nationwide Permit (NWP 48) for Commercial Shellfish Aquaculture Activities in NC. The NWP 48 is re-evaluated and renewed in five year cycles.

Continued improvements in spatial planning and siting shellfish leases, such as the UNC-W NC Shellfish Siting Tool[136] and the DMF Shellfish Leasing Application[137] can help provide a balance between habitat as well as social and economic considerations. Striking that balance can help facilitate sustainable development of shellfish mariculture and protection of SAV and other structural habitats, such as natural oyster rock. It can help reduce user conflicts, and provide information for scientifically based management. A recent report to the NC General Assembly provided recommendations for research needed to better understand the ecological and environmental effects of shellfish mariculture and develop standards to guide regulations and inform best management practices.[110]

Pathogens

Submerged aquatic vegetation needs to be monitored on a periodic basis to assess the status of wasting disease, and its association with human-induced stresses, and to assess the health and condition of SAV. Because the highest abundance of seagrass wasting disease occurs in the summer months, the possibility of global climate change, sea level rise, and increasing rates of marine diseases, baseline data on the distribution and abundance of wasting disease are needed in order to detect trends spatially and temporally.[124, 126] Anecdotally, another microbial stressor on SAV could be the gall-like growths on widgeon grass observed in low salinities areas such as Blounts Bay.[138] The effects of the gall-like growths on widgeon grass in Blounts Bay are unknown. However, the 2009 disappearance of widgeon grass in Blounts Bay may suggest a causal link.[139] Although outbreaks of diseases and microbial stressors are largely out of the control of coastal managers, these events need to be monitored for trends, which further supports the need for a comprehensive SAV monitoring and assessment program.

Chemical Control

A critical evaluation of ecosystem services that are provided by Eurasian watermilfoil and other invasive species may need to be considered in future management. The evaluation of organismal functional traits may provide one way to quantify the contributions of different species. These traits reflect species' tolerances to disturbance and ability to tolerate more nutrient rich waters than native SAVs, as well as their effects on primary productivity and other ecosystem functions. Invasive plants are often introduced by activities like "hitchhiking" on boats, trailers, or other equipment being moved from one location to another, being regenerated from a fragment, and being released intentionally.[140] Increasing public awareness of aquatic weeds, and aquatic invasive species in general, is paramount to a more proactive and preventative management approach. The DWR, in cooperation with WRC, has posted signs at over one hundred public boating access areas, intending to educate boaters and encourage them to clean and dry their equipment prior to going to other locations.

An objective of the ANS Plan is to increase coordination between agencies on control of aquatic nuisance species and impacts to native SAV as well as impacts to fish habitat. There is coordination between staff of DWR's aquatic weed control program and biologists in DMF's habitat enhancement section on projects that may impact native SAV resources. However, developing a more formal collaboration among the experts will only increase communication and participation with governmental agencies.

Other concerns are the use of herbicides by private waterfront landowners who are interested in the removal of SAVs, whether invasive or native, because of the impacts to aesthetics and recreational use of the adjacent waters. Outreach is needed to inform landowners of the importance of native SAVs, and best management practices to address invasive SAVs including processes that are currently in place to remove invasive SAVs.

4.4 Recommended Actions

4.4.1 Funding

4.1 By 2023, DEQ will obtain recurring funding that includes the adequate amount of staff to successfully evaluate and meet the SAV acreage goals and implement all of the SAV recommended actions that contribute to meeting the goals.

4.4.2 Planning

4.2 By 2022, DEQ will commit to protecting and restoring SAV to reach an interim goal of 191,155 acres coastwide with specific targets by SAV waterbody regions (Table 4.5; Figures 4.1-4.9).

4.3 By 2022, DEQ will form an interagency workgroup with NGOs, and local governments to inform and guide development of watershed restoration plans to protect, restore or replicate natural habitats (i.e., SAV, water quality, coastal habitats) and hydrology through natural and nature-based solutions.

4.4 By 2022, DEQ will form a workgroup with DWR, Soil and Water Conservation, local governments, and other partners to develop a plan to increase the use of BMPs related to water quality within the SAV waterbody regions by 50 percent (Table 4.5; Figures 4.1-4.9).

4.4.3 Mapping and Monitoring

4.5 By 2023, DEQ will develop and implement a full-scale assessment program to conduct coastwide SAV mapping and monitoring at regular intervals (≤ 5 years).

4.6 By 2023, DWR will evaluate and prioritize the incorporation of shallow water sites (< 1m mean lower low water (MLLW)) that currently or historically contain(ed) SAV into the statewide ambient monitoring system.

4.4.4 Potential Rulemaking

4.7 By 2022, the Nutrient Criteria Development Plan (NCDP) Scientific Advisory Council (SAC) will evaluate recommending the EMC establish a water quality standard for light penetration, with a target value of 22 percent to the deep edge (1.7 m) of SAV for all high salinity SAV waterbody regions, and a light penetration target of 13 percent to the deep edge (1.5 m) for all low SAV waterbody regions (Table 4.5 and Figures 4.1-4.9).

4.8 By 2022, the NCDP's SAC will evaluate the chlorophyll *a* water quality standard and as needed, recommend it be revised by the EMC to ensure protection of SAV in high and low salinity waterbody regions, beginning with the Albemarle Sound and Chowan River, and continuing with other waterbodies that support SAV (Table 4.5; Figures 4.1-4.9).

4.9 By 2024, EMC will adopt scientifically defensible nitrogen and/or phosphorus criteria if recommended through the NCDP process, to help protect and restore ~12,900 acres of low salinity SAV habitat in the Albemarle Sound SAV waterbody region and continuing with other waterbodies that support SAV.

4.4.5 Research

4.10 By 2025, DWR will determine with assistance from research academia, the loading and sources of nutrients and sediments, their quantitative linkages to chlorophyll *a* concentrations, and their effect on water quality and SAV.

4.11 By 2022, NC and DEQ, through the Secretary of Emergency Management, will request more accurate estuarine bathymetry data from NOAA.

4.12 By 2022, DWR will request the NC Policy Collaboratory to investigate the impacts of agricultural practices and land use change on water quality within SAV waterbody regions, to determine types and location of BMPs needed to effectively improve water quality.

4.4.6 Outreach

4.13 By 2022, DEQ Office of Education and Public Affairs will work with local governments and NGOs to start the development of public education and stewardship programs with social media campaigns and citizen science monitoring to increase public awareness of SAV's importance for fish habitat and other co-benefits, as well as instill public commitment to SAV conservation.

4.14 By 2022, DEQ through funding of NCSU by APNEP will provide an economic evaluation of the co-benefits SAV provides to the coastal economy in terms of habitat for fish, waterfowl, wildlife, recreation, shoreline stabilization, water purification, and carbon sequestration.

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5. WETLAND SHORELINE PROTECTION AND ENHANCEMENT WITH FOCUS ON NATURE-BASED SOLUTIONS

5.1 Issue

Wetlands occur throughout NC's estuaries and provide critical fish habitat and other ecosystem services that enhance ecological and community resiliency. While protections for wetlands are in place, losses continue to occur and threats remain, varying by wetland type and location. Addressing coastal wetland loss holistically will require a comprehensive approach incorporating: 1) an appraisal of existing and anticipated threats to coastal wetlands, 2) a synthesis of knowledge gaps, 3) a plan to build partnerships with local communities and encourage a participatory approach to coastal resource management, and 4) a list of high-priority, actionable policy or practice recommendations that could be implemented to offset past and expected losses.

5.2 Background

Wetlands are defined by the US Environmental Protection Agency (EPA) as "those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions." [40 CFR 230.3(t)] Coastal wetlands have long been recognized for their importance in estuarine productivity, habitat functions for finfish and shellfish, and many other ecosystem services. These services collectively make wetlands one of the most critical estuarine habitats for countless species of fish and other wildlife. The large extent of wetlands in North America's Coastal Plain substantially contributes to the high biodiversity.[1] Salt marshes provide grazing, foraging, and breeding ground for numerous threatened marine megafauna (e.g., sea turtles, porpoises, sharks, rays, and otters).[2] In NC, more than 70 percent of species listed as federally or state endangered, threatened, or of special concern are wetland-dependent.[3, 4] Some of NC's designated endangered species include mollusks (yellow lampmussel, *Lampsilis cariosa)*; fish (Atlantic and shortnose sturgeon, *Acipenser* spp.; Cape Fear shiner, *Notropis mekistocholas*); reptiles (Kemp's ridley sea turtle, *Lepidochelys kempii*); amphibians (river frog, *Rana heckscheri*); mammals (manatee, *Trichechus manatus*); and birds, (piping plover, *Charadrius melodus circumcinctus*).[5]

There are multiple classification systems used to differentiate classes of wetlands. For the purposes of this paper, a simplified Cowardin System which splits coastal wetlands into two broad classes, palustrine and estuarine, is used. Palustrine wetlands are freshwater wetlands that include all non-tidal wetlands that are dominated by trees, shrubs, or emergent vegetation, as well as any tidal wetlands where ocean-derived salinities are less than 0.5 parts per thousand (ppt). Wetlands with salinities greater than 0.5 ppt are categorized as estuarine wetlands, which can be further divided by vegetation type into forested, scrub/shrub, and emergent estuarine wetlands. This differs from the CRC's regulatory definition of coastal wetlands (15A NCAC 07H .0205), which includes ten specific species of salt marsh or other marsh subject to regular or occasional flooding by lunar or wind tides.

5.2.1 Ecological Value

<u>Productivity</u>

Wetland communities are among the most productive ecosystems in the world.[6, 7, 8] Some of the high primary production (creation of organic compounds through photosynthesis) of wetland vegetation is transferred to adjacent aquatic habitats via detritus and microalgae.[9] Primary production in salt/brackish marshes is converted into fish production in several ways. In Georgia, experiments using isotopes to trace organic matter flow in the salt marshes found the two major sources of organic matter used in fish production were from *Spartina* spp. detritus and algae.[10] A 2020 study conducted in Back Sound, NC, which used stable isotopes to analyze the diet of finfish and crustaceans within seagrass beds, found that consumers in these seagrass beds derived 20-23 percent of the basal primary production from saltmarshes, regardless of the proximity of the sampled seagrass bed to saltmarsh.[11] Benthic microalgae support herbivorous snails, whereas detritus supports finfish such as sheepshead, mummichogs, and their prey. Algae can be found on marsh grass, intertidal mudflats, and shallow subtidal bottom near the marsh. Saltmarsh edge is estimated to have production of 2.2 to 4.2 times greater than open water estuarine habitat for important fishery species (i.e., penaeid shrimp and blue crabs).[12] Primary production in tidal freshwater marsh, bottomland hardwood, and riverine swamp forest is similarly high and dependent on the frequency and duration of flooding.[13]

<u>Fish utilization</u>

The high productivity of coastal wetlands is in part why they are critically important to the productivity of the state's fisheries (Table 5.1). More than 90 percent of NC's commercial fisheries landings and 60 percent of its recreational harvest consist of species dependent on estuarine habitats including wetlands.[14] Of the wetland dependent species included in Table 5.1, seven commercial species ranked within the top ten for pounds landed in 2019 and seven recreational species ranked within the top ten for number of directed trips. The plant structure, high productivity, and landscape position in estuaries provide ideal conditions for small prey and juvenile fishery species. Similarly, palustrine wetlands are important habitat for many recreationally important freshwater fishes (e.g., largemouth bass, bluegill, crappie, chain pickerel) throughout their life histories.[15] A study in Virginia found that 79 percent of the number of fish collected at tidal freshwater marsh sites were larval and juvenile fish.[16] More information on how different species guilds use the estuarine and palustrine wetlands can be found in the 2016 CHPP source document.[17]

Photo Credit: NCWetlands.org

Table 5.1. Finfish and crustaceans and their use of wetland habitats in North Carolina.[7, 9, 18, 19, 20, 21, 22]

Species*	Wetland Functions					Fishery**
	Nursery	Foraging	Refuge	Spawning	Corridor	
RESIDENT FRESHWATER OR BRACKISH						
White perch	X			X		X
Yellow perch	X	X		X		X
Catfish	X	X	X	X	X	X
ANADROMOUS AND CATADROMOUS						
American eel		X	X		X	X
Sturgeon spp.	X	X	X		X	X†
River herring (alewife & blueback herring)	X	X	X	X	X	X†
Striped bass	X	X	X		X	X
ESTUARINE AND INLET SPAWNING AND NURSERY						
Atlantic rangia clam	X	X	X	X		
Banded killifish	X	X	X	X		
Bay anchovy	X	X		X		
Blue crab	X	X	X		X	X
Cobia	X	X			X	X
Grass shrimp	X	X	X	X		
Mummichog	X	X	X	X		
Naked goby	X	X	X	X		
Red drum	X	X	X		X	X
Sheepshead minnow	X	X	X	X		
Silversides	X	X		X		
Spotted seatrout	X	X	X		X	X
MARINE SPAWNING, LOW-HIGH SALINITY NURSERY						
Atlantic croaker	X	X	X		X	X
Atlantic menhaden	X	X			X	X
Shrimp	X	X	X		X	X
Southern flounder	X	X	X		X	X
Spot	X	X	X		X	X
Striped mullet	X	X	X		X	X
MARINE SPAWNING, HIGH SALINITY NURSERY						
Black sea bass	X	X	X		X	X
Pinfish	X	X	X		X	X
Summer flounder	X	X	X		X	X

* Species in bold font are species whose relative abundances have been reported in the literature as being generally higher in wetlands than other habitats. Note that lack of bolding may be due to lack of information rather than non-selective use of wetlands.

** Existing commercial or recreational fishery. Fishery and non-fishery species are also important as prey.

† Fishery species under harvest moratorium.

Chapter 5. Wetland Shoreline Protection and Enhancement with Focus on Nature-based Solutions

Wetland ecotones, the transitional landscapes between two adjacent habitats, are thought to be particularly important estuarine nursery areas. Juveniles of transient, estuarine-dependent species, which comprise a large portion of commercially and recreationally valuable species, often concentrate within the transition zones between marsh and other structured (e.g., seagrass beds, oyster reefs) or unstructured (soft bottom tidal creeks) habitats.[23, 24] These transition zones are thought to provide increased foraging opportunities that translate to higher growth rates, increased survivorship due to reduced mortality, and favorable physical environments for the development of juvenile nekton.[11, 25, 26, 27, 28, 29, 30, 31, 32, 33] As a dominant shoreline type within temperate estuaries, salt marsh complexes represent important foraging grounds for large mobile finfish and crustacean species, such as red drum, spotted seatrout, flounders, and blue crab.[34, 35]

The Fisheries Reform Act of 1997 requires DMF to prepare fishery management plans (FMP) for adoption by the NC Marine Fisheries Commission (MFC) for all commercially and recreationally significant species or fisheries that comprise state marine and estuarine resources. The goal of the plans is to ensure long-term viability of these fisheries. Fisheries habitat and water quality considerations are one of several requirements of these plans and are to be consistent with the CHPP. Several state FMPs recommend restoring wetlands, acquiring land to preserve wetlands and open space, reducing runoff from land use activities through voluntary and regulatory measures, restoring hydrology on developed, agriculture, and forestry lands using Best Management Practices (BMPs), and providing more incentives for low impact development (LID). The FMPs that included these wetland-related habitat and water quality actions are:

- Bay Scallop Amendment 2[36]
- Estuarine Striped Bass Amendment 1[37]
- Kingfishes[38]
- Red Drum Amendment 1[39]
- River Herring Amendment 2[40]
- Shrimp[41]
- Southern Flounder Amendment 1[42]
- Spotted Seatrout[43]
- Striped Mullet Amendment 1[44]

Ecosystem Services

Coastal wetlands, including those abutting and those that are not directly connected with surface waters, provide numerous ecosystem services that benefit fish, other coastal habitats, water quality, and communities. Coastal wetlands provide a wide variety of ecosystem services, such as wave energy dissipation, flood storage, shoreline stabilization, water filtration, open space, ecotourism opportunities, carbon sequestration, nursery grounds for commercially important species, and pollinator habitat. Updated valuations of selected coastal wetland ecosystem services including storm protection, erosion protection, and wastewater treatment, estimate monetary values for tidal marsh/mangrove at roughly $78,000 per acre per year.[45] While the co-benefits of interconnected coastal habitats and regional specificity make parsing out one single per-acre value of NC's coastal wetlands impractical, the ecosystem services provided by coastal wetlands are clearly a valuable public trust asset to the citizens of NC.

Storm Protection and Flooding

Coastal wetlands aid in storm and shoreline protection by reducing wave energy along the shoreline.[46, 47, 48] These reductions in wave energy and flooding translate to considerable economic impacts. Analysis of 34 major hurricanes impacting the US since 1980 found that, on average, one acre of coastal wetland loss resulted in an additional $13,360 of storm-related damages.[47] The total value of coastal wetlands in the US was estimated at $23.2 billion per year in storm protection services. Storms and hurricanes present major threats to coastal communities and infrastructure, the severity and cost of which will be further amplified by sea level rise (SLR) and ocean warming attributable to climate change.[49, 50] Presence of wetland vegetation appreciably reduces property damage by imposing drag on water flow, which in turn reduces wave energy and inland flooding during storm events.[51, 52] Near complete dissipation of wave energy has been documented by marshes extending approximately 30 m from the shoreline; however, due to the non-linearity of wave damping, marshes <10 m in width are frequently capable of reducing wave heights by 50-80 percent.[51, 53] Coastal wetlands were found to reduce flood heights and damages from Hurricane Sandy in 80 percent of the impacted region from Maine to NC.[54] Recent analyses found that over a 30-year period, the storm protection value of one square mile of coastal wetlands exceeds $2.5 million in eight of NC's 22 coastal counties, with the value approaching $25 million per square mile in highly developed New Hanover County.[55]

While palustrine wetlands play a lesser role in mitigating storm surge, they can dramatically slow the conveyance of stormwaters to receiving waterbodies and can store up to 330,000 gallons of water per acre per day and recharge up to 100,000 gallons of groundwater per acre per day.[7, 56] In doing so, palustrine coastal wetlands play an important role in reducing flooding in developed lands and reducing stormwater influx to coastal areas. This is a particularly important service when coastal regions have been inundated by storm related flooding.

Shoreline Stabilization

As mentioned above, estuarine wetland vegetation, whether natural or restored, can dramatically reduce wave energy due to friction between above-ground biomass and waves.[57] Wetland vegetation along shorelines subsequently traps suspended sediments, which can accrete at rates that keep pace with rising sea levels.[58] Further, wetland vegetation's below-ground biomass (e.g., roots and rhizomes) has been shown to reinforce substrate and reduce erodibility of sediments.[51, 59] It was found that over a four-decade period that Cedar Island, NC shorelines with estuarine emergent wetlands had roughly half the rate of erosion of unvegetated shoreline types.[60] Research synthesizing retreat rates of marsh over decadal time scales (1956-2004) has shown that erosion rates of unvegetated sediment banks (-0.39 m/year) are greater than double the rate for vegetated shorelines (-0.18 m/year) in NC's New River estuary.[61]

Water Quality Enhancement

In an analogy to human physiology, wetlands have been likened to nature's kidneys, serving as downstream receivers of contaminated waters, which they can help clean before the waters enter receiving waterbodies or are recharged to groundwater aquifers. In coastal regions, healthy wetlands are efficient at intercepting ground and surface water. As the flow of water is slowed by wetland vegetation, turbidity-causing suspended solids settle out, sediment-bound pollutants (e.g., phosphorous and heavy metals) are sequestered, and nutrients (e.g., nitrogen and phosphorous) are assimilated by plants and used by wetland-associated microorganisms.[62] This allows coastal palustrine and estuarine wetlands to appreciably improve coastal water quality. The biofiltration services of coastal wetlands are increasingly critical as growing industrial use of artificial fertilizers and increasing extent of impervious surfaces increases runoff in coastal regions.[63]

Many studies have documented the water cleansing ability of wetlands. A few examples include:

- Forested palustrine coastal wetlands in agricultural drainage areas reduced nitrogen by 90 percent and phosphorus by 80 percent[64]
- Stormwater wetlands within the NC Coastal Plain reduced peak flows and runoff volumes by 80 percent and 54 percent, respectively[65]
- Stormwater wetlands within the NC Coastal Plain reduced nutrients and bacteria between 60-70 percent[66]
- Saltmarshes, which are often the terminal wetland biofilter, were able to assimilate nearly 100 percent of ambient nitrate loads from coastal stormwater[67]

Carbon Sequestration

Coastal vegetated habitats (tidal marshes, seagrasses, mangroves, and macroalgae) are recognized for their ability to mitigate climate change via sequestration of disproportionately large amounts of carbon in both above- and below-ground plant biomass as well as within their soils.[68] Cumulatively, these vegetated habitats, which comprise 0.2 percent of the global ocean's surface, account for 50 percent of carbon burial in marine sediment.[69] Ranking among the densest carbon sinks globally, vegetated coastal habitats and their stores of carbon, dubbed "blue carbon", play a considerable role in addressing global climate change.[70]

Within tidal salt marshes, atmospheric carbon (CO_2) is assimilated into plant biomass, becomes trapped within the vegetation's structurally complex root system along with other sources of organic carbon, and is ultimately buried below the sediment at concentrations 30-50 times those found in terrestrial forests.[71] The dense network of roots and rhizomes, which frequently account for greater than 50 percent of saltmarsh biomass, stabilize low oxygen soils where decomposition occurs slowly. The carbon is then buried for centuries to millennia, provided the habitat remains intact.[72] The accretion of carbon in the soil of tidal marshes is integral to the marsh's ability to maintain an inundation regime as sea levels rise. Coastal wetlands that can keep pace with (SLR) and not drown in place have a near limitless capacity to sequester carbon.[73] In NC, coastal marshes store an estimated 64 million metrics tons of CO_2 and continue to sequester an additional 200,000 metric tons of CO_2 each year.[74] Saltmarsh's distinction of being among the highest, if not the highest vegetated habitat, to sequester carbon per unit area was noted in NC Risk Assessment and Resiliency Plan.[75] The plan notes that incentivizing conservation, protection of marsh migration corridors, and increasing active wetland restoration efforts are critical to coastal wetland's continued ability to sequester greenhouse gases. This sequestration is negatively correlated with the magnitude of anthropogenic disturbance in the form of physical, chemical, and biological stressors.[70]

Although rarely included in blue carbon accounting, both tidal wetlands in the upper reaches of estuaries and non-tidal freshwater wetlands in the Coastal Plain also have the potential to serve as major carbon sinks.[76] Palustrine wetlands in the U.S. store nearly ten-fold more carbon (sometimes referred to as "teal carbon") than their tidal saltwater counterparts, due in part to their considerably greater areal extent.[70] Accounting for approximately 93 percent of the areal extent of NC's coastal wetlands, palustrine wetlands are a key part of the state's wetland carbon inventory.

Recreation and Tourism

Tourism and coastal recreation support tens of thousands of jobs and contribute more than a billion dollars annually to the economies of NC's coastal counties.[77] Four coastal counties (Dare, Hyde, Currituck, and Carteret) rank within the top ten counties statewide in terms of average per capital economic contribution derived from tourism. Dare County ranked first in the state, with tourism contributing an average of $27,290 per year per resident. Many tourist activities rely on a healthy and clean estuarine environment, whether for oystering around the marsh, fishing in a creek, swimming in the sound, or eating fresh seafood at a restaurant. More than a third of U.S. adults participate in recreational and tourism opportunities found in wetlands, including hunting, fishing, birdwatching, kayaking, and wildlife photography. With participation rates in these activities exceeding world-wide averages, it is likely that the per acre recreational value of wetlands exceeds the $451 acre/year estimated in recent global meta-analysis work.[78] As such, coastal wetlands are integrally important to the economic development of NC's coastal counties. Highlighting the importance of coastal wetlands to the tourism industry, respondents to a survey of potential visitors to coastal NC ranked wildlife observation, state parks, national wildlife refuges, and wetland trails as four of the top five potential preferred activities.[79]

5.2.2 Status and Trends

Approximately 95 percent of NC's wetland resources are in the state's coastal plain.[80] The National Oceanic and Atmospheric Administration (NOAA) Coastal Change Analysis Program (C-CAP) recently published 2011-2016 data, providing 20 years of NC coastal plain wetland change data over five-year time steps beginning in 1996. According to that, NC had a total of 4.59 million acres of wetlands within the Coastal Plain. Of that, there were 4.35 million acres of palustrine (freshwater) wetlands, of which 71 percent are forested wetlands, 23 percent are scrub/shrub wetlands, and 6 percent are emergent wetlands. NC also has 235,425 acres of estuarine wetlands, of which 97 percent are emergent wetlands (Table 5.2; Figure 5.1).[81] According to the 2011 National Land Cover Database (NLCD), there was a total of 3.7 million acres within the four CHPP regions. That figure is lower because the CHPP region does not include the entire Coastal Plain.[82]

It is estimated that nearly half of NC's 11 million historical acres of wetlands were lost between pre-colonial times and the 1980s.[83] The percent of wetlands impacted to the point of no longer supporting their original function exceeded 50 percent by the 1980s.[84] These alterations were not evenly distributed between wetland types, with 52.4 percent of coastal palustrine wetlands having been altered by the 1980s, in contrast with 12.2 percent of estuarine wetlands. Unfortunately, wetland loss is not a relic of NC's past. Approximately 40 percent of total documented coastal wetland losses occurred between 1950 and 2000.

Table 5.2. Acres of palustrine (freshwater) and estuarine wetlands in the North Carolina Coastal Plain.[81]

Coastal Wetland Class	Extent (acres)
Palustrine Forested Wetland	3,069,690
Palustrine Scrub/Shrub Wetland	1,008,552
Palustrine Emergent Wetland	272,932
Estuarine Forested Wetland	166
Estuarine Scrub/Shrub Wetland	7,747
Estuarine Emergent Marsh	235,425
Total	4,594,513

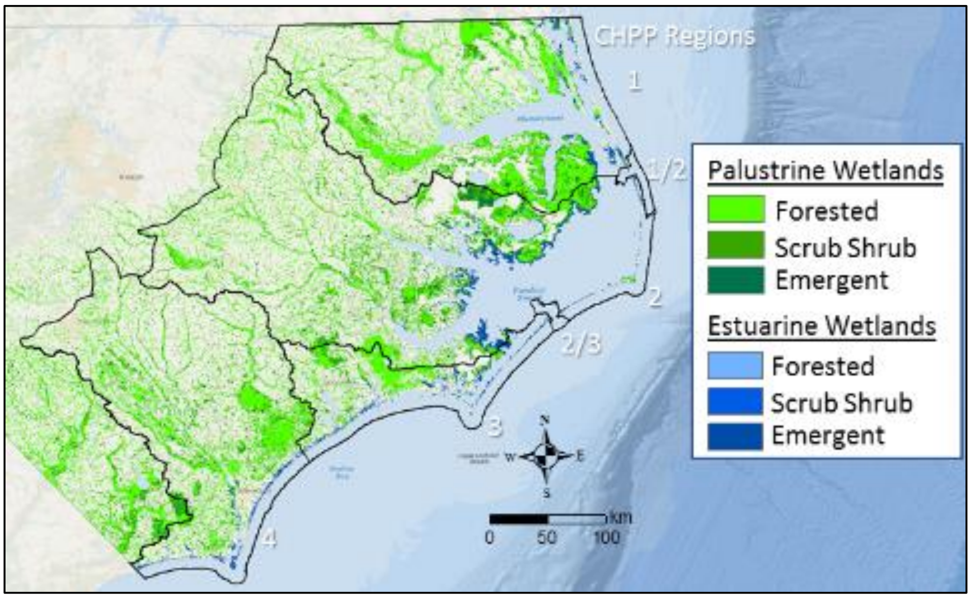

Figure 5.1. Distribution of palustrine and estuarine wetlands.[81]

The loss of NC's coastal wetlands has continued into the 21st century. Using the latest C-CAP data, wetland change was calculated over five-year intervals from 1996 to 2016. Documented within the 20-year period, 135,000 acres of palustrine wetland were lost in NC's Coastal Plain (Table 5.3).[81] Conversion to uplands was the land use change contributing most to palustrine wetland losses over the 20-year period, likely due to ditching and filling. Conversion to development, agriculture, and open water also contributed to loss. Roughly 72 percent of all documented coastal freshwater wetland losses occurred from 1996 to 2001. Over the 20-year period, the rate of net coastal freshwater wetland loss decreased. There was a reported net increase from 2011 to 2016 due to 3,128 acres gained from open water and upland.

Table 5.3. Net loss or gain of North Carolina's coastal palustrine wetland acreage to other land cover classes, by conversion type. Negative values represent a loss of coastal palustrine wetlands to the specified land cover class and positive values represent a gain. Net change represents net change from all land conversions during that time.[81]

Palustrine Wetland	Time Period				
Conversion To:	1996-2001	2001-2006	2006-2011	2011-2016	20-Yr Total
Development	-6,450	-2,172	-3,001	-1,317	-12,940
Agriculture	-9,218	-2,476	127	0	-11,567
Upland	-77,636	-13,493	-9,748	637	-100,240
Estuarine Wetlands	0	0	0	0	0
Unconsolidated Shore	46	16	-39	-144	-121
Open Water	-3,255	-6,840	-3,973	3,952	-10,116
Net Change	-96,513	-24,965	-16,633	3,128	-134,983

While the magnitude of cumulative losses to coastal palustrine wetlands are very high, the proportion of loss was not evenly distributed among palustrine subclasses. Palustrine forested wetlands, which account for 71 percent of all coastal palustrine wetland acreage, accounted for 99 percent of overall net losses incurred across all three classes over the 20-years of NOAA C-CAP data (Table 5.4).

Table 5.4. Net loss or gain of North Carolina's coastal palustrine wetland acreage by wetland type. Negative values represent a net loss of coastal palustrine wetlands and positive values represent a net gain of coastal palustrine wetlands.[81]

	Palustrine Wetland Type		
Time Period	Forested	Scrub/Shrub	Emergent
1996-2001	-279,324	147,607	35,204
2001-2006	-150,287	89,661	35,664
2006-2011	-115,836	99,574	-265
2011-2016	-42,969	40,277	5,816
20-Yr Total	-588,416	377,119	76,419

These losses, totaling 588,524 acres of forested palustrine wetlands between 1996 and 2016, were offset by gains to scrub/shrub and emergent wetlands over the same period (Table 5.5). Palustrine scrub/shrub wetlands were the only palustrine wetland class in which net gains in acreage were observed across all periods between 1996 and 2016 (Table 5.5). The gain of 377,119 acres of palustrine scrub/shrub wetland was likely due to conversion from palustrine forested wetland (64 percent) and palustrine emergent wetland (35 percent). Conversion from palustrine forested wetland was also the major contributor (>99 percent) to palustrine emergent wetland acreage gains between 1996 and 2016 (Table 5.5). While 219,520 acres of palustrine emergent wetland were gained by conversion from palustrine forested wetland, 135,360 acres of palustrine emergent wetlands were lost by conversion to palustrine scrub/shrub wetland, negating more those potential gains. Recent analysis of palustrine wetland losses in coastal counties of the conterminous U.S. found that 80 percent of palustrine wetland losses occurring between 1996 and 2010 occurred in five states, with NC ranking fifth and accounting for

8 percent of all losses incurred nationally over the period.[85]

Table 5.5. Net loss or gain of North Carolina's coastal palustrine forested, scrub/shrub, and emergent wetland acreage by type of conversion to other land cover classes. Negative values represent a net loss of the coastal palustrine wetland class and positive values represent a net gain of the coastal palustrine wetland class.[81]

	Time Period				
Conversion Type	1996-2001	2001-2006	2006-2011	2011-2016	20-year period
Palustrine Forested Wetland To:					
Development	-6,027	-1,281	-1,530	-870	-9,708
Agriculture	-7,784	-1,783	227	0	-9,340
Upland	-77,143	-10,993	-7,755	367	-95,524
Palustrine Scrub/Shrub Wetland	-122,149	-54,957	-57,626	-10,816	-245,548
Palustrine Emergent Wetland	-63,038	-77,125	-45,049	-34,308	-219,520
Estuarine	0	0	0	0	0
Unconsolidated Shore	11	-2	-2	-66	-59
Open Water	-3,193	-4,149	-4,206	2,724	-8,824
Net Change	-279,324	-150,290	-115,941	-42,969	-588,524
Palustrine Scrub/Shrub Wetland To:					
Development	-296	-719	-280	-297	-1,592
Agriculture	-704	-159	-33	0	-896
Upland	-37	-197	-783	-3	-1,020
Palustrine Forested Wetland	122,149	54,957	57,626	10,816	245,548
Palustrine Emergent Wetland	26,295	36,153	42,727	30,185	135,360
Estuarine	0	0	0	0	0
Unconsolidated Shore	4	1	7	-16	-4
Open Water	197	-376	310	-407	-276
Net Change	147,607	89,661	99,574	40,277	377,119
Palustrine Emergent Wetland To:					
Development	-127	-172	-1,190	-150	-1,639
Agriculture	-729	-534	-67	0	-1,330
Upland	-455	-2,303	-1,210	272	-3,696
Palustrine Forested Wetland	63,038	77,125	45,409	34,308	219,880
Palustrine Scrub/Shrub Wetland	-26,295	-36,153	-42,727	-30,185	-135,360
Estuarine	0	0	0	0	0
Unconsolidated Shore	31	16	-44	-62	-59
Open Water	-258	-2,315	-77	1,634	-1,016
Net Change	35,204	35,664	-265	5,816	76,419

In contrast to coastal palustrine wetlands, net change in estuarine wetland acreage exhibited an inverse temporal pattern (Table 5.6). Specifically, net gains of estuarine wetlands were observed from 1996 to 2006, while net losses were observed in the more recently from 2006 to 2016. The land conversion type that accounted for the greatest loss in each five-year period shifted considerably through time. Conversion of estuarine wetlands to agriculture and upland accounted for 48 percent and 42 percent of losses, respectively, between 1996 and 2001. Conversion to agriculture accounted for 80 percent of estuarine wetland losses between 2001 and 2006, while conversion to development and upland accounted for 37 percent of losses each between 2006 and 2011. From 2011 and 2016, conversion to unconsolidated shore and open water were the leading sources of estuarine wetland losses, accounting for 38 percent and 32 percent, respectively.

Table 5.6. Net loss or gain of North Carolina's estuarine wetland acreage by type of conversion between estuarine wetlands and other land cover classes. Positive values represent a net gain of estuarine wetlands from the specified land cover class and negative values represent a loss of the estuarine wetlands to the specific land class cover.[81]

Estuarine Wetland	Time Period				
Conversion To:	1996-2001	2001-2006	2006-2011	2011-2016	20-yr period
Development	-6	-16	-77	-15	-114
Agriculture	-30	-62	-1	0	-93
Upland	-26	4	-77	-9	-108
Palustrine	0	0	0	0	0
Unconsolidated Shore	252	1	-54	-31	168
Open Water	400	75	146	-26	595
Net Change	590	2	-63	-81	448

NC has wetland standards (15A NCAC 02B.0231) that provide protection of wetland functions. The NC 401 and Buffer Permitting Branch enforces the 401 certification, isolated waters permitting, buffer authorization, and buffer variance processes. Proposed projects may be exempted, deemed approved, approved with written notification (with or without mitigation requirements), requesting more information, or denied depending on the size and type of project. Some permitted projects may also require wetland, stream, and/or buffer mitigation to account for losses due to impacts above the mitigation thresholds (15A NCAC 02H .0506 and 15A NCAC 02H.1305). Mitigation impact thresholds for Wetlands (WLs) and Saltwater Wetlands (SWLs) are 0.10 acres. For isolated wetlands, thresholds are less than or equal to one acre in the coastal region, and less than or equal to 0.5 acres in the piedmont region. The DWR tracks wetland, stream and buffer impacts that are permitted through the 401 Wetland Program.

According to DEQ's Basinwide Information Management System (BIMS), 17,984 acres of wetland impacts were permitted statewide through 12,386 issued 401 certifications and Isolated Wetlands and Waters permits between January 1, 1990 and December 31, 2019 (Figure 5.2). The areas having the most impacted acres were frequently coastal counties, particularly in the 1990s. Brunswick, Onslow, and Carteret consistently had high impacts across the three decades. The DWR permit data for the 20 coastal counties indicate that in the 1990s, most impacts were attributable to water dependent structures (marinas, docks, bulkheads), followed by dredging. From 2000 to 2010, there was a large increase in mining impacts. Since 2010, most impacts were associated with transportation (Figure 5.3). Some of the impacts are offset by mitigation.

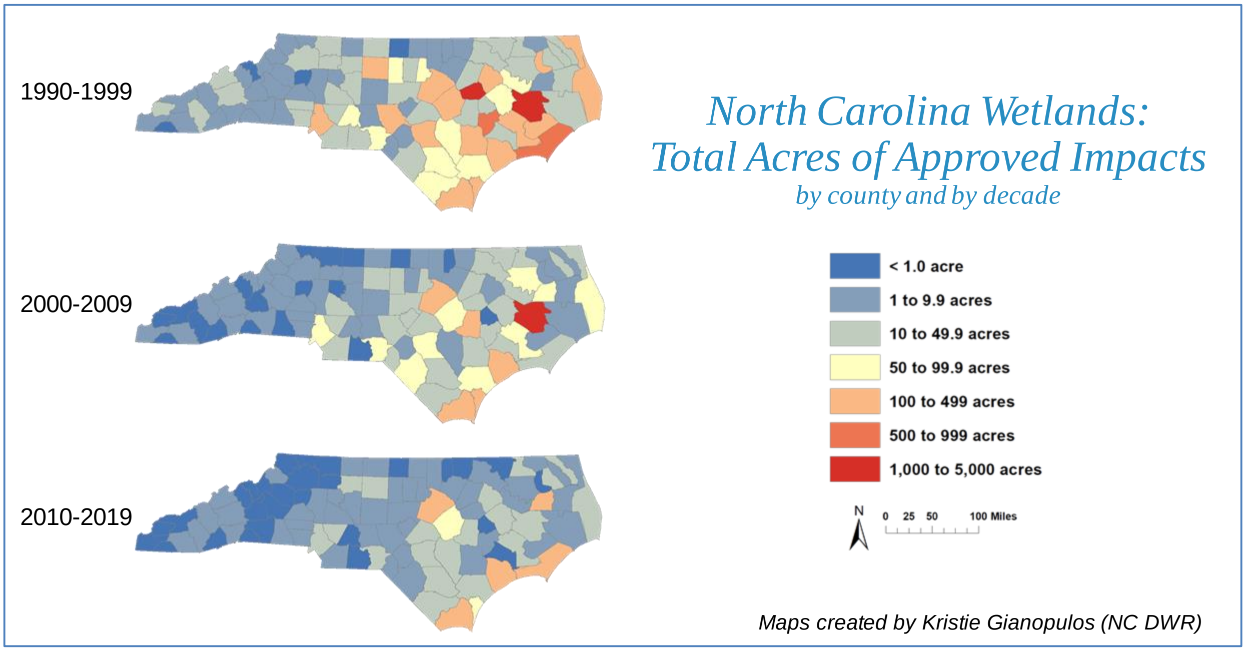

Figure 5.2. Total acres of statewide approved impacts over the past 30 years.[86]

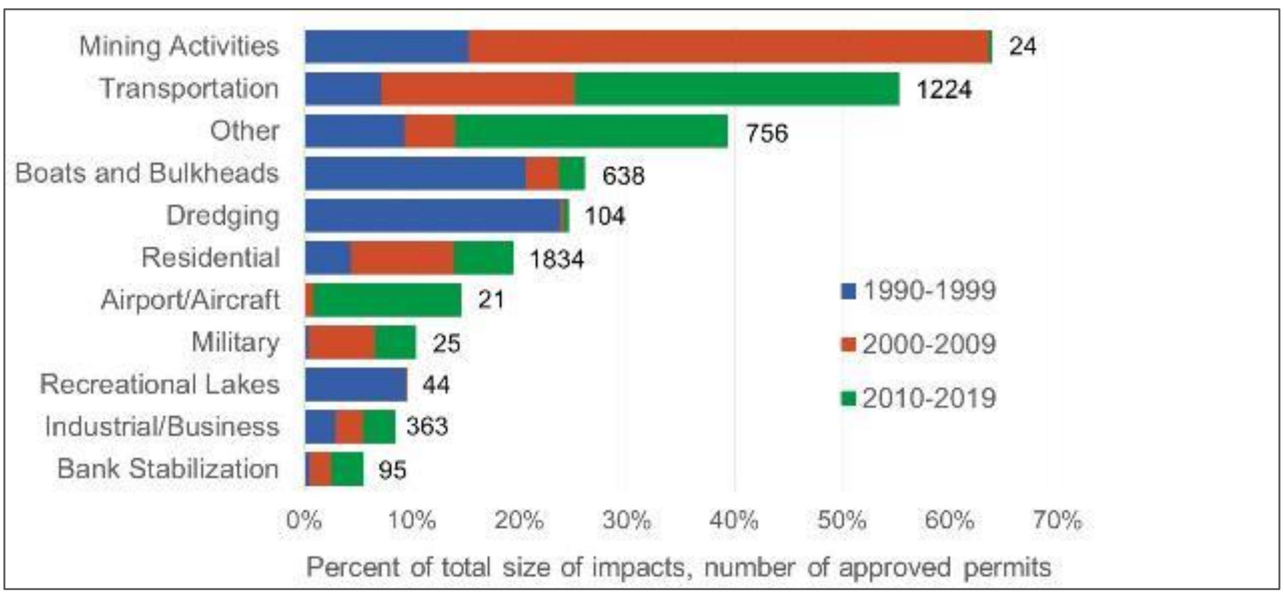

Figure 5.3. Permitted wetland impacts by primary activity type in the 20 coastal counties, over the past 30 years.[86]

5.2.3 Current and Future Threats

Dredge and Fill Alterations Associated with Development

In NC, the US Army Corps of Engineers (USACE), DWR through the Environmental Management Commission (EMC) and Division of Coastal Management (DCM) through the Coastal Resources Commission (CRC) have authority to regulate wetlands. The CRC has authority to regulate coastal wetlands and activities within the 20 Coastal Counties from the Coastal Area Management Act (CAMA) and NC Dredge and Fill Law. Coastal development rules are included in 15A NCAC 07B and 07H. Impacts to coastal wetlands (estuarine species listed in rule) must be avoided and minimized. The CRC rules do not allow mitigation for coastal wetland impacts unless the project is deemed to have a significant public benefit. The USACE has authority to regulate wetlands from Section 404 of the Clean Water Act (CWA) and Section 10 of the Rivers and Harbors Act. If a federal 404 permit is to be issued, DWR must also review the project and issue a 401 certification (Section 401 of the CWA and 15A NCAC 02B and 02H). Avoidance and minimization must be pursued before mitigation for impacts is considered.

The EMC has wetland standards for all classifications of wetlands (15A NCAC 2B .0230-.0231). The standards are used to assure existing uses of wetlands are protected. The uses include storm and flood water storage and retention, moderation of water level fluctuations, hydrologic function (groundwater discharge and recharge), filtration or storage of pollutants, shoreline protection, habitat for wetland dependent aquatic organisms including fish, as well as other wildlife species. The 401 Certification rules (15A NCAC 02H .0500) and NC Isolated Wetland and Waters rules (15A NCAC 02H .1300) allow property owners to apply for approval to conduct projects in wetlands. Projects exempted, deemed approved, or in receipt of an approval letter under these permitting rules satisfy the wetland standards in 02B .0231. However, thresholds exist under which wetland impacts are allowed without mitigation being required. As described in the previous section, the permitted impacts can be cumulatively significant over time.

A new concern is loss of jurisdiction over wetlands, due to changes in the EPA and the US Department of the Army's joint Navigable Waters Protection Rule (NWPR, 85 FR 22250) which redefined "Waters of the United States" (WOTUS, CWA Section 502(7)) on June 22, 2020. The revised definition of WOTUS eliminates certain waters and wetlands due to lack of direct surface water connectivity; therefore, reducing the scope of waters federally regulated under the CWA (CWA, 33 U.S.C. §§ 1251–1387). Under the modified definition, WOTUS includes all wetlands adjacent to: traditional navigable waters (including territorial seas); tributaries to those waters; jurisdictional ditches, lakes, and ponds; and impoundments of otherwise jurisdictional waters. Under this rule, wetlands continue to be defined as "those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas." Wetlands that do not directly abut or have a direct surface water hydrologic connection are not considered "adjacent" under the NWPR.

An analysis of the potential impacts of WOTUS, found that wetland types most at risk included floodplain pools, pine flats, pine savanna, non-riverine swamp forest, seeps, headwater wetlands, bottomland hardwood forest and bogs.[87] The study indicated that approximately 28 percent of headwater wetlands in the Coastal Plain would no longer be jurisdictional. Due to their position at the upper tributary, headwater wetlands are critical for filtering pollutants from the immediate watershed and storing large amounts of floodwaters, thereby improving downstream water quality and reducing flooding. Numerous state agencies provided comments in response to the proposed rule. The DWR, DEQ, and Office of the Attorney General of the State of NC (OAG) relayed concerns with the loss of wetlands that were previously covered under federal jurisdiction, and how the proposed rule would affect jurisdiction, regulation, and protection of these vital resources.

Since the recent adoption of the NWPR, which no longer uses the term “isolated,” there is now a category of federally non-jurisdictional wetlands that is no longer eligible for coverage under the 401 permitting regulations, nor are they eligible for coverage under the isolated wetlands permitting rules since they do not meet the definition of “isolated.” Without a permitting mechanism, proposed impacts to these federally non-jurisdictional wetlands will not satisfy 02B .0231. There is also concern that impacts could occur. To maintain the wetland permitting mechanisms at levels like those in existence prior to the NWPR, DEQ has adopted temporary rules to provide landowners with a mechanism for approval to conduct work in NC’s federally non-jurisdictional and non-isolated wetlands. The DEQ did not propose any modification to existing wetland protections or “exempted” features (e.g., man-made ponds, stormwater/wastewater measures, ditches).

<u>Ditching and Draining for Agriculture, Forestry, and Development</u>

As noted in the status and trends section, conversion of wetlands for forestry and agriculture has been a major source of wetland loss historically and in more recent decades. Ditching is done to drain water and lower the water table, allowing agricultural crops to grow and allowing heavy equipment to harvest forested wetlands. Ditching has also been done to lower the water table to allow development, leading to wetland loss and increased runoff. The process of ditching and draining not only alters the hydroperiod of the wetlands to non-optimal conditions that may not support wetlands, but also impacts their ability to store water onsite.[88, 89] Consequently, runoff to surface waters increases and is flashier during large rain events, resulting in less filtration of pollutants. Nutrients from loosened organic soils and fertilizer, as well as pesticides are transported in the runoff to surface waters. In Carteret County, when a 6,000-acre tract of ditched farmland was partially restored to wetlands with natural hydrology, water drainage from the site went from taking hours to taking days.[90]

The federal Clean Water Act exempts most agriculture and forestry activities from having to obtain a permit to disturb wetlands, described in Section 404(f)(1) of the CWA. While permitting is not required, the CWA still requires that the wetland not be converted to a non-wetland, and also requires those activities to implement measures prescribed in the CWA to minimize overall wetland disturbance, as well as the deployment of BMPs.[91]

However, in areas designated as NSW and having nutrient management rules (i.e., Neuse, Tar-Pamlico), agricultural nutrient loading requirements are included. In NC, the performance standards defined by 02 NCAC 60C .0100 to .0209 Forest Practices Guidelines Related to Water Quality must be met if a forestry operation is to remain exempt from submitting an erosion and sedimentation control plan, obtaining permits and meeting other requirements described under the state’s Sedimentation Pollution Control Act. The Forest Service relies on education and monitoring for FPG compliance to ensure that operations are complying. If a violation is not corrected, the agency will notify the DEQ to take potential enforcement action. The “Forestry Best Management Practices Manual to Protect Water Quality” provides a suite of BMP options to protect water quality and meet the criteria required in rule. The manual is on track to be updated in 2021, and in consultation with the USACE, some notable revisions are being made to the BMPs for silvicultural activities in wetlands, including more than a dozen new BMPs for harvesting timber in bottomland swamps, and new BMPs for minimizing erosion and sedimentation impacts when managing minor drainage.[92]

Shoreline stabilization

Since the 1980's, land use along coastal NC has shifted from agricultural uses to urban and rural development.[93, 94] These levels of development among the 20 coastal counties of NC have only continued to increase. The NC Office of State Budget and Management reported a 9.98 percent population increase from 2010 to 2019 (Table 5.7).[95] Between 2019 and 2039, the populations of numerous NC counties within the Coastal Plain are predicted to increase by more than 16 percent and multiple counties with estuarine coastlines are predicted to grow by greater than 30 percent (Figure 5.4).

Table 5.7. Estimates of the Total Population of North Carolina's 20 Coastal Counties for April 2010 and July 2019, as well as absolute and percent change over the same period.[95]

County	Total Population		Change	
	April 2010	July 2019	Number	Percent
Beaufort	47,784	47,436	-348	-0.7
Bertie	21,275	19,630	-1,645	-7.7
Brunswick	107,429	143,169	35,740	33.3
Camden	9,980	10,559	579	5.8
Carteret	66,463	70,986	4,523	6.8
Chowan	14,793	14,141	-652	-4.4
Craven	103,498	102,989	-509	-0.5
Currituck	23,547	27,677	4,130	17.5
Dare	33,920	37,599	3,679	10.9
Gates	12,185	11,954	-231	-1.9
Hertford	24,677	23,857	-820	-3.3
Hyde	5,817	5,145	-672	-11.6
New Hanover	202,683	233,062	30,379	15
Onslow	177,801	207,252	29,451	16. 6
Pamlico	13,143	13,286	143	1.1
Pasquotank	40,661	39,953	-708	-1.7
Pender	52,196	63,153	10,957	21
Perquimans	13,452	13,740	288	2.1
Tyrrell	4,407	3,773	-634	-14.4
Washington	13,193	12,113	-1,080	-8.2

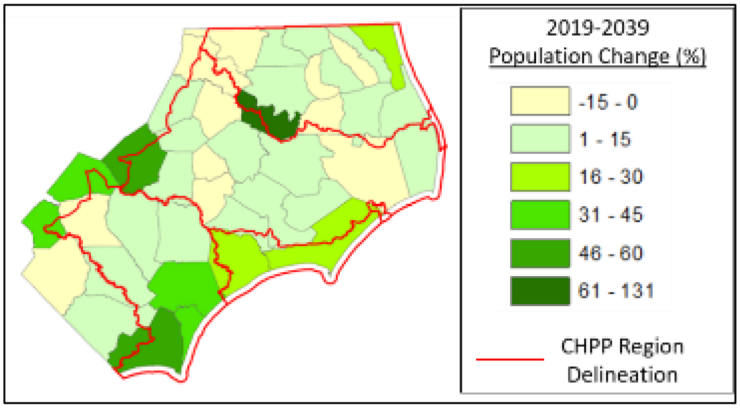

Figure 5.4. Predicted population growth from 2019 to 2039 for counties falling entirely or in part within Coastal Habitat Protection Plan (CHPP) regions.[95]

Increasing development on the coast is expected to bring increasing demand for shoreline stabilization. More than 48,000 properties valued at $13 billion are predicted to become chronically inundated by 2100 under relatively conservative SLR estimates values that could more than double under more extreme SLR scenarios. In 2012, DCM delineated the shoreline and stabilization and docking structures.[96] Bulkheads were the dominant type of stabilization structure. Of 10,658 miles of shoreline, the study identified approximately 500 miles of bulkheaded shoreline directly abutting surface waters, 75 miles with bulkheads with some amount of marsh waterward of the structure, and 17 miles of bulkhead with sediment bank waterward of the structure. Riprap was the next most common structure with 182 miles. As of 2012, there were roughly 815 miles of armored shoreline and only 4.9 miles of marsh sill, the term for living shorelines in rule (Figure 5.5). In the time since, the amount of shoreline armoring in NC has increased to 1,100 miles.[97]

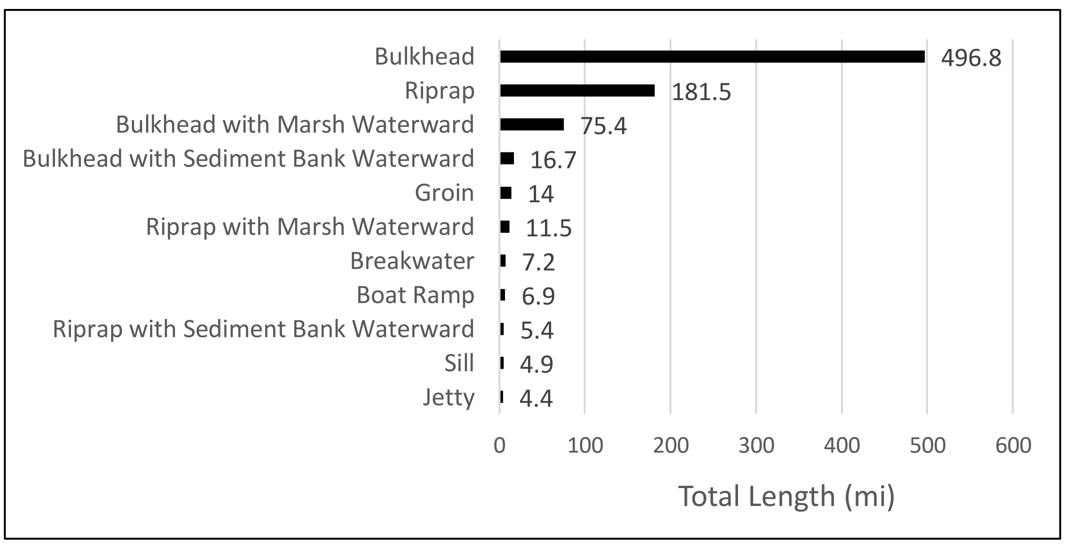

Figure 5.5. Coastwide extent of shoreline with shoreline structures within the 20 coastal counties, based on 2012 aerial imagery.[96]

In total, eight percent of the shoreline had some type of shoreline stabilization structure. In the US, it is estimated that approximately 14 percent of all estuarine shoreline has been hardened.[98] Shoreline hardening may, effectively maintain shoreline position in the shore-term, but their exacerbation of erosive processes via reflection of wave energy (Figure 5.6) and their reduced structural complexity compared to shoreline vegetation or fringing oyster reefs can lead to the loss of ecosystem services (e.g., fish habitat, water quality enhancement) provided by the shoreline habitats they replace.[99, 100]

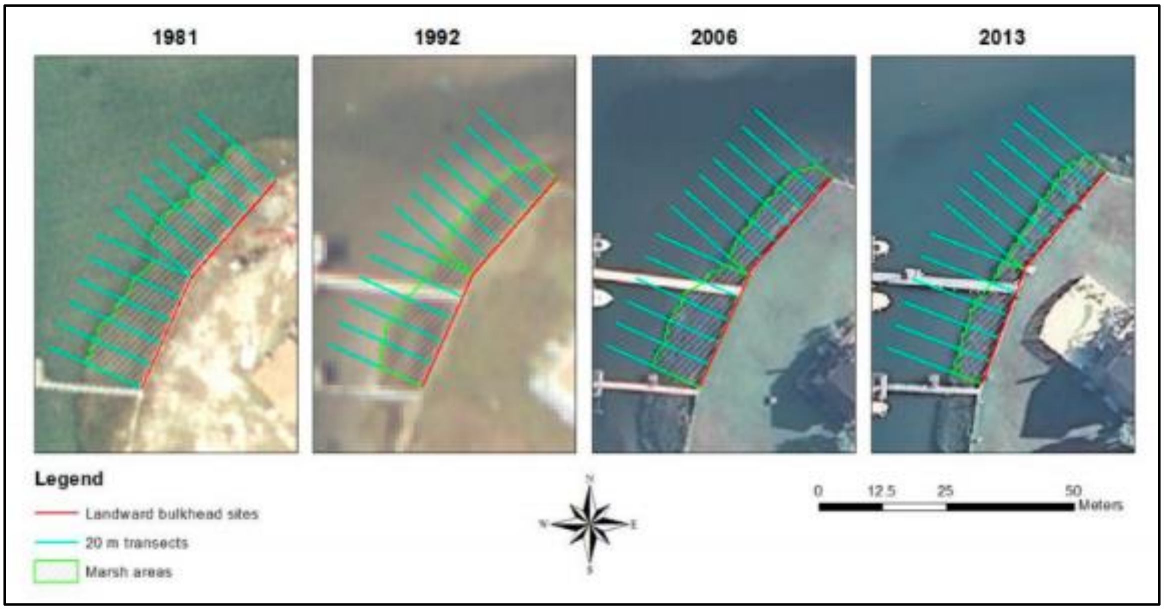

Figure 5.6. Time series of two bulkhead sites illustrating changes in marsh width, 1981-2013.[100]

<u>Shoreline Erosion</u>

Wetland loss also occurs along natural shorelines due to wave energy from wind and boat wakes. As noted in the ecosystem services section, shorelines with wetland vegetation are much more resilient to erosion. In a study looking at wave energy along different shoreline types, the presence of wetland vegetation had a stronger effect on erosion rates than wave energy, suggesting the value of living shorelines to reduce shoreline erosion.[101] Wave attenuation was positively correlated with stem density. A study in Carteret County that examined the effect of boat wake energy on shoreline erosion noted that in low wave energy settings, marshes that were subject to greater boat wake energy (closer to navigation channels or high boat dock density) were narrower than marshes subject to less boat-induced wave energy.[102] Measurements confirmed that boat wakes can contribute more to wave energy than wind in some settings. Studies indicate that severe storms and hurricanes do not significantly impact marshes. Since water levels are usually higher than normal, waves pass over the top of the plants, transporting sediment into the marsh, which in turn helps build elevation.[103, 102] Low to moderate storms that occur more frequently have a greater impact on salt marsh erosion, especially when they occur at low tide.

Living Shorelines are a viable and desirable alternative to vertical shoreline hardening and a solution to wetland erosion that include a suite of options for shoreline erosion control. The structures are designed to provide erosion control and maintain existing connections between upland, intertidal, estuarine, and aquatic areas, allowing ecosystem services such as fish habitat, water quality enhancement, and flood control to continue. Unlike vertical stabilization measures such as bulkheads, living shoreline techniques use native materials such as marsh plants, oyster shells, as well as rock or concrete-based material. While coastal wetland vegetation can effectively buffer shorelines in areas with low to moderate wave energy, in some locations or situations, other nature-based structures (e.g., oyster reef breakwaters, sills) may be needed to augment the coastal protection services of natural or restored vegetation on shorelines in areas with high wave energy (Figure 5.7).[104]

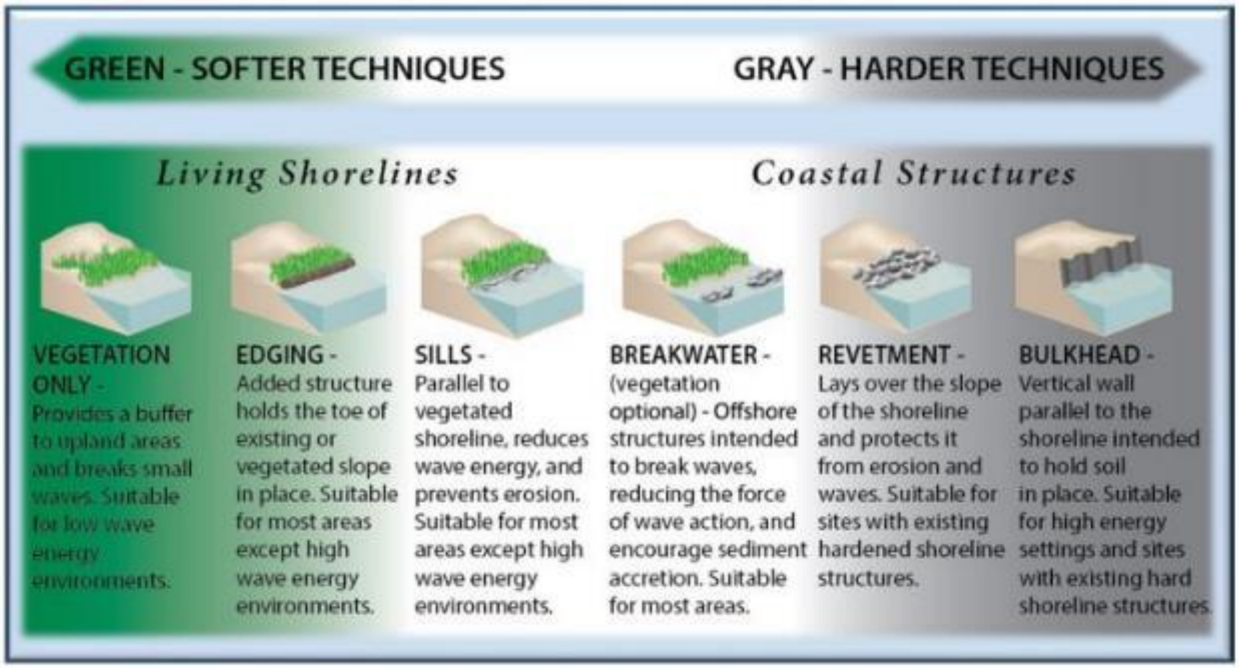

Figure 5.7. Continuum of shoreline stabilization methods, from most natural and softest (green) to least natural and hardest (gray), with the greenest methods being more effective in low to moderate wave energy, and grayest methods being more effective for high wave energy.[105]

Multiple studies from NC support use of living shorelines as an effective method of shoreline stabilization that also provides substantial ecosystem service benefits, including provision of fish nursery habitat.[85, 106, 107, 108, 109] A comparison of natural marsh shorelines to living shorelines with restored marsh and sill found that the living shorelines had 1.5 to 2 times greater sediment accretion rates, indicating their effectiveness in controlling erosion.[110] A study comparing shoreline change rates pre- and post-installation of living shorelines with sills found that 12 of 17 monitored living shorelines sites along the coast showed reduced erosion rates, and six of those sites showed accretion.[111] Research has also looked at the efficacy of living shorelines for erosion control during more extreme events, such as hurricanes and surveyed sites were more durable than bulkheads.[104, 106] Post-hurricane shoreline surveys in NC following Hurricane Irene found that, in contrast to the 76 percent of surveyed bulkheads that incurred damage, none of the estuarine marsh shorelines, with or without sills, experienced damage.[106] Other research has documented the value of wide-scale use of living shorelines for carbon sequestration and nitrogen removal.[107, 112] With mounting evidence of the damaging impacts of shoreline armoring to estuaries, there is a critical need to embrace alternative, environmentally friendly shoreline stabilization techniques.

Marine Debris

An emerging and less understood threat to wetlands is marine debris. The Marine Debris Act of 2006 defines marine debris as "any persistent solid material that is manufactured or processed and directly or indirectly, intentionally or unintentionally, disposed of or abandoned into the marine environment or Great Lakes". Worldwide, greater accumulation of marine debris is being observed in the oceans and estuaries, with plastic comprising 80 percent of coastal debris. Wetlands are susceptible to marine debris deposition from both ocean and land-based sources due to storms and tides pushing debris in from offshore, and drainage systems or stormwater discharges that bring debris from nearby developed land. Marine debris in wetlands can range in size from microplastics, abandoned fishing gear, sections of wooden docks, up to large items such as derelict vessels. Due to the complex structure of the wetland plants, debris often becomes trapped once in the wetland, and macroplastics break down over time to micro- and nanoplastics, where they aggregate with natural particles, becoming biologically available to organisms in the sediment. While larger marine debris can have negative effects on the physical and aesthetic condition of wetlands, small plastic pieces can alter carbon and nutrient fluxes within the water column and sediments, altering biological processes.[113] In January 2020, the NC Coastal Federation (NCCF) published the "North Carolina Marine Debris Action Plan", providing a strategic plan for prevention and the removal of marine debris in NC.[114]

The extent to which wetland habitat quality is impacted by marine debris is uncertain.[113] Previous research has predominantly focused on the role that plastics play in the environment. Studies have shown an accumulation of nano- and microplastics in water, sediment, and in the tissues of invertebrates and nekton in estuaries within proximity to urbanization. In Mosquito Lagoon, FL, a riverine system that has seen high increases in development in the last 30 years, elevated concentrations of microplastics were found in the organic tissues of the eastern oyster and Atlantic mud crab. Both species, which are common in tidal marshes, are potentially high-risk animals for microplastic accumulation.[115] More research is needed to determine the impact of degrading plastics and other litter on wetlands, and associated sediment and benthos.[113]

Climate change

The rate of SLR is expected to continue increasing as the oceans warm.[116] Coastal wetlands are highly vulnerable to SLR impacts.[75, 117] As sea levels rise, coastal wetlands only have two mechanisms to adapt to prolonged periods of inundation. The first mechanism is to adjust vertically within the water column through sediment accretion. Analyses of long-term monitoring sites in NC have shown many of the fringing marshes were failing to keep pace with rates of SLR and are essentially drowning in place.[118] These results indicate that marshes in these areas will require the ability to migrate upslope rather than building in elevation of existing habitat.

The second mechanism is for coastal wetlands to migrate inland. As sea levels rise, estuarine water inundates landward and increases soil salinity, making these areas less habitable for saltwater-intolerant species in low-lying forests and agricultural lands. Terrestrial and freshwater plants are eventually replaced by halophytic marsh vegetation as the marsh-upland boundary moves landward (Figure 5.8). There are many environmental factors that influence the ability of wetlands to transgress into adjacent areas, such as topography, hardened structures, or drainage features, but among the most impactful is land use. The ability of a marsh to transgress along its natural path of migration is impeded in areas where hardscapes, such as roads or urban development, are present. Where this occurs, the marsh erodes at the waterward extent and remains stationary at the landward extent. Trapped between rising sea levels and impediments to inland migration, marsh width decreases, a phenomenon referred to as coastal squeeze. The proximity of development along the waters of NC is restricted by buffer rules. However, as sea levels rise and affect tidally influenced shorelines, established buffers will be reduced.

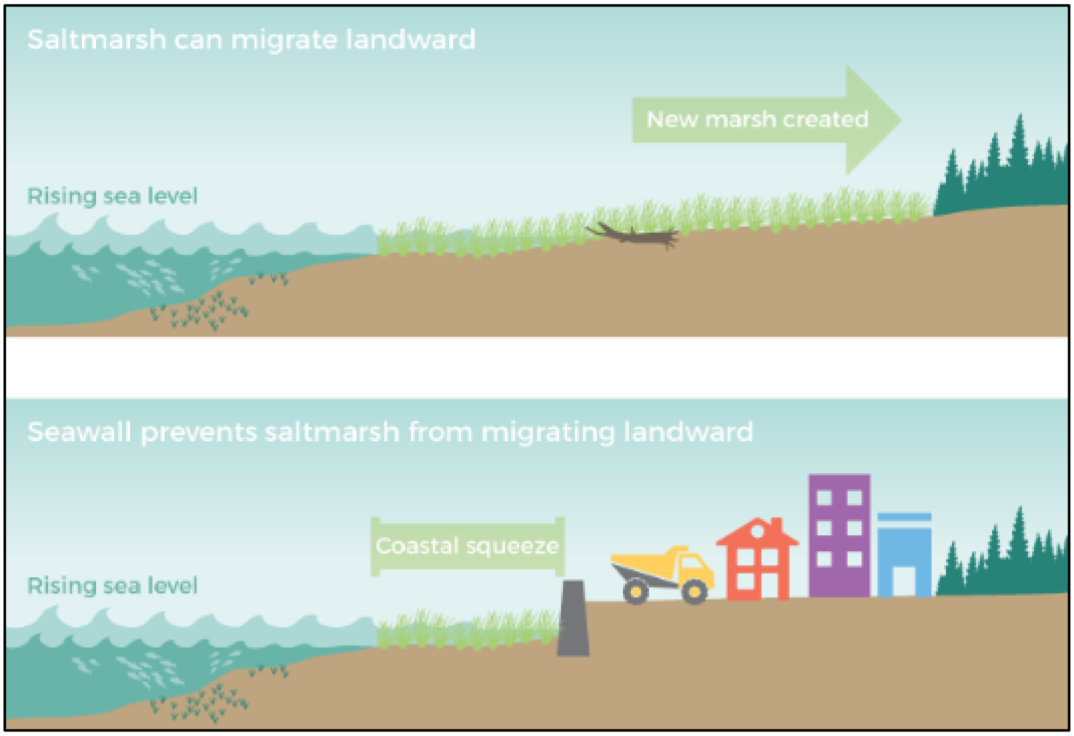

Figure 5.8. Conceptual diagram of process of natural marsh migration with sea level rise (SLR), and coastal squeeze when migration is impeded.

Rising sea levels also introduce the concern of increased saltwater intrusion along the coast. Saltwater intrusion (SWI) is the hydrological alteration of the interface of freshwater and saltwater caused by several environmental and anthropological factors. Natural influences of SWI may include storm surges from extreme weather events, droughts, periods of heavy rainfall, climatic changes, and subsidence or rebound. Human-induced SWI can be caused by land drainage, aquifer drawdown, reduction in freshwater discharge from dam operations, and land use changes.[119]

Shifts in salinity threaten native wetland habitats that are not salt-tolerant. Saltwater intrusion introduces saline water to soils and changes biochemistry which produces sulfides that are toxic to salt-intolerant species. Prolonged exposures and increasing frequencies of flooding tides containing higher salinity waters can result in permanent shifts in plant communities and conversion of tidal swamp to tidal marsh habitats.[120] Ghost forests, areas of dead trees in former freshwater forests, typically due to saltwater intrusion, are present along the coast and increasing, particularly on the Albemarle-Pamlico peninsula.[121] Once trees in tidal swamps cannot tolerate salinity and biogeochemistry changes, the habitat is replaced by herbaceous vascular plant species with higher salinity tolerances. Analysis of land cover change in the Alligator River National Wildlife Refuge (NWR) from 1985 to 2019 found 11 percent of the forested cover became ghost forest. Additionally, 2,844 acres of land were lost to erosion and 47,691 acres of forest converted to shrub or marsh. The ghost forests and land loss were attributed to SLR, salinization, and storm surge.

5.3 Discussion

In August 2020, three virtual wetland workshops were held by the CHPP Team to solicit input from coastal and palustrine wetland subject matter experts regarding wetland concerns and potential solutions. Seventy participants from state and federal agencies, non-government organizations, and academia participated. Topics of the three workshops were mapping and monitoring, threats and conservation, and restoration and living shorelines. Information and input gathered from these workshops was incorporated into this issue paper, particularly the discussion.[122] Meeting materials and a summary document are available at http://portal.ncdenr.org/web/mf/habitat/chpp/07-2020-chpp.

5.3.1 Mapping and Monitoring

Mapping

Comprehensive inventories of natural resources, including wetlands, are recognized as critical components for informed management, policy, conservation, and restoration actions. Inventories informed by robust mapping efforts provide managers the information needed to assess the impacts of anthropogenic activities, changes over time that are attributable to natural phenomena, and the outcomes of management actions and restoration efforts. Consequently, shortcomings in wetland mapping, either in their resolution or comprehensiveness, can impede the development of comprehensive wetland inventories, pose a challenge to conducting robust environmental impact assessments, and broadly hinder data-driven natural resource management. Therefore, safeguarding NC's natural resources, while allowing for sustainable development, hinges on the collection and availability of comprehensive data on the distribution, characteristics, and function of NC's wetlands, 95 percent of which occur within the Coastal Plain.

The two primary wetland mapping sources that provide coastwide wetland distribution data include DCM's Wetland Inventory, and the National Wetland Inventory (NWI). The NWI produces wetland and deepwater habitat maps throughout the United States using photo interpretation of aerial imagery and is the most extensive inventory of wetlands in the United States. Imagery costs and the lengthy time to delineate imagery deter the ability to produce new or update existing wetland maps. Further, the accuracy of imagery interpretation that informs NWI maps coming from multiple sources, is dependent on the quality of the imagery, availability of groundtruthing data, and repeatability by photo-interpretation analysts.

The DCM created a coastwide wetland inventory in the mid-1990's using NWI data, landcover classification from satellite imagery (Landsat data), and county-level soils data. The resolution and accuracy of DCM's wetland inventory, along with the older age of the imagery limits the products utility today.[123] Other federal mapping efforts related to wetlands are conducted by the United States Geological Survey (USGS), US Department of Agriculture Natural Resources Conservation Service (NRCS), and NOAA at different time intervals and mapping protocols. NOAA's C-CAP inventories coastal intertidal areas, wetlands, and adjacent uplands on one- to five-year intervals at a spatial resolution of 30 x 30 m pixels using Landsat data, aerial photography, and field observations.[124] Landsat data remains challenged by the relatively long period between revisits (16-18 days), cloud cover obstructing data collection, and shadows confounding interpretation.[125] As a result, the C-CAP has an accuracy target of 85 percent overall and 80 percent per habitat class.[126]

National and state inventories for land cover and wetlands are important tools used to formulate and evaluate the effectiveness of wetland policies and are integral to models used to predict the aerial extent of wetlands under a variety of future scenarios.[127] Therefore, the accuracy and resolution of these datasets have cascading effects throughout natural resource management and the research by which it is informed. While the spatial and temporal resolution of current NOAA C-CAP data has proven valuable for detecting large-scale changes in wetlands, particularly when the conversion occurs between distinct land cover types, numerous studies using higher-resolution imagery have documented wetland conversions that were not depicted using C-CAP data.[128, 129] Fortunately, there are efforts underway by NOAA C-CAP to generate spatially robust, high resolution (1m x 1m pixel) land cover inventories and map products. High resolution NOAA C-CAP mapping remains limited to a select few partner cost-share pilot projects around the country.[130] While nationwide one meter resolution mapping is a goal of NOAA C-CAP within the coming decade(s), acquiring this data in the near-term and deriving the competitive advantage will require collaboration and funding through establishing partnerships.

The dramatically improved maps resulting from these pilot projects hold considerable promise to improve natural resource managers' ability to track wetland loss, gain, and land conversions (Figure 5.9). Further, higher resolution mapping of land cover has appreciable potential to improve predictive models critical to allocating scarce conservation and restoration resources. For example, high-resolution mapping of impervious surfaces and other barriers to marsh transgression is imperative to the identification of priority marsh migration corridors.[131] During the CHPP Wetland Workshop, NOAA representatives indicated the possibility of including NC mapping at the one-meter resolution as a pilot project, however state matching funds would be required. The value of high-resolution land cover mapping extends well beyond coastal resource management applications, providing information invaluable to planning and administration of transportation, agriculture, utilities, infrastructure, habitat management, and other purposes. As such, coastal resource management agencies should consider working with other state agencies to pull together the funding necessary to commission one-meter land cover mapping.

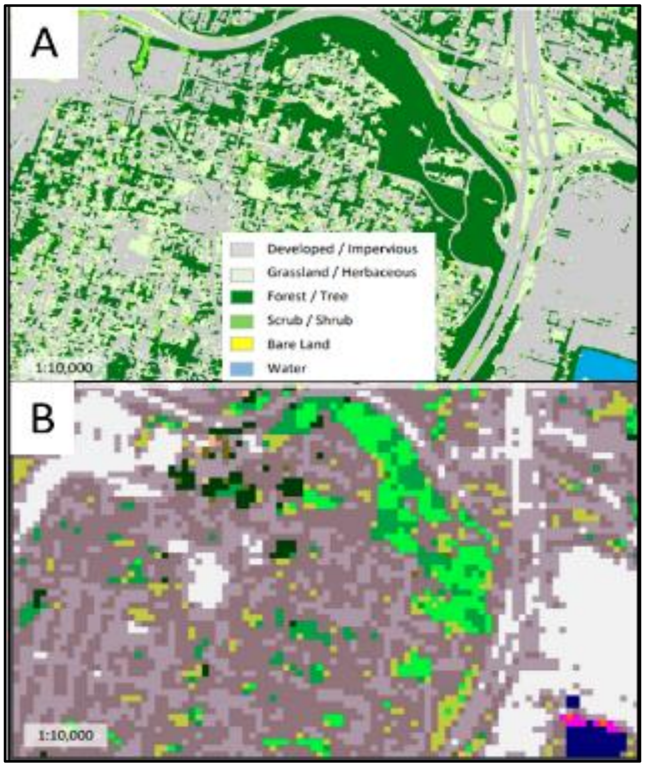

Figure 5.9. Land cover map of Seattle Tacoma, WA with (A) 1 m baseline draft mapping and (B) 30 m existing C-CAP mapping.[132]

There are several emerging technologies that have potential to allow more precise mapping with greater efficacy. Satellite data (Landsat) and aerial imagery are more available but have low to moderate resolution. Unmanned Aircraft Systems (UAS) (i.e., drones), can provide rapid high resolution mapping but are not practical for a coastwide assessment.[133] A process known as data fusion, can use the high resolution UAS imagery, that has been field verified, to train classifications of lower resolution satellite imagery, such as WorldView (1.24 m resolution) or RapidEye (5.0 m resolution), improving accuracy of habitat classification with the satellite imagery, and is a method to generate 3D data.[122, 134] Another technique known as deep learning neural network uses a time series of satellite imagery to evaluate land cover change in a way that reduces post-processing time and increases speed of map creation. The Duke Marine Lab evaluated change in land cover in the Albemarle-Pamlico peninsula between 1989 and 2011 with Landsat imagery and this deep learning technique. They were able to depict where farmland had transitioned to wetlands, particularly along ditches and canals, and wetland forests along the estuarine shoreline converted to ghost forests. Once proven, this technique would allow automated habitat classifications and rapid change analysis. The ability to assess wetland change rapidly and accurately is critical to focusing management and restoration actions in priority areas in a time-effective manner. Ury et al. (2021) similarly examined change in land cover in the Alligator River National Wildlife Refuge (NWR) using LandSat imagery from 1985 to 2019.[121]

Monitoring

NC's official wetland monitoring program was initiated by the Division of Water Quality (now DWR) in

2004. Since its inception, wetland monitoring conducted by DWR has been funded primarily by the EPA's Wetland Program Development Grants (WPDGs). While the first grant primarily supported efforts to monitor headwater wetlands, subsequent grants have provided funding to monitor basin wetlands, riverine swamp forests, and bottomland hardwood forests located across multiple watersheds. Between 2004 and 2015, projects funded largely by the EPA resulted in the monitoring of 248 wetland sites, 132 of which were within the CHPP region (Figure 5.10; Table 5.8). Due to the grant duration and project objectives, most (147 of 248, or 59 percent) were monitored for one year or less.

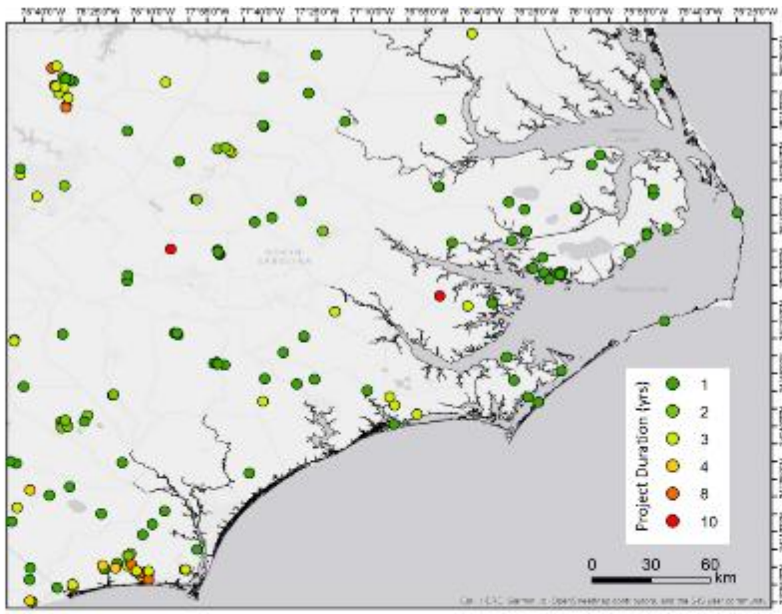

Figure 5.10. Location and sampling duration of wetland monitoring projects conducted by DWR and partners between 2004 and 2015.

Since 2004, wetland projects have conducted field evaluations of restored mitigation wetlands, studied headwater wetlands, characterized isolated wetland hydrologic connectivity, water quality, and biota, and assessed use of natural wetlands for stormwater assimilation, among others.[135] The Wetland Program Plan (NC WPP) was developed by NC DWR in 2015 and is updated every five years to guide actions to research and protect wetlands.[136] The plan is currently being updated and will be finalized for approval by the EPA in 2021. The Division of Mitigation Services (DMS) compiles monitoring reports for compensatory mitigation projects, and the Wildlife Resource Commission (WRC) has conducted monitoring to assess abundances of select fauna of interest.

Since the dissolution of the Wetland Program Development Unit in 2013, wetland monitoring efforts by state agencies have continued but on a short-term basis and much more limited scale. To provide a spatially robust inventory of the condition of the state's wetland resources over ecologically meaningful temporal scales, there is a need to move away from a dependence on external grant funding, which can be intermittent and variable in their research objectives, to a recurring state appropriation for standardized wetland monitoring that is critical to generating the data needed for science driven management.

Table 5.8. Number of sample sites by wetland type within CHPP regions. Includes sampling by DWR and partners, 2004-2015.

Wetland Type	CHPP Region				
	1	2	3	4	Total
Basin	0	1	2	27	30
Bottomland Hardwood Forest	0	4	0	2	6
Brackish/Salt Marsh	2	12	3	0	17
Estuarine Woody	0	4	0	0	4
Hardwood Flat	4	4	0	0	8
Headwater	1	11	1	6	19
Non-Riverine Swamp Forest	0	0	1	0	1
Non-tidal Freshwater Marsh	1	1	0	0	2
Pine Flat	1	4	0	2	7
Pocosin	1	2	1	4	8
Riverine Swamp Forest	7	8	1	14	30
Grand Total	17	51	9	55	132

In contrast to the short-term monitoring typical of EPA WPDG-funded projects that took place between 2004 and 2015, the NC Sentinel Site Cooperative (NCSSC), one of five cooperatives established throughout the US with NOAA funding in 2012, has established long-term monitoring surface elevation in coastal habitats in eastern NC. The cooperative consists of partners from NOAA, NC Coastal Reserve, DCM, NC Sea Grant, Department of Defense, National Park Service, the NC Aquarium at Pine Knoll Shores, academia, and town governments, with the goal of leveraging resources across organizations to provide stakeholders with information to address SLR and coastal inundation. A component of the work the NCSSC conducts is the monitoring of coastal habitats to address impacts of SLR. This has entailed leveraging existing and establishing new sites for the long-term monitoring of elevation change using surface elevation tables (SET), which are portable mechanical instruments that provide high-resolution measurements of elevation change within wetland sediments.[137] There are currently over 125 SETs throughout coastal NC generating information on the degree to which coastal marshes are keeping up with SLR (Figure 5.11).

Photo Credit: Nolen Vinay

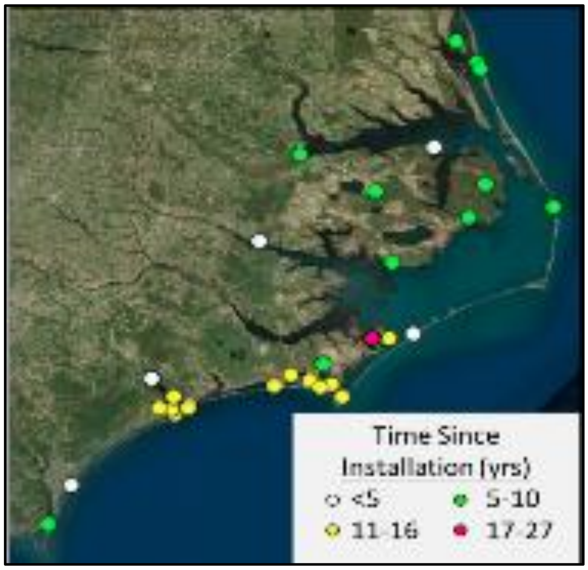

Figure 5.11. Surface elevation table (SET) locations in North Carolina.[138]

Numerous NC universities and non-governmental organizations (NGOs) are conducting research involving coastal wetland monitoring. However, the various sampling methodologies in these studies have impeded efforts to combine data to generate a meaningful picture of habitat condition at broader spatial or temporal scales. The development of standardized protocols to monitor wetlands, coupled with a central repository to submit reports or standardized data would facilitate policy managers and natural resource managers' ability to formulate actions based on robust, scientifically validated information. A repository of standardized wetland monitoring data, which would include information from both published and unpublished studies, could minimize redundant sampling by researchers unaware of similar projects and facilitate synergistic collaborations. At the 2020 CHPP Wetland Workshop, most participants recognized the value of standard sampling protocols but noted that it would be difficult to implement due to different research objectives and funding sources. There was strong support for a central repository that included a database of who and where monitoring was occurring and completed reports. Both the formulation of some minimum standardized sampling protocol and the development of a centralized repository will require an inclusive process of consultation between practitioners, managers, and other user groups.

5.3.2 Coastal Resilience Planning

In NC and globally, the long-term sustainability of coastal populations is inextricably linked to coastal ecosystem services, including fisheries production, storm protection, water quality enhancement, flood control, and carbon sequestration. Coastal resilience planning is a crucial first step to reducing vulnerability of coastal communities, including loss of habitats and ecosystem services due to climate change. Climate change is expected to bring an increasing rate of SLR and an increasing intensity of hurricanes, storms, and heavy rain events. These changes will increase flooding, shoreline erosion, and damage to community infrastructure, and consequently impact the coastal economy. Impacts to fish habitats are also expected due to changing water levels, water quality, and chemical properties (temperature and salinity). Expected impacts were described in detail in the CHPP 2021 climate change chapter, the NC Climate Science Report and the 2020 Resilience Plan.[75, 139]

Vulnerability assessments are valuable tools to assess where communities are most susceptible to hazard risks, including climate-change related weather events, and to provide these communities with actions that can be taken to prepare, adapt, and lower risks. Assessments can inventory extent and location of natural infrastructure that provides flood, erosion, and water quality benefits. The Nature Conservancy (TNC) and the National Centers for Coastal Ocean Science (NCCOS), along with other partners developed a coastal resilience decision support tool.[140] The tools show areas at risk under different flood events and SLR scenarios, wetland distribution change under various SLR scenarios, and a living shoreline suitability tool. The USACE also conducted a regional assessment of risk from storms and SLR to support resilient communities and habitats.

Another resilience project was developed as part of the Natural and Working Lands component of the 2020 Resilience Plan. The project is intended to help state and local government, land conservation trusts, and landowners identify natural and working lands that can provide the most benefit if they are protected or restored.[141] One ArcGIS story map prioritizes marsh for their importance to protecting assets, such as populated areas, historic sites, and key natural areas. Another depicts the distribution of marsh and SAV, natural habitats that provide water quality value. Potential future marsh migration, if not blocked by stabilization structures or development, are shown for different SLR scenarios (Figure 5.12). This could help communities decide where to strategically conserve land to allow for marsh migration.[74]

The NC Resilient Coastal Communities Program was a recommendation of the 2020 Resilience Plan. The program, a partnership with NC Office of Recovery and Resiliency, NC Sea Grant, TNC, and DCM, provides financial grants and technical assistance to support proactive local efforts to improve community resilience to climate change. The program aims to assist communities with risk and vulnerability assessments and development and implementation of prioritized projects that improve resiliency.[142, 143] Grant funding for developing watershed restoration plans is available through DWR's 319 grant program.[144] Watershed restoration plans often utilize nature-based solutions to address runoff and water quality issues.

Photo Credit: Jesse Bissette

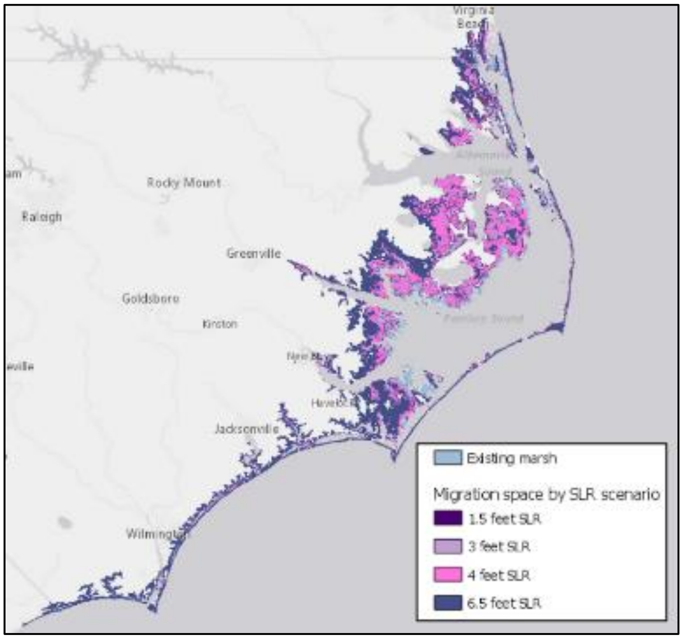

Figure 5.12. Migration space necessary for marsh to move inland to avoid inundation under four sea level rise (SLR) scenarios. The spaces shown do not identify where this is possible or not due to existing development.[141]

5.3.3 Nature-based Solutions

Despite NC's support of the Federal No Net Loss of wetlands policy objective, it is increasingly clear that this overarching policy goal has not been realized due to many factors, including policy choices exempting certain impacts from regulations, non-compliance, and the lack of mechanisms to address losses that cannot be attributed to discrete human activities. As such, it is increasingly recognized that conservation alone is likely insufficient to maintain the extent and function of NC's invaluable coastal wetland resources and that wetland restoration will be an integral component of a multipronged strategy to compensate for losses.

Nature-based solutions include a suite of strategies that use natural systems, mimic natural processes, or work in tandem with traditional approaches to address specific hazards. Communities across the country can incorporate nature-based solutions in local planning, zoning, regulations, and built projects to help reduce their exposure to flood and erosion impacts. Nature-based solutions, is based on the understanding that a habitat provides multiple ecosystem services.[145] Nature-based solutions can range from land preservation for creation of parks or open space, to constructing engineered structures like stormwater BMPs and living shorelines that include plants alongside nature-inspired features, such as oyster reef breakwaters. Protecting and restoring existing natural habitats is also a component of nature-based solutions. Conserving wetlands in the floodplain has been one tool used by towns to prevent development in vulnerable locations, which maintains flood and erosion protection provided by the wetlands, reduces infrastructure damage, provides community recreation (greenway trails), while protecting fish habitat and water quality.

Wetland restoration

Coastal wetland restoration methods can be classified as passive restoration, active restoration, or creation. Passive restoration methods are those that mitigate factors that induce degradation or destruction of coastal wetlands, allowing the wetland to "self-restore" once stressors are ameliorated.[146] Active restoration typically involved interventions to restore, improve, or recreate the processes and function of coastal wetlands through techniques such as topographic or hydrologic modification, adding sediment, and/or vegetation planting.[147] Creation involves the wholesale conversion of non-wetland land types (e.g., upland, agricultural land, subtidal flats), requiring hydrological modification, replication of soil physiochemical properties, and wetland plant introduction (Broome et al. 2019). Each of these forms of wetland restoration have been strategically used in projects throughout NC. These include various forms of living shorelines, hydrologic restoration, beneficial use of dredge material, and nature-based stormwater BMPs.[75]

Maintaining vegetated buffers is a passive nature-based solution to protecting wetlands and water quality. Due to the expected loss of wetlands associated with climate change, evaluation of the existing development buffer rules by a technical committee would be helpful is assess the future efficacy of those buffers when evaluating SLR, and whether changes to those rules are needed.

Work on nekton recovery following the restoration of salt marshes and other coastal wetlands has demonstrated that fish use recovered following wetland restoration efforts.[148, 149, 150, 151] Further, there is mounting evidence that living shorelines combining salt marsh with some form of nature-inspired structural feature (e.g., oyster breakwater, stone sill) can not only slow or reverse the retreat of salt marsh shorelines but can also increase their value as a nursery habitat for both finfish and crustaceans.[108, 110]

While wetlands are highly effective at trapping sediment and nutrients it is important to note that coastal wetlands cannot assimilate an indefinite amount of nutrients. Excess nutrient enrichment experiments have shown that eutrophication can increase above ground biomass while reducing bank-stabilizing below ground biomass.[152] Therefore, coastal wetlands can provide water quality enhancement benefits only if nutrient mitigation efforts are also in place.

Living shorelines

Living shorelines, as defined by the DCM and the Living Shoreline Steering Committee (LSSC), are a suite of options for shoreline erosion control that maintain existing connections between upland, intertidal, and aquatic areas which are necessary for maintaining water quality, ecosystem services, and habitat values. Unlike vertical stabilization measures such as bulkheads, living shoreline techniques are a nature-based solution to shoreline erosion, typically using native materials such as marsh plants, oyster shells, and occasionally structural materials (e.g. stone) to stabilize estuarine shorelines, minimize erosion, and enhance habitats for native species.

As previously noted in **Chapter 2. Implementation Progress on Priority Habitat Issues (2016-2021)**, since 2005, substantial progress has been made in documenting the benefits and limitations of living shorelines. This research verifies that living shorelines support a higher diversity and abundance of fish and shellfish than bulkheaded shorelines, effectively deter erosion, survive storm events well, and provide additional ecosystem services. Consequently, this alternative to bulkheading has been supported by the CRC and included as a recommendation of CHPP.[109, 153] Encouraging living shorelines as the preferred shoreline stabilization method is a key nature-based solution that can protect and restore wetlands, as well as oysters in some areas. Outreach efforts have been done to increase awareness of this technique to the public and contractors. NGOs and DCM have constructed several demonstration projects. The CHPP Steering Committee requested that efforts continue to focus on encouraging living shorelines to protect property, restore shoreline habitat, and improve water quality.[75]

The LSSC was formed during the summer of 2018 to bring together federal and state agencies, NGOs and universities to communicate and collaborate on education and outreach, research, and implementation of living shorelines to support sustainable management of estuarine shorelines. This Committee also acts as the Albemarle-Pamlico National Estuary Partnership (APNEP) Living Shoreline Implementation Team and is co-led by APNEP and NCCF. The Living Shoreline Steering Committee meets multiple time a year to discuss ongoing research, outreach, and implementation of living shorelines in NC. In the past five years, research and monitoring efforts have continued. Outreach and education efforts have increased the awareness and shown the benefits of living shoreline techniques to professionals (e.g., real estate agents, contractors, engineers) and the public. Efforts to install living shorelines has resulted in the construction of nearly 2,400 feet of living shorelines along NC's coast in 2019.

A major regulatory accomplishment for increasing use of living shorelines in NC was the establishment of a new Regional General Permit (RGP) for living shorelines by the Wilmington District of the USACE in March 2019. The USACE RGP is consistent with the state general permit for living shorelines. The CRC adopted 15A NCAC 7H .2700 General Permit for Construction of Marsh Sills for Wetland Enhancement in Estuarine and Public Trust Waters in July 2019. These new federal and state permits do not require any coordination with state and federal agencies if the permit conditions are met; therefore, creating a streamlined general permit process that is consistent with other CAMA general permits. An increase in applications has already been observed by DCM staff.

The Nature Conservancy and NOAA scientists have developed a Living Shoreline Explorer application tool for Carteret and Onslow Counties to assist users with determining where it is suitable to use a living shoreline.[140] The Nature Conservancy's Restoration Explorer application on the Coastal Resilience Tool helps users identify where they can use oyster reefs to stabilize their shoreline. Using this online tool helps identify sites for subtidal shoreline oyster reef restoration within the Pamlico Sound, which could also aid in living shoreline siting.

Other actions implemented through the 2016 CHPP include outreach and education by the National Estuarine Research Reserve's (NERRs) staff who hosted numerous living shoreline workshops to educate real estate agents, homeowners associations, marine contractors, engineers, land use planners, landscape architects, and coastal decision-makers in the promotion of living shorelines for erosion control.[75] Construction events hosted by NCCF and University of North Carolina – Wilmington (UNC-W) were held up and down the coast hosting hundreds of volunteers who assisted in plantings and construction of living shorelines.

Research and monitoring of living shorelines are ongoing with results from studies on response of natural and sill-stabilized fringing marshes to SLR, impacts of hurricane on natural and stabilized living shorelines, as well as research on wave attenuation by natural marshes and living shorelines. Alternative living shoreline construction materials such as concrete-coated burlap, oyster shell and rock gabions are being tested. The NCCF is also working on the development of a degradable alternative to traditional plastic mesh bags for use for oyster shells. Additionally, research is ongoing on socioeconomic impacts of shoreline management strategies and how to effectively incentivize property owners to use living shorelines. It has been found that small economic incentives, such as cost-share programs, can substantially alter homeowner decisions to select living shoreline methods over other harder stabilization techniques.[154]

At the CHPP Wetland Workshop on living shorelines and restoration, attendees discussed thoughts on incentives versus disincentives and strategies to encourage use of living shorelines. They agreed that more attention needs to be given to the science regarding post-storm success of living shorelines in shoreline stabilization. The living shoreline portion of the workshop noted that despite NC having many successful living shorelines throughout the coast and growing research demonstrating their efficacy for shoreline stabilization and value for ecosystem services, they continue to be under-utilized compared to vertical hardened structures. Attendees concluded that the greatest needs for advancing the use of living shorelines was strong state agency support for their use; financial incentives; increased awareness and installation of living shorelines by the public and marine contractors; and business programs for marine contractors.

The 2021-2025 NC Oyster Blueprint, produced by NCCF with support from a collaboration of agencies, universities, and NGOs, is an oyster protection and restoration plan that provides stakeholders direction and guidance as a united force to implement restoration, management and economic development strategies that benefit both the environment and the economy.[155] The Oyster Blueprint identifies strategies and actions needed to rebuild NC's oyster resources. An additional approach in this plan is identifying living shorelines that include oysters as a distinct strategy to restore and protect oyster habitat. The overarching goal for the living shoreline strategy is to expand the use of living shorelines to become the most used stabilization method in estuaries that support oyster habitats.

When living shorelines are constructed with oyster reef materials, such as recycled shells, oyster castles, or reef balls, they provide intertidal habitat for shellfish resources. Building living shorelines along eroding waterfront properties where oysters grow, is one way to expand oyster habitat, reduce shoreline erosion, and protect and improve water quality. With the inclusion of living shorelines to the Oyster Blueprint, strategies to expand their use in estuaries will provide additional substrate to support oyster habitat, while also protecting and restoring wetlands.

Protection of Oyster-Based Living Shorelines from Harvest

With the 2021 Oyster Blueprint including construction of oyster-based living shorelines as a strategy for enhancing oyster habitat, there are concerns of allowing the harvest of oysters from living shorelines. Presently oyster harvesting from living shorelines is not prevalent, but as the use of living shorelines increases, the issue may become more widespread. Oyster harvesting is managed by DMF through a Fisheries Management Plan and is subject to management through gear types, area, harvest limits, and seasons. In addition, the Shellfish Sanitation Section of DMF is responsible for monitoring and classifying coastal waters for their suitability for shellfish harvesting for human consumption based on bacteriological sampling. The DCM permits living shorelines. To address this issue, DMF has developed a living shoreline oyster protection committee. The group will evaluate management area protection, conservation leasing/easement, or another management mechanism to protect oysters on constructed living shorelines. These options will most likely require statutory changes in current statutes to address contractual agreements, marking and enforcement.

Hydrologic restoration

Humans have directly and indirectly changed the hydrology of coastal wetlands through ditching and draining, installation of levees and dikes, and reducing natural infiltration of runoff due to impervious surfaces in developed watershed. The history of hydrologic alteration in Hyde County in the Lake Mattamuskeet watershed was summarized in the Lake Mattamuskeet Watershed Restoration Plan.[156] This lake, the largest natural lake in NC, was extensively modified by a series of canals and pump stations for drainage. The canals allow fish movement into the lake, and blue crab and several anadromous fish species occur in it. The lake receives runoff from ditching and landscape changes in the surrounding area and is highly eutrophic. This has caused harmful algal blooms and extensive loss of SAV since the 1980s.[157] The lake waters were classified by DWR as impaired in 2016. Additionally, shellfish harvest closures have occurred in Pamlico Sound tributaries receiving canal waters that drain the lake. While these hydrologic modifications were carried out largely to protect agricultural lands from flooding and flood-related damage, many communities surrounding these modifications now face increasing flooding impacts due to altered hydrology exasperated by climate change. There is growing science that a better approach for flood prevention is by use of nature-based methods that replicate natural hydrology.

Efforts to reverse these hydrological modifications and return wetlands to their pre-impact hydrology fall under the umbrella of hydrological wetland restoration. The Mattamuskeet Drainage Association, NRCS, and NCCF developed a watershed restoration plan in 2013 for a 42,500-acre area located northeast of Lake Mattamuskeet and operated by the Association.[158] With input from agencies and stakeholders, the watershed plan with management actions was developed. The plan called for reducing and treating stormwater that was traditionally pumped through canals into Otter Creek and Berry Bay, Pamlico Sound, and the Alligator River. The altered drainage was contributing to impairment of shellfish harvest waters. Several of the strategies involve pumping water from the canals to low-lying areas of farmland and managing water levels to establish bottomland hardwood trees and other wetlands. It was thought that runoff historically flowed in this northwest direction. Approximately 2,000 acres were restored and more is underway.

Another watershed restoration plan, the Lake Mattamuskeet Watershed Restoration Plan (LMWRP) was developed in 2018 to address the deteriorating conditions in the lake and its surrounding watershed.[159] Concerns included 1) extensive SAV loss and water quality degradation in the lake, 2) flooding in the surrounding watershed, and 3) declining performance of the existing drainage system that relies on canals and tide gates. The plan called for improving drainage management through several actions, including conducting engineering studies to evaluate the feasibility of redirecting water in the current drainage canals to re-establish and replicate the natural movement of water from the lake to the Alligator River drainage area. The preferred design alternative is to identify, design, and prioritize projects where water diverted from the lake could move via sheet flow over created or restored wetlands, allowing nutrients and sediment to be absorbed before discharging into surface waters.[156]

One successful example of large-scale hydrologic restoration is North River Preserve. The 6,000-acre wetland restoration project undertaken by NCCF was completed on former farmland, primarily by restoring the hydrology.[160] Before restoration, runoff from the farmlands at North River Farms, which had been smoothed, crowned and ditched, often left the fields and discharged into the surrounding estuaries on the order of hours to days. Various wetland restoration techniques used across the farm increased the surface storage and controlled the outflow. This increased the time it took for the runoff to leave the site - often on the order of weeks to months, depending on wetland restoration design and proximity to the estuary. In addition, because of additional evapotranspiration and infiltration that occurred in the wetland environment, the volume of runoff was also often reduced.[90] Another example of nature-based solutions in NC involved TNC and US Fish and Wildlife Service (USFWS) collaboration to restore hydrology of pocosin through installation of water control infrastructures, such as culverts, weirs, flashboard risers, berms, and beaver dam analogs. This work was focused on Alligator River, Pocosin Lakes, and Great Dismal Swamp NWRs.[161] Atlantic white cedar and bald cypress were planted at Pocosin Lakes. Oyster reefs have been constructed adjacent to Alligator River and Cedar Island NWRs to reduce wetland shoreline erosion.

It is imperative that nature-based solutions be developed and/or incorporated into drainage or watershed restoration management plans to minimize the unintended negative impacts resulting from the interaction of hydrologic alteration and future SLR. Many goals and objectives included in watershed restoration plans can be achieved by restoration or enhancement of wetlands. For example, rather than using sheet piling to prevent flooding of farmland, wetlands could be restored to provide natural flood management and reduce nutrient loading. Continued use of manmade structures such as tide gates can be beneficial hydrologically when properly planned and maintained but can impede fish migration. A more active approach to drainage management could work in conjunction with wetland water storage capacity to minimize flooding impacts. Combining adaptive hydrologic management strategies with wetland easements can provide a multi-pronged approach to restoration. By utilizing wetland easements or grant programs, communities can minimize the economic cost of wetland restoration and instead use those funds to implement hydrologic restoration projects.

Beneficial use of dredge material for marsh creation or restoration

Beneficial use of sediments is a term used by USACE for environmentally and economically positive uses of dredged material, including fish and wildlife habitat enhancement. Dredged materials have been used for decades in wetland creation and restoration efforts.[162] Historically, this has consisted of dredge materials being deposited within unvegetated areas adjacent to the shoreline until a target elevation has been reached.

There is increasing data that suggests given the rate of SLR, sediment supply dynamics in many areas are insufficient to sustain upward and landward marsh migration.[118, 163, 164] Using dredge material as a supplement sediment supply for existing marshes is a potential strategy to enhance the ability of a marsh to keep pace with SLR. Building marsh elevations with sediment delivered from nearby dredging projects, referred to as thin-layer sediment placement, deposition, or dispersal, is potentially valuable for creating, restoring, and maintaining coastal marshes, and may slow or reverse losses of wetlands due to coastal development, geological or drought related subsidence, and SLR.[165, 166] Sediment is applied to the marsh surface by spraying a slurry of water, sand, and silt. The resulting increase in elevation reduces the marsh inundation period and improves soil drainage, resulting in greater marsh productivity.[167] The optimum elevation varies based on local tide conditions. Sediment additions that are too thin may not be sufficient to reduce flood stress to plants and limit the marsh's ability to keep up with SLR. Conversely, sediment additions that are too thick may reduce plant and invertebrate recolonization success and make the marsh vulnerable to invasive species such as *Phragmites australis*.[168] While higher marsh elevation increases marsh resilience, fish access to the marsh increases when marshes are lower in elevation and inundated more. Therefore, the resulting elevation is critical to the success of this type of restoration for overall continuation of marsh ecosystem services.[167, 169, 170] When done correctly, dredged sediment additions to marshes can be beneficial, converting dredged materials from a waste product to a resource that benefits sediment limited marshes.[168] A primary goal of using dredge material to restore wetlands should be to build the marsh surface to an elevation that allows vigorous growth of desired plant species, so that natural processes can then maintain the marsh for future years and allow fish use to continue.

There are limited published studies on the efficacy of thin-layer placement specific to NC. Peer reviewed research from Masonboro Island,[169] grey literature from studies in Wysocking Bay,[171] and unpublished data from the New River estuary,[172] all point to the potential value of thin-layer placement as an approach to mitigate the effects of SLR on NC's coastal wetlands. However, given the diversity of factors that can influence the outcome of thin layer placement, further research is needed, a point emphasized by participants at the CHPP Virtual Wetland Workshops.

Stormwater BMPs

Urbanization of coastal watersheds has led to appreciable conversion of natural land covers to impervious surfaces. Impervious surfaces in coastal watersheds prevent infiltration on land and increase the volume of polluted stormwater that is received by coastal wetlands. The resulting changes to the timing, quantity, and quality of the stormwaters received by wetlands dramatically alter the species composition and ecological function of wetlands.[173]

While using natural wetland features to capture runoff can improve water quality and reduce flooding, negative impacts can occur to the wetlands. In a DWR study, in certain circumstances, stormwater discharge to natural wetlands caused channelization, sedimentation, tree mortality and change in wetland vegetation.[174] When directing stormwater to natural wetlands, impacts can be minimized by proper site selection (sufficiently large and disturbed rather than pristine wetlands), dense vegetation, and diffuse entrance flow.

Increasing use of stormwater best management practices (BMPs) that retain and filter more runoff on-site is needed to address the threats that urbanization induced hydrodynamic changes pose to susceptible coastal wetlands. A promising approach to reduce stormwater volume received by coastal wetlands is the use of low-impact development (LID), which is the practice of using techniques that recreate the natural processes and landscapes, resulting in infiltration (e.g., permeable pavements) and evapotranspiration (e.g., bioretention ponds, rain gardens) of stormwater or the use of stormwater as a resource (e.g., vegetated rooftops). Such practices can dramatically reduce stormwater runoff, which is the leading source of surface water degradation across the US.[175]

Studies have found LID successful at reducing the concentration of nutrients, pathogens, and other pollutants in stormwater. A North Carolina State University (NCSU) study on bioretention cells found that these cells were capable of reducing phosphorous loading by 22-65 percent, nitrogen loading by 40-70 percent, copper and zinc loading by 56-99 percent, and fecal coliform by over 90 percent at sites throughout NC.[176] A NC study comparing LID to conventional development practices at commercial development sites found runoff and nutrients to be 95 percent lower at the LID sites.[177] Additional studies have shown that runoff from developments with low impact design can be comparable to export from forested watersheds.[178] Small modifications, such as replacing impervious surfaces with permeable pavers or disconnecting and redirecting gutter ends to vegetated areas has been shown to dramatically reduce, and in some cases completely eliminate, runoff otherwise destined for receiving wetlands and coastal waters.[179, 180, 181, 182] While there is a common misconception that LID is often more costly and requires greater maintenance than projects that use conventional design, research has shown that LID often requires considerably less maintenance and is frequently (11 of 12 LID projects evaluated in Pender County, NC) less expensive than conventional design alternatives.[183, 184]

The DEMLR updated the Stormwater Design Manual in 2020.[185] The revised manual includes an increasing number of nature-based BMPs and LID that focus on mimicking natural hydrology and on-site infiltration. The manual now includes Runoff Volume Match and LID as a component of stormwater design options, incentivizing methods that are nature-based and retain runoff onsite. Storm Control Measures (SCMs) that enhance or restore wetlands include infiltration systems, bioretention cells, wet ponds, and stormwater wetlands. Ratings of the SCMs for removal of bacteria and nutrients indicate that infiltration outperforms all other SCMs.

In 2021, NCCF and Pew Charitable Trusts developed an action plan for nature-based stormwater strategies (NBSS).[186] The effort involved work groups that discussed and made recommendations on nature-based stormwater strategies to reduce flooding and improve water quality in four areas: 1) new development, 2) stormwater retrofit of existing land, 3) roadways, and 4) working lands. A committee was formed for each of these four areas. The report notes that new approaches are needed to address increasing rain associated with climate change. The foundation of the plan is that restoring and mimicking natural watershed hydrology is the most cost-effective approach, and therefore a critical first step is development of watershed restoration plans. These voluntary plans can be done by state agencies, local government, or NGOs. Funding is available through DWR's 319 grant program.[144] By effectively improving water quality, advancing this effort will also directly benefit oysters and SAV (for more information, see **Chapter 4. Submerged Aquatic Vegetation Protection and Restoration through Water Quality Improvements**). The key impediments to advancing nature-based stormwater strategies were lack of awareness, inflexible planning, regulations, and policy, design challenges, and funding.

A few examples of recommendations from each of the four committees are listed below:

- State and local government should lead by example using nature-based stormwater strategies when constructing or repairing facility property.
- Develop detailed information maps to assist with watershed management plans (i.e., Duke, TNC, NCCOS resiliency maps).
- Use nature-based stormwater strategies to bring failing stormwater systems into regulatory compliance (also supports the **Chapter 6. Environmental Rule Compliance to Protect Coastal Habitats** Issue Paper recommendations).
- Increase economic incentives from local, state, and federal sources to landowners to preserve wetlands within forest lands, and to preserve forested and agricultural floodplains.
- Begin a collaborative effort to pursue additional funding from the Farm Bill and other programs for conservation, wetland restoration, conservation easements, and large-scale hydrologic restoration projects.
- Work with the military to identify priority properties used for training and where hydrologic

restoration is feasible.

Recognizing the damaging impacts of stormwater runoff and the value of LID, in 2007, the US Congress enacted Section 438 of the Energy Independence and Security Act (EISA). EISA Section 438 stipulates that the sponsor of any development or redevelopment project involving a federal facility with a footprint that exceeds 5,000 ft^2 shall use strategies to design, construct, and maintain, to the maximum extent feasible, the predevelopment hydrology of the property. The mandate requires that, to the extent technically feasible, annual runoff from sites post-development must be no greater than the percentage before development. Following the federal government's lead in adopting a policy requiring that state funded construction utilize low impact design practices would be a major step towards protecting NC's coastal wetlands. This would benefit wetlands, SAV, and the overall health of the estuary.

The NC Soil and Water Conservation Commission and Division of Soil and Water Conservation, through funding from NRCS, provide cost share funds for qualified BMPs under the Agricultural Cost Share Projects (ACSP) and Community Conservation Assistance Program (non-agricultural) (CCAP). The purpose of CCAP is to reduce nonpoint source pollution from existing development through installation of BMPs. Some of the BMPs allowed under the CCAP include constructing living shorelines, rain gardens, stormwater wetlands, and bioretention areas. However, funding for the program, which became effective in 2020, has been very low, receiving approximately $136,000 annually in state appropriations for the entire state.

<u>Land Acquisition and Conservation</u>

One solution that has been utilized to offset the natural and anthropogenic impacts to wetlands is the acquisition of land for wetland conservation and restoration. The ability to preserve a privately owned area in its natural or restored state are goals that are most effectively achieved through land acquisition by governments (local, state, or federal), NGOs, or government-NGO partners via a purchase or easement agreement with the private landowner. As a coastal resource management approach, land acquisition has an important role in offsetting damages via active restoration, passive restoration, wetland creation, and allowing for the natural migration of coastal wetlands with SLR. Land conservation can reduce sediment and nutrient pollution that reaches waterbodies, as wetlands produce less pollutants than crops, and are naturally able to remove pollutants from soil.

In NC, the leading NGO's involved in land acquisition for wetland conservation and restoration are NCCF, TNC, Coastal Land Trust, and Conservation Trust for NC. At the local and state levels of government, municipalities' stormwater management and water conservation divisions, and The NC Department of Cultural and Natural Resources, Wildlife Resources Commission, and the NC Coastal Reserve are typically partners in land acquisition for wetland management purposes.

There are three state conservation trust funds in NC. The NC Land and Water Fund (NCLWF), formerly known as the Clean Water Management Trust Fund, was created in 1996 to finance projects that improve water quality, including land acquisition. The NCLWF is a primary source of grants allowing local governments, state agencies, and conservation nonprofits to address water pollution, protect clean water, and conserve lands that are ecologically, culturally, or historically significant. Through this program, landowners sell their land to the state or establish a perpetual easement; after completion of the project, the property is owned and protected by state or local government as public land or remains private land that is managed for conservation. Projects funded through this program involve development/restoration of riparian buffers, providing greenways, stream restoration and enhancement, and innovative improvements to stormwater management. Appropriations have declined since 2009, going from $100 million/year from 2005 to 2008, to $13 million in 2019.[187, 188] The Parks and Recreation Trust Fund is used for land acquisition, improvements within the state's park system, and beach and estuarine access. The Agricultural Development and Farmland Preservation Trust Fund funds programs that support working family farms through conservation easements on threatened farmland and agricultural development projects. Funding for all three programs has declined significantly since 2009.

The USDA offers a variety of financial assistance programs for landowners in NC, with funding through the Farm Bill.[189] NRCS purchases eligible land through the USDA's Wetlands Reserve Easement (WRE). Currently, NRCS has over 54,000 acres enrolled in the Wetland Reserve Program nationally, with approximately 99 percent being in the Atlantic Coastal Plain.[190] Once the land has been acquired, the NRCS develops and implements a wetlands reserve restoration easement plan to restore and expand wetlands. The NRCS offers various options for enrollment in this program, including permanent easements, 30-year easements, term easements, and 30-year contracts. Under these options, NRCS will pay more than half of the easement value, and cover most of the restoration costs. This program provides private landowners an opportunity to maximize restoration/protection potential while minimizing their costs. This is critical in many agricultural areas of coastal NC where socioeconomics often impact the ability of landowners to conduct these activities. Between 2014 and 2019, the NRCS's Agricultural Conservation Easement Program (ACEP), a program that helps to conserve agricultural lands and wetlands and their related benefits, awarded over $28 million dollars in funding to NC projects, ranking eighth in the US.

Additionally, NRCS offers a Wetland Reserve Enhancement Partnership (WREP), which allows NRCS to enter into agreements with eligible partners (i.e., state/local government, tribes, and NGOs) to carry out restoration/enhancement projects that are a high priority for wetland protection, restoration, and enhancement. This program allows sharing of costs and staffing, which is beneficial to all parties by alleviating some of the budgetary and staffing constraints that often coincide with implementing restoration projects.

State agencies or eligible entities in coastal states may also apply for a USFWS programs including National Coastal Wetlands Conservation grants and North American Wetlands Conservation Act (NAWCA) grants. Awarded grants provide funding that can be used for acquiring property from private landowners and using it for long-term wetlands restoration and enhancement. Funds provided through these grants may also be used to manage wetlands (as opposed to just the acquisition of the land) to meet an agency's goals. Like the WREP, these funds can alleviate many cost restrictions faced by those looking to conduct wetland restoration/enhancement projects. Since 1991, $21.3 million in NAWCA grant funding and $69.3 in partner contributions have protected or restored a total of 116,367 acres of wetlands in NC.

The USDA also offers enrollment in the Conservation Reserve Enhancement Program (CREP), which provides funds to restore wetlands, improve water quality, reduce soil erosion, and reduce the amount of sediment, nutrients, and pollutants entering surface waters. This program allows landowners to convert agricultural lands in sensitive areas from land that is farmed or ranched to land that provides conservation benefits. Property owners can enroll in 10 or 15-year programs that involve removal of agricultural production and replace it with native vegetation to restore wetland habitat. Typical eligible practices are tree planting, establishing filter strips or riparian buffers, and wetland restoration. Eligible landowners may receive up to 50 percent of the cost to install the conservation practice, an annual rental payment, and a cost-share payment, as well as additional incentives for longer easement enrollments.

Conservation and restoration of wetlands through land acquisition represents an increasingly valuable approach to safeguarding the continued existence and functioning of NC's coastal wetland resource. By reducing nutrients and sediment reaching nearby waterways, wetlands help to improve water quality conditions, also benefiting SAV and oysters. Federal grants have proven to be a reliable source of funding for land acquisition but, importantly, a number of available federal grant programs have a state match requirement. As such, availability of state funds directly influences NC's ability to effectively leverage these opportunties to safeguard existing, restored degraded, or create new coastal wetlands. Given the challenges facing NC's coastal wetlands, increasing recognition of the need for marsh migration space to accommodate SLR, and a surplus of evidence that coastal restoration and conservation supports the state's continued economic development, increasing state funding for coastal land acquisition is likely a cost-efficient and effective approach within a multi-faceted strategy to conserve coastal wetlands and their services.

The Natural Working Lands Action Plan includes strategies to build ecosystem and community resilience, provide ecosystem benefits, sequester carbon, and enhance the economy.[191] The plan recommends developing incentives with state and local governments and other public and private stakeholders to protect coastal habitats and migration corridors to allow for future landward migration. These actions would help faciliate conservation and restoration of wetlands.

<u>Funding Restoration</u>

Wetland restoration and nature-based solutions have been embraced as a tool to address coastal wetland losses in NC. However, a recent synthesis of federally-funded, voluntary wetland restoration in coastal counties of the conterminous United States found that coastal wetland restoration is failing to keep pace with losses and will likely need to increase dramatically in coming decades to compensate for losses.[85] Over the most recently reported decade of federally funded coastal wetland restoration (2006-2015), NC ranked third out of 22 coastal states in cumulative acreage of coastal palustrine wetlands restored, with 15 projects restoring a total of 12,988 acres. While considerable, the approximately 13,000 acres of palustrine wetland restoration that occurred within NC's coastal counties during this decade fell well short of compensating for losses incurred over the previous decade. North Carolina was less competitive in terms of the acreage of estuarine wetland restored through federally funded projects between 2006 and 2015, ranking seventh out of 22 coastal states, with the restoration of 5,067 acres of estuarine wetlands. However, as the proportion of estuarine wetland losses increases due to SLR and storms, the need for voluntary wetland restoration is likely to grow.

While wetland restoration can be resource intensive, studies quantifying the value of ecosystem services of restored wetlands suggest that benefits frequently exceed costs.[192, 193, 194, 195] For example, an estimated return of $46.5 billion dollars in economic benefits is anticipated from a $12.1 billion investment in restoration of the Florida Everglades, a return of $4.04 dollars for every dollar invested in restoration.[196] Economic benefit analysis of coastal ecosystem restoration projects in San Francisco Bay and Virginia's Seaside Bays have reported benefit-cost ratios as high as 18:5 and 26:5.[197] In NC, analyses found that a $2.4 million investment to conduct the North River Farms restoration project, the largest coastal restoration project in NC history, increased business revenue in coastal NC by $5.2 million and household income by $1.8 million while creating 66 full-time jobs.[198] The growing body of research indicates that coastal wetland restoration can serve as an important component of coastal community economic development in NC.

The federal government provides the majority of wetland restoration funding in the United States through federal funding programs administered by multiple agencies, including the US Department of Agriculture (USDA), the USFWS, NOAA, and the USACE. In addition to their federal regulatory roles, multiple federal agencies administer funding programs. Not all, but many of these funding opportunities require state matches for wetland restoration grants. Low availability of state funds as match has therefore limited the ability to fully utilize available federal funds.

The DMS is a statewide In-Lieu Fee program that provides a variety of mitigation types to offset unavoidable impacts for the NC DOT as well as other developers. DMS provides wetland mitigation for impacts to riparian, non-riparian and coastal wetlands. DMS has three types of wetland credit it can produce: wetland restoration, wetland enhancement or wetland re-establishment. In general, compensatory wetland mitigation does not increase the amount of natural resources (i.e. wetlands) but rather offsets impacts to support no net loss of these resources. The DMS applies payments from its various programs to implement mitigation where the need and opportunity is greatest by utilizing watershed planning and working with state and local partners. Successful project procurement and implementation requires DMS to work with mitigation providers, regulatory agencies, and landowners to locate, design and construct wetland mitigation projects. In 2020, NC legislature passed HB 1087, which establishes a program within DMS to develop flood storage capacity projects in targeted watersheds, through creation or restoration of wetlands, streams and riparian areas, temporary flooding of fields or forests, and other nature-based projects. While this will assist somewhat, providing matching state funds is still problematic.

5.4 Recommended Actions

The 2021-2025 NC Oyster Blueprint, NC Natural Working Lands Action Plan, and the Action Plan for Nature-based Stormwater Strategies include numerous actions that would protect or restore coastal wetlands, consistent with the CHPP. A subset of these recommendations specifically supported by the CHPP Steering Committee (CSC) are provided in **Chapter 9. Summary of Recommended Actions**, Table 9.1. Refer to the individual plans for a complete list of actions.

5.4.1 Mapping and Monitoring

5.1 By 2023, DEQ will obtain state matching funds for the NOAA C-CAP program to map NC's Coastal Plain at 1m resolution and additional funding to expand coastal wetland monitoring conducted by DWR and other state agencies.

5.2 By 2024, DEQ will pursue the use of emerging technologies such as data fusion or deep learning neural networks, that rely on a combination of satellite imagery, drone imagery, and field verification for coastal wetland mapping and change analyses.

5.3 By 2022, DEQ will form an interagency workgroup to develop a coastal wetland mapping and monitoring plan, including a minimum set of standardized metrics and a potential centralized location to store relevant reports and information.

5.4 By 2026, DEQ will determine the status and trends of coastal wetland acreage, condition, and function, based on the additional mapping and monitoring data obtained.

5.4.2 Conservation

5.5 By 2022, DEQ will provide information to NC legislators regarding the need for increased appropriated funds for the three state conservation trust funds to increase conservation of critical wetland properties and critical corridors that will allow for future marsh migration.

5.6 By 2022, DEQ will actively participate in and support the development of a Southeast Regional Marsh Conservation Plan, which is a partnership with the Department of Defense along with federal, state, and private groups that have been initiated by the Southeast Partnership for Planning and Sustainability (SERPPAS).

5.7 By 2026, DEQ will work with researchers, federal and local governments and NGOs to facilitate marsh migration through the conservation of migration corridors, including participation in the Pew Charitable Trust-SERPPAS Salt Marsh Initiative.

5.4.3 Restoration and Living Shoreline

5.8 By 2022, DMF will determine potential mechanisms to prevent harvesting from living shorelines constructed with oysters.

5.9 By 2025, DEQ will determine if living shoreline projects can be built in a manner that qualifies for salt marsh or nutrient mitigation credits.

5.10 By 2025, DEMLR and other divisions should increase education, outreach, and training to consultants, local government, and landowners for nature-based stormwater and watershed management strategies.

5.4.4 Research

5.11 By 2024, DEQ should partner with other organizations to facilitate coastwide completion or enhancement of coastal vulnerability assessment tools, such as living shoreline siting, and marsh migration and wetland restoration prioritization.

5.12 Determine optimal parameters for thin layer sediment deposition to ensure wetland success.

5.13 Assess trends in salt marsh elevation, inundation, and distribution to prioritize areas for wetland restoration.

5.14 Determine the impact of degrading plastics and marine debris on wetlands, sediment, and the benthos.

5.15 Research the nutrient (nitrogen, phosphorus) reduction benefits provided by living shorelines and use that information to provide incentives for living shoreline projects.

5.16 Study the effects of silvicultural timber harvesting in palustrine (bottomland swamp) forests on hydrology, water quality, and wetland condition; include assessment on the efficacy of forestry

BMPs to minimize ecological impacts.

5.17 By 2022, DEQ should support efforts to incorporate coastal wetlands into NC's Greenhouse Gas (GHG) Inventory.

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Chapter 5. Wetland Shoreline Protection and Enhancement with Focus on Nature-based Solutions

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Photo Credit: Casey Knight

6. ENVIRONMENTAL RULE COMPLIANCE AND ENFORCEMENT TO PROTECT COASTAL HABITATS

6.1 Issue

The River and Harbors Act (RHA) of 1899 represented the beginning of federal laws that provided authority to regulate discharges to navigable waters. The passing of the Water Quality Improvement Act (WQI) in 1970 established a state certification procedure to prevent degradation of waters that was subsequently followed by an amendment to the Federal Water Pollution Control Act commonly referred to as the Clean Water Act (CWA) of 1972. Additionally, the Coastal Zone Management Act (CZMA) of 1972 was passed as a national policy to preserve, protect, develop, and where possible, restore or enhance, the resources of the Nation's coastal zone for this and succeeding generations.

Since that time, an emphasis has been placed on permitting impacts to wetlands and the surface waters of the United States. To meet mandated 401 wetland and other permit processing deadlines, issuing permits often takes precedence over compliance and enforcement programs due to staff and funding shortfalls. There is limited literature on the effectiveness of compliance and enforcement program efforts associated with wetland protections that exist at the state level.[1] With the unknowns of compliance and enforcement programs, the estimates of further loss and impairment of the existing wetlands and surface waters can only be inferred. However, we do know that the extent of impaired waters in NC's coastal waters is significant. There is a need to quantify this loss and impairment to stop future loss through the measured success of current and future management actions.

A more balanced approach between compliance and enforcement program efforts and the process of written authorizations for impacts to wetland and surface waters, will ensure transparency and fairness within the application of regulatory framework. The predictability of compliance efforts and possible enforcement action would serve to reinforce the reason for property owners and/or permittees to adhere to written authorization conditions and other applicable laws and regulations. It also serves as a deterrent for potential violators to adhere to the applicable regulations and laws for the risk of receiving monetary loss in civil penalties and/or criminal penalties. There is strong support from the public to enforce existing rules to improve effectiveness in wetland and water quality protection.[2, 3]

6.2 Background

6.2.1 Scale of the North Carolina's Wetland and Surface Waters and their Services

North Carolina has the tenth largest acreage of wetlands and surface waters in the Nation. The 2010 National Resources Inventory Summary Report utilizing the non-regulatory Cowardin classification system estimates that approximately 7.4 million acres of NC lands (non-federally owned) are wetlands.[4, 5] According to the 2011 National Land Cover Database (NLCD), there were approximately 3.7 million acres of woody and emergent herbaceous wetlands present in the CHPP Regions, representing 21 percent of total land area.[6, 2] More information on wetland trends and stressors is provided in the priority habitat issue papers, **Chapter 5. Wetland Protection and Restoration through Nature-Based Solutions** and **Chapter 8. Coastal Habitat Mapping and Monitoring to Assess Status and Trends**.

Wetlands provide a variety of functions that include surface and subsurface water storage, nutrient cycling, particulate removal, maintenance of plant and animal communities, water filtration or purification, and groundwater recharge.[7] Because of the many water quality benefits provided by wetlands, their protection and enhancement benefits the water column and all other aquatic habitats. Loss of wetlands can lead to increased stormwater runoff and increased loading of pollutants, leading to increased shellfish closures, impaired conditions for survival of SAV and shell bottom, algal blooms, and fish kills.

There are eight coastal draining river basins, of which only four (Cape Fear, Neuse, Tar-Pamlico, and White Oak) are entirely contained within the State. The major rivers and sounds within the four CHPP Regions include the Roanoke River, Chowan River, Pasquotank River, Albemarle and Currituck Sounds, Pamlico Sound, Neuse River, Tar-Pamlico River, Core Sound, Bogue Sound, New River, White Oak River, and Cape Fear River. The Albemarle-Pamlico Sound estuary with an estimated area of 31,478 square miles is the second largest estuary by area in the eastern United States. Approximately 20 percent of the total CHPP area, which includes the coastal plain up to the fall line consists of surface waters (2,813,620 acres).[2] Streams and waters can be ephemeral, intermittent, and perennial in nature and serve to protect communities from flooding by storage of surface waters, retain harmful pollutants, keep sediment and nutrients from reaching downstream waters, provide habitat throughout all life stages for a diverse assemblage of flora and fauna, and provides economic benefits such as fishing, hunting, manufacturing, and agriculture.[8]

North Carolina's coast hosts a wide diversity of waters and wetlands, from the Black River, containing some of the world's oldest trees (2,624 years old) to the pocosin wetlands, the most critically endangered wetland in the US, the coastal plain. North Carolina is home to some 61 federal threatened or endangered species and 604 State species that are listed as threatened, significant concern, or significantly rare.[9, 10] Most of these species spend a portion, if not all, of their life cycles within the wetlands and waters of the State.

6.2.2 Demography and Demands on the Wetland and Surface Waters of NC

A 2020 estimate of NC's population has approximately 10.6 million people residing in the State. The estimated State's population has increased by 10.3 percent since 2010 with the majority of the increase resulting from in-migration from other states.[11] The NC Office of Budget and Management projects the State's population will increase by approximately 1.4 million people by 2030.[12] Although the majority of the projected growth is concentrated within Charlotte and Triangle Regions (74 percent of State growth), additional projected growth ranging from six to more than 18 percent is also to occur in the coastal plain counties of Currituck, Dare, Pitt, Carteret, Duplin, Cumberland, Onslow, Pender, New Hanover, and Brunswick.[13]

As NC's population continues to expand, the stress on the State's waters and ecosystems will also intensify. Development pressure will cause a rise in impervious surface coverage thus compounding the amount of stormwater runoff entering downstream receiving waters and amplifying the potential for both point and nonpoint pollution. The current estimate from the EPA is approximately 7 million of NC's residents depend on the State's surface water as their primary potable water source. Over 750,000 acres of the State's waters (encompassing the streams, sounds, and Atlantic Ocean) are considered impaired and listed on the Section 303(d) of the Clean Water Act.[14]

The coastal plain contains the majority of wetland resources in the State and serves as the discharge point for seven of the major rivers into the Atlantic Ocean. The wetlands within these river basins and others serve as protections to neighboring communities by storing and slowing rapid runoff of stormwater thus minimizing the danger of damaging floods. One estimate found one acre of wetlands can store approximately 330,000 gallons of water. When an acre of wetland is filled, the 330,000 gallons of water is not retained but rather is discharged directly into the waterway thus increasing the risk of flooding.[15] Additionally, hurricanes have had a significant influence on flooding and coastal damage over the past two decades or more, emphasizing the importance of protecting and restoring coastal wetlands to enhance coastal resiliency. For additional information, see **Chapter 3. Climate Change and Coastal Habitat Resiliency**.

Wetlands also serves as a “sink” for suspended sediments by acting as a filter that serves as a retention area that slow down the flow of water allowing sediments to be assimilated by the wetlands prior to reaching waters of the US. In addition, excess nutrients such as nitrogen and phosphorus are only a few of the ecological services that wetlands provided to clean waters and ensure the best usage. When wetlands are under drained conditions, nitrogen and phosphorus otherwise bound in the soil matrix or held in the biomass of plants can be transported by ditches or other drainages features allowing possible pollutant source to migrate to receiving waterways.

From the headwaters of coastal rivers where recreational fisheries are popular, to the estuaries of the coast that bolster the State’s commercial fisheries, wetlands play a vital role in both protection of the existing water quality and supporting the livelihood of the State’s citizens. Over 90 percent of NC’s commercial fisheries landings and 60 percent of the recreational harvest (by weight) are comprised of estuarine-dependent species.[2] In NC during 2018 over $77.8 million of revenue was generated from commercial fishery landings and approximately $156.9 billion of economic impact was generated from recreational anglers, hunting and wildlife watching.[16]

6.2.3 Introduction to North Carolina Regulatory History for Wetlands and Waters

Precise historic estimates of total area of wetlands in NC are lacking and only anecdotal estimates of wetlands exist. A common reference is approximately 11 million acres of wetlands existed prior to the European pre-colonization of NC and by mid-1980s only 5.7 million acres or about one-half of the historic acreage remained.[17] From the mid-1970’s to mid-1980’s, NC experienced a conversion of approximately 1.2 million acres of wetlands to silviculture, agriculture or other uses representing the highest acreage of wetland losses in the southeastern US.[18] In 2011, estimates of wetland acreage was approximately 3.7 million acres within the four CHPP regions and approximately 4.6 million acres within the entire NC Coastal Plain.[19, 20]

The foundation of NC’s authority to regulate discharge to wetland, streams, and waters of the State can be traced to the State’s passage of the Dredge and Fill Act of 1969 and the federal passage of the CWA and CZMA of 1972. Subsequently, state and federal laws and regulations have followed that have sought to clarify jurisdiction and define regulatory authority. In 1985, Congress passed key provisions within the Farm Bill commonly known as “Swampbuster” to financially discourage the conversion of jurisdictional wetlands or highly erodible lands to produce agricultural uses, although loss of jurisdictional wetlands acreage continued through the use of ditching and draining. Over the years, federal laws have had a major influence on wetland loss, particularly from regulatory changes associated with the 1993 Tulloch Rule, which resulted in approximately 11,580 acres of wetlands being drained in the coastal plain.[2, 21, 22] In 1999, after determining that wetland ditching and draining activities were under the state’s authority, the EMC adopted a wetland drainage policy. Inspections of previously ditched wetlands resulted in restoration of 50 percent of the wetlands area found to be in violation of the wetland standard.[2] In 2002, the NC Court of Appeals upheld that wetlands were considered part of the definition of "waters" of the State and therefore, subject to enforcement under the State wetlands standards.

The DWR has the regulatory authority to issue permits for impacts to isolated and other non-404 jurisdictional wetlands and waters. The agency also has regulatory authority over riparian buffer programs in two coastal watersheds – Neuse and Tar-Pamlico. The National Pollution Discharge Elimination System (NPDES) program, established under the Section 402 of the CWA of 1972 and succeeding federal and state rules and regulations, granted the regulatory authority to permit a discharge of wastewater or stormwater from a known point source to surface waters. The regulatory oversight under the NPDES program is shared between the DWR and the DEMLR. The DEMLR also has authority established under the Sedimentation Pollution Control Act (SPCA) of 1973, and other related laws, regulations, and amendments to regulate activities associated with erosion and sediment control, mining, dam safety activities, and stormwater management.

Currently, NC's programmatic approach to proposed development impacting jurisdictional wetlands, streams, and/or waters begins with the applicable permitting requirements of the USACE and/or the DCM. The USACE under authority of Section 404 of the CWA and Section 10 of RHA regulates the discharge of dredge and fill material into waters of the United States. The DCM regulates and issues permits for development in or affecting an Area of Environmental Concern (AEC) within NC's 20 coastal counties under the CAMA and State Dredge and Fill Law. Any permits issued by either the USACE, DCM, or other federal licensing and permitting agencies that propose impacts to jurisdictional wetlands, streams and/or waters will require a corresponding Section 401 of CWA Water Quality Certification (401-WQC) issued by DWR. This is to ensure the proposed activity does not violate wetland or water quality standards under authority of Section 401 of the CWA and other state regulations and laws.

Traditionally, DWR's staff reviews about 1,500 to 2,000 individual and nationwide permits per year via 404 and DCM permits, Section 10 permits and Federal Energy Regulatory Commission permits to ensure compliance with 401-WQC and other State regulations and laws (DEQ unpublished data). Over the period of 1999 to 2019, DWR issued 11,591 401-WQC within the seven coastal draining river basin that represents 8,125 acres of wetland and 1.3 million linear feet of stream of impacts.

The DEMLR stormwater post-construction program is responsible for providing oversight on existing stormwater permits, as well as reviewing and issuing permits for new stormwater permit applications. Since stormwater permits do not expire, the number of permits continues to grow over time. In 2020, there were over 15,000 permittees. The ten staff are responsible for 50-70 new permit applications per year in addition to assisting about 1,500 existing permittees per year, leaving little time for compliance.[23]

6.2.4 Compliance and Enforcement Programs

Different agencies have varying ways of achieving compliance within their established regulatory authorities. For the purpose of this report, compliance will be defined as an inspection of a site to determine if it conforms to either the conditions of a written approval (i.e., a permit or certification) or the relevant State regulations associated with a development activity resulting in a discharge or impacting wetlands, streams, waters or riparian buffer.[1] The State agencies with regulatory authority over these activities included the DCM, DEMLR, and DWR.

Typically, site inspections are the result of complaints or referrals received from the general public, an organization, or government agencies concerning activities that do not comply with the regulatory mandates of the respective agencies. Other inspections can be routine in nature such as a site inspection associated with application review or monitoring of a site for compliance with written approvals. Inspections may also result from self-reporting of a violation. The failure of authorized persons, parties, and/or entities to comply with written approval or relevant state rules may result in the issuance of notice of deficiency (NOD), notice of violation (NOV), after-the-fact written approval, cease and desist order (C&D), injunctive relief, enforcement action, and/or civil penalty. In extreme cases, even criminal charges with penalties may result from non-compliant inspection.

Reporting on the effectiveness of individual state's compliance and enforcement programs associated with wetlands, streams, and waters regulations are limited. Generally, only specifics on guidance associated with compliance and enforcement policies for individual states (Vermont and Southern Florida 2014) or federal jurisdiction (Sacramento District 2014) are available.[1] Variations in state laws that establish states authority to protect wetlands and waters and how each implements their authority compounds the task of comparing the individual states regulatory success. For example, in 2016, 23 states had a wetland permitting program that complemented their states' 401 certification program, but only six states had adopted some sort of water quality standards specific to wetlands, and ten were in the process of developing standards.[24] The specifics of those programs between states vary greatly. Other states rely solely on EPA and the USACE to perform compliance and enforcement on sites that are non-compliant with conditions of 401-WQC.

Published information regarding the historic effectiveness of compliance and enforcement programs associated with development activities that impact wetlands and waters across the State's regulatory agencies is lacking. General discussion regarding past work indicated that overall compliance was less than 50 percent for NC Sedimentation and Erosion Control Program during their study period.[1, 25] Due to concerns regarding the lack of adequate information pertaining to compliance and enforcement programs, DWR applied for and was awarded an EPA Wetland Development Grant CWA Section 104(b)(3) in 2005. Before the grant was awarded, DWR estimated that staff visited less than one percent of all permitted site per year, mainly based on complaints received by the Regional or Central Office.[1] The grant funded three full time inspection positions (one per regional office in Washington, Raleigh, and Mooresville) to conduct compliance and enforcement activities for written authorization and unauthorized activities associated with 401-WQC, riparian buffer, state stormwater, and water quality and wetland standards for a period of three years.

Over the period from 2007 to 2011 (2010 and 2011, grant was extended two years), compliance rates rose from 15 percent in 2007 to 82 percent in 2011 for permitted sites and 10 percent in 2007 to 69 percent in 2011 for unpermitted sites. In addition, the amount of civil penalty assessments dropped from $151,000 in 2007 to $41,579 in 2011.[1] The end goal of the grant was met by inspecting at least 15 percent of the sites authorized in the previous year and demonstrating the outcome of the addition of a limited number of compliance and enforcement staff on overall compliance. Unfortunately, at the conclusion of the grant, the three compliance positions were not funded by DWR.

From 2008 to 2018, 367 positions were eliminated within the Department of Environmental Quality and the budget decreased from $136 million in fiscal 2008 to $90 million in 2018 when adjusted for inflation.[26] The additional regulatory burden associated with the elimination of staff has led to a decrease in number of compliance inspection and an increase in the number of non-compliant sites. Inspection data were requested from the DWR, DCM, DEMLR and NC Department of Agriculture Forest Service (Forest Service) in order to understand any correlation between the staffing of individual agencies and its effects on regulatory compliance and enforcement program within the agency's respective authority. These divisions provided results of initial site inspections conducted within the four CHPP Regions over the period of January 1, 2014 through December 31, 2019 (reporting period) to gain an understanding of the rate of compliance for any subject written authorization or regulation prior to conducting a follow up compliance inspection.

The DWR staff conducted 3,517 initial site inspections within the four CHPP Regions for the reporting period for projects with written authorization for NC Department of Transportation (DOT) and non-DOT projects for 401-WQC and/or buffer authorization or in response to a complaint or referral of possible violations of wetlands or stream standards for water quality or riparian buffer regulations. Of the total reported initial inspections, 2,230 inspections were associated DOT projects. Compliance with the written authorizations and/or other regulations associated with DOT projects were reported at 88.7 percent with only three inspections in response to citizen complaints. DWR staff inspections of non-DOT projects encompassed the remaining 1,287 inspections. Of the total number of initial inspections, 493 inspections were in response to citizen complaints regarding possible unauthorized activities and 794 were considered routine inspections. Reported compliance for complaint inspections were 22.5 percent and the routine inspection were 68.2 percent. The total unauthorized impacts for the wetlands, streams, waters, and riparian buffer (if applicable) for the four CHPP Regions within the reporting period are summarized in Table 6.1.[27] Looking at the same time period, there were 1.54 acres of unpermitted wetland impacts for every one-acre of permitted wetland impacts, indicating that non-compliance is a significant issue.

Table 6.1. Summary of reported DOT and non-DOT unauthorized 401 wetlands and buffer resource impacts annually within the CHPP region.

Annual Unauthorized Resource Impacts	2014	2015	2016	2017	2018	2019
Wetlands (ac.)	1.91	37.16	15.62	41.7	2,028.47	7.06
Stream (ft.)	13,653	16,248	5,130	1,825	12,008	3,880
Waters (ac.)	0.07	0.10	0.00	1.00	0.56	0.00
Buffers (ac.)	1.09	2.07	10.29	2.53	2.49	4.06

Within the four CHPP Regions, DWR has seven regulatory staff (non-DOT projects) and four regulatory staff (DOT projects) in four regional offices that are responsible for review and processing of 401 and buffer authorization applications, review and providing comment for other regulatory agency permits for compliance with wetlands standards, water quality standards, riparian buffer rules, and conducting compliance and enforcement activities. The agency's central office in Raleigh has additional regulatory staff responsible for permit review for DOT and non-DOT projects for 401-WQC and buffer authorization and oversight of the State's compliance and enforcement programs for the Section 401, stream and wetland water quality standards, and riparian buffer programs.

The number of site inspections and percent compliance by agency from 2014 to 2019 is shown in Table 6.2. Division of Coastal Management staff conducted 4,688 initial site inspections associated with processing of general or CAMA major development permits, monitoring of site conditions, routine site inspections, or responding to complaints over the reporting period.[28] Only nine site inspections resulted in significant violations of CAMA regulations, and an unknown amount of minor violations were brought into compliance without formal action. The DCM has three district offices and the central office in Morehead City. The DCM regulatory staffing commonly consists of a district manager, three to four county field representatives (non-DOT projects), one representative (DOT-projects), and a district land use planner. The Morehead City office also oversees compliance and enforcement programs supervision, public policy, permitting, and are within the administration. Local Permitting Officers for townships or counties can issue minor CAMA development permits. Regulatory staff issue minor and general, process applications for review of major CAMA development permits and conduct compliance and enforcement activities under the authority of the CAMA and State Dredge and Fill Law.

Table 6.2. Compliance inspections and percent compliance by agency, 2014-2019.

Agency	Program Type	Initial Site Inspections (#)	Compliance (%)
Division of Water Resources (DWR)	401 WQC, buffers, wetland and stream standards - DOT	2,230	88.7
	401 WQC, buffers, wetland and stream standards - non-DOT; routine inspection	794	68.2
	401 WQC, buffers, wetland and stream standards - non-DOT; complaint	493	22.5
Division of Coastal Management (DCM)*	GP and Major permits	4,688	99.8
Division of Energy, Minerals, and Land Resources (DEMLR)	NPDES State and Phase 2 Stormwater	4,910	72
	Erosion and Sedimentation Control	8,188	38
Department of Agriculture - Forest Service (Forest Service)	Forest Practice Guidelines Related to Water Quality	11,545	98.5

*One year of data within this time period was not available for DCM.

The DEMLR staff conducted 4,910 initial compliance inspections under the NPDES programs for state stormwater and stormwater Phase II Rule (Phase II) associated with development within the four CHPP Regions over the reporting period. Of the reported initial inspection, 1,401 sites were reported to be non-compliant with the associated written authorization or stormwater regulations. Compliance rates for initial inspection for NPDES state and Phase II over the reporting period was 72 percent. In addition, DEMLR staff also conducted 8,188 initial site inspections for compliance with approved Erosion and Sediment Control Plan (ESCP), NPDES General Permit No. NCG100000 (Construction stormwater permit), and other related regulations. Of the reported initial inspection, 5,075 sites were reported to be non-compliant with their associated written authorization or construction stormwater regulations. Compliance rates for initial inspection for ESCP, Construction stormwater permit (NCG01) and associated regulations over the reporting period was 38 percent.

The DEMLR regulatory staff within the four CHPP Regions for ESCP and NPDES programs are composed of 37 regulatory staff within the four regional office and 12 regulatory staff within the Central Office in Raleigh. The regulatory staff are responsible for processing ESCP, state stormwater, and Phase II applications, and enforcement and compliance activities under the authority of the SPCA and NPDES rules and regulations. Please note, that sites that were reported as non-compliant may not have required the issuance of an NOD or NOV.

Stormwater permit compliance has been a concern of agencies, the General Assembly, and others. In 2005, a study conducted in five counties within the WIRO district found compliance rates for permitted projects at high-density and low-density sites were 26.9 and 34.9 percent, respectively. Non-compliance was primarily due to improper maintenance for engineered ponds, and improper installation of stormwater control measures for low-density sites. Follow-up inspections in the same counties two years later found 91 percent non-compliance, primarily due to poor or no maintenance.[29] Permit education is one of the primary reasons for low compliance since permits are transferred in new developments from the developer to homeowner associations and from owner to owner on individual property. In 2019, the General Assembly raised concerns about stormwater permit transfer and compliance, and subsequently DEMLR conducted a program review.

The Forest Service is responsible for inspecting forestry-related land-disturbing activities to determine compliance with the standards required by the state's Forest Practices Guidelines Related to Water Quality, (02 NCAC 60C) as part of the Sedimentation Pollution Control Act. Forest Service staff conducted 11,545 initial site inspections within the reporting period with a compliance rate of 98.3 percent.[30] The Forest Service is composed of eight district offices within the four CHPP Regions with technical assistance staff in each district generally composed of a district forester, assistant district forester, one to two district rangers, and one to two service foresters. Water quality inspections are often carried out by county rangers and assistant county rangers, after they have completed training specific to water quality. Each county generally has one county ranger, with one to three assistant county rangers. Regionally, Water Quality Foresters cover two to three districts, and deal specifically with BMP and water quality technical assistance, answering compliance questions, communicating with loggers and landowners, and handling violations. The CHPP Regions are covered by four separate Water Quality Foresters.

6.3 Discussion

The effectiveness of a successful compliance and enforcement program has been documented.[1] As previously discussed, an EPA Program development grant provided funding for three full time position (one position per regional office) compliance positions (one position per regional office) over the period of 2007 to 2011. Over the grant period the reported number of annual site inspections associated with written approvals rose along with the rate of compliance. In addition, the amount of civil penalties assessed dropped over the reporting period. When comparing the reported results of the DWR grant with the current inspection data over the past five fiscal years, routine inspection compliance rates for non-DOT projects have dropped from 82 percent in 2011 to 69 percent in 2019. In addition, the rate of compliance for non-DOT project complaint inspections has fallen from 68.2 percent in 2011 to 22.5 percent to 2019. Subsequent to the completion of the grant, legislative budget cuts resulted in the compliance positions not being funded by the DWR.

Additional staff could help conduct stormwater and sedimentation compliance inspections with written authorizations associated with 401-WQC, riparian buffer authorization, water quality standards for stream and wetland, and riparian buffer rules. Staff could also be responsible for the issuance of any NODs, NOVs, review of response letters and associated site restoration plans, review of applications for after-the-fact written authorizations, oversight of site restoration activities, and pursuing any enforcement action needed to bring the site back into regulatory compliance.

The DCM and Forest Service, with a greater staff to need inspection ratio, have reported higher compliance rates associated with initial inspections over the reporting period of 2014-2019. Conversely, DEMLR reported a higher rate of compliance (72 percent) with regards to inspections of the NPDES program permits under state stormwater and Phase II, but reported lower compliance rates (38 percent) associated with inspections of ESCP and NCG01 permitted sites. There is further evidence that increased site inspections improve regulatory compliance.[31] When the CWA permit inspections declined between 2015 and 2018, there was a 10 percent increase in serious water pollution incidents. Similarly, with Clean Air Act (CAA) inspections, there was a 28 percent increase in permit violations. In a 2005 study, 63 percent of the companies examined took additional compliance related actions after learning that other companies had received penalties for environmental law violations.[32] This is attributed to the "deterrence model". Applicants are deterred from violating environmental regulations if the risk of penalties is real, compliance is cheaper than the expected penalties, as well as concern over reputation.[31, 33]

Although there is some overlap in regulatory jurisdiction among DWR, USACE, and DCM, there are differences in permitting and enforcement authority. Due to these differences, as well as limited staffing resources, implementation of any effective compliance and enforcement program is difficult and complex. Additionally, exemptions exist from both State and federal permitting and regulatory requirements resulting in impacts to wetlands and waters for certain silvicultural, farming and ranching practices, dam maintenance, maintenance of drainage ditches, construction of temporary sediment and erosion or best management practices (BMPs) required by NC ESCP, and construction of farm roads, forest roads, and temporary roads for moving mining equipment. With DWR's regulatory authority differing in scope from DCM and USACE, as well as limited staffing resources, implementation of any effective compliance and enforcement program has become more problematic.

A possible solution to address the lack of an effective compliance and enforcement program within the DWR 401 and buffer section could be the hiring of additional staff for the regional offices within the four CHPP Regions whose sole responsibility is to conduct inspections and implement any needed enforcement actions. Although these positions would be non-revenue generating, and therefore more likely subject to budgetary cuts, the historic data indicates the existence of a more consistent compliance and enforcement program reduces the number of and rate of non-compliance and overall enforcement costs. Over the period of 2014 to 2019, DWR reported wetlands impacts authorized under 401-WQCs of approximately 1,499 acres within the seven coastal draining river basins. Conversely, DWR's reported unauthorized impacts to jurisdictional wetlands within the same period totaled approximately 2,312 acres within the seven coastal draining river basins.

Chapter 6. Environmental Rule Compliance and Enforcement to Protect Coastal Habitats

To address compliance and other concerns with DEMLR's stormwater program, a stakeholder group met and developed a 2020-2022 action plan (DEMLR 2020). In addition to securing additional staff, key recommendations to improve compliance included conducting permittee training and outreach, requiring an annual electronic certification on new, transferred, and renewed permits, adding a chapter in the Stormwater Design Manual on permit renewal and transfer to provide guidance on how to comply, launch an electronic permitting system, and modify stormwater control measures where possible that encourage disconnecting impervious surfaces and utilizing onsite infiltration (nature-based solutions, LID). These techniques are cost-effective and technically sound.

Other strategies to address environmental compliance when staff limitations continue include improving detection of non-compliance through technology, lowering compliance costs through focused inspections, and increasing public disclosure. It has been suggested that remote sensing and machine learning can be used to focus compliance inspections on companies predicted to have the highest risk of non-compliance and focus on areas of the greatest environmental risk.[33] Requiring self-inspection assessments has been shown to result in improved compliance rates where agency inspections cannot get to at least 12 percent of the permitted sites. Making the public aware of violators (naming and shaming) can damage reputations and trigger public scrutiny, and consequently serve as an incentive to comply. For example, when EPA's Clean Air Act began publicizing a facility "watch list", violations decreased 10 to 23 percent.

Currently, NC Division of Environmental Assistance and Customer Service (DEACS) assists in the routing of complaints to the applicable agencies through the DEACs public portal and telephone inquiries received by DEACS staff. Both, DWR and DEMLR have maintained a list of recent civil assessments on a period basis. However, no active or long-term lists of assessments or repeat violators exist and the formulating of such lists should be vetted through upper management of the Divisions and legal staff prior to the implementation. Utilizing citizen science and public reporting portals has been utilized to supplement site inspections and increase public awareness.[33]

The historical losses of wetland and water resources from unauthorized development have not been well documented. Lack of regulatory staffing have resulted in a larger number of sites that do not comply with regulations related to water quality. Over the last five fiscal years, the DWR reported unauthorized jurisdictional wetland impacts exceeded authorized impacts by a margin of 1.54:1. Given this relatively high proportion of wetland impacts due to non-compliance, actions are needed to address it.

6.4 Recommended Actions

6.4.1 Funding

6.1 By 2023, through legislative appropriations or budget reallocations, DEQ will increase staffing in DWR and DEMLR by a minimum of two staff (one per office, per agency) in the Washington and Wilmington regional offices.

6.2 By 2023, DEQ will seek funding through grants or other sources to supplement state-appropriated compliance efforts.

6.4.2 Outreach

6.3 By 2022, DWR and DEMLR should work with the DEACS to establish a public portal on DEQ's website that provides information on compliance issues, allows the public to submit complaints, and potentially highlights a list of repeat violators.

6.4 By 2023, DWR, DEMLR, and DCM should develop and hold outreach workshops for NGOs, HOAs, and other interested public, on rules related to land disturbing activities that affect wetlands and water quality, and how to identify violations to improve the effectiveness of public complaints.

6.5 By 2022, DEMLR will initiate and continue outreach to stormwater permit holders on rules and required maintenance of stormwater control measures and structures.

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Photo Credit: Nolen Vinay

7. WASTEWATER INFRASTRUCTURE SOLUTIONS FOR WATER QUALITY IMPROVEMENT

7.1 Issue

The water column provides essential conditions for fish survival and healthy habitats, and therefore good water quality is key to a healthy coastal ecosystem. There are many contributing sources of water quality degradation.[1] Sanitary sewer overflows (SSOs) from wastewater collection systems are one pollutant sources that contribute to water quality degradation and impact coastal habitats. Failing and deteriorating wastewater infrastructure, often referred to as inflow and infiltration (I & I), is often the underlying cause of SSOs. Untreated or incompletely treated sewage entering estuaries after a SSO can increase bacteria, nutrient, and toxin levels, potentially resulting in shellfish closures, algal blooms, fish kills, and contaminated water and sediment that can impair aquatic life.

7.2 Background

Effective management of wastewater is critical to protection of surface waters, fish habitat, public health, and the economy. Pollutants entering estuaries degrade water quality, impairing its ability to support healthy fish habitat, fish populations, and fisheries. Untreated wastewater can enter surface waters when SSOs occur due to failures associated with collection infrastructure, lift stations, or wastewater treatment plants. Inflow and infiltration is a significant problem in coastal NC that results in raw wastewater entering estuarine waters.

A sanitary sewer or collection system is an underground pipe system used to convey wastewater to a treatment facility and is comprised of conventional gravity lines, pump stations, and force mains. Inflow and infiltration (I & I) is the term for groundwater and stormwater entering a sewer system. Inflow refers to the entry of stormwater into the sewage collection system during storm events, whereas infiltration refers to the movement of groundwater into the sewer pipe system. There are multiple mechanisms contributing to I & I (Figure 7.1). Gutters connecting to lateral pipes (the pipe from an individual building to the roadside main line), uncapped sewer line cleanouts, faulty sewer manhole covers, and improper cross connections of stormwater lines with sewer lines are all possible ways stormwater can enter sewer lines. Groundwater can enter the sewer pipes through cracks, leaky pipe joints, deteriorated manholes, and broken lateral pipes.

Photo Credit: CFPUA

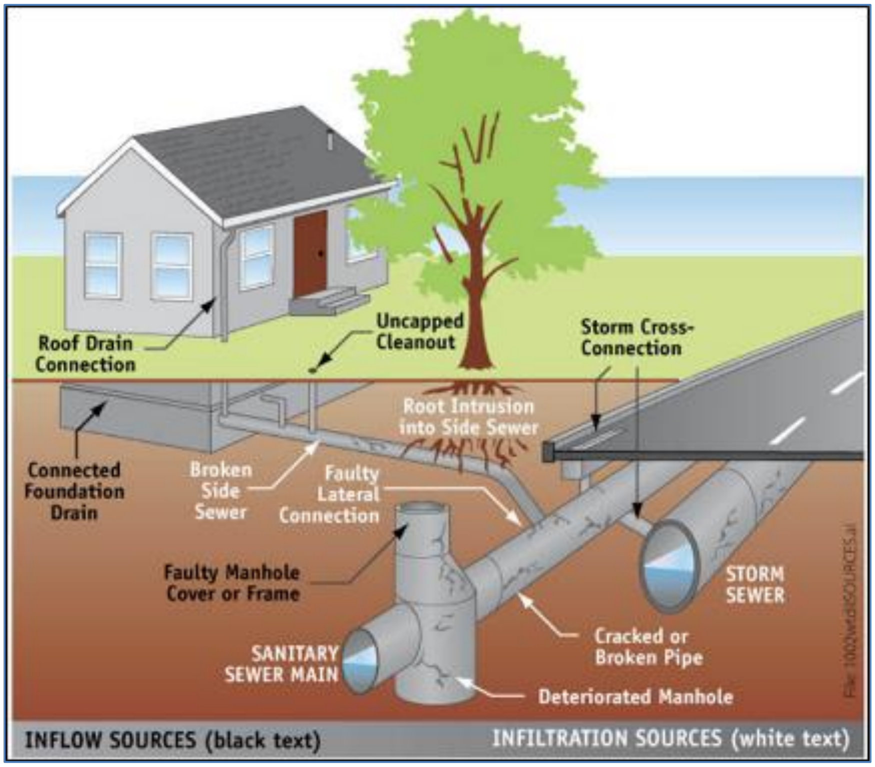

Figure 7.1. Example of inflow and infiltration (I & I) pathways.[2]

Together, these two processes increase the volume and overload the sewage collection system, particularly during wet weather, which in turn can cause SSOs to occur.[3] Climate change may further exacerbate the problems with increased rainfall and higher groundwater levels. Nearly all sanitary sewer systems and receiving wastewater facilities in coastal NC are subject to issues and complications resulting from I & I due to aging infrastructure, proximity to waterways, severe storms, and high ground water levels.

Sewer collection systems vary in age and construction materials. Older pipes and certain construction materials, such as metal and masonry, are more susceptible to deterioration. The degree and magnitude of I & I within a sewer collection system can be based on several factors. Along with system age, sewer line construction material, and poor construction methods, the following operational challenges can also contribute to I & I problems:[4]

- Insufficient maintenance of lateral pipes connecting to sewer lines (responsibility typically lies with property owner)
- Insufficient maintenance and clean out of main sewer lines (responsibility of facility owner, such as a municipality)
- Removal of clean-out caps by property owners
- Damage from road work (can result in increased flows)
- Disposal of fats, oils, and greases down the drain, causing pipe blockages and subsequent overflows
- Illicit connection of stormwater from roof drains, parking lots, etc., into the collection system

The severity of I & I is often a factor of groundwater table and weather conditions. Inflow often peaks during heavy or prolonged rainfall events. Chronic rainfall may result in an elevated groundwater table intersecting sewer pipes, resulting in higher infiltration rates.

Sewer lines, pump stations, and wastewater treatment plants (WWTPs) are designed for specific flows and peak flow volumes and rates. Contribution of flow from I & I is not a standard design component for most sewer systems and receiving wastewater systems. Consequently, flows in excess of the sewer system capacity may result in SSOs, which is a release of untreated or partially treated sewage from a sanitary sewer at unpermitted locations. These sewage spills often occur at manholes and pump stations when pumps cannot keep up with incoming flows. Excessive I & I can also result in reduced level of treatment at the receiving WWTP, discharge of insufficiently treated effluent to surface waters or land-application fields, overflows at WWTPs of untreated or insufficiently treated wastewater, and discharge of residual solids from WWTPs.[4]

The SSO spill volumes may range from hundreds to millions of gallons. Excessive flows at WWTPs may result in potential of discharge of residual solids depending on actions taken by facility operators. Discharge of residual solids creates a potential for solids to settle on surface water sediments, with multiple water quality implications.

The location of discharging and non-discharging wastewater treatment facilities along coastal NC is widespread and consequently, so is the extensive network of collection lines carrying raw wastewater to those facilities (Figures 7.2 and 7.3). In 2020, there were 282 discharge wastewater treatment facilities and 295 non-discharge facilities permitted within the CHPP region and managed by the DWR (Table 7.1 and 7.2).[5] Facilities with wastewater discharge permits release treated effluent directly from a pipe into surface waters. Facilities with non-charge permits apply treated effluent on land, retention ponds, or reuse it for other purposes such as irrigation.

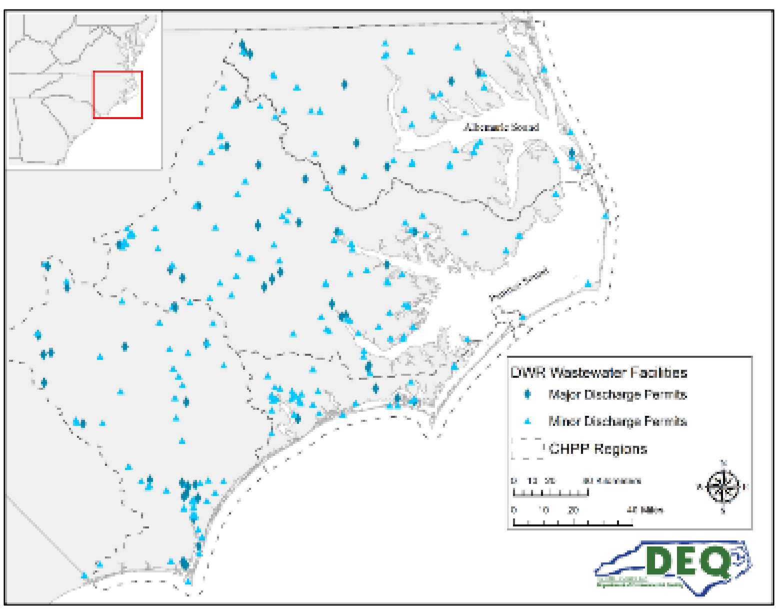

Figure 7.2. Wastewater Discharge Facilities Located Across Coastal NC.[6]

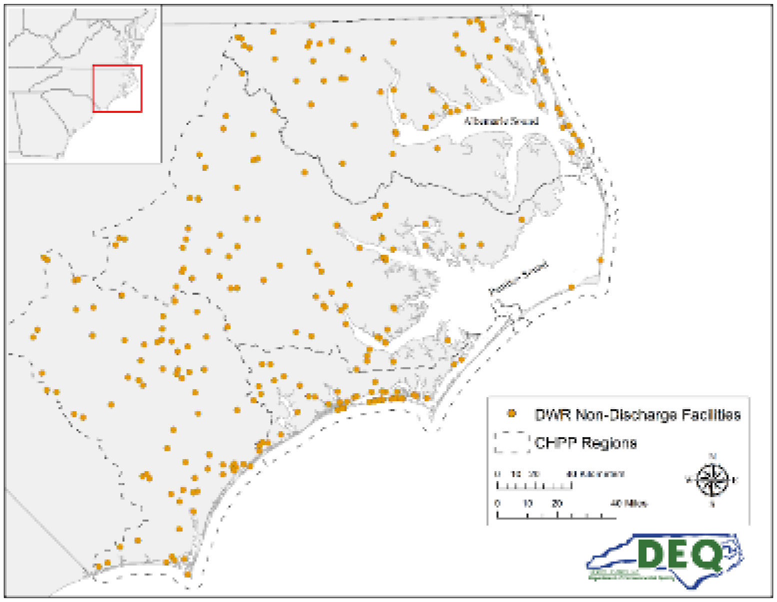

Figure 7.3. Wastewater facilities with non-discharge permits located across coastal NC. Note: Identified facilities also include residual land application facilities and "other" types of non-discharge systems.[6]

Discharge facilities are categorized as industrial/commercial, municipal, domestic only, drinking water plants, water conditioning, and groundwater remediation. Municipal and domestic wastewater facilities (combined) are the most common type of facility. There are several categories of non-discharge wastewater facilities. The most common is wastewater irrigation, where treated wastewater is applied to land via spray irrigation, drip irrigation or other technology. High-rate infiltration is increasingly permitted in coastal areas where the water table is high. With this method, groundwater is often lowered around a disposal area to increase the depth of "dry" soil under a retention area by installing perimeter sub-surface drainage pipes, wells, or ditching around the perimeter and discharging the clean groundwater to nearby surface waters. Treated wastewater is then discharged to a retention area with permeable soils and allowed to seep into the ground. For each of these systems, particularly municipal systems, there are many miles of sewer lines beneath the ground transporting wastewater to a treatment plant.

Table 7.1. Numbers of NPDES discharge facilities by type within the four CHPP regions.[6]

Number of Facilities				Permit Type					
CHPP Region	Minor	Major	Total	Discharging 100% Domestic < 1MGD	Industrial Process & Commercial Wastewater Discharge	Municipal Wastewater Discharge, < 1MGD	Municipal Wastewater Discharge, Large	Water Plants and Water Conditioning Discharge	Ground water Remed. Discharge
1	40	11	51	5	10	9	8	19	0
2	89	23	112	7	37	17	16	33	2
3	33	4	37	16	3	3	2	12	1
4	53	29	82	9	30	14	14	12	3
Total	215	67	282	37	80	43	40	76	6

Table 7.2. Numbers of non-discharge permits by type within the four CHPP regions. Note: closed-loop recycle system, distribution of residual solids systems, and land application of residual solids systems pose potential for impacts to surface waters. Although such systems do not convey wastewater, they often address nutrient management needs and are referenced in the following table.[6]

Number of Facilities				Permit Type						
CHPP Region	Minor	Major	Total	Waste-water Irrigation*	High-Rate Infiltration	Reclaimed Water and Distribution**	Land Application Residual Solids	Closed Loop Recycle	Distribution of Residual Solids	Other
1	15	52	67	25	18	6	11	2	2	3
2	44	46	90	41	4	16	18	3	7	1
3	13	41	54	11	30	5	5	1	2	0
4	31	53	84	32	9	11	17	7	7	1
Total	103	192	295	109	61	38	51	13	18	5

*Combined single family and other wastewater irrigation

**Combined reclaimed water and distribution

†Combined exempt and non-exempt from EPA 503 regulations for land application and disposal of residual solids

7.2.1 Effect on Water Quality

A major concern with SSOs that enter oceans, bays, estuaries, rivers, lakes, streams, or brackish waters is their direct impacts on water quality. Wastewater treatment plants and infrastructure are often sited in low-lying areas along the coast, since sewers are typically gravity-fed. Consequently, spills resulting from SSOs and WWTP operational complications often discharge to nearby surface waters.

Spills of untreated or partially treated sewage may convey or result in high bacteria levels to surface waters, elevated nutrient levels and loadings to surface water systems, depressed dissolved oxygen (DO) levels in surface waters, increased potential for algal blooms due to nutrient loading at chronic SSO locations, and stress or mortality of fish and other aquatic organisms. The unpredictable and random nature of SSOs makes them very difficult to monitor and study.[7] Prior investigations and case studies have helped characterize and quantify impacts to surface waters resulting from wastewater spills.

A study in Wilmington, NC monitored water and sediment quality following a sewer main break that discharged approximately three million gallons of raw sewage into the upper portion of Hewlett Creek[8], which dispersed throughout the creek and into the Intracoastal Waterway (IWW). Sampling found very high levels of fecal coliform bacteria (270,000 Colony Forming Units (CFU)/)/100 ml) in the creek initially. After three days, levels dropped below 100 CFU/100 ml in the channel and lower portion of the creek. However, in two tributaries, maximum counts remained high for five days, dropped slightly, then increased one week later after a rainfall. The increase after rain was attributed to runoff carrying residual sewage and resuspension from bottom sediment. Bacteria levels slowly decreased to normal levels over several more weeks. Fecal coliform bacteria in the sediment was also highly elevated and remained elevated for over a month, longer than the water column. The study found that the sediment served as a reservoir for fecal bacteria. Rainfall and experimental prop washing verified that bottom disturbance caused resuspension and fecal coliform to increase in the water column.

The biochemical oxygen demand (BOD) of the nutrient rich sewage caused severe hypoxia and several large fish kills two to three days after the spill. Dead organisms included American eels, flounder, mullet, bait fish, and birds. Nutrient concentrations in these sewage pipes are normally very high, approximately

40.2 mg/l total Kjeldahn nitrogen (TKN), 23.3 mg/l ammonium (NH_4), and 5.3 mg/l total phosphorus (TP). Once in the creek, nutrient levels declined rapidly (1-1.5 days), being taken up by phytoplankton, resulting in several algal blooms. The decline in nutrients was also attributed to absorption by marsh plants, sediment and the sediment microbial community, benthic microalgae, macroalgae, and tidal flushing. The authors noted that the marsh community's ability to remove and cycle nutrients demonstrated the high value of conserving wetlands to improve water quality.[8] In addition to nutrients and bacteria, raw sewage can contain other materials hazardous to aquatic life, such as toxic chemicals, heavy metals, and endocrine disrupting chemicals. There is growing evidence that sewage discharges contribute to increasing harmful algal blooms (HABs) and changes in biodiversity and ecosystem health. Additionally, there are many pathogens present in sewage that can impact human health, and consequently shellfish harvest and recreational swimming activities.[7]

Sewage spills can cause significant localized acute impacts within the affected waterbody; however, their overall contribution to water quality in NC is less certain. To assess the prevalence and magnitude of I & I in coastal NC residential wastewater treatment systems, a study analyzed flows under different rainfall and temperature conditions using 2010-2011 data.[9] Of the 93 WWTPs analyzed, 92 percent exhibited a statistically significant flow response to rainfall, with increased flows averaging 12 percent more than rainless flows, with a maximum of 35 percent. Most of the flow increase was attributed to infiltration rather than inflow.

The location of the systems with significant I & I occurred in both small and large municipalities throughout the coast, from Elizabeth City in the north, to Southport in the south. Central sewage treatment systems are often utilized in areas of high population density, such as cities and towns, as well as in areas where the groundwater table is too high for septic systems to function properly. Consequently, many of the wastewater collection pipes are sitting below ground, surrounded by groundwater. As pipes age and deteriorate, cracks in the pipes or joints allow groundwater to enter. Where the pipes are sitting in the groundwater, infiltration rates will be greater, particularly during wet periods. During dry periods, those same cracks can let wastewater leak out into the groundwater. Modelling predicted infiltration rates at over 40 percent where a two-inch rain event occurred after two weeks of dry weather. Modelling for a two-inch rain event occurring once a week for three weeks estimated average infiltration rates at 66 percent. Cumulative rain and lower temperatures drove significantly higher flows in the collection system suggesting that heavy rains in the cooler winter months are more likely to cause I & I problems.[10]

Deteriorating wastewater infrastructure plays a role in bacterial pollution, although stormwater runoff is considered the primary cause of water quality degradation.[1] Both SSOs and stormwater runoff occur with rainfall, complicating the ability to determine the contributing sources of fecal coliform concentrations. Similarly, where the groundwater table is low, wastewater can exfiltrate or leak out of sewer lines, and contaminate groundwater, which moves laterally to surface waters during rain events.[9] In urban settings, stormwater conveyances act as a conduit for sewage originating from leaking wastewater collection pipes.[11, 12] Studies in coastal NC comparing bacteria concentrations in septic and sewered watersheds showed both watershed types had increased bacteria counts in streams during rain events. The sewered watersheds had high increases due to leaky infrastructure or greater impervious surfaces.[13, 14] For a resilient system, managers must address multiple sources of pollution.

The coastal plain is more at risk to I & I than other regions of NC due to its low-lying geography and expansive hydrology. High groundwater levels, whether from rain or sea level rise (SLR), make wastewater infrastructure in coastal areas more at risk to infiltration, potentially resulting in more SSOs and improper treatment at the WWTPs.[15] The coastal plain is subject to higher average annual rainfall than other regions of NC and more extreme rainfall events, often associated with tropical storms. Climate change will exacerbate these conditions, and coastal wastewater collection systems may be increasingly vulnerable to effects of I & I and sewer spills. For additional information, see **Chapter 3. Climate Change and Resiliency**.

Over the years, many incidents have occurred across coastal NC counties where elevated sewer system flows or other causes resulted in unpermitted discharges of wastewater or discharges of poorly treated wastewater to coastal waters and habitat.[4] Most of these SSOs can be traced back to the aging and failing water and sewer systems in the inner coastal region. A majority of NC's water systems are 40 years old or older, with many of them 60 to 70 years old. Some sewer lines in the towns of Columbia and Bellhaven are 90 and 100 years old, respectively. The average age of wastewater treatment plants in the state is approximately 40 years old, though many of them have undergone renovations to comply with current state and federal regulations. The NC section of the American Society of Civil Engineers gave NC a statewide grade of "C" due to its extensive wastewater infrastructure problems.[16]

The DWR requires that SSOs to be reported to DWR by the permittee (15A NCAC 02B .0506 - Reporting Requirements). Specifically, the permittee shall verbally report by phone to a DWR staff member at the appropriate Regional Office, as soon as possible, but in no case more than 24 hours following first knowledge of the occurrence of either 1) any SSO and/or spill over 1,000 gallons to the ground, or 2) any SSO and/or spill, regardless of volume, that reaches surface water. These SSO incidents are tracked using an internal DWR database. The permittee is required to follow up with DWR by providing a written report within five days. It should be noted that the spill volumes in the database are estimated by the reporting party, can be difficult to estimate visually, and may vary in accuracy. From 2015 through 2019, there were 501 SSO incidents reported in the twenty coastal counties (Table 7.3). The average sewer spill volume was estimated to be 50,170 gallons, median spill volume was 1,500 gallons, and maximum spill volume was 4 million gallons. In addition to estimating the volume of the spill, an estimated volume reaching surface waters is also provided. The total volume of wastewater reaching surface water was estimated to be more than 24 million gallons for this five-year period for NC's 20 twenty coastal counties. The data indicate that most of the spills reported are relatively small. The largest of the spill volumes, those that exceed approximately 33,000 gallons, represent 10 percent of the reported overflows for the five-year period. Brunswick, New Hanover, and Craven counties had the highest number of incidents during that time period (Figure 7.4). In contrast, Onslow County had the highest total volume of sewage spilled to surface waters, followed by New Hanover and Chowan counties (Figure 7.5).

Table 7.3. Sanitary sewer overflows (SSO) incident data from North Carolina's 20 coastal counties, 2015-2019. A dash is reflective of no information being available for the data type and may be a condition of potential reporting deficiencies in some cases.

Coastal County	No. of Reported Incidents (2015-2019)	Total Gallons of Wastewater Spilled to Surface Waters	No. of Incident Related to Storm Events	Total Gallons of Wastewater Spilled to Surface Waters Related to Storm Events
Beaufort	9	1,008,995	1	1,000,000
Bertie	22	1,549,600	2	1,000,000
Brunswick	101	883,072	4	20,650
Camden	0	0	-	0
Carteret	20	1,347,558	1	210,000
Chowan	19	2,748,141	-	0
Craven	81	791,147	4	87,300
Currituck	4	600	-	0
Dare	11	40,389	-	0
Gates	0	0	-	0
Hertford	15	109,062	4	81,122
Hyde	2	850	-	0
New Hanover	100	2,762,765	14	11,300
Onslow	47	10,299,536	-	0
Pamlico	18	130,949	3	40,149
Pasquotank	24	1,221,700	3	1,200,000
Pender	8	3,200	-	0
Perquimans	14	576,450	1	1,000,000
Tyrrell	0	0	-	0
Washington	6	11,275	1	10,000
TOTAL	501	23,485,289	38	4,660,521

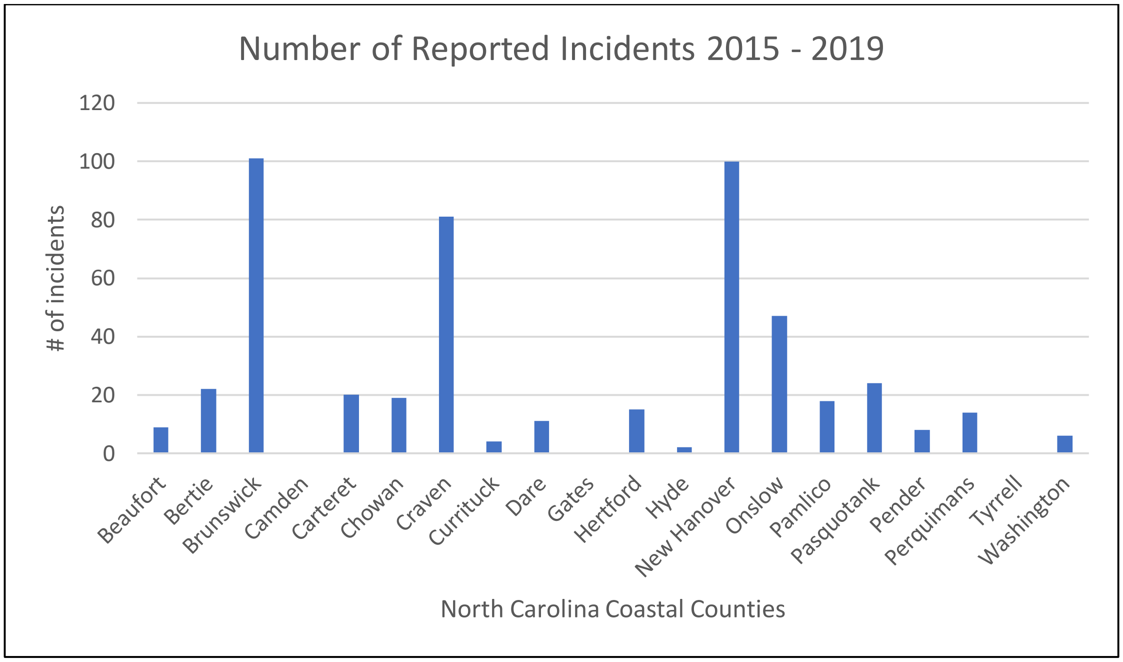

Figure 7.4. Number of reported sanitary sewer overflow (SSO) incidents by North Carolina's 20 coastal county, 2015-2019.

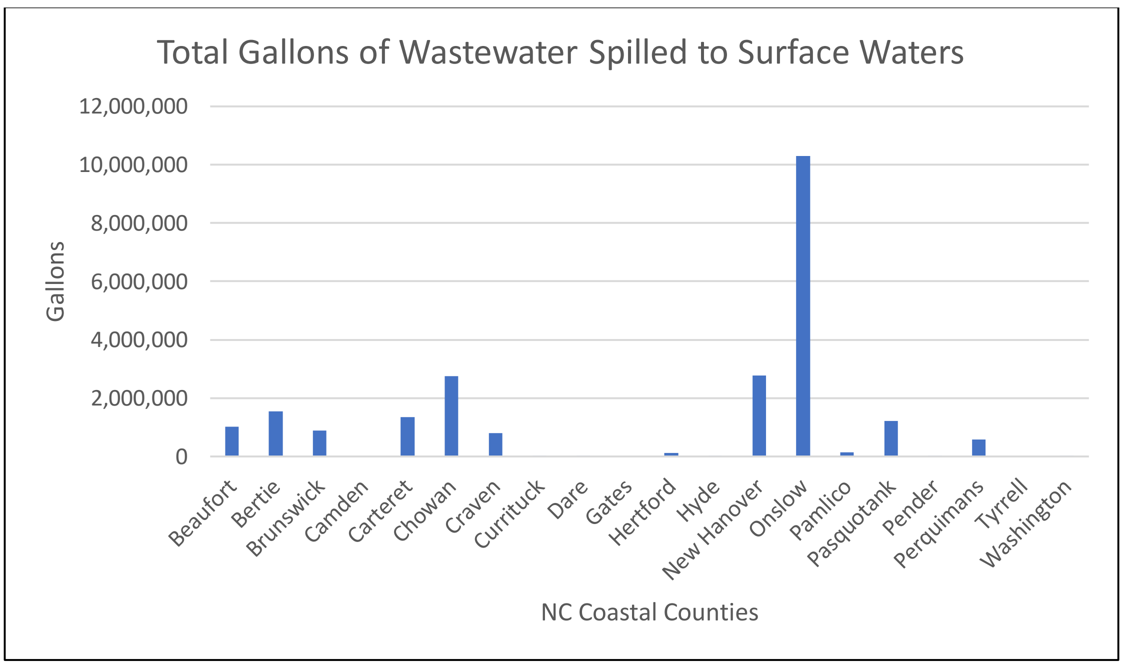

Figure 7.5. Estimated wastewater volume in gallons spilled to surface waters for North Carolina coastal counties, 2015-2019.

Data revealed that several coastal counties had no reports of SSOs over the five-year timeframe while other counties had what appear to be much higher instances of an SSO. Experience of DWR staff indicates that it is unlikely that no SSOs occurred in those counties reporting zero SSOs.[4]

There can be many reasons a SSO is not reported or is failed to be identified; some examples include:

- Smaller collection systems may experience hydraulic loading for shorter duration and the operator is simply unaware of the occurrence.
- Problematic collection system segments can be in landscape positions where visual operations or reports from the public are infrequent due to lack of access.
- Some collection system operators actively seek out and target the identification of SSOs during severe precipitation events, other systems owners may have staffing issues that limit such proactive efforts.
- Operators and/or permittees of select systems may be unaware of the reporting requirements.

It is also the experience of DWR staff that counties with a higher population density and larger, more widely distributed collection systems tend to result in a higher likelihood of SSO incidents being reported. Both DWR and the permittee often receive notification of SSOs or a pump station alarm from adjacent homeowners and business. In addition, foot traffic along greenways having collection lines above ground results in routine and fast notification of infrastructure failures (SSOs). The identification and tracking of these events help target line cleaning and maintenance needs; Fat, Oil and Grease program implementation; and other I & I priorities.

Additional outreach, technical assistance, more intensive compliance oversight, and increased inspection frequency may result in a reduction in the number of SSO's and more accurate/robust reporting. The data provided are intended to help demonstrate the need to properly maintain, operate, and in some cases upgrade wastewater collection and treatment systems. Such action may result in fewer sewer spills to surface waters, resulting in less impact to receiving waters and coastal habitats.

Replacing leaky pipes is an expensive and disruptive process. There are several alternative methods to control leaks in collection systems. These include chemical grouting, Cured-In-Place-Pipe (CIPP) lining, fold-and-form-liner, and slip lining.[17] While these have the advantage of not requiring excavation, they have disadvantages, particularly they may not stop I & I, and are also relatively expensive.

Not all SSOs result in wastewater reaching surface waters. However, due to the vast hydrology of the NC coastal plain with numerous small creeks and ditches, it is likely that the sewage reaches surface waters directly or indirectly through runoff.[18] On a national scale, 10 percent of U.S. beach/swimming closures and advisories in 2012 were attributed to sewage spills and overflows.[19] This category includes combined sewer overflows, SSOs, breaks or blockages in sewer lines, and faulty septic systems. Combined sewer systems, where stormwater and wastewater are transported together in the same collection lines, do not occur in NC. Stormwater runoff, including agricultural sources, was the largest known source contributing to closures and advisories. Despite not being the major contributor, the Natural Resource Defense Council (NRDC) report notes that wastewater spills are an increasing concern due to climate change and includes several strategies to improve the resiliency of wastewater infrastructure.

From 2005 to 2019, data from Division of Marine Fisheries (DMF) Shellfish Sanitation Section indicates that there were 19 recreational advisories reported due to SSOs (Table 7.4).[20] This number only includes spills that resulted in a temporary shellfish closure or swimming advisory. These numbers are likely an underestimate of total sewage spills that reach coastal waters because those that occur in waters already closed or where the entire spill is within a safety buffer zone already established around permitted WWTP discharges are not included.[21]

Since 2011, only one recreational advisory has occurred. Closures have declined in part due to a concerted effort to improve wastewater infrastructure in counties or municipalities that had repeated problems in the early 2000s, such as New Hanover, Carteret, and Onslow counties. While sewer spills result in localized water quality issues, they account for less than 1 percent of shellfish closures and swimming advisories.[21]

Table 7.4. Sewage spill recreational advisories, 2005-2019.[20]

County	Number	Waterbodies Affected
Beaufort	1	Pamlico River near downtown Washington
Carteret	3	Town and Taylor creeks in Beaufort; Atlantic Ocean at Atlantic Beach
Craven	1	Neuse River between Wilkinson Pt and Pierson Pt, including Gatlin Creek and other creeks near New Bern
Hyde	1	Swanquarter Bay near Swanquarter
New Hanover	6	Hewlett, Bradley, and Futch creeks, ICW, Cape Fear River in Wilmington; Carolina Beach Yacht Basin
Onslow	3	Ward Creek, Swansboro; New River, Mill and Chaney creeks in Jacksonville
Pamlico	1	Neuse River between Wilkinson Pt and Pierson Pt, including Gatlin and other creeks near ???
Pasquotank/ Camden	3	Pasquotank River near Elizabeth City

7.2.2 Economic Challenge

Problems with wastewater infrastructure contribute to a financial burden incurred by the sewer and wastewater system owner and economic impacts to the surrounding communities. Consequently, adequate funding and planning for proper maintenance and operation of wastewater infrastructure is sometimes not adequately provided. Increased flows associated with I & I result in increased volumes of wastewater to be managed and treated, translating into increased operational and system upkeep costs. In most cases, customers pay sewer fees based on the amount of water used over a time period or an established sewerage flat fee. Wastewater system owners may often be covering the added expense of managing, treating, and disposing of the additional volume of wastewater attributed to I & I while customers face increased rates. Because SSOs are not permitted, they are illegal and can result in regulatory agencies taking enforcement actions, which may include expensive fines when bodies of water cannot be used for drinking water, shellfish harvesting, fishing, or recreation, communities experience an economic loss. Remedial action may also be needed by owners in response to spills to minimize potential environmental impacts. The level of cost for such remedial response varies based on the characteristics of a spill. SSOs also impact local economies when they result in closure of beaches, impacting tourism and waterfront home values. Fishing and shellfish harvesting may be restricted or halted, in turn impacting production, supply, and distribution.

Aging infrastructure, particularly in low income areas, reduced available federal funding, high cost of infrastructure repair and replacement, and lack of strong capital improvement plans (CIPs) or asset management plans collectively contribute to making this issue economically challenging.[22] Efforts to control I & I may be viewed as an ongoing continuous process, as opposed to a one-time project that will address all needs indefinitely into the future.

7.3 Discussion

Given the coastwide distribution of over 500 WWTPs, documented prevalence of I & I issues, and magnitude of SSOs, improvements to wastewater infrastructure are needed for long-term water quality management. This problem has been previously recognized multiple times as a priority to address. Since 2007 reducing pollution from wastewater infrastructure and treatment plants was listed as a habitat and water quality management action in five MFC Fishery Management Plans – Kingfishes (2007), Southern Flounder Amendment 1 (2013), Spotted Seatrout Revision (2014), Bay Scallop Amendment 2 (2015), and Striped Mullet Amendment 1 (2015).[23, 24, 25, 26, 27] The management actions were to aggressively reduce point source pollution from wastewater treatment facilities, improve maintenance of collection infrastructure, and establishment of additional incentives to local governments for wastewater treatment plant upgrading.

In 2006, the North Carolina Rural Economic Development Center (NC Rural Center) released a series of reports, as part of a Water 2030 Initiative, with data on public infrastructure and water supply. It concluded that approximately $17 billion in improvements were needed for water, sewer, and stormwater systems to keep pace with the growing population and repair of old infrastructure.

In 2010, a study on emerging estuarine issues was conducted by the NC Coastal Resources Law, Planning, and Policy Center, with financial support from Sea Grant and NOAA, and informational support from a steering committee.[28] The study was done in response to public requests following a 2009 Ocean Policy Study, thus providing a comprehensive study of emerging management and policy issues for the entire NC coast. The Estuarine Policy Steering Committee selected SSOs as one of four key emerging natural resource issues in the coastal counties. This was considered an emerging issue due to rapid development occurring on the inner coast and the expectation that infrastructure issues were likely to intensify with SLR. North Carolina is expected to be one of the top three most threatened areas from SLR in the U.S. as more than 2,000 square miles of the coast are less than three feet in elevation.[29]

The report had several recommendations related to SSOs.[28] Two recommendations address “deemed permitted” collection systems. Deemed permitted collection systems are those with an average daily flow of less than 200,000 gallons per day (GPD) (15A NCAC 2T.0303). In the NC Department of Environmental Quality (DEQ) Washington Regional Office, approximately 50 percent of the wastewater systems were deemed permitted. One recommendation of the report was that the NC Environmental Management Commission (EMC) and DEQ revise rule 15A 02T.0403 to require that a minimum of 10 percent of a deemed permitted collection system’s lines be cleaned on an annual basis. This requirement exists for permitted systems but deemed permitted systems are exempt.

Regular cleaning of pipes can reduce SSOs. However, a better approach for these smaller systems would be to require collection lines be cleaned annually on a systematic basis (e.g. three to five years) reducing equipment mobilization cost.[18] Further, because a deemed permitted collection system is not covered under an individually issued collection system permit, discussion may be needed to establish a mechanism to better capture such a need and ensure that collection system owners are aware of such a requirement.

Another recommendation of the Estuarine Policy Steering Committee report was for the EMC and DEQ to modify rules to require municipal wastewater collection systems with 100,000 or more GPD have a certified operator as an Operator in Responsible Charge (ORC). Existing EMC rules do not require an ORC for collection systems deemed permitted. Having an ORC would ensure that a qualified operator was responsible for operating, inspecting, and maintaining the system, potentially reducing SSOs and identifying problems proactively. While more oversight by an ORC would be helpful, there is a shortage of licensed wastewater and collection system operators in coastal and other regions of the state, and therefore an expansion of facilities required to have a designated licensed wastewater collection system operator could be challenging for some operations. As such, further evaluation may be warranted to assess implications of expanding the number of sewer systems requiring oversight by licensed wastewater operators or develop appropriate criteria for deemed permitted systems where an ORC should be required. Criteria could include a maximum GPD, history of problems, vulnerability of lines, SLR and storms, and risk to high quality waters and valuable coastal habitat. During the interim evaluation period, provisions within rule 15A NCAC 2T .0403(c) provide a mechanism for the DWR to bring a deemed permitted collection system under an individual permit, in cases where it may be appropriate to do so. In cases where a deemed permitted sewer system experiences chronic compliance issues, including chronic SSOs, the operation may be required to apply for and come under an individual collection system permit. Conditions with the individual permit could provide a mechanism to require oversight of the system by a certified operator, as well as the necessity to conduct routine cleaning of sewer lines.

The report also recommended that the NC General Assembly put in place a dedicated fund for water and wastewater infrastructure maintenance and repairs. The report suggested establishment of a working group of experts to discuss and develop recommendations to address the issues associated with SSOs, as well as broader water and wastewater infrastructure issues, in NC's rural counties and municipalities. Finally, the report recommended that local governments focus on capital improvements planning and asset management planning, to aid in budgeting for improvements that will avoid and minimize the effects of wastewater collection system failures. While there is no dedicated funding for water and wastewater infrastructure operation and maintenance, some actions have since occurred to address the issues.

In 2013, the NC General Assembly, through G.S. 159G-70 created a nine-member State Water Infrastructure Authority (SWIA). Responsibilities include awarding both federal and state funding for water and wastewater infrastructure projects, establishing criteria to prioritize applications, and developing a state water infrastructure master plan. Additionally, the SWIA duties include assessing the state's water and wastewater infrastructure needs, evaluating the role of the state in funding needed infrastructure, assessing the adequacy of funding programs currently available to local governments and utilities and assessing the need for a troubled system protocol. The NC General Assembly also created the Division of Water Infrastructure (DWI) at that time to provide support to the SWIA.

Early in the SWIA work, it was realized that for the state to meet its water and wastewater infrastructure needs, it is crucial that individual utilities are, or are on a path to be, viable systems. Viability is defined as a system that functions as a long-term, self-sufficient business enterprise; establishes organizational excellence; and provides appropriate levels of infrastructure maintenance, operation, and reinvestment that allow the utility to provide reliable water services now and in the future, without reliance on grant funds. The SWIA addresses this and many other issues in its "Statewide Water and Wastewater Infrastructure Master Plan – The Road to Viability."[22]

The issue of I & I is more than just the physical condition and operation of a wastewater collection system. No matter how resilient and sustainable the physical infrastructure is, its ability to serve customers reliably for the long-term ultimately depends on decisions made by the owner – usually elected officials – about how system needs are identified and funded, and the skill level of its utility employees. For example, decisions about water and sewer rates and fees impact the amount of revenue generated by a utility and its ability to keep the system well-maintained and make needed repairs in a timely manner. Decisions made about staff training impact the operation of the infrastructure components and overall system. Decisions about communicating with customers about the critical nature of infrastructure affects customer's understanding of and support for needed rates and fees. The organizational structure and management of a utility, from the elected officials to the operating staff, directly affects the quality of its physical infrastructure and its ability to maintain compliance.

Water and sewer utilities are intended to operate as self-sufficient business enterprises. As mentioned previously, this requires the ability to financially support the full cost of capital projects, replacement and renewal projects, as well as appropriate system operations and maintenance. Unfortunately, simply mandating utilities to fully fund infrastructure, operations and maintenance is not a realistic approach. As far as funding support, only a fraction of NC's infrastructure needs can be met with the level of funding currently available from state and federal subsidized funding sources, and increased funds from these sources does not appear likely.

Many WWTPs and sewer systems in the state were constructed years ago either with revenue from a large manufacturing customer base or with the help of federal grant funds, both of which have diminished considerably. In 1970, over half of NC's population lived in rural areas and supported farming and manufacturing including tobacco, furniture, and textiles. Today, the number and size of large water-using industries has declined and only one third of the state's residents live in rural areas. Wastewater treatment plants and sewers in many rural areas, originally built for large flows from manufacturing facilities, are now oversized for the much smaller domestic flows that remain. These rural utilities are still burdened with the upkeep and operation of these large systems, but now lack the significant sources of revenue that once paid for such work. In addition to decreasing population and industrial customers, water usage overall is declining, which also reduces revenues.

Some small utilities have not raised rates in years and continue to defer needed rehabilitation of their aging infrastructure. Other small utilities have worked to replace this revenue by raising water and sewer rates, and, as a result, some of the smallest, most economically distressed communities have some of the highest water and sewer rates in the state. These rates are unaffordable and unsustainable in the long-term. The US Environmental Protection Agency (EPA) recognizes that pricing decisions involve consideration of equity as well as efficiency. Low-income households, especially those served by high-cost systems, may face affordability problems if prices are raised.[30] The growing issue of water and wastewater service affordability is also being elevated by the American Water Works Association and the Water Environment Federation.[31] Small utilities also face requirements to meet more stringent water quality regulations, especially regarding nutrient sensitive waters, which increases costs.

The SWIA recognizes that viability issues result from many different circumstances that are specific to each utility and require approaches tailored to individual needs. However, when utilities are not viable or are not on a path to become viable, other possible courses of action must be explored. The DWI administers the following two grant programs that provide funding designed to help utilities take the first steps toward viability:

- Asset Inventory and Assessment (AIA) Grants - support a utility as it examines the purpose and value of its infrastructure, and the processes it uses to determine when and how to spend infrastructure dollars. Outcomes include identifying the most critical projects and the ability to demonstrate and explain why they are critical, which will help gain support from governing bodies, customers, and stakeholders to make the needed investments. Funds are provided for a utility to:
    - Identify the water and wastewater infrastructure components that comprise its water and wastewater systems.
    - Create an asset inventory.
    - Determine the condition of these assets.
    - Prioritize the most critical infrastructure needs.
    - Develop a capital improvement plan (CIP) to fund the projects.
- Merger/ Regionalization Feasibility Grants - investigate voluntary partnerships, such as consolidating two or more systems into one, that can result in improvements to physical infrastructure and organizational and financial management.

These options are best utilized in a proactive manner and well before a utility's infrastructure and financial situation become critical.

In addition to the above grants, permanent solutions can also be created when elected officials and utility governing boards explore potential advantages of a range of partnership solutions that might include regionalization, consolidation, shared management opportunities, contract operations, interlocal agreements, public-private partnerships, privatization, and other activities or arrangements; and Utilities reach out to other entities such as the North Carolina Rural Water Association, Southeast Rural Community Assistance Project, regional North Carolina Councils of Government, Department of State Treasurer, University of North Carolina at Chapel Hill School of Government Environmental Finance Center, the North Carolina League of Municipalities, the North Carolina Association of County Commissioners and the DWI to understand infrastructure issues and develop potential options.

The SWIA also administers other grant and loan programs to support construction of needed infrastructure repairs or modifications:

- Clean Water State Revolving Fund – provides low-interest loans to local governments to fund wastewater collection and treatment facility projects including the relocation of infrastructure outside of the 100-year and 500-year floodplains. Loans are also available for stormwater quality improvement projects, such as BMPs and stream restoration
- State Wastewater and Drinking Water Reserve Programs – provides grants and loans for wastewater treatment and collection systems as well as drinking water treatment and distribution systems
- Community Development Block Grant (Infrastructure) – provides grants to local governments to address wastewater infrastructure needs in HUD qualified low to moderate income communities

On July 1, 2020, Session Law (SL) 2020-79, "An Act to Improve the Viability of the Water and Wastewater Systems of Certain Units of Local Government…" was signed by Governor Cooper. SL 2020-79 requires review of local government units to determine if they are distressed due to issues in their water or wastewater enterprise fund and provides for a new Viable Utility Reserve (VUR) grant fund. Several units of local government in coastal areas will likely be designated as distressed due to issues with their water/wastewater systems.

The goal of SL 2020-79 is to facilitate comprehensive, permanent solutions for distressed water or wastewater utilities through a process framework and grant funding to accomplish the solutions. Both the SWIA and the Local Government Commission of the Office of State Treasurer must approve the use of VUR grant funds. However, the initial appropriation of only $9 million for the VUR fund supports just the beginning of this process. A secure, reliable, on-going, and increased source of funding is needed for the long-term success of the new program. From January 2014 to September 2020, the SWIA has awarded more than 900 projects, totaling approximately $1.9 billion to Local Government Units (LGUs). In 2019-2020, a total of $182 million of grant and loan funding was awarded, excluding the drinking water project funding.[32] Funding programs included 18 projects from the Community Development Block Grant-Infrastructure, 31 projects from the Asset Inventory and Assessment grant program, 10 from the Merger/Regionalization Feasibility Grants, 31 from the Federal-State Clean Water State Revolving Fund, and four from the State Wastewater Reserve. While this is a substantial amount of assistance, the DWI continues to receive more grant and loan funding requests from throughout the state than are available.

The 2020 Resilience Plan also recognized failing infrastructure and SSOs as a growing concern to coastal water quality.[33] Climate change issues that can impact wastewater infrastructure include SLR, extreme heat, inundation and rainfall events, increased temperatures, flooding, storm surge, and dam failure. Flooding associated with extreme storm events can result in increases in I & I and more frequent SSO events. The frequency and magnitude of extreme storm events is expected to increase due to climate change and cause lift stations to flood and break down. Loss of power during storm events can also cause operation issues resulting in SSOs at wastewater treatment plants or lift stations.

To improve ecosystem and community resiliency, the plan suggests that state and local governments utilize policies or rules to encourage siting development, WWTPs, and other pollution sources away from riparian areas and floodplains. Also, utilities can continue to flood-proof assets such as WWTPs and upgrade sewer infrastructure to reduce the risk of I & I and SSO. The plan notes that improving wastewater management and maintaining wastewater infrastructure can help reduce the loading rates of nutrients and sediments into estuaries, resulting in more resilient conditions for submerged aquatic vegetation (SAV), other fish habitats, and coastal communities. When WWTPs are inundated and infrastructure is damaged, available federal funding could be utilized as much as possible to repair and reduce future flood risks. The plan sites a near-term priority as identifying and voluntarily moving WWTPs out of the floodplains.

The plan recommends that immediate focus is needed to develop strategic priorities for public and natural infrastructure improvements. Future climate conditions and resiliency should be integrated into current public investment decisions in local and regional water and transportation infrastructure improvements and other critical assets. By building resilience into infrastructure, risks for small businesses and communities are lowered.

As part of the EPA's Creating Resilient Water Utilities (CRWU) initiative, APNEP conducted the Climate Resilience Evaluation and Awareness Tool Exercise with the towns of Manteo and Columbia. Potential impacts of rising sea levels on wastewater infrastructure were examined using the EPA Climate Risk Evaluation and Assessment Tool (CREAT). The report provides engineering and financial recommendations for realistic measures the towns might take to improve their resiliency to coastal hazards and flooding to consider for integration into their capital improvement planning processes.[34]

For many years, NRDC has provided an annual analysis of water quality by state. To deter increasing SSOs due to increasing SLR, extreme rain events, and flooding, NRDC recommended that wastewater utilities immediately implement climate-smart strategies, similar to what was recommended in the 2020 Resilience Plan.[19, 33] In addition to flood-proofing and relocating high-risk facilities where possible, other strategies included:

- Update water and wastewater emergency response and maintenance procedures to prepare for more common and more extensive coastal flooding of vulnerable infrastructure.
- Plan for alternative power supplies to support operations in case of loss of power.
- Install effluent pumping systems for wastewater treatment plants affected by SLR and ensure the adequacy of emergency generator systems.
- Until vulnerable facilities can be relocated, build berms as a short-term protective measure.

The DWR emphasizes to utility owners the need for proper operation and maintenance of sewer lines to prevent many SSOs, but this also requires funding. Maintenance includes routinely inspecting sewer lines and cleaning them at a frequency sufficient to address blockages from grease and fat, roots, and pipe deflections. Smoke testing, dye testing, and using cameras are examples of tools that can be used to detect sources of broken lines, obstructions, and illicit connections.

In 2017, as an incentive to correct illicit discharges from wastewater infrastructure, DWR approved a new nutrient reduction practice, "Design Specifications and Nutrient Accounting for Remedying Illicit Discharges to Surface Waters or Stormwater Systems".[35] Illicit discharges were defined to include SSOs caused by I & I during wet weather, sewage leakage out of the pipe (exfiltration) during dry periods, and sanitary direct connections. Nutrient credits can be received for remedying such problems for compliance with applicable Nutrient Management Strategy Rules. This would only be applicable in NSW watersheds. Further information regarding Nutrient Practices and Crediting, as well as topics including Stormwater Nutrient Accounting Tools, Approved Nutrient Reduction Practices, and Nutrient Offset and Trading information maintained by DWR can be found here.[36]

7.4 Recommended Actions

Charging and assessing fees to customers at rates necessary to cover costs, including long-term expenses that may require extensive re-investment in the system when components have reached or exceeded their life cycle expectancies, seems like a commonsense approach. However, as discussed previously, many communities cannot afford the increase that would be required to do this. In 2020, the NCDWI annual report therefore included the following recommendations:[32]

- Request adequate and recurring state appropriated funds needed for the viable utility reserve.
- Request the NC General Assembly modify legislation to allow SWIA flexibility in establishing grant conditions for programs under their authority, to ensure grant funds are used to help systems achieve long-term viability.

Other studies have also recognized the significance of this issue and provided recommendations. Most recently, the 2020 NC Climate Risk Assessment and Resilience Plan (2020 Resilience Plan) recommended wastewater infrastructure improvements be addressed for coastal resiliency.[33] Expanding funding ability from current state level resources is clearly needed to protect water quality and increase coastal community resiliency. The CHPP Steering Committee strongly supports the NCDWI and 2020 Resilience Plan recommendations, as well as the following recommendations.[32]

7.4.1 Policy

7.1 By 2024, DEQ will request that funding programs under the purview of the SWIA give additional priority for projects with a direct benefit to sensitive estuarine waters, including SA waters, fish nursery areas, and impaired waters, particularly those adversely impacting estuarine fish and their habitat.

7.2 By 2025, DWR will develop additional incentives to encourage improved maintenance of the collection system (e.g. incentivize owners and operators of wastewater lines for both existing systems and potential new systems to adopt construction designs that minimize the potential for sewer spills over the long-term).

7.3 By 2025, DCM and DWR will work with NC Office of Recovery and Resiliency (NCORR) and local governments in the coastal counties to develop strategies regarding flood-proofing wastewater infrastructure; siting new and relocating existing infrastructure away from sensitive estuarine waters and floodplains; upgrading sewer infrastructure; and develop strategic priorities for public and natural infrastructure improvements

7.4.2 Potential Rulemaking

7.4 By 2023, DWR will evaluate modifications of EMC rules to require deemed permitted collection systems under select criteria (e.g. 100,000 or more GPD) to have a certified operator as an Operator in Responsible Charge (ORC). DWR shall provide an update on this evaluation effort to the Water Quality Committee in approximately one year.

7.5 By 2023, DWR will investigate modification of EMC rules to require deemed permitted collection systems to be cleaned annually on a systematic basis (e.g. 3 to 5 years). The DWR shall provide an update on this evaluation effort to the Water Quality Committee in approximately one year.

7.4.3 Research

7.6 Prioritize research on alternative wastewater collection system designs that may be better suited for coastal conditions (i.e., alternative sewer systems, composting toilets).

7.7 Evaluate the feasibility of re-designing and re-engineering existing systems that are inadequately protecting ground and surface water quality.

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8. COASTAL HABITAT MAPPING AND MONITORING TO ASSESS STATUS AND TRENDS

8.1 Issue

An understanding of the status and trends of NC's six coastal habitats, and the ability to monitor them over time, is needed to assess both the long-term changes to the habitats and the causative effects. Comprehensive mapping and monitoring of all of NC's coastal habitats is needed to quantifiably measure the necessity and success of management actions and restoration efforts. Adequate spatial coverage and resolution can inform protection and restoration efforts and can provide indicators of larger changes in the system that may need to be investigated in the future.[1] Various levels of mapping and monitoring of the six coastal habitats occur in NC. However, more unified, robust, and standardized approaches would increase the ability to report on the health of NC's coastal ecosystem including detecting change and potential causation. This approach will better inform protection and restoration efforts and support current or potential management actions. The need for rapid habitat assessment to facilitate habitat restoration and protection has been recognized by the Coastal Habitat Protection Plan (CHPP) since its inception.[2] Building from this, generating metrics for assessing habitat trends was a priority issue in the 2016 CHPP.[3] While some progress was made, the purpose of this paper is to advance standardized and regular monitoring of NC's coastal habitats.

8.2 Background

The Fisheries Reform Act of 1997 (G.S. 143B-279.8) specifies that the CHPP identify threats and recommend management actions to protect and restore habitats critical to NC's coastal fishery resources. The legislative goal of the CHPP is ***"…the long-term enhancement of coastal fisheries associated with coastal habitats."*** The statute specifies the plan must include evaluation of the status and trends of fish habitat. A species' use of specific areas can depend on various factors, including life stage, time of day, and tidal stage. Together, these habitat areas form a functional and connected system that supports the fish from spawning until death. Because of the interconnectedness and functions that each habitat provides, the status of one habitat can affect others. Within NC's coastal ecosystem, six habitat types were distinguished: water column, shell bottom, submerged aquatic vegetation (SAV), wetlands, soft bottom, and hard bottom.

Recognizing the problems caused by degradation and destruction of the environment and identifying the causes, both natural and human induced, is essential in raising public awareness. Yet, this is only the starting point for environmental management.[4] Coastal resource managers have to consider the complex interactions between and within the coastal habitats, the estuarine ecosystems as a whole, and the human population creating the need for standardized monitoring and assessments of these habitats. The primary purpose of monitoring is to collect information that can be used for development of policy, examine the outcomes of management actions, and guide management decisions (Kull et al. 2008).[5] Habitat monitoring at local to regional scales is essential given their vulnerability to human pressures and those associated with climatic fluctuation.[6]

To quantifiably achieve the main goal of the CHPP, the status and trends of these six coastal habitat types must be monitored over time to assess long-term changes. This information can then be used, not only to educate the public on the condition of the coastal habitats, but also to inform protection and restoration decisions and evaluate and adapt management actions and strategies (Figure 8.1).

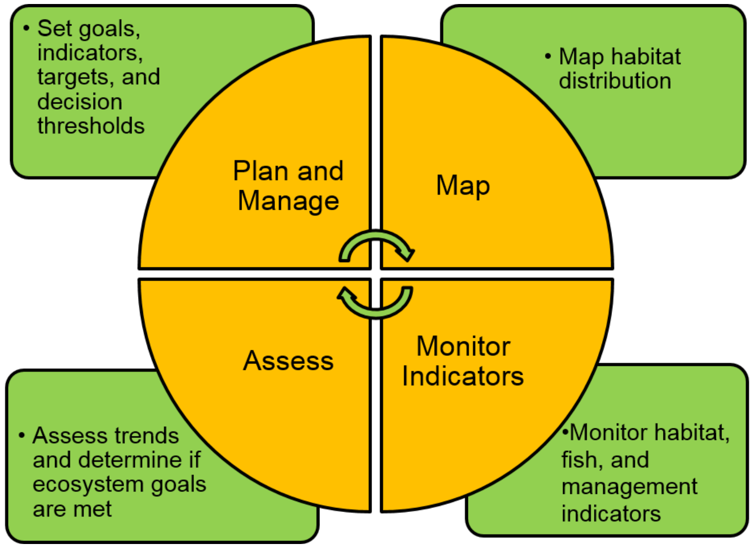

Figure 8.1. The role of monitoring in successful habitat management.[7]

The integration of social and ecological information relevant to stakeholders and managers is an essential component when trying to reach management goals and remediate environmental impacts.[8] The 2016 CHPP recognized this and the need to incorporate ecosystem-based management (EBM) into coastal resource conservation strategies.[3] The following management options were proposed:

1. Develop indicator metrics for monitoring the status and trends of each of the six habitat types within NC's coastal ecosystem (water column, shell bottom, SAV, wetlands, soft bottom, hard bottom)
2. Establish thresholds of habitat quality, quantity, or extent, similar to limit reference points or traffic lights, which would initiate pre-determined management actions
3. Develop indicators for assessing fish utilization of strategic coastal habitats
4. Develop performance criteria for measuring success of management decisions
5. Include specific performance criteria in CHPP management actions where possible

Ecosystem based management is a shift away from a limited or partial consideration of the interactions of the natural systems and society. The emphasis of EBM is: 1) factoring in complex linkages in social-ecological systems; 2) dealing with adequate scales (both spatially and temporally); 3) promoting adaptive management of complex and dynamic systems; and 4) adopting integrated assessment and management frameworks.[9] While the concept of EBM has been widely accepted and research into social-ecological systems has provided a very promising direction for improved environmental management, to date there has been limited progress in incorporating such practice into large scale policy.[4] This is evident in the implementation of the above proposed management options. Although notable implementation progress has been made in developing indicators for assessing fish use of strategic habitat areas (for additional information, see **Chapter 2. Implementation Progress 2016-2020**), substantial work is still needed on the proposed management options to develop indicator metrics and performance criteria. Therefore, a first step in understanding ecosystem level trends is to assess individual habitat status and trends.

While there are permanently funded programs for monitoring fish and water quality, programs for continuous monitoring and assessment of the coastal habitats are very limited or absent due to lack of funding for long-term data collection not directly related to agency mission statements and regulatory compliance. The description, distribution, ecological role, and functions of the six coastal habitats can be found in the 2016 CHPP source document. The following details the most up to date status and trends for each of the six coastal habitats using the most current and available monitoring data. For additional information on SAV and wetlands, see **Chapter 4. Submerged Aquatic Vegetation Protection and Restoration Through Water Quality Improvements** and **Chapter 5. Wetland Protection and Restoration through Nature-Based Solutions** issue papers.

8.2.1 North Carolina's Coastal Habitats Mapping and Monitoring

Water Column

The water column habitat is defined as "water covering a submerged surface and its physical, chemical, and biological characteristics".[2] The chemical and physical properties of the water affect the biological components of the water column - including fish distribution. The water column is the medium through which all aquatic habitats are connected and is therefore critical to the overall health of the ecosystem.

Water quality describes the condition of waters based on selected physical, chemical, and biological characteristics, usually with respect to its suitability for a particular purpose such as drinking, recreation, or supporting aquatic life. Fish species and other organisms, such as SAV and oyster that also provide fish habitat, exhibit threshold tolerances. Conditions of the water column that are outside the threshold tolerance are considered impaired, polluted, or otherwise not supporting aquatic life. Basic parameters of water impairment include: pH, temperature, dissolved oxygen (DO), turbidity, bacteria, and chlorophyll *a*. Additional parameters impacting water quality include nutrients, such as nitrogen and phosphorous. However, currently there are no nutrient standards used to asses for water quality impairment. Excessive nutrient-rich sediment from land-based activities can exacerbate eutrophication, decreasing DO and water clarity and increasing toxic contamination. Therefore, flow and movement play a vital role in distributing the drivers of eutrophication and chemical pollution.

2010 National Coastal Condition Assessment (NCCA)

A national assessment, the United States Environmental Protection Agency (EPA) 2010 National Coastal Condition Assessment (NCCA) found in the Southeast Coastal region (NC to FL), 21 percent of the coastal area is in good condition based on the water quality index, 69 percent is in fair condition, and nine percent is in poor condition (Figure 8.2).[10] Ratings for chlorophyll *a* and phosphorus contribute most to the region's fair and poor water quality scores. Between the 1999 to 2001 and the 2005 to 2006 reporting periods, the Southeast coastal region that was rated good based on the water quality index declined significantly by 27 percent (Figure 8.3). Dissolved oxygen and water clarity seem to be primary drivers for this decrease in quality. Between the 2005 to 2006 and the 2010 reporting periods, there was a modest increase in the percent area rated good based on the water quality index. A significant rise in the percent area rated good for dissolved oxygen and water clarity conditions and a small but significant change in nitrogen conditions contributed to the improvement in 2010.

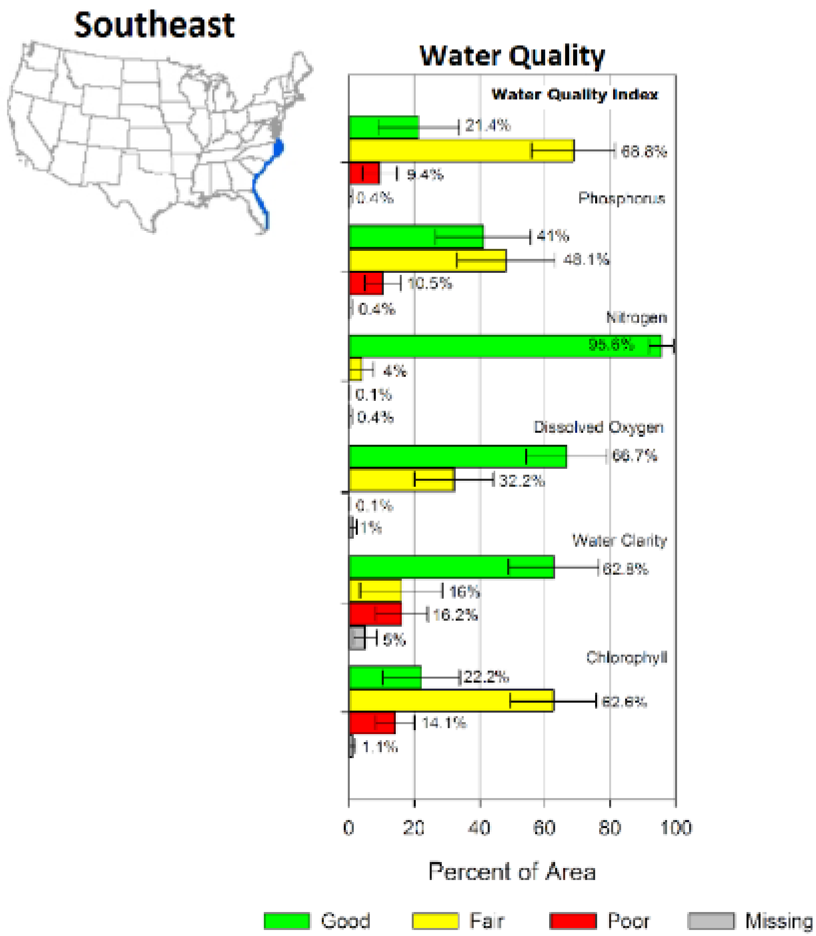

Figure 8.2. The United States Environmental Protection Agency (EPA) National Coastal Condition Assessment (NCCA) 2010 water quality index results for the Southeast Coastal region. Bars show the percent of coastal area within a condition category for specific indicators. Error bars represent 95 percent confidence intervals. Note: The sum of percent of area for each indicator may not add up to 100 percent due to rounding.[10]

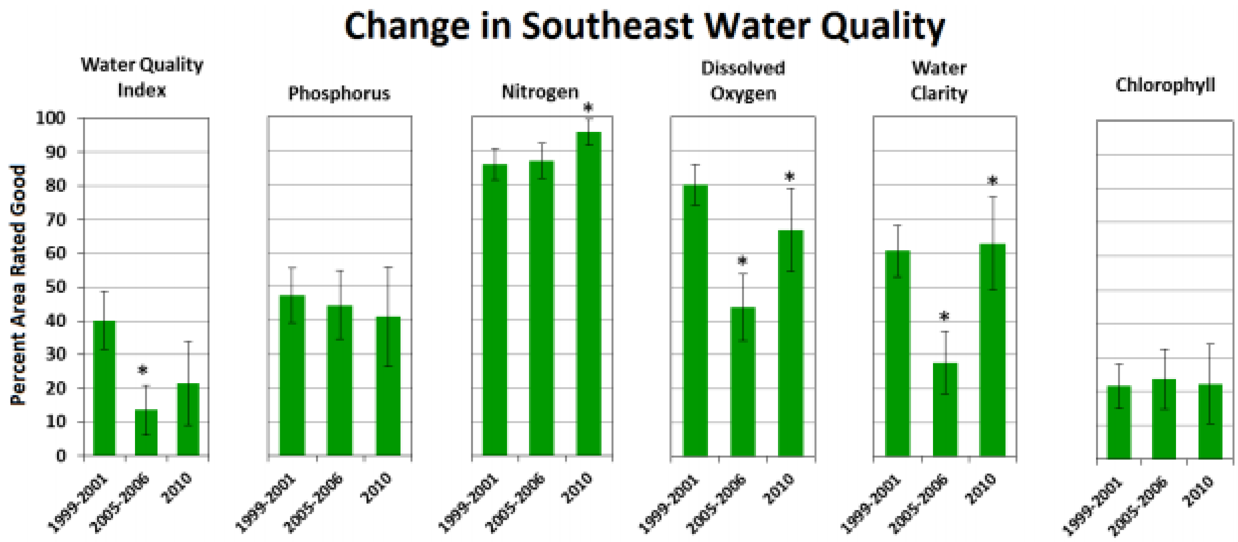

Figure 8.3. Comparison of the percent area rated good for water quality indicators over three periods in the Southeast Coast. Note: Asterisks (*) indicates statistically significant change between periods.[10]

North Carolina Division of Water Resources (DWR) Ambient Monitoring System (AMS)

The DWR is the primary water quality monitoring agency in NC. Surface waters in NC are assigned a classification reflecting the uses of that waterbody (e.g., water supply, shellfish harvest, primary recreation, aquatic life, agriculture). To determine how well waterbodies are meeting their best-intended uses, chemical, physical, and biological parameters are regularly assessed by DWR. The assessment of water quality in NC, known as the Integrated Report (IR) is required under Sections 303(d) and 305(b) of the Clean Water Act and is completed biennially.[11] This assessment indicates the general condition of NC's waters and identifies waters that are not meeting water quality standards where sufficient data exists. The impaired waters (acres and miles) listed in the 2018 IR are shown in Table 8.1 by region and for the overall coast.

Table 8.1. The impaired waters (acres and miles) listed in the 2018 Integrated Report. Percent of waters assessed in parentheses.

	2018 Integrated Report Impaired Waters				
	Region 1	Region 2	Region 3	Region 4	Overall
Freshwater (ac)	15,600 (42%)	0.0 (0.0%)	0.0 (0.0%)	289 (67%)	15,889 (34%)
Freshwater (mi)	43 (5%)	304 (18%)	12.4 (14%)	123 (9%)	482 (12%)
Saltwater (ac)	349,699 (43%)	204,534 (15%)	47,597 (6%)	16,470 (42%)	618,300 (20%)
Atlantic Coast (mi)	0.0 (0.0%)	0.0 (0.0%)	0.6 (0.4%)	0.0 (0.0%)	0.6 (0.2%)

Several of DWR's water quality management activities use data produced by the Ambient Monitoring System (AMS). The AMS consists of a network of stations established to provide site-specific, long-term water quality information on significant waterbodies throughout the state (Figure 8.4). The program has been active for over forty years and is used in development of the IR, Basinwide Water Resources Plans, Total Maximum Daily Loads (TMDLs), and National Pollutant Discharge Elimination System (NPDES) permit limits. Active stations are visited at least quarterly for the collection of a variety of physical, chemical, and bacterial pathogen samples and measurements. Stations monitoring water quality are concentrated in riverine and upper estuarine waters. Currently there are 329 active stations, 149 of which are within the coastal boundaries of the CHPP regions. Water quality data (e.g., chlorophyll *a*, nutrients, pH, dissolved oxygen (DO), and turbidity) from a representative 18 DWR AMS stations throughout the CHPP regions are shown in Figure 8.4 and summarized graphically by year in Figures 8.5-8.8. The graphs are not statistical trends or meant to show standard exceedance, but are generated to show general trends over the years. These sites were also summarized in the 2016 CHPP.[3]

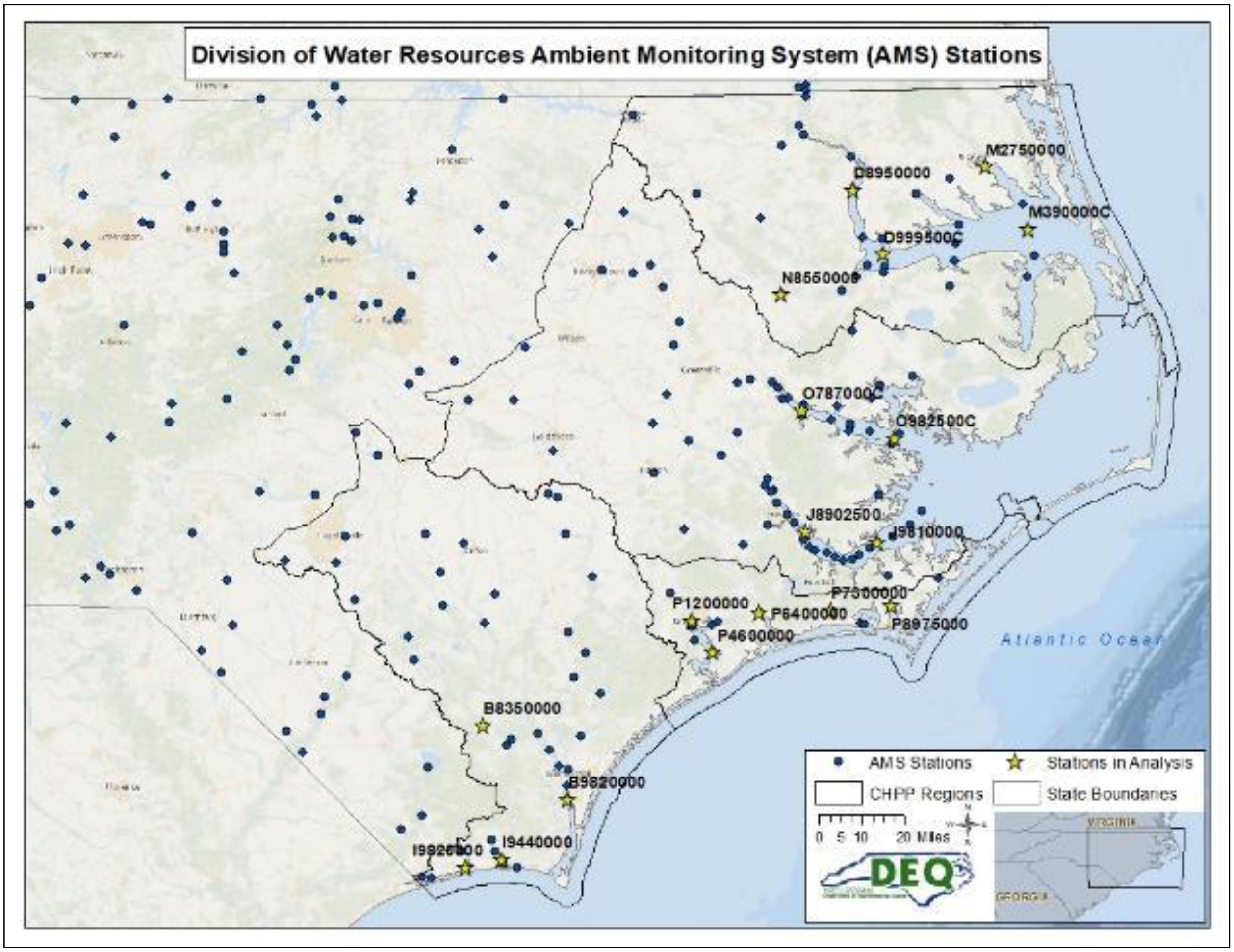

Figure 8.4. The Division of Water Resources (DWR) Ambient Monitoring System (AMS) Stations. Stars indicate stations used in analysis.

Ambient Monitoring System (AMS) Coastal Habitat Protection Plan (CHPP) Region 1

The five selected stations in CHPP Region 1 include:

- Roanoke River near Williamston (N8550000)
- Chowan River near Colerain (D8950000)
- Albemarle Sound near Edenton (D999500C)

- Albemarle Sound near Frog Island (M390000C)
- Pasquotank River near Elizabeth City (M2750000; Figure 8.4)

Annual mean water quality data indicate:

- Total phosphorus (TP) levels are higher in the rivers versus Albemarle Sound.
- Total nitrogen (TN) is increasing in all the stations, the Pasquotank River showed higher concentrations especially during the wetter years.
- Turbidity data show peaks during wetter years and higher concentrations in the Roanoke River.
- High and low DO levels may indicate the growth and crash of algal production within these waterbodies. The low DO in the Roanoke and Pasquotank is due to excess swamp drainage during wet years.
- Median pH levels fluctuate at each station with the levels not indicating any extended periods of standard exceedance. The Roanoke and Pasquotank are influenced by swamp water draining into these systems which can result in naturally low DO and pH levels.
- Chlorophyll *a* concentrations indicate that the mean concentration is increasing throughout this region. A dramatic increase has been identified in the Chowan River at the Colerain station (D8950000) where summer nuisance algal blooms have been documented since about 2015 (Figure 8.5).

Photo Credit: NCWetlands.org

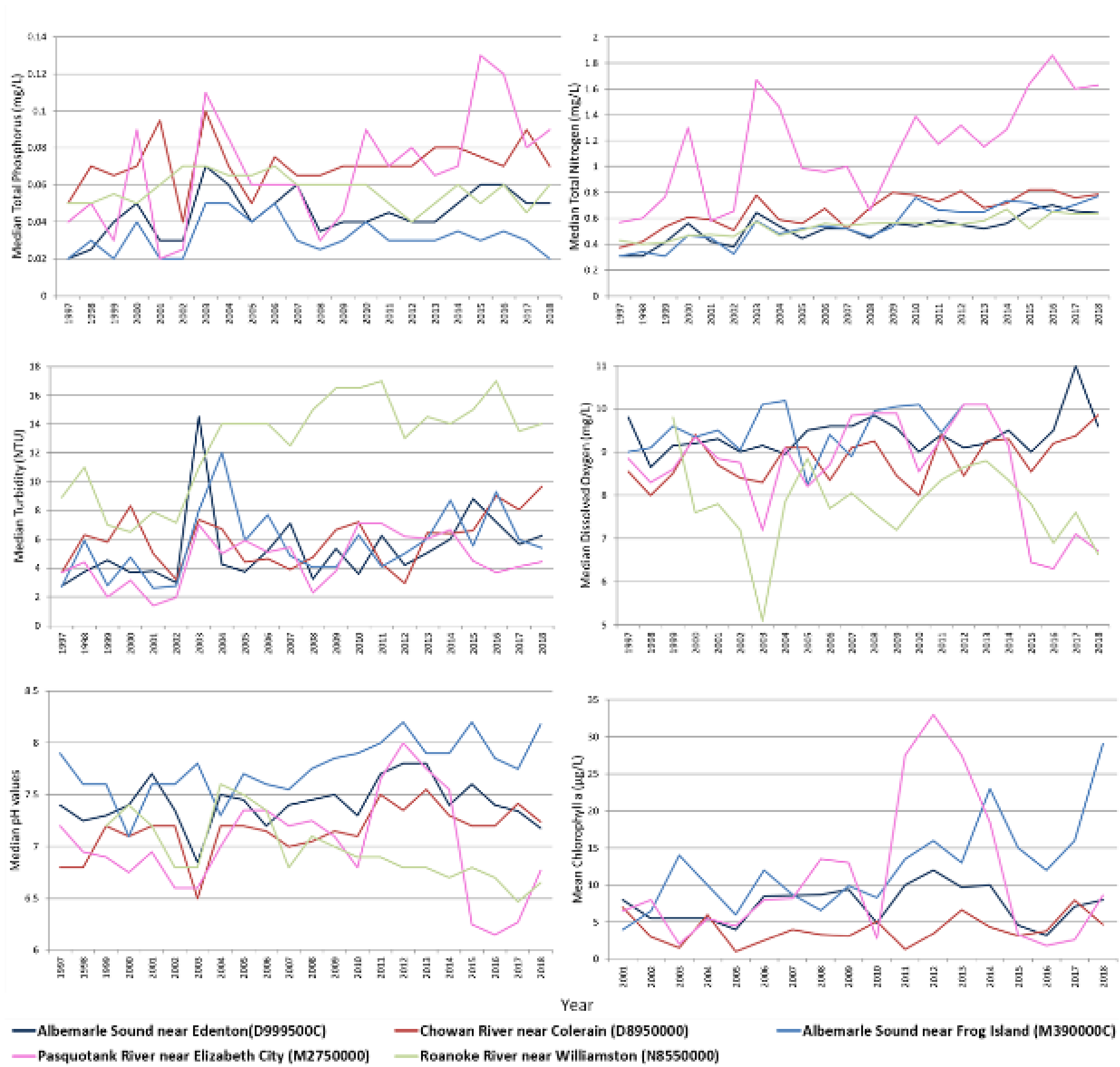

Figure 8.5. Annual median Total Phosphorus (mg/L), total Nitrogen (mg/L), Turbidity (NTU), DO (mg/L) concentrations, and pH values, and mean Chlorophyll *a* (µg/L) concentrations for representative Ambient Monitoring System (AMS) stations in Coastal Habitat Protection Plan (CHPP) Region 1.

Ambient Monitoring System (AMS) Coastal Habitat Protection Plan (CHPP) Region 2

The four selected stations in CHPP Region 2 include:

- Pamlico River mid-channel at the mouth of Brad Creek near Bunyon (O787000C)
- Pamlico River mid-channel between the mouths of the Pungo River and Goose Creek (O982500C)
- Neuse River near Thurman (J8902500)

- Neuse River near Oriental (J9810000; Figure 8.4)

Annual mean water quality data indicate:

- Data from the two upper and lower estuary stations show similar patterns over the years.
- The graphs clearly show higher nutrient levels in the upper estuary, whereas dilution and biological uptake has occurred resulting in lower concentrations of TP and TN at the lower estuarine stations.
- The median TN concentrations are clearly increasing over the 21-year period.
- Chlorophyll *a* concentration has remained fairly consistent over this time period with elevated concentrations at the upstream station and a significant spike in the 2014 annual mean concentration of 117 µg/L at the Neuse River J8902500 station. A prolonged period of elevated biological productivity occurred between July and December 2014. The chlorophyll *a* concentration ranged between 55-780 µg/L, with a mean concentration of 206 µg/L (Figure 8.6).


Photo Credit: Michael Burchell

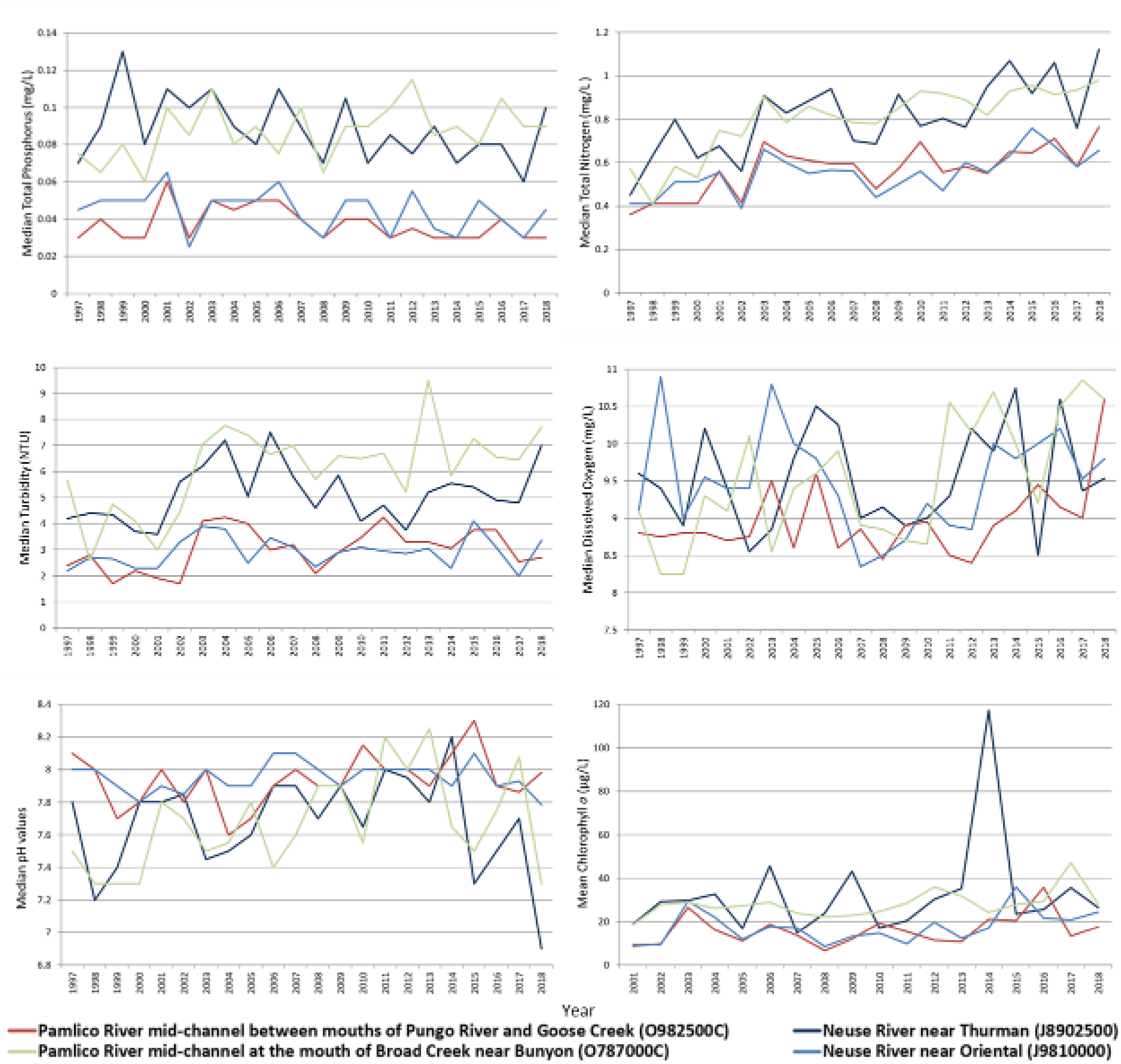

Figure 8.6. Annual median Total Phosphorus (mg/L), total Nitrogen (mg/L), Turbidity (NTU), DO (mg/L) concentrations, and pH values, and mean Chlorophyll *a* (µg/L) concentrations for representative Ambient Monitoring System (AMS) stations in Coastal Habitat Protection Plan (CHPP) Region 2.

Ambient Monitoring System (AMS) Coastal Habitat Protection Plan (CHPP) Region 3

The five selected stations in CHPP Region 3 include:

- North River near Bettie (P8975000)
- Newport River near Newport (P7300000)
- White Oak River near Stella (P6400000)
- New River near Jacksonville (P1200000)

- New River upstream of French Creek (P4600000; Figure 8.4)

Annual mean water quality data indicate:

- Nutrient data were only collected at the New River stations; these data show much higher concentrations near Jacksonville than downstream in the New River estuary.
- This is generally reflected in the chlorophyll *a* biological response with higher mean concentrations at the New River near Jacksonville station (P1200000). Higher concentrations can occur downstream when flows are high enough to limit the productivity upstream due to stream flows limiting for algal bloom development.
- Turbidity data show much higher concentrations in the North River near Bettie station (P8975000) than in other coastal rivers.
- DO and pH levels are much lower at the Newport River near Newport station (P7300000) than other coastal stations (Figure 8.7).

Photo Credit: Nolen Vinay

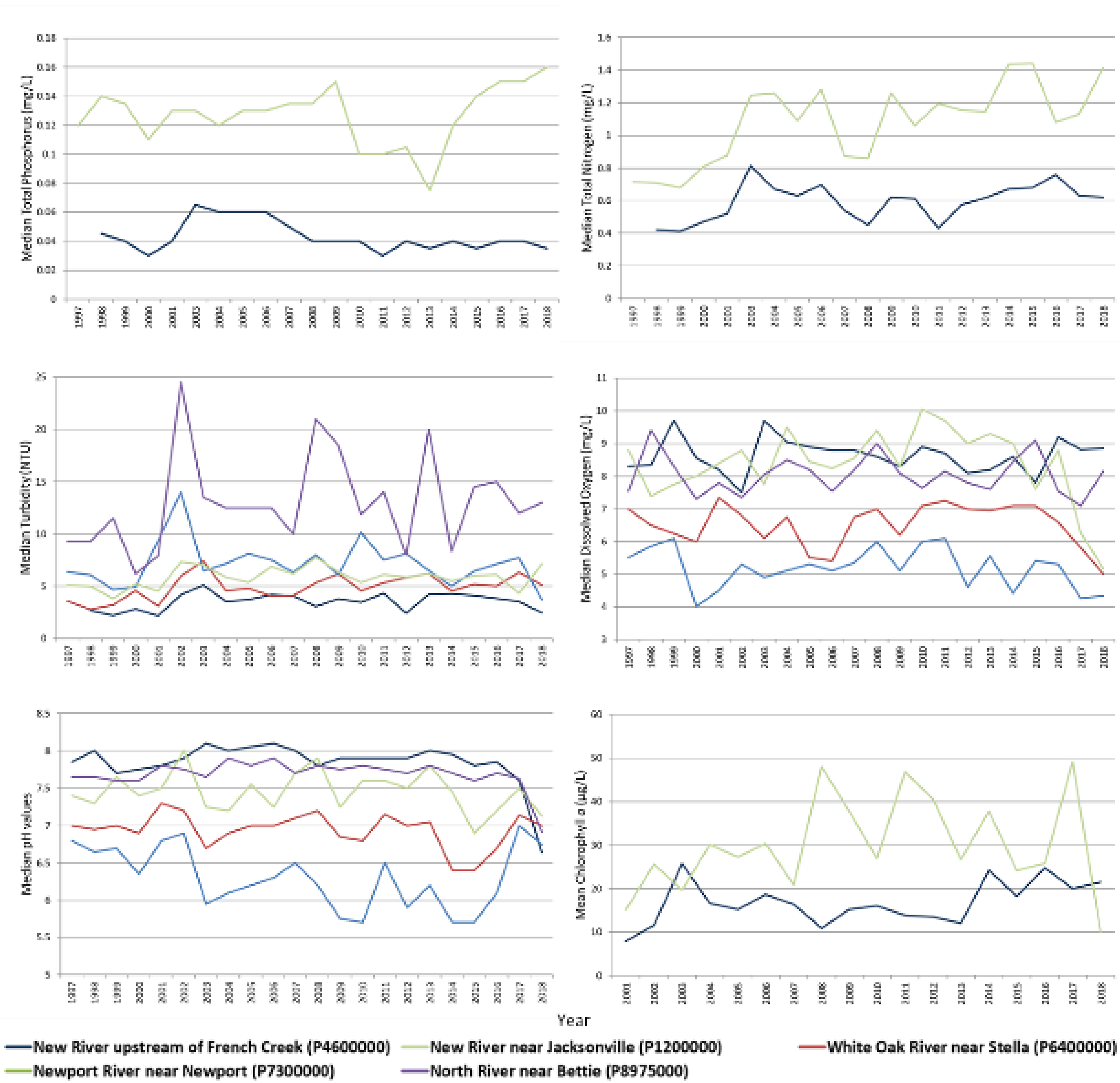

Figure 8.7. Annual median Total Phosphorus (mg/L), total Nitrogen (mg/L), Turbidity (NTU), DO (mg/L) concentrations, and pH values, and mean Chlorophyll *a* (µg/L) concentrations for representative Ambient Monitoring System (AMS) stations in Coastal Habitat Protection Plan (CHPP) Region 3.

Ambient Monitoring System (AMS) Coastal Habitat Protection Plan (CHPP) Region 4

The four selected stations in region 4 include:

- Cape Fear River near Kelly (B8350000, below lock and dam #1)
- Cape Fear River near Wilmington (B9820000)
- Lockwood Folly near Varnum (I9440000)
- Shallotte River near Shallotte (I9820000; Figure 8.4)

Annual mean water quality data indicate:

- Nutrient data were only collected at the Cape Fear River stations with the higher concentration data indicated in the upstream station.
- The upstream Cape Fear River station (B8350000) also shows a larger range of turbidity concentrations.
- Lower pH conditions in the Cape Fear River stations are likely the result of swamp drainage influence (Figure 8.8).

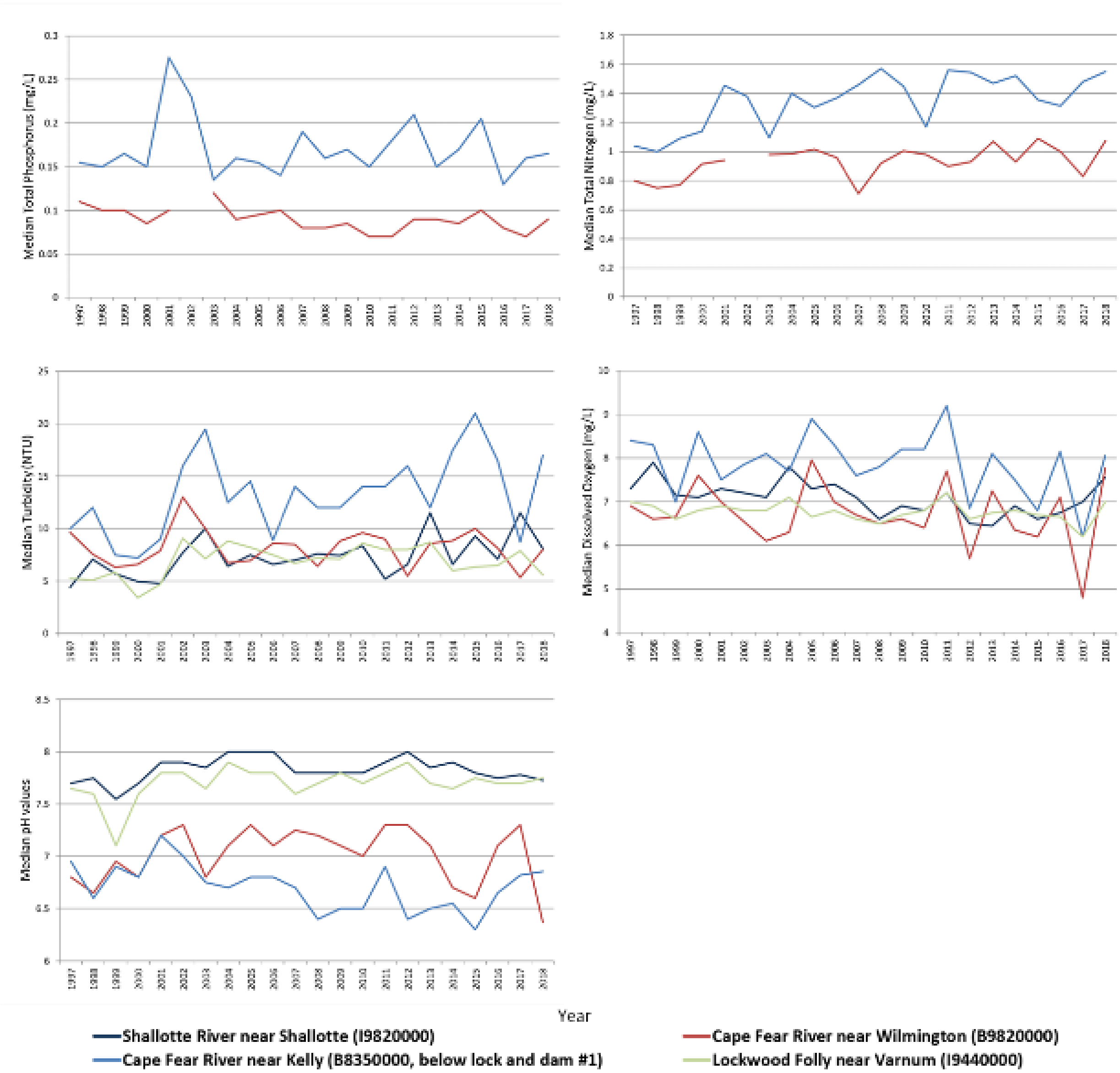

Figure 8.8. Annual median Total Phosphorus (mg/L), total Nitrogen (mg/L), Turbidity (NTU), DO (mg/L), and pH values, and mean Chlorophyll *a* (µg/L) concentrations for five representative Ambient Monitoring System (AMS) stations in Coastal Habitat Protection Plan (CHPP) Region 4.

There is a general trend of increasing nutrients and Chlorophyll *a* coastwide, in almost every CHPP region. This is especially evident in the upstream AMS stations. Increases in turbidity, especially during wet years, are also being observed. Eutrophication and decreased water clarity due to increased turbidity, not only degrade water quality, but can lead to algal blooms and fish kills, as well as having detrimental effects on other coastal habitats such as SAV and oysters.

Toxic chemical contamination is not evaluated by DWR in estuarine and nearshore ocean waters. The current standards do not completely eliminate risk from toxins because: (1) values are not established for many toxic chemicals, (2) mixtures and breakdown products are not considered, (3) effects of seasonal exposure to high concentrations have not been evaluated, and (4) some potential effects, such as endocrine disruption and unique responses of sensitive species, have not yet been assessed.

Nutrient Sensitive Waters

Nutrient Sensitive Waters (NSW) is a supplemental classification intended for waters needing additional nutrient management due to excessive growth of microscopic or macroscopic vegetation. Currently, there are no water quality standards for nutrients, except 10mg/L nitrate for drinking water; nutrient enrichment is presently measured by chlorophyll *a* response in the water column. Four basins carry the supplemental classification of NSW, including all waterbodies in the Tar-Pamlico, Neuse, and Chowan river basins, and the New River in the White Oak Basin (i.e., Onslow Bay Basin). Nutrient Sensitive Waters are subject to nutrient reduction strategies for wastewater discharge limitations (T15A NCAC 2B .0223), and different nutrient management strategies, including stormwater and agriculture, as well as riparian buffer protection (15A NCAC 02B .0700 - .0715) are in place to help reduce nutrient loads in these waterbodies.

Chowan Nutrient Sensitive Waters Strategy

Algal blooms and subsequent fish kills in the Chowan River led to its NSW classification in 1979, with a nutrient control plan in 1982 calling for a basinwide reduction of 35 percent TP and 20 percent TN. Implementation to reduce nutrient loads by point sources included limits of 1 mg/L TP and 3 mg/L TN, and the conversion of many municipal point source discharges to land application non-discharge systems resulted in improved water quality. The basin was a priority for implementation of agriculture BMPs, reducing nutrient runoff. Data through 2012 did not indicate chlorophyll *a* levels exceeding standards in the Chowan River. The nutrient measures taken did result in water quality improvements for almost 30 years. During that time period, an increase in SAV occurred, an indicator of improved water quality.

However, since about 2015, the Chowan River has experienced a resurgence in recurrent summer algal blooms and harmful algal bloom (HAB) activity. Harmful algal blooms are those that produce toxic or harmful effects on people, aquatic organisms, or birds. These HABs have occurred mainly south of Harrellsville (near AMS station D8356200) down to the Edenhouse Bridge (near AMS station D9490000). Many of the blue-green algal bloom species detected have been identified as potentially harmful, such as *Dilochospermum* and *Microcystis*. The blooms evaluated in 2019 were widespread throughout the Chowan River system but were most intense from Indian Creek (Dillard Millpond) downstream to Rockyhock Creek. These intense blooms were associated with elevated microcystin cyanotoxin concentrations. In response, DEQ has issued press releases “urging the public to avoid contact with the green or blue water in the Chowan River due to algal blooms that have lingered in the area”.

The central Chowan River near Colerain is tracked by DWR as a coarse gauge of productivity trends for the basin. For the current draft Chowan River Basinwide Plan, DWR compiled biannually tabulated five year statistics for this station beginning in 2016; the results are provided in Table 8.2.[12]

Table 8.2. Chowan River near Colerain, Chlorophyll *a* Integrated Report (IR) Summaries for IR 2016, 2018, IR 2020 (Draft) and IR 2022 (Partial; Missing Year 2020).

	Integrated Report Period			
	2016	2018	2020 (Draft)	2022* (Partial)
Mean Chl *a* Conc. (µg/L)	7.6	9.2	18.6	24.9
Number of Samples	50	45	45	33
Number > 40 µg/L Chl *a*	1	2	4	5
% > 40 µg/L	2	4.4	8.9	15.2
Integrated Report Date Window	2010-2014	2012-2016	2014-2018	2016-2020

*The data as of June 2020 for the partial 2022 IR is for 2016-2019. It is missing data for 2020. Final 2022 IR values will be different than what is presented here.

The DWR also analyzed longer-term temporal trends in nutrient loading for the current draft Chowan Basinwide Plan. While most nutrient parameters were generally unremarkable, a pronounced upswing was evident in Total Kjeldahl Nitrogen (TKN) concentrations, which is total concentration of organic nitrogen and ammonia, and loads since about 2000 across most watersheds. The Chowan River Colerain station results are provided in Figure 8.9 as illustrative of this TKN phenomenon, which is attributed to the organic nitrogen fraction.

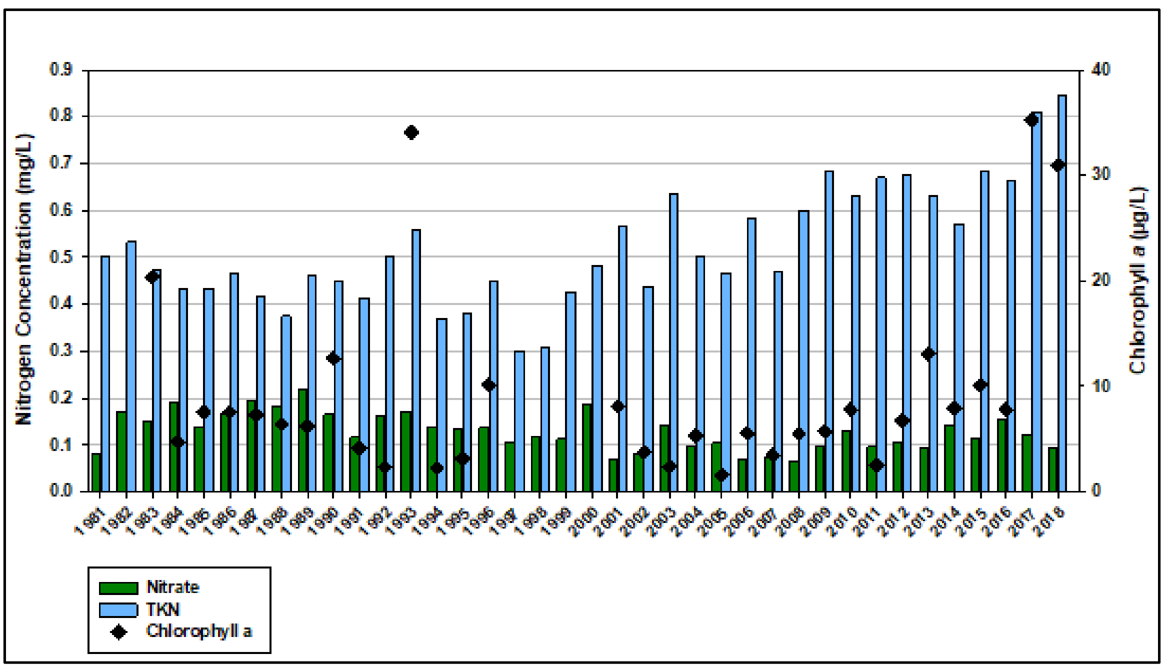

Figure 8.9. Annual Mean Total Kjeldahl Nitrogen (TKN), Nitrate and Chlorophyll *a* Concentrations at the Chowan River near Colerain Ambient Monitoring System Station (D8950000).

Tar-Pamlico Nutrient Sensitive Waters Strategy

The Tar-Pamlico Basin was classified as NSW in 1989. The basin has a TMDL goal to help meet chlorophyll *a* standards in the Pamlico estuary. Water quality data are assessed at Grimesland (O65600000) along the Tar River to determine whether or not nutrient levels in the Tar-Pam Basin are meeting standards, including reductions of 30 percent TN and not increasing TP from the 1991 baseline data. Trend analysis of the nutrient parameters data from 1991 to 2016 at Grimesland indicate an increase in TKN and TN flow-normalized loads (Figure 8.10). The organic nitrogen increase wholly offsets earlier decreases in nitrate loading. Interestingly, the flow-normalized TP loads showed a pronounced and unexplained rise and fall since 2010 (Figure 8.11).

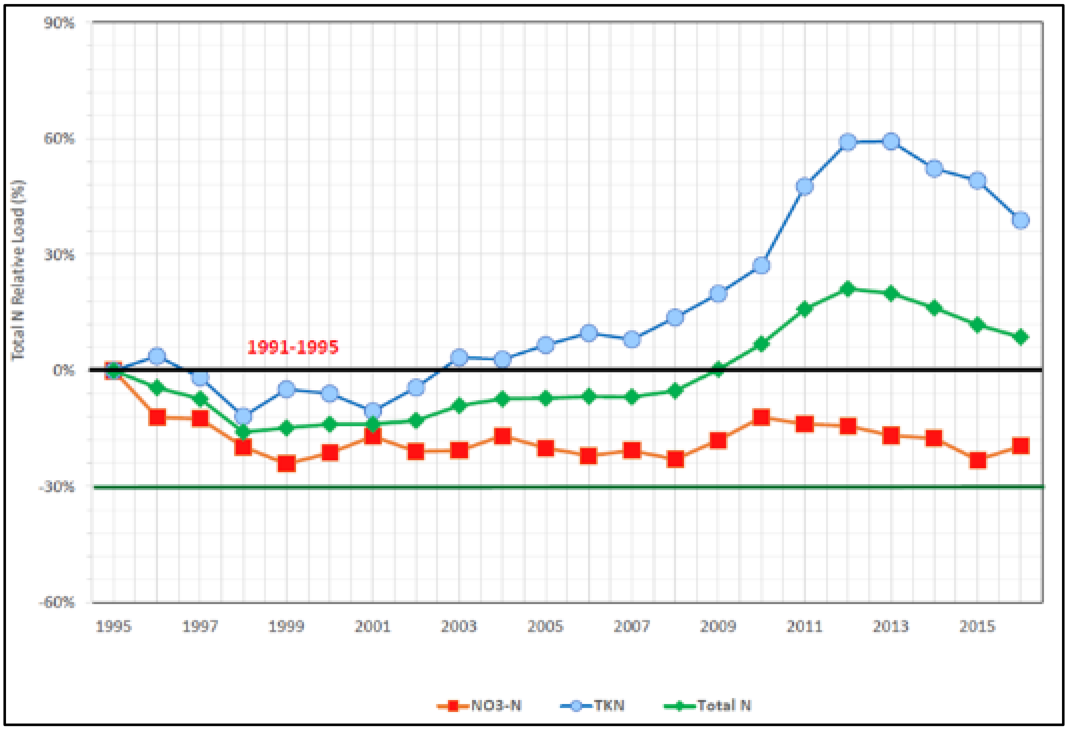

Figure 8.10. Flow-normalized nitrogen loads, at the Tar River at Grimesland Ambient Monitoring System Station (O65600000; Percent Change vs. 1991 to 1995).

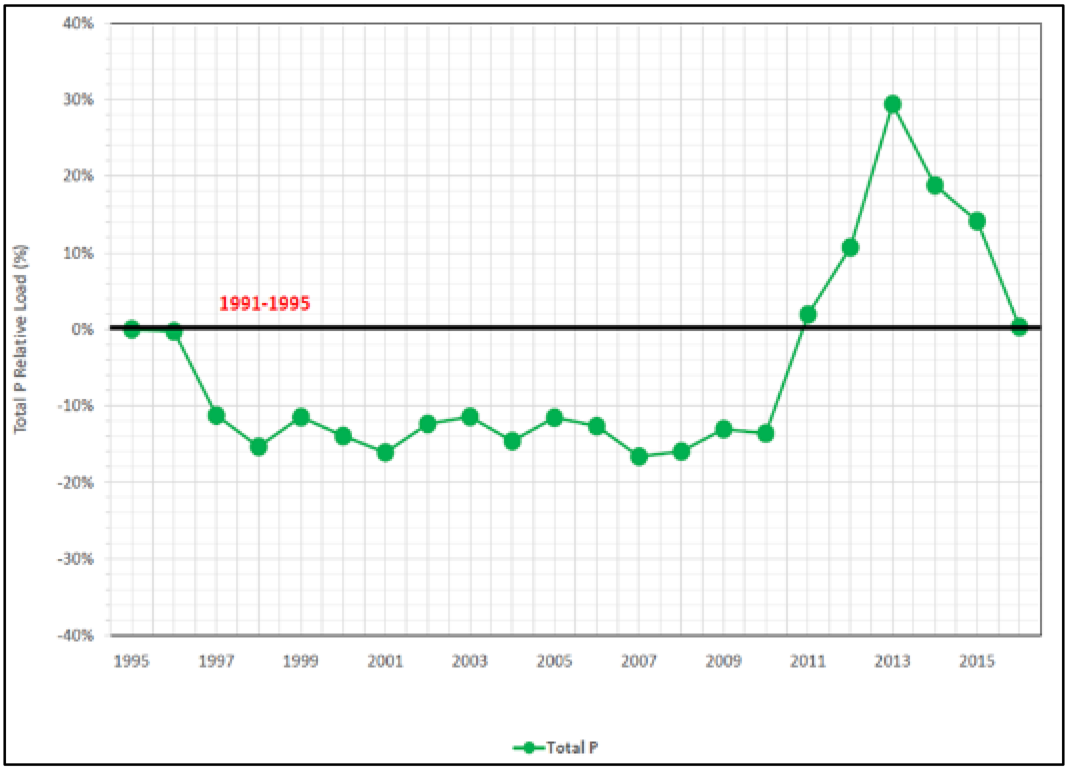

Figure 8.11. Flow-Normalized Total Phosphorus Loads, at the Tar River at Grimesland Ambient Monitoring System Station (O65600000; Percent Change vs. 1991 to 1995).

Nutrient loading is flow dependent, with levels falling below baseline only during extreme low flows. The Tar-Pamlico and Neuse river basins indicate a rise in TKN, specifically organic nitrogen. The USGS LOAD ESTimator (LOADEST) tool was used to estimate TN and TP annual load time series at the compliance point in the Tar-Pamlico basin (NCDWR unpublished). Load assessments are impacted by precipitation as seen in 1996 (Hurricane Fran), 1999 (Hurricane Floyd) and 2003 (unusually wet year). The annual load time series of the Tar-Pamlico River at Grimesland shows that the load fell below the targeted TMDL goal of 3,000,491 lbs/yr in 2007, 2008, 2011. The LOADEST TP annual load time series at the same station fell below the targeted TP load of not-to-exceed 396,832 lbs/yr in 2007, 2008, 2010 and 2011. These were drought years as seen by the low flow at the USGS gage station.

Neuse Nutrient Sensitive Waters Strategy

The Neuse River Basin was classified as NSW in 1988. Data for the Neuse River TMDL requiring a 30 percent decrease in TN load from the 1991-1995 baseline is assessed at Ft. Barnwell. Data from 1991-2011 indicate decreasing trends in TN, TP, NH_3 and NOx concentrations, and an increase in concentrations of TKN. Portions of the Neuse River Estuary remain impaired due to nutrient enrichment.

Like the Tar-Pamlico, the Neuse river basins indicate a rise in TKN, specifically organic nitrogen, and the LOADEST tool was used to estimate TN at the Neuse River compliance point. Load assessments are impacted by precipitation as seen in 1996 (Hurricane Fran), 1999 (Hurricane Floyd) and 2003 (unusually wet year). The annual load time series for the Neuse River at Fort Barnwell indicates that only during the low flow years of 2001, 2002, 2005, 2007, 2008, 2011 and 2012 does the TN load at the compliance point fall below the TMDL target of <6,750,000 lbs/yr of TN.

The DWR's longer-term trend analysis, normalizing for the effects of flow, shows an upswing in organic nitrogen loading very similar to the other coastal watersheds since around 2000, as captured in TKN values. Figure 8.12 illustrates this trend above the estuary near Fort Barnwell. Again, organic nitrogen loading increases wholly offset early nitrate decreases.

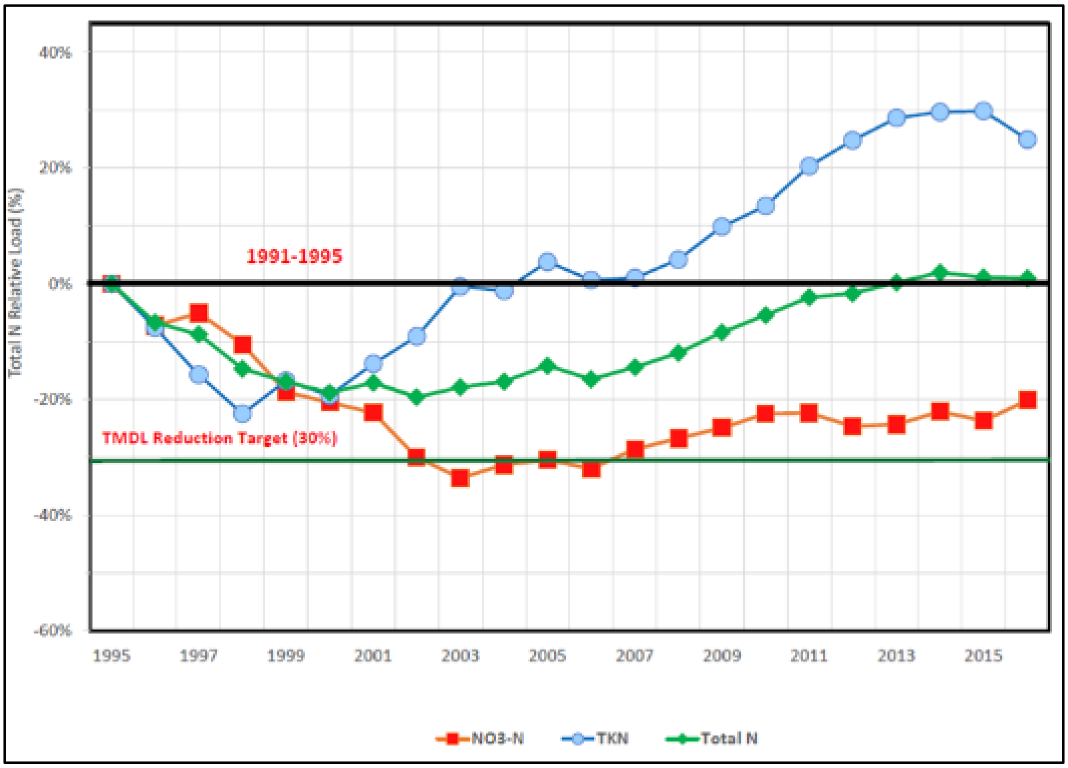

Figure 8.12. Flow-Normalized Nitrogen Loads, Neuse River at Fort Barnwell Ambient Monitoring System Station (Percent Change vs. 1991 to 1995).

New River Nutrient Sensitive Waters Strategy

The New River was classified NSW in 1991. The strategy to reduce point source nutrients to the upper estuary include: TP and TN limits on existing discharges, and monitoring for TN and TP for facilities without limits. It was recommended that no new discharges be permitted, and expansions of existing facilities only be allowed if there is no increase in loading of oxygen-consuming waste. Ambient water quality data through 2018 indicate nutrient enrichment is still a problem in the upper New River Estuary resulting in continued excursions of the chlorophyll *a* standard (Figure 8.13). The DWR White Oak River Basin Plan will be completed in 2021 and will include additional water quality assessments and possible recommendations to address nutrient contributions to the New River Estuary. The point source reduction only strategy has not resulted in sufficient nutrient reductions in the estuary. There is a need to understand the overall load reductions achieved from point sources and to initiate nutrient reductions from all nonpoint sources in the watershed.

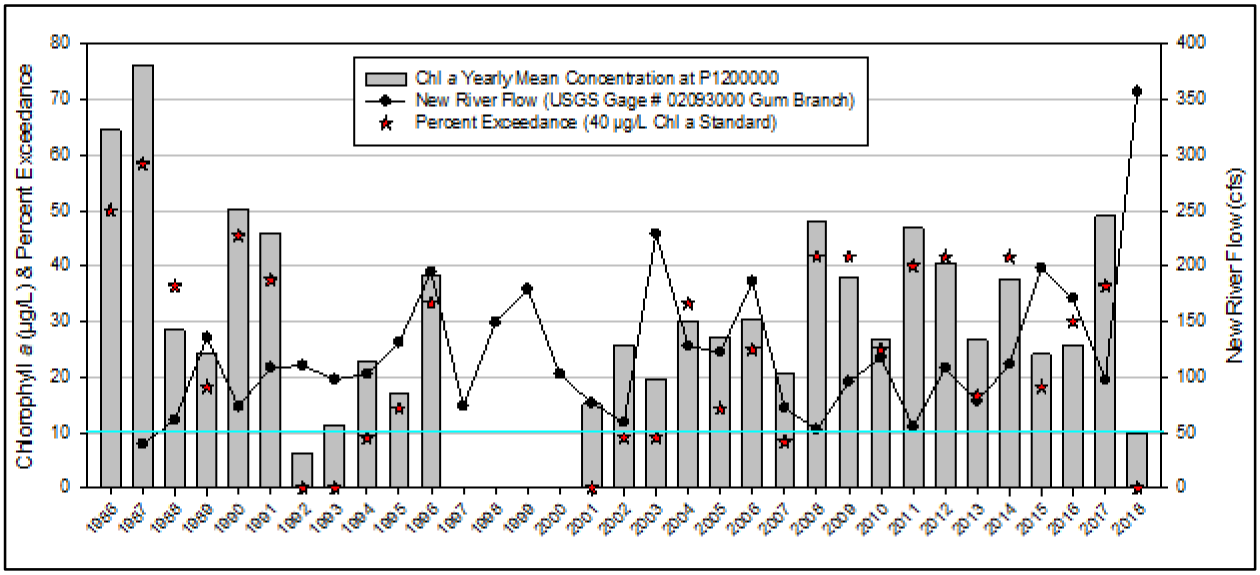

Figure. 8.13. Annual Mean Chlorophyll *a* Concentrations at the New River at Jacksonville US 17 Bridge Ambient Monitoring System Station (P1200000) with Corresponding Percent Exceedance of the 40 µg/L Chlorophyll *a* Standard and Annual Mean New River Flow (blue line denotes the 10 percent excursion level).

Nutrient Criteria Development Plan

The DWR is currently revisiting nutrient-related water quality criteria statewide in accordance with the Nutrient Criteria Development Plan (NCDP).[13] The plan was adopted in 2014 and last revised in 2019. The goal is to develop scientifically defensible criteria based on the linkage between nutrient inputs and the protection of designated uses. The first priority is to evaluate nutrient criteria for one specific water body within each of the three water body types. The development of these site-specific criteria will occur for the following water bodies in this order: 1) Reservoir/Lake - High Rock Lake, 2) Estuary – Chowan River/Albemarle Sound, and 3) River/Stream - Middle Cape Fear River.

Evaluation of nutrient-related criteria for the Chowan River and Albemarle Sound is currently underway. An initial evaluation process and identification of research needs were coordinated by the Albemarle-Pamlico National Estuary Partnership (APNEP) with a phase I report documenting those interim findings in 2018. The DWR, Scientific Advisory Council (SAC) members, and academic partners are currently filling those research gaps and continuing with the evaluation of nutrient criteria in this region. Both the APNEP phase I report and more recent input from the SAC have identified linkages between potential nutrient-related criteria and the protection of water column and submerged aquatic vegetation habitats. For additional information, see **Chapter 4. Submerged Aquatic Vegetation Protection and Restoration through Water Quality Improvements**.

Fish Kills and Algal Blooms

Algal blooms occur when specific environmental conditions are met, such as increased nutrient (nitrogen and phosphorus) concentrations, increased water temperature, prolonged solar radiation, and stagnant water flows. These conditions can cause algae to grow rapidly ("bloom"), thus creating negative effects in the system, including decreased DO, increased pH levels, and fish kills. They are aesthetically unappealing and if comprised of HABs, can impact health of humans and aquatic organisms. Not all algal blooms result in fish kills, and they are not the only cause of hypoxic conditions, however they are often related.

The number of reported algal bloom events along the NC coast varied annually from 2015 through 2019. During this time, the number of reported blooms reached a maximum in 2015 with 50 events and a minimum in 2017 with 25 events. Blooms are either reported by concerned citizens through the algal bloom reporting app or by DWR staff during routine monitoring. As with fish kills, investigations of bloom reports depend on the availability of field and laboratory staff to collect and analyze the samples. Even when an investigation does not occur, suspected bloom reports are recorded to help analyze overall trends in algal activity across the state.

Certain types of algae are also known to produce various taste and odor compounds as well as toxins, which can harm aquatic organisms, humans, and terrestrial animals that interact with the contaminated water (e.g. dog drinking, bird feeding). DWR has the capabilities to test for Microcystin, a common toxin produced by bloom-forming algae known as cyanobacteria. In particular, the Chowan River and portions of the Pasquotank River basin including the Albemarle Sound have experienced algal blooms since the 1970s. Blooms in these systems have increased in recent years, prompting DWR to begin evaluation of numeric nutrient criteria for the systems.

In 2019, DWR investigated 13 fish kill events across NC and provided reports under its investigation protocols (Figure 8.14).[14] In addition, 64 sightings of fish kills or algal blooms were reported by the public to DWR via its online app. Some public sightings were accounted for in DWR reports, but much of the public information remained unconfirmed by DWR staff members. Confirmed and unconfirmed activity was reported during the year in 12 of the state's 17 major river basins and in 35 counties. Fish kill information for the current year is posted weekly from June to November on the DWR fish kill website: https://ncdenr.maps.arcgis.com/apps/dashboards/7543be4dc8194e6e9c215079d976e716

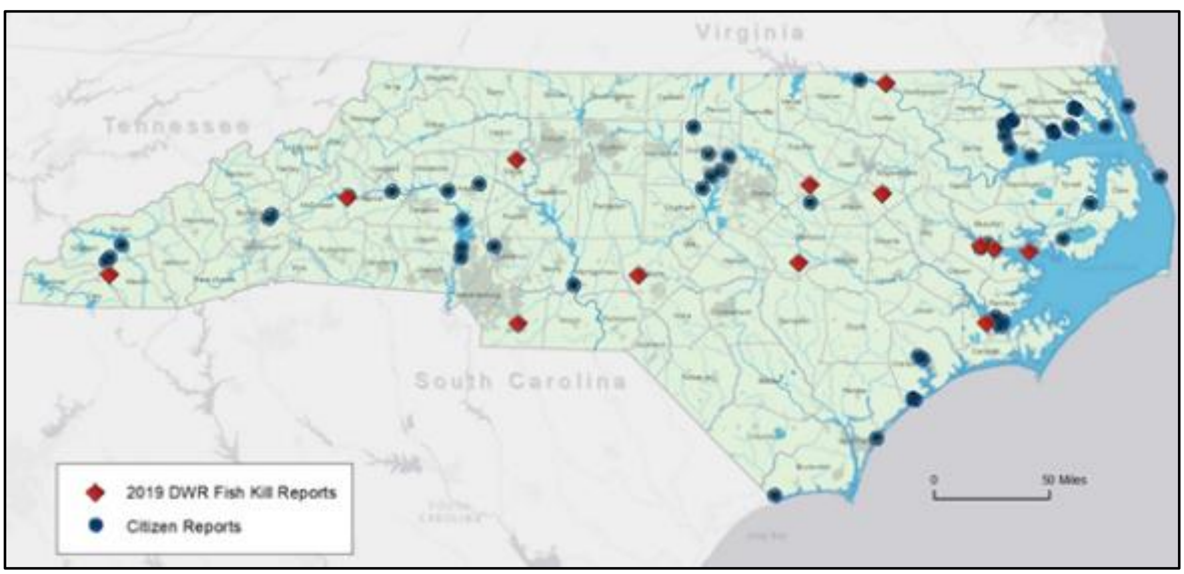

Figure 8.14. Fish kill activity reported to NC Division of Water Resources (DWR) in 2019.

During 2019, DWR received 65 reports of fish kill or algal bloom activity from the public often via the mobile app (Figure 8.14).[14] Developed in 2016, the app has proven useful in notifying regional staff of possible fish kill activity and as a means for initial contact with regards to dead fish and related algal bloom sightings. Public reports were reviewed and forwarded as soon as possible to the appropriate regional office staff for further investigation. Less available oxygenated waters, termed habitat compression, has resulted in increased fish mortality in NC, due to algal bloom events as well as hurricanes, potentially pushing fish into less suitable habitat conditions or making them more vulnerable to predation. Habitat compression may be associated with a 10-50 percent worldwide decline of pelagic predator diversity.[15] Increasing occurrence of hypoxic or anoxic waters is problematic for the coastal habitats and the organisms that call them home. Fish kill and algal bloom activity can be reported through the website or the Hotline #: (800) 858-0368.[16]

Shellfish Sanitation and Recreational Water Quality (SSRWQ)

Various sections of DMF, including Fisheries Management, Habitat Enhancement, and Shellfish Sanitation and Recreational Water Quality (SSRWQ), also collect water quality data within the CHPP regions. The SSRWQ is responsible for monitoring and classifying coastal waters as to their suitability for shellfish harvesting and monitoring and issuing advisories for coastal recreational swimming areas. The Shellfish Sanitation Program is conducted in accordance with the guidelines set by the Interstate Shellfish Sanitation Conference (ISSC) contained in the National Shellfish Sanitation Program (NSSP) Guide for the Control of Molluscan Shellfish Model Ordinance. The NSSP is administered by the U.S. Food and Drug Administration and is based on public health principles to prevent human illness associated with the consumption of molluscan shellfish. To fulfill this purpose, the SSRWQ section performs water sampling at 968 shellfish growing area (SGA) stations.

All SGAs are surveyed every three years to document all existing or potential pollution sources, to assess the bacteriological quality of the water, and to determine the hydrographic and meteorological factors that could affect water quality. Water samples are collected at least six times a year from each SGA and are tested for fecal coliform bacteria, which are an indicator that human or animal wastes are present in the water. In addition, reviews of SGA bacteriological data and pollution sources are conducted annually. This information is then used to classify each SGA as either approved, conditionally approved open/closed, restricted or prohibited. Approved areas are consistently open to shellfish harvest while prohibited areas are permanently closed (Table 8.3). Conditionally approved areas can be open to shellfish harvest under certain conditions. An area’s status can change quickly due to temporary closures after significant rainfall resulting in runoff, high results during routine bacteriological sampling, or an unexpected pollution event (ex. sanitary sewer overflow). For additional information, see **Chapter 7. Wastewater Infrastructure Solutions for Water Quality Improvement Issue Paper**. The area remains closed until water sampling indicates a return to acceptable bacteria levels. Restricted waters can be used for harvest at certain times as long as the shellfish are subjected to further cleansing before they are made available for consumption. For the most up to date closures, refer to the Shellfish Sanitation Temporary Closure Public Viewer.[17]

Table 8.3. Classification of shellfish growing areas (SGAs) in acreage from 2007-2020 from the NC Division of Marine Fisheries' (DMF's) Shellfish Sanitation and Recreational Water Quality Section (SSRWQ).

	Open Area		Closed Area		
Year	Approved	Conditionally Approved Open	Conditionally Approved Closed	Prohibited	Restricted
2007	1,732,069	45,699	11,775	429,475	NA
2008	1,734,339	43,184	12,793	428,685	NA
2009	1,734,192	43,281	12,788	428,739	NA
2010	1,734,938	43,054	12,552	428,414	NA
2011	1,734,938	43,054	12,552	428,414	NA
2012	1,732,888	44,599	12,708	428,835	NA
2013	1,733,069	44,649	11,834	429,531	NA
2014	1,733,155	44,261	11,827	429,796	NA
2015*	1,418,373	43,849	11,739	745,169	NA
2016	1,416,960	44,785	12,008	745,597	NA
2017	1,414,709	44,425	12,209	747,759	NA
2018**	1,414,525	44,122	11,859	729,761	18,933
2019	1,414,877	43,217	12,721	730,550	20,260
2020	1,416,179	42,857	10,138	735,791	18,658

*314,710 acres administratively closed on 2/4/15 due to budget cuts and office closures.

**First year of use for Restricted classification. Previously these waters were included in our Prohibited classification.

While changes in acreage closed to shellfish harvest is one useful indicator of water quality trends, the number and duration of temporary harvest closures due to contamination associated with rainfall and stormwater runoff is another useful metric to examine (Table 8.4). These temporary closures can have a significant impact on the shellfish industry due to their unpredictability and length, and the number of closure days has been trending upwards in recent years due to increasing annual rainfall and coastal development. For example, research on the upper Newport River, which is home to several popular natural shellfish reefs as well as a number of shellfish aquaculture leases, has found that bacteria levels in this portion of the river often exceed the standards for safe shellfish harvesting following rain events totaling one inch or more within a 24-hour period. The current management plan for this area dictates that this portion of the river be closed following these rain events, and it remains closed until sampling indicates that bacteria levels have once again fallen to below safe harvest standards. Over the last five years (2016-2020), this portion of the river has been closed for an average of 168 days per year, although in 2016, 2018, and 2020, the Newport River watershed received well above average annual rainfall, and in these three years, portions of the harvesting area were closed for 198, 232, and 194 days, respectively.

Table 8.4. Temporary Shellfish Growing Area (SGA) closures due to rainfall in the upper Newport River based on estimated annual rainfall in Morehead City (MHC).

Year	Est. Annual Rainfall - MHC	Number of Closures	Total Days Closed	Avg. Closure Duration (Days)
2010	55.74	6	75	13
2011	48.34	6	58	10
2012	56.41	10	91	9
2013	54.69	10	141	14
2014	71.65	12	136	11
2015	82.47	11	163	15
2016	70.13	11	198	18
2017	52.47	12	109	9
2018	85.97	14	232	17
2019	51.99	12	107	9
2020	68.65	11	194	18

The NC Recreational Water Quality Program began testing coastal waters in 1997 with the mission to protect the public health by monitoring the quality of NC's coastal recreational waters and notify the public when bacteriological standards for safe bodily contact are exceeded. The coastal waters monitored include the ocean beaches, sounds, bays, and estuarine rivers. The program tests water at 204 swimming sites approximately weekly during the swimming season from April through September. Similar to the Shellfish Sanitation Program these samples are tested for bacteria; general water quality parameters are also recorded. Instead of fecal coliforms, these samples are tested for *Enterococcus* bacteria, an indicator organism found in the intestines of warm-blooded animals. While it will not cause illness, its presence is correlated with organisms that can and it survives better in the higher salinities associated with the ocean beaches.

Additional monitoring for water quality and swimming advisories are collected by NGOs and academics along the coast. For example, Sound Rivers publishes weekly water alerts (https://soundrivers.org/swimguide/) and the Lower Cape Fear River program publishes yearly reports on the water quality of the Lower Cape Fear Watersheds (https://uncw.edu/cms/aelab/lcfrp/).

Other Water Quality Monitoring

The DMF has over 20 different sampling programs with coastwide spatial cover. Most DMF programs were already collecting abiotic environmental variables, such as temperature, salinity, DO, depth, sediment and bottom composition. In 2009, DMF modified monitoring programs to ensure those parameters were being accurately recorded, and to collect additional habitat metrics such as secchi depth, and shoreline alteration. While these are point in time measurements, they can be useful for looking at long-term averages. For example, DMF program data, along with the AMS data and data provided by Wildlife Resources Commission (WRC), were used to make interpolated salinity maps for high, mean, and low flow years from 1988 to 2017 (Figures 8.15-8.24). High and low flow years were determined if the yearly mean was +/- two standard deviations from the time period mean.[18]

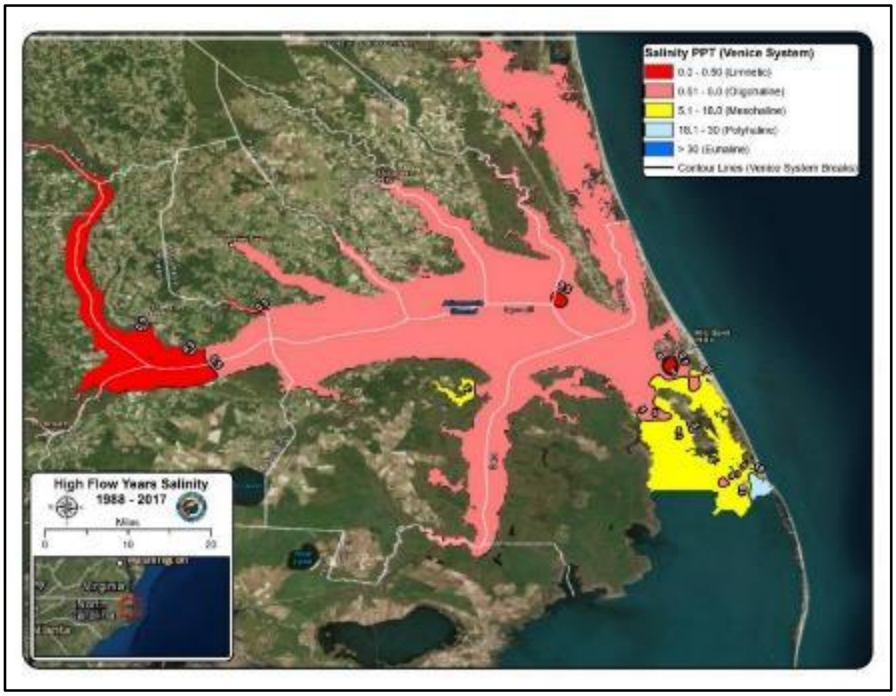

Figure 8.15. Interpolated salinity maps for high flow years for Coastal Habitat Protection Plan (CHPP) Region 1, 1988-2017.

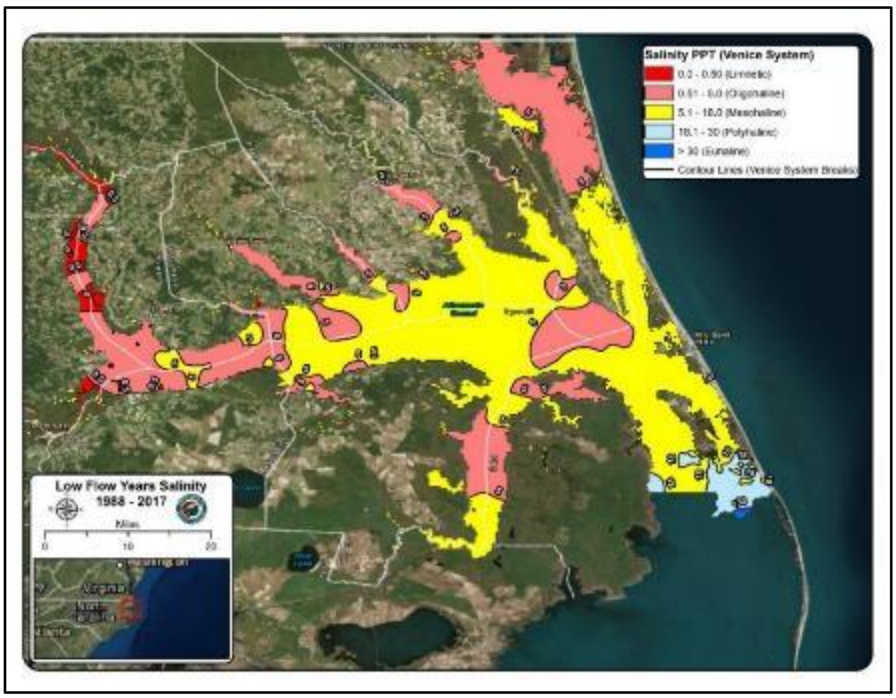

Figure 8.16. Interpolated salinity maps for low flow years for Coastal Habitat Protection Plan (CHPP) Region 1, 1988-2017.

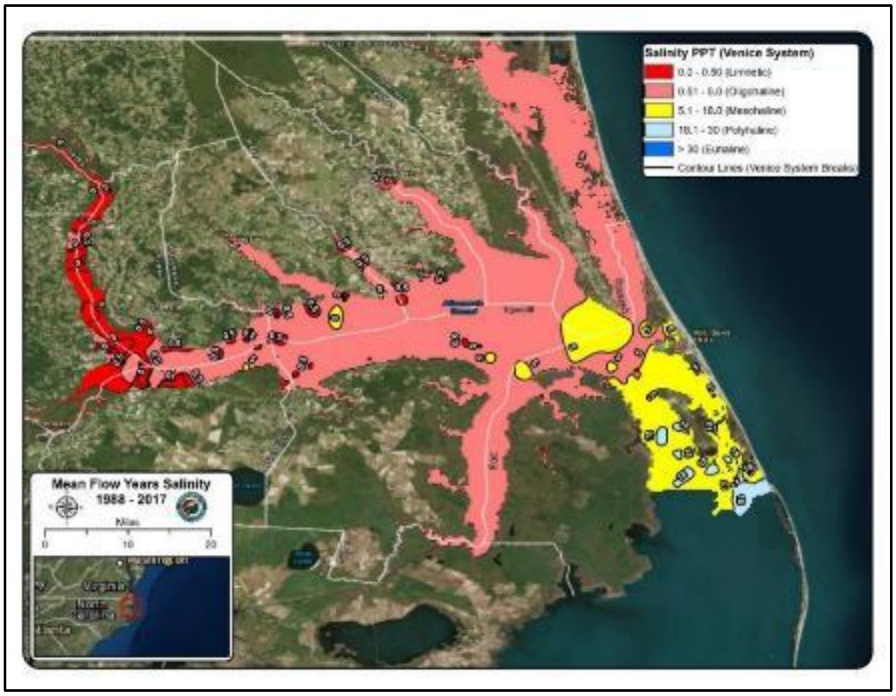

Figure 8.17. Interpolated salinity maps for mean flow years for Coastal Habitat Protection Plan (CHPP) Region 1, 1988-2017.

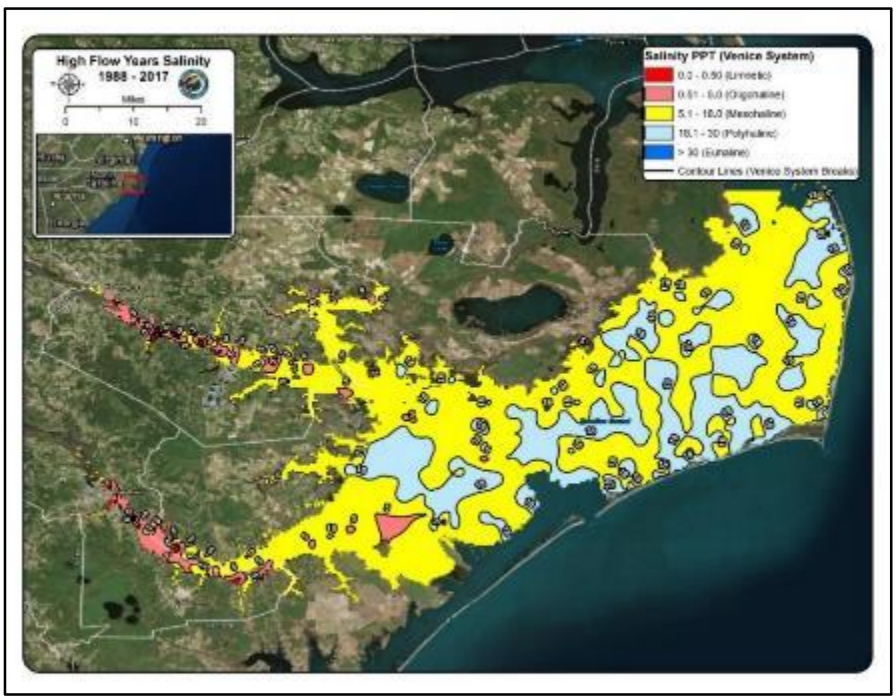

Figure 8.18. Interpolated salinity maps for high flow years for Coastal Habitat Protection Plan (CHPP) Region 2, 1988-2017.

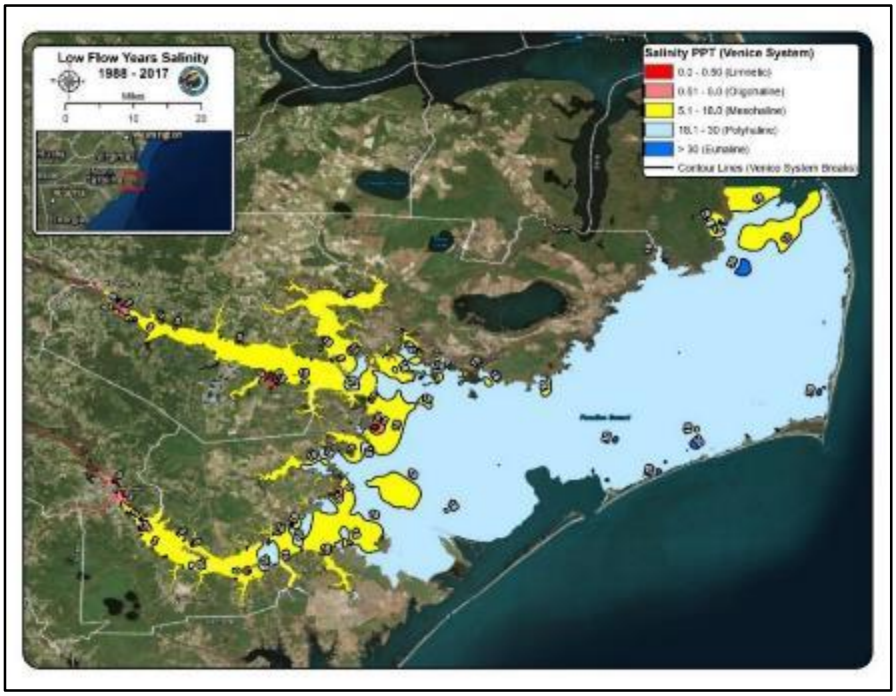

Figure 8.19. Interpolated salinity maps for low flow years for Coastal Habitat Protection Plan (CHPP) Region 2, 1988-2017.

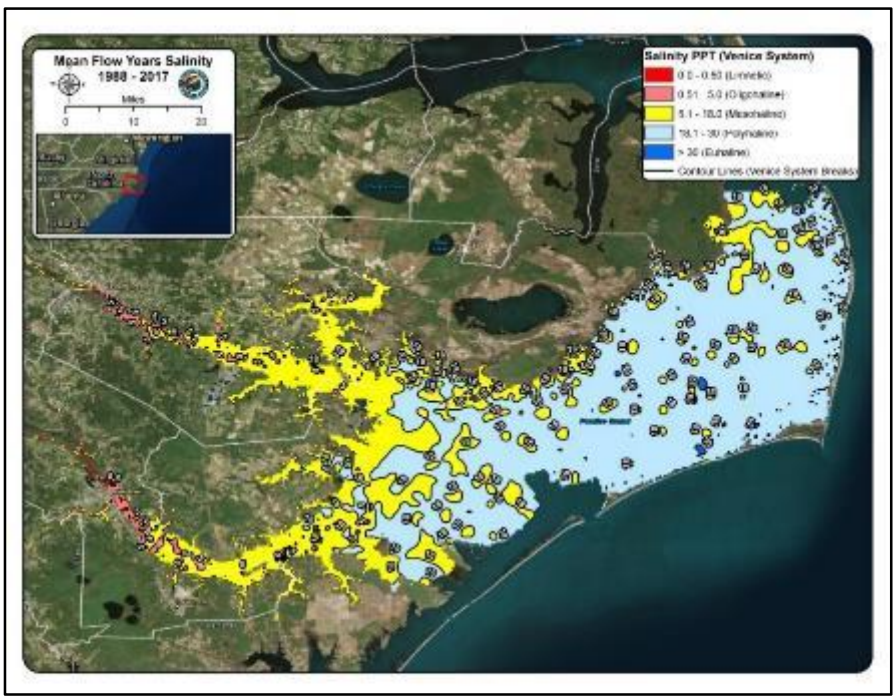

Figure 8.20. Interpolated salinity maps for mean flow years for Coastal Habitat Protection Plan (CHPP) Region 2, 1988-2017.

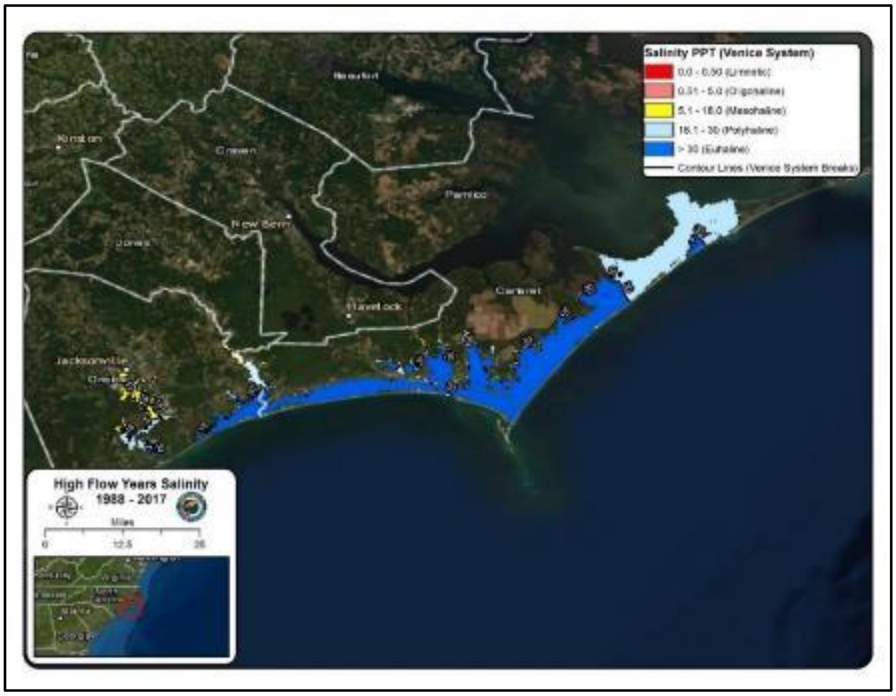

Figure 8.21. Interpolated salinity maps for high flow years for Coastal Habitat Protection Plan (CHPP) Region 3, 1988-2017.

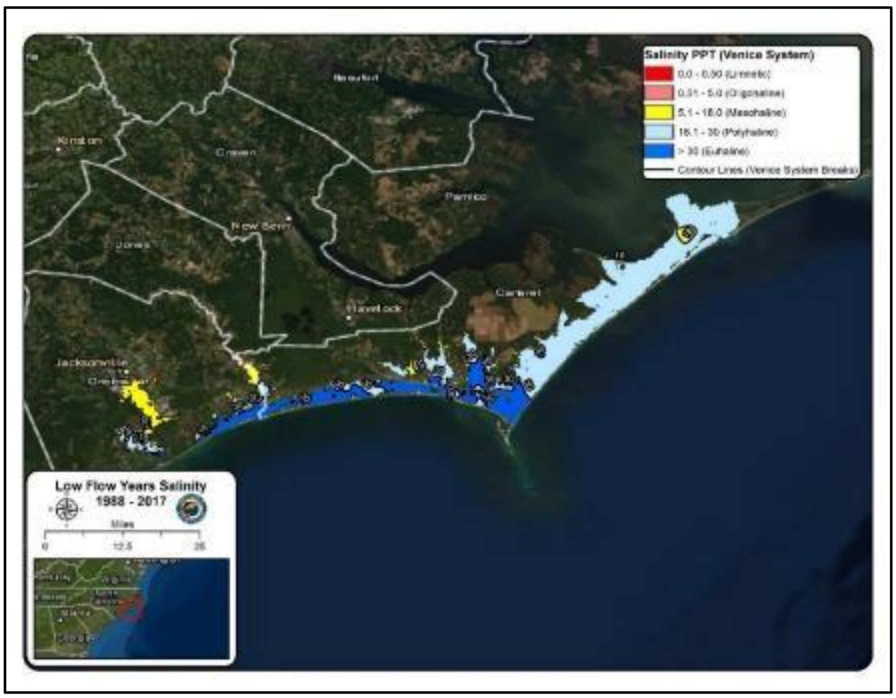

Figure 8.22. Interpolated salinity maps for low flow years for Coastal Habitat Protection Plan (CHPP) Region 3, 1988-2017.

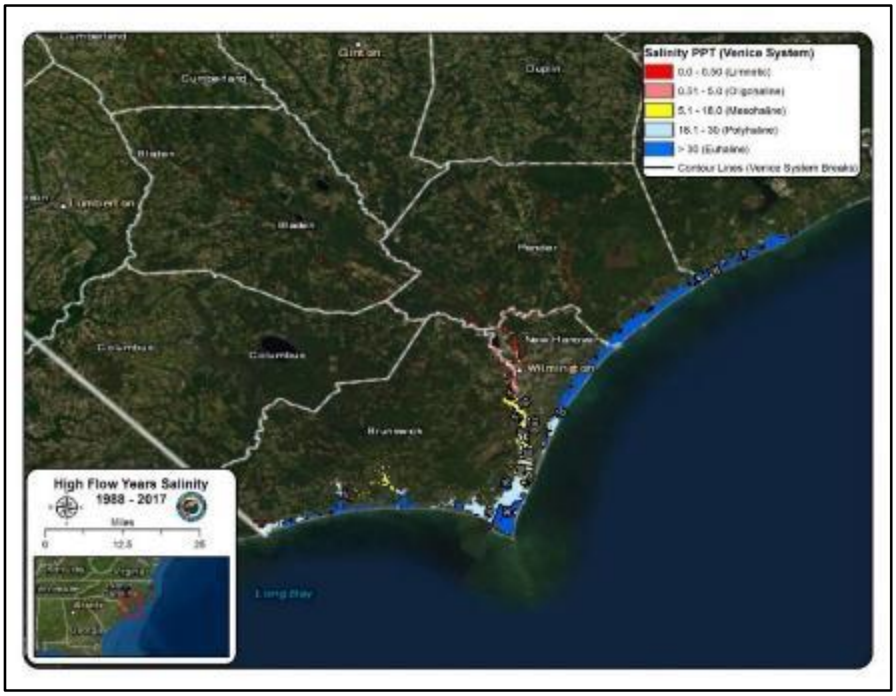

Figure 8.23. Interpolated salinity maps for high flow years for Coastal Habitat Protection Plan (CHPP) Region 4, 1988-2017.

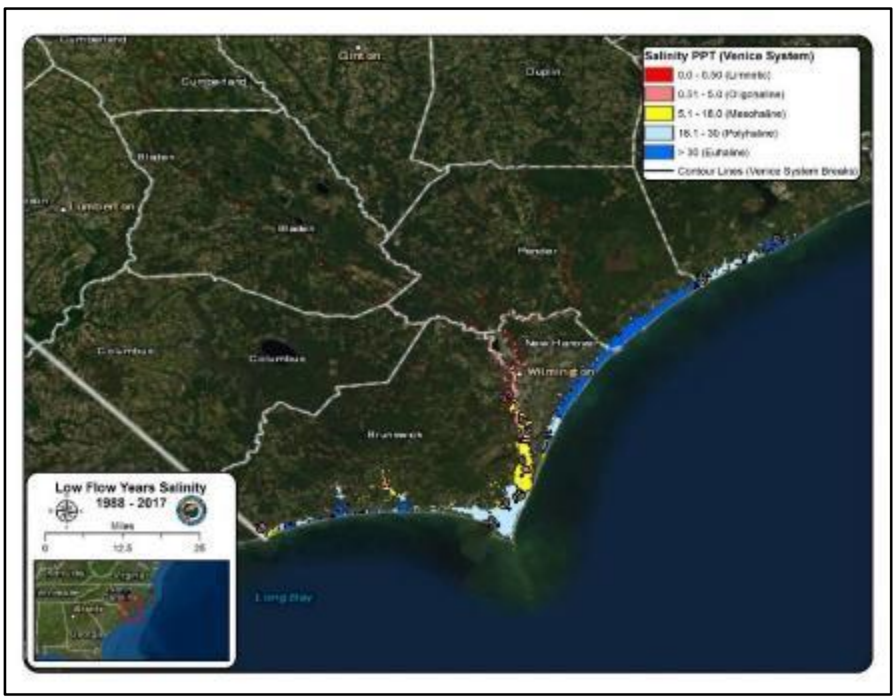

Figure 8.24. Interpolated salinity maps for low flow years for Coastal Habitat Protection Plan (CHPP) Region 4, 1988-2017.

The DMF has used continuous water quality data sondes for the management of several programs. The Spotted Seatrout Cold Stun Monitoring Program, beginning in October 2015, deploys a coastwide array of 80 Onset HOBO Water Temperature Pro V2 loggers to collect water temperature data. The objective of this array is to monitor water temperatures that trigger cold stun events for spotted seatrout. Data loggers are deployed at 52 stations throughout the coastal rivers and creeks of NC to detect changes in water temperature throughout the year. If water temperatures in at least two spotted seatrout cold stun management areas met the triggers of 3°C for 24 hours and/or 5°C for eight consecutive days, and the DMF director closed the spotted seatrout commercial and recreational fishery temporarily. Data sondes that record additional parameters, including DO, have been used for river herring management and to assist with site selection and monitoring of oyster sanctuaries. These sondes require extensive maintenance however, and were discontinued in 2021 due to insufficient staff time and funds.

Shell Bottom

Shell bottom in NC has seen dramatic changes since colonial times when oyster reefs were so extensive along the coast they were a hazard to navigation.[19] For the purposes of the CHPP, shell bottom is defined as estuarine intertidal or subtidal bottom composed of surface shell concentrations of living or dead oysters (*Crassostrea virginica*), hard clams (*Merceneria merceneria*), and other shellfish and is limited to estuarine waters.[2,3] Healthy oyster reefs are vital to the estuarine ecosystem, providing three dimensional structure for fish and important ecological services such as particulate and nutrient filtration, shoreline stabilization, and benthic habitat for fish, shrimp, and other invertebrates.[3,20,21,22,23] While oysters provide the major fish habitat from shellfish, hard clams and bay scallops contribute shell material to shell hash.

The eastern oyster occupies a unique position in the estuaries of NC because its colonization of estuarine bottom creates a productive habitat and the animal itself is harvested as a food item. Due to the combined effects of habitat destruction, overfishing, disease, and deteriorated water quality, eastern oyster populations have experienced tremendous declines world-wide, particularly within subtidal oyster reefs that occur along the mid-Atlantic coastline of the United States.[24, 25, 26, 27] A 2011 study that examined the condition of oyster reefs across 144 bays and 44 ecoregions estimated that 85 percent of oyster reefs have been lost globally.[28] Additionally, this study found that most of the world's remaining wild capture of native oysters (> 75 percent) comes from just five ecoregions in North America, yet the condition of reefs in these ecoregions is poor at best, except in the Gulf of Mexico. The historical losses of oyster reefs in NC, primarily in the Pamlico Sound region, has been summarized and historical distributions have been documented.[2, 3, 27, 29, 30, 31, 32, 33]

Commercial Harvest

The need for extensive shellfish management in NC has been recognized since the 1947 NC General Assembly authorized the Division of Commercial Fisheries to conduct a rehabilitation program to restore the declining oyster fishery. Although the Fisheries Management Section of DMF has been actively managing these shellfish resources since 1964, it has done so with limited resource base information. In NC, commercial oyster landings from public bottom have been variable, but have been in general decline for most of the past century.[33] The decline in the oyster stock was likely initiated by poor harvesting practices resulting in overharvest and low spawning stock biomass, but compounded by habitat disturbance, pollution, and biological and environmental stressors including disease and storm damage. In the past decade, landings from private bottom aquaculture have increased significantly due to more interest in shellfish aquaculture industry with oyster aquaculture landings eclipsing wild harvest landings for the first time in 2017. Yet, there are insufficient data to conduct a traditional stock assessment for the eastern oyster in NC;[34] therefore, population size and rate of removals from the wild oyster population are not known.

Management Monitoring

Shellfish management by DMF includes monitoring and managing natural harvest (cultch planting program), enhancing oyster habitat to increase larval recruitment (oyster sanctuary program), shellfish habitat mapping, and shellfish leasing. Monitoring is conducted in association with management activities. Supplement A to the Oyster FMP Amendment 2 established the trigger for closing areas to mechanical harvest to protect the resource and habitat, which was approved to continue under Amendment 4 of the Oyster FMP.[31, 33] Sampling efforts targets areas and oyster rocks that are fished by commercial oystermen, directly before the opening of and throughout the mechanical harvest oyster season. Only areas where commercial oystermen are working are sampled to determine localized depletion and address habitat protection.

Sampling began in September 2009 with pre-season oyster sampling using mechanical harvest methods. Sampling has consistently continued with a target of 10 sites per management area, throughout the four management areas. More intensive sampling is conducted if samples are near the trigger percentage. Sampling continues after an area is closed to assess the possibility of reopening. Sampling is discontinued when it is apparent that reopening is not likely to occur. This sampling is not intended for use as a species abundance index, but instead to reflect the conditions of the habitat during the open oyster mechanical harvest season to determine closure of an area as a protection measure. The 2012 to 2019 mechanical harvest season trigger sampling revealed low abundance and percent legal in all mechanical harvest management areas.

Oyster Sanctuaries and Cultch Planting Programs

To combat the generally declining trends of shellfish, shellfish habitat restoration efforts have been occurring throughout NC's estuarine waterbodies for over half a century. The Shellfish Rehabilitation Program, which began in 1947, has contributed to the restoration of depleted oyster grounds through the planting of cultch material and seed oysters.[35, 36, 37] State-sponsored cultch plantings began in 1915. The primary purpose of DMF cultch planting (Program 610) and oyster sanctuary (Program 611) programs is oyster fishery enhancement, which provides temporary habitat value as well as fishery benefits. These efforts also increase the co-benefits of the ecosystem services oysters provide, including water filtration and shoreline protection against waves and storms. As of 2020, DMF has constructed 15 oyster sanctuaries in the Pamlico Sound, totaling 396 permitted acres, and annually deploys several thousand bushels of cultch rock strategically throughout the estuaries of NC (Figure 8.25). Since standard record keeping began in 1980, the Habitat Enhancement section of DMF has planted over 12 million bushels of cultch.

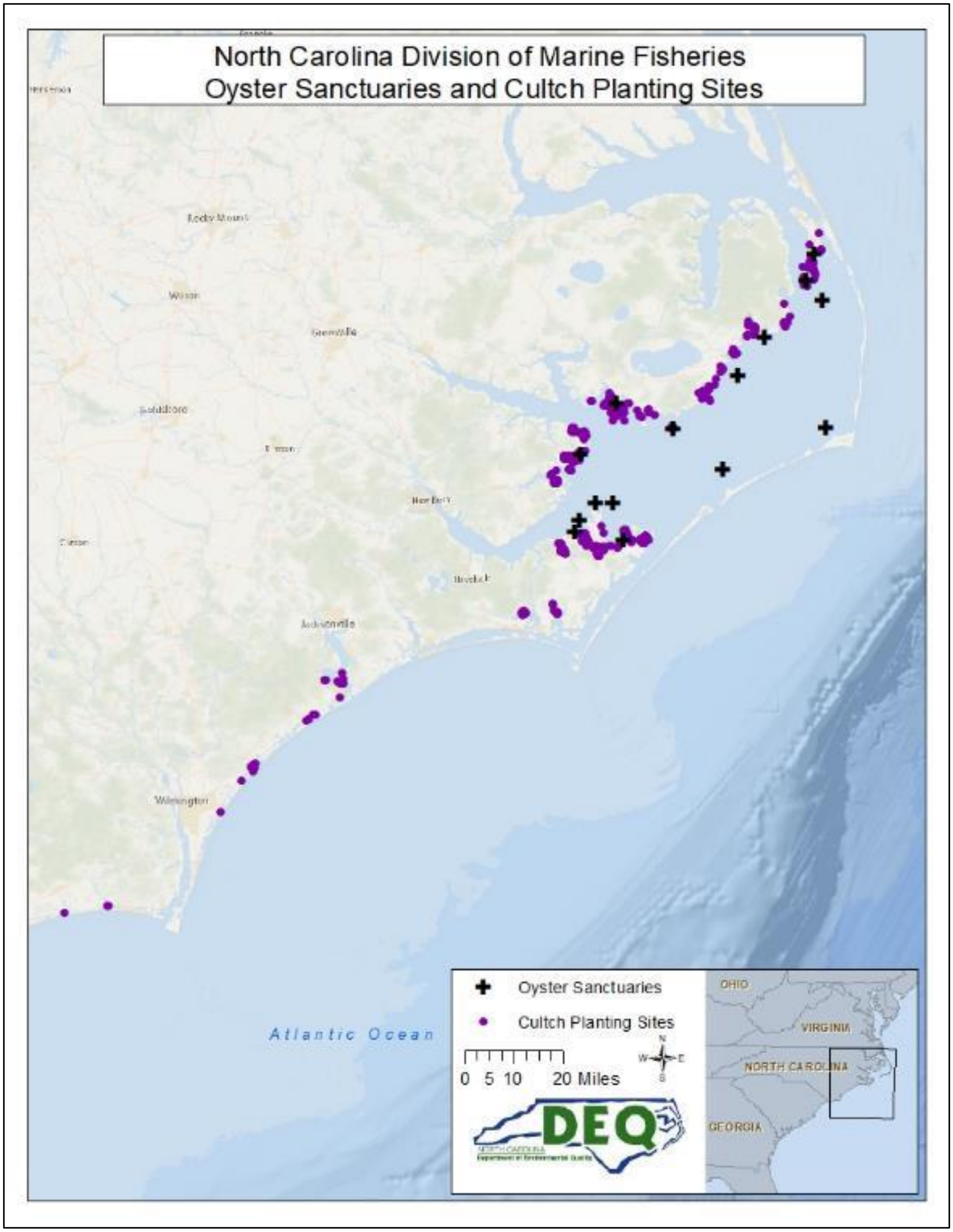

Figure 8.25. The NC Division of Marine Fisheries (DMF) Oyster Sanctuaries and Cultch Planting Sites.

Monitoring occurs at both oyster sanctuaries and cultch reefs to evaluate reef performance and potential for contribution to the state's fishery and benthic oyster habitat. Generally, oyster sanctuaries are evaluated annually for oyster densities, size frequencies, and population demographics via quadrat material extraction and subsequent oyster measurements (Figure 8.26). Cultch sites are sampled annually for three years, post-construction, using a mechanical dredge survey to track oyster settlement and growth towards suitable densities of harvestable oysters (figure 8.27). Both reef types are additionally evaluated opportunistically via side scan to provide a metric of material persistence and reef rugosity through time. However, monitoring and site selection methods are currently evolving.

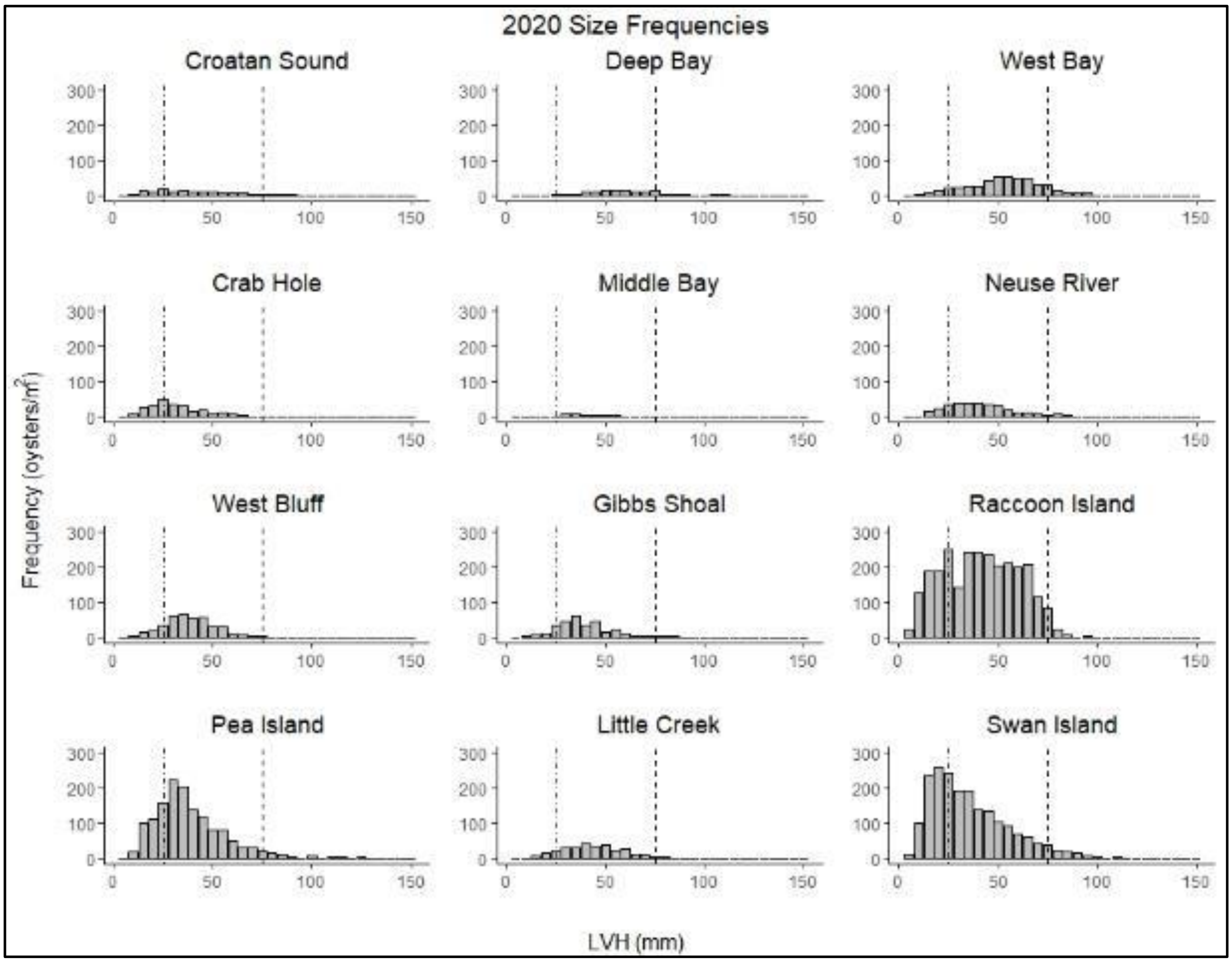

Figure 8.26. The NC Division of Marine Fisheries (DMF) 2020 Oyster Sanctuary sampling length frequency data. Data has consolidated into 5mm bins. Dashed and dotted vertical lines indicate recruit maximum (25mm) and legal minimum (75mm) oyster size class, respectively.

North Carolina oyster sanctuaries have demonstrated the capacity to maintain higher population density and greater abundance of large, fecund oysters in comparison to non-protected oyster reefs. Based on data collected from 2011-2014, oyster sanctuaries generally become "established" as oyster recruitment densities start high (~200 oysters/m^2), then generally settling around a density that can be supported within the body of water the reef is located. Many of the sanctuaries within the network are considered stable, with annual fluctuations reflecting recruitment and survival year to year. Newer oyster sanctuaries like Raccoon Island and Swan Island are still exhibiting larger densities of live spat, sublegal, and legal oysters (Figure 8.26). When comparing no-take to unprotected oyster reefs, there is a striking decrease in densities. Oyster Sanctuary mean density is approximately 72 oysters/m^2 which is eight times higher mean oyster recruitment in natural reefs and approximately 12 times higher in cultch-planted reefs. The average reproductive potential per square meter of oyster sanctuaries can also be up to 30 times greater than unprotected reefs.[38, 39, 40, 41] Integrating total reef area and reproductive potential per square meter, oyster sanctuaries potentially provide 26.2 percent of all larvae to the system while accounting for 1 percent of reef area. The most recent sampling of the state's oyster sanctuary network indicated a wide distribution of oyster sizes were present on each reef sampled in 2020, with densities well above the 10 oysters/m^2 established by researchers as successful.[42] Variability between sanctuaries results from a variety of factors including location, proximity to both major freshwater and saltwater sources, and age of the reef among other drivers of oyster survival and persistence.

Oyster recruitment (spatfall) on newly deployed cultch can be an indicator of potential larval availability and recruitment potential. The spatfall data (Program 610) from cultch planting sites over the past 31 years indicate a decline in maximum spatfall relative to similar surveys in the 1950s.[32, 35] During the 1990s, average oyster spat per shell (spatfall) in Pamlico Sound declined considerably, representing less than half the number of spat per shell recorded during the 1980s.[30] From the late 1990s to the mid-2010s, spatfall showed a pronounced increase, surpassing 1980s spat densities. However, for the past five years there has been an overall declining trend, with the 2018 and 2019 indices being the lowest, falling below the 10-year average (annual average number of spat across all sampling sites).[43]

Figure 8.27. The NC Division of Marine Fisheries (DMF) Cultch Sampling Program 610 annual spatfall (average # of oyster spat/cultch unit) in northern and southern coastal waters (southern district includes from Newport River to South Carolina), 1980-2020.

From 1980 to 2000, annual spatfall from north and south of Newport River has been somewhat variable from year to year, but generally stable overall (Figure 8.27). In the early 2000s, both regions saw increases in spatfall densities. The southern region continued to see increased spatfall densities through the mid-2010s and has been declining since. The northern region densities peaked around 2010 and have also been declining, but has since seen a slight increase in the last few years. Some researchers suspect that subtidal oysters in Pamlico Sound are becoming spawner-limited, while others attribute the decline to stress and mortality from infectious diseases and poor water quality, including hypoxia due to nutrient rich runoff following intense rain and storm events, or physical damage from fishing activities.[30, 44, 45]

Extent in North Carolina

Estuarine Bottom Mapping Program

The first large scale shellfish bottom survey in NC waters was done by the US Navy in the late 1880s, but was limited to the larger estuaries.[29] This survey was targeted solely toward oysters and potential oyster producing grounds and found that nearly 700,000 acres of potentially productive oyster bottom existed in NC. Although it was quite an extensive survey, it is now outdated. In the early 2000s, a study revisiting this surveyed oyster bottom found many once-productive high profile reefs consisted of low profile shell rubble, low density reefs, or buried reef.[46] It was also reported that the larger solid reefs had less live oysters, attributed to the ease of locating the reefs by fishermen. Anecdotal information and DMF sampling have noted that sediment has buried oysters in some locations that were once abundant, including the northeast side of the Neuse River, and Newport and North rivers.

In 1978, DMF began a shellfish bottom survey of the commercial shellfish-producing waters in the coastal area. The purpose of the survey is to locate and map shellfish-producing areas and to delineate potentially productive benthic shellfish habitats. The objectives include: 1) summarizing existing shellfish information and evaluate shellfish producing habitat based on environmental and utilization criteria; 2) surveying shellfish habitats to obtain baseline data and production potential information; 3) defining and delineating existing and potential shellfish habitat through a series of resource maps; and 4) providing for better utilization of the estuarine resources through improved information for management and increased public awareness.

A preliminary survey of the Newport River system was conducted from November 1980 to April 1981. Newport River was selected as a testing ground for survey techniques because of its close proximity to sampling headquarters, its diverse fisheries and environmental characteristics, and the pressing need for resource base data in that system. From this survey it was deemed that the mapping techniques and survey methods proved acceptable, and in 1987 the estuarine waters were divided into areas based on shellfish habitat suitability criteria. In 1989, based off the pilot study data, the Shellfish Resource Mapping Proposal was introduced which led to the creation of the Estuarine Bottom Mapping Program 635 in 1990. From 1990 to 2019, this program mapped the shellfish habitat of the coast of NC from Roanoke Sound to the South Carolina line. Along with the delineation of bottom types, gross determinations of shellfish concentrations within productive bottom types were determined through a stratified random sampling program. In 2019, the mapping of 567,691 acres of the intended 589,071 acres of coastal waters delineated into 24 bottom type strata was completed (Tables 8.5 and 8.6 and Figures 8.28-8.30).

Table 8.5. The NC Division of Marine Fisheries (DMF) Estuarine Bottom Mapping Program 635 acreage and percentages of estuarine bottom habitat mapped, 1990-2019.

CHPP Regions*	Area Intended for Mapping	Acres Mapped**	Percent Mapped	Total Mapped Shell Bottom		Mapped Subtidal Shell bottom		Mapped Intertidal Shell Bottom	
				Acres	Percent	Acres	Percent	Acres	Percent
Albemarle Sound to Northeastern Coastal Ocean (1)	64,810	64,918	101%†	615	2.79%	571	3.42%	44	0.82%
Pamlico Sound System (2)	278,477	286,890	103%†	4,290	19.45%	4,213	25.21%	77	1.44%
White Oak River Basin (3)	200,697	170,973	85%	10,543	47.79%	9,123	54.60%	1,420	26.53%
Cape Fear River Basin (4)	45,088	44,820	99%	6,612	29.97%	2,801	16.76%	3811	71.21%
Total	589,071	567,601	96%	22,060		16,709	75.74%	5,351	24.26%

*Oregon Inlet acres included in Albemarle Region; Ocracoke Inlet acres included in White Oak River Basin Region.
**Excludes areas that cannot be mapped due to military prohibitions, leases, bridge restrictions, depths, hazards.
† More than intended was mapped.

Photo Credit: Nolen Vinay

Table 8.6. The NC Division of Marine Fisheries (DMF) Estuarine Bottom Mapping Program 635 mapped estuarine bottom habitat acreage by strata, coastwide and by Coastal Habitat Protection Plan (CHPP) regions, 1990-2019.

	Acreage				
Strata Description	Coastwide	Region 1	Region 2	Region 3	Region 4
Subtidal Soft Vegetated Shell (A)	0	0	0	0	0
Subtidal Soft Vegetated w/o Shell (B)	1,290	1	1,142	147	0
Subtidal Soft Non-vegetated Shell (C)	1,134	2	570	551	11
Subtidal Soft Non-vegetated w/o Shell (D)	62,806	1,248	43,462	14,748	3,347
Subtidal Firm Vegetated Shell (E)	333	0	1	331	0
Subtidal Firm Vegetated w/o Shell (F)	2,228	63	548	1,617	0
Subtidal Firm Non-vegetated Shell (G)	10,046	144	3,044	4,898	1,960
Subtidal Firm Non-vegetated w/o Shell (H)	68,807	7,131	26,925	26,336	8,415
Subtidal Hard Vegetated Shell (I)	128	4	9	115	0
Subtidal Hard Vegetated w/o Shell (J)	89,064	1,142	72,520	15,402	0
Subtidal Hard Non-vegetated Shell (K)	5,067	421	588	3,228	830
Subtidal Hard Non-vegetated w/o Shell (L)	281,907	53,637	136,180	86,002	6,088
Intertidal Soft Vegetated Shell (M)	12	0	0	0	12
Intertidal Soft Vegetated w/o Shell (N)	42	0	0	25	16
Intertidal Soft Non-vegetated Shell (O)	65	0	0	22	43
Intertidal Soft Non-vegetated w/o Shell (P)	750	0	0	146	604
Intertidal Firm Vegetated Shell (Q)	459	0	4	388	67
Intertidal Firm Vegetated w/o Shell (R)	27,191	76	97	13,606	13,413
Intertidal Firm Non-vegetated Shell (S)	2,905	0	1	402	2,502
Intertidal Firm Non-vegetated w/o Shell (T)	4,386	2	6	209	4,170
Intertidal Hard Vegetated Shell (U)	220	5	3	137	74
Intertidal Hard Vegetated w/o Shell (V)	2,647	779	1,276	418	174
Intertidal Hard Non-vegetated Shell (W)	1,617	39	69	471	1,038
Intertidal Hard Non-vegetated w/o Shell (X)	4,496	225	444	1,772	2,055
Total	567,601	64,918	286,890	170,973	44,820

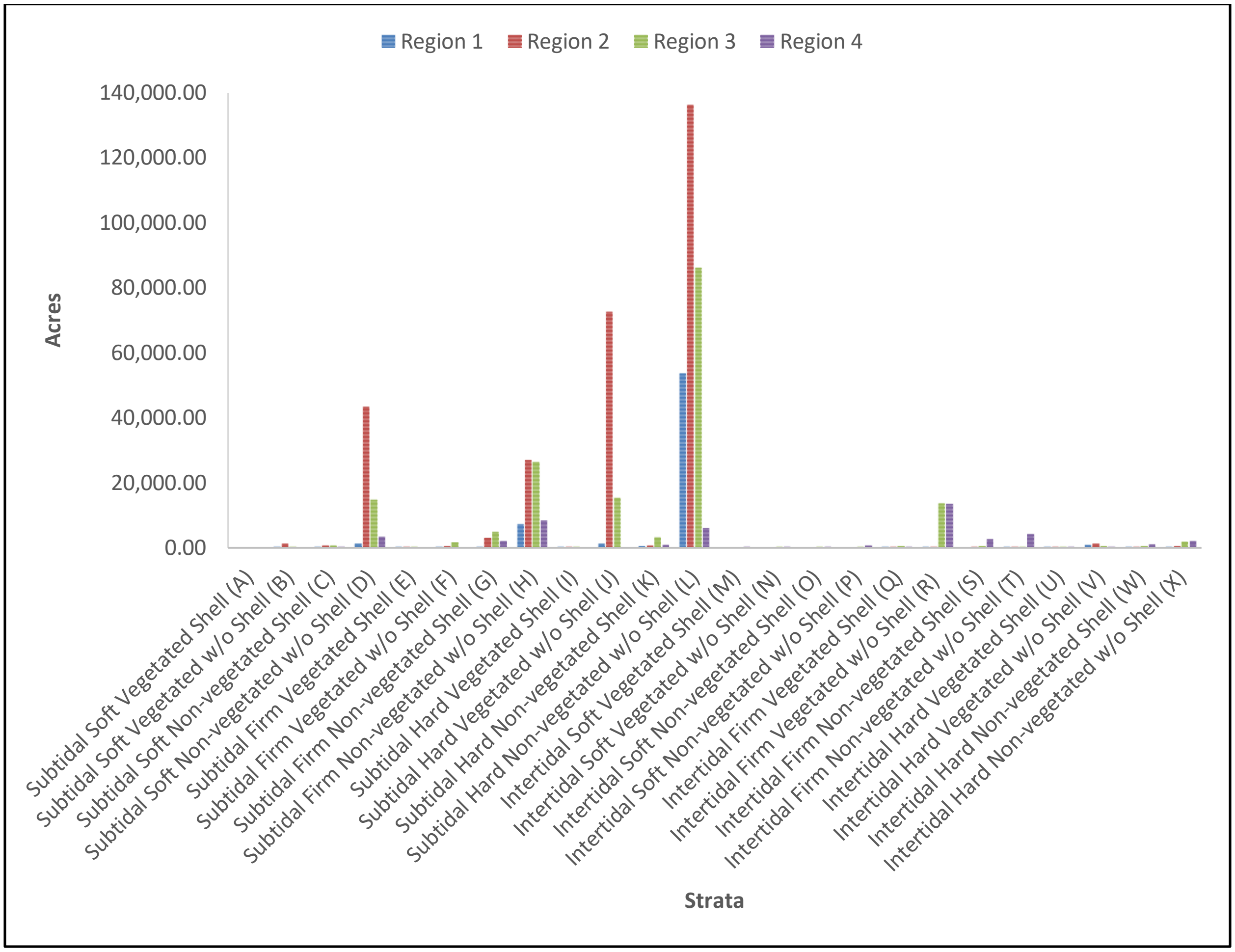

Figure 8.28. The NC Division of Marine Fisheries (DMF) Estuarine Bottom Mapping Program 635 mapped estuarine bottom habitat acreage by strata and Coastal Habitat Protection Plan (CHPP) regions, 1990-2019.

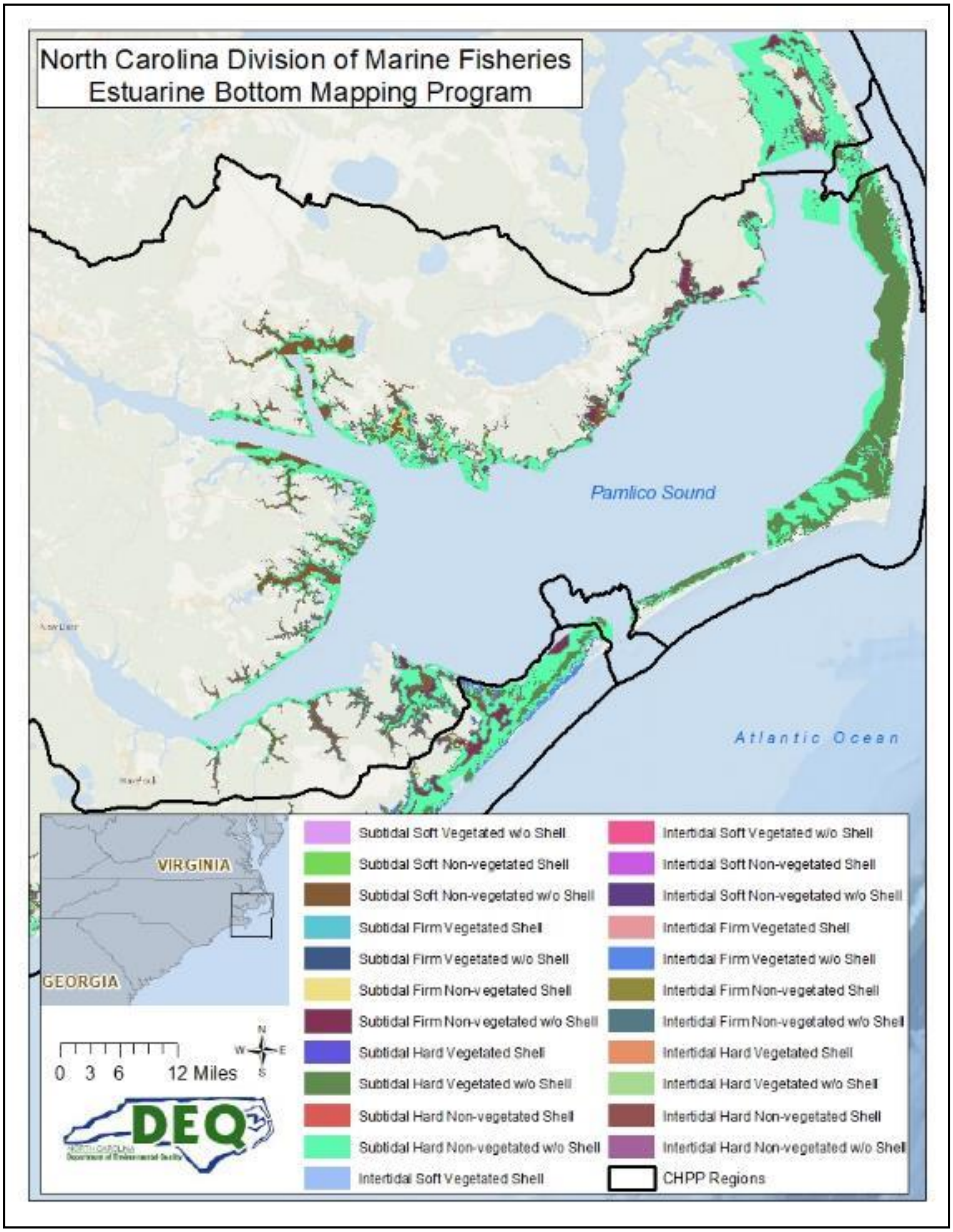

Figure 8.29. The NC Division of Marine Fisheries (DMF) Estuarine Bottom Mapping Program 635 strata for the northern Coastal Habitat Protection Plan (CHPP) regions 1, 1/2, and 2, 1990-2019.

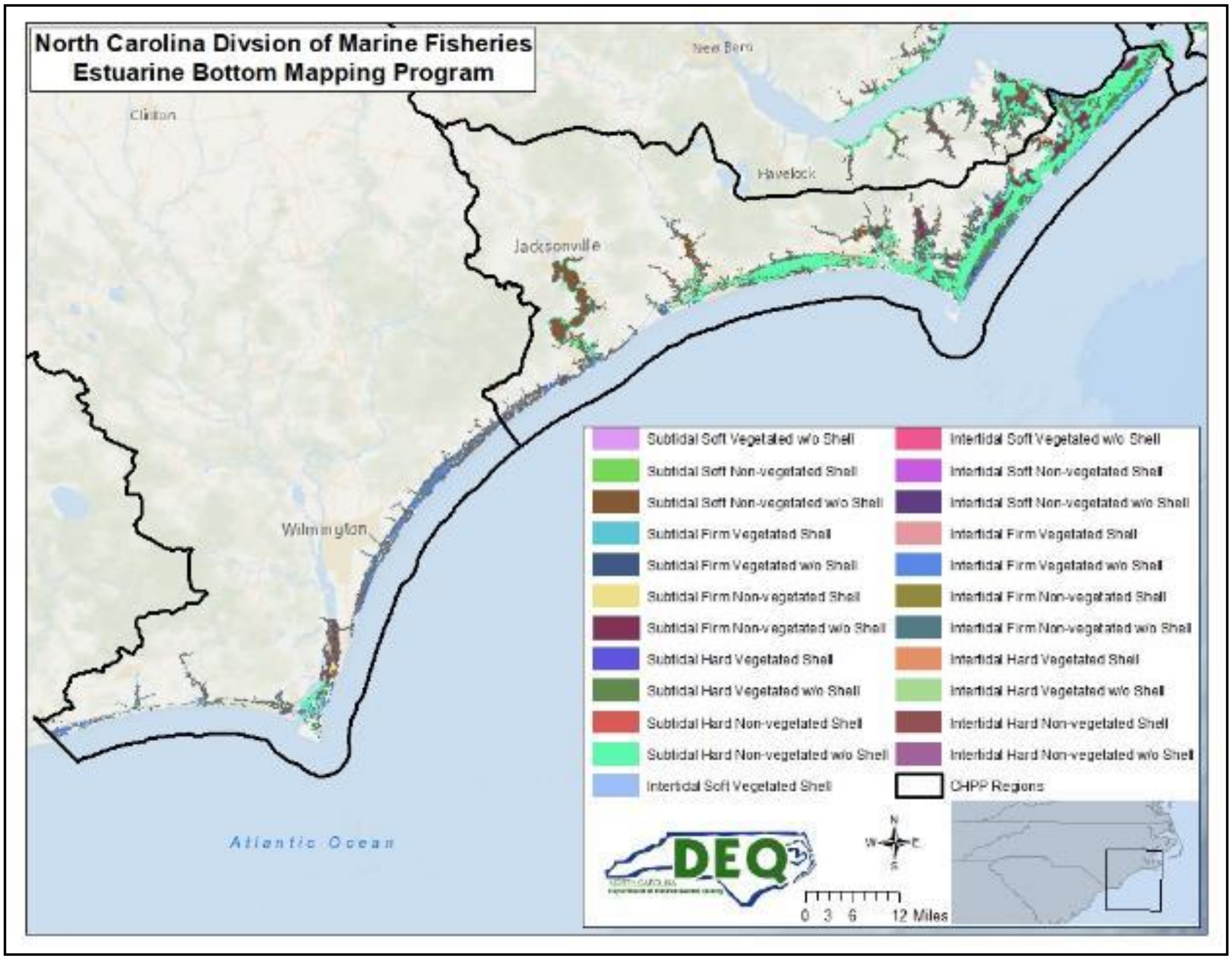

Figure 8.30. The NC Division of Marine Fisheries (DMF) Estuarine Bottom Mapping Program 635 strata for the southern Coastal Habitat Protection Plan (CHPP) regions 3, 3/4, and 4, 1990-2019.

After the strata were mapped, sampling was done to quantify the number of eastern oysters, hard clams, and bay scallops present. Since mapping and sampling took place over a long time series, data should be interpreted only as general trends of the density and distribution of shellfish resources across the coast of NC over the last 30 yrs. Comparing shellfish densities across CHPP regions, the White Oak (Region 3) and Cape Fear River (Region 4) river basins had the highest densities for oysters (20.11 oysters/m^2 and 38.95 oysters/m^2, respectively) and clams (0.63 clams/m^2 and 1.21/m^2, respectively) with the White Oak (Region 3) having the highest density for scallops (0.09 scallops/m^2).

The rest of the data presented will focus on eastern oysters since they comprise the majority of shell bottom. To determine the highest density oyster strata coastwide and across CHPP regions, weighted means (oysters/m^2) were examined (Table 8.7 and Figure 8.31). The Subtidal Soft Vegetated Shell (A) strata does not exist anywhere along the coast due to photosynthetic restraints of vegetation. Across the coast and in every region, Subtidal Firm Non-vegetated Shell (G), Subtidal Hard Non-vegetated Shell (K), Intertidal Firm Non-vegetated Shell (S), and Intertidal Hard Non-vegetated Shell (W) strata were significantly different, with the exception of Intertidal Firm Non-vegetated Shell (S) which did not occur in the Albemarle Sound to Northeastern Coastal Ocean (Region 1; p<0.05).

Table 8.7. The NC Division of Marine Fisheries (DMF) Estuarine Bottom Mapping Program 635 eastern oyster weighted means (oysters/m^2) by strata, coastwide and by Coastal Habitat Protection Plan (CHPP) region, 1990-2019.

	Weighted Mean of Oysters (per m^2)				
Strata Description	Coastwide	Region 1	Region 2	Region 3	Region 4
Subtidal Soft Vegetated Shell (A)	-	-	-	-	-
Subtidal Soft Vegetated w/o Shell (B)	0.09	1.40	0.00	0.00	-
Subtidal Soft Non-vegetated Shell (C)	4.75	19.74	3.28	3.21	5.94
Subtidal Soft Non-vegetated w/o Shell (D)	0.08	0.20	<0.01	0.12	0.00
Subtidal Firm Vegetated Shell (E)	7.49	3.45	0.72	12.81	-
Subtidal Firm Vegetated w/o Shell (F)	1.01	0.17	<0.01	1.93	-
Subtidal Firm Non-vegetated Shell (G)	*9.56	*11.26	*6.85	*11.82	*8.05
Subtidal Firm Non-vegetated w/o Shell (H)	0.21	*0.38	0.07	0.22	0.18
Subtidal Hard Vegetated Shell (I)	4.04	12.97	3.33	1.80	-
Subtidal Hard Vegetated w/o Shell (J)	0.05	0.06	0.08	0.04	-
Subtidal Hard Non-vegetated Shell (K)	*16.11	*9.53	*11.60	*19.00	*33.53
Subtidal Hard Non-vegetated w/o Shell (L)	0.04	0.02	0.02	0.02	0.23
Intertidal Soft Vegetated Shell (M)	16.51	-	-	-	23.44
Intertidal Soft Vegetated w/o Shell (N)	4.49	-	-	0.00	4.15
Intertidal Soft Non-vegetated Shell (O)	*41.33	-	-	*55.79	19.50
Intertidal Soft Non-vegetated w/o Shell (P)	0.01	-	-	0.00	0.01
Intertidal Firm Vegetated Shell (Q)	*37.84	3.25	1.53	*34.68	*51.10
Intertidal Firm Vegetated w/o Shell (R)	*2.29	*4.11	0.00	*0.98	*4.69
Intertidal Firm Non-vegetated Shell (S)	*43.23	-	*5.15	*35.74	*46.81
Intertidal Firm Non-vegetated w/o Shell (T)	0.51	0.00	0.00	0.45	0.57
Intertidal Hard Vegetated Shell (U)	*50.23	7.76	4.95	*50.12	*59.41
Intertidal Hard Vegetated w/o Shell (V)	1.29	0.34	<0.01	2.63	0.00
Intertidal Hard Non-vegetated Shell (W)	*91.23	*2.32	*12.89	*101.27	*108.46
Intertidal Hard Non-vegetated w/o Shell (X)	0.01	0.04	<0.01	<0.01	0.00

*significantly different from overall weight mean p<0.05

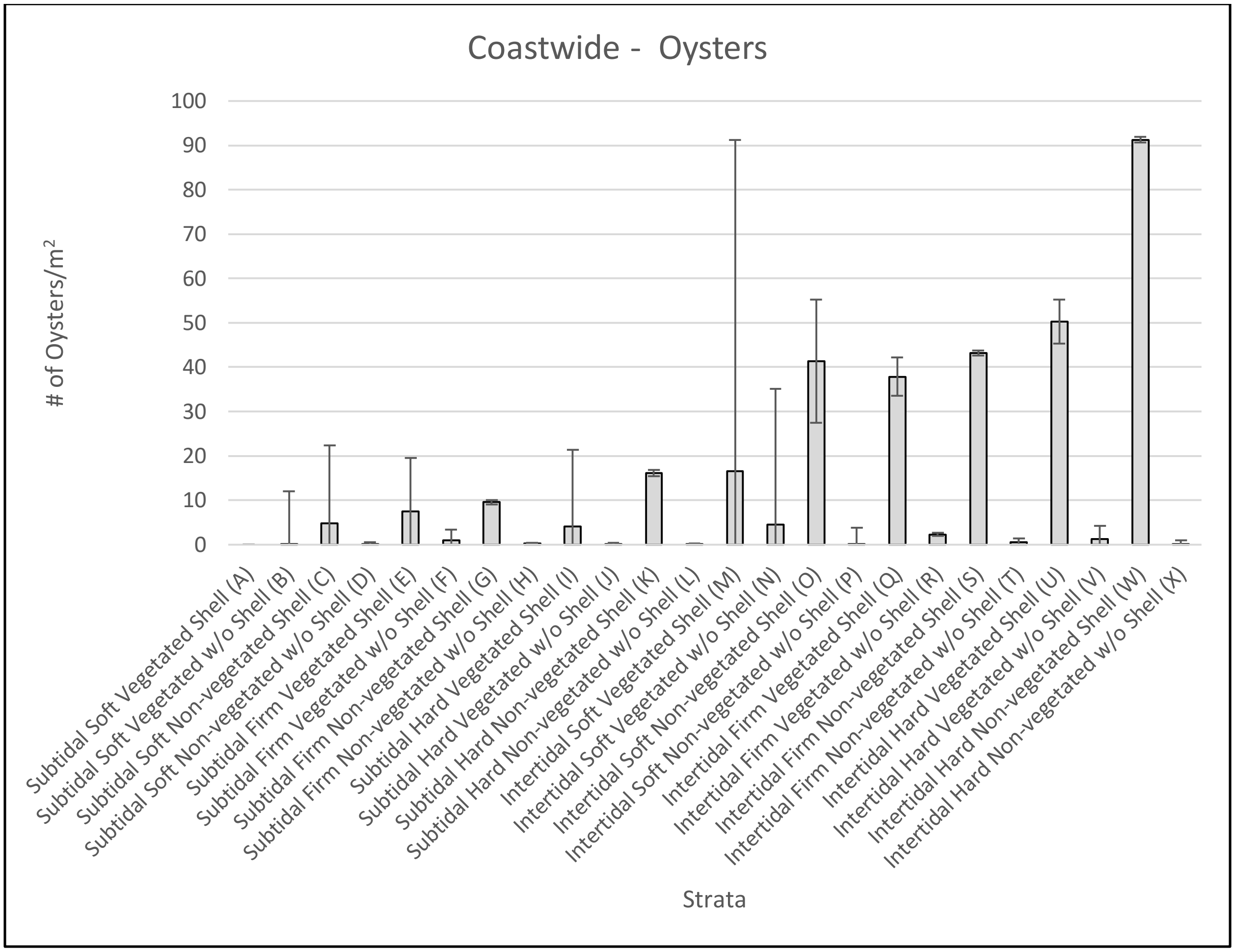

Figure 8.31. The NC Division of Marine Fisheries (DMF) Estuarine Bottom Mapping Program 635 coastwide eastern oyster weighted mean densities (# oysters/m^2) by strata, 1990-2019.

Across the NC coast, the top five highest density strata were: Intertidal Hard Non-vegetated Shell (W; 91.23 ± 0.64 oysters/m^2), Intertidal Hard Vegetated Shell (U; 50.23 ± 4.93 oysters/m^2), Intertidal Firm Non-vegetated Shell (S; 43.23 ± 0.56 oysters/m^2), Intertidal Soft Non-vegetated Shell (O; 41.33 ± 13.88 oysters/m^2), and Intertidal Firm Vegetated Shell (Q; 37.84 ± 4.34 oysters/m^2). These five strata were significantly different ($p<0.05$; Table X.6 and Figures X.32-X.33). The majority of the oyster resource across the coast, within the mapped study area, were intertidal. Subtidal Firm Non-vegetated Shell (G; 9.56 ± 0.50 oysters/m^2), Subtidal Hard Non-vegetated Shell (K; 16.11 ± 0.68 oysters/m^2), and Intertidal Firm Vegetated w/o Shell (R; 2.29 ± 0.30 oysters/m^2) were also significantly different for oysters coastwide. Two strata, Intertidal Soft Vegetated Shell (M) and Intertidal Soft Vegetated w/o Shell (N), were not significantly different from any other strata for oysters coastwide. Most of NC's shell bottom can be found in the Southern CHPP Regions 3 and 4, the White Oak and Cape Fear River Basins. The White Oak Region 3 is dominated by subtidal shell while intertidal shell is dominate in the Cape Fear region 4. These regions also had the highest density of mapped shell strata.

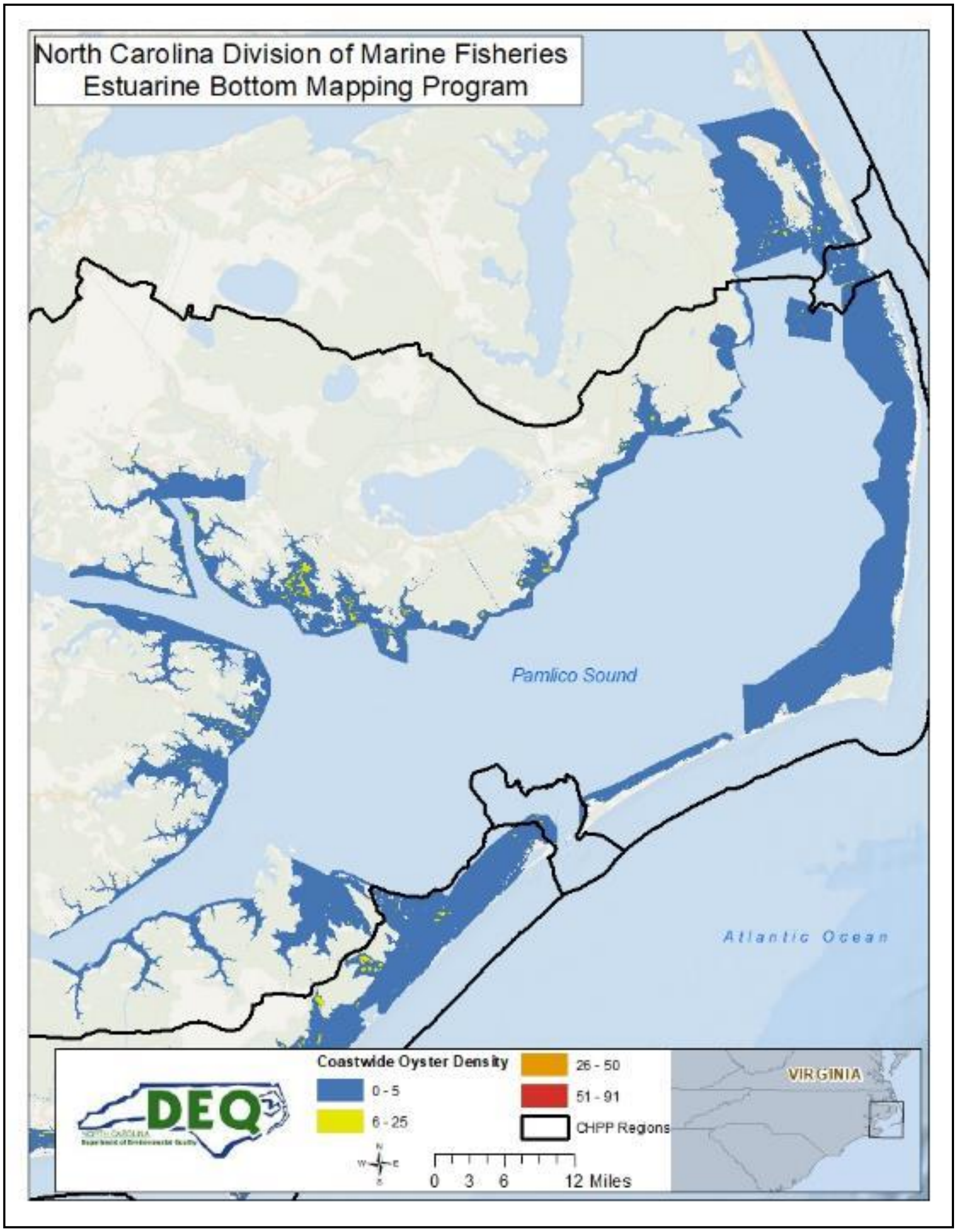

Figure 8.32. The NC Division of Marine Fisheries (DMF) Estuarine Bottom Mapping Program 635 coastwide oyster density (weighted mean; # of oysters/m^2) for the northern Coastal Habitat Protection Plan (CHPP) regions 1, 1/2, and 2, 1990-2019.

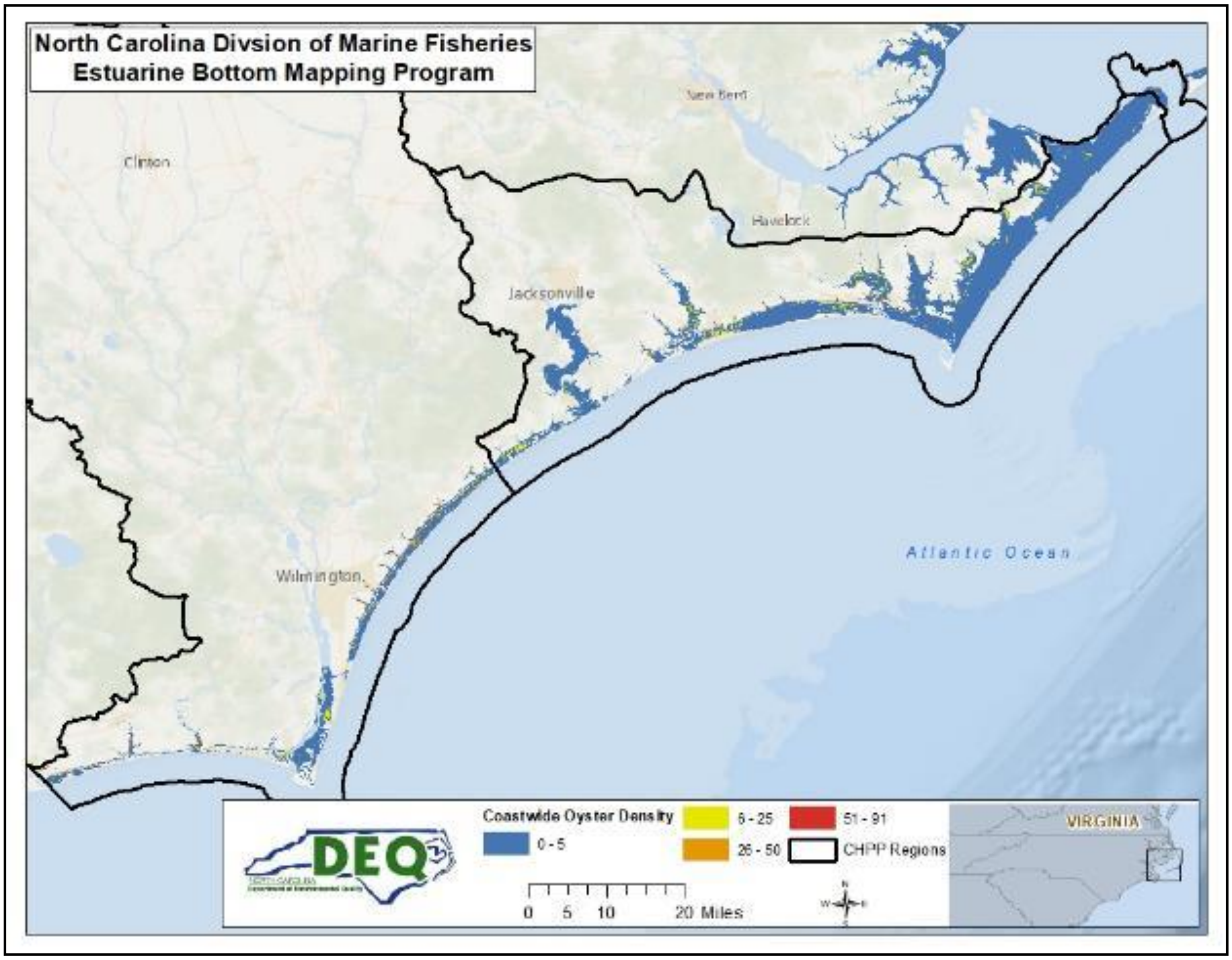

Figure 8.33. The NC Division of Marine Fisheries (DMF) Estuarine Bottom Mapping Program oyster density (weighted mean; # of oyster/m^2) for the southern Coastal Habitat Protection Plan (CHPP) regions 3, 3/4, and 4, 1990-2019.

Submerged Aquatic Vegetation (SAV)

Background

Currently, NC is steward to one of the most productive and biodiverse SAV resources on the Atlantic seaboard, including the largest in-tact polyhaline and mesohaline seagrass meadows in the temperate western Atlantic.[3, 47, 48, 49, 50, 51] There are two distinctive groups of SAV ecosystems in NC distributed according to estuarine salinity. One group, referred to as low salinity SAV or underwater grasses, thrives in fresh and low salinity riverine waters (≤10 ppt), and includes species such as Redhead grass (*Potamogeton perfoliatus*), Wild celery (*Vallisneria Americana*), and Sago pondweed (*Stuckenia pectinate*). The second group, referred to high salinity SAV or seagrass, occurs in moderate to high (>10 ppt) salinity estuarine waters of the bays, sounds, and tidal creeks, and includes three species, temperate eelgrass (*Zostera marina*), tropical shoal grass (*Halodule wrightii*), and cosmopolitan widgeon grass (*Ruppia maritima*). Collectively, they are referred to as SAV.

When SAV beds are subjected to human-induced impacts, such as physical damage and water quality degradation, in addition to natural stressors, such as storm damage and climate change, large-scale losses may occur. Globally, SAV abundance is declining. Of the 72 known species of seagrass, 10 are at an elevated risk for extinction and three are endangered.[52] A summary of status and trends information of SAV at a global scale found reports of large-scale SAV losses in the European Mediterranean, Japan, and Australia.[53] Reports of SAV recovery were very low by comparison. A summary based on over 215 studies and 1,800 observations dating back to 1879 showed seagrasses disappearing at rates similar to coral reefs and tropical rainforests.[54] The compilation of studies shows a 29 percent decline in known SAV extent since 1879. The study also indicated an acceleration of loss since 1940. In North America, losses of seagrass beds have been as high as 50 percent in Tampa Bay, 43 percent in northern Biscayne Bay, 30 percent in the northern portion of Indian River Lagoon, and as much as 90 percent in Galveston Bay, Texas, and Chesapeake Bay.[55, 56, 57, 58] For more information, see **Chapter 4. Submerged Aquatic Vegetation Protection and Restoration Through Water Quality Improvements**.

Mapping and Monitoring

Quantitative information on SAV status and trends comes in three forms: 1) station monitoring, 2) transect monitoring, and 3) areal coverage monitoring. In NC, some of the earliest data comes from a 70+ year history of station and transect monitoring in Currituck Sound.[59, 60] Studies have documented the status of SAV in Currituck Sound since 1909. Major declines occurred in 1918, which were mostly caused by increased turbidity from dredging for the locks of the Albemarle and Chesapeake Canal. In 1932, operation of the canal locks was modified and SAV began to recover; fully recovering by 1951. During 1954 and 1955, four hurricanes along NC's coast increased turbidities and resulted in widespread destruction of SAV beds.[61] The community recovered rapidly, as growth was considered good by 1957 (Davis and Brinson 1983, 1990).[59, 60] After a severe nor'easter in 1962, saltwater intrusion in Currituck Sound raised the average salinity by 4.4 ppt, causing major reductions in freshwater SAV biomass. As SAV beds recovered in Currituck Sound after 1962, non-native Eurasian watermilfoil (*Myriophyllum spicatum*) began to spread across the sound, possibly encouraged by improved water clarity that resulted from dry conditions and higher post-1962 salinities. This caused a major change in composition of the native SAV.

Since the 1980s, various other mapping and monitoring projects have been conducted by universities and state and federal agencies across the coast of NC in both high and low salinity areas. Each of these mapping events produced individual GIS files, that when compiled together, make up the historically known presence and suitable habitat of SAV along NC's coast, suggesting a historic extent of approximately 191,155 acres of SAV in the public trust waters of coastal NC (Tables 8.8; Figure 8.33). The data sources, mapping years, methodology, and extent of each individual mapping event and individual maps by regions can be found in **Chapter 4. Submerged Aquatic Vegetation Protection and Restoration through Water Quality Improvements**. Additional mapping and monitoring of fresh and brackish SAV has occurred through hydroacoustic surveys, the recent establishment of sentinel sites in recent years in the Neuse and Pamlico rivers and Albemarle Sound and a coastwide aerial photography mapping event that occurred in 2019 and 2020 with funding from DEQ and APNEP.[62, 63, 64, 65] As these more current data layers become available they will be incorporated into this mosaic of SAV mapping events to better inform the known historic and current extent of SAV and SAV habitat in NC.

Table 8.8. Historical extent of submerged aquatic vegetation (SAV) and SAV habitat in North Carolina.

Salinity Zone	SAV Region #	SAV Region Name	Historic Extent* (ac)	Percent of Historical Extent* (%)
Low	1	Currituck and Back Bay	21,613	11.3
Low	2	Albemarle Sound	12,872	6.7
Low	3	Tar-Pamlico & Neuse rivers	4,581	2.4
High	4	Pamlico Sound	712	0.4
High	5	Roanoke Sound to Ocracoke Inlet	101,739	53.2
High	6	Core Sound	36,862	19.3
High	7	Bogue Sound	10,826	5.7
High	8	Bear Inlet to Snow's Cut	1,950	1.0
High/Low	9	Cape Fear River to SC line	0	0.0
Total			191,155	100.0

*SAV Mosaic 1981 to 2015 (as of 6/3/2020)

Photo Credit: Nolen Vinay

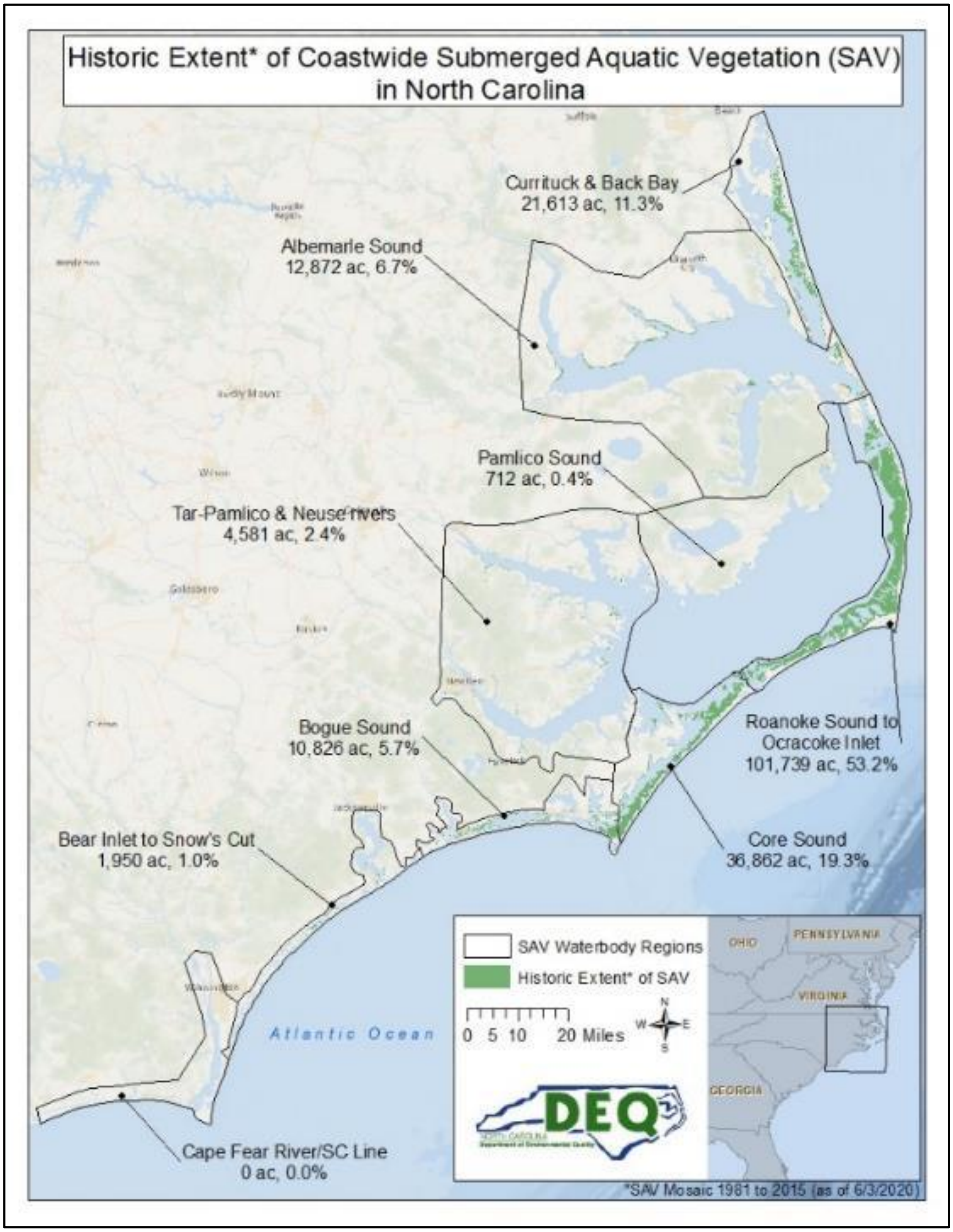

Figure 8.33. Known historic extent of submerged aquatic vegetation (SAV) and SAV habitat in NC, mapped from 1981 to 2015. Absence of SAV does not suggest actual absence, as surveys have not been conducted in all areas. Presence of SAV does not reflect current state, as data dates to 1981.

Extent and Loss in North Carolina

The extent of SAV loss has not been well quantified in NC, but anecdotal reports indicate SAV beds may be reduced by as much as 50 percent, especially on the mainland side of the coastal sounds.[3, 66] However, more recent efforts have been made to quantify these losses in both high and low salinity SAV habitats.[65, 67] Mapping and monitoring low salinity SAV is more difficult due to low water clarity compared to high salinity SAV areas of the estuary. However, despite the limited availability of historical baseline data of low salinity SAV habitat, fluctuations in SAV abundance have been observed through hydroacoustic surveys and other sentinel site observations. Based on the most recent hydroacoustic surveys of linear SAV extent along the 1-m isobath in the Neuse, Pamlico and Albemarle river sub-estuaries, there has been an estimated 33 percent decline from the historical extent of low salinity SAVs (Table 8.9).

Table 8.9. Net change from known historic extent in North Carolina to 2014-2017 linear extent (LE) data along 1-meter isobaths line for low salinity SAV based on hydroacoustic surveys.[65, 67]

Estuary	Known Historical* SAV LE (m)	2014-2017 SAV LE (m)	No change in SAV from historical (m)	Change in SAV LE (gain)	Change in SAV LE (loss)	Percent change in SAV LE (loss)
Albemarle Sound	117,778	90,565	56,457	+34,108	-61,321	-23.10
Tar - Pamlico River	29,223	6,036	756	+5,280	-28,467	-79.33
Neuse River	10,512	9,519	2,821	+6,692	-7,685	-9.42
Total	157,513	106,120	60,034	+46,080	-97,473	-32.62

*From 1981-2015 SAV Mosaic

Although there is less known about low salinity SAV, there are some recurring themes. These include fluctuations in abundance, changes in species composition, a proliferation of non-native, persistent SAV species, high turbidity, extreme weather events and large amounts of precipitation, increases in harmful algal blooms, and fluctuations in salinity. This all represents an important and needed effort to develop numeric nutrient criteria, so that progress on water quality improvements can be made for the benefits of SAV.[67] The high salinity seagrasses appear to be in slightly better health than the low salinity SAVs. There is a good baseline of data on distribution and abundance for most of the high salinity SAV resource, along with a good understanding of species composition, persistence, and resilience. However, little water quality data are collected in this part of the estuary and represents a crucial data gap.

The APNEP metric report: *Extent of Submerged Aquatic Vegetation, High-Salinity Estuarine Waters*, provides an analysis of SAV change based on spatial coverage detected from aircraft during two survey periods: 2006-2007 (Survey 1) and 2013 (Survey 2). Survey 1 represents late spring aerial surveys of Bogue and Back Sounds and fall aerial surveys between Roanoke Island and Barden's Inlet. Survey 2 represents late spring aerial surveys between Roanoke Island and Bogue Inlet.[68] Due to weather conditions during the second survey, extent and location measurements for SAV in much of Core Sound were not included in this report. For the analysis, the coastal areas were broken down into three geographic regions: 1) the "North Zone" from the U.S. Highway 64 Bridge at Roanoke Island to Hatteras Inlet, 2) the "Central Zone" from Hatteras Inlet to Ophelia Inlet and, 3) the "South Zone" from Barden's Inlet at Cape Lookout to Bogue Inlet. The data were also subdivided into the categories showing all possible categorical changes in SAV: continuous to none, patchy to none, continuous to patchy, patchy both years of analysis, none to patchy, continuous both years of analysis, patchy to continuous, and none to continuous.

All three regional zones showed declines in SAV acreage (Table 8.10).[68] However, the southern zone, where there is more development and higher population densities, declined by over 10 percent at a rate of 1.7 percent loss per year (Table 8.11). The northern and central regions are less developed, receive less direct riverine input, and therefore had a lower estimated SAV acreage loss. SAV can grow at depths generally up to ≤ 2.0 m, yet much of the available benthic habitat within this depth range was not occupied by SAV. An additional concern is the amount of continuous beds that were converted to patchy beds. The biggest component of the overall change in the northern region was the conversion of 15,327 acres (6,202.8 ha) of continuous seagrass in Survey 1 to patchy seagrass in Survey 2.

Table 8.10. Net change in seagrass extent in North Carolina from Survey 1 (2006/2007) to Survey 2 (2013) in three regional zones 1) the “North Zone” from the U.S. Highway 64 Bridge at Roanoke Island to Hatteras Inlet, 2) the “Central Zone” from Hatteras Inlet to Ophelia Inlet and, 3) the “South Zone” from Barden’s Inlet at Cape Lookout to Bogue Inlet and overall (acres, hectares in parentheses).[68]

Regional Zones	Survey 1	Survey 2	Change	% Change
North	70,861 (28,676)	66,445 (26,889)	-4,416 (-1,787)	-6.2
Central	24,132 (9,766)	23,477 (9,501)	-655 (-265)	-2.7
South	5,850 (2,367)	5,235 (2,119)	-615 (-249)	-10.5
Overall	100,843 (40,810)	95,157 (38,509)	-5,686 (-2,301)	-5.6

Table 8.11. From-to calculations for the net change in seagrass extent in the three North Carolina zones 1) the “North Zone” from the U.S. Highway 64 Bridge at Roanoke Island to Hatteras Inlet, 2) the “Central Zone” from Hatteras Inlet to Ophelia Inlet and, 3) the “South Zone” from Barden’s Inlet at Cape Lookout to Bogue Inlet and overall (acres, hectares in parentheses).[68]

Conversion		Zone		
From	To	North	Central	South
No SAV	Patchy SAV	4,462 (1,810)	4,386 (1,775)	638 (258)
No SAV	Continuous SAV	203 (82)	150 (601)	60 (24)
Gain		4,665 (1,888)	4,537 (1,836)	698 (283)
Continuous	None	1,895 (766)	401 (162)	88.4 (36)
Patchy	None	7,009 (2,837)	4,782 (1,935)	1,218 (493)
Loss		8,904 (3,603)	5,184 (2,098)	1,306 (528)
Net Loss (Loss – Gain)		4,239 (1,715)	647 (262)	607 (246)
Total		70,861 (28,676)	24,132 (9,766)	5,850 (2,367)
% Change		-6.2	-2.7	-10.5
% Change yr-1		-1.1	-0.5	-1.7

A global assessment of 215 studies found that seagrasses around the world have been disappearing at a rate of 110 km^2 per year since 1980 with an overall global average rate of decline of 1.5 percent per year.[54] Although rates of decline within the northern and central regions of NC are lower than this global average, the higher rate of decline in Back and Bogue sounds (1.7 percent per year) is comparable.[68]

Bogue and Back Sounds may be especially vulnerable to the impairment of water quality associated with shoreline development and other anthropomorphic impacts (boat wakes, dredging, fishing gears, etc.).

Wetlands

There are multiple classification systems used to differentiate classes of wetlands, but for the purposes of this paper, we will be using a simplified Cowardin System which splits coastal wetlands into two broad classes: palustrine and estuarine.[69] Palustrine wetlands include all non-tidal wetlands that are dominated by trees, shrubs, or emergent vegetation, as well as any tidal wetlands where ocean-derived salinities are less than 0.5 parts per thousand (ppt). Wetlands with ocean-derived salinities greater than 0.5 ppt are categorized as estuarine wetlands, which can be further divided by vegetation type into forested, scrub/shrub, and emergent estuarine wetlands.

Wetland resources in the United States have declined considerably (>50 percent) since the colonial period.[70] It is estimated nearly half of NC's 11 million historical acres of wetlands were lost (physically or functional) between pre-colonial times and the 1980s.[71] These alterations were not evenly distributed between wetland types, with 52.4 percent of coastal palustrine wetlands having been altered, in contrast with 12.2 percent of estuarine wetlands.[72] The loss of NC's coastal wetlands has continued into the 21st century. Approximately 40 percent of total documented coastal wetland losses occurred between 1950 and 2000. For additional information, see **Chapter 5. Wetland Protection and Restoration through Nature-Based Solutions.**

Extent in North Carolina

Approximately 95 percent of NC's wetland resources are in the state's Coastal Plain.[73] According to the most recent NOAA Coastal Change Analysis Program (C-CAP) data, NC has 4.35 million acres of palustrine (freshwater) wetlands, of which 71 percent are forested wetlands, 23 percent are scrub/shrub wetlands, and 6 percent are emergent wetlands, as well as 235,425 acres of estuarine wetlands, of which 97 percent are emergent wetlands (Table 8.12 and Figure 8.34).[74]

Table 8.12. Acres of palustrine (freshwater) and estuarine wetlands in North Carolina's Coastal Plain.[74]

Coastal Wetland Class	Acres
Palustrine Forested Wetland	3,069,690
Palustrine Scrub/Shrub Wetland	1,008,552
Palustrine Emergent Wetland	272,932
Estuarine Forested Wetland	166
Estuarine Scrub/Shrub Wetland	7,747
Estuarine Emergent Marsh	235,425
Total	4,594,513

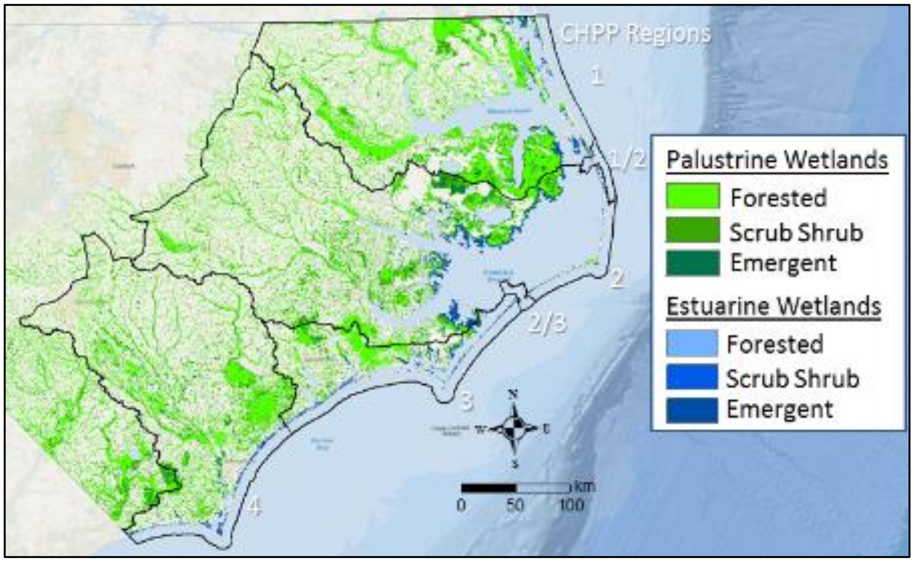

Figure 8.34. Distribution of palustrine and estuarine wetlands.[74]

Calculating wetland change over five year periods beginning in 1996, the recent C-CAP publication of 2011-2016 data provides 20 years of wetland change data for NC's Coastal Plain.[74] Documented within the 20-year period from 1996-2016, 135,000 acres of palustrine wetland were lost in NC's coastal plain (Table 8.13). Roughly 72 percent of all coastal freshwater wetland losses documented occurred in the first five-year period from 1996 to 2001. A net loss of coastal freshwater wetland was observed 1996 to 2011, with the conversion of freshwater wetlands to upland habitat accounting for the majority of losses (54 to 80 percent). From 1996 to 2011, the rate of net coastal freshwater wetland loss decreased with 2011 to 2016 reporting a net increase. The conversion from upland habitat resulted in a net gain in freshwater wetlands, while conversion to development accounted for 90 percent of all observed palustrine wetland losses.

Table 8.13. Net loss or gain of North Carolina's coastal palustrine wetland acreage to other land cover classes, by conversion type. Negative values represent a loss of coastal palustrine wetlands to the specified land cover class and positive values represent a gain. Net change represents net change from all land conversions during that time period.[74]

Palustrine Wetland	Time Period				
Conversion To:	1996-2001	2001-2006	2006-2011	2011-2016	20-Yr Total
Development	-6,450	-2,172	-3,001	-1,317	-12,940
Agriculture	-9,218	-2,476	127	0	-11,567
Upland	-77,636	-13,493	-9,748	637	-100,240
Estuarine Wetlands	0	0	0	0	0
Unconsolidated Shore	46	16	-39	-144	-121
Open Water	-3,255	-6,840	-3,973	3,952	-10,116
Net Change	-96,513	-24,965	-16,633	3,128	-134,983

While the magnitude of cumulative losses to coastal palustrine wetlands from 1996 to 2011, the proportion of loss was not evenly distributed among palustrine subclasses. Palustrine forested wetlands, which account for 71 percent of all coastal palustrine wetland acreage, accounted for 99 percent of overall net losses incurred across all three classes over the 20-years of NOAA C-CAP data (Table 8.14).

Table 8.14. Net loss or gain of North Carolina's coastal palustrine (freshwater) wetland acreage by type palustrine wetland classes. Negative values represent a net loss of coastal palustrine wetlands and positive values represent a net gain of coastal palustrine wetlands.[74]

	Palustrine Wetland Type		
Time Period	Forested	Scrub/Shrub	Emergent
1996-2001	-279,324	147,607	35,204
2001-2006	-150,287	89,661	35,664
2006-2011	-115,836	99,574	-265
2011-2016	-42,969	40,277	5,816
20-Yr Total	-588,416	377,119	76,419

These losses, totaling 588,523 acres of forested palustrine wetlands between 1996 and 2016, were offset by gains of 377,119 acres and 76,684 acres of coastal palustrine scrub/shrub and emergent wetlands, respectively, over the same period.[74] Between 1996 and 2016, conversion to palustrine scrub/shrub wetland accounted for 42 percent of cumulative palustrine forested wetlands losses, conversion to palustrine emergent wetland accounted for 37 percent of cumulative losses, and conversion to upland accounted for 16 percent of losses (Table 8.15). Palustrine scrub/shrub wetlands were the only palustrine wetland class in which net gains in acreage were observed across all four five-year periods between 1996 and 2016. Of 381,426 acres of palustrine scrub/shrub wetland gained between 1996 and 2016, conversion from palustrine forested wetland accounted for 64 percent of gains and palustrine emergent wetland accounted for 35 percent. Conversion of palustrine scrub/shrub to development, which totaled 1,592 acres over the 20-year period, accounted for the largest percentage (42 percent) of cumulative losses. Conversion from palustrine forested wetland was also the major contributor (>99 percent) to palustrine emergent wetland acreage gains between 1996 and 2016. Of the 219,520 acres of palustrine emergent wetland gained through conversion of palustrine forested wetland, the leading contributor to palustrine emergent wetland losses, conversion to palustrine scrub/shrub wetland, negated 62 percent of those potential gains. Indeed, recent analysis of palustrine wetland losses in coastal counties of the conterminous U.S. found that 80 percent of palustrine wetland losses occurring between 1996 and 2010 occurred in five states, with NC ranking fifth and accounting for 8 percent of all losses incurred nationally over the period.[75]

Table 8.15. Net loss or gain of North Carolina's coastal palustrine forested, scrub/shrub, and emergent wetland acreage by type of conversion to other land cover classes. Negative values represent a net loss of the coastal palustrine wetland class and positive values represent a net gain of the coastal palustrine wetland class.[74]

	Time Period				
Conversion Type	1996-2001	2001-2006	2006-2011	2011-2016	20-year period
Palustrine Forested Wetland To:					
Development	-6,027	-1,281	-1,530	-870	-9,708
Agriculture	-7,784	-1,783	227	0	-9,340
Upland	-77,143	-10,993	-7,755	367	-95,524
Palustrine Scrub/Shrub Wetland	-122,149	-54,957	-57,626	-10,816	-245,548
Palustrine Emergent Wetland	-63,038	-77,125	-45,049	-34,308	-219,520
Estuarine	0	0	0	0	0
Unconsolidated Shore	11	-2	-2	-66	-59
Open Water	-3,193	-4,149	-4,206	2,724	-8,824
Net Change	-279,324	-150,290	-115,941	-42,969	-588,524
Palustrine Scrub/Shrub Wetland To:					
Development	-296	-719	-280	-297	-1,592
Agriculture	-704	-159	-33	0	-896
Upland	-37	-197	-783	-3	-1,020
Palustrine Forested Wetland	122,149	54,957	57,626	10,816	245,548
Palustrine Emergent Wetland	26,295	36,153	42,727	30,185	135,360
Estuarine	0	0	0	0	0
Unconsolidated Shore	4	1	7	-16	-4
Open Water	197	-376	310	-407	-276
Net Change	147,607	89,661	99,574	40,277	377,119
Palustrine Emergent Wetland To:					
Development	-127	-172	-1,190	-150	-1,639
Agriculture	-729	-534	-67	0	-1,330
Upland	-455	-2,303	-1,210	272	-3,696
Palustrine Forested Wetland	63,038	77,125	45,409	34,308	219,880
Palustrine Scrub/Shrub Wetland	-26,295	-36,153	-42,727	-30,185	-135,360
Estuarine	0	0	0	0	0
Unconsolidated Shore	31	16	-44	-62	-59
Open Water	-258	-2,315	-77	1,634	-1,016
Net Change	35,204	35,664	-265	5,816	76,419

In contrast to coastal palustrine wetlands, net change in estuarine wetland acreage exhibited an inverse temporal pattern (Table 8.16).[74] Specifically, net gains of estuarine wetlands were observed between 1996 and 2006, while net losses were observed from 2006 to 2016. The type of land conversion that accounted for the majority of loss shifted considerably through time. Conversion of estuarine wetlands to agriculture and upland land accounted for 48 percent and 42 percent of losses from 1996 to 2001, respectively. Conversion to agriculture land accounted for 80 percent of estuarine wetland losses between 2001 and 2006, while conversion to development and upland accounted for 37 percent of losses each between 2006 and 2011. From 2011 to 2016, conversion to unconsolidated shore and open water were the leading sources of estuarine wetland losses, accounting for 38 percent and 32 percent, respectively.

Table 8.16. Net loss or gain of North Carolina's estuarine wetland acreage by type of conversion between estuarine wetlands and other land cover classes. Positive values represent a net gain of estuarine wetlands to the specified land cover class and negative values represent a loss gain of the estuarine wetlands from the specific land class cover.[74]

Estuarine Wetland	Time Period				
Conversion To:	1996-2001	2001-2006	2006-2011	2011-2016	20-yr period
Development	-6	-16	-77	-15	-114
Agriculture	-30	-62	-1	0	-93
Upland	-26	4	-77	-9	-108
Palustrine	0	0	0	0	0
Unconsolidated Shore	252	1	-54	-31	168
Open Water	400	75	146	-26	595
Net Change	590	2	-63	-81	448

Permitting and Impacts

In NC, EMC has wetland standards (15A NCAC 02B.0231) that provide protection of wetland functions. Projects can impact wetlands if below the allowed threshold. If unavoidable, and a project meets other EMC rule criteria, a project may be permitted, but mitigation is required (15A NCAC 02H.1305). Impact thresholds not requiring a permit are less than or equal to one acre in the coastal region, and less than or equal to 0.5 acres in the piedmont region. The DWR tracks wetland, stream, and buffer impacts that are permitted through the 401 Wetland Program. According to DEQ's Basinwide Information Management System (BIMS), 17,984 acres of wetland impacts were permitted statewide through 12,386 issued 401 certifications and Isolated Wetlands and Waters permits between January 1, 1990 and December 31, 2019 (Figure 8.35).[76] The areas of the most impacted acres can be found in some of the coastal counties. The DWR permit data for the 20 coastal counties indicate that in the 1990s, most impacts were attributable to water dependent structures (marinas, docks, bulkheads), followed by dredging. From 2000 to 2010, there was a large increase in mining impacts. Since 2010, most impacts were associated with transportation (Figure 8.36). Some of the impacts are offset by mitigation.

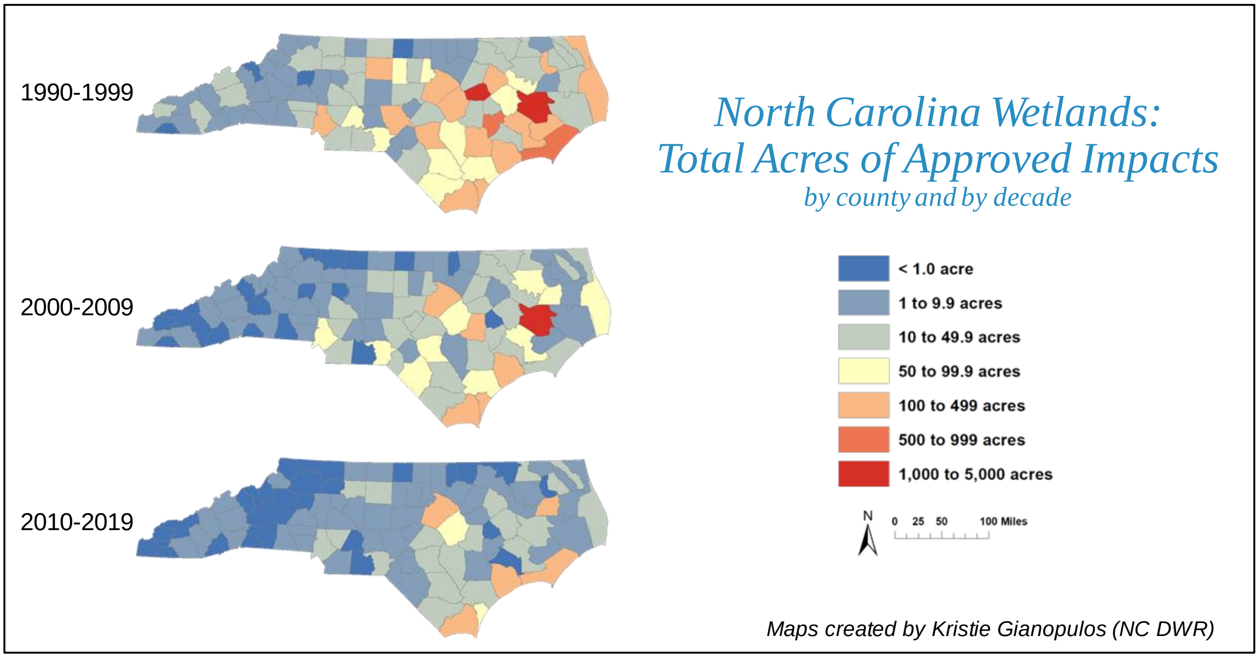

Figure 8.35. Total acres of approved impacts in North Carolina, statewide, over the past 30 years.[76]

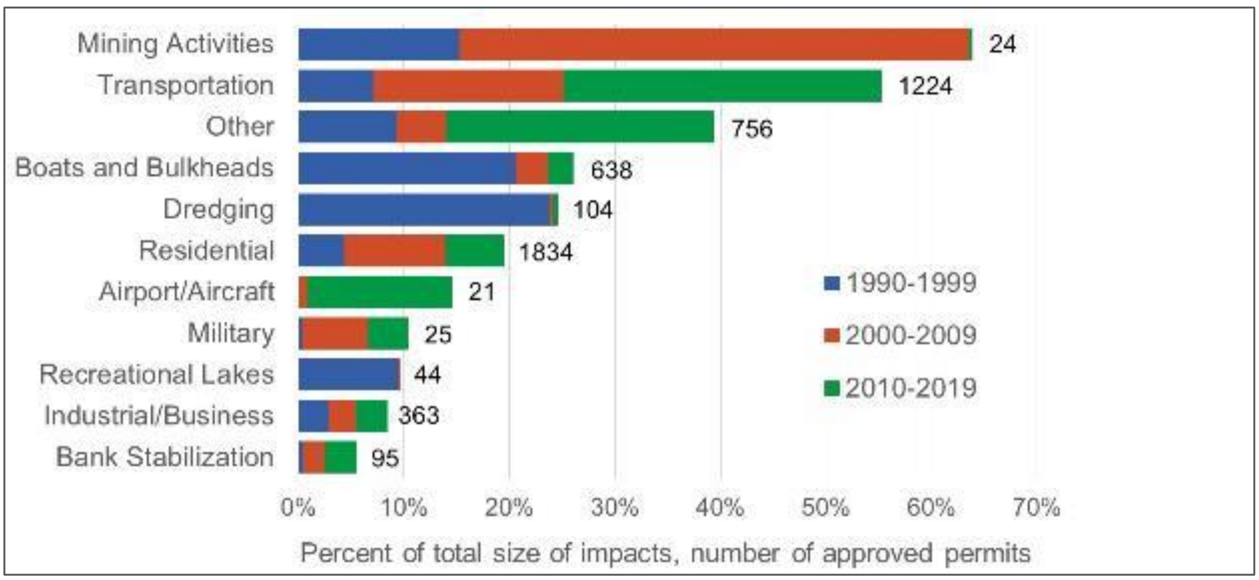

Figure 8.36. Permitted wetland impacts by primary activity type in North Carolina's 20 coastal counties, over the past 30 years.[76]

North Carolina's official wetland monitoring program was initiated by the Division of Water Quality (now DWR) in 2004. Since its inception, wetland monitoring conducted by DWR has been funded primarily by the EPA Wetland Program Development Grants (WPDG). While the first grant primarily supported efforts to monitor headwater wetlands, subsequent grants have provided funding to monitor basin wetlands, riverine swamp forests, and bottomland hardwood forests located across multiple watersheds. Between 2004 and 2015, projects funded largely by the EPA resulted in the monitoring of 248 wetland sites, 132 of which are in the CHPP region (Figure 8.37). Due to the grant duration and project objectives, most (147 of 248, or 59 percent) were monitored for one year or less.

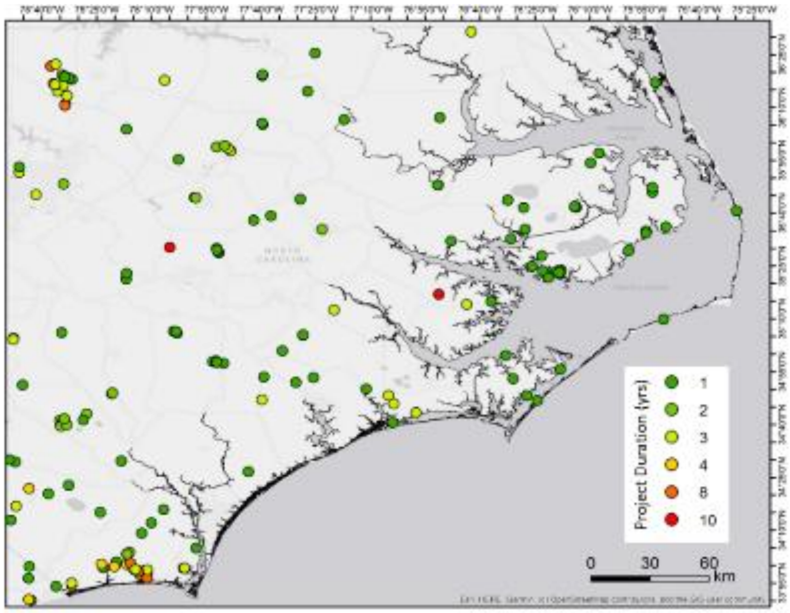

Figure 8.37. Location and sampling duration of wetland monitoring projects conducted by DWR and partners between 2004 and 2015.

Since 2004, NC DWR wetland projects have ranged from field evaluation of restored mitigation wetlands, to study of headwater wetlands, characterizing isolated wetland hydrologic connectivity, water quality, and biota, and assessing use of natural wetlands for stormwater assimilation, among others.[77] These were all short-term studies. Since the dissolution of the NC DWR Wetland Program Development group in 2013, some wetland monitoring efforts by state agencies have continued, but at a much more limited scale. The Wetland Program Plan (NC WPP) is developed by NC DWR with a stakeholder group on five year cycles to guide actions to research and protect wetlands. The plan is currently being updated and will be finalized in 2021. The Division of Mitigation Services (DMS) also compiles monitoring reports for compensatory mitigation projects, and the Wildlife Resource Commission (WRC) has conducted monitoring to assess abundances of select fauna of interest.

In contrast to the short-term monitoring by NC DWR typical of EPA Wetland Program Development Grant-funded projects that took place between 2004 and 2015, the NC Sentinel Site Cooperative (NCSSC), one of five cooperatives established throughout the US with NOAA funding in 2012, has established long-term monitoring of coastal habitats in eastern NC. The cooperative consists of partners from NOAA, NC Coastal Reserve, DCM, NC Sea Grant, Department of Defense, National Park Service, the NC Aquarium at Pine Knoll Shores, academia, and town governments, with the goal of leveraging resources across organizations to provide stakeholders with information to address sea level rise (SLR) and coastal inundation. A component of the work the NCSSC conducts is the monitoring of coastal habitats to address impacts of SLR. This has entailed leveraging existing and establishing new sites for the long-term monitoring of elevation change using surface elevation tables (SET), which are portable mechanical instruments that provide high-resolution measurements of elevation change within wetland sediments.[78] There are currently over 125 SETs throughout coastal NC generating information on the degree to which coastal marshes are keeping up with SLR (Figure 8.38).

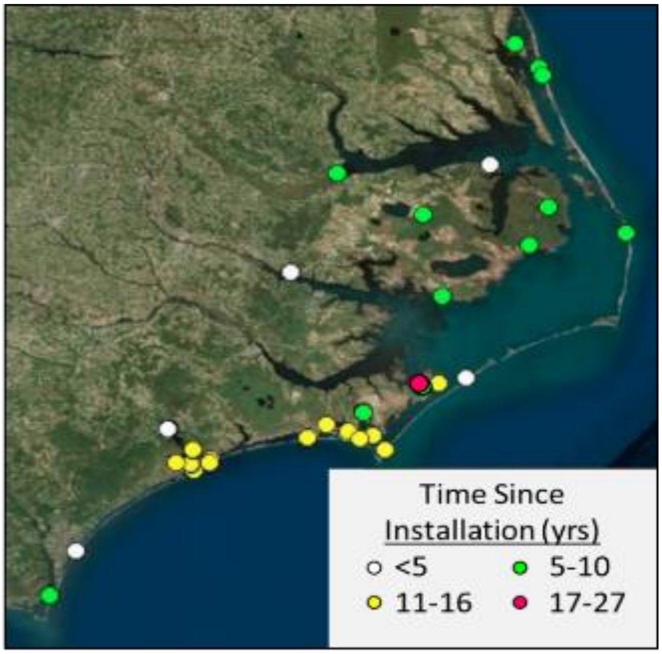

Figure 8.38. Surface elevation table (SET) locations in NC for monitoring long-term of elevation change.[79]

Hard Bottom

Background

Oceanic hard bottom is the primary habitat for offshore marine organisms on the continental shelf of NC.[80, 81] These exposed structures function as foundation for sessile invertebrates and algae, refuge for free moving benthic invertebrates and vertebrates, as well as juvenile, bait, and economically important fishes.[82, 83]

Extent in North Carolina

Hard bottom in NC is limited to specific areas of the continental shelf with 90 percent of existing hard bottom occurring south of Cape Hatteras. These natural and important areas are susceptible to overfishing due to their scarcity and abundance of inhabitants. A 1983 study estimated the amount of natural hard bottom reefs between Cape Hatteras and Cape Fear to be around 504,095 acres, or 14 percent of the substratum.[84] Nearshore hard bottoms were considered to be in “good general” condition overall in 1998.[85] Although limited information exists on the distribution of hard bottom off the NC coast, little information is available to evaluate the status and trends of hard bottom habitat in state territorial waters.[86, 87, 88, 89]

While some surveys have been conducted by federal agencies and the energy exploration industry, the exact extent and distribution of productive live bottom habitat on the continental shelf north of Cape Canaveral is unknown. Although a number of attempts have been made, estimations of the total area of hard bottom are confounded due to the discontinuous or patchy nature of the habitat type. It has been estimated that about 4.3 percent of the Georgia Bight is hard bottom, but this is considered an underestimate.[90] It has also been reported that live bottom reef comprises a larger area of the South Atlantic Bight.[91]

Anecdotal information from fishermen and residents in coastal NC suggests that many nearshore hard bottom sites in the mid-twentieth century are now covered by sand, reducing the abundance of fish in these areas. Some areas have already been lost to the effects of beach nourishment.[92] Hard bottom habitat off the coast of Wrightsville Beach was buried under two to six inches of sand through erosion off the nourished beach. These once productive fishing grounds no longer support the number or diversity of fish they once did. The observed declines in species abundance and richness lead researchers to conclude that the conflict between beach nourishment and hard bottom productivity is a very serious conflict that will only get worse.[80, 93]

Artificial Reef Program

As of 2020, DMF's Artificial Reef Program manages 63 artificial reefs including 22 estuarine reefs, 15 of which serve as oyster sanctuaries, and 43 offshore reefs (13 in state waters and 30 in federal waters) with the goal of supporting and functioning similarly to nearby natural reefs while providing user access opportunities (Figure 8.39). The artificial reefs have been shown to support a similar community as natural reefs on multiple metrics.[94, 95] The artificial reefs also provide habitat for top predators and fishes at the edges of their distribution ranges.[96, 97]

Photo Credit: ncoif.com

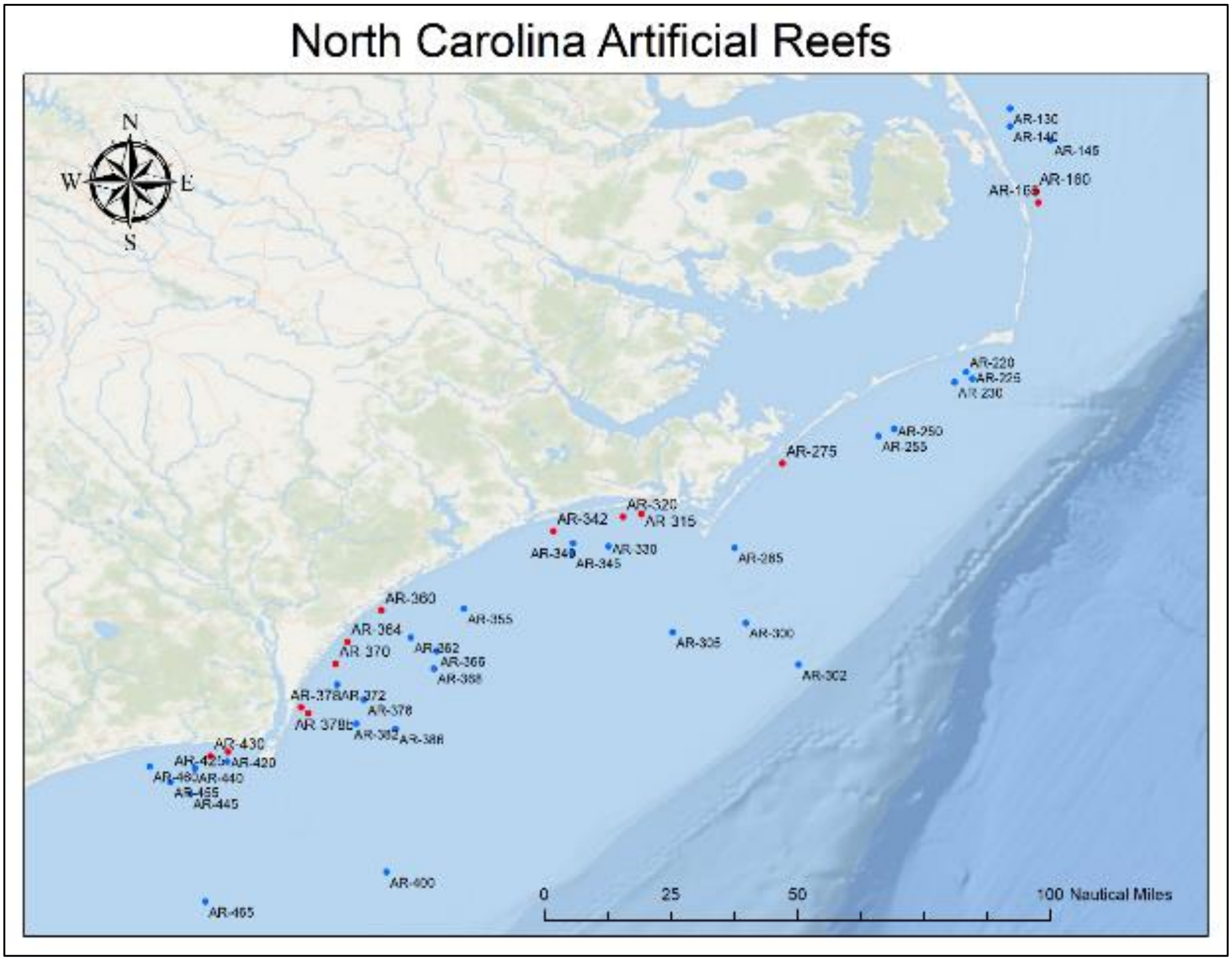

Figure 8.39. Map of all offshore artificial reefs in North Carolina. Blue sites are located in federal waters and red sites are located in state waters.

Currently, the artificial reefs in NC are being monitored by the Artificial Reef Program for material stability and major storm effects on a yearly basis. These reefs are also the focus of research supported by a CRFL grant to compare them to neighboring natural reefs being conducted by NC State University (NCSU) and the National Centers for Coastal Ocean Science (NCCOS). The goal of this research is to determine usage of artificial and natural reefs by fishes at fine and broad scales as well as develop tools for improved monitoring and planning of artificial reef construction. The NCCOS is also in the process of prioritizing the offshore areas of NC, SC, and GA to survey more of the natural and artificial reefs in the areas.

Soft Bottom

Background

Marine sediments constitute one of the largest habitat types on earth, covering roughly 80 percent of the ocean bottom.[98] The only requirement for the persistent presence of soft bottom is sediment supply. These soft sediment environments are complex ecosystems containing strong physical gradients that affect the distribution of species and physicochemical conditions .[99] Environmental characteristics, such as grain size, salinity, DO, depth, and flow conditions affect the condition of the habitat and the organisms using it. The characteristic common to all soft bottom is the mobility of unconsolidated sediment.[100] Soft bottom is in a constant state of flux, as other habitats expand or contract. The loss of more structured habitat, such as SAV, wetlands, and shell bottom, leads to gains in soft bottom habitat. Gains in new soft bottom habitat may not be as beneficial as mature soft bottom habitat. An analysis of satellite images (1984-2016) that mapped the global extent of tidal flats, defined as sand, rock, or mud flats that undergo regular tidal inundation, found that this habitat type occupies over 31 million acres worldwide.[101] About 70 percent of the global extent of tidal flats is found in three continents (Asia, 44 percent; North America, 15.5 percent; and South America, 11 percent), with 49 percent being concentrated in just eight countries (Indonesia, China, Australia, the United States, Canada, India, Brazil and Myanmar). It is estimated that approximately 16 percent of tidal flats were lost between 1984 and 2016 due to coastal development, lack of sediment transport, increased erosion, and SLR.

Extent in North Carolina

In NC, soft bottom covers approximately 90 percent of the estuaries and coastal rivers.[102] As part of the Strategic Habitat Area (SHA) assessments, soft bottom area has been described for all CHPP regions and was usually derived using a combination of the DCM's estuarine shoreline GIS layer, the NOAA bathymetry contour dataset, and the NWI dataset (Table 8.17).[103, 104, 105, 106] As expected, the most extensive amounts of soft bottom can be found in CHPP regions 1 and 2, which include the vast open waters of the Albemarle and Pamlico sound systems. The deep soft bottom (>6 ft) is dominant with at least more than twice the amount of shallow soft bottom (≤6 ft) in every region. However, due to overlapping inlet regions, and the resolution of the data used, this is an over estimation of soft bottom habitat in NC. No targeted mapping efforts exist for soft bottom and bathymetry data are out dated. Therefore, it is not possible to quantify how the extent of soft bottom habitat has changed through time.

Table 8.17. Estimated acreage of estuarine and marine shallow, deep, and unknown depth soft bottom habitat within CHPP regions of North Carolina. Due to overlapping inlet regions, and the resolution of the data used this is an over estimation of soft bottom habitat in NC.[30, 31, 32, 33]

CHPP Regions	Shallow Soft Bottom (≤6 ft)	Deep Soft Bottom (>6 ft)	Soft Bottom (Unknown)	Total Soft Bottom
Albemarle Sound to Northeastern Coastal Ocean (1)	232,608	610,733	64,908	908,248
Pamlico Sound System (2)	193,417	1,172,449	63,887	1,429,753
White Oak River Basin (3)	128,282	242,402	10,996	381,680
Cape Fear River Basin (4)	31,951	184,556	13,978	230,485
Total				2,950,166

Benthic Community

The condition and quality of soft bottom habitat can affect species abundance and diversity of the benthic community and could be considered a more important factor for soft bottom than extent.

Sediments in soft bottom habitat can accumulate both chemical and microbial contaminants, potentially impacting benthic organisms and the community structure. Tidal creeks are sensitive to various aspects of human activity, but sensitivity depends on the size and location of the creeks. Because tidal creeks are the nexus between estuaries and land-based activities, the potential for contamination is great. Smaller intertidal creeks closer to headwaters demonstrate greater concentrations of nonpoint source contamination than larger systems closer to the mouth.[107]

The EPA NCCA is the only regular monitoring of soft bottom in NC. In 2010, the biological quality of 77 percent of the waters in the Southeast coastal region was rated as good based on the benthic index (Figure 8.40).[10] Based on the sediment quality index, 65 percent of the Southeast Coast region was rated good, and sediment toxicity findings indicated that 81 percent were in good condition. The contaminants that most often exceed the lowest observed adverse effect level (LOAEL) thresholds were selenium, mercury, arsenic, and (in rare instances) total DDTs.

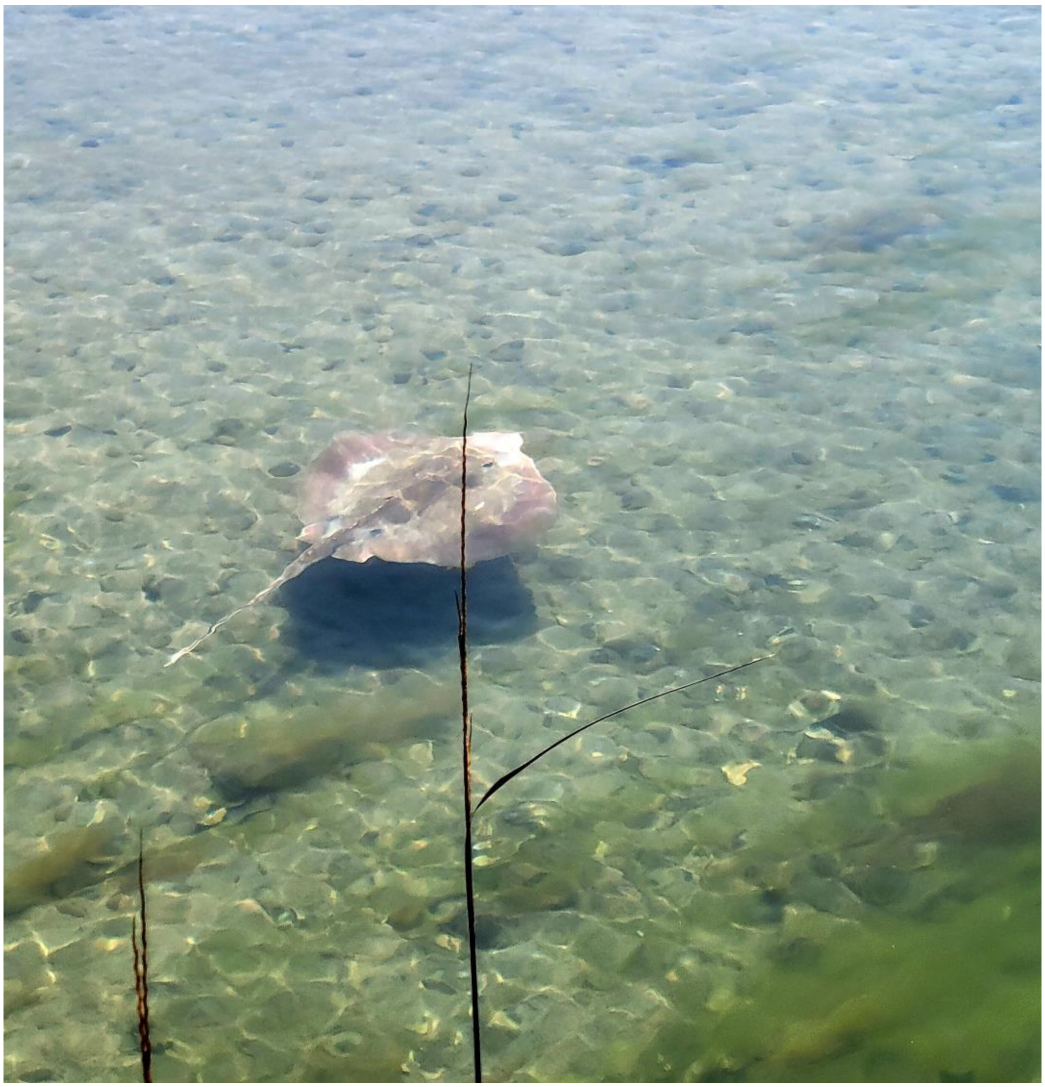

Photo Credit: Nolen Vinay

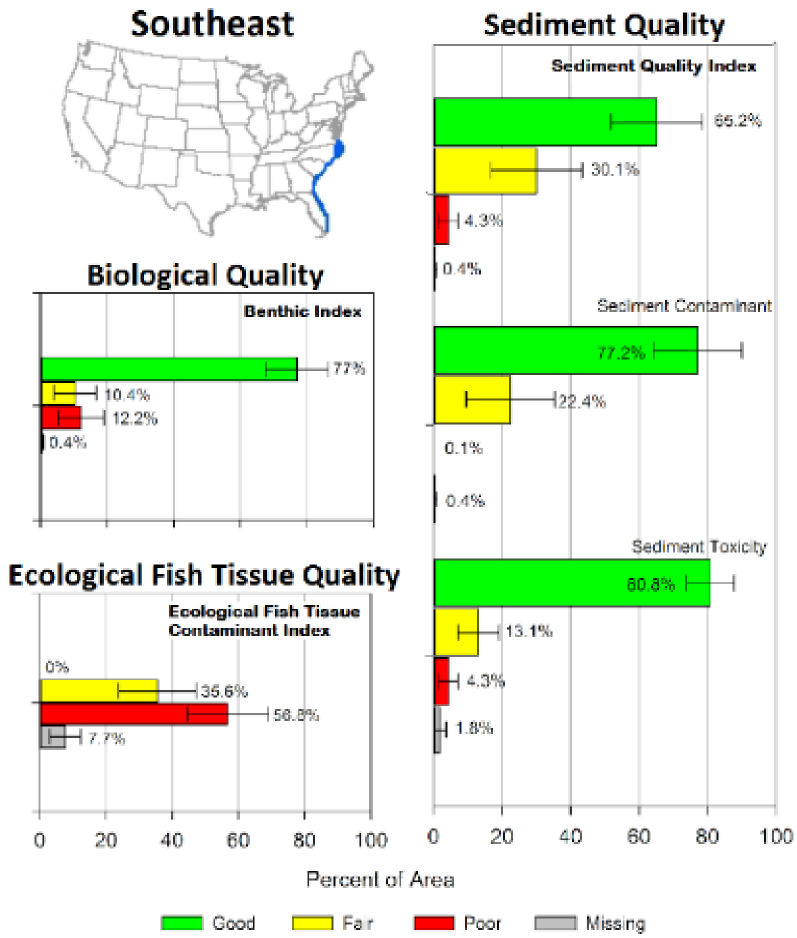

Figure 8.40. The United States Environmental Protection Agency (EPA) National Coastal Condition Assessment (NCCA) 2010 biological, sediment, and ecological fish tissue quality index results for the Southeast Coastal region. Bars show the percent of coastal area within a condition category for specific indicators. Error bars represent 95 percent confidence intervals. Note: The sum of percent of area for each indicator may not add up to 100 percent due to rounding.[10]

Between 2005–2006 and 2010, there was a significant decrease of 27 percent in the area rated good for sediment quality. The sediment contaminants indicator appears to be the driver for this change, while the sediment toxicity indicator shows an opposite result. For the benthic quality index, there is a large, statistically significant increase of 14 percent in waters rated good between 2005–2006 and 2010 (Figure 8.41). While these results might appear contradictory, the sediment and benthic indicators do not necessarily respond to stressors in the same manner. As additional data are collected and analyzed for the NCCA 2015, clearer patterns may emerge. However, in NC it has been shown that sites having higher concentrations of contaminants have lower indices of biotic integrity.[108] This study also found the spatial extent of sediment contamination and toxicity in NC to be much less compared to other US coastal regions where similar studies have been performed.

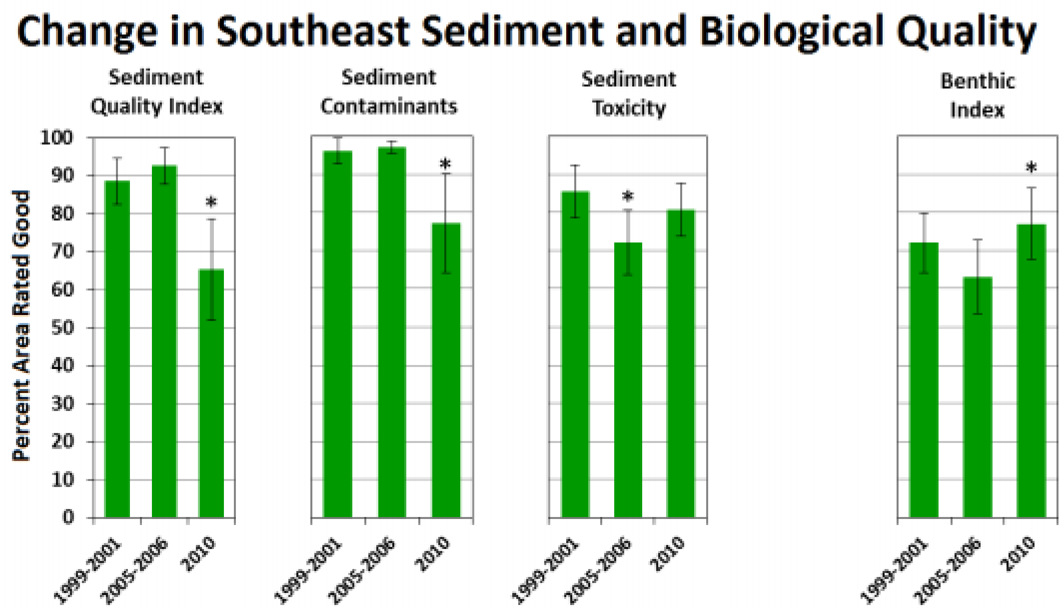

Figure 8.41. Comparison of the percent area rated good for sediment and biological quality over three periods in the Southeast. Note: Asterisks indicate statistically significant change between periods.[10]

Since 1978, DWR Bioassessment Branch has been sampling benthic macroinvertebrates in the wadeable and non-wadeable lotic waters of the state. To date, no benthic sampling occurs within the estuarine waters.

8.3 Discussion

The first step for coastal resource managers is to raise public awareness of the problems caused by degradation and destruction of the natural environment and identify the social causes of environmental damage.[4] The complex interactions between and within NC's coastal habitats, the estuarine ecosystems as a whole, and the human population has to be considered by coastal resource managers. This creates the need for regular standardized monitoring and assessments of these habitats in order to quantify their extent and condition using habitat and ecosystem indicators. Ecosystem indicators are measures of a state or level that informs about what is happening in the environment by using a set of metrics, or quantitative measures that provide a standard used to assess an ecosystem indicator, to detect changes in status and trends over time. This information is then used to educate the public about the condition of NC's coastal habitats, inform protection and restoration efforts, and evaluate the effectiveness of management actions and strategies to achieve the CHPP goal of *the long-term enhancement of coastal fisheries associated with coastal habitats*. This need has also been acknowledged in several of DMF's fisheries management plans (Table 8.18).

Table 8.18. A list of North Carolina Division of Marine Fisheries (DMF) fishery management plans that included habitat and water quality management actions.

NC Fishery Management Plan	Habitat and Water Quality Management Actions
Bay Scallop Amendment 2[109]	• Identify and designate SHAs that will enhance protection of the bay scallop • Remap and monitor SAV coverage in NC to assess distribution and change over time • Accelerate and complete mapping of all shell bottom in coastal
Kingfishes[110]	• Identify and delineate SHAs that will enhance protection of southern, Gulf, and northern kingfishes • Completely map all SAV in NC
Red Drum Amendment 1[111]	• Identify and designate SHAs using ecologically based criteria, analyze existing rules and enact measures needed to protect SHAs, and improve programs for conservation and acquisition of areas supporting SHAs • Complete and continue mapping of SAV to assess distribution and change over time. • Conduct cooperative DMF/NOAA research to assess environmental conditions needed to support SAV, and model potential SAV habitat • Complete shell bottom mapping throughout the coast
River Herring Amendment 2[112]	• Develop, identify and clarify what critical habitat actions are needed to protect, enhance and restore habitats and water quality affecting river herring
Southern Flounder Amendment 1[113]	• Coordinate SAV mapping efforts such that statewide monitoring and trend analysis can be conducted most efficiently • Identify and designate Strategic Habitat Areas (SHAs) and Primary Nursery Areas (PNAs) that will help conserve southern flounder habitat • Acquire updated and coast-wide data on bathymetry, sediment type, and pollutant concentrations • Continue mapping and monitoring the extent and quality of shell bottom in coastal NC • Employ land use data and sea level rise projections to determine priorities for wetland protection, enhancement, or restoration • Increase coverage of waters assessed for aquatic life and increase coverage of continuous monitoring stations • Monitor estuarine salinities for long-term trends related to climate change
Spotted Seatrout Revision[114]	• Continue mapping of SAV in NC to assess distribution and change over time • Identify and designate SHAs that will enhance protection of spotted seatrout • Expand nursery sampling to include high and low salinity SAV beds to adequately evaluate their use by spotted seatrout and other species, and trends in those species • Accelerate and complete mapping of all shell bottom in coastal NC
Shrimp[115]	• Identify and delineate SHAs that will enhance protection of penaeid shrimp • Completely map all low and high salinity SAV in NC
Striped Mullet Amendment 1[116]	• Develop and maintain accurate maps and documentation of wetlands, soft bottom, SAVs, and water column • Monitor to determine if additional areas should be designated as Primary Nursery Areas due to their nursery importance to mullet

The background section summarizes the most up to date and available monitoring and assessment data to describe the current status and trends of coastal habitats. However, there is no formal process in place for continuously monitoring or establishing standardized ecosystem indicators, thresholds, or reference points for coastal habitats. Ecosystem indicators including quantitative biological, chemical, physical, social, or economic measurements can be used as proxies of the conditions of attributes of the coastal habitats, the estuarine ecosystem, and socio-economic systems.[117, 118] The integration of social and ecological information relevant to stakeholders and managers is an essential component when trying to reach management goals and remediate environmental impacts (Figure 8.42).[8, 119]

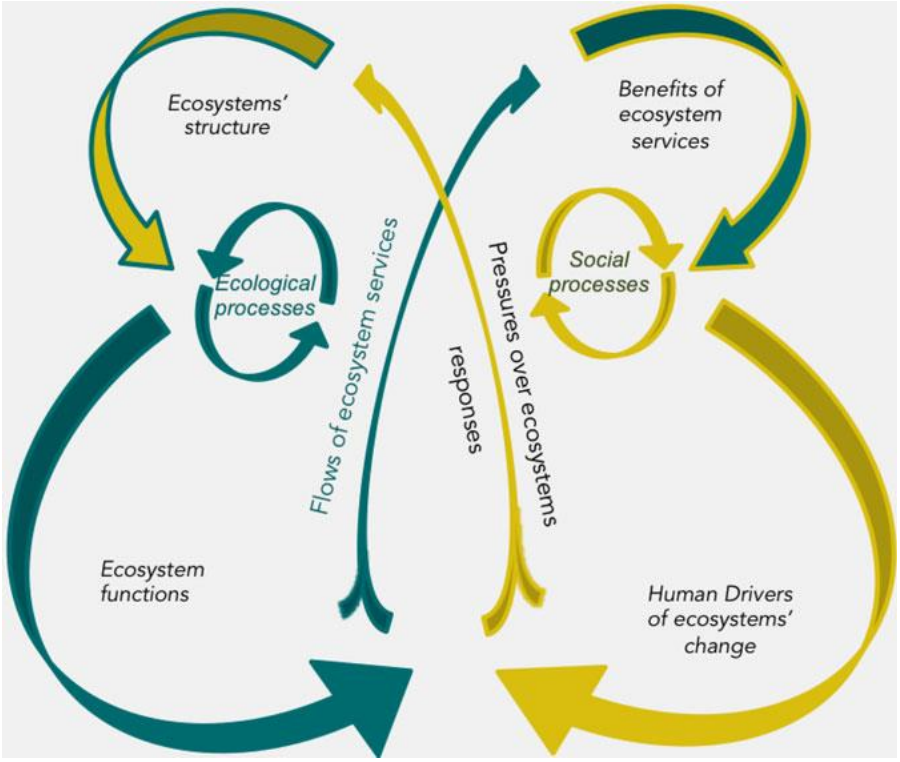

Figure 8.42. The butterfly diagram, a new model for the assessment and design of Ecosystem-Based Management. Supply side is shown in blue; demand side is shown in yellow. Social-ecological systems as interlinked, complex, adaptive systems.[119]

The APNEP has taken significant steps towards identifying coastal habitat and estuarine ecosystem indicator metrics in NC in their comprehensive ecosystem assessment of the Albemarle-Pamlico region.[120] This and similar efforts could be the foundation to identify the suite of indicators to be reported for coastal habitat types as well as by CHPP regions and coastwide .[121, 122] Once indicator metrics with reference points or thresholds are selected, the monitoring needs and data gaps in the extent, resolution, and frequency of the data needed to calculate those metrics can be addressed. Then the condition of coastal habitats, as well as overall estuarine and regional conditions, can be reported in regular intervals. With the push toward EBM, this would give managers the ability to assess changes over time and develop performance criteria for management actions while also creating a condition report, vital signs, or report card, for communicating coastal habitat and ecosystem conditions to the public.[10, 123]

8.3.1 Monitoring Needs and Data Gaps

Habitat indicators metrics by coastal habitat types, CHPP regions, and coastwide should be defined by agency and monitoring program staff along with regional experts and academics. Through this process, monitoring needs and data gaps should be determined and addressed to obtain the best available continuous data to inform these metrics. Existing DEQ programs and efforts should be evaluated and standardized whenever possible, and the expansion of existing programs should be explored to fill data gaps before initiating new programs. While some of these efforts are currently underway and several data gaps and monitoring needs have already been identified, this is a vast undertaking that should be done systematically and with the best available data and technologies while also taking into consideration the funding, staff, and resource limitations.

Water Column

Water quality monitoring is of the utmost importance for determining the health and condition of the estuarine ecosystem. Poor water quality can have significant impacts on the extent and distribution of coastal habitats and the fauna that use them. Having the ability to determine long-term temporal and spatial trends of water quality indicators and cause and effect relationships are critical for coastal managers. This information is needed to make informed management decisions and evaluate the effectiveness of management actions. While several state and federal agencies and academic institutes collect water quality data at various spatial and temporal scales, DWR's AMS is the most comprehensive long-term, continuous monitoring program along NC's coast. However, the 149 active monitoring stations within the CHPP boundaries are mostly concentrated in riverine and upper estuarine waters with some large spatial gaps existing along the coast. Currently, except for Albemarle Sound, there are no AMS stations in the sounds, at the mouths of the White Oak, New, and Cape Fear rivers, or many of the southern tidal creeks. Concerns for this lack of stations, especially in New River, were discussed by the DMF Shrimp Fishery Management Plan Advisory Committee at their March 2021 workshops.

Most AMS stations are monitored monthly and a core suite of indicators are measured at all stations. These include water temperature, specific conductance, pH, turbidity, total suspended solids (TSS), dissolved oxygen (DO), and fecal coliform. Additional indicators may be included depending on site-specific concerns such as stream classification, discharge types, and historical or suspected issues. Examples of site-specific indicators, which are monitored monthly or quarterly, include salinity, water clarity, flow, nutrients (NH_3, NO_2+NO_3, TKN, TP), fluoride, sulfate, total hardness, color, oil and grease, and chlorophyll *a*. These and all other water quality parameters should be evaluated to determine indicator metrics for tracking the status and trends of the water column habitat. Water quality indicator metrics may also involve other coastal habitats that have threshold tolerances like SAV and shell bottom. Expansion of the AMS to fill the identified spatial data gaps along with the addition of selected parameters chosen for indicator metrics will increase the ability to determine causal relationships between water quality and the natural and human-induced impact to the estuarine system, including fish populations. These data can be used, not only to track the status and trends of the water quality of coastal NC, but also to evaluate the effectiveness of a suite of management actions and allow for the potential for adaptive management of other coastal habitats like SAV and shell bottom that exhibit threshold tolerances. However, like most existing monitoring programs, funding and staff resources are a limiting factor. In addition to the AMS station monitoring, environmental conditions and evaluations associated with a response to fish kills, algal blooms, or other environmental investigations in coastal waterbodies requires dedicated staff.

Algal blooms and fish kill events often involve a host of factors and underlying causes. Therefore, it is crucial to gather as much information as possible surrounding an event from all involved parties. In 1996 the DWR Water Sciences Section (WSS), in consultation with Regional Office staff, Wildlife Resources biologists, and DMF personnel, instituted a new fish kill investigation procedure to be used by the DWR Regional Offices, Monitoring Teams, and other agencies to collect and track information on fish kills throughout the state. Fish kill and fish health data are recorded via standardized methods and sent to WSS where the data are reviewed. Fish kill investigation reports and supplemental information are compiled in a central database where the data can be managed, retrieved, and reported to state officials, scientists, and other concerned parties. Similar efforts have been undertaken with algal blooms, but a standardized procedure for algal bloom investigation across involved agencies is needed to collect the appropriate metrics at the time of the event, which can often be hard to capture. With increased reporting of both fish kills and algal blooms through the online portal and hotline, cross-training staff to perform these investigations is of increasing importance.

Public health concerns arise from some algal blooms that are harmful (HABs), producing toxins such as Microcystin that can cause adverse health effects. With technical support from DWR, local health departments and the NC Department of Health and Human Services, appropriate responses (swimming closures, contact advisories, issuance of public notifications, etc.) need to be determined. Due to these concerns, DMF's SSRWQ is currently conducting a pilot study and has prepared a Marine Biotoxin Contingency Plan to quickly respond to the emergence of any harmful algae species within State waters that may threaten the health and safety of shellfish consumers. The plan includes sentinel site monitoring for early warning of potential issues, the actions that will be taken to protect public health, and the steps that will be taken to reopen areas to shellfish harvest once the threats have subsided. This plan will begin to collect baseline data in areas not previously covered while complementing DWR's current monitoring efforts. Tracking the number of fish kills and algal blooms could prove to be useful indicator for overall estuarine ecosystem health, as well as development of criteria for determining success of management actions.

Shell Bottom

Despite what is currently understood regarding the value and necessity of retaining a healthy oyster population in NC's estuaries, there remains several critical knowledge gaps that limit management's ability to confidently evaluate restoration success, oyster reef performance, and estimate population sizes (stock assessment). There is a lack of contemporary, high resolution maps of subtidal hard bottom habitat that naturally occur throughout waterbodies suitable for sustaining oyster populations. There is also limited information regarding the impacts of the commercial oyster dredge fishery on natural oyster reefs, its ability to recover post-harvest, and the proportion of annual harvest that originates from cultch planted reefs.

Through grant funding, DMF is currently working in collaboration with NCSU, The Nature Conservancy, and local oystermen to conduct research in support of a stock assessment survey for oysters in NC.[34] To best assess the subtidal oyster populations, a fishery-independent methodology was developed and piloted across natural reefs in the Pamlico Sound. This methodology makes use of side-scan sonar, diver excavation surveys, and oyster dredges to establish oyster densities, new mortality, size-frequency demographics, and reef condition. This can result in an ideal overall representation of the area's oyster reefs due to careful calibration of the oyster dredge using diver surveys, standardized sampling methods, and the incorporation of gear experts from the commercial fishery. While the typical oyster dredge has low efficiency, this research is demonstrating how it can be effectively used to sample large areas and generate a robust overall average density and abundance estimates.

While this work is focused on modifying DMF's subtidal oyster management trigger sampling program for use in a stock assessment, these outcomes can also be used to standardize subtidal oyster sampling methods and metrics across all programs that encounter subtidal oysters, including oyster sanctuary and cultch planting monitoring. A similar gear comparison pilot study on cultch planted reefs in Stump Sound will be conducted during the 2021 season. Data from this pilot study will be used to assist DMF staff in determining future monitoring of cultch planted reefs to update the Spatfall Evaluation Program 610. Standardizing metrics across the programs that sample subtidal oysters will provide more robust data to be used in the stock assessment that will be used to better track the status and trends of NC's subtidal oyster population. Along with standardized metrics, modified and expanded monitoring designs will also improve siting of future oyster sanctuary and cultch planting sites and the ability to report metrics of success for the rehabilitative efforts.

Methods to evaluate and monitor NC's intertidal oyster population are also being evaluated. NC's intertidal oyster reefs remain difficult to access and navigate for monitoring due to the short tide windows that they are exposed and the shallow muddy characteristics of the habitat. To address such challenges, remote sensing technology paired with traditional quadrat groundtruth sampling is being explored. Remote sensing by use of Unmanned Aerial Systems (UAS) has considerable potential to radically improve environmental monitoring.[124] Compared to traditional air or space borne remote sensing, UAS-mounted sensors provide high spatial detail over relatively large areas in a cost-effective way and an entirely new capacity for enhanced temporal retrieval. These new survey methods can be used to evaluate the ability to detect changes in density, size-frequency demographics, and reef footprint over time (Bowling et al 2021 unpublished).[34] Preparations are underway to start an updated bottom mapping program. This new shellfish mapping program pilot study Remote Sensing Estuarine Bottom Habitat Mapping (Program 636) will use the remote sensing technology in conjunction with groundtruth sampling to obtain higher resolution mapping with standardized metrics with a focus on the natural intertidal oyster populations along the NC coast.

During the initial pilot study phase (2021-2022), 12 sites across the coast were selected to be mapped and sampled to develop best practices for drone monitoring and standardize groundtruth sampling methods. The sites are 100 acres and were chosen to represent the differing geography, hydrography, and available resource across the CHPP regions. All or a subset of these sites may be selected as long-term monitoring sites, or sentinel sites. The same 24 bottom type strata from the original Estuarine Bottom Habitat Mapping Program will be used, but may be modified and groundtruth sampling methods will be standardized across all DMF subtidal and intertidal oyster sampling programs whenever possible to provide more robust data for an oyster stock assessment to better track trends in the NC oyster population. A new and improved rapid assessment method would allow for a better understanding of the status and trends of the intertidal oyster population in NC, while also producing metrics that could also be used to evaluate and support the effectiveness of management actions.

Initial sampling for the subtidal portion of the study found notable impacts from hurricanes Florence and Dorian were also observed. These observations included heavy sedimentation on oyster reefs, strong water column stratification, hypoxic and anoxic conditions, and reduction in reef material. This sampling showed an overall decrease in oyster density during the same time period. In some cases, a 90 percent decrease in oyster density per square meter across study reefs were found, with an average overall decrease in density of 64 percent for the entire study area.[34] With a projected increase in the strength and intensity of tropical storms, fishery-independent surveys will be important for monitoring water quality and storm-induced mortality. While further study is needed, oyster reef size, profile, and location are thought significantly influence the severity of storm disturbance and resulting oyster mortality. This information could prove to be critical in providing resilience to oyster sanctuary and cultch planting sites through improved site selection and construction criteria.

Submerged Aquatic Vegetation

Understanding the distribution and health of SAV in NC is critical to understanding the dynamics of shifts in SAV species extent, distribution, and compositions. As previoulsy described, mapping of SAV has occurred at irregular intervals over the last 40+ years by several different agencies and universities, across different extents, and with varying methologies and resolutions. A comprehensive monitoring and assessment program for SAV should be developed using the best available technology. The use of the most comprehensive, highest resolution, and cost effective methods available should be explored and used. This program should be developed by a team of partners, and should include a full-scale, routine (occurring at least every five years), coast-wide assessment and monitoring program. Sentinel sites should be re-evaluated and expanded along the coast, with regular groundtruthing using standardized metrics (i.e. water quality, species composition, density, and condition). This will allow managers to account for changes in SAV over time, giving the ability to evaluate the success of management actions and determine causative relationships between changes in SAV species extent, distribution, and composition. Through regular monitoring and assessment, protection of this habitat can be improved and targeted, benefiting the diversity and resiliency of the entire coastal ecosystem.

Initial steps towards a coastwide, long-term, standardized SAV monitoring plan have been undertaken by APNEP.[125] The APNEP monitoring plan provides the information needed to initiate an SAV monitoring strategy for the Albemarle-Pamlico Estuarine System (APES). The assessment questions used to guide the development of the monitoring design were: 1) how is SAV condition changing in estuarine waters? and 2) are estuarine water quality conditions suitable to sustain the ecosystem services provided by SAV species? The SAV monitoring recommendations within the SAV monitoring plan for APES were based on a series of APNEP SAV Team high-salinity subcommittee and low-salinity subcommittee meetings during September and October 2020. The APNEP SAV team includes APNEP and DMF staff, as well as SAV experts and researchers from across the NC coast. A three-tiered hierarchical framework for SAV monitoring was adopted by both subcommittees and the APNEP Leadership Council to guide the development of recommendations.

This method was first tested in northeastern U.S. and has since been applied in other regions, including the Gulf of Mexico, and is an efficient and feasible way to detect and predict changes in seagrass systems in relation to management actions.[126, 127] In short, Tier 1 monitoring characterizes a few ecosystem properties simultaneously over large spatial scales, typically using satellite or remote sensing methods which are useful to quantify the extent and distribution of the SAV across the coast and geographic regions. Next, Tier 2 monitoring addresses specific environmental issues or ecosystem properties at a higher resolution, generally using ground-based approaches. This allows for monitoring of a limited number of metrics at a large number of sites across the coast or geographic regions. Tier 2 data can be used to quantify stressor/response relationships, and produce estimates of the ecological condition of resources over broad areas, or the quality of the system as a function of physical, chemical, or biological parameters. However, Tier-2 data are generally insufficient for developing predictive capabilities. Finally, Tier 3 monitoring addresses a larger number of metrics at a much smaller number of locations or subset of locations (e.g., sentinel sites). Intensive monitoring of drivers of change, ecosystem responses, and ecological processes at Tier 3 focuses on determining cause and effect relationships and can be used to help explain system wide changes. Both Tier 1 and Tier 2 data can influence targeted monitoring in Tier 3 and can be used to inform the adaptive management process.

Due to limited funding and staff resources, the APNEP monitoring plan proposes a rotational monitoring design, where one SAV region in the APES would be monitored per year until all regions were monitored one time, at which time the rotation would begin again (Figure 8.33).[125] The exact sampling design, including sampling numbers, site selection, sampling techniques, and collected metrics for Tier 2 was determined prior to the 2021 monitoring season. Tier 3 monitoring metric and sites still being determined. Once the three-tiered monitoring framework in the APNEP SAV monitoring plan is established in the high and low salinity regions within APES, this monitoring plan could be expanded to include the southern SAV regions of the state outside of the APES (Figure 8.33). However, like most monitoring, dedicated funding and staff are needed to ensure the long-term continuation of coastwide SAV monitoring. This monitoring is crucial to the understanding of the extent and condition of NC's SAV, as well as supporting management actions and decisions.

Wetlands

Comprehensive inventories of natural resources are recognized as critical components for informed management, policy, and conservation actions. Wetland maps are fundamental to wetland inventories, which are critical to management, restoration, protection, and informed development. Inventories informed by robust mapping efforts provide managers the information needed to assess the impacts of anthropogenic activities, changes over time that are attributable to natural phenomena, and the outcomes of management actions and restoration efforts. Consequently, shortcomings in wetland mapping, either in their resolution or comprehensiveness, can impede the development of comprehensive wetland inventories, pose a challenge to conducting robust environmental impact assessments, and broadly hinder data-drive natural resource management. Therefore, safeguarding NC's natural resources, while allowing for sustainable development, hinges on the collection and availability of comprehensive data on the distribution, characteristics, and function of NC's wetlands, 95 percent of which occur within the coastal plain.

The two primary wetland mapping sources that provide coastwide wetland distribution data include DCM's Wetland Inventory, and the National Wetland Inventory (NWI). The NWI produces wetland and deepwater habitat maps throughout the United States using photo-interpretation of aerial imagery and is the most extensive inventory of wetlands in the United States. A major shortcoming of the use of aerial imagery is the time lapse between image acquisition and production of wetland maps.[128] Further, the accuracy of imagery interpretation that informs NWI maps coming from multiple sources, is dependent on the quality of the imagery, availability of groundtruthing data, and repeatability by photo-interpretation analysts.

The DCM created a coastwide wetland inventory in the mid-1990's using NWI data, landcover classification from satellite imagery (Landsat data), and county-level soils data. The resolution and accuracy of DCM's wetland inventory, along with the older age of the imagery limits the products utility today. The United States Geological Survey (USGS) and NOAA have federal mapping efforts related to wetlands. NOAA's C-CAP inventories coastal intertidal areas, wetlands, and adjacent uplands on one- to five-year intervals at a spatial resolution of 30 x 30 meter pixels using Landsat data, aerial photography, and field observations.[129] Landsat data remains challenged by the relatively long period between revisits (16-18 days), cloud cover obstructing data collection, and shadows confounding interpretation.[130] As a result, the C-CAP has an accuracy target of 85 percent overall and 80 percent per habitat class.[131]

National and state inventories for land cover and wetlands are important tools used to formulate and evaluate the effectiveness of wetland policies and are integral to models used to predict the aerial extent of wetlands under a variety of future scenarios.[132] Therefore, the accuracy and resolution of these datasets have cascading effects throughout natural resource management and the research by which it is informed. While the spatial and temporal resolution of current NOAA C-CAP data has proven valuable for detecting large-scale changes in wetlands, particularly when the conversion occurs between distinct land cover types, numerous studies using higher-resolution imagery have documented wetland conversions that were not depicted using C-CAP data.[133, 134] Fortunately, there are efforts underway by NOAA C-CAP to generate spatially robust, high resolution (1m x 1m pixel) land cover inventories and map products. High resolution NOAA C-CAP mapping remains limited to a select few partner cost-share pilot projects around the country.[135] While nationwide one-meter resolution mapping is a goal of NOAA C-CAP within the coming decade(s), acquiring this data in the near-term and deriving the competitive advantage will require collaboration and funding through establishing partnerships.

The dramatically improved maps resulting from these pilot projects hold considerable promise to improve natural resource managers' ability to track wetland loss, gain, and land conversions. Further, higher resolution mapping of land cover has appreciable potential to improve predictive models critical to allocating scarce conservation and restoration resources. For example, high-resolution mapping of impervious surfaces and other barriers to marsh transgression is imperative to the identification of priority marsh migration corridors.[136] During the CHPP Wetland Workshop, NOAA representatives indicated the possibility of including NC mapping at the one-meter resolution as a pilot project, however state matching funds would be required. The value of high-resolution land cover mapping extends well beyond coastal resource management applications, providing information invaluable to planning and administration of transportation, agriculture, utilities, and infrastructure, to name a few. As such, coastal resource management agencies should consider working with other state agencies to pull together the funding necessary to commission one-meter land cover mapping.

There are several emerging technologies that have potential to allow more precise mapping with greater efficacy. Satellite data (Landsat) and aerial imagery (LIDAR) are more available but have low to moderate resolution. Unmanned Aircraft Systems (UAS) (i.e. drones), can provide rapid high resolution mapping but are not practical for a coastwide assessment.[137] A process known as data fusion, can use the high resolution UAS imagery, that has been field verified, to train classifications of lower resolution satellite imagery, such as WorldView (1.24 m resolution) or RapidEye (5.0 m resolution), improving accuracy of habitat classification with the satellite imagery, and is a method to generate 3D data Gray et al. in press; DEQ 2020). Another technique known as deep learning neural network uses a time series of satellite imagery to evaluate land cover change in a way that reduces post-processing time and increases speed of map creation. The Duke Marine Lab evaluated change in land cover in the Albemarle-Pamlico region between 1989 and 2011 with Landsat imagery and this deep learning technique. They were able to depict where farmland had transitioned to wetland; wetlands transitioning particularly along ditches and canals; and wetland forests along the estuarine shoreline converting to ghost forests (dead trees due to saltwater intrusion).[138, 139] Once proven, this technique would allow automated habitat classifications and change analysis rapidly. The ability to assess wetland change rapidly and accurately is critical to focusing management and restoration actions in priority areas in a time-effective manner.

North Carolina is also home to numerous universities and NGOs conducting research involving coastal wetland monitoring. However, the various sampling methodologies in these studies have impeded efforts to combine data to generate a meaningful picture of habitat condition at broader spatial or temporal scales. The development of standardized protocols to monitor wetlands, coupled with a central repository to submit reports or standardized data would facilitate policy managers and natural resource managers' ability to formulate actions based on robust, scientifically validated information. A repository of standardized wetland monitoring, which would include information from both published and unpublished studies, could minimize redundant sampling by researchers unaware of similar projects and facilitate synergistic collaborations. At the 2020 CHPP Wetland Workshop, most participants recognized the value of standard sampling protocol but thought that would be difficult due to different research objectives and funding sources. There was strong support for a central repository that included a database of who and where monitoring was occurring and completed reports. Both the formulation of some minimum standardized sampling protocol and the development of a centralized repository will require an inclusive process of consultation between practitioners, managers, and other user groups.

Expanded long-term funding opportunities should also be explored. Wetland monitoring conducted by DWR has been funded primarily by the EPAs WPDG that typically focus on short term monitoring projects. To provide a spatially robust inventory of the condition of the state's wetland resources over ecologically meaningful temporal scales, there is a need to move away from a dependence on external grant funding, which can be intermittent and variable in their research objectives, to a recurring state appropriation for standardized wetland monitoring that is critical to generating the data needed for science driven management.

Hard Bottom

Many aspects of the artificial and natural reef systems in NC have yet to be explored. A major concern with artificial reefs is if they are aggregating fishes from natural reefs where they are more easily overfished. Determining whether artificial reefs function only as refuge or if they support and increase fish populations is an important distinction that has not yet been addressed. There is also limited information on the biomass that can be supported by natural reefs and the comparison of artificial reefs. Currently, the artificial reefs in NC are being monitored by the Artificial Reef Program for material stability and major storm effects annually. However, there is no consistent monitoring of the condition of natural hard bottom within state waters. In addition to material and storm monitoring, and research to determine the function of artificial reefs, a monitoring program should be evaluated to inform the extent of natural hard bottom in NC state waters as well as the condition of both natural and artificial reefs.

Soft Bottom

Coastal soft bottom, sandy shoals and muds flats, are dynamic and ever shifting as other habitats expand or contract. These soft sediment environments are complex ecosystems containing strong physical gradients that affect the distribution of species and physicochemical conditions.[99] As coastal managers continue to mitigate environmental impacts with human needs, bathymetry data and the information that can be derived from it such as predictive models of tides, currents, temperature, and salinity, play a pivotal role in using and managing and understanding the status and trend of NC's coastal resources. Improved and updated bathymetry data of the sounds and NC's coastal waters will not only aid in the management of NC's soft bottom resource for activities such as aquaculture, but it will also contribute important information needed to determine the condition and support management decisions for almost all of the other coastal habitats as well.

In addition to updated information on the extent of soft bottom, it is also important to know the condition and quality of soft bottom habitat since it can affect species abundance and diversity of the benthic community. Monitoring of the sediments in soft bottom habitat for accumulated chemical and microbial contaminants, as well as the benthic organisms potentially impacted by these contaminants, is vital to understanding the status and trends of the soft bottom habitat. While some academic studies have been conducted and the NCCA does collect sediment quality data, the spatial and temporal scales are limited and there is no comprehensive coastwide estuarine soft bottom monitoring in NC. The Bioassessment Branch of DWR has been conducting benthic macroinvertebrate assessments in the wadeable and non-wadeable lotic waters of NC since 1978. However, most sampling stations occur in the headwaters and very few occur in the tidal creeks. This program should be evaluated to expand existing sampling and parameters to fill this monitoring need.

8.4 Recommended Actions

8.4.1 Planning

8.1 By 2022, convene interagency workgroups of DEQ agency staff, academics, and subject matter experts by coastal habitat type (i.e., water column, shell bottom, SAV, wetlands, hard bottom, and soft bottom) to define indicator metrics and identify data gaps and monitoring needs for the ability to determine long-term status and trends of coastal habitats and the estuarine ecosystem.

8.4.2 Outreach

8.2 By 2026, develop a document determined by the workgroups to communicate the ecosystem conditions of NC to the public.

8.4.3 Water Column

8.3 By 2023, DWR will evaluate and prioritize estuarine ambient monitoring system sites to address gaps in spatial, habitat, or parameter coverage.

8.4 By 2022, DWR will update standardized procedures for algal bloom investigations and evaluate the potential to cross-train other DEQ divisions to perform estuarine and marine investigations.

8.4.4 Submerged Aquatic Vegetation

As recommended in the Chapter 4. Submerged Aquatic Vegetation Protection and Restoration through Water Quality Improvements Issue Paper.

4.5 By 2023, DEQ will develop and implement a full-scale assessment program to conduct coastwide SAV mapping and monitoring at regular intervals (≤ 5 years).

4.6 By 2023, DWR will evaluate and prioritizes the incorporation of shallow water sites (< 1m mean lower low water (MLLW)) that currently or historically contain(ed) SAV into the statewide ambient monitoring system.

8.4.5 Wetlands

As recommended in the Chapter 5. Wetland Shoreline Protection and Enhancement with Focus on Nature-Based Solutions Issue Paper.

5.1 By 2023, DEQ will obtain state matching funds for the NOAA C-CAP program to map NC's Coastal Plain at 1m resolution and additional funding to expand coastal wetland monitoring conducted by DWR and other state agencies. 5.2 By 2024, DEQ will pursue the use of emerging technologies such as data fusion or deep learning neural networks, that rely on a combination of satellite imagery, drone imagery, and field verification into coastal wetland mapping and change analyses. 5.3 By 2022, DEQ will form an interagency workgroup to develop a coastal wetland mapping and monitoring plan, including a minimum set of standardized metrics and a potential centralized location to store relevant reports and information. 5.4 By 2026, DEQ will determine the status and trends of coastal wetland acreage, condition, and function, based on the additional mapping and monitoring data obtained.***Hard Bottom***

8.5 By 2023, DMF will develop a monitoring strategy to determine how best to map natural hard bottom reefs in NC state waters and monitor the condition of both natural and artificial reefs.

8.4.7 Soft Bottom

8.6 By 2023, DWR will examine the feasibility of expanding the benthic macroinvertebrate sampling to address spatial gaps in assessing the estuarine soft bottom benthic community condition.

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9. SUMMARY OF RECOMMENDED ACTIONS

9.1 Priority Habitat Issues Recommendations

9.1.1 Chapter 4. Submerged Aquatic Vegetation Protection and Restoration Through Water Quality Improvements

Funding

4.1 By 2023, DEQ will obtain recurring funding that includes the adequate amount of staff to successfully evaluate and meet the SAV acreage goals and implement all of the SAV recommended actions that contribute to meeting the goals.

Planning

4.2 By 2022, DEQ will commit to protecting and restoring SAV to reach an interim goal of 191,155 acres coastwide with specific targets by SAV waterbody regions (Table 4.5; Figures 4.1-4.9).

4.3 By 2022, DEQ will form an interagency workgroup with NGOs, and local governments to inform and guide development of watershed restoration plans to protect, restore or replicate natural habitats (i.e., SAV, water quality, coastal habitats) and hydrology through natural and nature-based solutions.

4.4 By 2022, DEQ will form a workgroup with DWR, Soil and Water Conservation, local governments, and other partners to develop a plan to increase the use of BMPs related to water quality within the SAV waterbody regions by 50 percent (Table 4.5; Figures 4.1-4.9).

Mapping and Monitoring

4.5 By 2023, DEQ will develop and implement a full-scale assessment program to conduct coastwide SAV mapping and monitoring at regular intervals (≤ 5 years).

4.6 By 2023, DWR will evaluate and prioritize the incorporation of shallow water sites (< 1m mean lower low water (MLLW)) that currently or historically contain(ed) SAV into the statewide ambient monitoring system.

Potential Rulemaking

4.7 By 2022, the Nutrient Criteria Development Plan (NCDP) Scientific Advisory Council (SAC) will evaluate recommending the EMC establish a water quality standard for light penetration, with a target value of 22 percent to the deep edge (1.7 m) of SAV for all high salinity SAV waterbody regions, and a light penetration target of 13 percent to the deep edge (1.5 m) for all low SAV waterbody regions (Table 4.5 and Figures 4.1-4.9).

4.8 By 2022, the NCDP's SAC will evaluate the chlorophyll *a* water quality standard and as needed, recommend it be revised by the EMC to ensure protection of SAV in high and low salinity waterbody regions, beginning with the Albemarle Sound and Chowan River, and continuing with other waterbodies that support SAV (Table 4.5; Figures 4.1-4.9).

4.9 By 2024, EMC will adopt scientifically defensible nitrogen and/or phosphorus criteria if recommended through the NCDP process, to help protect and restore ~12,900 acres of low salinity SAV habitat in the Albemarle Sound SAV waterbody region and continuing with other waterbodies that support SAV.

Research

4.10 By 2025, DWR will determine with assistance from research academia, the loading and sources of nutrients and sediments, their quantitative linkages to chlorophyll *a* concentrations, and their effect on water quality and SAV.

4.11 By 2022, NC and DEQ, through the Secretary of Emergency Management, will request more accurate estuarine bathymetry data from NOAA.

4.12 By 2022, DWR will request the NC Policy Collaboratory to investigate the impacts of agricultural practices and land use change on water quality within SAV waterbody regions, to determine types and location of BMPs needed to effectively improve water quality.

Outreach

4.13 By 2022, DEQ Office of Education and Public Affairs will work with local governments and NGOs to start the development of public education and stewardship programs with social media campaigns and citizen science monitoring to increase public awareness of SAV's importance for fish habitat and other co-benefits, as well as instill public commitment to SAV conservation.

4.14 By 2022, DEQ through funding of NCSU by APNEP will provide an economic evaluation of the co-benefits SAV provides to the coastal economy in terms of habitat for fish, waterfowl, wildlife, recreation, shoreline stabilization, water purification, and carbon sequestration.

9.1.2 Chapter 5. Wetlands Shoreline Protection and Enhancement with Focus on Nature-Based Solutions

Mapping and Monitoring

5.1 By 2023, DEQ will obtain state matching funds for the NOAA C-CAP program to map NC's Coastal Plain at 1m resolution and additional funding to expand coastal wetland monitoring conducted by DWR and other state agencies.

5.2 By 2024, DEQ will pursue the use of emerging technologies such as data fusion or deep learning neural networks, that rely on a combination of satellite imagery, drone imagery, and field verification for coastal wetland mapping and change analyses.

5.3 By 2022, DEQ will form an interagency workgroup to develop a coastal wetland mapping and monitoring plan, including a minimum set of standardized metrics and a potential centralized location to store relevant reports and information.

5.4 By 2026, DEQ will determine the status and trends of coastal wetland acreage, condition, and function, based on the additional mapping and monitoring data obtained.

Conservation

5.5 By 2022, DEQ will provide information to NC legislators regarding the need for increased appropriated funds for the three state conservation trust funds to increase conservation of critical wetland properties and critical corridors that will allow for future marsh migration.

5.6 By 2022, DEQ will actively participate in and support the development of a Southeast Regional Marsh Conservation Plan, which is a partnership with the Department of Defense along with federal, state, and private groups that have been initiated by the Southeast Partnership for Planning and Sustainability (SERPPAS).

5.7 By 2026, DEQ will work with researchers, federal and local governments and NGOs to facilitate marsh migration through the conservation of migration corridors, including participation in the Pew Charitable Trust-SERPPAS Salt Marsh Initiative.

Restoration and Living Shoreline

5.8 By 2022, DMF will determine potential mechanisms to prevent harvesting from living shorelines constructed with oysters.

5.9 By 2025, DEQ will determine if living shoreline projects can be built in a manner that qualifies for salt marsh or nutrient mitigation credits.

5.10 By 2025, DEMLR and other divisions should increase education, outreach, and training to consultants, local government, and landowners for nature-based stormwater and watershed management strategies.

Research

5.11 By 2024, DEQ should partner with other organizations to facilitate coastwide completion or enhancement of coastal vulnerability assessment tools, such as living shoreline siting, and marsh migration and wetland restoration prioritization.

5.12 Determine optimal parameters for thin layer sediment deposition to ensure wetland success.

5.13 Assess trends in salt marsh elevation, inundation, and distribution to prioritize areas for wetland restoration.

5.14 Determine the impact of degrading plastics and marine debris on wetlands, sediment, and the benthos.

5.15 Research the nutrient (nitrogen, phosphorus) reduction benefits provided by living shorelines and use that information to provide incentives for living shoreline projects.

5.16 Study the effects of silvicultural timber harvesting in palustrine (bottomland swamp) forests on hydrology, water quality, and wetland condition; include assessment on the efficacy of forestry BMPs to minimize ecological impacts.

5.17 By 2022, DEQ should support efforts to incorporate coastal wetlands into NC's Greenhouse Gas (GHG) Inventory.

9.1.3 Chapter 6. Environmental Rule Compliance and Enforcement to Protect Coastal Habitats

Funding

6.1 By 2023, through legislative appropriations or budget reallocations, DEQ will increase staffing in DWR and DEMLR by a minimum of two staff (one per office, per agency) in the Washington and Wilmington regional offices.

6.2 By 2023, DEQ will seek funding through grants or other sources to supplement state-appropriated compliance efforts.

<u>Outreach</u>

6.3 By 2022, DWR and DEMLR should work with the DEACS to establish a public portal on DEQ's website that provides information on compliance issues, allows the public to submit complaints, and potentially highlights a list of repeat violators.

6.4 By 2023, DWR, DEMLR, and DCM should develop and hold outreach workshops for NGOs, HOAs, and other interested public, on rules related to land disturbing activities that affect wetlands and water quality, and how to identify violations to improve the effectiveness of public complaints.

6.5 By 2022, DEMLR will initiate and continue outreach to stormwater permit holders on rules and required maintenance of stormwater control measures and structures.

9.1.4 Chapter 7. Wastewater Infrastructure Solutions for Water Quality Improvement

<u>Policy</u>

7.1 By 2024, DEQ will request that funding programs under the purview of the SWIA give additional priority for projects with a direct benefit to sensitive estuarine waters, including SA waters, fish nursery areas, and impaired waters, particularly those adversely impacting estuarine fish and their habitat.

7.2 By 2025, DWR will develop additional incentives to encourage improved maintenance of the collection system (e.g. incentivize owners and operators of wastewater lines for both existing systems and potential new systems to adopt construction designs that minimize the potential for sewer spills over the long-term).

7.3 By 2025, DCM and DWR will work with NC Office of Recovery and Resiliency (NCORR) and local governments in the coastal counties to develop strategies regarding flood-proofing wastewater infrastructure; siting new and relocating existing infrastructure away from sensitive estuarine waters and floodplains; upgrading sewer infrastructure; and develop strategic priorities for public and natural infrastructure improvements

<u>Potential Rulemaking</u>

7.4 By 2023, DWR will evaluate modifications of EMC rules to require deemed permitted collection systems under select criteria (e.g. 100,000 or more GPD) to have a certified operator as an Operator in Responsible Charge (ORC). DWR shall provide an update on this evaluation effort to the Water Quality Committee in approximately one year.

7.5 By 2023, DWR will investigate modification of EMC rules to require deemed permitted collection systems to be cleaned annually on a systematic basis (e.g. 3 to 5 years). The DWR shall provide an update on this evaluation effort to the Water Quality Committee in approximately one year.

<u>Research</u>

7.6 Prioritize research on alternative wastewater collection system designs that may be better suited for coastal conditions (i.e., alternative sewer systems, composting toilets).

7.7 Evaluate the feasibility of re-designing and re-engineering existing systems that are inadequately protecting ground and surface water quality.

9.1.5 Chapter 8. Coastal Habitat Mapping and Monitoring to Assess Status and Trends

Planning

8.1 By 2022, convene interagency workgroups of DEQ agency staff, academics, and subject matter experts by coastal habitat type (i.e., water column, shell bottom, SAV, wetlands, hard bottom, and soft bottom) to define indicator metrics and identify data gaps and monitoring needs for the ability to determine long-term status and trends of coastal habitats and the estuarine ecosystem.

Outreach

8.2 By 2026, develop a document determined by the workgroups to communicate the ecosystem conditions of NC to the public.

Water Column

8.3 By 2023, DWR will evaluate and prioritize estuarine ambient monitoring system sites to address gaps in spatial, habitat, or parameter coverage.

8.4 By 2022, DWR will update standardized procedures for algal bloom investigations and evaluate the potential to cross-train other DEQ divisions to perform estuarine and marine investigations.

SAV

See the Submerged Aquatic Vegetation (SAV) Protection and Restoration Through Water Quality Improvements Issue Paper Mapping and Monitoring recommended actions 4.5 and 4.6 in section 9.1.1.

Wetlands

See the Wetlands Shoreline Protection and Enhancement with Focus on Nature-Based Solutions Issue Paper Mapping and Monitoring recommend actions 5.1-5.4 in section 9.1.2.

Hard Bottom

8.5 By 2023, DMF will develop a monitoring strategy to determine how best to map natural hard bottom reefs in NC state waters and monitor the condition of both natural and artificial reefs.

Soft Bottom

8.6 By 2023, DWR will examine the feasibility of expanding the benthic macroinvertebrate sampling to address spatial gaps in assessing the estuarine soft bottom benthic community condition.

9.2 Coastal Habitat Protection Plan Supported Recommendations from Other Plans

Since the 2016 Coastal Habitat Protection Plan (CHPP), several coastal resilience planning documents and reports were developed citing the CHPP with recommendations that are consistent with and are supported by the issue papers in this Amendment. These include the NC Risk and Resiliency Plan 2020, the Natural Working Lands Action Plan 2020, the NC Oyster Blueprint 2021-2025, the Action Plan for Nature-Based Stormwater Strategies, and the State Water Infrastructure Authority Report.[1, 2, 3, 4, 5]

Table 9.1 includes a partial list of existing recommendations adapted from these other plans that are strongly supported by the CHPP and the CHPP Steering Committee (CSC). Several DEQ divisions that implement CHPP recommendations participated in the development of these planning documents and included specific recommendations in the plans to implement through the CHPP. These staff will continue to support and assist with the implementation of these plans through the CHPP and other avenues.

Photo Credit: NCWetlands.org

Table 9.1. Recommendations adapted from planning documents that will benefit protection and restoration of coastal habitats and are consistent with the goals and recommendations of the Coastal Habitat Protection Plan (CHPP).

Source(s)	Recommendations	Issue Paper
NC Risk and Resiliency Plan[1]	Enhance outreach, particularly to landowners and decision makers, on the need to have accurate and updated wetland maps due to their high value for fisheries, ecosystem services, and coastal resilience.	Wetlands
	Incorporate climate risk and expected hydrologic and shoreline changes into wetland related policies, such as buffers and wetland impact permitting.	Wetlands
	Actively pursue partnerships with state and federal agencies and NGOs to increase wetland restoration and conservation along coastal rivers and streams to increase ecosystem services and coastal resiliency, taking climate change and SLR into consideration.	Wetlands
Natural Working Lands Action Plan[2]	Facilitate increased conservation and restoration of forested wetlands within floodplains through economic incentives, acquisition, easements, and strategic floodplain buyouts to conserve forested wetlands, enhance ecosystem services, and improve coastal community resilience.	Wetlands
	Facilitate the development of specific policies through local, state, and federal pathways that encourage and incentivize the protection of coastal habitats (including SAV).	SAV
NC Risk and Resiliency Plan & Action plan for nature-based stormwater strategies[1, 4]	Advance state and local policies that promote and incentivize the use of nature-based strategies for public and private landowners when rebuilding damaged infrastructure and managing stormwater runoff to increase coastal resilience. Nature-based stormwater strategies should be designed to achieve "runoff volume matching" as specified in the state's stormwater design manual.	Wetlands
Action plan for nature-based stormwater strategies[4]	Educate the North Carolina congressional delegation on opportunities to substantially increase the amount of financial resources for working lands and conservation coming from the federal Farm Bill and other federal programs.	Wetlands
The Oyster Blueprint 2021-2025[3]	The NC Living Shoreline Steering Committee will devise and implement communication and education strategies and publicize the benefits of living shorelines, targeting property owners and contractors.	Wetlands
	Expand current science-based tools for siting and design of living shorelines in all coastal counties.	Wetlands
	Seek monetary incentives (cost share, funding, tax credits, mitigation credits, etc.) to increase the development of living shorelines in place of bulkheads where appropriate.	Wetlands
State Water Infrastructure Authority Report[5]	Request adequate and recurring state appropriated funds needed for the viable utility reserve.	Wastewater
	Request the NC General Assembly modify legislation to allow SWIA flexibility in establishing grant conditions for programs under their authority, to ensure grant funds are used to help systems achieve long-term viability.	Wastewater

9.3 Literature Cited

[1] NCDEQ (North Carolina Department of Environmental Quality). 2020. North Carolina Climate Risk Assessment and Resiliency Plan. North Carolina Department of Environmental Quality, Raleigh, NC. https://files.nc.gov/ncdeq/climate-change/resilience-plan/2020-Climate-Risk-Assessment-and-Resilience-Plan.pdf

[2] NCDEQ (North Carolina Department of Environmental Quality). 2020. North Carolina Climate Risk Assessment and Resiliency Plan, Appendix B: North Carolina Natural and Working Lands (NWL) Action Plan, Raleigh, NC.

https://files.nc.gov/ncdeq/climate-change/resilience-plan/Appendix-B-NWL-Action-Plan-FINAL.pdf

[3] NCCF (North Carolina Coastal Federation). 2021. The Oyster Restoration and Protection Plan for North Carolina: A Blueprint for Action 2021-2025. Ocean, NC. https://www.nccoast.org/wp-content/uploads/2021/04/Oyster-Blueprint-2021-2025-April-2021.pdf

[4] NCCF (North Carolina Coastal Federation). 2021. Action plan for nature-based stormwater strategies: Promoting natural designs that reduce flooding and improved water quality in NC. Ocean, NC. 28 p.

[5] NCDWI (North Carolina Division of Water Infrastructure). 2020. Report on the water infrastructure fund and state water infrastructure authority. Fiscal year 2020. North Carolina Department of Environmental Quality. Raleigh, NC. 183 p.

Photo Credit: NEERS?