NC Marine Fisheries Commission

Coastal Habitat Protection Plan

August 2026 Quarterly Business Meeting

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Introduction

The state of North Carolina contains the largest estuarine system of any coastal state on the eastern seaboard, comprised of over 2.9 million acres of estuarine and coastal waters and 12,000 miles of estuarine shoreline, containing diverse habitats that are vital for sustaining the state's economically and ecologically important fisheries and resilient coastal communities. However, these habitats and the species they support are increasingly facing degradation and loss from a multitude of ongoing and cumulative anthropogenic impacts. The Coastal Habitat Protection Plan (CHPP) originates in the Fisheries Reform Act of 1997 (FRA; G.S. 143B-279.8), which requires the Marine Fisheries Commission, Coastal Resources Commission, and Environmental Management Commission to adopt and implement the plan through coordinated management. The CHPP serves as plan to 1) describe and classify biological systems in the habitats, 2) evaluate the function, value to fisheries, status, and trends of habitats, 3) identify existing and potential threats to the habitats and the impact on coastal fishing, and 4) recommend actions to protect and restore habitats.

The CHPP is developed and implemented by NCDEQ staff with expertise in marine fisheries, coastal development, and water quality issues. Updated every five years, previous CHPPs were released in 2005, 2010, 2016, and 2021. The 2021 CHPP served as an amendment to the 2016 CHPP (sometimes referred to as the "source document"), and this CHPP also serves as an amendment to the 2016 CHPP. Increasing water quality degradation, habitat loss, and climate change continued to build pressure on coastal habitats and the fisheries that depend on them. Accordingly, this CHPP aims to build upon recommendations from the 2021 CHPP to address salt marsh loss and resilience, submerged aquatic vegetation (SAV) habitat loss and restoration, strategic habitat area validation, and ecosystem-based management for coastal habitats.

The status and trends of North Carolina's coastal ecosystems: ecosystem indicator metrics and a statewide coastal ecosystem report card

An understanding of the status of NC's coastal habitats is needed to assess and address the drivers of long-term habitat change and the cascading effects on the fish, shellfish, and crustaceans dependent on them. Since acquiring substantial resources remains a barrier to establishing comprehensive long-term monitoring for a suite of indicators for each habitat, DEQ must explore alternative approaches such as an ecosystem level evaluation. This chapter identifies ecosystem report cards as a stakeholder driven assessment and communication tool to evaluate the ecological, social, and/or economic aspects of North Carolina's coastal ecosystems. DEQ will co-design a framework for the report card with a stakeholder workgroup, and scientists and managers will select metrics to best reflect the ecosystems and distill trends into easy-to-understand grades (A, B, C, D, F). The completed ecosystem report card will provide a simple, accessible way for the public and decision makers to understand the current ecosystem status and how it has changed over time.

Strategic Habitat Area validation and implementation plan development

Through previous CHPPs, DMF used a conservation planning tool that incorporated spatial analysis and subject matter expert input to identify a network of high-quality habitat areas in coastal watersheds, referred to as Strategic Habitat Areas (SHAs). SHA nominations for the four CHPP regions were completed in 2017, and field sampling was conducted in two regions (Regions 3 and 4) to verify that the habitat condition and biological productivity of nominated areas were high. Results from the field survey validate that nominated areas support a higher abundance of diverse fish populations. In combination with findings that Strategic Habitat Areas have a more diverse estuarine landscape, a higher area of structured habitats, and less alteration than areas outside of SHAs, the results of this validation study further support the designation of the nominated Strategic Habitat Areas. These results will be combined with additional analysis of DMF independent sampling data in a future issue paper that presents validation of Strategic Habitat Areas statewide and proposes designation options to the Marine Fisheries Commission. Strategic Habitat Area management options will then be developed through stakeholder engagement and collaboration with state, federal, and private partners and presented in another issue paper to rulemaking commissions and external partners.

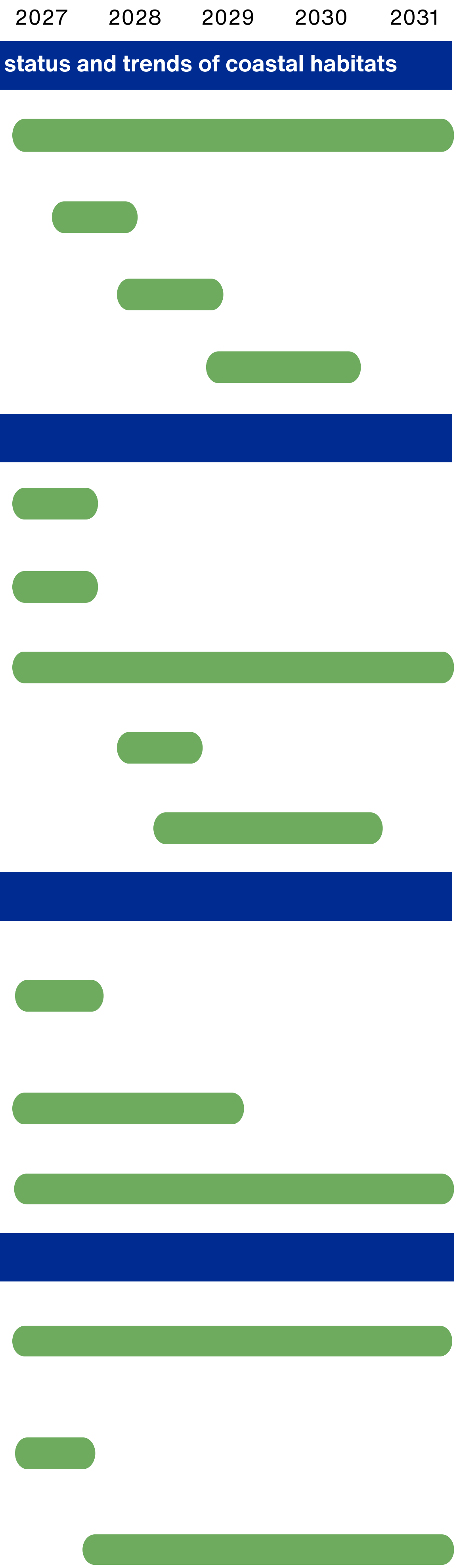
Thin Layer Placement

North Carolina has approximately 235,000 acres of estuarine wetlands in its coastal waters, which provide essential nursery habitat for fish species, foraging and nesting sites for shorebirds and small mammals, shoreline stabilization and erosion control, and enhance water quality through nutrient and pollutant retention. However, those estuarine wetlands are increasingly threatened by sea level rise, saltwater intrusion, and erosion, and the 2021 CHPP called for expanding collaborations between state, federal, and private partners to protect and restore impacted wetlands through nature-based solutions. This CHPP builds on those 2021 CHPP recommendations by outlining the benefits, resource impacts, and policy and permitting concerns with thin-layer placement, which is a restoration, enhancement, and resilience strategy broadly defined as the application of sediments (primarily dredged material) to coastal wetlands in order to increase elevation and surface area, promote sediment accretion, and restore impaired habitat. During development of this CHPP, DEQ staff hosted a workshop to discuss thin layer placement and to share successes, challenges, concerns, and lessons learned associated with the ecological impacts of placing sediment on deteriorating wetlands, and feedback from staff attending the workshop was incorporated into this chapter of the CHPP. The information and guidance summarized in this chapter will serve as an additional resource for regulatory and resource agency staff, commission members, restoration practitioners, and researchers as additional thin layer placement projects are proposed in North Carolina.

Submerged aquatic vegetation protection and restoration

North Carolina's coastal waters have historically supported nearly 200,000 acres of submerged aquatic vegetation (SAV), which provides critical spawning, foraging, and nursery habitat for most of North Carolina's fisheries, and provides additional ecosystem services including carbon sequestration, nutrient filtering, and sediment stabilization. However, degraded water clarity, sea level rise, and rising temperatures represent growing threats to SAV across the state, with rates of habitat loss currently exceeding 1% per year, plus increasing conversion of continuous meadows to patchy SAV beds. The 2021 CHPP set a statewide goal of ensuring a SAV extent of 191,155 acres and recommended new and updated water quality standards to ensure adequate light penetration to allow SAV to regrow in areas where poor water clarity has led to its loss. To ensure progress on slowing the rate of SAV loss across the coast, this CHPP highlights the need to continue to advance a water clarity standard to protect SAV, outlines an approach for a habitat-based rulemaking framework for the MFC to implement additional SAV protections, and summarizes the regulatory framework and ecological and practical concerns for future seed- and transplant-based SAV restoration projects.

2026 Recommended Actions



Applying the Integrated Ecosystem Assessment approach to assess the status and trends of coastal habitats

Establish internal working group to establish goals of an ecosystem assessment and state ecosystem report card.

Conduct workshop with stakeholders, scientists and managers to select ecosystem indicators and establish appropriate thresholds.

Calculate scores and create a state report card that is easily accessible to a wide audience.

Communicate status and trends of coastal ecosystems to stakeholders, decisionmakers, and the public.

Strategic Habitat Area validation and implementation

Explore feasibility of using DMF independent sampling data to validate SHAs for Albemarle Sound and Pamlico Sound regions

Develop issue paper that presents validation of Strategic Habitat Areas statewide and propose designation options to the MFC

Establish internal working group to develop management options for Strategic Habitat Areas.

Conduct a workshop with state partners to further establish potential management strategies.

Complete a SHA management issue paper and present management options to the appropriate commissions and external partners.

Submerged aquatic vegetation protection and restoration

Prioritize progress on the recommended actions from the 2021 CHPP amendment to improve water quality for SAV, especially by collaborating to facilitate the passage and implementation of a water clarity standard to protect SAV.

Initiate formal MFC rulemaking process to develop a CHPP habitat-based rule framework

Work group to explore barriers to on-the-ground SAV restoration and identify research needs

Thin layer placement (TLP)

Create a state-wide multi-agency workgroup to progress TLP to facilitate establishment of best practices for TLP specific to North Carolina.

Evaluate the status and trends of wetlands across coastal North Carolina, incorporating high-resolution land cover data obtained through the 2021 CHPP.

Leverage existing tools and data sources to identify candidate areas that may benefit most from TLP.

The status and trends of North Carolina coastal ecosystems: ecosystem indicator metrics and a statewide coastal ecosystem report card

Executive summary

An understanding of the status of NC's coastal habitats is needed to assess and address the drivers of long-term habitat change and the cascading effects on the fish, shellfish, and crustaceans dependent on them. Since acquiring substantial resources remains a barrier to establishing comprehensive long-term monitoring for a suite of indicators for each habitat, DEQ must explore alternative approaches such as an ecosystem level evaluation. This chapter identifies ecosystem report cards as a stakeholder driven assessment and communication tool to evaluate the ecological, social, and/or economic aspects of North Carolina's coastal ecosystems. DEQ will co-design a framework for the report card with a stakeholder workgroup, and scientists and managers will select metrics to best reflect the ecosystems and distill trends into easy-to-understand grades (A, B, C, D, F). The completed ecosystem report card will provide a simple, accessible way for the public and decision makers to understand the current ecosystem status and how it has changed over time.

Introduction

An understanding of the status of NC's coastal habitats is needed to assess and address the drivers of long-term habitat change and the cascading effects on the fish, shellfish, and crustaceans dependent on them. To accomplish this goal, long-term monitoring of each coastal habitat (water column, shell bottom, SAV, wetlands, soft bottom, and hard bottom) needs to occur at appropriate spatial scales and regular intervals.

While there is a range of active long-term programs to monitor fish and water quality, programs that monitor habitat area and function are limited or absent due to the lack of funding for long-term data collection not directly related to agency regulatory compliance. The 2021 CHPP Amendment called to expand mapping and monitoring programs across all habitats to enable formal assessment of ecological indicators (2021 CHPP Recommended Action 8.6), but limited progress has been made to expand in coverage or frequency, let alone establish new monitoring.

Current habitat and water quality monitoring programs

The following sections describe the status of active long-term monitoring programs for coastal water quality and habitats in North Carolina. For historical mapping and monitoring information, please see *Chapter 8. Coastal habitat mapping and monitoring to assess status and trends* in the 2021 CHPP. Complete descriptions, distribution, ecological function, and threats of the six coastal habitats can be found in the 2016 CHPP source document.

Water column

The water column habitat includes all water covering a submerged surface and is the medium that connects all aquatic habitats and associated fauna. The water quality describes the condition of water based on the physical, chemical, and biological characteristics, usually with respect to its suitability for a particular purpose such as drinking, recreation, or supporting aquatic life. While there are multiple programs that measure water quality data in the state, there is not sufficient spatial or temporal coverage within CHPP boundaries.

The NC Ambient Monitoring System (AMS), conducted by NC Division of Water Resources across the entire state, is the most comprehensive long-term, continuous water quality monitoring program along NC's coast. There are 149 active monitoring stations within the CHPP boundaries. However, stations are concentrated mostly in riverine and upper estuarine waters, with some large spatial gaps existing along the coast (2021 CHPP Chapter 8). Water temperature, specific conductance, pH, turbidity, total suspended solids (TSS), dissolved oxygen (DO), and fecal coliform are monitored monthly at each site. Some sites receive specific additional measurements based on stream classification, discharge types, and historical/suspected issues, which can include salinity, water clarity, flow, nutrients (NH3, NO2+NO3, TKN, TP), fluoride, sulfate, total hardness, color, oil and grease, and chlorophyll a. The 2021 CHPP (Recommended Action 8.3) called for DWR to evaluate and prioritize estuarine ambient monitoring system sites by 2023, but there was no capacity to address gaps in the spatial, habitat, or parameter coverage.

DEQ also tracks the occurrence of fish kills and algal blooms. Algal blooms occur when specific environmental conditions in the water column are met (e.g., increased nutrient concentrations, high water temperature, prolonged solar radiation, stagnant water flows). Algae rapidly grow or "bloom" and some can contain toxic compounds for fauna and humans. Additionally, as they decompose, large areas of low dissolved oxygen or high pH can occur. In addition to public health concerns, if fish cannot seek refuge from hypoxic events, large schools can die and result in a fish kill. Outreach to the public occurs each year as algal blooms and fish kills are reported to DEQ. DWR staff investigates some public sightings, but not all events are formally investigated.

Since 1925, the DMF Shellfish Sanitation Program has collected water quality data to assess suitability for harvesting shellfish in 968 shellfish growing areas. A detailed shoreline survey is conducted every three years to identify confirmed and potential pollution sources to determine their potential impact on shellfish growing waters and public health. These detailed surveys involve visits to properties throughout each Growing Area watershed, where potential sources of pollution such as marinas, on-site wastewater systems, agricultural areas, wastewater treatment plants, and stormwater drainage systems are all evaluated for their potential impacts on surrounding water quality. Fecal coliform bacteria, an indicator for human or animal waste, is measured a minimum of six times a year and used with the identified potential pollution sources to classify if the area is open to shellfish harvest. The salinity, temperature, tide, and weather conditions are also measured at sampling stations.

The Recreational Water Quality Program is another DMF program that has tested water quality since 1997 to protect public health by notifying the public when bacteriological standards for safe bodily contact are exceeded. The program tests water at 204 swimming sites during the April through September swimming season, with additional sites tested by NGOs (e.g., Sound Rivers weekly Swim Guide). This program measures Enterococcus bacteria, an indicator organism found in the intestines of mammals, and standard water quality parameters. The salinity, temperature, tide, and weather conditions are also measured at sampling stations.

All DMF independent sampling programs collect abiotic water quality parameters such as temperature, salinity, DO, depth, and Secchi depth, which have been used to look at long-term trends interpolated across waterbodies. For instance, the 2021 CHPP presented interpolated salinity maps that were created using DMF, AMS, and NC Wildlife Resources Commission measurements for different river flow regimes, and Secchi depths from DMF independent sampling programs were used to develop the proposed water clarity standard (Hall 2022).

Few continuous water quality monitoring stations are active in North Carolina. The National Parks Service runs a water quality station for the Cape Hatteras National Seashore in Ocracoke. NC Division of Coastal Management's (NC DCM) Coastal Reserve and National Estuarine Research Reserve (NC CR & NERR) have a limited number of water quality stations at three reserve sites as part of the NERRS System Wide Monitoring Program (Zeke's Island and Masonboro Island Reserves) as well as a partnership with the National Parks Service (Rachel Carson Reserve and Shackleford Banks). These stations collect continuous temperature, salinity, dissolved oxygen, turbidity, and pH; monthly chlorophyll a and nutrient concentrations are also sampled.

DMF deploys a coastwide array of temperature loggers at 52 stations to collect continuous water temperature data to monitor cold stun events for Spotted Seatrout management (NCDMF 2025b). DMF previously used water quality sondes that record additional continuous parameters, including DO, for River Herring management and to assist with site selection and monitoring of oyster sanctuaries and artificial reefs. However, they required extensive maintenance and were discontinued in 2021 due to insufficient staff time and funds.

Shell bottom

Shell bottom habitat includes areas that have surface shell concentrations of living or dead oysters (*Crassostrea virginica*), hard clams (*Merceneria merceneria*), or other shellfish in estuarine waters. Oyster reefs are vital to the estuarine ecosystem, providing structured habitat for fish and invertebrates to forage and seek refuge, in addition to enhancing sediment stabilization, shoreline protection, and nutrient cycling. Historical loss of shell bottom habitat has occurred in NC due to habitat destruction, overfishing, disease, and deteriorating water quality (NCDMF 2025a; Lenihan and Peterson 1998; Powers et al. 2009).

In addition to being a structured habitat, North Carolina has regulated the oyster fishery as far back as 1872. Under the Fisheries Reform Act of 1997, the DMF has been developing and reviewing fishery management plans for oysters since 2001, with the most recent amendment to the Eastern Oyster Fishery Management Plan adopted in 2025 (NCDMF 2025a). DMF monitors commercial landings from wild harvest as well as landings from private aquaculture, but there are insufficient data to conduct a traditional stock assessment. DMF partnered with researchers at North Carolina State University and The Nature Conservancy to design a statistically robust fishery-independent population survey for oysters in North Carolina; however, DMF currently lacks sufficient resources to implement the program.

DMF monitoring of oyster habitat occurs through SCUBA surveys (Program 612) and tong surveys (Program 628), spanning artificially enhanced habitats (sanctuaries and cultch reefs) and natural oyster beds. These surveys aim to evaluate reef performance and quantify the contribution to the state's oyster fishery and benthic habitat. Generally, oyster sanctuaries are evaluated annually for oyster density and population demographics via quadrat extraction and subsequent oyster measurements. Cultch sites are sampled annually for three years, post-construction, using a tong survey (formerly a mechanical dredge) to track oyster density and population demographics. While cultch planting has been occurring since 1915, formal record keeping of geospatial data began in 1981 with limited resolution. Furthermore, long-term monitoring on cultch sites beyond three years post-construction is not conducted due to funding and logistical constraints. Both sanctuary and cultch reefs are also evaluated opportunistically via side scan sonar and multi-beam bathymetry to provide a metric of material persistence and reef rugosity through time.

A pre-season and mid-season survey occurs to assess oyster condition in DMF's efforts to manage the mechanical (dredge) wild oyster fishery. With the adoption of Amendment 5 to the Eastern Oyster FMP in 2025, this survey was redesigned and replaced the oyster dredge as sampling gear to a hydraulic tong to improve standardization and cohesion with existing oyster surveying programs. Under the new survey, historical cultch sites are surveyed as well as areas open to mechanical harvest identified by stakeholders. Ten locations in each of the four management areas will be sampled for oyster metrics before the start of the mechanical harvest season as well as before the mid-season point to determine the length of the area's mechanical harvest season.

Additionally, two Deepwater Oyster Recovery Areas (DORAs) were established at the mouth of the Pamlico and Neuse Rivers as part of Amendment 5 to the Eastern Oyster FMP to prohibit mechanical harvest of deep-water reefs, which are vulnerable to hypoxia events. Monitoring is underway and includes side-scan sonar and multi-beam bathymetric surveying to assess the reef footprint as well as SCUBA surveys to assess oyster density and population structure throughout the course of five years prior to the next fishery management plan review.

Intertidal reefs, which occur in high salinity regions, are currently monitored with a remote sensing pilot program. The Remote Sensing Estuarine Bottom Habitat Mapping Program (DMF Program 636), pairs remote sensing in conjunction with ground truthing to produce high resolution maps of intertidal oyster habitat. Fifteen 100-acre sentinel sites were selected to develop best practices for drone monitoring and ground truth sampling methods which tentatively will be visited every three years.

Submerged aquatic vegetation

Submerged aquatic vegetation (SAV) is habitat dominated by one or more species of underwater vascular plants. SAV is recognized as essential fish habitat because of five integrated features – primary production, structural complexity, modification of energy regimes, sediment and shoreline stabilization, and nutrient cycling. 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 as 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*).

DMF and APNEP have collaborated on statewide SAV monitoring projects since 2006. In 2021, APNEP adopted a robust three-tiered monitoring plan for the Albemarle Pamlico Estuary System region to support their Comprehensive Conservation and Management Plan (APNEP 2025). Tier 1 monitoring characterizes the distribution and extent of SAV using remote sensing and has been conducted intermittently since 2006. Tier 2 monitoring captures the spatial-temporal variation in seagrass population structure and abundance to describe the ecological condition over time. Some Tier 2 data have been collected since 2006, but with the adoption of the 2021 SAV monitoring plan, sampling now includes a wider scope of SAV and environmental data. Tier 3 monitoring is conducted more frequently, and at a smaller spatial scale, to address the drivers and outcomes of patterns observed in Tier 1 and 2 monitoring.

Monitoring in the APES region has found that high-salinity SAV meadow area has continually declined and shifted towards more patchy and fragmented meadows (Field et al. 2026). The 2021 CHPP aimed to develop and implement a full-scale assessment program to conduct coastwide SAV mapping and monitoring at regular intervals (≤ 5 years). Some SAV mapping and monitoring has been conducted outside of the APES region, but it does not occur on a regular basis.

Wetland

The CHPP uses a simplified Cowardin System to classify wetlands in NC, which splits wetlands into two broad classes: palustrine and estuarine (Cowardin et al. 1979). 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 maps are fundamental to wetland inventories, which are critical to management, restoration, protection, and informed development. The two primary wetland mapping sources that provide coastwide wetland distribution data include the National Wetland Inventory (NWI) and DCM's Wetland Inventory. NWI produces wetland and deepwater habitat maps throughout the United States using aerial imagery and is the most extensive inventory of wetlands in the United States. The accuracy of imagery interpretation that informs NWI maps is dependent on the quality of the imagery, availability of ground truthing data, and repeatability by photointerpretation analysts. 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 these efforts, along with older imagery, limit the modern applications of DCM's wetland inventory.

NOAA Coastal Change Analysis Program (C-CAP) data has been used to measure wetland area over five-year periods since 1996 at 30m x 30m resolution. NOAA C-CAP now can generate spatially robust, high resolution (1m x 1m pixel) land cover inventories and map products. In 2024, the DMF, DCM, DWR and APNEP combined monetary resources with South Carolina agencies to fund an update to C-CAP land classification for the states using 2020-2021 imagery at one meter resolution. These maps are expected to be available in early 2027 and will enable North Carolina to better identify and quantify wetland change (2021 CHPP action 5.1).

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. It emphasizes the need for systematic monitoring to track wetland health and called for standardized wetland mapping methods for the state. The plan is currently being updated and will be finalized in 2026.

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. North Carolina Surface Elevation Table Community of Practice is a voluntary partnership of stakeholders who have SETs in North Carolina coastal wetlands or use SET data (North Carolina SET Community of Practice 2024). There are currently over 130 SETs throughout coastal NC generating information on the degree to which coastal marshes are keeping up with sea level rise. This partnership has provided on the ground validation of wetland vulnerability modeling at greater scales (e.g., remotely sensed unvegetated-vegetated ratios) and found the majority of marshes monitored by SETs are not keeping up with sea level rise (North Carolina SET Community of Practice 2024).

There are also numerous short term data sources from DEQ programs, universities, and NGOs conducting research on coastal wetlands. However, the inconsistent 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 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.

Expanded long-term funding opportunities should also be explored. Wetland monitoring conducted by DWR has been funded primarily by the EPAs Wetland Program Development Grants 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 recurring funding for standardized wetland monitoring that is critical to generating the data needed for science driven management.

Hard-bottom

Natural hard bottom habitat includes exposed areas of rock or consolidated sediments, distinguished from surrounding unconsolidated sediments, which may or may not be characterized by a thin veneer of live or dead biota (Street et al. 2005). Hard bottom is the primary structured habitat for offshore marine organisms on the continental shelf of NC. The hard structure provides a foundation for sessile invertebrates and algae, and the structural complexity provides a refuge and foraging habitat for mobile fauna, including both juvenile and adult life stages of economically important fish.

There is limited information on the distribution of productive live hard bottom off the NC Coast (Riggs et al. 1996; Moser and Taylor 1995; Udouj 2007). The majority is limited to specific areas of the continental shelf. Ninety percent of known hard bottom is found south of Cape Hatteras in the ocean rather than estuarine systems(Moser and Taylor 1995). Sampling methods and classification can be subjective, making it difficult to determine the distribution (Conery et al. 2022). The ephemeral nature also makes it particularly difficult to quantify because it can become periodically buried with sand (Riggs et al. 1996).

The NC DMF Artificial Reef Program maintains 43 oceanic artificial reefs to provide public recreational opportunities for fishing and diving, while adding structured hard-bottom habitat to primarily soft-bottom systems. The constructed reefs are monitored annually using SCUBA surveys for material stability, environmental parameters, and fauna communities. Hydrographic mapping surveys are also conducted on established artificial reefs periodically according to programmatic need.

The 2021 CHPP Amendment called for DMF to develop a monitoring strategy to map natural hard bottom reefs in NC state waters and monitor the condition of both natural and artificial reefs (2021 CHPP Recommended Action 8.5). Although DMF has established workflows to conduct monitoring, the scale of operations necessary to provide consistent mapping requires significant resources, including long-term funding for survey staff, boats, and equipment. Furthermore, other programmatic needs (oyster sanctuary, cultch planting, artificial reefs) limit existing available resources for devoting survey efforts towards hard-bottom mapping. The division will continue to periodically review the feasibility of adding new monitoring of hard-bottom habitat to its existing efforts.

Applying ecosystem-based management tools to understand coastal habitat status and trends

Coastal landscapes are made up of a mosaic of habitat components, including the ones above, that are affected by humans who live there. The CHPP has recognized the need to incorporate ecosystem-based management (EBM) into coastal resource conservation strategies in North Carolina. This approach incorporates the entire ecosystem, including humans, into resource management decisions, and is guided by adaptive management. Both the 2016 CHPP and 2021 CHPP amendment outlined management actions to develop indicator metrics for monitoring the status and trends of each individual habitat and establish thresholds to initiate pre-determined management actions. Since substantial resources are needed to establish comprehensive long-term monitoring for a suite of indicators for each habitat, DEQ must explore alternative approaches such as an ecosystem level evaluation.

Ecosystem assessments are used to provide the necessary science to carry out ecosystem-based management. An Integrated Ecosystem Assessment (IEA) is a formal synthesis and quantitative analysis of natural and socio-economic factors relative to specific management objectives (Levin et al. 2014). The framework as described by Levin et al. (2009) is used by NOAA to support adaptive Ecosystem Based Management. This framework was supported by the CHPP since 2016 and was recommended by the NC Policy Collaboratory as a model of a qualitative indicator-based evaluation of the estuarine and coastal ecosystems in its report (NC Collaboratory 2026).

This process relies on clearly defined management objectives that are co-designed with stakeholders. Scientists, managers, and stakeholders establish the vision and determine which ecosystem components, threats, and spatial scale are relevant to the management objectives. Examples of objectives include seafood production, commercial profits, recreational opportunities, ecosystem stability, social and cultural values, and protected species (Northeast Fisheries Science Center (U.S.) 2026). Conceptual modeling is conducted to describe and define the ecological system of interest including important connections and cascading effects of changes in components.

Ecosystem assessments use monitoring data as environmental indicators to characterize the aspects of the ecosystem that are relevant to the established management goals. Indicators are most effective when they are directly observable, scientifically rigorous, supported by a historical time series, cost effective to measure, understandable to the public, and sensitive to change in the ecosystem or management actions (Levin et al. 2014). In the assessment process, potential indicators are inventoried and then are evaluated to determine if they are an appropriate metric. In North Carolina, the Albemarle Pamlico National Estuary Program conducted an ecosystem assessment in 2012 (Carpenter and Dubbs 2012). In the development they defined and evaluated indicators for a comprehensive ecosystem assessment of the APES region that describes the status of the system and identifies threats to prioritize addressing through management. The range of data sources on coastal habitats and water quality discussed above in the *Current habitat and water quality monitoring programs* section serve as likely candidates to use as ecosystem indicators, along with additional data collected by external partners.

To track progress towards EBM goals, indicator variables need to have science-based reference levels to measure ecosystem state and determine the magnitude of ecosystem pressures. Indicators then need an established target level to identify quantitatively if the desired ecosystem status is reached. Targets as well as established thresholds can also be used to trigger management actions.

Once indicator data is compiled, the ecosystem is assessed using the status of the selected indicators. NOAA's IEA programs teams produce Ecosystem Status Reports for management regions that describe the status and trend of each indicator that was selected for specific management needs. Ecosystem status reports have been produced for each fishery management council region in the United States; however, the South Atlantic has only had one ecosystem status report (Craig et al. 2021), while other regions have annual ecosystem assessments with communication tools for outreach with the public.

Even though ecosystems assessments are co-designed with stakeholders, they are long technical reports, which can be hard for decision makers to interpret and apply to management strategies. While the ecosystem status reports synthesize ecosystem information, "state of the ecosystem" reports are commonly produced in some regions (e.g. the 2025 New England State of the Ecosystem report), putting decisions into a broader context.

Ecosystem report cards are another stakeholder driven assessment and communication tool used to compare ecological, social, and/or economic information (Vargas-Nguyen et al. 2020; Costanzo et al. 2017). Report card developers set evaluation goals and criteria to calculate a number or letter grade, like a school report card, to determine the status of the ecosystem. Report cards distill complex data from multiple sources into a format that is easily accessible to wide audiences. By incorporating a range of stakeholders in the development process, the report card helps create a shared vision for the future of the ecosystem. This information is then used to educate the public about the habitat condition, inform protection and restoration efforts, and evaluate the effectiveness of management strategies to achieve the overarching CHPP goal of the long-term enhancement of fisheries associated with coastal habitats.

Report cards can be flexible in that managers can choose indicators from the data that are available, and report cards can be easily updated if new data streams become available. The University of Maryland's Integration & Application Network (UMCES IAN) has developed a process for creating ecosystem report cards since 2006 and has refined its processes for stakeholder facilitation and index analysis (Costanzo et al. 2017). One example produced by UMCES IAN, the Coastal Georgia Ecosystem Report Card, evaluates the health of Georgia's ecosystems and uses twelve indicators to examine human health, fisheries, and wildlife annually (2014-2024). The evolution of the coastal Georgia ecosystem report cards, which updated indices based on relevance and importance, is an example of how this approach can be refined as more data or an improved understanding of the ecosystem is available. Another example, the Chesapeake Bay ecosystem report card, implements an especially data rich reporting effort (Logan et al. 2020) that produces a static report card publication as well as an interactive counterpart through Eco Health Report Cards, which allows users to explore data time series at various spatial scales.

Using a state report card for a coastwide ecosystem assessment

An ecosystem report card would provide the foundation to work toward ecosystem-based management in North Carolina and meet CHPP goals of understanding the status and trends of the state's coastal habitats (2021 CHPP recommended actions 8.1 and 8.2). DMF will begin with internal scoping discussions to establish broader ecosystem-scale fishery management objectives based on relevant legislation, regulatory requirements, established management practices, and the agency's mission and strategic guidance. This process will help determine the conceptual scope of the report card and ensure that the development and final products can be integrated into decision-making.

As a collaborative process, development will require stakeholder engagement. To ensure that the final product has been co-designed and fosters stakeholder buy-in, DEQ will conduct a stakeholder mapping exercise at the start of development to identify the breadth of stakeholders (both in role and spatial variation) in the state. These stakeholders will be invited to participate in a workshop which will be held to identify both local values and challenges to meet ecosystems objectives. This process helps ensure that the final product has concurrence, relevance, and meets the values of stakeholders. The stakeholder workshop output will be a conceptual framework and a short list of potential indicators and thresholds associated with the values and identified threats.

Although stakeholder driven, the foundation of an ecosystem report card is a thorough ecosystem assessment. Sourced from stakeholders and experts, data inputs will include the indicators that were identified in the stakeholder workshops. The NC Collaboratory's Legislative Study of Coastal and Marine Fisheries Report has already analyzed 170 potential indicators to understand how ecosystems are changing over time, the drivers of change, and the status of current monitoring (NC Collaboratory 2026). Indicators that meet the spatial and temporal resolution requirements can be included in the report card.

Once the conceptual framework and potential indicators are established by the stakeholder workgroup, scientists and managers will evaluate those indicators to determine which indicators best reflect the ecosystems and develop thresholds that will be transformed into easy-to-understand grades (A, B, C, D, F).

The report card will be drafted to include information capturing the existing health of the state's coastal ecosystems, distilling the key messages into an image-rich format easily accessible to a wide audience. A second stakeholder meeting will be held to discuss report card draft results, conclusions, and recommendations. Relevant feedback will then be taken into consideration for the final version. The complete methodology will be documented to ensure that the report card is scientifically defensible and can be updated regularly between each CHPP cycle.

The completed ecosystem report card will offer several benefits to DEQ and stakeholders. The report card will provide a simple, accessible way for the public to understand the overall status of coastal ecosystems and how that has changed over time. The report card will also serve as an additional tool for decision makers when considering environmental and fishery management options. This tool will also aid in facilitating discussions for building capacity and enhancing resolution and frequency of monitoring ecosystems.

Improving the use of ecosystem data in fishery management

In addition to providing tools for the public, the ecosystem assessment and report card development processes will help enhance the use of ecosystem data in DMF's fishery management. Integrating ecosystem data into fishery management decision-making will require a division-wide effort that can be initiated across DMF's programs. Beginning with the ecosystem data assembled as input for the ecosystem report card, a working group should be established to discuss how to accomplish integrating ecosystem data into development of FMP strategies.

One approach to better incorporating ecosystem data into fishery management could be emphasizing fish habitat use and life history bottlenecks during each fishery management plan cycle. Like the process of defining the ecosystem for an assessment, this approach would identify a conceptual map of a species' life cycle along with indicators and thresholds that would support management decisions. This process would also help identify specific research gaps and data needs to support incorporation of ecosystem data into a fishery stock assessment.

Once ecosystem assessments are conducted at regular intervals, DMF could also begin to apply risk assessments into the fishery management process. Risk assessments evaluate the impacts that natural disturbances and human activities would have on the ecosystem status. The goal of risk assessment is to qualitatively or quantitatively determine the likelihood that an ecosystem indicator will reach or remain above reference points (e.g., an established baseline level) that indicate an undesirable status. At a basic level, the sensitivity of an indicator to a stressor and the exposure to that stressor is calculated or mapped into high, medium, or low risk categories. More comprehensive risk assessments can be used to evaluate the cumulative effects of multiple stressors on many ecosystem components. Improved understanding of the risks to fisheries associated with the status of ecosystem indicators can inform decision-making in fishery management when traditional management tools (i.e. stock assessments) are unavailable, or when fishery decision-makers want to base decisions on a broader range of information.

Recommended actions

1. Establish internal working group to establish goals of an ecosystem assessment and state ecosystem report card.
2. Conduct workshops with stakeholders, scientists and managers to select ecosystem indicators and establish appropriate thresholds.
3. Calculate scores and create a state report card that is easily accessible to a wide audience.
4. Communicate status and trends of coastal ecosystems to stakeholders, decisionmakers, and the public.

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Strategic Habitat Area validation and implementation plan development

Executive summary

Through previous CHPPs, DMF used a conservation planning tool that incorporated spatial analysis and subject matter expert input to identify a network of high-quality habitat areas in coastal watersheds, referred to as Strategic Habitat Areas (SHAs). SHA nominations for the four CHPP regions were completed in 2017, and field sampling was conducted in two regions (Regions 3 and 4) to verify that the habitat condition and biological productivity of nominated areas were high. Results from the field survey validate that nominated areas support a higher abundance of diverse fish populations. In combination with findings that Strategic Habitat Areas have a more diverse estuarine landscape, a higher area of structured habitats, and less alteration than areas outside of SHAs, the results of this validation study further support the designation of the nominated Strategic Habitat Areas. These results will be combined with additional analysis of DMF independent sampling data in a future issue paper that presents validation of Strategic Habitat Areas statewide and proposes designation options to the Marine Fisheries Commission. Strategic Habitat Area management options will then be developed through stakeholder engagement and collaboration with state, federal, and private partners and presented in another issue paper to rulemaking commissions and external partners.

Introduction

Early in the development of the first Coastal Habitat Protection Plan (CHPP), the CHPP Steering Committee identified the need to prioritize conserving areas that were most critical for fishery production and in need of protection. The second goal of the original CHPP was to "Identify, designate, and protect Strategic Habitat Areas (SHA)." (Street et al. 2005) Strategic Habitat Areas were defined as "locations of individual fish habitats or systems of habitats that provide exceptional habitat functions or that are particularly at risk due to imminent threats, vulnerability, or rarity" (15A NCAC O3I .0101 (4)(h), (Street et al. 2005, Deaton et al. 2010, NCDEQ 2016). To prioritize areas to protect, CHPP staff applied the understanding that ecosystems with diverse arrays of interconnected habitats can function better and provide more services compared to discrete isolated patches of habitats (Preston et al. 2025). Choosing areas representative of the entire ecosystem can help protect habitats necessary for various life stages to support fisheries.

The process to identify Strategic Habitat Areas was established in 2006 under the guidance of a committee of scientists and natural resource managers with a wide scope of expertise in fisheries and coastal habitats (Deaton et al. 2006). The committee developed a scientifically based process for identifying candidate areas for designation using biological data and the consensus of a regional expert panel, with a target of designating approximately 20% of the area of natural resource targets in each of the four CHPP regions as Strategic Habitat Areas (NRC 2001).

The desired areas would have high biodiversity and ecological function, be relatively unaltered, have strong landscape connections between structured habitats, and need protection (Figure 1). Management options would be site specific – SHAs with exceptional ecological function would be priority locations for protection, while areas experiencing threats that risk diminishing their ability to support coastal fisheries would be candidates for restoration or enhancement.

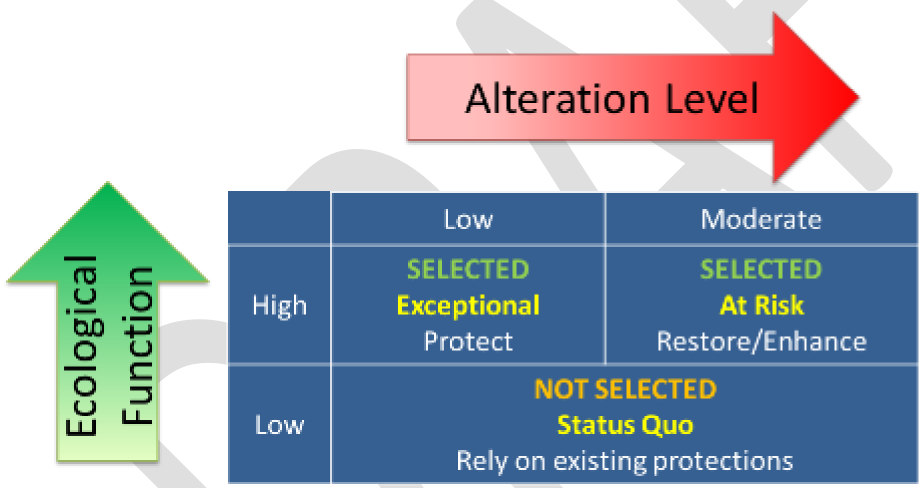

Figure 1. Selection criteria for Strategic Habitat Areas based on level of ecological function and habitat alteration level and the resulting management strategies (e.g., protect, restore/enhance) based on these gradients.

The SHA identification process consists of three main phases, each of which requires input from a regional advisory committee. The first phase in the SHA process is to identify priority species and habitats and build a GIS database of existing biological and anthropogenic use data for the region. For each region, the DMF Management Review Team (now the Directors Advisory Team) selected the priority and/or traditional fisheries for the area based on their importance to both the recreational and commercial fishing industries in the region.

DMF staff assembled the available data, which was reviewed by the regional advisory committee to ensure that it had sufficient spatial coverage and relevance to be included.

Then the committee examined the priority fish species for the region and recommended representation levels of each habitat (natural resource target) that should be included in the final SHA network. The committee also recommended how to rank alteration factors to calculate and map an alteration index for the region. The second phase of the process was to run the site selection software Marxan (Game and Grantham 2008, Ball et al. 2009) to select initial areas that met the established criteria for selection.

Once the Marxan modeling was complete, in the third phase an expert committee reviewed selections and used corroborating information and their own ecological knowledge to modify the boundaries of the SHAs and derive a final network of SHA nominations. Final SHA nominations incorporate expert scientific knowledge to consider additional biological information and socio-economic factors that may not have been included in the Marxan inputs.

Nominations were then peer-reviewed, sent for public comment, and presented to the Marine Fisheries Commission. For additional details about the specific data layers, prioritization, and expert decision-making process, see the Strategic Habitat Area nomination report for each region.

Region overviews

Four regional analyses were done to identify SHAs in coastal waters for each CHPP region. Region 1 (Albemarle Sound System), Region 2 (Pamlico Sound system), Region 3 (White Oak River Basin), Region 4 (Cape Fear River Basin) were completed in 2009, 2011, 2014, 2019 respectively.

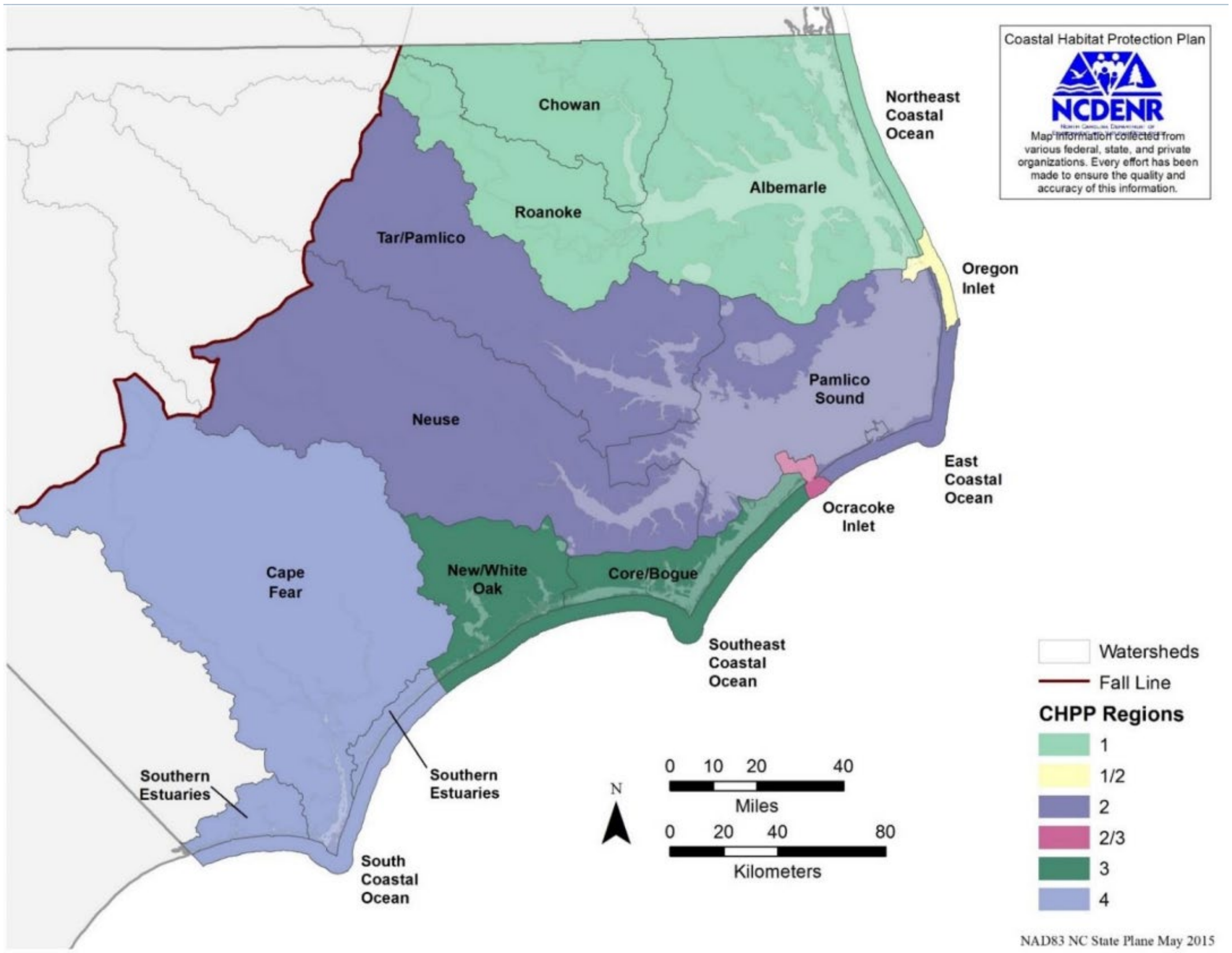

Figure 2. Map of CHPP regions and watersheds. Oregon Inlet is counted toward both regions 1 and 2, and Ocracoke Inlet is counted toward both regions 2 and 3.

Table 1. Characterization of nominated Strategic Habitat Areas broken down by number of units, area, and proportion of region (%).

Region	SHA Units	Area (a)	Area (%)
1	20	490315	20
2	67	322843	26
3	48	134547	19
4	43	74451	21

Albemarle Sound System (Region 1)

Region 1 includes the waters and adjacent wetlands draining into and out of Albemarle Sound through Oregon Inlet to the adjoining coastal ocean (NCDMF 2009). It includes the sounds and tributaries of the Albemarle, Currituck, Roanoke, and Croatan Sounds, as well as the nearshore ocean.

Most of the Albemarle Sound system is lined with bottomland hardwood wetland forests. The eastern sounds are lined with brackish marsh and support SAV habitat and scattered areas of shell bottom habitat. Because Oregon Inlet is the only inlet in the northern portion of the Albemarle-Pamlico system, it is a critical fish corridor. Priority species included the traditional fisheries of blue crab, river herring, and striped bass. SHA nominations included 20 areas that make up 490,315 acres or 20% of the region.

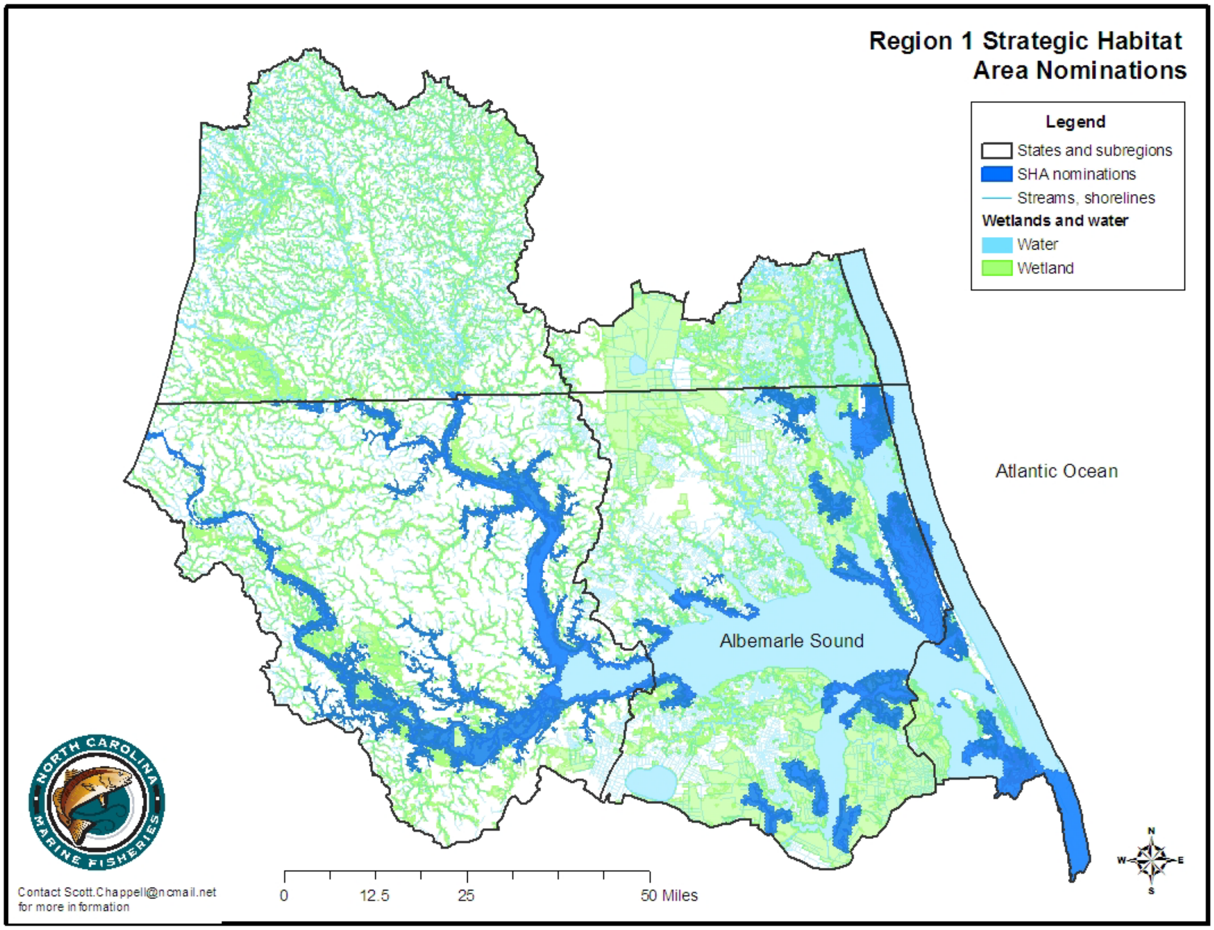

Figure 3. Nominated Strategic Habitat Areas within CHPP Region 1.

Pamlico Sound System (Region 2)

Region 2 includes the waters and adjacent wetlands draining into and out of Pamlico Sound through both Oregon and Ocracoke Inlets to the adjoining coastal ocean (NCDMF 2011). It comprises the sounds and tributaries of Pamlico Sound and the Tar-Pamlico and Neuse rivers up to the fall line separating Coastal Plains and Piedmont physiographic regions. The boundaries of the study area were based on the CHPP subregions of Pamlico Sound, Tar-Pamlico River, Neuse River, adjacent coastal ocean, Oregon Inlet and Ocracoke Inlet (Deaton et al. 2010).

Habitat features that contribute to the integrity and exceptional productivity of the Pamlico Sound system include extensive SAV beds behind the Outer Banks and along the rivers, intertidal and subtidal oyster rocks, and Primary Nursery Areas. Priority species include blue crab, Eastern Oyster, Red Drum, shrimp, Southern Flounder, and Spotted Seatrout. 67 discrete areas have been nominated in Region 2 that make up 322,843 acres or 26% of the region.

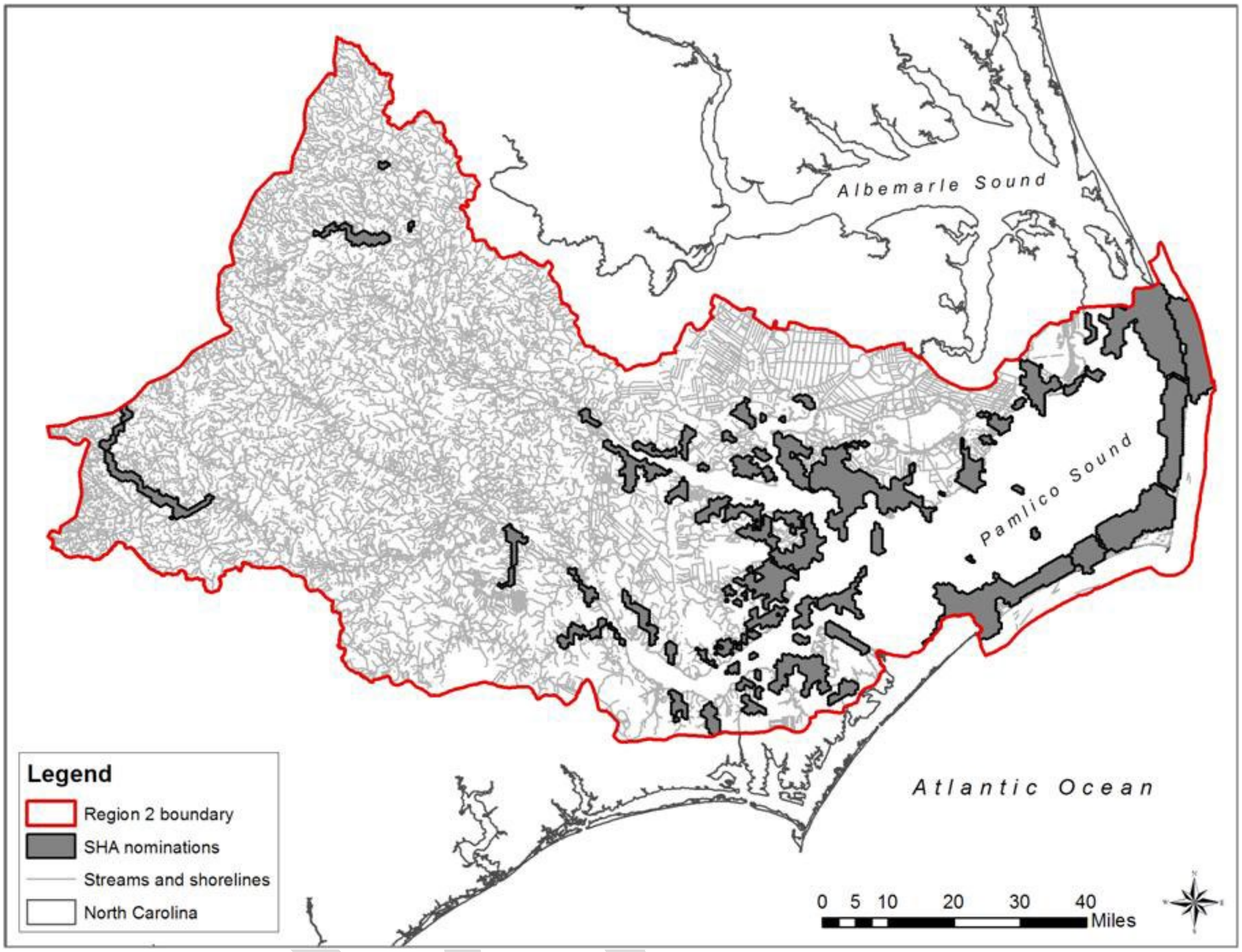

Figure 4. Nominated Strategic Habitat Areas within CHPP Region 2.

White Oak River Basin (Region 3)

Region 3 includes waters in Carteret and Onslow counties, as well as a small amount of Jones and Craven counties, and the entire watershed is contained within the White Oak River Basin (Jensen et al. 2014). This region lacks extensive riverine systems and consists primarily of estuarine waters and small to moderate sized sounds such as Core, Bogue, and Stump sounds. New River is the largest river.

Submerged Aquatic Vegetation (SAV) and wetlands (marsh and forest) are extensive, and intertidal and subtidal oyster reefs and ocean hard bottom are also present. Oyster, clam, Bay Scallop, Blue Crab, shrimp, Southern Flounder, Red Drum, Spotted Seatrout, Weakfish, and Spot were determined to be priority fishery species in this region, and an important nursery area for gag grouper and black sea bass. There were 48 discrete SHA units selected within region 3, comprising 134,547 acres or 19% of the region.

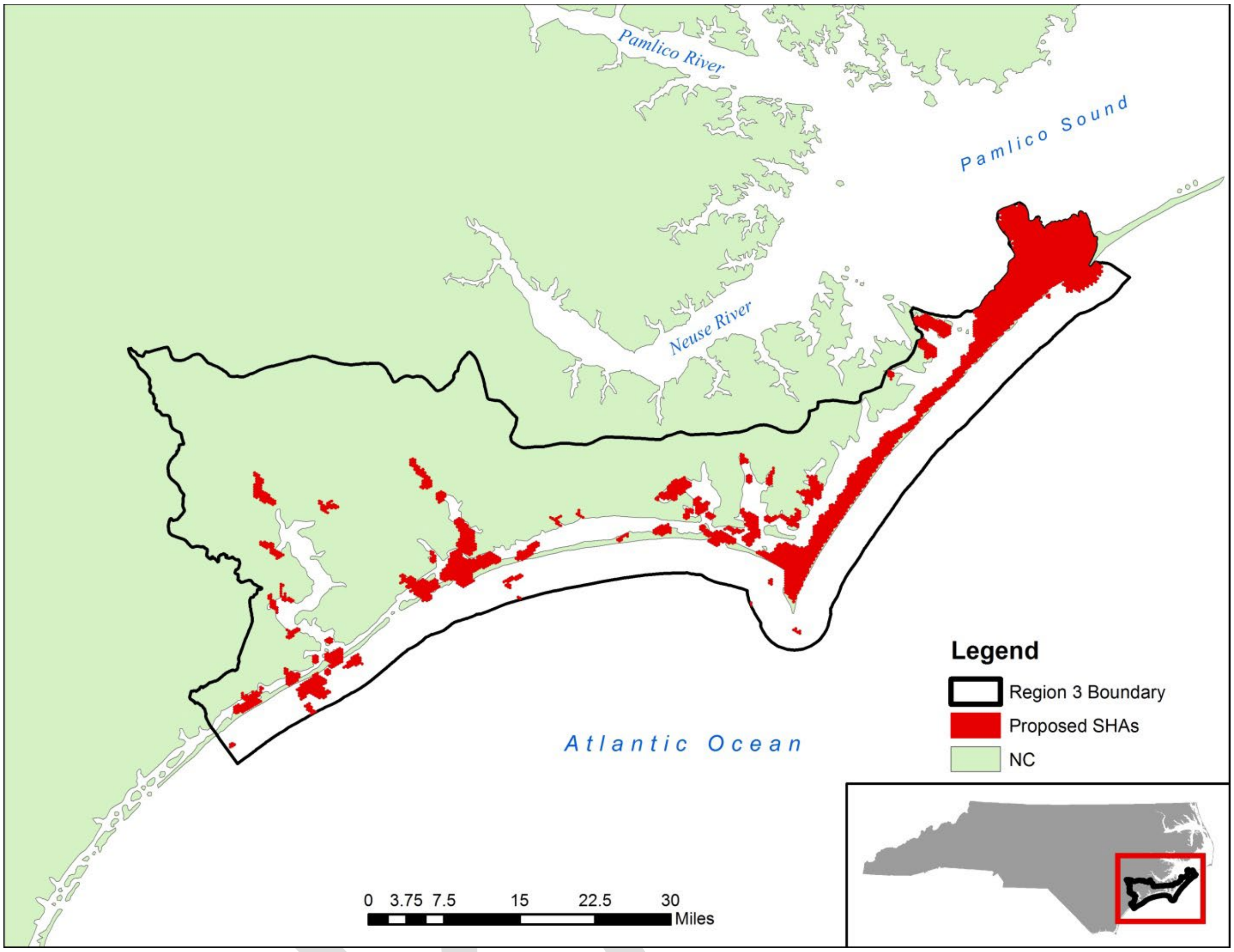

Figure 5. Nominated Strategic Habitat Areas within CHPP Region 3.

Cape Fear River Basin (Region 4)

Region 4 is the southernmost region and includes riverine and estuarine waters in Pender, New Hanover, and Brunswick counties, as well as portions of Duplin, Sampson, Bladen, and Cumberland counties (Knight and Deaton 2018). It includes the Cape Fear River system upstream to approximately Lillington, the historical anadromous fish spawning grounds of Smiley Falls (approximate fall line).

The estuarine waters include multiple small tidal creeks and sounds, and extensive intertidal oyster reefs and marsh habitats. Relatively small areas of SAV occur in the northern portion of the region. The priority fisheries species of the Cape Fear River Basin include Eastern Oyster, Hard Clam, Blue Crab, shrimp, Bay Scallop, Southern Flounder, Red Drum, Spotted Seatrout, kingfishes, and Spot. The Cape Fear River system is vital to anadromous species, including Striped Bass, American shad, River Herring, and sturgeon, that migrate upstream for spawning; while the nearshore provides important habitat for gag grouper, black sea bass, sheepshead, and mackerels. There were 43 discrete SHAs selected within Region 4 comprising 74,451 acres or 21% of the area's waterbodies.

Figure 6. Nominated Strategic Habitat Areas within CHPP Region 4.

Strategic Habitat Area Validation (region 3 and 4)

Origin

While it is assumed that areas nominated as SHAs are beneficial to fish populations, DMF staff sought to further validate this assumption. Previous and ongoing research has provided additional scientific understanding of the relationship between nekton, habitat, and alteration (Peterson et al. 2000; Wyda et al. 2002; Lowe and Peterson 2014), informing the establishment of a validation program (DMF Program 215) to verify habitat conditions and fish productivity of SHAs. The objective of the study was to verify habitat condition and biological productivity by conducting extensive field sampling of target fish species in three fish habitats inside and outside of SHAs.

Methods

Sampling design

A stratified random sampling design was established for Region 3 and 4. The sampling universe consisted of 1 nmi^2 grids and was modified for boat access. For each sampling year approximately sixteen proportionally allocated SHA and reference sites outside of SHA boundaries were randomly selected to sample from February 15 -November 15. The time window was chosen to follow the timing of the Juvenile Trawl Survey (Program 120) and Fisheries Independent Assessment (Program 915). Within Region 3, 252 sites were sampled in 2018-2019, however, sampling was limited in September 2018 due to Hurricane Florence. Within Region 4, 126 sites were sampled in 2020-2021, with a suspension of sampling from March 26th until June 2nd, 2020, for the COVID-19 Pandemic. In Region 4, the sampling grid was downstream of Lyon Thorofare on the Cape Fear River and Cowpen Branch on the Northeast Cape Fear River. Sampling difficulties resulted in the exclusion of 16 SHAs in that area. Full details of sampling gear and techniques can be found in the NC DMF Program 215 program documentation (NC DMF 2018)

Nekton sampling

Fish sampling was conducted using Breder traps, gill nets and bottom trawls. An otter trawl was towed for 1 minute in duration across 75 yards. Four Breder traps were set, alternating orientation from perpendicular and parallel from the habitat edge. A scientific gill net (2", 3", 4", 5" stretched mesh panels) was set within 100 ft of shore where water depth is roughly 3 ft at MLW. Breder traps and gill nets were set at low tide and soak for at least three and four hours, respectively. All collected fish were identified to species level and counted. Target species were measured and weighed, and total biomass of all fish was recorded.

Mean standardized catch (MGMS) was calculated to create an index to represent the total catch of the three gear types (Gibson-Reinemer et al. 2017). Catch per unit effort was also calculated to conduct community level analyses for each gear type.

Habitat Characteristics

At each sampling location, the types of structured habitats present were recorded (marsh, SAV, shell). Habitat characteristics were quantified for habitat present using three haphazard $1/4m^2$ quadrats. For marsh quadrats, shoot densities of *Spartina spp.* and *Juncus spp.* were counted and all other species present within the quadrat were recorded. In addition, the stem height of the tallest and three random shoots were measured. In shell habitats, the point intercept method was used (n=16) to calculate percent cover of live oysters. All biota in the quadrat was recorded. To quantify the oyster density, a smaller 1/16 m^2 quadrat was used and a subsample of 30 oysters was measured. To quantify SAV, the point intercept method was used (n=16 intercepts) to measure the cover (%) of SAV in the quadrat. All species present in the quadrat were recorded, and the shoot height of the tallest and three random shoots were measured.

The area of all structured habitats was calculated within each sampling grid. Shell bottom area was calculated from DMF's Estuarine Benthic Habitat Mapping Program's shell bottom maps, produced from 1990 to 2019. NOAA Coastal Change Analysis Program (CCAP) land cover data from 2016 were used to quantify wetlands extent ((National Oceanic and Atmospheric Administration, Office for Coastal Management 2016)). The NC DEQ SAV "mosaic" dataset, which outlines a historical extent of SAV habitat from aerial surveys conducted from 1981-2021, was used to calculate SAV area.

Alteration

At each sampling location the extent of hardened shoreline and eroded edge, and presence of shoreline basins, marinas and/or boat ramps, rock or wood structures perpendicular to shore, low profile (riprap) or wood structure parallel to shore, and vertical structures (i.e. bulkheads) was recorded.

Analysis

Since the sampling of the two regions did not occur at the same time, all statistical analyses were conducted within regions, so inferences between regions are limited to qualitative observations. All analyses were performed in R version 4.6.0 (R Core Team, 2026).

A permutational analysis of variance (PERMANOVA) was used to test differences in community composition between SHA treatments. The PERMANOVA used Bray-Curtis distances and 1,000 permutations, and was run using the 'vegan' package in R. A non-metric multidimensional scaling (NMDS) ordination was used to visualize community composition between SHA and non-SHA sites for each region. SIMPER analysis was used to identify which species contributed the most to dissimilarities. Hill-Shannon diversity index (Kempton 1979) species richness, and a rank-abundance curve were calculated to examine the biodiversity of the nekton species.

Because of the variance in species present, most variables violated the assumptions of ANOVA (non-normal distribution and unequal variances) so differences among groups were tested using the non-parametric Kruskal–Wallis test. Kruskal-Wallis tests were used to test differences between designated SHA and undesignated sites (reference, or "non-SHA," sites) for each region independently for habitat metrics. Pearson Chi-squared tests were used to compare the frequency of habitat presence and alteration frequency between Strategic Habitat Areas and reference sites.

Results

Habitat Metrics

Analysis of the Region 3 and 4 habitat data confirm greater overall extent of the habitats investigated in this study (wetlands, shell bottom, and SAV) in the SHA sites compared to the non-SHA sites (Figure 7). SHAs had a significantly greater area of structured habitats in in Region 3 with 1,074,587±79,487 acres in SHAs and 568,885± 82,752 acres in non-SHAs ($\chi^2(1) = 18.596$, $p < 0.001$) and Region 4 with 1,402,093± 82,953 acres in SHAs and 637,418± 79,487 acres in non-SHAs ($\chi^2(1) = 29.510$, $p < 0.001$).

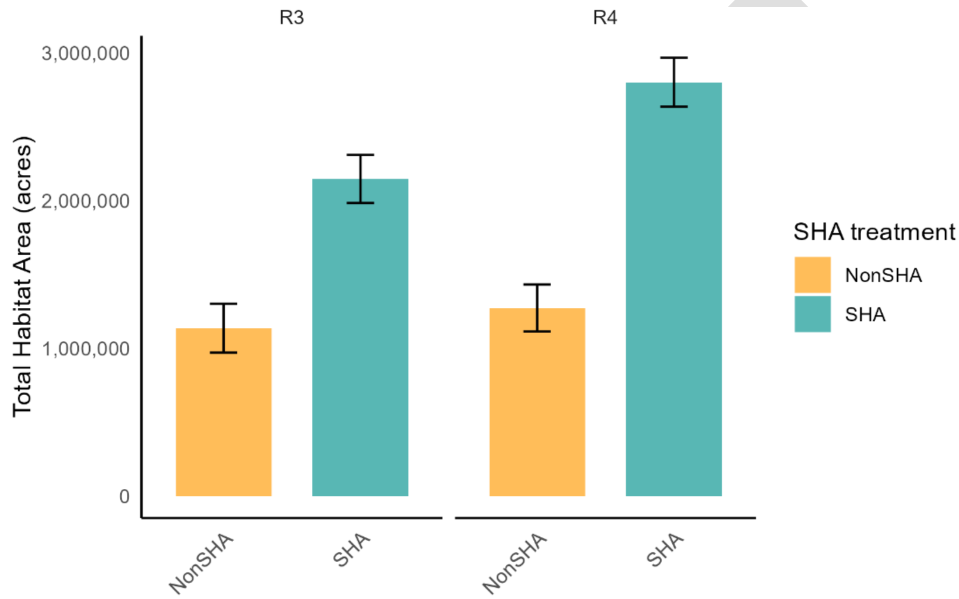

Figure 7. Total habitat area (acres) of structured habitats (SAV, oyster, wetlands) in sampling grids inside (SHA) and outside of Strategic Habitat Areas (non-SHA). Error bars represent ±1 standard error.

SHAs were also more likely to have multiple types of habitats present than reference sites. When looking at the average number of habitats at each sampling location, SHAs had a higher number of habitats (marsh, oyster, SAV) within the same landscape (Figure 8). In Region 3, SHAs had an average of 1.9 habitats present, while non-SHAs had only 1.4 habitats present on average ($\chi^2(1) = 18.596$, $p > 0.001$). Although the two regions were not statistically compared, the difference between reference sites and SHAs was greater in Region 4. On average, SHA sites had 2.2 habitats present and non-SHA reference sites had only 1.4 habitats present ($\chi^2(1) = 429.510$, $p > 0.001$). When examining the frequency of habitat presence, marsh habitats were present at nearly the same frequency in all SHA and reference sites. Oyster reefs occurred more frequently in SHAs than non-SHAs in both regions, but Region 4 had a higher frequency (Region 3, $\chi^2(1) = 10.297$, $p = 0.001$; Region 4 ,

$\chi^2(1) = 22.766$, $p > 0.001$). There was no significant difference in the frequency of SAV in Region 3, although SAV was higher in SHAs. In Region 4, SAV was only present in SHA sites ($\chi^2(1) = 10.242$, $p > 0.001$).

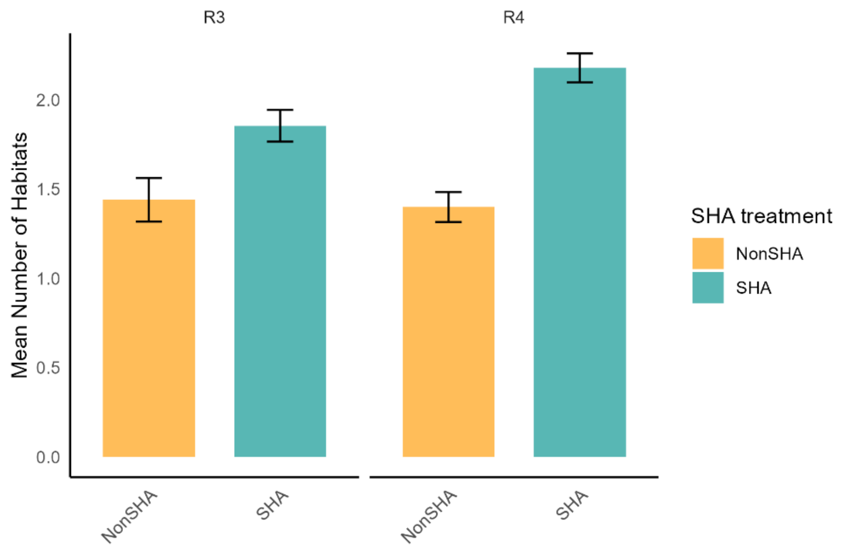

Figure 8. The mean number of structured habitats (marsh, oyster, SAV) found in Strategic Habitat Areas and reference sites. Error bars represent ±1 standard error.

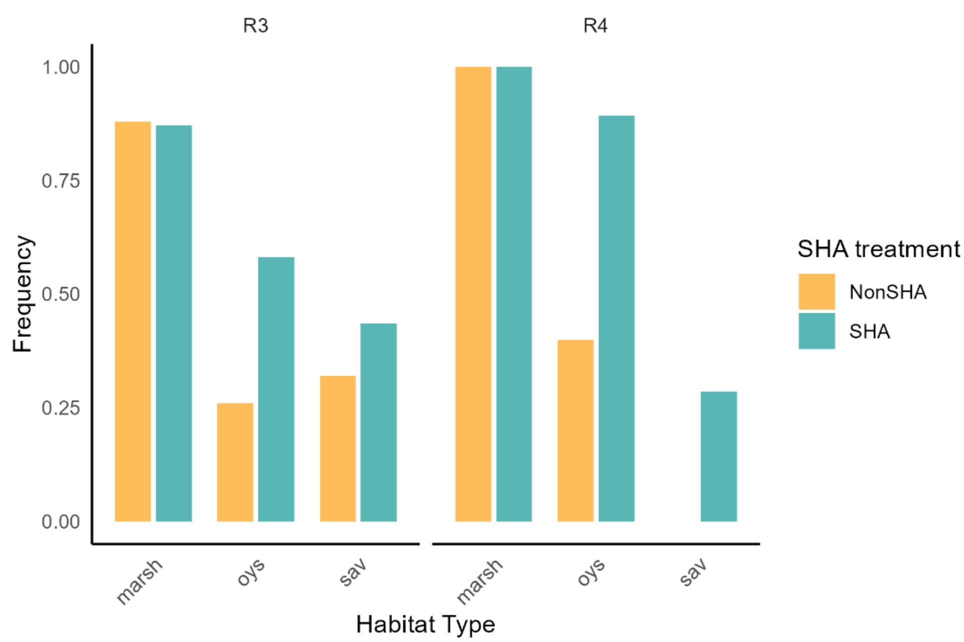

Figure 9. Frequency of structured habitats (salt marsh, oyster reef, SAV) in Strategic Habitat Areas and reference sites outside of Strategic Habitat Areas.

There is evidence that habitats in Strategic Habitat Areas were higher quality. In marsh habitats, *Spartina alterniflora* stem density (shoots / 0.25 m^2) was higher in SHAs than non-

SHAs (Figure 10; Region 3, $\chi^2(1) = 30.1$, $p < 0.001$; Region 4, $\chi^2(1) = 42.8$, $p < 0.001$). Oyster reefs had a higher live oyster cover (%) in SHAs than reference sites (Figure 11; Region 3, $\chi^2(1) = 4.883$, $p = 0.027$; Region 4, $\chi^2(1) = 14.090$, $p < 0.001$). SAV percent cover had the same pattern as habitat occurrence, with no difference between SHAs and reference sites in Region 3 (Figure 12; $\chi^2(1) = 0.973$, $p = 0.324$). Since SAV was absent from reference sites in Region 4, we could not test for statistical differences.

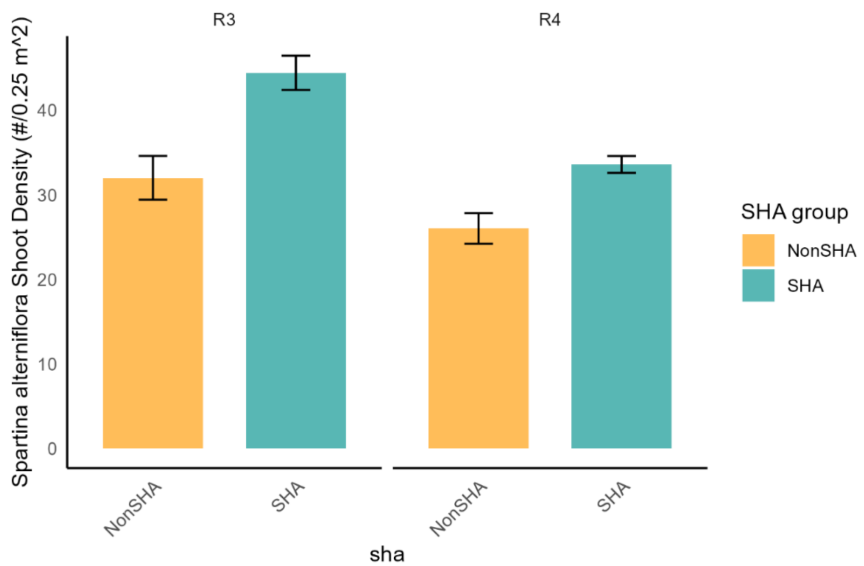

Figure 10. Spartina alterniflora shoot density (#/0.25 m^2) in Strategic Habitat Areas and reference sites. *Error bars represent ±1 standard error.*

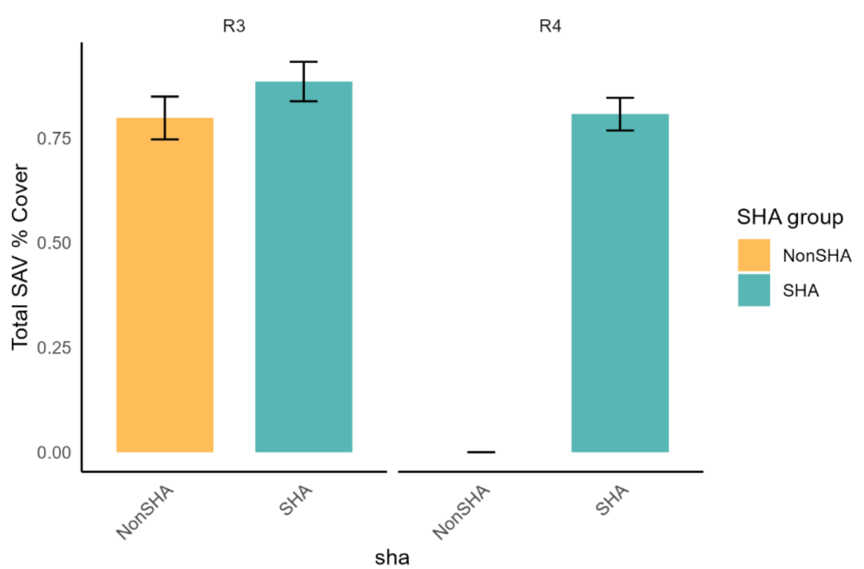

Figure 11. Percent cover of submerged aquatic vegetation in Strategic Habitat Areas and reference sites. Error bars represent ±1 standard error.

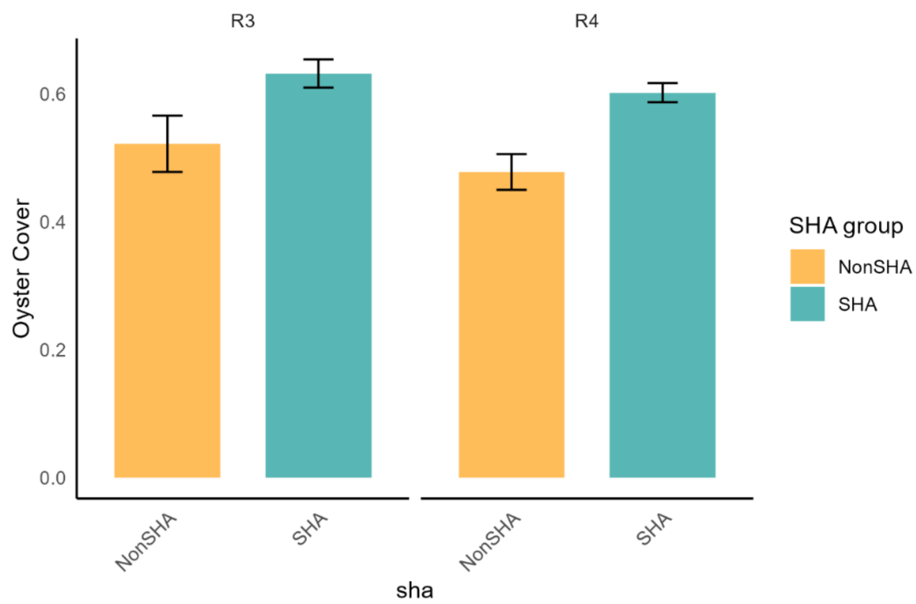

Figure 12. Percent cover of live oysters on oyster reefs in Strategic Habitat Areas and reference sites. Error bars represent ±1 standard error.

Nekton community

When examining the total multi-gear meal standardized catch, there were only differences between SHA and reference catch in Region 4 (Figure 13, $\chi^2(1) = 4.342$, $p = 0.037$). Strategic Habitat Areas had a higher abundance of nekton for mean-standardized catch as well as each individual gear. No statistical difference was found in the total abundance of nekton in Region 3 across all gear types ($\chi^2(1) = 1.113$, $p = 0.291$).

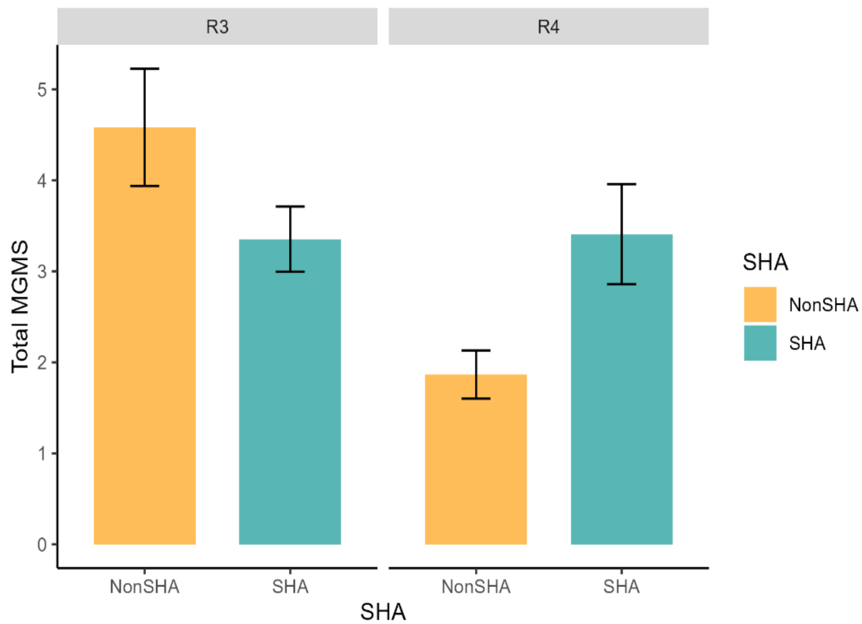

Figure 13. The total multi-gear mean standardization for Strategic Habitat Areas in Region 3 and 4. Error bars represent ±1 standard error.

Biodiversity

Overall, communities in SHAs had a higher species richness, and had a higher abundance of rare species. The difference in species richness was significant in Region 4 (Figure 14, $\chi^2(1) = 4.122$, $p = 0.042$). When examining the Shannon-Hill biodiversity of nekton measured in the multi-gear mean standardization index, there were no statistical differences between groups, but some patterns were present when examining each gear independently. When examining the trawl nekton, there was a higher diversity in the SHA sites than non-SHA reference sites ($\chi^2(1) = 4.324$, $p = 0.038$) in Region 3 (Figure 15). The opposite, however, was observed in Region 4, with higher diversity in the non-SHA sites than SHA sites ($\chi^2(1) = 5.418$, $p = 0.020$). No differences were found in Region 3 trap samples, but there was a higher diversity in SHA samples relative to diversity in the reference sites in Region 4 (Figure 16; $\chi^2(1) = 5.150$, $p = 0.023$).

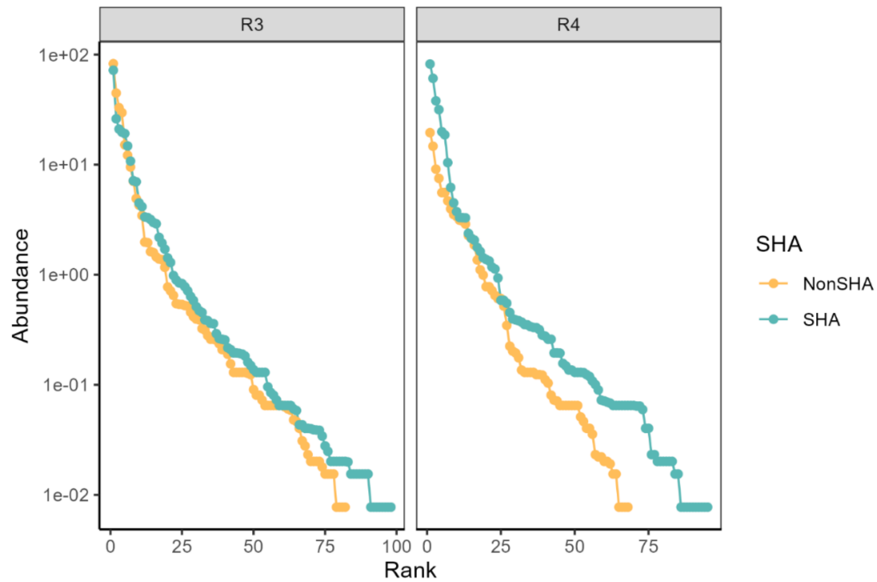

Figure 14. Species rank abundance curves for nekton multi-gear mean standardized catch in SHA and non-SHA sites in the White Oak (Region 3) and Cape Fear (Region 4) River regions.

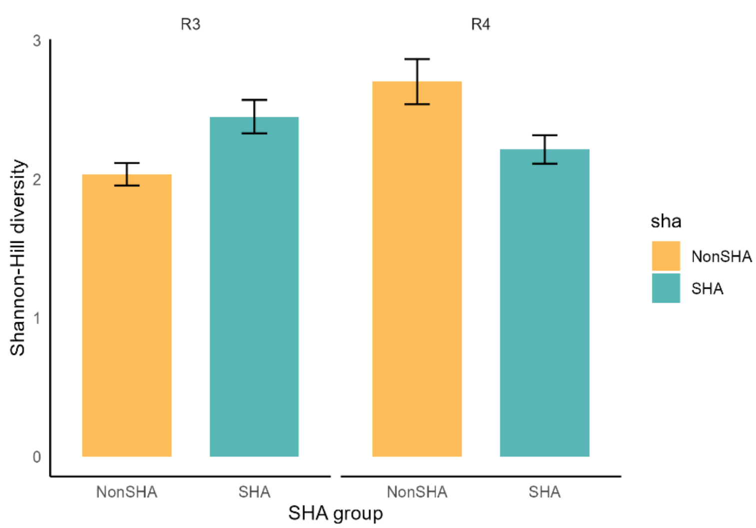

Figure 15. The Shannon-Hill Diversity index for nekton from trawl sampling in Strategic Habitat Areas and non-SHA reference sites. Error bars represent ±1 standard error.

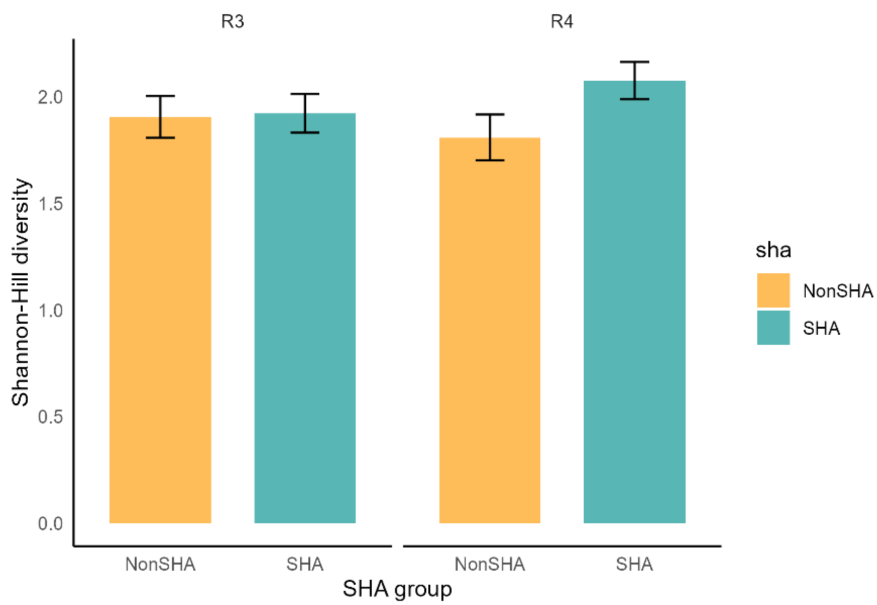

Figure 16. Shannon-Hill diversity index for nekton trap samples in Strategic Habitat Areas and non-SHA reference sites. Error bars represent ±1 standard error.

Community Analysis

Community analyses were not appropriate for the multi-gear mean standardization index or when examining most gear types due to high stress (stress > 0.2) and low squared correlation coefficient (r^2). The 2-dimensional NMDS of trawl catch per unit effort in both regions had an appropriate stress (Region 3 stress = 0.129, Region 4 stress = 0.110) and Region 3 trawl data had a significantly different community in SHA sites than reference sites (Figure 17, PERNAMOVA: Region 3 pseudo-F = 3.400, R^2 = 0.014, p = 0.014). Trawl community composition was not statically significant in Region 4 (pseudo-F = 1.767, R^2 = 0.008, p = 0.117).

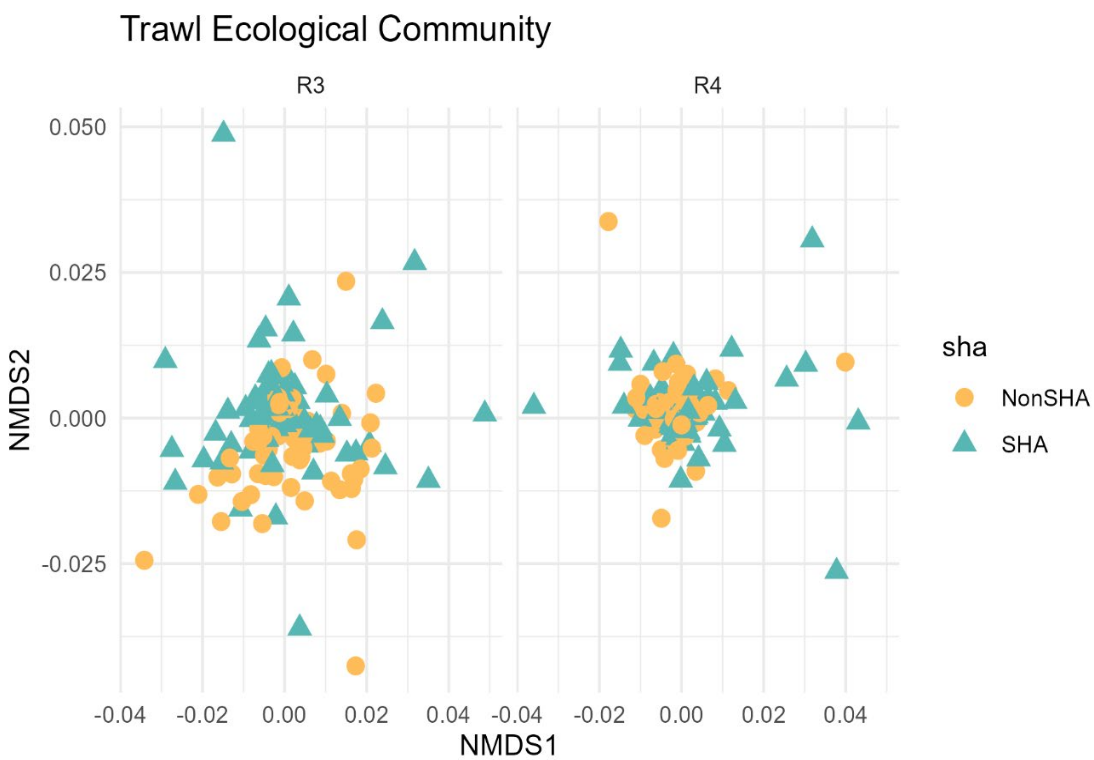

Figure 17. NMDS for community composition in trawl samples across Region 3 and 4 in SHA and non-SHA sites.

Alteration

Habitat alterations were observed more in non-SHA sites; however, frequency also varied between regions. Culverts were only found at one sampling location across both regions, in a non-SHA site in Region 3. There are no differences between the frequency of channeling at sites between treatments, but Region 4 was found to have higher channelization than Region 3. Region 4 also had higher frequency of bridges in non-SHA sites than SHA sites ($\chi^2(1) = 9.110$, $p = 0.003$).

Non-SHA sites had more eroded edge than SHAs. In Region 3, non-SHAs were overrepresented in the frequency of higher categories of eroded edge (26-50%, >50%) when compared to SHA sites (Figure 18, $\chi^2(1) = 66.908$, $p < 0.001$). In Region 4, the there was a marginal significance ($\chi^2(1) = 7.751$, $p = 0.051$), with significant pairwise comparisons only occurring at the 26-50% eroded category, with non-SHAs being overrepresented.

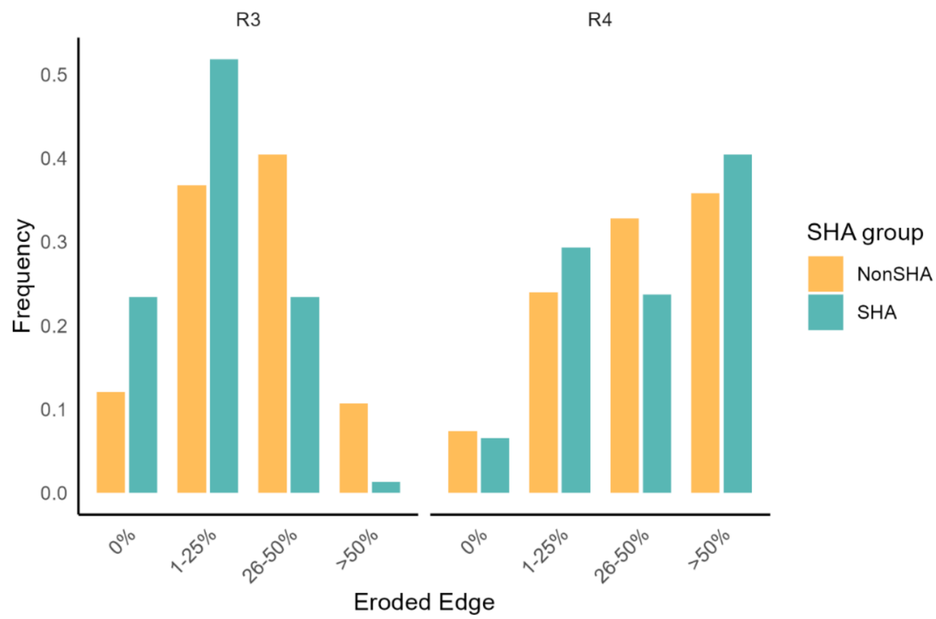

Figure 18. The frequency of SHA and non-SHA sites having 0%, 1-25%, 26-50%, and >50% eroded marsh edge.

SHAs had lower hardened shoreline scores than reference areas, but patterns depended on the region (Figure 19; Region 3, ($\chi^2(1) = 30.088$, $p < 0.001$; Region 4, ($\chi^2(1) = 75.477$, $p < 0.001$)). In Region 3, non-SHAs were overrepresented in sites that were over 50% hardened, while SHAs were overrepresented, but not significantly, in all categories 0-50%. In Region 4, pairwise comparisons were significant in the 10-25% hardened category with SHAs being overrepresented and in the >50% category with non-SHAs being overrepresented.

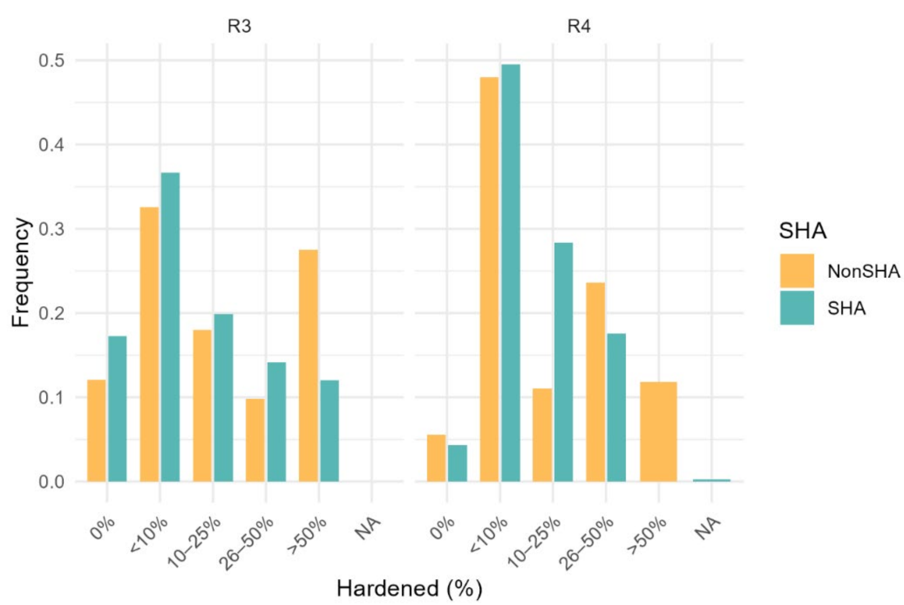

Figure 19. The frequency of SHA and non-SHA sites having 0%, 1-25%, 26-50%, and >50% hardened shorelines.

Conclusions

These results verify that the SHA designation process accurately selected areas with a greater extent of relatively unaltered, diverse habitats, with high ecological function. SHAs had a larger area of structured habitats than the reference sites as well as more habitats present in the landscape. SAV meadows were only present in SHA sites in Region 4. Habitat conditions within SHAs were also higher- salt marshes had higher *Spartina alterniflora* stem density and live oyster cover than the reference sites.

Strategic Habitat Areas were also less altered than reference sites. Reference areas outside of SHAs were more likely to have high levels of eroded marsh shoreline and more hardened shoreline present at sampling locations. Observations of manmade culverts and bridges were also lower in Strategic Habitat Areas, adding to the validation that areas nominated for SHAs were relatively unaltered.

The lack of difference between the total fish abundance in and outside of SHAs in Region 3 may be due to a combination of lower alteration level, smaller differences in habitat presence, and basin geography. Additionally, large catches of schooling species (e.g., spot, menhaden) may have limited differences in total catch. However, Strategic Habitat Areas in Region 3 did show evidence of higher biodiversity indices and different community composition in the trawl data.

Finally, Strategic Habitat Areas had higher nekton abundance and biodiversity in Region 4. This validates the initial goals of identifying areas that provide exceptional habitat function by supporting a higher abundance of diverse fish populations. In combination with findings that Strategic Habitat Areas have a more diverse estuarine landscape, a higher area of structured habitats, and less alteration than areas outside of SHAs, the results of this validation study lend further support to the designation of the nominated Strategic Habitat Areas.

Due to the high time and cost of this sampling program, DMF will explore using current independent sampling for validation of the remaining two regions. In Region 1, data from DMF Programs 100, 135, and 150 can be used, and for region 2, data can be pulled from DMF Programs 120, 915, 610, 611, and 195. Given the differences between the regions, additional factors or habitat characteristics may need to be measured. The complete analysis of validation for all regions will be presented in a future issue paper to the Marine Fisheries Commission that includes options for the designation of Strategic Habitat Areas.

Strategic Habitat Area Management

Following validation of all regions, DMF will reconvene the internal SHA workgroup to develop management strategies. A workshop with state, federal, NGO, and academic partners will be held to prioritize and further develop ideas to protect strategic habitat areas. The leading management options from these discussions will be presented to the MFC and any other appropriate commissions in an issue paper(s). Since each SHA unit has different threats and alterations, a site-specific approach may be needed based on the area function and the severity of threats.

Strategic Habitat Areas can be used in conservation planning by federal, state, and local agencies. They could be added to the NC Conservation Planning Tool which identifies and prioritizes essential high quality natural resources required to maintain healthy and sustainable ecosystem (NC NHP 2025). When planning for sea level rise, marsh migration corridors upland or adjacent to SHAs should be prioritized in land acquisition (see 2021 CHPP Amendment, Chapter 5: *Wetland shoreline protection and enhancement with a focus on nature-based solutions*). SHAs could also be a ranking criterion for the Coastal and Estuarine Land Conservation Program (NC CELCP) plan.

Areas that remain relatively unaltered may need additional protection. SHA locations overlap with Deep Water Oyster Recovery Areas (DORAs: Oyster FMP, NCDMF 2025). DORAs prioritize the ecological value of oyster habitat and protect oyster habitat by prohibiting mechanical harvest. Reducing disturbance from harvest will allow oyster communities to have a higher relief and lower risk of total loss of live oysters during hypoxia events. Additionally, DORA closures have the benefit of providing a refuge for fish during these events. DORA closures in region 2 protecting 81% of identified deep water oyster habitat includes three nominated SHA areas (SHA 52, 86, 137 which are Swanquarter Bays, Neuse Mouse 1, Neuse Mouth 2, respectively).

Strategic Habitat Areas can be prioritized for restoration and enhancement. DMF should consider SHA units when selecting sites for restoration or enhancement when appropriate and prioritize projects that increase connectivity of habitats and SHA units. Funding programs that support enhancement and restoration of fish passage, hydrology, and habitats could also use Strategic Habitat Areas to as a ranking criterion for proposals.

SHA designation could be added to local land use plans, permitting guidance, and watershed planning to bridge marine conservation priorities and land-use decision making. Management actions may also include pursuing funding for agriculture cost-share programs to implement best management practices in watersheds draining to SHAs.

General outreach to the public should include encouraging best management practices adjacent to SHAs.

Recommended Actions

1. Explore feasibility of using DMF independent sampling data to validate SHAs for Albemarle Sound and Pamlico Sound regions.
2. Develop an issue paper that presents validation of Strategic Habitat Areas statewide and propose designation options to the Marine Fisheries Commission.
3. Establish an internal working group to develop management options for Strategic Habitat Areas.
4. Conduct a workshop with federal, state, and private partners to further develop potential management strategies.
5. Complete a SHA management issue paper and present management options to the appropriate commissions and external partners.

Acknowledgements

Anne Deaton, Casey Knight, Yan Lee, field staff

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Thin Layer Placement (TLP)

Executive summary

North Carolina has approximately 235,000 acres of estuarine wetlands in its coastal waters, which provide essential nursery habitat for fish species, foraging and nesting sites for shorebirds and small mammals, shoreline stabilization and erosion control, and enhance water quality through nutrient and pollutant retention. However, those estuarine wetlands are increasingly threatened by sea level rise, saltwater intrusion, and erosion, and the 2021 CHPP called for expanding collaborations between state, federal, and private partners to protect and restore impacted wetlands through nature-based solutions. This CHPP builds on those 2021 CHPP recommendations by outlining the benefits, resource impacts, and policy and permitting concerns with thin-layer placement, which is a restoration, enhancement, and resilience strategy broadly defined as the application of sediments (primarily dredged material) to coastal wetlands in order to increase elevation and surface area, promote sediment accretion, and restore impaired habitat. During development of this CHPP, DEQ staff hosted a workshop to discuss thin layer placement and to share successes, challenges, concerns, and lessons learned associated with the ecological impacts of placing sediment on deteriorating wetlands, and feedback from staff attending the workshop was incorporated into this chapter of the CHPP. The information and guidance summarized in this chapter will serve as an additional resource for regulatory and resource agency staff, commission members, restoration practitioners, and researchers as additional thin layer placement projects are proposed in North Carolina.

Introduction

Preface

Thin layer placement (TLP) is a restoration, enhancement, and resilience strategy broadly defined as the intentional application of sediments (primarily dredged material) to coastal wetlands in order to increase elevation and surface area, promote sediment accretion, and restore impaired habitat. Further defined and described in Berkowitz et al. (2019), TLP is intended to maintain a natural mosaic of low- to high- wetland habitat and support associated ecosystem functions and plant and animal communities. TLP is often proposed for wetlands experiencing low sediment supply, subsidence, and erosion that subsequently have the inability to keep pace with sea level rise and / or do not have an adequate pathway for upland migration (Fig. 1). For the purpose of this document, TLP is viewed as a tool for enhancing the resilience of existing wetlands that are susceptible to or actively drowning and experiencing vegetation loss, interior ponding, and other deteriorating conditions. TLP is not viewed as a tool for the disposal of dredged material, for the creation of new wetlands, or for the mitigation of wetland impacts made elsewhere.

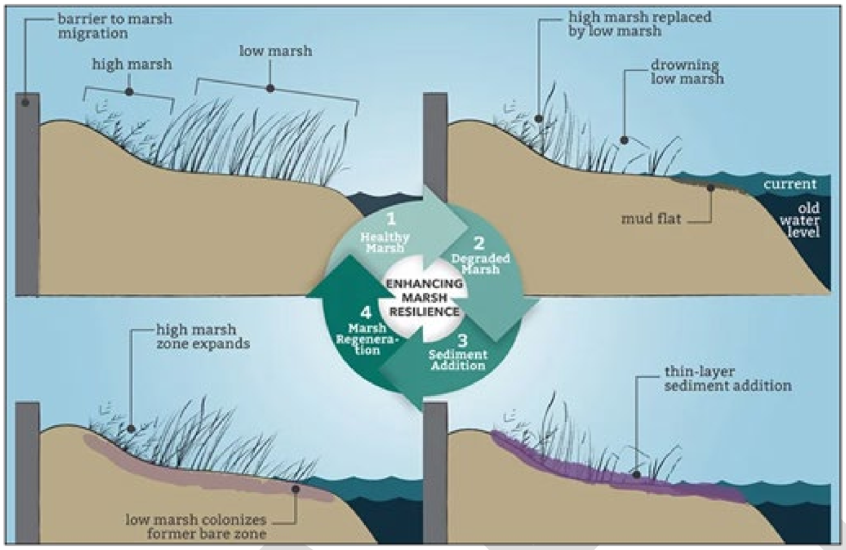

Fig. 1: Conceptual diagram of the thin layer placement process (Raposa et al. 2023).

In North Carolina, dredged material is typically disposed offshore, in upland spoil sites, or when appropriate, used for beach nourishment. However, there is growing nationwide interest in the Beneficial Use of Dredged Material (BUDM) for habitat restoration, including TLP and, while outside the scope of this document, other novel uses besides nourishment such as expanding estuarine shorelines and creating and enhancing islands and offshore artificial reefs. The 2021 CHPP amendment included preliminary discussions about TLP (see Chapter 5.3: Wetland Shoreline Protection and Enhancement with Focus on Nature-based Solutions) and recommended the development of parameters that could be used to evaluate the success of TLP in North Carolina (2021 CHPP Recommended Action 5.12).

CHPP staff, in consultation with the CHPP Steering Committee and coordinating agencies (NC Divisions of Coastal Management, Marine Fisheries, and Water Resources; Albemarle-Pamlico National Estuary Partnership; NC Coastal Reserve and National Estuarine Research Reserve), subsequently identified the need to include TLP as a priority issue for the 2026 CHPP amendment due to expressed interest and curiosity amongst several stakeholder groups including state and federal resource and regulatory agencies, landowners, conservation agencies, environmental non-profits, and local municipalities. For example, state and federal resource and regulatory agencies are interested in habitat trade-offs, resource impacts, permitting requirements, and project efficacy while landowners, municipalities, and environmental groups are interested in expanding options for restoring critical habitats that provide important ecologic and economic services.

Including TLP as a priority issue for the 2026 CHPP amendment also aligns with several conservation and restoration initiatives described in the NC Division of Coastal Management 2022-2026 Estuarine Shoreline Strategy[1], NC Division of Water Resources 2021-2025 Wetland Program Plan[2], 2024 NC Salt Marsh Action Plan and 2026 Implementation Roadmap[3], and the Albemarle-Pamlico National Estuary Partnership 2025-2030 Comprehensive Conservation and Management Plan[4].

The Evolution of TLP

The disposal of dredged material in shallow estuarine environments historically involved side casting, or the simple movement of material "to the side" or away from a given project area, to create elevated intertidal berms that facilitated the recruitment of wetland vegetation but did not necessarily support any kind of ecological function. An early rudimentary study exploring the effects of placing dredged material onto a *Spartina alterniflora* salt marsh in Brunswick, Georgia showed that within one growing season, invertebrate communities recovered and plants were able to penetrate through up to approximately 20 cm of sediment (Reimold et al. 1978). Over the past several decades, TLP has primarily involved the hydraulic dredging, liquification, and pumping of sediments through a high-pressure spray nozzle. The resulting "slurry" is subsequently applied in a rain-like consistency over the surface of a recipient wetland (Fig. 2).

[1]The 2022-2026 Estuarine Shoreline Strategy aims to explore the implementation of resilience strategies including thin layer placement and the protection of marsh migration pathways.
[2]The 2021-2025 Wetland Program Plan aims to determine status and trends in wetland acreage, condition, and functions while promoting statewide wetland restoration and protection.
[3]The 2024 Salt Marsh Action Plan and 2026 Implementation Roadmap aim to facilitate and advance salt marsh research and assessment to protect and restore existing salt marshes and improve salt marsh function, including the advancement of beneficial use tools.
[4]The 2025-2030 Comprehensive Conservation and Management Plan includes proposed actions that refine and implement regional wetland protection and restoration strategies by mapping, monitoring, and identifying critical habitats.

Fig. 2: Typical method used for thin layer placement (Image Source: U.S. Army Corps of Engineers)

TLP can also involve direct, low-pressure end-of-pipe discharge when slurry application is not feasible due to logistical or resource constraints. End-of-pipe discharge involves the distribution of sediment through passive sheet flow or the manual re-working of sediment over the wetland surface. While it can be successful (see Feigin et al. 2026), this approach often results in non-uniformity in sediment distribution because relative to fine sediments, coarser materials tend to drop out of suspension and form mounds near the discharge pipe (Davis et al. 2022; Whitbeck et al. 2019). Additionally, end-of-pipe discharge can scour the marsh surface and bury plants that are most proximate to the discharge pipe. Regardless of application method, TLP is often done in conjunction with shoreline stabilization measures (e.g., living shorelines, breakwaters, wave attenuators) that help retain material within the system. This topic is discussed further in subsequent sections.

2026 CHPP Objectives

The following sections are intended to provide a comprehensive review of existing literature (i.e., research studies and guidance documents) and large-scale case studies primarily along the east coast of the United States. This review will provide insight into lessons learned and best practices to consider for planning, implementing, and monitoring successful TLP projects. This paper will also highlight relevant TLP policies and regulations and the results from a multi-agency stakeholder workshop held on March 30, 2026 (Appendix B) that identified permitting and resource concerns, research and information needs, and knowledge gaps associated with the implementation of TLP in North Carolina.

In North Carolina, TLP remains relatively unexplored at large scales relative to other states (e.g., Georgia, Maryland, Delaware, New Jersey, New England states) that have permitted and implemented TLP projects beyond the experimental stage (see more in "Eastern U.S. Case Studies"). TLP projects are currently ineligible for permitting under the North Carolina Coastal Area Management Act (CAMA) and Dredge and Fill Law but may be approved through a variance from the NC Coastal Resources Commission (further discussed in "Regulation, Policy, and Permitting"). The information summarized throughout this document build significantly on existing guidance developed by the North Carolina Division of Coastal Management (further discussed in "Guidance Document Review") and is therefore intended to serve as a source document for regulatory and resource agency staff, commission members, restoration practitioners, and researchers as TLP projects are proposed and considered for variance. Overall, this document will ensure stakeholders are well positioned to evaluate TLP proposals and if needed, help inform next regulatory steps as determined by the Coastal Resources Commission.

Further detailed in the "Looking Ahead" and "Specific Recommended Actions" sections, we recommend future work that evaluates potential candidate areas for TLP in North Carolina. We also recommend the development of a multi-agency TLP or beneficial use workgroup to move forward TLP efforts and, if warranted, establish best practices specific to the state. Overall, the information provided in this document highlights the growing trend of implementing novel beneficial use projects within coastal ecosystems that are susceptible to negative impacts from environmental change.

Abbreviated Primary Literature Review

Experimental research within the last 10-20 years has examined the impacts of TLP on coastal wetland function to determine optimal conditions for restoration success (see short reviews by VanZomeren and Piercy 2020 and Ray 2007). Recent work has broadly considered the importance and response of sediment characteristics and biogeochemistry, the thickness or amount of applied material, target elevation and change over time, the response and recovery of plant and animal communities, and long-term resilience to sea level rise and environmental change.

Sediment Characteristics

Comparing sediment characteristics between source materials and potential recipient wetlands is one of the most important considerations associated with TLP. Traditionally, compatible source material is that which shares similar physical and chemical properties (e.g., grain size, bulk density, organic matter content) as the recipient wetland to ensure normal ecological function (sometimes referred to as "like-on-like" application). At low elevations, tidal wetlands are typically characterized by anoxic, organic and nutrient-rich fine sediments (over 90% silt + clay) with low rates of decomposition. Wetland sediments are among the most productive on Earth and support high above and below ground biomass and facilitate the accumulation of and potential long-term storage of carbon. In North Carolina, compatible source material would most likely derive from the maintenance dredging of federal or private navigation channels, canals, and other large excavation projects (e.g., marina basins, etc.).

Some evidence suggests that material compatibility is not always important. For example, Raposa et al. (2023) and VanZomeren et al. (2018) have shown that the application of coarse sediments (i.e., sand and other terrestrial sources comprised of 75% sand and 25% silt + clay) on wetland surfaces is effective at maintaining biological productivity (i.e., the growth and survival of plant and invertebrate communities) while enhancing wetland elevation and preventing further sediment loss as long as a specific range of bulk densities (i.e., the degree of sediment compaction) is maintained to support the growth of target plant species. Further, the application of coarse sediments can sequester legacy contaminants[5] within recipient wetlands especially when amended with emerging activated carbon technologies (e.g., biochar, compost, etc.). These emerging technologies are designed to enhance the adsorption and retention of pollutants (Gilmour et al. 2018; Patmont et al. 2014) and ameliorate sulfide (a toxic metabolite) accumulation in sediments (Anchor QEA 2025), though these technologies can also increase soil respiration and methane emissions without subsidizing plant growth (Wilburn et al. 2024).

There may be other risks associated with material incompatibility. While "unlike-on-like" application can effectively maintain biological communities and surface elevation, it generally takes longer for recipient wetlands to return to ambient conditions (Harris et al. 2021; La Peyre et al. 2009). For example, the application of coarse sediments impacts sediment biogeochemistry and reduces rates of carbon accumulation because coarse sediments are more oxygenated and less rich in organic matter compared to fine sediments (Wilburn et al. 2024). A mismatch in sediment properties can therefore alter wetland ecosystem services and increase greenhouse gas emissions if there is a shift from anaerobic (without oxygen) carbon accumulation to aerobic (with oxygen) carbon decomposition. Additionally, the application of coarse sediments can impact ecological

[5]In North Carolina, the contamination of sediments with heavy metals, per- and polyfluoroalkyl substances (PFAS), and other degradation-resistant chemicals are a major concern associated with TLP and the beneficial use of dredged material especially within the Cape Fear region. Since the detection of high concentrations of PFAS in the Cape Fear River about a decade ago (Sun et al. 2016), these compounds have accumulated in a wide variety of organisms and environmental media (Ehsan et al. 2023). Any proposal to use dredged sediments for TLP would therefore have to undergo enhanced scrutiny to determine the concentration, distribution, and fate of PFAS and other contaminants within a given project area. These considerations are further outlined in the "Guidance Document Review" and Resource and Regulatory Concerns" sections of this paper.

interactions even if broad metrics used to describe plant and animal communities (e.g., diversity and abundance) do not change. The application of coarse sediments, for example, can promote crab burrowing and alter other invertebrate behaviors that extend beyond typical one-to-five-year monitoring periods (Raposa et al. 2023).

Sediment Processes and Biogeochemistry

Assuming "like-on-like" material application, recent work has shown that TLP typically preserves and can even enhance belowground biomass, microbial activities, and important biogeochemical functions (e.g., carbon and nitrogen retention) relative to other types of restoration (e.g., living shorelines and rip rap revetments to control edge erosion, native plantings to stabilize existing sediment, land acquisition to facilitate wetland migration, etc.) and to wetlands not subject to TLP. The application of new material to wetland surfaces introduces organic matter and nutrients that supplement sediment microbial communities and their metabolic processes (Bartolucci and Fulweiler 2026; Cornwell et al. 2025; VanZomeren et al. 2018) but increase the risk that sulfide and other dissolved gases accumulate (Berkowitz and VanZomeren 2020). However, these processes most likely respond to an initial "fertilization effect" and ultimately diminish in the long-term before returning to ambient, though sustained, conditions over time (Morris and Staver 2024). TLP can also help maintain the role of tidal wetlands as net greenhouse gas sinks, though some studies have reported variable but enhanced methane emissions even with "like-on-like" application (Bartolucci and Fulweiler 2024; Punchkoff and Lawrence 2022). The overall effects of TLP on sediment biogeochemistry are location-specific, highly variable, and represent an area needing additional research. There is also very limited understanding of how TLP impacts microbial interactions and long-term carbon and organic matter dynamics.

Placement Volume, Elevation, and Vegetation Response

It is important to note that TLP projects are associated with an "ugly phase" characterized by temporary wetland disturbance, plant smothering, and localized increases in turbidity. Approaches to minimizing any adverse impacts from construction activities are highlighted in subsequent sections and are discussed relative to necessary trade-offs and potential long-term benefits of properly executed TLP projects. While temporary impacts are inevitable during initial sediment placement, our review of existing literature mostly shows successful plant recovery and growth after one or two growing seasons with longer recovery times (up to four years) that are typically correlated with placement volume as discussed below (Fig. 3).

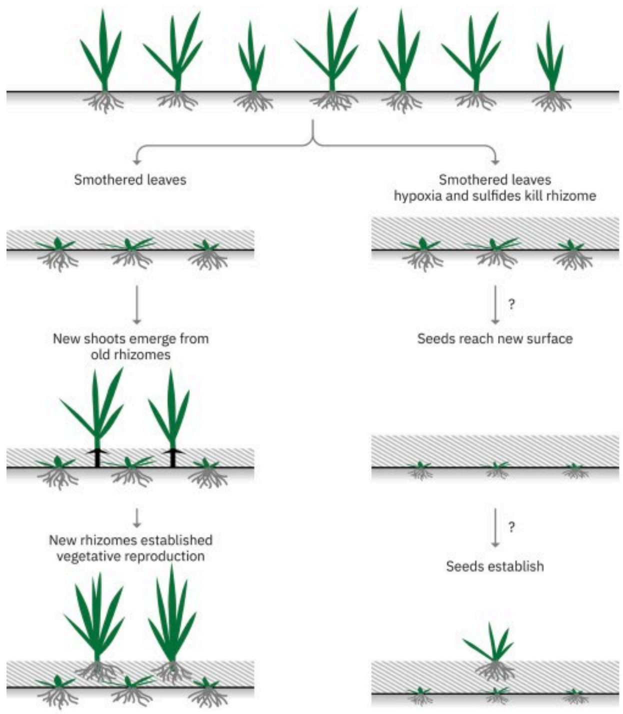

Fig. 3: Expected wetland vegetation recovery as a function of placement volume and thickness. Figure modified from Anchor QEA (2025) as adapted from Mohan et al. (2016) and Wilber and Engler (1993).

The response of wetland vegetation to sediment placement is partially dependent on the amount (volume) of material applied and may be the most important consideration and concern associated with TLP. The optimal amount or thickness of the applied sediment layer is highly project-specific and guided by the interaction between sediment characteristics, local tidal frames and resulting elevation-biomass relationships (Fig. 4; Raposa et al. 2023; Davis et al. 2022). For example, early studies in Louisiana by Schrift et al. (2008) and Slocum et al. (2005) used comprehensive multi-factorial treatment designs to test sediment applications along an elevation gradient and to compare results to control (equally degraded) and reference (goal or target condition) wetlands that received no sediment. Ultimately, the natural recovery and growth of native plant species was governed primarily by adequate tidal inundation, elevation gain, high organic matter content and bulk densities, and rhizome survival that were all sustained with sediment applications that ranged between 5-12 cm thick along the elevation gradient (Schrift et al. 2008; Slocum et al. 2005). TLP should therefore deliver enough sediment that achieves and maintains a target elevation within the intertidal zone, ideally near the mid-range between sea level and mean high water.

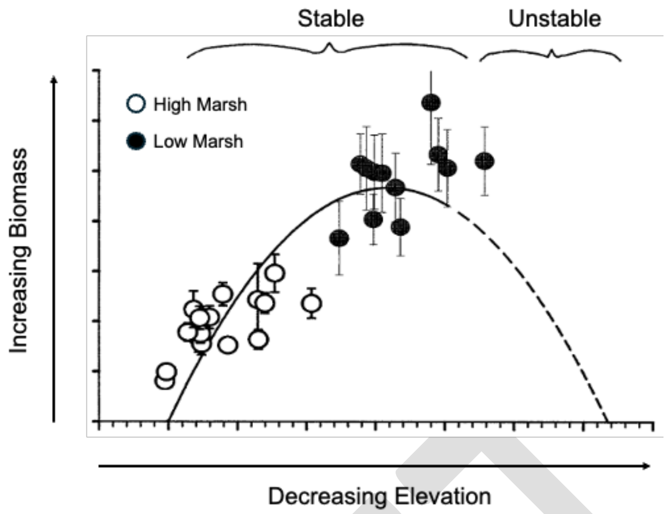

Fig. 4: The relationship between wetland elevation (horizontal axis) and plant biomass (vertical axis) within a typical *Spartina alterniflora* salt marsh. Open circles represent average measurements taken within high marsh sites while closed circles represent average measurements taken within low marsh sites. Vertical bars represent the error associated with each measurement. Overall, plant biomass peaks at certain elevations within the local tidal frame and decreases when elevation is too high (less tidal inundation) or too low (more tidal inundation or drowning). Figure modified from Morris et al. (2002) and adapted from NC DEQ (2025).

There are no absolute thresholds (e.g., 5, 10, 15 cm) that define TLP success, though previous work has demonstrated some trade-offs associated with a wide range of placement volumes and thicknesses relative to project goals and local hydrological characteristics (Appendix A). Generally, wetland vegetation and associated ecological functions recover more quickly the less material is applied, but this does not mean that longer recovery times associated with more material are indicative of unsuccessful projects. For example, Punchkoff and Lawrence (2022) and VanZomeren et al. (2018) showed that in Connecticut and New Jersey wetlands, respectively, sediment layers as thin as 5 cm increase above and belowground plant productivity and biomass, enhances carbon dioxide uptake, and reduces the potential for accumulating toxins and greenhouse gases in as little as six months. Raposa et al. (2023) showed that within a few years at several wetland sites across the National Estuarine Research Reserve System, 10 cm additions increased sediment accretion rates and elevation gain that were expected to withstand long-term subsidence compared to control sites. Stagg and Mendelssohn (2010) report similar successes with applications up to 36 cm in Louisiana wetlands. Regardless of placement thickness, plant recovery can be expedited by pre-seeding sediment slurries prior to application or with supplemental plantings after application. In some cases, 100% of post-application plantings can survive and either reach or exceed the richness and density of reference sites (Howard et al. 2020).

For projects that aim to maintain existing "low marsh" edges that sit at lower elevations within the tidal frame and less inundated "high marsh" interiors that sit at higher elevations within the tidal frame, low marshes tend to recover more quickly than high marshes regardless of placement thickness. Studies have generally shown a more positive initial response to TLP from wetlands dominated by low marsh plant species (e.g., *Spartina alterniflora*) compared to those dominated by *Spartina patens* or other higher marsh species (Raposa et al. 2023; Payne et al. 2021). Some studies also suggest that interior, low-elevation ponds within drowning wetlands might benefit the most from TLP (La Peyre et al. 2009; Mendelssohn and Kuhn 2003). However, the response to and recovery from TLP is most likely inconsistently reported across wetland elevations and species. For example, higher marsh species may simply take longer to reach similar metrics (e.g., biomass, stem density, etc.) as their lower marsh counterparts (Raposa et al. 2023). These results underscore the importance of evaluating TLP impacts on species besides *Spartina alterniflora* and establishing adequate monitoring timeframes.

Higher placement volume correlates with higher initial elevation gain and increases the likelihood that habitats convert between sub-tidal open water ponds, intertidal low and high marsh, and supratidal uplands that sit entirely above the tidal frame. For projects that aim to enhance long-term resilience to particularly high rates of sea level rise and wetland loss, habitat conversion associated with the application of large amounts of sediment could be a desirable outcome assuming created uplands eventually convert back to intertidal wetlands (Anchor QEA 2025). Habitat conversion may also be desirable to achieve project goals associated with the restoration of habitats specific to birds or other taxonomic groups. While TLP can be successful with a wide range of placement volumes, there are risks associated with over-application such as permanent smothering, over-compaction and elevation loss, excess turbidity and leakage, and lower plant productivity over time (Correll et al. 2024; Graham and Mendelssohn 2013). Elevating wetlands too high or above the appropriate tidal frame can also facilitate the colonization of invasive species such as the common reed *Phragmites australis* and reduce available fish habitat below mean high water. Additionally, final "as built" elevations are difficult to predict, particularly with issues associated with fine sediments such as excessive drainage, compaction or consolidation (Myszewski et al. 2017).

Faunal Community Response

Compared to plant communities, research investigating the response of faunal communities to TLP is sparse and primarily emphasizes the impacts of sediment placement on subtidal benthic communities. However, previous work has shown that intertidal benthic invertebrate communities (e.g., snails, crabs, worms, other epi- and in-fauna) recover at a rate that corresponds to placement thickness (Tong et al. 2013) and material compatibility (Wilber et al. 2006). That is, benthic faunal communities will recover more quickly the less material is applied through vertical or lateral migration from adjacent areas, particularly if fine sediment is applied to the wetland surface. While recovery rates are typically determined by calculating the abundance of individual species, overall community recovery (i.e., structure and function) is dependent on maintaining local hydrological and vegetation characteristics once sediment is applied to the wetland surface (Tong et al. 2013). For example, sediment applications that convert intertidal to supratidal environments can result in community shifts that favor more mobile, terrestrial invertebrates (McAtee et al. 2020; Wilber et al. 2006). Lastly, the response of nekton and avian communities to TLP is even less studied but is also predominantly dependent on changes to vegetation cover and elevation over time (NJ DEP 2023). Regardless of placement thickness, significant initial changes in faunal communities are expected but most likely temporary assuming projects are planned and implemented responsibly.

Natural Sediment Deposition and Horizontal Movement. Aside from artificial processes like TLP, wetlands susceptible to natural overwash, flooding, and associated sediment deposition events (e.g., hurricanes or inland storms) can build and sustain wetland elevation, plant growth and biological productivity even under moderate to high (up to 16 mm per year) sea level rise scenarios (Baustian and Mendelssohn 2018; Baustian and Mendelssohn 2015; Walters and Kirwan 2016; McKee and Cherry 2009). These same natural events can deposit too much sediment or, depending on additional factors such as wind, waves and flooding velocity, can significantly scour or erode wetland ecosystems (Walters and Kirwan 2016; Hill et al. 2020; Guntenspergen et al. 1995). Overall, the ability of natural events to provide long-term resilience to changing environmental conditions is unpredictable and highly dependent on the thickness and texture of deposited sediment, storm frequency and intensity, and resulting long-term changes in sediment accretion and organic matter accumulation.

Horizontal sediment movement and distribution is another important consideration when evaluating the impacts of TLP on wetland surfaces. For example, Ganju (2019) showed that higher marsh elevations are more susceptible to "slumping" (e.g., structural failure and subsequent decrease in elevation) or post-application erosion due to sediment redistribution. Additionally, the horizontal movement of sediments can impact adjacent habitats (e.g., shellfish beds, submerged aquatic vegetation, etc.) especially if TLP projects do not incorporate erosion control measures during and after sediment placement. Impacts to adjacent habitats are localized, however, and the long-range export of material is unlikely (Thorne et al. 2019). Nonetheless, the significance of localized impacts can be reduced by placing sediments in less sensitive habitats (e.g., avoiding nursery areas, submerged aquatic vegetation, active shell fishing or high-quality waters, etc.) or areas within larger marsh systems. TLP can also be coupled with other nature-based strategies (e.g., living shorelines) to develop a more holistic restoration approach that incorporates the protection of adjacent habitats.

Long-Term Resilience

There is general consensus that TLP is an effective tool for mitigating wetland loss (Morris and Staver 2024). However, the amount of time TLP protects wetlands from further deterioration is determined by placement thickness, the number of repeated applications, and existing environmental conditions. Recent work has shown that over time, wetlands in North Carolina that received just one sediment application continued to build elevation compared to those that did not receive sediment and expedited the rate at which wetlands reached an elevation that could otherwise take decades to achieve (Davis et al. 2022). As another example, TLP efforts in Rhode Island provided a recipient wetland with an estimated 67–320 years of ambient elevation gain and subsequently with long-term resilience to environmental change (Raposa et al. 2022).

Most of the studies described in previous sections are based on relatively short-term impacts and monitoring data that only lasted a few years. Longer studies over five years indicate that while ecosystem function remains stable over time, recipient wetlands can still deviate from baseline or control conditions (Cheng et al. 2025). Further, modelling studies have shown that Virginia wetlands subject to TLP will not retain elevation capital or provide long-term protection against particularly high rates of sea level rise (over 15 mm per year), though increased resilience is more likely with wetlands characterized by existing, gently sloping migration corridors without physical barriers (e.g., bulkheads or other infrastructure) to migration (Barksdale et al. 2026). Overall, the extent to which TLP contributes to long-term wetland resilience most likely varies by geographic location and is dependent on a suite of project-specific factors and objectives. This degree of uncertainty underscores the need for large scale pilot studies across diverse wetland types, some of which are described in subsequent sections.

Eastern U.S. Case Studies

Some of the earliest "slurry" applications of TLP were conducted in Mississippi River Delta wetlands. While initial applications were considered disposal, the region began to leverage dredge projects for wetland restoration in response to rapid sea level rise and sediment deficits that prevented wetlands from maintaining or gaining elevation. Hence, early work along the U.S. Gulf Coast aimed to find the balance between disposal and beneficial use by determining the amount of material placed on wetland surfaces that would limit negative impacts to the ecosystem (Ford et al. 1999; DeLaune et al. 1990; Cahoon and Cowan 1988). For the purpose of this document, we emphasize recent studies conducted along the east coast of the United States and within wetland ecosystems (tidal freshwater to salt marshes) subject to tidal patterns similar to those found in North Carolina. However, additional studies along the U.S. west and Gulf coasts are summarized in Appendix A.

Eastern U.S. states are at various stages of implementing large-scale TLP projects (Fig. 5). For example, North Carolina, South Carolina, and Virginia are currently in the exploratory phase and have no regulatory pathway for TLP with limited (if any) experimental studies. Georgia, Maryland, and Delaware have successfully conducted few large-scale TLP projects, though the planning, permitting and implementation processes are not yet streamlined, and quantified monitoring results are rarely reported. New England states such as Rhode Island, Connecticut, Massachusetts, and New York also have limited success with TLP projects, the results of which are sparsely reported in primary or gray literature. Based on our review, New Jersey has established perhaps the most robust beneficial use regulatory framework (to include TLP) that extends beyond the pilot stage. The state has developed a programmatic approach to beneficial use that includes collaborations between regulators, dredgers, and landowners that begin with engaging new policies that first and foremost address environmental needs that are also of value to dredgers. Establishing buy-in is therefore a crucial pillar amongst stakeholders. While developing a catch-all approach (relative to a case-by-case approach) to TLP and beneficial use might streamline project development and implementation, it may not always generate desirable outcomes. Case studies from each of these states are summarized below.

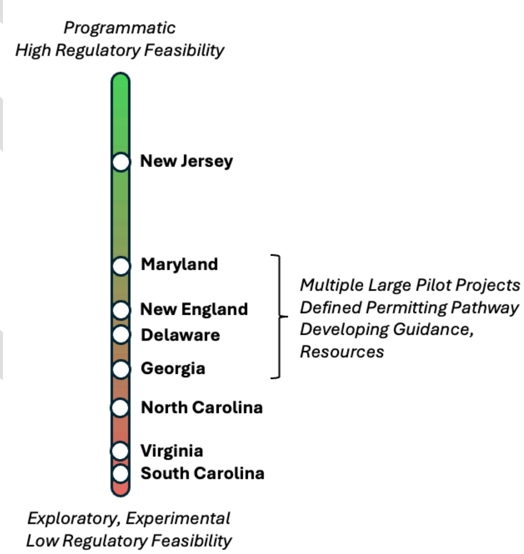

Fig. 5: Eastern U.S. states and their relative position along the TLP implementation spectrum as subjectively determined based on a review of regulatory feasibility, number and scale of reported TLP projects, and available TLP and beneficial use resources.

North Carolina

Studies specific to North Carolina have been relatively limited, small-scale, and strictly experimental (Fig. 6). Wilber et al. (1992) first evaluated impacts of sediment placement (1-20 cm) on Gull Rock in Hyde County and found that recipient wetlands remained well-vegetated, albeit less dense, and that while resulting sediment properties (e.g., higher bulk density and lower organic matter content) differed from reference sites, faunal distributions (i.e., peracarid crustaceans, oligochaetes, and polychaetes) and cursory sampling of large mobile macroinvertebrates and fishes were indicative of productive wetlands. This study also highlighted the uncertainty associated with the effects of pre-application conditions on post-application results. For example, differences in sediment and vegetation characteristics could have resulted from differences in initial concentrations, biomass, susceptibility to disturbances, etc. that are difficult to realize without standardizing monitoring criteria.

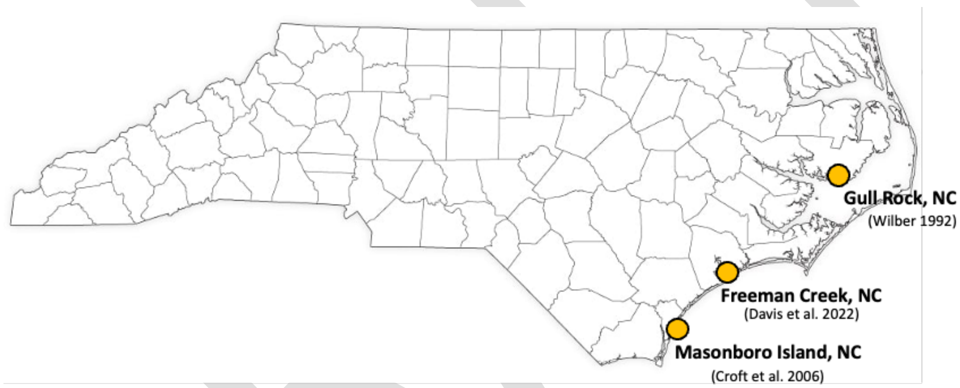

Fig. 6: Experimental (plot level) thin layer placement studies conducted in North Carolina.

On Masonboro Island in New Hanover County, the placement of fine sediments (2.5-10 cm thick) had a positive effect on deteriorating marsh plots after two growing seasons by increasing plant density and with sediment properties returning to pre-application conditions (Croft et al. 2006). However, there was evidence that placement increased the mobility and degradability of wetland sediments especially with thicker (near 10 cm) applications. Faunal response to sediment placement was also highly variable. At Freeman Creek in Camp Lejeune, Onslow County, Davis et al. (2022) reported positive gains (approximately 6 cm) in elevation and vegetative biomass that were maintained over five growing seasons. These net gains exceeded control sites.

Georgia

In addition to the early study conducted by Reimold et al. (1978) previously described, Georgia has conducted two more recent large-scale TLP pilot projects. In 2019, the Georgia

Department of Natural Resources in collaboration with the Georgia Federal Consistency Program, the U.S. Army Corps of Engineers, The Nature Conservancy, and Jekyll Island Authority placed approximately 5,000 cubic yards of sediment 15-25 cm thick over five acres of healthy *Spartina alterniflora* wetlands to increase wetland resilience to sea level rise (Appendix B; https://coastalgadnr.org/JekyllCreek). After five years, 84% of vegetation had regrown with most success at the wetland edge (Fig. 7). However, re-vegetation took longer than anticipated and did not support the vision of full re-growth between 3-5 years. Benthic species diversity decreased, and there was no evidence that the placement site met reference site conditions. Overall, project partners highlighted that monitoring could have been improved but was limited due to funding constraints.

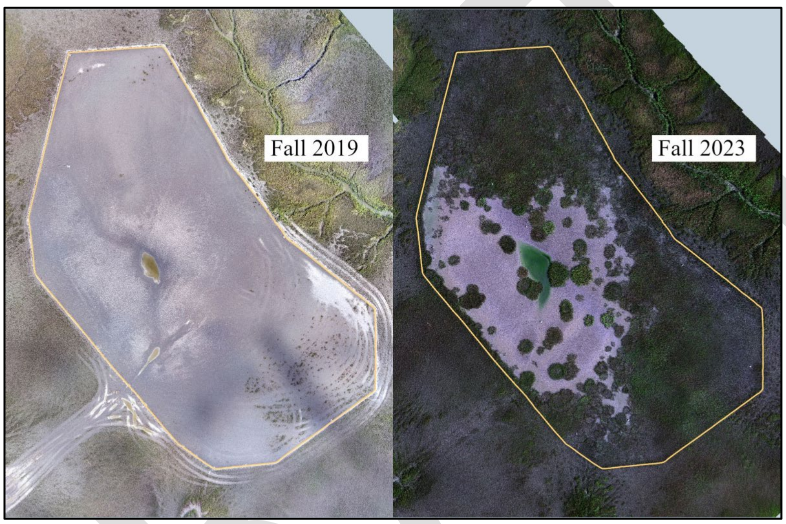

Fig. 7: Wetland vegetation growth (2019-2023) following thin layer placement on Jekyll Island, Georgia. Image courtesy of the GA Department of Natural Resources (https://coastalgadnr.org/JekyllCreek).

A TLP project conducted in Brunswick, Georgia with robust engineering considerations yielded more success (Mohan et al. 2021). In this study, sediments (a combination of sand and silt) up to 30 cm thick were hydraulically conveyed onto degraded wetlands at an angle (between 30 and 45 degrees) that ensured uniform distribution of sediments across the wetland surface. While coarse sediments distributed more evenly than fine sediments, project partners were able to optimize the placement of fine sediments with a baffle plate and temporary access road within the marsh to control the location of the discharge pipe. While the inclusion of an access road optimized placement, it resulted in additional environmental impacts that required post-project restoration. However, physical and vegetative monitoring conducted over a two-year period indicated strong natural recolonization of vegetation and the re-establishment of benthic invertebrate species.

New Jersey

Several TLP pilot projects have been implemented within the barrier island sounds and Delaware Bay regions of New Jersey (Harris et al. 2025; NJ DEP and TNC 2023; Harris et al. 2021; VanZomeren et al. 2018). In summary, up to approximately 80 cm of dredged material was placed on degrading wetlands within these regions to increase and maintain optimal tidal elevations for native wetland species (particularly *Spartina patens*), increase the cover and health of native wetland vegetation, and return all other metrics to baseline conditions unless changes were expected from habitat conversion. An assessment of short-term impacts revealed that while recipient wetlands quickly recovered ecosystem services associated with biochemistry, water quality, and nutrient retention, placement sites experienced initial plant smothering, weaker sediment strengths, and subsidence from over-compaction. Some revegetation (more than 50%) occurred after three growing seasons and matched control sites, but not with the target species. Subsequent longer-term monitoring revealed that gradual improvements in sediment properties and vegetation growth were accompanied by elevation gains estimated to offset impacts from sea level rise by 18-28 years. However, these projects collectively resulted in uneven sediment distribution, variable rates and success in invertebrate, avian, and nekton recovery, and difficulty in detecting small elevation changes even after ten years. Overall, these results may not represent the most desirable outcome and underscore the need for detailed planning and design phases. Elsewhere in the state, TLP has been successful when coupled with hydrological restoration to restore wetlands to regularly flooded elevations that facilitate and maintain the rapid recovery of *Spartina alterniflora* (Feigin et al. 2026).

Delaware

While the state has few reported case studies, the Delaware Department of Natural Resources and Environmental Control conducted a TLP project in Pepper Creek, Sussex County within a low elevation wetland system situated adjacent to both a dredging project and adjacent higher elevation reference wetlands (DNREC 2016). This project involved the hydraulic dredging and placement of approximately 35,000 cubic yards of sediment up to 15 cm thick. While project results were not quantified, project partners reported elevation gains and successful revegetation.

Maryland

Early TLP efforts in Maryland were experimental and part of a long-term climate adaptation strategy associated with the Blackwater National Wildlife Refuge and in collaboration with The Conservation Fund, Audubon Mayland-DC, the U.S. Fish and Wildlife Service, and the Maryland Department of Natural Resources (McCullough et al. 2021; Whitbeck et al. 2019). This project involved predictive and suitability modelling to implement the first TLP project in the Chesapeake Bay region. In summary, approximately 26,000 cubic yards of dredged sediment up to 15 cm thick were applied over 40 acres of a subsiding and fragmented wetland comprised of *Spartina alterniflora, Spartina patens,* and the bulrush *Schoenoplectus americanus* with the goal to create higher elevation wetlands for the saltmarsh sparrow *Ammodramus caudacutus* and to increase wetland resiliency to sea level rise and storm impacts. While project partners observed significant revegetation and recolonization of wetland bird species, the proliferation of invasive *Phragmites australis* remained a long-term problem.

In 2024, the National Oceanic and Atmospheric Administration in collaboration with the U.S. Fish and Wildlife Service and the U.S. Army Corps of Engineers conducted a large-scale TLP pilot study at Deal Island Wildlife Management Area (Fig. 8). This project involved the application of 167,000 cubic yards of material up to 46 cm thick over 72 acres of low wetland habitat. Sediment placement was accompanied by straw bales to contain material and supplemental plantings over two growing seasons. Overall, the project was effective at restoring densely vegetated habitat but took several years to reach equilibrium. The project also required re-plantings and the installation of new straw bales over time to ensure long-term success (Davis et al. 2025; Appendix B)

Fig. 8: Wetland vegetation growth (2024-2025) following thin layer placement at Deal Island Wildlife Management Area. Image courtesy of Dr. Jenny Davis, NOAA (Appendix B).

New England

Relative to the southeast, northeast U.S. marshes are generally less productive in terms of plant biomass, positioned higher in the tidal frame, and experience larger tidal ranges and lower relative rates of sea level rise. As a result, New England wetlands generally respond to TLP more quickly (and with less material) relative to southeast and mid-Atlantic U.S. wetlands. For example, pilot studies in wetlands across Connecticut, Rhode Island, New Hampshire, and Massachusetts have shown that sediment layers between just 5-10 cm promoted rapid revegetation, enhanced carbon dioxide uptake, and reduced methane emissions (Punchkoff and Lawrence 2022; Payne et al. 2021). However, larger placement volumes up to 48 cm thick have also been shown to build elevation capital without compromising the recovery of plant and animal communities in sandier microtidal regions of New England (Raposa et al. 2022).

TLP projects have also been implemented in urban New York wetlands. For example, the deepening of New York Harbor yielded 42 million cubic yards of material between 2004 and 2014, a portion of which was used beneficially within the Jamaica Bay region. One of the larger-scale TLP projects was conducted within a barren, non-vegetated mudflat which received supplemental plantings and 8,000 cubic yards of sediment an average of 20 cm but up to 100 cm thick. Like many other projects across the U.S. east coast, *Spartina alterniflora* and associated wetland ecosystem services recovered quickly with less material but eroded and did not recover with applications over 20 cm thick (Frame et al. 2005). More calculated efforts in recent years suggest that low elevation urban wetlands receiving no more than 15 cm of sediment recover to nearly 100% of reference conditions (i.e., based on percent cover and stem height) after two growing seasons, though restored higher elevation wetlands take longer to respond (Haight et al. 2026).

Guidance Document Review

In response to the growing number of peer-reviewed studies and pilot projects, several agencies and organizations have developed TLP guidance documents including the U.S. Army Corps of Engineers (USACE) and Fish and Wildlife Service (USFWS), National Estuarine Research Reserve System (NERRS), National Oceanic and Atmospheric Administration (NOAA), The Nature Conservancy (TNC), and other consulting, engineering, and research groups such as the Southeast Regional Partnership for Planning and Sustainability and the Georgia Coastal Research Council. In 2022, the North Carolina Division of Coastal Management in partnership with the Divisions of Marine Fisheries, Water Resources, and Wildlife Resources Commission and the USACE (Wilmington District), USFWS (Raleigh Field Office), and NOAA National Marine Fisheries Service (Southeast Regional Office) developed guidance for site assessment and monitoring of TLP in North Carolina (NC DCM 2022). This guidance was intended to help permit applicants design TLP projects in a way that optimized project scoping, interagency permitting reviews, and future outcome evaluations and provided a starting point for progressing TLP in the state. This and other documents are summarized below and highlight lessons learned and best practices for designing, implementing, monitoring, and adaptively managing large scale TLP projects informed by research and case studies like those described above (Fig. 9). These guidance documents also discuss important logistical, engineering, and funding considerations.

Fig. 9: Process flowchart for thin layer placement. Figure modified from Anchor QEA (2025) and adapted from Piercy et al. (2023).

Planning and Design

Planning and designing TLP projects require a diverse interdisciplinary team of local, state, and federal stakeholders consisting of resource agencies; regulatory and permitting agencies; restoration practitioners; research scientists; landowners; dredgers, engineers, and consulting agencies; and fishers and recreationists. This team should be charged with identifying suitable wetlands for TLP, determining target elevations[6], and developing quantifiable objectives, success criteria, and associated monitoring and adaptive management plans (discussed further in subsequent sections). Example objectives are provided below:

- Restore a certain area (e.g., 50 acres) of bare, drowned wetland with enough sediment to re-establish dense wetland vegetation (e.g., 80% plant cover)
- Raise an entire wetland system by a pre-determined elevation (e.g., 10 cm) to facilitate sediment accretion (e.g., 3 cm per year for five years)
- Provide enough resilience for a pre-determined number of years or sea level rise scenario (at least 10 years is recommended by Anchor QEA 2025)

[6]Target elevations should be identified for both construction and post-construction TLP phases to account for fluctuations in wetland surface elevation after placement. Project teams should also establish a range of acceptable outcomes given potential differences in "as-built" versus designed wetland elevations that result from uncertainties in the absolute volume of material that is contained or lost post-application.

An alternatives analysis that includes the "no action" alternative should be conducted to ensure that TLP is the most effective long-term solution for achieving project objectives while recognizing and accepting trade-offs associated with the conversion between subtidal, intertidal, and supratidal habitats (discussed in further detail under "Resource and Regulatory Concerns"). For example, facilitating natural marsh migration without TLP may be most appropriate and cost-effective in areas with adequate natural sediment supply and migration corridors[7]. Additionally, wetlands subject to erosive conditions stemming from high energy wave impacts rather than subsidence, inadequate sediment supply, or rising sea levels may benefit more from erosion control structures such as breakwaters or wave attenuators rather than TLP. In other cases, historically modified wetlands (e.g., from impoundments, ditching, damming, etc.), especially those in microtidal regions, likely benefit most from hydrological interventions that restore ambient flow conditions and facilitate sediment deposition, accretion, and overall ecosystem function.

Appropriate site selection is important for satisfying project objectives and success criteria (Fig. 10). Aside from selecting degraded wetlands[8] with compatible sediment properties as discussed previously, wetlands with short fetch, large tidal ranges, ample migration area, and gradual slopes (1-3%) are generally exposed to less wave energy and are more likely to retain and accrete sediment. In this case, fine sediment placement is most appropriate and suitable (Myszewski et al. 2017). Wetlands with long fetch and steep slopes are more susceptible to sediment loss and may benefit most from coarse sediment placement. Site selection is also driven by matching dredge projects (and availability of source material) with recipient wetlands that meet restoration needs, are in close proximity to each other, and are financially and logistically feasible. TLP projects are predominantly executed in partnership with the U.S. Army Corps of Engineers due to their existing contracting resources and capacity to dredge large volumes of compatible material. However, smaller projects can be achievable with private excavation companies. In some cases, piloting TLP projects on public or state and federally managed lands can streamline project coordination and permitting (Hametz et al. 2025). Regardless of the site selected, nearby

[7] In North Carolina, for example, a highly developed region with many barriers to natural marsh migration (e.g., New Hanover County) may not benefit from TLP as much in the long-term compared to scarcely developed regions with higher migration potential (e.g. Hyde County). On the other hand, more developed regions could benefit more in the short term from TLP since options to enhance regional wetland resilience through facilitating wetland migration are limited.

[8] Stakeholders that participated in the NC DEQ multi-agency stakeholder workshop (hereafter referred to as "TLP workshop") indicated that identifying "degraded" wetlands may not be the most effective way to determine whether a site is a good candidate for TLP. Instead, practitioners should consider wetlands that are "at risk" of vegetation loss and ponding while also accounting for factors such as a site’s proximity to existing infrastructure, the proposed dredge area and established migration corridors. North Carolina stakeholders also believe that just because a marsh is near a dredge area does not automatically make it a good candidate for TLP.

wetlands that do not receive sediment should be used as controls (i.e., an equally degraded wetland) and references (i.e., a goal or target) to evaluate project performance.

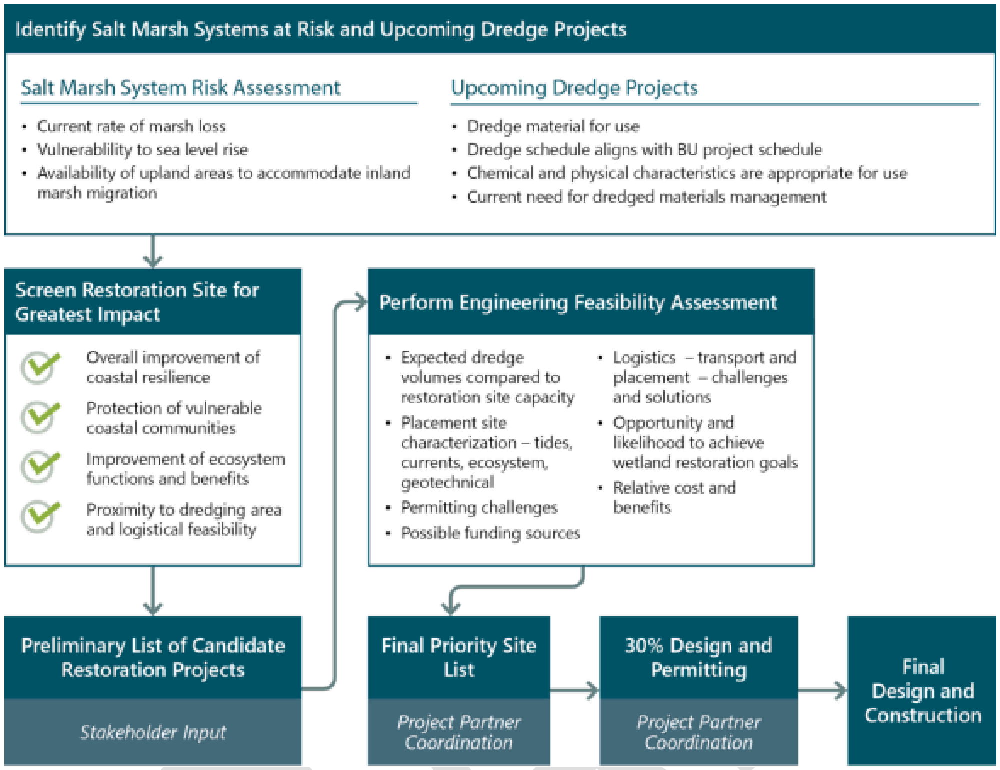

Fig. 10: Design process for thin layer placement. Figure adapted from Anchor QEA (2025).

Once all sites are selected (source, recipient, control, reference), geotechnical analyses are needed to evaluate baseline conditions and ensure material compatibility. Metrics might include grain size, bulk density, porosity, permeability, organic matter and nutrient content, dissolved oxygen, trace metals, contaminants, redox (metabolic) potential, composition and abundance of benthic invertebrate communities, or others mutually agreed upon by project partners or those required by permitting or resource agencies. Existing guidance also unanimously recommends a baseline understanding of local hydrological characteristics (e.g., wave conditions, flow velocities, currents, tides, and water levels) to help determine and achieve target elevations. Depending on funding and available resources, hydrological studies can involve high resolution numerical modelling (e.g., the Mid-Atlantic Tidal Wetland Rapid Assessment Method and other predictive sedimentological models) or coarser remote sensing technologies such as Light Detection and Ranging (LiDAR) coupled with *in situ* transect surveys that use surface elevation tables, marker horizons, tide and wave gauges, and real time kinematic global position systems (RTK-GPS).

While TLP project designs are iterative and progress through conceptual, preliminary, and intermediate stages, near-final plans should include a defined TLP work cell with a built-in buffer zone for added flexibility in placement location, staging and access, pipeline crossings, the construction of erosion control and sediment containment structures, and avoiding impacts to adjacent habitats outside the work cell (Hametz et al. 2025). Work cells should also be sited an adequate distance from tidal channels or wetland edges to increase the likelihood that sediment is deposited and contained on top of the wetland surface platform (Piercy et al. 2023). Based on existing guidance, the most effective TLP designs reduce complexity by minimizing the number of placement areas within a single work cell, the number of individual containment structures, and the number of discharge and dewatering points. Basic metrics specific to engineering and construction are described below under "Implementation."

Lastly, the planning and design phases for TLP projects require a cost assessment to ensure that equipment, resources, and personnel are available for all construction activities and post-construction monitoring and adaptive management needs (Table 1). Establishing reliable long-term funding sources is therefore critical for successfully implementing TLP and other beneficial use projects. Correll et al. (2024), for example, suggest leveraging annual calls for federal grant applications intended to fund large-scale restoration projects under a phased approach (e.g., decoupling planning and design, construction and implementation, and monitoring and adaptive management) to help guarantee multiple years of funding. Otherwise, continuous funding is dependent on local and state regulatory commitments or legislation.

Table 1: Cost considerations for thin layer placement projects. Table adapted from Anchor QEA (2025).

Cost Items	Supporting Elements
Mobilization and Demobilization	• All costs to mobilize and demobilize equipment, material, and labor to the project site • Proof of insurance • Removal of temporary containment structures • Surveys of pre-construction conditions and post-construction conditions • Project Management
Submittals	• Pre-work submittals • Health and safety plans • Work plans • Cost breakdown • Baseline schedule and schedule updates • Daily/weekly/monthly reports • Maintenance and monitoring plan • Quality assurance plan
Site Preparation	• Preparatory grading • Construction of access roadways • Preparation of staging areas, material transfer areas, or slurry equipment • Erosion and sediment control measures • Temporary containment structures • Temporary warning signs
Dredging and Sediment Placement	• Dredge type (cutterhead, hopper, etc.) and application method (high or low pressure; slurry or end-of-pipe discharge) • Pipeline configuration and transportation distance[9] • Containment structures • Magnitudes of estimated quantities, units, and costs understood to have little uncertainty and are incorporated into construction bid schedule • Excluding change orders, construction cost estimate should be highly accurate with respect to final construction cost
Debris Removal and Disposal	• Tonnage of debris removed from the dredging template
Vegetation Establishment	• All labor, material, and equipment for vegetation re-establishment, including plugs, seeds, plants, soil preparation, staking, goose protection netting, etc. • Acceptable variance for initial acceptance of vegetation establishment
Monitoring and Maintenance	• Monitoring equipment such as settlement plates, grade stakes, etc. • Surveys, data collection, and reporting for monitoring and permit compliance • Re-establishment of vegetation • Regrading, if necessary

Implementation

Most topics within the implementation stage of TLP, such as engineering, labor, construction specifications, bidding, timelines, and contracting are highly technical and outside the scope of this document but are described with great detail in Piercy et al.

[9]For example, thinner and more precise applications requiring constant adjustments are more expensive compared to thicker, in-place applications where there may be more room for error

(2023). However, implementation teams should expect lengthy project durations due to site recovery times, delays from storm events, wetland growing seasons, and environmental work windows or time-of-year restrictions required to avoid or minimize impacts to sensitive habitats (e.g., nursery and anadromous fish spawning areas) during periods of peak productivity and biological activity[10].

Relevant to the purpose of this document, existing guidance emphasizes the importance of using biodegradable or temporary containment structures (e.g., straw bales, coir logs, earthen dikes, sandbags, geotubes, and other structurally diverse materials further described in Hametz et al. 2025) consistent with local sediment migration patterns that prevent sediment loss and impacts to adjacent habitats or, if nearby, navigation channels. However, Anchor QEA (2025) warns that "over containing" sediments can increase both project costs and overall environmental disturbance associated with their installation and removal. More permanent containment structures (e.g., offshore breakwaters, marsh toe revetments, oyster sills, etc.) can also be incorporated into project designs to facilitate long-term sediment containment and capture.

Monitoring, Adaptive Management, and Success

TLP is generally considered successful when the application of dredged material increases wetland elevation, supports and maintains desired foundational vegetation communities, sustains key ecological functions and processes, and satisfies pre-determined project objectives and success criteria as determined through long term-monitoring and regular reporting. North Carolina stakeholders also consider TLP successful if there is consistent sediment placement and containment across the marsh surface, adequate post-construction tidal flow, benefits that exceed financial and ecological costs, and demonstrable returns on investment and public perception. If monitoring indicates unsatisfactory project performance, adaptive management may be necessary to reach the desired outcome or minimal thresholds as defined by project partners (Table 2).

[10]In some cases, minimization measures and other best management practices such as turbidity curtains are used in lieu of time-of-year restrictions to contain suspended sediments until pre-determined conditions are met.

Table 2: Example monitoring metrics, effectiveness criteria, and potential adaptive management actions if criteria are not met. Table adapted from Correll et al. (2024).

Project Phase	Monitoring Metric	Performance Criteria	Adaptive Action
Construction	Target Elevation	Placement depth meets target	Adjust placement strategy to achieve target
Post Construction	Plant Cover	Percent cover of aboveground native biomass increases to pre-determined metric within three years	Conduct additional plantings and consider different species if elevation changed
Maintenance	Shoreline Position	Shoreline change rates less than a pre-determined rate	Stabilize shoreline against further erosion

Based on the results of the TLP workshop, stakeholders in North Carolina believe that at minimum, monitoring plans should include basic metrics such as vegetation abundance and recovery to include invasive species; the recovery and response of invertebrates, birds, fishes, and reptiles; changes in elevation; sediment properties; turbidity and water quality. Myszewski et al. (2017) showed that even simple monitoring of bulk density and organic matter content are effective precursors of plant growth and expansion (associated with higher bulk densities) and soil productivity (associated with higher organic matter content). Depending on funding and resource availability, monitoring metrics could also include hydrological responses; microbial processes; and quantifying ecosystem services such as flood reduction or economic benefits. In some cases, it may also be appropriate to monitor and mitigate for temporary environmental impacts associated with wetland mats, pipelines, or other construction activities and to integrate adaptive best management practices (like those typically used for stormwater and sediment and erosion control) during implementation. Ultimately, stakeholders in North Carolina also believe that securing reliable funding for long-term post-construction monitoring is important for ensuring success and generating data to support subsequent TLP projects.

While most guidance recommends at least quarterly monitoring for five years (Anchor QEA 2025; Hametz et al. 2025; Correll et al. 2024; Raposa et al. 2020; Myszewski et al. 2017) with associated maintenance to control invasive species or replant bare sediments, our review of existing documents suggests a best practice of monitoring throughout the entire project lifespan (before, during, and after sediment placement) at regular intervals and for up to ten years as determined *a priori* by project planning teams. Adequate monitoring must also reliably compare results from placement, control and reference sites using consistent and robust statistical methods. For example, Raposa et al. (2020) recommends more replication when there is higher spatial and temporal variation across sites. A scientifically rigorous Before-After-Control-Impact (BACI) design (Underwood 1992; Stewart-Oaten et al. 1986) can also be used to compare changes over time between placement, reference, and control sites to isolate TLP impacts from natural fluctuations in ecosystem state.

Existing guidance recommends the development of standard operating procedures (SOPs) for monitoring and adaptive management plans during the planning and design phases to ensure consistency across projects, to establish acceptable thresholds for monitoring criteria and duration, to standardize data for analyzing inter-project performance, and to develop appropriate budgets and project timelines. As TLP and other beneficial use projects expand nationwide, Reilly et. al (2026) specifically calls for improved reporting and standardization of project design, implementation, framework development and quantitative monitoring by 1) explicitly describing project goals and linking them to monitoring metrics, 2) defining success criteria, 3) using consistent terminology referencing sediment placement, 4) reporting placement depth, range, and initial elevations, 5) including local tidal range and datum, 6) clarifying controls versus references, 7) considering longer monitoring timeframes, and 8) sharing comprehensive results beyond peer-reviewed summaries.

Regulation, Policy and Permitting

Regardless of state policies, TLP proposals are subject to a myriad of federal regulations that could limit or even prevent their implementation (Table 3). Before submitting permit applications, project teams are typically encouraged to consult permitting agencies during the planning stage and throughout the project lifespan to ensure that federal requirements are satisfied and that preferred alternatives maximize long-term environmental benefits. Involving permitting agencies at the onset also helps with establishing budgets and project timelines for the completion of necessary documentation.

Table 3: Overview of federal natural resource laws, regulations, and associated agencies[11] that may be applicable to thin layer placement projects. Adapted from Kordesch et al. (2024) and Raposa et al. (2020).

	Law	Agency	Permit or Authorization	Regulated Activity or Resource
Water	Section 401, Clean Water Act	State Water Board (EPA Oversight)	Water Quality Certification	Discharges requiring a federal license or permit to comply with state or federal water quality standards
	Section 404, Clean Water Act	USACE	General Permit (Nationwide, Regional); Standard Permit (Individual); Letter of Permission	Discharge of dredge or fill material into waters of the U.S., including wetlands
	Section 10, Rivers and Harbors Act	USACE	Section 10 Permit	Work in, under, or over a navigable waterway
Water and Land	Coastal Zone Management Act	NOAA	Federal Consistency Determination	Project modifies land or water use in the coastal zone of a state with an approved Coastal Management Program
Species	Section 7 and 10, Endangered Species Act	USFWS / NMFS	Incidental Take / Biological Opinion (Section 7); Incidental Take Permit	Activities affecting species listed as threatened or endangered under the Act
	Marine Mammal Protection Act	USFWS / NMFS	Letter of Authorization; Incidental Harassment Authorization	Activities affecting marine mammals and their products
	Section 305(b)(4)(A), Magnuson-Stevens Fishery Conservation and Management Act	NMFS	Essential Fish Habitat Consultation	Activities affecting federally designated essential fish habitat and habitat areas of particular concern.
Cultural Resources	National Environmental Policy Act	Federal Lead Agency (EPA Oversight)	Environmental Assessment; Finding of No Significant Impact; Environmental Impact Statement	Major federal actions significantly affecting the quality of the human environment
	National Historic Preservation Act	State Historic Office / Federal Lead Agency	Memorandum of Agreement / Programmatic Agreement	Activities affecting cultural resources

Regulating and permitting TLP differs across state boundaries. In Maryland, Virginia, and Massachusetts, in-water unconfined placement of dredged material is not allowed under state enforceable policies unless it is used for beneficial use, restoration, or other projects

[11]USACE = U.S. Army Corps of Engineers; NOAA = National Oceanic and Atmospheric Administration; USFWS = U.S. Fish and Wildlife Service; NMFS = National Marine Fisheries Service; EPA = Environmental Protection Agency

intended to benefit aquatic resources (Anchor QEA 2025; MassDEP 2024). Georgia law allows TLP and other beneficial uses if the project is of public interest (Shudtz et al. 2025). In Delaware (DNREC; https://regulations. delaware.gov/AdminCode/title7/7504) and New York (NY DEC; https://dec.ny.gov /regulatory/permits-licenses/waterways-coastlines-wetlands), state regulations do not explicitly prohibit wetland fill (and therefore TLP), though any proposal to do so must be appropriately justified. In Connecticut (CT DEEP; https://portal.ct.gov/DEEP/Coastal-Resources/Coastal-Permitting/Overview-of-the-Connecticut-Coastal-Permit-Program), Certificates of Permission rather than formal permits can be issued for projects intended to restore degraded wetlands. As mentioned previously, New Jersey's administrative code speaks directly to dredged material placement (NJ DEP; https://www.law. cornell.edu/regulations/new-jersey/N-J-A-C-7-7-15-12).

In North Carolina, TLP is currently not permissible under the NC Coastal Area Management Act (CAMA) and Dredge and Fill Law which prohibit and classifies TLP as wetland fill. If submitted, an application for TLP would be denied but eligible for a variance from the Coastal Resources Commission, the state's rulemaking body. The Commission can elect to approve projects that technically violate state regulations if the following criteria are met:

- Strict application of state development standards would result in unnecessary hardships.
- Hardships result from conditions peculiar to the property (i.e., location, size or topography).
- Hardships did not result from actions taken by the petitioner.
- The variance is consistent with the spirit, purpose and intent of state development standards; will secure public safety and welfare; and will preserve substantial justice.

As such, applicants must demonstrate that a TLP project has public benefits consistent with protecting coastal resources, public benefits that outweigh the adverse impacts of the project, no alternate site available for the project, and a design and implementation plan that incorporates all means and measures to mitigate adverse environmental impacts (Table 4). The variance process also allows the Coastal Resources Commission to proceed with rulemaking to establish thresholds or other criteria for future, related projects. In addition to CAMA and the NC Dredge and Fill Law, TLP proposals would also require state authorization from the NC Divisions of Water Resources and potentially the Division of Energy, Mineral, and Land Resources or applicable town, city, or county permits.

Because there is growing interest in TLP and other types of beneficial use across the state, the NC Division of Coastal Management anticipates a potential need for future rulemaking that would authorize TLP and related projects through the typical CAMA permit process (see NC DCM 2022 for recent guidance on state-specific site assessments and monitoring). The syntheses presented here are therefore intended as a TLP source document to help inform next regulatory steps as needed.

Table 4: CAMA & Dredge and Fill Permit Considerations in North Carolina. Adapted from Shudtz et al. (2025).

Factors for Permit Denial	Implication for TLP Project Applications
General Factors	
The development is inconsistent with written state guidelines or local land-use plans.	Review guidelines and land-use plans to ensure project is consistent; discuss concerns with relevant agencies early in the project proposal phase.
There is a practicable alternative that would accomplish the overall project purposes with less adverse impact on public resources, considering engineering requirements and all economic costs.	Provide research and data on the benefits of TLP, including the value of ecosystem services such as hazard reduction and recreation opportunities that will benefit local communities; provide comparison to costs of offshore disposal or upland containment.
The proposed development would contribute to cumulative effects that would be inconsistent with specific written guidelines on various state Areas of Environmental Concern.	Emphasize that TLP intended and designed to have myriad positive environmental and ecosystem benefits; include monitoring and adaptive management plans.
Areas of Environmental Concern	
In coastal wetlands, the project would contradict any order to promote public safety, health, and welfare or to protect public and private property, wildlife, and marine fisheries in coastal wetlands.	Emphasize that TLP is intended to specifically achieve state goals and policies to promote public safety, health, and welfare and to protect property and wildlife in and around coastal wetlands; provide research and data on the benefits and success of smaller pilot projects.
In estuarine waters, a permit would also be denied per the state's Dredge and Fill law for having a significant adverse effect on public use of water, on the value and enjoyment of property of riparian owners, on public health, safety, or welfare; on conservation of public and private water supplies; on wildlife or fresh water, estuarine, or marine fisheries	Cite scientific research and data on the ecosystem services provided by healthy and intact coastal wetlands; on the property value increase; anticipate implementing best management practices for sediment and erosion control during project implementation period.
In a fragile or historic area or area containing environmental or natural resources of significance, the development will result in major or irreversible damage to one or more of the historic, cultural, scientific, environmental or scenic values or natural systems.	Emphasize how the proposed project will support and improve resilience in coastal areas; cite scientific research that show negative impacts of a "do nothing" alternative.
On public trust lands, the project will jeopardize the public rights or interests in those lands.	Highlight recreational opportunities, increased ecosystem resilience, and other public benefits TLP
In natural hazard areas, the project would occur in such a manner as to unreasonably endanger life or property.	Cite scientific research and data that demonstrates coastal marsh benefits for estuarine beaches, shoreline of estuarine and public trust waters, floodways and floodplains
Variance Approval	
The requested variance is consistent with the spirit, purpose, and intent of the rules, standards, or orders; will secure public safety and welfare; and will preserve substantial justice.	Cite language from CAMA and other state policies that support preserving coastal wetlands and their values; provide evidence of public benefits from healthy coastal wetlands and bird islands, such as recreation, hazard reduction, and productive fisheries.

Resource and Regulatory Concerns

While TLP may be an effective tool to enhance wetland resilience, there are several concerns associated with the impacts of sediment placement on long-term wetland function. Results from the TLP workshop indicated that material compatibility, invasive species, a lack of post-project regulatory oversight, unforeseen impacts to subtidal or intertidal fish habitat or adjacent habitats, and sediment contamination and associated risks to fish, wildlife, and public health would be of particular concern in North Carolina. Elsewhere, resource concerns are also generally associated with the following, all of which are most likely applicable to North Carolina:

- Lack of geographically relevant studies and regulatory approval pathways
- Sediment compaction and heavy equipment
- Plant smothering and recovery
- Establishing appropriate environmental windows and work moratoria
- Property ownership / land use conflicts
- Funding and equipment needs
- Ecological and water quality impacts
- Turbidity during initial placement and settlement of material
- Benthic and infaunal invertebrates
- Migratory birds and waterfowl
- Submerged aquation vegetation and shellfish
- Formation of sulfidic soils
- Length of time needed to meet "reference conditions"
- Cumulative impacts associated with repeated applications or amendments
- Establishing what qualifies as marsh restoration to justify TLP
- Establishing a definition for a "degraded" marsh
- Overdesigning projects
- Containing material once placed

During alternatives development, TLP may not be considered in the short-term as the "least environmentally damaging practical alternative" due to initial impacts from sediment placement on ecological function. However, reviewing agencies should consider and identify acceptable trade-offs between temporarily disruptive but long-term beneficial projects that prevent permanent wetland loss under future environmental change[12]. Alternatives development should also address concerns related specifically to habitat

[12]To alleviate additional resource and regulatory concerns, selecting extremely degraded sites with little ecological value minimizes risks but maximizes potential benefits.

trade-offs. Correll et al. (2024) suggest that like most restoration projects, TLP should be planned around ecosystem-based management rather than individual species management when evaluating trade-offs in project design. For example, while raising wetland elevation could help restore intertidal and upland habitat for certain avian or mammalian communities, it may also reduce intertidal and subtidal habitat for submerged aquatic vegetation, fish and aquatic invertebrate communities. Such tradeoffs merit consideration during project planning.

Information Needs

Based on reviews of primary literature, existing guidance documents, and results from the TLP workshop, there is a general need in North Carolina to evaluate more large-scale projects at the acreage scale that incorporate at least 10 years of monitoring to supplement recent and ongoing studies that are restricted to the experimental plot scale. Quantifying the response of fisheries and other faunal communities to habitat change represents another major knowledge gap. Lastly, there is a lack of information on the cumulative impacts associated with repeat sediment applications, and there is a need to develop high resolution regional models that project the outcome of sediment placement. For specific projects, information needed to effectively evaluate TLP projects includes the history of local wetland loss and future trends associated with migration corridors; the ecologic and economic function of recipient wetlands; detailed site mapping to include existing elevations, soil and vegetation characteristics, hydrological and geomorphological dynamics, and relevant archaeological surveys; and overall baseline site characterization.

Conclusion

TLP is an effective tool to enhance wetland resilience to environmental change by building elevation and facilitating sediment accretion within degrading ecosystems. To ensure success, projects must be carefully planned by a diverse team of stakeholders and subsequently executed, monitored, and adaptively managed with specified goals, objectives, and reliable long-term funding, resources, and support from research labs, contracting firms, funding agencies, and environmental organizations.

TLP projects at minimum should consider sediment compatibility, target elevation and thickness, and baseline hydrology and environmental characteristics that are compared between placement, reference, and control sites. Generally, recipient wetlands should maintain an elevation between sea level and mean high water to promote adequate tidal inundation and the natural growth of native plant species. While coastal states are at various stages of TLP implementation ranging from exploratory to well-established programmatic frameworks, there is persistent widespread interest in TLP and other beneficial use techniques to combat sea level rise and wetland loss. As a result, coordinated efforts to establish science-informed purpose and need statements, standard operating procedures, monitoring and reporting requirements, and permitting and regulatory pathways for emerging projects are both timely and critical for building stakeholder confidence.

In North Carolina, implementing TLP in the future will most likely occur on a case-by-case basis with local and regional factors in mind. Based on the success of projects elsewhere and the comfort level of North Carolina stakeholders, initial projects are expected to involve smaller-scale "like-on-like" application of dredged material (e.g., from a maintenance event) onto a deteriorating salt marsh (e.g., one experiencing active vegetation loss, interior ponding, inadequate sediment supply or migration pathway) with the goal of raising surface elevation enough to support the restoration of vegetated intertidal habitats and the facilitation of sediment accretion and long-term resilience to future change. Early projects would most likely also be coupled with robust temporary or permanent containment structures within isolated systems that minimize potential impacts to adjacent habitats or infrastructure.

Looking Ahead

The information presented in this document, including the results of the TLP workshop, represents an action item completed for the 2026 CHPP amendment. This paper is intended to enhance agency understanding of TLP and to ensure stakeholders are well-poised to evaluate projects as they are developed. Over the next five years and before the next CHPP update, DEQ staff will create a state-wide multi-agency workgroup to progress TLP (and possibly other beneficial use efforts) in North Carolina through regular meetings, additional workshops (e.g., those focused specifically on regulation, permitting, engineering, etc.) and discussions and to establish best practices specific to the state. This group could update existing guidance or develop a toolkit for North Carolina that includes standard monitoring procedures or design considerations. DEQ staff will also evaluate regional statuses and trends of existing wetlands across coastal North Carolina, incorporating new high-resolution land cover data obtained through the 2021 CHPP (2021 recommended action 5.1). DEQ staff will additionally leverage existing resources such as the NC Flood Resiliency Blueprint, NC Executive Order 305 Hub, Southeast Conservation Blueprint, Marsh Restoration Community Benefit Calculator, the U.S. Army Corps of Engineers Resiliency Urgency and Beneficial Use Map, and other geospatial tools to identify candidate areas that may benefit most from TLP with the ultimate goal of planning for ongoing and future environmental change to enhance wetland resilience.

Specific Recommended Actions

1. DEQ staff will develop an issue paper that summarizes the best available science and guidance for TLP, including case studies, information needs, success criteria, an overview of important scientific and permitting considerations, policy and resource concerns, and outcomes from a multi-agency TLP workshop (this document).
2. DEQ staff will create a state-wide multi-agency workgroup to progress TLP and facilitate the establishment of best practices specific to North Carolina
3. DEQ staff will evaluate the status and trends of wetlands across coastal North Carolina, incorporating high-resolution land cover data obtained through the 2021 CHPP.
4. DEQ staff will leverage existing tools and data sources to identify candidate areas that may benefit most from TLP.

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Appendix A: Summary of Thin Layer Placement Projects Described Throughout This Paper

Site	State	Dominant Plant Species	Mean Tidal Range (m)	SLR Rate (mm yr^{-1})	Existing Marsh Elevation (m, NAVD88)	Project Goal	Project Size	Target Elevation Increase (cm)	Placement Thickness (cm)	Sediment Type	Marsh Recovery Time (years)	Study Duration (years)	Reference
Seal Beach National Wildlife Refuge	CA	*Spartina foliosa, Batis maritima*	0.34–3.56	0.98–6.23	1.34	Offset high SLR risk and subsidence, build elevation capital, enhance habitat for *Spartina foliosa* and Ridgway's Rail	10 acres	7.6	22–32	Coarse (84–85% sand)	1–1.5	1–3	McAfee et al. (2020); Thorne et al. (2019)
San Francisco Bay	CA	*Salicornia pacifica*	1.25	Not Specified	1.08–1.79	Enhance wetland resilience to rising seas; compare low to high marsh performance to TLP	0.7 x 0.7 m plots	10	7–14	Coarse (75% sand)	3	3	Raposa et al. (2023)
Elkhorn Slough	CA	*Salicornia pacifica*	1.60	Not Specified	1.43–1.86	Enhance wetland resilience to rising seas; compare low to high marsh performance to TLP	0.7 x 0.7 m plots	10	7–14	Coarse (75% sand)	3	3	Raposa et al. (2023)
Guilford Yacht Club	CT	*Spartina alterniflora*	1.70	4–6	Not Specified	Examine how differential thickness alters plant-soil carbon dynamics and promotes resilience to SLR.	1 x 1 m plots	5–15	5–20	Fine (84% silt and clay)	1–2	2	Puchkoff and Lawrence (2022)
Glynn County Marsh (Brunswick)	GA	*Spartina alterniflora*	Not Specified	Not Specified	Not Specified	Investigate capability of high salt marsh to recover from dredged material disposal	0.9 m diameter plots	Not Specified	8–91	Coarse sand	within 1 (under 23 cm placement thickness)	2	Reimold et al. (1978)
Glynn County Marsh (Brunswick)	GA	*Spartina alterniflora*	Not Specified	Not Specified	Not Specified	Evaluate considerations, impacts, and system recovery associated with TLP placement over a representative area	12 acres	Not Specified	15–23	Fine Sand and Silt	0.75	2	Mohan et al. (2021)
Jekyll Island	GA	*Spartina alterniflora*	Not Specified	Not Specified	Not Specified	Encourage plant growth at higher elevations, reducing the probability that the marsh grass will be degraded by increased saltwater inundation	5 acres	Not Specified	15–25	Fine (Unspecified)	3–5	5	https://coastalgadnr.org/JekyllCreek
Mississippi River Delta	LA	*Spartina alterniflora, Scirpus americanus, Vigna luteola, Potamogeton spp.*	0.40	9.40	open water marsh pond	Ameliorate SLR impacts; test sediment subsidies to counter subsidence; restore emergent vegetation.	1.24–106 acres	5–15, up to 30	0–22	Coarse and Fine (4-58% sand)	1–3	2–3	Mendelssohn and Kuhn (2003); Slocum et al. (2005); Ford et al. (1999); Stagg and Mendelssohn (2010)
Mississippi River Delta	LA	*Spartina patens, Schoenoplectus americanus*	Not Specified	3.6–17.7	Not Specified	Examine functional response of vegetated brackish marsh and interior ponds to sediment enhancement.	27–1373 acres	Varied By Location	15–20	Not Specified	within 1, pond sites only	1	La Peyre et al. (2009)
Leeville / Bayou LaFourche	LA	*Spartina alterniflora*	0.30	11.1	0.04–0.30	Increase elevation and enhance plant recovery following drought-induced marsh dieback	400 m transects within 1.24 acre plots	14–36	6–41	Not Specified	1–5	1–7	Schrift et al. (2008); Stagg and Mendelssohn (2010); Tong et al. (2013)
Bayou Dupont	LA	*Phragmites australis, Spartina alterniflora, Spartina patens, Scirpus americanus*	0.32	9.1	open water marsh pond	Increase soil surface elevation to support vegetation growth; prevent conversion to open water	160 acres	15	15	Not Specified	2	2	Howard et al. (2020)
Barataria Basin / Bay	LA	*Spartina alterniflora*	Not Specified	Not Specified	Not Specified	Examine effects of sediment addition on plant regeneration and productivity in a deteriorating marsh	1.44 x 1.44 m plots	8–10	2–10	Coarse and Fine (40% sand)	within 2 growing seasons	1.5	DeLaune et al. (1990)
Paul J. Rainey Wildlife Sanctuary	LA	*Spartina patens*	Not Specified	Not Specified	0.37	Determine if elevation change, soil compression, and sediment consolidation were differentially affected by different amounts of sediment; assess sediment effects on ecosystem function	4 x 4 m plots	Not Specified	2–20	Fine (82% silt and clay)	within 1, then subsided	2.5	Graham and Mendelssohn (2013)
Chesapeake Bay, MD	MD	*Spartina alterniflora, Spartina patens, Distichlis spicata, Juncus roemerianus*	0.74	Not Specified	0.40	Enhance wetland resilience to rising seas; compare low to high marsh performance to TLP	0.7 x 0.7 m plots	10	7–14	Coarse (75% sand)	3	3	Raposa et al. (2023)
Shorters Wharf	MD	*Spartina patens, Distichlis spicata, Spartina alterniflora*	0.24	Not Specified	Not Specified	Increase resiliency to SLR; restore elevation capital; extend lifespan of habitat for Saltmarsh Sparrow and Black Rail	40 acres	30	15–35	Semi Fine (68% silt and clay)	2	2	McCullough et al. (2021); Whitbeck et al. (2019)
Poplar Island	MD	*Spartina alterniflora, Spartina patens*	0.34	5.7	0.24–0.64	Mitigate marsh drowning and assess the effect of TLP on carbon sequestration and resilience under rising sea levels	30–50 acres	Varied By Location To Achieve 80% Low Marsh	15–30	Fine (Not Specified)	within 1	2–7 with longer model simulations	Morris and Staver (2024); Cornwell et al. (2025)
Waquoit Bay	MA	*Spartina alterniflora, Spartina patens, Distichlis spicata, Juncus roemerianus, Iva frutescens*	0.55	Not Specified	0.40–0.64	Enhance wetland resilience to rising seas; compare low to high marsh performance to TLP	0.7 x 0.7 m plots	10	7–14	Coarse (75% sand)	3	3	Raposa et al. (2023)
Great Bay	NH	*Spartina alterniflora, Spartina patens, Juncus gerardii, Distichlis spicata, Salicornia depressa, Schoenoplectus robustus*	2.7	4.17	0.73–1.05	Enhance wetland resilience to rising seas; compare low to high marsh performance to TLP	0.7 x 0.7 m plots	10	7–14	Coarse (75% sand)	3	3	Raposa et al. (2023)
Avalon	NJ	*Spartina alterniflora*	1.39	10	0.26–0.61	Increase marsh elevation and improve soil aeration to allow marshes to keep pace with SLR and restore deteriorated back barrier wetlands	100 m transects	73–91	5–83	Coarse and Fine (15-80% sand)	0.5–3.5	6	Harris et al. (2021); VanZomeren et al. (2018); Cheng et al. (2025)
Thompsons Beach	NJ	*Spartina alterniflora*	1.60	Not Specified	0.12	Offset elevation loss caused by historic farm impoundments and create conditions for plant recolonization	1.11 acres	49	42	Fine (100% silt and clay)	5	5	Feigin et al. (2026)
Sturgeon Island	NJ	*Spartina alterniflora, Phragmites australis*	1.3	4.2	0.5–1.3	Enhance surface elevation to support nesting bird habitat and stabilize the low-lying northern portion of the island.	13 acres	Not Specified	37–39	Fine (Not Specified)	3	4	Harris et al. (2025)
Jamaica Bay	NY	*Spartina alterniflora*	Not Specified	2.9–4.3	0.6–0.7	Increase marsh elevation, enhance bird habitat, and document lessons for future TLP applications.	1.5–2.5 acres	23-43	up to 100	Coarse and Fine	within 2 growing seasons	1–4	Hartig et al. (2024); Haight et al. (2026); Frame et al. (2005)
Masonboro Island	NC	*Spartina alterniflora*	1.2	Not Specified	Not Specified	Determine if placing dredged material on sediment-starved back barrier marshes could offset submergence without negatively affecting marsh function	6.4 x 6.4 m plots	8.5–10	0–10	Coarse Sand	1–2	2	Croft et al. (2006)
Masonboro Island	NC	*Spartina alterniflora, Spartina patens, Distichlus piscata, Borrichia frutescens*	1.2	1.9	-0.26–0.48	Enhance wetland resilience to rising seas; compare low to high marsh performance to TLP	0.7 x 0.7 m plots	10	7–14	Coarse (75% sand)	3	3	Raposa et al. (2023)
Freeman Creek	NC	*Spartina alterniflora*	0.8	12.3	-0.012 – -0.11	Increase elevation capital and marsh resilience to SLR by raising the platform to an optimal elevation for vegetative growth	8 x 3 m plots	Not Specified; Dependent on Elevation-Biomass Relationship	6	Coarse (90% sand)	within 1	5	Davis et al. (2022, 2017)
Gull Rock	NC	*Juncus roemerianus, Spartina alterniflora, Distichlis spicata*	Not Specified	Not Specified	Not Specified	Reduce environmental impacts associated with dredged material placement; describe long-term effects	Not Specified (8-12,000 cubic yards of material)	3–10	1–20	Fine (Unspecified)	within 1	10 years post-placement	Wilber (1992)
Ninigret Marsh	RI	*Spartina alterniflora, Spartina patens, Distichlis spicata, Juncus gerardii*	<1	2.83–4.78	-0.109	Restore high marsh species; increase marsh resilience to future SLR by building elevation capital; test the efficacy of sediment placement with adaptive management.	22 acres	18–30 Depending on Elevation Zone	10–48	Coarse (90% sand)	3–4	5–6	Raposa et al. (2022)
Narragansett Bay	RI	*Spartina alterniflora, Spartina patens, Distichlis spicata, Juncus gerardii*	1.2	Not Specified	0.40–0.64	Enhance surface elevation to support nesting bird habitat and stabilize the low-lying northern portion of the island.	0.7 x 0.7 m plots	10	7–14	Coarse (75% sand)	3	3	Raposa et al. (2023)
Coggeshall Marsh	RI	*Spartina alterniflora*	1	1.5–5.3	Not Specified	Increase resilience to SLR by boosting elevation to allow vegetation to recolonize; investigate impacts on nitrogen cycling	0.5 x 0.5 m plots	10	7–14	Coarse (90% sand)	4	1–4	Bartolucci and Fulweiler (2024, 2026)
Chesapeake Bay, VA	VA	*Spartina alterniflora, Spartina patens, Distichlus spicata*	0.76	5–6	0.19–0.46	Enhance wetland resilience to rising seas; compare low to high marsh performance to TLP	0.7 x 0.7 m plots	10	7–14	Coarse (75% sand)	3	3	Raposa et al. (2023)

Appendix B: Thin Layer Placement Coordination Workshop Report

Summary

The purpose of this workshop was to discuss thin layer placement (TLP) of sediment as a tool for enhancing wetland resilience and to share successes, challenges, concerns, and lessons learned associated with the ecological impacts of placing sediment on deteriorating wetlands. Workshop attendees were provided a scientific overview of TLP and how other coastal states manage projects related to TLP and the beneficial use of dredged material. These discussions included several case studies along the U.S. east coast from New Jersey to Georgia. The workshop included small group discussions on topics related to post-construction monitoring, best management practices, habitat trade-offs, success criteria, selecting appropriate placement sites, and identifying information needs. When evaluating the potential for TLP in North Carolina, workshop attendees highlighted the importance of clearly identifying the goals, objectives, purpose and need for these projects on a case-by-case basis while considering the above topics on a specifically defined local or regional scale. As a result, a collaborative multi-agency network of stakeholders is most likely needed to progress TLP in a responsible manner. Information gathered from this workshop will be incorporated into the 2026 amendment to the Coastal Habitat Protection Plan, which identifies TLP as a priority issue within the broader theme of planning for multi-decadal wetland change.

Introductory Remarks

Charlie Deaton, NC Division of Marine Fisheries (DMF) Habitat Protection Program Supervisor, began the workshop with introductions (see Subappendix A; attendee list) and an outline of the purpose and objectives of the meeting to inform the 2026 Coastal Habitat Protection Plan (CHPP) amendment (see Subappendix B; workshop agenda).

Daniel Govoni, NC Division of Coastal Management (DCM) Policy Section Chief, reinforced that the workshop was not intended to discuss the permitting, policy, or regulatory components of TLP; rather, it was intended to discuss the relationships between TLP and coastal habitats and resources. Nonetheless, Mr. Govoni summarized that TLP is not currently permissible in North Carolina because in most cases, the Coastal Area Management Act (CAMA) and associated guidelines for areas of environmental concern prohibit wetland fill. However, TLP could be permitted by the NC Coastal Resources Commission (CRC) through the CAMA variance process. There has been growing interest in TLP across coastal North Carolina, and NC DCM anticipates a potential need for future rulemaking that would authorize TLP through the typical CAMA permit process.

Research Overview

Dr. Jenny Davis, Research Ecologist with the National Oceanic and Atmospheric Administration (NOAA) Coastal Resilience, Response and Assessment Branch (CRABB), provided a broad overview of TLP and related methods for the Beneficial Use of Dredged Material (BUDM) with a presentation entitled Beneficial Use of Sediments for Habitat Restoration and Creation. The presentation began with a brief description of three beneficial use techniques to reverse or offset estuarine habitat loss:

- **Thin Layer Placement:** adding elevation to a deteriorating marsh to create more suitable conditions for marsh plant growth. This term is often used interchangeably with 'beneficial use.' However, TLP is just one type of beneficial use amongst others such as those defined below.
- **Thick Layer Placement:** creation of intertidal or upland habitat where it currently does not exist (i.e., habitat conversion).
- **Strategic Placement:** nearshore placement that allows for the natural distribution of sediments via waves and tides.

The remainder of the presentation focused on thin layer placement with an additional case study highlighting thick layer placement. Dr. Davis explained that the goal of each technique is to elevate existing wetlands that are vulnerable to sea level rise so that they are less vulnerable to sea level rise but remain within a vegetation-specific growth range. As such, target elevations are defined by marsh position relative to the tidal frame, and accurate placement of thin sediment layers on the marsh surface to achieve a specific target elevation becomes challenging. Dr. Davis emphasized that while TLP results in the short-term disruption of natural marsh processes, there are potential long-term benefits for marsh resilience.

Dr. Davis highlighted three TLP studies conducted in North Carolina, emphasizing that studies specific to the state have been limited and small-scale:

- Gull Rock (Wilber 1992)
- Masonboro Island (Croft et al. 2006)
- Freeman Creek, Camp Lejeune (Davis et al. 2019)

The bulk of Dr. Davis's presentation described two collaborative, large-scale case studies in Maryland: Deal Island Wildlife Management Area (thin layer placement) and Swan Island (thick layer placement):

Deal Island Wildlife Management Area

- Completed in 2024
- 167,000 cubic yards of material covering 72 acres
- Goal: raise majority of marsh platform to high-marsh elevation
- Sediment Source: Wicomico River
- Sediment Texture: fine
- Methods: sediments pumped across land (14 miles) to placement site and distributed by sheet flow across the marsh platform
- Placement Depth: up to 18 inches
- Containment Method: approximately 30,000 straw bales
- Plantings: hand planting over 700,000 native species over two growing seasons to discourage the establishment of invasive species.
- Outcomes and Lessons Learned

- Straw bales were effective containment structures except when the structure became compromised during a winter storm.
- Site access was challenging due to limited nearshore depth and submerged aquatic vegetation (SAV).
- Recommendation to "plant like crazy" wherever sediment is bare.
- Vegetative response is dynamic in early years and likely influenced by nutrients in deposited sediments and plant community changes in response to increased marsh elevation.
- Native vegetation that did not persist after the first year was replanted.
- Existing invasive common reed (*Phragmites australis*) on the site that was not treated before sediment placement had notably expanded by year two.
- It can take several years to reach equilibrium (i.e., target elevation profile)
- Created new habitat for salt marsh sparrow.

Swan Island

- Completed in 2019
- 60,000 cubic yards of material covering 12 acres
- Goal: create new habitat matrix (low and high marsh, dunes)
- Sediment Source: Chesapeake Bay Navigation Channel
- Sediment Texture: fine and coarse
- Methods: thick layer deposition of dredged material
- Placement Depth: a few centimeters up to one meter
- Containment Method: coir logs
- Plantings: hand planting approximately 200,000 native plants over two years
- Outcomes and Lessons Learned:
  - An as-built survey is needed to track changes over time and compare to intended design.
  - The containment structure remained in place.
  - It was more difficult to contain fine sediments, but installing fresh containment structure helped mitigate some loss.
  - Adjacent SAV was covered due to the loss of some fine sediments. While unintentional, it is necessary to evaluate whether potential trade-offs such as this are acceptable if they occur.
  - Creating high marsh was more successful than creating low marsh.

The Swan Island project was characterized by several performance thresholds and subsequent adaptive actions if thresholds were not met (see below). As such, Dr. Davis emphasized the need to identify a source of funding to support corrective action.

- **Vegetative Percent Cover:** If vegetation in planting zones did not spread to 50-75% of the total placement area, failing areas had to be replanted. If elevation changed, planting compatible species was required.

- **Sediment Surface Elevation:** If elevations did not remain within the appropriate range, additional sediment placement was required.
- **Shoreline Position:** If the designed shoreline did not maintain its position over time, the shoreline had to be rebuilt with additional sediment or plantings.

Dr. Davis concluded her presentation with closing thoughts and several best practices to consider for BUDM projects:

- Design for sediment leakage and plan/budget for additional fortification of containment structures.
- Plan/budget for replacing at least 50% of plants by the second year of the project.
- Attempt to control invasive species before sediment placement.
- Develop a monitoring and adaptive management plan with a temporal component to support corrective actions.
- Consider a range of acceptable outcomes.
- Offshore and upland disposal of dredged material deprives marshes of sediment that is critical for their survival (i.e., a "missed opportunity").
- Habitat trade-offs are inevitable.

At the conclusion of her presentation, Dr. Davis (JD) answered several questions from workshop attendees (A), which are paraphrased below:

- A: Who completed the work on Deal and Swan Island?
  JD: The work was contracted out but managed by the United States Army Corps of Engineers (USACE).

- A: Is there a way to determine a project's carrying capacity for plants and the nutrients needed to sustain them?
  JD: Due to variable site conditions, plant success is often driven by continuous planting and re-planting. Plant communities will most likely go through a "boom and bust" cycle until dense vegetation is established.

- A: For Deal Island, were straw bales used for containment allowed to naturally degrade?
  JD: Yes

- A: What is the strongest driving factor when determining placement depth?
  JD: Placement depth is incredibly project-specific, but it is important to establish boundaries. For example, identify a maximum allowable elevation or thresholds for other environmental variables.

- A: For Swan Island, can you discuss a bit more about comparing an as-built survey to intended designs?
  JD: Conducting as-built surveys are not part of the application process but are standard for projects on which NOAA participates. There was supposed to be more high marsh constructed from the dredged material, but during placement, some decisions had to be made on the fly which affected the end result.

- A: Was sediment characterized to ensure that dredged material matched that of the placement site?
  JD: Generally. At Swan Island, sand was used to construct high marsh and dune habitats. Fine sediments were used to construct low marsh.

- A: Are TLP projects ever paired with other types of marsh restoration, for example tidal flow restoration?
  JD: Most likely.

- A: Should thin layer placement specifically be defined as “no change in habitat” even though Deal and Swan Island were characterized by the destruction of existing vegetation and the conversion from low to high marsh?
  JD: While converting to a different marsh elevation, the habitat itself still functions as a marsh.

- A: Did the US Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) have different perspectives on project goals?
  JD: Yes. The USFWS service is typically more upland habitat-oriented for bird populations while NMFS is more intertidal habitat-oriented for fish populations. State resource agencies requested them to scale back the volume of sediment used for the project.

State Resource Agency Panel

The workshop continued with a panel of representatives from several resource agencies outside of North Carolina to discuss progress on TLP and BUDM in other states (see Subappendix C; state resource agency panelist slides):

- Sarah Bouboulis, Coastal Programs Manager, Delaware Coastal Zone Management Program
- Tyler Kinney, Coastal Biologist, New Jersey Department of Environmental Protection
- Maggie Cavey, Beneficial Use Planner, Maryland Department of Natural Resources
- Jan Mackinnon, Program Manager, Georgia Department of Natural Resources

<u>Delaware</u>

Sarah indicated that in Delaware, they are in ‘the thick of it’ in terms of implementing TLP with only a few recent projects completed. There is a state-run dredge / beneficial use work group that meets regularly (approximately every 6-8 weeks) to ensure all participating agencies are on the same page and to check-on the status of active projects. This workgroup is comprised of researchers, restoration experts, the USACE, the Delaware Department of Natural Resources and Environmental Control (DNREC) Fish and Wildlife, the USFWS, and non-profit and contracting partners.

The state is currently developing a Dredge Material Management Plan to establish goals for how dredge material is used, including those uses that are not considered beneficial. While the USACE handles the majority of projects, Sarah indicated that the Watershed Stewardship Section of DNREC handles projects that involve dredging smaller waterways and evaluating potential resource impacts. Delaware often has issues with avoiding archaeological resources, and there are frequently challenges related to water quality and matching material types with restoration projects. For any beneficial use project in Delaware, adaptive management plans are required.

Looking to the future, Delaware is interested in better streamlining the process for BUDM projects (there is often a lot of "waiting around" due to permitting constraints, etc.) and working more closely with regulatory partners to develop a framework for establishing criteria that satisfies the concerns of all participating agencies (e.g., number and types of samples required to assess dredged material compatibility).

New Jersey

In New Jersey, TLP and BUDM projects have already been scaled beyond the pilot stage through a programmatic approach and careful coordination between regulators, dredgers, and landowners. Tyler indicated that building a successful network, not the science, is the most challenging barrier to overcome. Tyler emphasized that successful programs begin at the policy level, and it is important to establish clear standards that do not lead to continuous permit battles with every project that is proposed.

New Jersey created their programmatic approach to TLP and BUDM projects by first building trust with regulators to develop, pilot, and if successful, engage in new policies for establishing project planning programs and systems. Tyler emphasized that successful programs must first and foremost address environmental needs that are also of value to dredgers (i.e., establish buy-in) and recommended that projects begin with land owned by state and federal governments to ensure proper scaling and consistency. The state's approach to TLP and BUDM is based on a logistics system and not a project-by-project approach: 1) regulators must develop methods for a programmatic approach once trust is earned, 2) landowners must develop and enforce a project development system to build trust, and 3) dredge teams must engage at the project level and buy-in to the concept of restoration.

Maryland

Maggie introduced the Maryland Beneficial Use Playbook and associated toolkit used by local counties and planners for navigating the BUDM landscape. The toolkit includes:

- Guidance Document: provides an overview of state regulations and associated considerations for dredged material management and types of beneficial use. This document can be used as a "grading system," and it outlines standards and criteria for implementing successful BUDM (for example, ensuring sediment type and chemistry are compatible between dredged and placement sites).
- Digital Matchmaking Tool / MD Coastal Atlas: a spatial planning tool that allows users to identify restoration sites and match dredge projects with potential BUDM projects.
- Roadmap and Process Diagram: provides flow charts and decision trees that outline the process for planning and implementing successful BUDM projects.

Maggie serves as a liaison between the regulatory community and restoration practitioners. She offered tips on how to discuss TLP and BUDM with mixed audiences to gain public trust and support for these projects:

- Dredge 'spoil' appears negative or a 'bad thing' to the public. Sediment is not a waste but an opportunity to build resilience. Adopting the term 'dredged material' removes that negativity and is more meaningful.
- Talk openly about the 'ugly phase' of TLP (short-term temporary impacts).
- Humanize projects and create outreach products beyond simple fact sheets.
- Refer to TLP as 'elevation enhancement.' It is more easily understood by the public and captures all types of sediment placement (thin versus thick layer).

Maryland currently has a "random assortment" of TLP and BUDM projects. Maggie indicated that their long-term goal is to create a state-wide matchmaking program that includes innovative, out-of-water reuse (for example, covering landfill material with dredged sediment) and traditional TLP and BUDM projects. To achieve this goal, the state is in the process of developing a twenty-year dredge management plan and playbook. The state has coordinated workshops and developed specific funding calls for BUDM projects. The state is also in the process of conducting a Shallow Draft Channel and Restoration Assessment to identify areas of concern that would benefit from BUDM. Maggie concluded her presentation by highlighting a successful, recent TLP project and associated outreach materials at the Chesapeake Bay Environmental Center in Queen Anne County, Maryland.

<u>Georgia</u>

Jan provided an overview of TLP on Jekyll Island, Georgia in coordination with the Georgia Federal Consistency Program, the USACE, The Nature Conservancy, and the Jekyll Island Authority. This was one of just a few projects that have been implemented in the state. Unlike typical TLP projects, dredged material was placed on a healthy marsh rather than a deteriorating marsh. Details below:

- Completed in 2019
- 125,000 cubic yards of material (5,000 used specifically for TLP) over 5 acres
- Goal: keep dredged sediment within the system and increase marsh resilience to sea level rise.
- Sediment Source: Jekyll Creek and shallow areas of the Intracoastal Waterway
- Sediment Texture: fine
- Methods: direct pipe discharge with manual re-working of the material at low tide.
- Placement Depth: 6-10 inches
- Containment Method: coir logs
- Plantings: none

Jan discussed several outcomes and lessons learned from the project. Uncrewed Aerial Vehicle (UAV) imagery was used to evaluate aboveground plant biomass several years post-placement. After five years, 84% of the marsh had regrown primarily from the marsh edge inward. Revegetation took longer than anticipated and did not support the vision of full regrowth between 3-5 years. There has been no evidence that the placement site has "caught back up" with the reference site since monitoring began, and benthic species diversity has decreased with evidence of ponding along the perimeter of the placement site. Overall, Jan acknowledged that monitoring could have been improved but was limited due to funding constraints.

Panel Discussion

At the conclusion of their presentations, Sarah (SB), Tyler (TK), Maggie (MC) and Jan (JM) answered several questions from workshop attendees (A), which are paraphrased below:

- A: Most coordination appears to involve state and federal agencies' relationship with the USACE. Are there any examples of TLP or BUDM projects conducted by private organizations, non-profits, or smaller agencies?
  JM: The Jekyll Island project was completed on state-owned land, so it was easiest to work with the USACE.
  MC: The Chesapeake Bay Environmental Center project was led by Queen Anne County in Maryland. The County selected a contractor and managed the project.

- A: What type of marsh was selected for the Jekyll Island project?
  JM: The Jekyll Island site was 100% *Spartina alterniflora* and was selected based on its elevation at the time and its proximity to the dredge location.

- A: How have state resource agencies evaluated concerns with potentially contaminated dredge material?
  TK: The New Jersey Department of Environmental Protection has a section devoted to testing sediments to ensure they are safe (Sediment Innovation Lab).
  SB: Delaware is addressing this concern through framework development. The state might test sediments from both dredged and placement sites and place contaminated dredge material on already-contaminated placement sites.
  MC: The Maryland Beneficial Use Toolkit provides guidance on determining allowable contaminant levels in dredged material for BUDM projects. The Toolkit provides information about concentration thresholds and the number of samples needed to complete such an evaluation. Sediment is treated as hazardous material if it is determined to be unsafe for beneficial use.

- A: Any suggestions for local dredge operators who do not have experience with TLP or BUDM but may have an interest in bidding on these types of projects?
  TK: Contact those with experience (e.g., the USACE) for assistance. In New Jersey, the Department of Transportation Maritime Services has been a valuable resource for dredgers.

- A: Were any of the projects discussed considered compensatory mitigation for impacts associated with other development activities?
  SB: It has been discussed in Delaware but has not yet been authorized.
  TK: Not in New Jersey
  MC: Not in Maryland

JM: Not in Georgia

- A: What are the key policy decision points that allow projects to move forward?
  TK: It is most important to negotiate on the amount of data needed to guide successful restoration and satisfy participating agencies.
- A: Any projects that have less drastic impacts on vegetation in relation to building trust and alleviating concerns with habitat alteration?
  MC: It is difficult to completely avoid impacts to existing vegetation, especially for larger projects with high sediment volume.

Small Group Breakouts and Discussion

The final portion of the workshop involved small group discussions that addressed four questions developed by the workshop planning team and informed by attendees' input during the registration process:

1. What are your biggest concerns about sediment placement? What should be monitored? What does success look like? Do we need BMPs for sediment placement (e.g. suspended sediment control)? How to minimize impacts to adjacent habitats?
2. What do we need more information on to use sediment placement to increase marsh resilience?
3. These projects are happening in a changing ecosystem – how should we evaluate tradeoffs between current environmental impact and project longevity? What long term target should we be shooting for, end goal? How far out do you plan (i.e. SLR scenario?)
4. How do we define a degraded wetland to justify thin layer placement of sediment. How do you prioritize wetlands for TLP, what does that look like?

Attendees were organized into small groups and rotated between each question (roving flipcharts), building on previous groups' responses. Moderators for each question summarized key takeaways once all groups provided input:

Question 1 Summary

What are your biggest concerns about sediment placement? What should be monitored? What does success look like? Do we need BMPs for sediment placement (e.g. suspended sediment control)? How to minimize impacts to adjacent habitats?

Biggest Concerns

Success uncertainties were identified as a primary concern with TLP projects. Attendees noted that in some cases, TLP could do "more harm than good" especially if there is a lack of regulatory oversight once projects are implemented. As a result, it is necessary to develop an adaptive permitting framework that would be responsive to lessons learned.

Some attendees were concerned about effectively matching sediment types between dredged and placement sites. Likewise, there was concern about the impacts of contaminated sediments (e.g., heavy metals, forever chemicals, etc.) on placement sites and associated risks to fish, wildlife, and public health.

Lastly, attendees expressed concern over the potential loss of wetland function once sediments are placed (e.g., loss of SAV and fish habitat, introduction of invasive species such as *P. australis* or nutria).

Monitoring and Success Considerations

Attendees identified several parameters that could be monitored once sediment is placed on an existing wetland. These parameters could be validated with the NC Wetland Assessment Method (NCWAM) and the Uniform Mitigation Assessment Method (UMAM). Generally, attendees agreed that choosing what to monitor should be dependent on specific success criteria and may include some or all the following:

- Vegetation abundance and recovery, including invasive species
- Recovery and response of invertebrate, bird, fish, and reptile species
- Hydrology
- Elevation
- Funding costs
- Water quality and turbidity
- Soil chemistry, microbiome pre- and post-application
- Ecosystem services (e.g., reduced flooding, economic assessment)

Attendees stressed the importance of securing reliable funding for long-term post-construction monitoring, which could be a barrier to success. Likewise, attendees identified the need to develop standard operating procedures (SOPs) for monitoring to ensure consistency across projects (e.g., establishing relevant monitoring durations, identifying appropriate control and reference sites, etc.). These SOPs should account for potential site recovery time, impacts from storm events, environmental work windows, and marsh growing seasons. Some attendees agreed that SOPs should also require monitoring and mitigation for any temporary habitat and species impacts associated with wetland mats, pipelines, or other construction activities. As such, adaptive best management practices (like those typically used for stormwater and sediment and erosion control) should be integrated into TLP monitoring plans. Collectively, these factors would help restoration practitioners develop appropriate budgets and timelines for effective monitoring once projects are complete.

According to workshop attendees, TLP could be considered successful if there is evidence of consistent sediment placement and containment across the marsh surface, adequate post-construction tidal flow, and benefits that exceed financial and ecological costs. Successful projects are also those that evaluate public perception and demonstrate a return on investment.

Minimizing Impacts to Adjacent Habitats

To minimize impacts to adjacent habitats, attendees recommended that initial sediment placement should occur in less sensitive habitats (e.g., avoiding primary nursery areas, SAV, open shell fishing waters, outstanding resource waters, etc.) or areas within larger marsh systems. Attendees also recommended coupling TLP with other nature-based approaches (e.g., living shorelines) to develop a more holistic restoration strategy that incorporates the protection of adjacent habitats.

Question 2 Summary – Information Needs

What do we need more information on to use sediment placement to increase marsh resilience?

Attendees identified a suite of factors that need careful attention before TLP is used to enhance marsh resilience to sea level rise. They were broadly categorized as follows:

- Sediment contaminants and establishing acceptable thresholds
- Acceptable habitat trade-offs and adaptive management
- Evidence of need
- Sediment characteristics and texture
- History of wetland loss and future trends (couple with marsh migration efforts)
- Tidal, geomorphological, and hydrological information
- Projections of outcomes / modeling
- Detailed site mapping (elevation, soil and vegetation types, archaeological surveys)
- Additional demonstration and pilot studies
- Frequency of repeat sediment applications
- Current ecological and economic function of any given marsh system

Question 3 Summary

These projects are happening in a changing ecosystem – how should we evaluate tradeoffs between current environmental impact and project longevity? What long term target should we be shooting for, end goal? How far out do you plan (i.e. SLR scenario?)

Evaluating Trade Offs

Attendees highlighted the need to evaluate acceptable trade-offs relative to project-specific purpose and need. For example, trade-offs are different for projects that aim to either restore or create new habitat. Like environmental impact statements required for large projects, TLP proposals should consider an array of action alternatives, including the “no action” alternative, when evaluating acceptable trade-offs. In some cases, no intervention and the subsequent conversion of intertidal to subtidal habitat could be most appropriate. In areas with adequate natural sediment supply and undeveloped corridors, facilitating natural marsh migration may be most appropriate and cost-effective.

Attendees also discussed trade-offs between TLP and public trust rights. For example, sediment placement that results in the fill of canals or ditches or in the creation of new upland habitats may eliminate navigable waters and public trust resources. As such, it is important to consider TLP success relative to community and stakeholder benefits. One attendee noted that if TLP results in the creation of new upland areas, conditions should be in place to prevent new development on those areas.

Long Term Planning Scenarios

In North Carolina, the life span of TLP projects and the associated ecosystem services they provide would most likely be determined by several location-specific factors such as current and future rates of sea level rise, the ability to match dredge frequency and sediment availability to marsh vulnerability (e.g., number of applications needed), the time frame in which a restored marsh reaches equilibrium and recovers post-construction, and the potential for future development and subsequent barriers to marsh migration. Attendees cautioned that using sea level rise alone to justify TLP could result in the "convenient disposal" of dredged material. As emphasized throughout the workshop, it is therefore necessary to consider a variety of factors that specifically target the restoration of deteriorating wetlands. In some cases, wetland loss may be driven by other stressors such as boat wakes and wave impacts. Wetlands susceptible to multiple stressors could benefit from protective measures other than TLP such as wave attenuating structures.

Lastly, attendees compared long-term TLP planning and implementation to beach nourishment and prescribed burns. Attendees suggested that once established, TLP could be incorporated into local resiliency plans to garner additional public support and funding from municipalities. Compared to beach projects, wetland change is typically slower and less obvious which could impact public perception or support. However, stakeholders could show a higher risk tolerance with TLP and associated uncertainties since candidate areas for sediment placement comprise a relatively small fraction of total wetland area across the state.

Question 4 Summary – Prioritizing Wetlands for TLP

How do we define a degraded wetland to justify thin layer placement of sediment. How do you prioritize wetlands for TLP, what does that look like?

Attendees agreed that characterizing a wetland as "degraded" may not be the most effective way to determine whether a site is a good candidate for TLP. Instead, practitioners should consider wetlands that are "at risk" of vegetation loss and ponding while also accounting for factors such as a site's proximity to existing infrastructure, the proposed dredge area and established migration corridors. Attendees also emphasized that just because a marsh is near a dredge area does not automatically make it a good candidate for TLP.

Evaluating regional status and trends of existing marshes is particularly important (e.g., natural conditions, future change, tidal ranges, salinity, ecology). For example, a highly developed region with many barriers to natural marsh migration (e.g., New Hanover County) may not benefit from TLP as much in the long-term compared to scarcely developed regions with higher migration potential (e.g. Hyde County). On the other hand, more developed regions could benefit more in the short term since options to enhance resilience are limited.

Conclusion and Next Steps

When evaluating the implementation of and trade-offs associated with TLP in North Carolina, workshop attendees highlighted the importance of clearly identifying the goals, objectives, purpose and need for these projects on a case-by-case basis – rather than as a catch-all approach – while considering the above topics on a specifically defined local or regional scale. As a result, a collaborative multi-agency network of stakeholders is most likely needed to progress TLP in a responsible manner.

The information gained from this workshop will be incorporated in and directly inform the 2026 CHPP amendment. TLP will be addressed as a stand-alone issue paper within the proposed Planning for Wetland Change thematic area. This paper will synthesize the best available science and guidance related to TLP, identify research needs and knowledge gaps, discuss policy, permitting, and regulations, and highlight concerns and best practices related to TLP that may collectively inform next regulatory steps and identifying priority areas where TLP may be successful in North Carolina.

SUBAPPENDIX A: WORKSHOP ATTENDEES

First Name	Last Name	Organization
Aaron	Bunch	The Nature Conservancy
Abby	Williams	NC Coastal Reserve and NERR
Ana	Zivanovic-Nenadovic	North Carolina Coastal Federation
Anne	Deaton	NOAA National Marine Fisheries Service
April	Hall	NC Coastal Federation
Billy	Standridge	US Army Corps of Engineers
Brandon	Puckett	NOAA National Centers for Coastal Ocean Science
Byron	Toothman	NC Coastal Reserve and NERR
Caroline	Causey	US Fish and Wildlife Service
Carolyn	Currin	EA Engineering, Science, and Technology
Cat	Bowler	Audubon North Carolina
Catherine	Otero	NC Division of Water Resources
Cathy	Brittingham	NC Division of Coastal Management
Charlie	Deaton	NC Division of Marine Fisheries
Claire	Rapp	NC Coastal Federation
Daniel	Govoni	NC Division of Coastal Management
Derek	Detweiler	NC Division of Marine Fisheries
Emily	Hughes	US Army Corps of Engineers
Gregg	Currey	US Army Corps of Engineers
Gregg	Bodnar	NC Division of Coastal Management
Jacob	Boyd	NC Coastal Federation
Jenny	Davis	NOAA National Centers for Coastal Ocean Science
Jonathan	Lucas	NC Division of Coastal Management
Justin	Ridge	NC Coastal Reserve and NERR
Kate	Jones	NC Dept. of Natural and Cultural Resources
Kelsey	Beachman	Division of Coastal Management
Kristina	Hellinghausen	NC Division of Water Resources
Lisa	Wickliffe	NOAA National Marine Fisheries Service
Mary	Plummer	NC Dept. of Natural and Cultural Resources
Melanie	Flood	NC Natural Heritage Program
Michael	Meilinger	NC Division of Water Resources
Michael	Schafale	NC Natural Heritage Program
Michelle	Brodeur	NC Division of Marine Fisheries
Michelle	Moorman	US Fish and Wildlife Service
Molly	Bost	NOAA National Centers for Coastal Ocean Science
Paula	Gillikin	NC Coastal Reserve and NERR
Richard	Mahoney	NC Division of Coastal Management
Sara	Ward	NC Dept. of Natural and Cultural Resources
Sarah	Marschhauser	Audubon North Carolina

Shane	Staples	US Army Corps of Engineers
Stephen	Lane	NC Division of Coastal Management
Trish	Murphey	NC Division of Marine Fisheries
Whitney	Jenkins	NC Coastal Reserve and NERR
Zach	Harrison	NC Division of Marine Fisheries

SUBAPPENDIX B: WORKSHOP AGENDA

Thin-Layer Placement Coordination Workshop
to inform the Coastal Habitat Protection Plan (CHPP) update

Thin-layer placement of sediment (TLP) is a strategy to restore or maintain a tidal marsh's elevation relative to sea level, to support marsh resilience. The approach leverages a marsh's natural ability to withstand large, storm-driven sediment deposits. TLP mimics this natural process by applying layers of sediment, often dredged material, to the marsh's surface.

Date: Monday, March 30, 2026

Location: Duke University Marine Lab, Repass Lecture Hall, 135 Duke Marine Lab Rd, Beaufort NC 28516

Time: 10:00am - 3:00pm

Target audience: Resource agencies, researchers, restoration practitioners

Workshop Objectives – Participants will:

- Share and discuss the latest Thin-Layer Placement of sediment (TLP) research and project implementation best practices,
- Discuss state policies and challenges in assessing project proposals, and
- Identify information needs to inform policy and permitting.

Workshop Outcomes:

- Regulatory agencies can better assess the purpose, need, and habitat impacts/tradeoffs from proposed TLP projects,
- Researchers understand knowledge gaps and connect with restoration practitioners for potential study sites, and
- Resource managers incorporate perspectives presented into planning and policy through the CHPP.

Agenda

Time	Item
9:30am	Workshop check-in
10:00am	Welcome & Introductions
10:15am	TLP Research Overview – Jenny Davis, NOAA
10:55am	15-minute break
11:10am	Resource agency panel via Zoom • Sarah Bouboulis, DE Department of Natural Resources and Environmental Control • Tyler Kinney, NJ Department of Environmental Protection • Maggie Cavey, MD Department of Natural Resources

	• Jan Mackinnon, GA Department of Natural Resources
12:10pm	TLP – Tasty Lunch Provided! Thank you, NC Coastal Federation!
1:00pm	Small group discussion • What are your biggest concerns about sediment placement? • What do we need more information on to use sediment placement to increase marsh resilience? • These projects are happening in a changing ecosystem – how should we evaluate tradeoffs between current environmental impact and project longevity? • How do we prioritize wetlands for thin-layer placement of sediment?
2:45pm	Action Items & Next Steps
3:00pm	Adjourn

SUBAPPENDIX C: STATE RESOURCE AGENCY PANELIST SLIDES

to be added to final PDF

Submerged Aquatic Vegetation Protection and Restoration

Executive Summary

North Carolina's coastal waters have historically supported nearly 200,000 acres of submerged aquatic vegetation (SAV), which provides critical spawning, foraging, and nursery habitat for most of North Carolina's fisheries, and provides additional ecosystem services including carbon sequestration, nutrient filtering, and sediment stabilization. However, degraded water clarity, sea level rise, and rising temperatures represent growing threats to SAV across the state, with rates of habitat loss currently exceeding 1% per year, plus increasing conversion of continuous meadows to patchy SAV beds. The 2021 CHPP set a statewide goal of ensuring a SAV extent of 191,155 acres and recommended new and updated water quality standards to ensure adequate light penetration to allow SAV to regrow in areas where poor water clarity has led to its loss. To ensure progress on slowing the rate of SAV loss across the coast, this CHPP highlights the need to continue to advance a water clarity standard to protect SAV, outlines an approach for a habitat-based rulemaking framework for the MFC to implement additional SAV protections, and summarizes the regulatory framework and ecological and practical concerns for future seed- and transplant-based SAV restoration projects.

Part 1: Background and water quality improvements to protect and restore SAV

Introduction

North Carolina (NC) is home to one of the most productive and biodiverse submerged aquatic vegetation (SAV) resources on the Atlantic seaboard, including the largest polyhaline and mesohaline seagrass meadows in the temperate western Atlantic (Thayer et al. 1984; NCDEQ 2016). SAV habitat is the foundation for ecological services that directly benefit the coastal ecosystems of North Carolina, including primary and secondary fisheries production, habitat for fish, wildlife and waterfowl, sediment and shoreline stabilization, wave energy attenuation, water purification, and carbon sequestration (Mtwana Nordlund et al. 2016). All these services are important to ecosystem health and provide increased community and ecosystem resilience (NCDEQ 2020). 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 (Costanza et al. 1997; Barbier et al. 2011; Sutherland et al. 2021). In addition to its contributions to coastal resilience and economic production, SAV also provides cultural value and contributes to human wellbeing for local coastal communities and residents globally, making it an integral part of coastal socio-ecological systems (Cullen-Unsworth et al. 2013).

Submerged aquatic vegetation includes marine, estuarine, riverine and lacustrine vascular plants that are rooted in unconsolidated sediment. 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 (Stevenson 1988; NCDEQ 2016). SAV can become stressed by eutrophication and other environmental conditions that 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 (Dennison et al. 1993; Biber et al. 2008). There are two distinct groups of SAV habitats in NC distributed according to water salinity. One group thrives in fresh and low salinity riverine waters (<10 ppt), referred to as low salinity SAV. The second group occurs in the moderate to high (>10 ppt) salinity estuarine waters of the bays, sounds, and tidal creeks, referred to as high salinity SAV or seagrasses.

These groups are distinguished by different species composition and environmental requirements, and they have characteristics similar to SAV communities found in many other estuaries in the US (Table 1) (Stevenson 1988; Orth et al. 2017). Low salinity SAV includes southern naiad (*Najas guadalupensis*), coontail (*Ceratophyllum demersum*), horned pondweed (*Zannichellia palustris*), naiads (*Najas* spp.), redhead grass (*Potamogeton perfoliatus*), sago pondweed (*Stuckenia pectinata*), slender pondweed (*Potamogeton pusillus*), water stargrass (*Heteranthera dubia*), water starwort (*Callitriche heterophylla*), waterweeds (*Elodea* spp.), wild celery (*Vallisneria americana*), and two non-native species, Eurasian milfoil (*Myriophyllum spicatum*) and hydrilla (*Hydrilla verticillata*). High salinity SAV includes eelgrass (*Zostera marina*), shoal grass (*Halodule wrightii*), and Widgeon grass (Ruppia maritima), a eurytolerant species that grows best in moderate salinity areas.

Table 1. Average environmental requirements at locations where submerged aquatic vegetation (SAV) occurred in coastal NC, 1988-1991 (Thayer et al. 1994).

	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)

High Salinity SAV Extent and Distribution

SAV mapping was conducted by DMF and partners in 2021 from Bogue Inlet south to Carolina Beach, and that survey is now included in the statewide SAV "mosaic" dataset, which includes all available aerial surveys from 1981 to 2021. Additional mapping of SAV beds from Bogue Inlet north to Roanoke Island that occurred from 2021-2025 will be available in the near future. However, the bigger-picture trends in SAV habitat are expected to be generally comparable to those previously reported, with rates of loss of SAV extent on the order of approximately 1% per year over a 30-40 year timespan, though with spatial variability in rates of loss. While extensive new mapping is currently unavailable, APNEP released a 2nd edition metric report on the *Extent and Distribution of Submerged Aquatic Vegetation in High Salinity Estuarine Waters* (Field et al. 2026), which analyzed the changes in high-salinity SAV meadows documented across three survey periods occurring in 2006-2007, 2013, and 2020.

In North Carolina, high salinity SAV is predominantly eelgrass (*Zostera marina*) and shoal grass (*Halodule wrightii*) with widgeon grass (*Ruppia maritima*) having a relatively lower (< 10%) abundance (Bartenfelder et al. 2022). In North Carolina, seasonal temperature variability exposes the temperate seagrass *Zostera marina* and the tropical seagrass *Halodule wrightii* to periods of both favorable and stressful thermal conditions (Thayer et al., 1984; Short et al., 2016; Bartenfelder et al., 2022). During summer, water temperatures exceed the thermal optimum of *Z. marina* (≥ 25°C up to three months), increasing respiratory demand and light requirements, resulting in seasonal declines in abundance (Zimmerman et al., 1989; Biber et al., 2008; Bartenfelder et al., 2022). Additionally, warming water temperatures in the region have extended the duration of *Z. marina*'s stressful season from 84 to 156 days between 1962 and 2019 (Bartenfelder et al., 2022). Although warmer water temperatures could increase habitat suitability for the tropical species *H. wrightii* to expand (Hyndes et al., 2016; Pinsky et al., 2020), the species has not increased in abundance or colonized areas of *Z. marina* loss, specifically at the meadow deep edge (Field et al. 2021; Bartenfelder et al., 2022). The lack of expansion is likely a result of annual winter water temperatures consistently occurring below the thermal optimum of *H. wrightii* (≤ 20°C up to three months), reducing metabolic performance required to sustain photosynthesis and limiting annual growth (Stevenson et al., 2025; Wheeler et al. 2025; Lytle et al. 2026). Together, these patterns indicate that both species are constrained by opposing thermal stressors that impact their life cycles. These contrasting thermal sensitivities highlight uncertainty in how seagrass meadow composition and structure will respond to continued climate change trajectories (Chefaoui et al., 2018; Kunkel et al., 2020; Pinskey et al., 2020).

APNEP conducted aerial surveys to map high-salinity SAV distribution along the coast from Roanoke Island south through Bogue Sound. Seagrass extent was mapped as continuous (>70% cover) or patchy (>10% and <70% cover), with a minimum mapping unit of approximately 0.2 ha and rasterized 2 m pixel size. Comparison of seagrass extent was limited to areas with interpretable imagery in subsequent surveys (e.g. areas uninterpretable in 2020 were removed from maps from 2007-2007 and 2013 for comparison), so figures do not represent all seagrass mapped. Across the survey range, of the originally mapped high salinity SAV extent of 99,398 acres in 2006 – 2007 (Figure 1) declined to 83,269 acres in 2020, representing a loss of 16,129 acres over the 14-year period, or a loss of 16.2%, or 1.16% per year (Figure 2) The extent of continuous meadows decreased by approximately 50%, from 44,978 to 20,804 acres, while patchy seagrass meadow extent increased approximately 15%, from 54,420 to 62,465 acres, indicating that not only is seagrass extent in North Carolina declining, but seagrass cover is also shifting toward more patchy and fragmented meadows.

The APNEP aerial survey data are divided into 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 Barden Inlet near Cape Lookout, and 3) the "South Zone" from Barden Inlet to Bogue Inlet (Figure 1). Spatial patterns of seagrass change over the 14-year period varied by region (Figure 2). In the Northern Zone, which contains the largest seagrass extent, most losses occurred along the outer western edges of patchy beds on the back-barrier shelf. In the Central Zone, much of the change reflected a transition from continuous to patchy meadows along the deep-water edge of the back-barrier shelf and on flood tidal shoals around Hatteras and Ocracoke Inlets. In contrast, the Southern Zone exhibited both gains and losses, with substantial seagrass expansion in western Bogue Sound and declines in the eastern portion of the zone. Northern and Central Zones surveyed lost seagrass extent, with regional rates of loss reaching as much as 3.08% per year in subareas from Drum Inlet to Hatteras Inlet. The APNEP report notes that the Chesapeake Bay and Indian River Lagoon both experienced substantially larger losses of seagrass over the same time period, but the seagrass loss reported in NC is on par with globally reported rates of seagrass declines (Dunic et al. 2021).

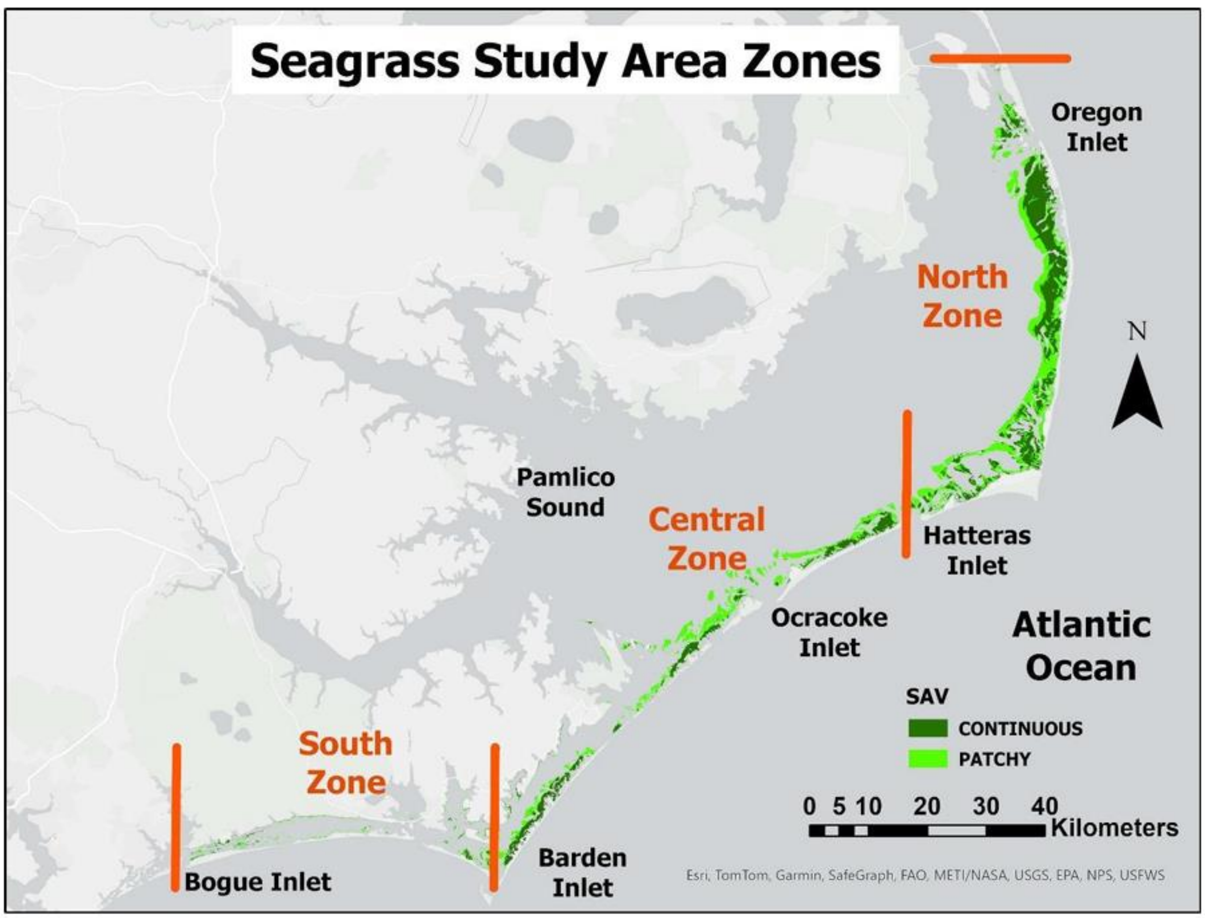

Figure 1. The three regional zones for the high salinity aerial surveys: 1) the "North Zone" from the U.S. Highway 64 Bridge at Roanoke Island to Hatteras Inlet, 2) the "Central Zone" from Hatteras Inlet to Barden Inlet near Cape Lookout and, 3) the "South Zone" from

Barden Inlet to Bogue Inlet. The high salinity SAV mapped in the figure is from interpretation of the 2006/2007 imagery (Field et al. 2026).

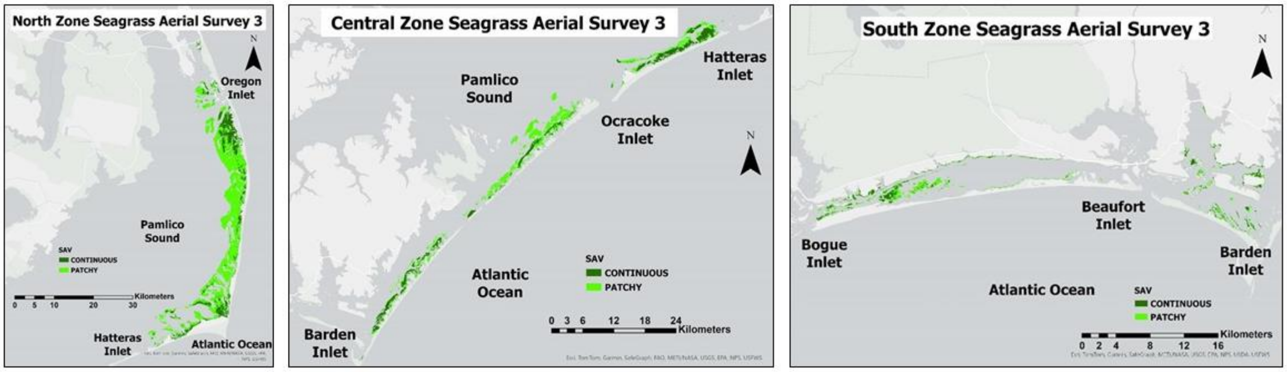

Figure 2. The three zones for the high salinity monitoring from Survey 3 (2020) imagery interpretation. Colors demote the SAV location and spatial cover classes (continuous and patchy). Modified from Field et al. 2026.

The APNEP mapping analysis highlights that a common area of loss was at the deeper-water edge of the seagrass meadows, which are generally also exposed to the largest fetch and wave energy. Seagrass growing at the deep edge of the beds is likely growing at or near the threshold of light limitation, so loss in this area can also be driven by sea level rise and poor water clarity. Increasing water temperatures also exacerbate the impacts of light limitation, especially for eelgrass, which is already growing near its thermal tolerance in North Carolina and has experienced documented long-term declines in Back Sound (Bartenfelder et al 2022 MEPS). Flood tidal deltas at Hatteras and Ocracoke Inlets experienced large losses of seagrass extent, associated with the widening of both inlets, shifting of sand shoals, and notably Hurricane Dorian in 2019, which produced a large storm surge in north Core Sound and southeastern Pamlico Sound.

The reported reductions in seagrass habitat over the past 14 years reflect the multi-decadal patterns of loss noted in previous CHPPs, and this ongoing pattern emphasizes the need for management action to protect North Carolina's remaining SAV habitat and restore the meadows that have been lost. It is important to manage the threats within the domain of existing management paradigms, including sediment and nutrient loading, water quality, and land use, but given the threats posed by climate change, new approaches will need to be developed to mitigate the impacts of increased storminess, rising temperatures, and sea level rise. While the 2021 CHPP set a statewide SAV acreage goal of 191,155 acres, of which 149,427 acres is high-salinity SAV, based on seagrass extent mapped from 1981-

2015. The APNEP report recommends an interim target for high salinity SAV extent of 109,167 acres, representing the seagrass extent mapped in 2006-2007, as such a target may be more immediately achievable. Finally, while over 16,000 acres of seagrass meadows were lost between 2006 and 2020, at least some of that lost acreage remains viable seagrass habitat that can be repopulated as long as management practices preserve the environmental conditions that sustain persistent seagrass meadows and promote their reestablishment.

Low Salinity Extent and Distribution

The Currituck Sound and Back Bay, Albemarle Sound, and Tar-Pamlico and Neuse Rivers regions are home to North Carolina's low salinity SAV. The known historical extent of low salinity SAV mapped in NC, from 1981 – 2015 is 39,066 acres or 20.4% of the state's total SAV extent (NCDEQ 2021). Mapping and monitoring low salinity SAV is more difficult due to low water clarity compared to the areas of the estuary where high salinity SAV grows. Despite low water clarity and 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 (Speight 2020; APNEP 2020). Comparing alongshore hydroacoustic surveys conducted 2014-2017 to the historical extent of SAV (from the 1981-2015 SAV mosaic dataset, though the earliest surveys contained in that dataset for the low salinity regions date to 1990), approximately 33 percent of the linear extent of low-salinity SAV was estimated to have been lost (APNEP 2020).

The 2026 amendment to the CHPP proposes three strategies going forward to support SAV protection:

1. Completion of the recommendation from the 2021 CHPP amendment for the EMC to be presented with a water quality standard for light penetration, along with continuation of the other recommended actions to improve water quality for SAV.
2. Outlining the permitting process for active SAV restoration where conditions may be supportive of long-term reestablishment through seeding or transplantation.
3. A plan for developing comprehensive management options for SAV protection from physical disturbance under the authority of the MFC, in accordance with the MFC's request during implementation of Amendment 2 to the Shrimp Fishery Management Plan.

Continued work on water quality improvements to protect and restore SAV

Chapter 4 of the 2021 CHPP amendment (NCDEQ 2021) explored the declines in SAV statewide and illustrated the connections to decreased water clarity, in addition to describing the component factors driving this reduction, with a focus on chlorophyll (driven by nutrient input), but also including turbidity and chromophoric dissolved organic matter (CDOM) (Hall, 2022). The 2021 CHPP amendment recommended 13 actions under the theme of *Protection and Restoration of Submerged Aquatic Vegetation (SAV) through Water Quality Improvements*, with a heavy emphasis on establishing water clarity solutions through new and/or improved water quality standards. As underwater plants, SAV species require waters to be clear enough for sunlight to penetrate the water column during the growing season, and light availability typically limits the depth at which SAV can grow. Required light conditions vary by species; low salinity SAV 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 (Kemp et al. 2004; Funderburk et al. 1991; USEPA 2003). These biological light requirements, along with modeling by Hall (2022), formed the basis of the 2021 CHPP Amendment's recommendation for a light penetration (clarity) standard to protect and restore SAV. A study conducted in 2022 (Lytle et al. 2026) evaluated light availability relative to the 2021 CHPP amendment recommendation of a 22% surface irradiance threshold for high-salinity SAV up to depths of 1.7 m. During a three-week study conducted in a seagrass meadow in Back Sound between August and September, observed light availability was 14 percent surface irradiance at 1.0 m depth, with an estimated 9.8 percent surface irradiance reaching 1.7 m, substantially below the recommended threshold. These data highlight the need to continue to characterize the light conditions currently experienced by SAV habitats across North Carolina to inform efforts to improve water clarity for SAV restoration.

Efforts to reduce algal blooms and chlorophyll a impairments in North Carolina's estuaries have been ongoing for over 20 years, to mixed results. The NC Division of Water Resources' Nonpoint Source Planning Branch's draft *20-Year Neuse and Tar-Pamlico Nutrient Management Strategy Retrospective* (NCDWR 2023) provides an overview of the history and progress of nutrient management in the two primary watersheds that impact the Pamlico Sound estuary, including a large portion of the state's SAV habitat, from the early 2000s to the early 2020s. Among the preliminary findings are that (a) progress on nutrient reduction has been mostly limited to point source improvements, and that the increase in organic nitrogen loads has offset the nitrogen loading reductions achieved from point sources; (b) loading from developed lands has approximately doubled, while loading from cropland has not substantially decreased; and (c) agricultural lands dominate nutrient loading in high precipitation years, while urban areas dominate in low precipitation years, indicating that both agricultural and urban sources must both continue to be addressed to protect downstream environments.

The impacts of climate change threaten to exacerbate water clarity issues as rainfall patterns change. According to North Carolina's 2020 Climate Science Report (Kunkel et al. 2020), the intensity of the strongest hurricanes is likely to increase with warming temperatures, which will result in increased heavy precipitation from hurricanes impacting NC. Additionally, it is likely that the frequency of severe thunderstorms and the annual total precipitation in NC will increase. The expected increase in heavy precipitation events will lead to increased runoff from both agricultural and developed lands, which will result in an increase in nutrients, sediments, and other pollutants carried to North Carolina's estuaries. Paerl et al. (2019) analyzed rainfall records from coastal NC going back to 1898, and their findings suggest that this increase in precipitation and pollutant delivery to estuaries has already begun. Specifically, they found "a period of unprecedentedly high precipitation since the late-1990's, and a trend toward increasingly high precipitation associated with tropical cyclones over the last 120 years," and that those changes represent "a recent regime shift with major ramifications for hydrology, carbon and nutrient cycling, [and] water and habitat quality." As the magnitude and frequency of rainfall and storm events increase, it will be even more important for state agencies to implement policies that encourage the use of agriculture, forestry, and urban stormwater best management practices (BMPs) and explore complementary regulatory updates to reduce the amount of runoff reaching North Carolina's estuaries. Each edition of the CHPP has emphasized the need for increased use of BMPs, along with other actions to improve water quality, and increased implementation will be necessary to mitigate the impacts from anticipated climatic changes.

The 2021 CHPP amendment recommended 3 incrementally progressive regulatory solutions to be brought to the EMC: (1) a clarity standard to protect SAV, (2) an update to the existing chlorophyll standard to address deficiencies in the standard and its assessment, and (3) nitrogen and phosphorus standards. While not accomplished in the ambitious timeframes initially proposed, the 2021 CHPP recommendations for water quality improvements to protect and restore SAV habitat remain DEQ's top priorities to advance SAV protection and restoration coastwide.

Since the 2021 CHPP amendment's passage, the Scientific Advisory Council (SAC) to the Nutrient Criteria Development Plan (NCDP) made a recommendation for a clarity standard that included the photosynthetically active radiation (PAR) extinction coefficients (K_dPAR) recommended in the 2021 CHPP amendment of 1.36 m^{-1} for low-salinity SAV (allowing for 13% of incident light to reach 1.5 m depth) and 0.89 m^{-1} for high-salinity SAV (allowing for 22% of incident light to reach 1.7 m depth), applied across a growing season of March through October to areas that are currently or have historically been vegetated by one or more of the 14 species identified in the MFC definition of SAV habitat (15A NCAC 03I .0101(4)(i)(i)). The NCDP SAC reviewed presentations on chlorophyll in their final few meetings, however the SAC's appointment concluded without action on either updates to the chlorophyll standard or new nitrogen and phosphorus standards.

Following the conclusion of the SAC's appointment, DWR NCDP staff developed the SAC's recommendation into a draft water clarity standard, which was presented to the Criteria Implementation Committee (CIC). CIC member feedback was solicited as a group and in one-on-one meetings, and NCDP staff have been developing a regulatory impact analysis (commonly referred to as a fiscal note) in accordance with NCGS § 150B-21.4 to identify, describe, and quantify the expected effects of the proposed standard to the extent possible. Upon completion of the fiscal note, DWR staff will complete the rulemaking package and present the draft standard to the EMC, with a vote on the standard anticipated in 2027.

While passage of a water clarity standard protective of SAV would mark a comprehensive approach to reversing the decline of North Carolina's SAV habitat, the earliest initiation of restoration activities in clarity-impaired waterbodies will likely take at least 8-10 years after passage of the standard, accounting for standard implementation, monitoring and assessment, development of restoration plans, and on-the-ground restoration projects.

In public meetings since passage of the 2021 CHPP amendment, commercial and recreational fishing stakeholders have made clear their frustration with continued declines in water quality and the impacts of those declines on fish and fish habitats. Accordingly, this CHPP amendment recommends continuing to prioritize progress on the recommended actions from the 2021 CHPP amendment to improve water quality for SAV, specifically that DMF, DWR, and partners should continue to collaborate in facilitating the adoption of a water clarity standard to protect SAV. Additionally, in acknowledgment of the long timeframe anticipated to achieve comprehensive water clarity solutions for SAV, this CHPP amendment provides guidance for further SAV protection and restoration measures that, while less wide-ranging, still represent meaningful steps that can be taken to slow the rate of coastwide SAV loss. Specifically, this CHPP amendment explores the range of SAV protections that may be available under the authority granted to the Marine Fisheries Commission, and this amendment also lays out the permitting framework, best practices, and next steps for active restoration of SAV habitat across North Carolina's coast. The approaches present additional tools for DEQ and partner organizations to work with while long-term solutions to the threats to SAV from water quality degradation are simultaneously addressed.

Recommended Action

DMF, DWR, and partners should continue to prioritize progress on the recommended actions from the 2021 CHPP amendment to improve water quality for SAV, especially by collaborating to facilitate the passage and implementation of a water clarity standard to protect SAV.

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Part 2: Submerged Aquatic Vegetation Restoration

This paper synthesizes the state of active submerged aquatic vegetation (SAV) restoration as it bears on management decisions in North Carolina, summarizes the regulatory framework currently governing active SAV restoration in state waters, and notes practical and ecological concerns to address before attempting or permitting active SAV restoration. While this issue paper does not attempt to summarize restoration methods (e.g., transplant unit design, anchoring techniques, or seed handling), researchers and practitioners are directed to the manuals cited below and others.

Background

North Carolina estuaries support SAV across a wide salinity range, broadly grouped into high-salinity communities of polyhaline and mesohaline waters (dominated by eelgrass *Zostera marina*, shoal grass *Halodule wrightii*, and widgeon grass *Ruppia maritima*) and low-salinity communities of the oligohaline and tidal freshwater rivers and sounds (dominated by wild celery *Vallisneria americana*, sago pondweed *Stuckenia pectinata*, pondweeds *Potamogeton* spp., and other freshwater taxa) along with the invasive hydrilla *Hydrilla verticillata*, which is widespread and in many areas the dominant low-salinity SAV by biomass. The two groups differ in species composition, dominant stressors, bed dynamics, and climate vulnerability. The presence of hydrilla complicates restoration planning in low-salinity systems both because of its competitive effects on native species and because of the herbicide treatments used to control it. Active restoration considerations, including donor sourcing and species suitability under changing conditions, may differ substantially between groups, and project planning should be informed by the ecological and management context of the relevant salinity zone.

Where water quality or physical impacts to SAV habitat have been mitigated but natural revegetation has not occurred, active placement of transplants or seeds can help overcome source and dispersal limitations that may prevent recovery. Active restoration is therefore distinct from the stressor-reduction actions (e.g., water clarity needs) addressed in Part 1 of this issue paper. Active restoration is most appropriate as a follow-up measure once underlying stressors have been removed or reduced, not as a mitigation for them. However, there may be localized areas where stressors are not as prevalent and active restoration can be considered despite water clarity measures not met within the broader geography.

In addition to benefits to fish and wildlife that depend on the habitat, SAV restoration presents an opportunity to restore lost blue carbon stocks. North Carolina's Coastal Habitat Greenhouse Gas Inventory (NC Coastal Habitat GHG Workgroup 2023) uses a single carbon sequestration rate for both patchy and continuous high-salinity seagrass meadows (-0.17 t C $acre^{-1}$ yr^{-1}; IPCC 2014), indicating that, based on North Carolina's 2021 mapped seagrass extent, statewide carbon sequestration in seagrass soils totaled 14.69 kt C yr^{-1}, or 55.14 kt CO_2eq yr^{-1}, though uncertainty in that estimate is poorly constrained. Key et al. (2026) found that continuous seagrass beds have higher carbon concentrations stored in their soils than discontinuous (patchy) seagrass beds (1.5-2.0% vs. 0.64-1.0% organic matter), and those sediments are more resistant to erosion and are better preserved by storm burial than discontinuous seagrass beds. These findings would suggest that restoration of lost seagrass beds, or of continuous beds that have become patchy, would increase both carbon sequestration rates and long-term storage of soil carbon in high-salinity seagrass habitats.

Under changing climate conditions, restoration planning may also need to account for shifting species suitability and consider the role of assisted migration. For example, eelgrass, which is near its southern thermal limit in North Carolina, is increasingly vulnerable to warming temperatures, whereas shoal grass is more heat-tolerant and may expand northerly under future conditions (Bartenfelder et al. 2022). In such cases, restoration efforts that incorporate climate-adapted species or genotypes may improve long-term persistence (e.g., Hoegh-Guldberg et al. 2008; van Katwijk et al. 2021).

A growing body of literature exists to inform SAV restoration practice. Guidance for U.S. seagrass restoration was set out in Fonseca et al. (1998), and the Chesapeake Bay SAV Restoration Manual (Jasinski et al. 2021) provides region-specific protocols developed in the most directly analogous Atlantic Coast system. More recently, Unsworth et al. (2025) discuss ten guiding principles for seagrass restoration, beginning with the principle that *protection* of extant meadows is more effective than replanting and that restoration is not a substitute for reducing the stressors that caused decline. The single most consistent finding across syntheses of seagrass restoration is that restoration is unlikely to succeed where the impacts that caused loss have not been mitigated, particularly when those impacts originate from degraded water quality. Van Katwijk et al. (2016), in a global meta-analysis of 1,786 restoration trials, found that sites previously impacted by reduced water quality (principally eutrophication) and by construction activities had poorer restoration outcomes than sites impacted by dredging, localized direct impacts, or natural causes. Persistent water-quality stressors are therefore a strong reason to postpone active restoration regardless of the techniques used.

Several factors are positively associated with restoration success. Van Katwijk et al. (2016) identified that larger planting efforts (number of plants or seeds), proximity to existing donor beds, and use of effective anchoring techniques are among the strongest factors for survival and population growth. Proximity to donor beds is generally interpreted as an indicator that the receiving environment is suitable for seagrass growth, but it may also reflect benefits from locally adapted genotypes and from shorter handling time between collection and planting. Recent work also points to potential benefits from microbial inoculation (Sun et al. 2024). However, with these successes the drawbacks must also be considered. The high salinity SAV species *Zostera marina* exhibits a mixed annual life-history strategy in which aboveground shoots senesce during summer and plants re-established each year from the seed bank that was established the year prior (Jarvis et al. 2012). *Z.marina's* dependence on annual seed recruitment makes seed production and seed bank persistence critical to the North Carolina population resilience. Consequently, restoration efforts that rely on harvested seeds must ensure seed collection does not deplete the limited seed reserves required for natural annual recovery of the species.

Van Katwijk et al. (2016) concluded that larger trials succeed more often than smaller ones, suggesting that plantings must reach a sufficient density and spatial footprint to overcome negative factors (e.g., sediment resuspension, grazing, hydrodynamic stress) and persist. In a synthesis of 82 eelgrass restoration projects conducted along the U.S. West Coast between 1989 and 2020 reinforce these conclusions (Ward and Beheshti 2023). Project failure rates were 32–60% depending on how success was defined, and the authors attributed the regional failure rate in part to the small scale at which most West Coast restoration has been conducted (a total of only ~85.5 ha across all 82 projects). Practitioners most often attributed failure due to environmental conditions such as algal blooms, sedimentation, and light limitation. This is consistent with Van Katwijk et al. (2016) finding that water quality and other persistent stressors are dominant causes of restoration failure. Ward and Beheshti (2023) also showed a substantial documentation gap (only 6 of 82 projects were peer-reviewed; few projects monitored ecosystem functions or maintained co-monitored reference sites. North Carolina will need to develop a standardized and well-documented monitoring approach for restoration sites. This approach will need to be accessible to practitioners and contain information that reports restoration sites, restoration efforts implemented, and restoration progress (success or failure) to inform future restoration decisions.

The contrast between eelgrass improvements or declines in Chesapeake Bay and the adjacent Virginia coastal bays on the Eastern Shore is an illustration of how stressor context determines restoration outcomes. Orth et al. (2009) reported that eelgrass beds in Chesapeake Bay, which had begun to recover from earlier diebacks, declined over the period 2000–2009. This was attributed to declining water quality as the main stressor as there was bay-wide dieback in 2005 associated with very high summer water temperatures and poor water clarity. Over the same period, eelgrass abundance increased substantially in the Virginia coastal bays on the Eastern Shore, where a large-scale seed-based restoration program initiated in 2001 was able to take advantage of better water clarity and produced expanding, self-sustaining beds. This shows that the same general restoration approaches, in the same region, can produce different outcomes depending on whether the underlying water quality and thermal regime supported eelgrass. Numerous transplant projects in Chesapeake Bay over this same period failed to persist beyond one to two years (Orth et al. (2009), reinforcing the conclusion that active restoration in waters that have not recovered the conditions supporting natural revegetation should be treated as experimental rather than as a reliable management tool.

Criteria for successful SAV restoration

Active SAV restoration in North Carolina is most likely to succeed under the following circumstances. These are offered as decision criteria for evaluating proposed restoration projects; however, site-specific judgment by qualified practitioners and resource managers is essential.

1. Stressors have been mitigated or reduced enough for successful restoration. The causes of historical SAV loss at the site, whether they are degraded water clarity, nutrient enrichment, persistent physical disturbance (e.g., shellfish operations), or other stressors, have been reduced to the point where conditions fall within the target species' water quality conditions that support SAV growth. Where stressors persist, restoration should generally be deferred until conditions improve. However, smaller localized areas with adequate conditions may persist within the larger area in question.

2. Water quality conditions support SAV growth. Light availability, salinity, temperature, and dissolved-oxygen conditions at the proposed site are within the documented ranges for the target species and life stage to accommodate survival and growth.

3. Physical site conditions are appropriate. Sediment composition, depth, and current and wave energy are consistent with conditions at nearby reference beds and within the species' tolerance thresholds. Sites with persistent high energy disturbance or unsuitable sediments are unlikely to support persistent SAV regardless of planting effort.

4. Natural revegetation has not occurred despite suitable conditions. Measurements of adequate conditions for growth and evidence that a site has remained unvegetated over a period long enough to indicate that natural recolonization is constrained by seed or propagule limitation, dispersal limitation, or density-dependence rather than by a current stressor that planting cannot overcome.

5. Donor material and type can be sourced appropriately. Donor beds within a reasonable proximity to the restoration site are healthy and large enough to supply the needed material without compromising the donor population. Genetic and disease considerations should be addressed in donor selection (see below). The use of propagules (shoots) or seeds will need to be determined.

6. Climate-adapted species and genotype selection are considered. Where projected changes in temperature, salinity, or other conditions may push current SAV species or genotypes outside their tolerance ranges, restoration planning should consider whether the historically dominant species remains the most appropriate target, and whether donor genotypes from populations adapted to warmer or more variable conditions should be incorporated. Decisions about climate-adapted sourcing carry their own risks and should be made with input from genetic and ecological expertise.

7. Grazing pressure can be limited. Grazing and foraging from waterfowl, fish, and other wildlife (e.g., turtles, rays) can quickly cause disturbance and in some cases cause complete restoration failure, especially in small-scale experimental planting areas. Where this is a concern, there may be options such as temporary grazer exclosures (e.g., fencing) that could be placed around individual plants, groups, or the entire restoration site.

8. Project scale is commensurate with the goal. Project design includes sufficient planting effort (i.e., number of plants or seeds, spatial footprint, and density) to exceed plausible thresholds for establishment and to allow the planting to generate the self-reinforcing conditions (e.g., sediment stabilization, light improvement, energy attenuation) that support persistence. Small pilot plantings have value for testing site suitability and providing source material to an area but should not be expected to produce self-sustaining meadows on their own.

9. Monitoring duration is sufficient to evaluate persistence. A monitoring commitment of at least five years is in place, with the recognition that short-term (one- to two-year) survival is a weak predictor of long-term outcome. Many seagrass restoration projects globally have shown initial survival followed by failure within the first few years; therefore, persistence, not initial establishment, should be the success criterion.

10. Active restoration will not be impacted by herbicidal treatment for invasive species. Broad-scale usage of herbicidal treatments to exterminate an invasive species (e.g., hydrilla) can harm active restoration areas of native SAV. Planning and coordination with appropriate agencies should occur to minimize impacts (see Recommendation # 7).

11. Additional criteria as needed. For example, projects should be aligned with regional restoration priorities, presence of compatible adjacent habitats, and minimized conflicts with existing uses. These and other criteria as they arise will also be relevant for evaluating specific projects.

Current regulations pertaining to active SAV restoration

The regulatory framework governing active SAV restoration in North Carolina state waters is summarized below. In brief, the current framework allows for on-land culture and collection of SAV but provide limited mechanisms for in-water restoration efforts.

1. In-water leases for marine plants are not currently available. North Carolina General Statutes Chapter 113, Article 16, authorizes the Secretary to issue bottom and water-column leases for the cultivation of shellfish (N.C.G.S. §§ 113-202, 113-202.1, 113-202.2). The statutory authority is specific to shellfish and does not extend to marine plants. There is no analogous lease authority for SAV in current statute, and creating one would require legislative action. As a result, researchers and practitioners seeking to conduct active SAV restoration cannot obtain an in-water lease providing exclusive use, or a defined management footprint for the planted area.

2. Limited in-water protections for restored SAV sites. Once SAV has been re-established, it is generally afforded the same protections as naturally occurring SAV through existing rules governing impacts to SAV habitat. SAV is designated as Essential Fish Habitat (and as Habitat Area of Particular Concern in the South Atlantic) under the Magnuson-Stevens Act, triggering NOAA Fisheries consultation on federal actions that may adversely affect SAV. SAV is also protected through USACE Nationwide Permit conditions, and restrictions on shellfish lease siting in mapped SAV areas. The NCDMF Director may, by proclamation, designate a temporary research sanctuary that restrict fishing and equipment use for a SAV restoration project, renewable on an annual basis (15A NCAC 03I .0109). Beyond these mechanisms, NCDMF does not currently have a discrete tool for designating, managing, or providing long-term legal protection to a restoration site.

3. Land-based SAV culture. Collection, culture, and planting of SAV that involves land-based culture can be permitted under NCDMF's existing aquaculture authorities. Under 15A NCAC 03O .0503(a), it is unlawful to conduct aquaculture operations using marine and estuarine resources without an Aquaculture Operation Permit (AOP), and it is unlawful to take marine or estuarine resources from coastal fishing waters for aquaculture purposes without an Aquaculture Collection Permit (ACP). Both permits are issued by the NCDMF Fisheries Director and renewed annually. Holders of an ACP must submit an annual report stating the amount and disposition of resources collected, including any additional reporting required by other state or federal agencies. SAV falls within the scope of these authorities. N.C.G.S. § 113-129 defines "marine and estuarine resources" to include all uncultivated or undomesticated plant and animal life inhabiting or dependent upon coastal fishing waters, which encompasses SAV. The Marine Aquaculture Article (N.C.G.S. § 113-217) defines "marine aquatic species" to include aquatic plants found in coastal fishing waters. Through the conditions attached to AOPs and ACPs, NCDMF may regulate the amount of material collected, the location and timing of collection, and the methods used. These conditions are set on a permit-by-permit basis under the NCDMF Director's authority, providing flexibility but not a uniform standard for SAV.

4. Activities exempt from NCDMF permitting. Harvest and transplanting of SAV that does not involve land-based storage or culture is unlikely to trigger AOP or ACP requirements as currently written. For example, direct collection from a donor bed and immediate planting at a restoration site is exempt from permitting. The AOP requirement applies to "aquaculture operations," and the ACP requirement applies to take "for aquaculture purposes" (15A NCAC 03O .0503(a)(1) – (2)). Under the statutory definition, aquaculture involves the propagation and rearing of aquatic species in controlled or selected environments. Neither clearly applies to direct bed-to-bed transplantation.

5. Permitting requirements from other agencies. Individual SAV restoration projects may also involve other state and federal agencies, including the U.S. Army Corps of Engineers (USACE), the Division of Water Resources (DWR) for Section 401 Water Quality Certification, and the Division of Coastal Management (DCM) for Coastal Area Management Act (CAMA) major or minor permits and Dredge and Fill permits. Additional permitting requirements for transplanting SAV and protective structures are generally not anticipated to be burdensome, but consultation with agency staff through DEQ's Division of Environmental Assistance and Customer Service (DEACS) is highly recommended to confirm, as permitting requirements vary on a case-by-case basis.

Recommendations for policy and regulatory updates

The current regulatory landscape provides only partial coverage of active SAV restoration. Land-based operations can be permitted, but in-water collection and transplanting are largely unregulated, and there is no mechanism for in-water lease or for restoration-specific in-water protection. The recommendations below are offered for consideration during the 2026 CHPP amendment process.

Recommendation 1: Develop SAV considerations for AOP and ACP conditions. Authority to attach permit conditions to AOPs and ACPs already exists under 15A NCAC 03O .0502 and N.C.G.S. § 113-169.1 (also, N.C.G.S. § 113-134, N.C.G.S. § 113-169.1, N.C.G.S. § 113-182, N.C.G.S. § 143B-289.52, and 15A NCAC 03O .0500). NCDMF could work with partners to develop a set of standard considerations for permit reviewers to ensure best practices when an AOP or ACP involves SAV. This could address allowable donor sources, take limits, seasonal restrictions on collection, disease and biosecurity screening, genetic considerations, and reporting requirements. Given that North Carolina is in the process of developing restoration best practices and evaluating long-term management needs, priority should be placed on conserving in-state donor material to support restoration and resilience of North Carolina's own SAV resource, and consideration should be given for limiting the collection of North Carolina SAV seeds or plants for restoration projects outside the state.

Recommendation 2: Address potential donor bed impacts. Harvest from a donor bed can be a source of impact in seagrass restoration van Katwijk et al. 2021. Even when transplant material is taken at modest intensities, the spatial and temporal patterns of harvest may affect donor bed density, structure, and recovery. NCDMF should consider requiring donor bed monitoring and reporting as a condition of permits authorizing SAV collection and should establish standardized criteria for evaluating donor bed suitability and post-harvest recovery. North Carolina donor bed monitoring protocols should be developed.

Recommendation 3: Address transplant sourcing. Transplant sourcing decisions affect the probability of restoration success and the broader management risks of the project. Four considerations are particularly relevant. First, disease and pathogen transmission risk increases with movement of plant material between water bodies where donor screening or quarantine in land-based culture may be appropriate. Second, there can be genetic differentiation among populations (Olsen et al. 2004). Locally sourced material is more likely to carry adaptations to local conditions, but genetically diverse populations may also be more resilient to environmental variability. For example, Campanella et al. (2010) documented genetic population structure along the U.S. Atlantic Coast and found that the Chesapeake Bay may be the best donor source for eelgrass for restoration. Third, sourcing should avoid moving material from areas where non-target species (including invasive species) may be inadvertently translocated and (or) have a mechanism for identifying non-target species prior to restoration activities. Fourth, physical proximity of donor to recipient site is among the more reliable predictors of restoration success (Van Katwijk et al. (2016)) and reduces handling time. Standard considerations attached to AOP/ACP conditions for SAV operations (Recommendation 1) should address each of these factors.

Recommendation 4: Address protection of restored SAV sites. As noted above, the only restoration-specific protection currently available is the temporary research sanctuary mechanism, which is time-limited and tied to a research purpose. Regulators may wish to consider a long-term protective designation. Because no current statute authorizes a marine plant lease, this would likely require either a statutory amendment extending lease authority to marine plants, or creation of a new designation under existing rule authority (e.g., extended-duration research areas or restoration-specific management zones).

Recommendation 5: Develop guidance for climate-adapted restoration decisions. North Carolina sits at a biogeographic transition where projected warming may affect species and genotype suitability for SAV restoration. NCDMF, in coordination with research partners (e.g., APNEP, NC Sea Grant, university research programs), should develop guidance on when and how to consider assisted migration or sourcing of climate-adapted genotypes as alternative restoration tools. Such guidance should address the trade-offs between local adaptation and projected conditions and should be developed in coordination with the AOP/ACP considerations identified in Recommendations 1 and 3.

Recommendation 6: Coordinate active restoration with aquatic weed control activities. Invasive species control under the Aquatic Weed Control Act of 1991 (N.C.G.S. § 113A-220 et seq.) is administered by NCDEQ with interagency advisory input through the North Carolina Aquatic Weed Control Council. Herbicide treatments (e.g., fluridone) intended for hydrilla in low-salinity systems can impact native SAV beds. NCDMF, which holds a seat on the Aquatic Weed Control Council (15A NCAC 01T .0107), should use that role to develop a coordination protocol with the Council and treatment agencies that identifies active native SAV restoration sites in advance of herbicide treatment planning to allow for buffer zones, treatment timing adjustments, or use of more selective methods where feasible. Also, where treatment is planned in waters that support native SAV, schedule treatment to allow harvest of native SAV material in advance of herbicide application for land-based culture under existing AOP/ACP authorities (Recommendation 1). This would allow for replanting into the treated area once herbicide residues have cleared and site conditions support re-establishment. Coordinated native restoration during herbicidal treatments requires planning across multiple seasons and species-specific consideration of holding feasibility, replanting timing, and post-treatment monitoring.

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Part 3: MFC Authority for Submerged Aquatic Vegetation Protections

Background

Impacts from physical disturbance remain a major consideration for the protection of high and low salinity SAV. Protections of SAV in North Carolina from physical disturbance include both state and federal policies that are wide-ranging, though room for improvement remains. The Albemarle-Pamlico National Estuary Partnership (APNEP) published a summary and assessment of the policies, permitting, and management of SAV in North Carolina (Ragain, in preparation). The report summarizes the various state and federal protections currently protecting SAV, ongoing threats to SAV conservation, and recommendations to address gaps in SAV policy and protection. The federal regulations covered are characterized by federal designations under the Magnusen-Stevens Act - SAV is designated as Essential Fish Habitat (EFH), and further as Habitat Areas of Particular Concern (HAPC) - which allow for federal protection. State regulations are characterized by state law and rules developed by the MFC, CRC, and EMC that aim to protect SAV by addressing specific impacts.

Recommendations made in the APNEP report fall into categories of regulatory, non-regulatory, and research suggestions. The regulatory recommendations include additional policy or rule recommendations addressing impacts from mariculture, development, boating, and water quality. The non-regulatory recommendations include outreach and education and further work from state agencies on mariculture, fisheries, development, and boating. The research suggestions cover directions for state agencies and university researchers to further explore impacts from water quality, fisheries, and boating, and to continue or expand monitoring. Among these, some specific examples of areas to improve included reducing the impacts on SAV from shellfish aquaculture operations, further research trawling impacts to SAV, and improving the compensatory mitigation for permitted SAV impacts.

MFC directive to develop additional SAV protections

Amendment 2 to the N.C. Shrimp Fishery Management Plan (FMP), adopted by the North Carolina Marine Fisheries Commission (MFC) in February 2022, was developed to further reduce bycatch of non-target species and minimize ecosystem impacts. The MFC's management strategy included adaptive management for future action to address issues related to SAV identified through North Carolina Division of Marine Fisheries (DMF) collaboration with the Coastal Habitat Protection Plan (CHPP) support staff, the Habitat and Water Quality (HWQ) Advisory Committee (AC), and stakeholder groups (NCDMF, 2022).

In February 2024, the DMF proposed additional SAV protections to the MFC in the Shrimp FMP Amendment 2 Revision. In response, the MFC passed a motion to refer the issue paper to the Northern and Southern Regional and Shellfish/Crustacean ACs for input. The response from shrimp fishery participants and the ACs to the MFC was against SAV-centered place-based management. While the ACs acknowledged the need to protect SAV, they cited that shrimp trawling was not the primary threat to SAV and further noted the need to address poor water quality as well as other bottom disturbing activities (e.g., propeller scarring, anchoring). The HWQ AC further recommended that a monitoring program be established to measure the status of SAV habitat in North Carolina (NCDMF, 2022). This led the DMF to recommend a broader approach to SAV protections. At its May 2024 business meeting, the MFC unanimously passed the following motion on the Shrimp FMP Amendment 2 Revision (emphasis added):

"to accept the Division of Marine Fisheries (DMF) recommendation that it is <u>advantageous to examine issues and develop management actions related to the broader conservation of Submerged Aquatic Vegetation (SAV) habitat conservation</u>. Therefore, action to address SAV protection under the Shrimp FMP Amendment 2 has concluded. The Marine Fisheries Commission (MFC) requests the DMF work with the MFC's Habitat and Water Quality Advisory Committee to <u>examine and develop more comprehensive options to protect identified SAV habitat related to all activities under the authority of the MFC</u>, consistent with the N.C. Coastal Habitat Protection Plan."

Following this action, DMF and partners have evaluated the MFC's authority for physical protections, historical management actions, and the basis for further actions to strengthen protections from physical impacts to SAV. This evaluation was undertaken in the context of the Shrimp FMP and Bay Scallop FMP, as well as other aspects of marine and estuarine fisheries resources that are under the MFC's authority.

Evaluation of MFC authority for physical protections

MFC statutory authority

This evaluation began with a broad review of the statutory authority of the MFC. N.C.G.S. § 113-132, gives the MFC authority over the conservation and regulation of marine and estuarine resources.

Marine and estuarine resources are defined by N.C.G.S. § 113-129 (11) as:

"All fish, except inland game fish, found in the Atlantic Ocean and in coastal fishing waters; all fisheries based upon such fish; all uncultivated or undomesticated plant and animal life, other than wildlife resources, inhabiting or dependent upon coastal fishing waters; and the entire ecology supporting such fish, fisheries, and plant and animal life."

The inclusion of the phrase "entire ecology" in this statute provides an expansive basis of authority over all organisms and the environment supporting the plant and animal life in the State waters of the Atlantic Ocean and coastal fishing waters.

The MFC's authority over marine and estuarine resources is subject to specific grants of authority to other state agencies, which are summarized below. Even accounting for those exceptions, the MFC retains broad jurisdiction over the conservation and regulation of marine and estuarine resources, including the entire ecology of coastal fishing waters. For areas outside its jurisdiction, the MFC is able to coordinate and collaborate with the respective commissions and agencies on reducing impacts to marine and estuarine resources.

Regarding the MFC's jurisdiction, there are three primary laws that delegate authority to the MFC to implement its powers and duties. First, N.C.G.S. § 113-134 grants explicit rulemaking authority to the MFC. The implementation of this authority includes adopting rules to define and designate specific areas that are subject to certain restrictions for the protection of resources that in some instances are referenced in other Commissions' rules.

Second, in addition to the broad authority over marine and estuarine resources, N.C.G.S. § 113-182 authorizes the MFC to regulate marine and estuarine fishing and fisheries related to these resources. This includes the power to authorize, license, regulate, prohibit, prescribe, or restrict all forms of marine and estuarine resources with respect to gear and activities.

Finally, the MFC has the power and duty to establish standards and adopt rules for the management, protection, preservation, and enhancement of marine and estuarine resources within its jurisdiction, per N.C.G.S. § 143B-289.52. This statute further elaborates on these duties and powers through: specific powers and rulemaking authority regarding commercial and recreational fisheries and mariculture in subsection (a); rulemaking authority for specific sections and statues of Chapter 113 in subsection (b); and management and potential restriction of fish take, equipment and vessel usage, and possession and movement of marine and estuarine resources as needed to carry out its duties in subsection (c). The remainder of the statute sets requirements for the MFC's administrative powers and duties pertaining to the powers and duties of subsections (a), (b), and (c).

As mentioned above, the MFC's authority over marine and estuarine resources is subject to specific grants of authority to other state agencies, including the Department of Agriculture and Consumer Services, the Pesticide Board, the Commission of Public Health, the Environmental Management Commission (EMC), other DEQ divisions regulating air or water, and the Coastal Resources Commission. The MFC's authority is also subject to the concurrent jurisdiction of the Wildlife Resources Commission (WRC) for instances of overlap between the MFC and the WRC. The delineation of the respective authorities of these agencies highlights not only the distinct ways that each agency can affect coastal habitat, but also the need for agencies to collaborate to develop holistic solutions.

The jurisdiction of the Department of Agriculture and Consumer Services is defined in N.C.G.S. 143A Article 7 and the authorities outlined in N.C.G.S. Chapter 106. The authorities in these statutes, as it pertains to coastal habitat impacts, includes regulatory authority over agricultural runoff, insecticides, forestry, and other impacts. As a result, the MFC authority does not include regulating impacts from or connected to agriculture or forestry but could, knowing the boundaries, coordinate with the Department of Agriculture and Consumer Services on overlapping issues.

The jurisdiction of the Pesticide Board is defined in N.C.G.S. 143 Article 52. Within this Article, N.C.G.S. § 143-437 grants the Pesticide Board the powers and duties to "carry out a program of planning, environmental and biological monitoring, and of investigation into long-range needs and problems concerning pesticides." The authority prescribed in these statutes means that the MFC cannot regulate or directly monitor impacts on marine and estuarine resources from pesticides but could coordinate ongoing DMF monitoring with monitoring from the Pesticide Board to enable concurrent evaluation and future regulatory coordination.

The authority of the Commission for Public Health is defined in N.C.G.S. § 130A-29. This statute grants express rulemaking authority to implement public health programs related to sewage, sanitation, and biological agents, among others. These instances of effects are, therefore, outside of the authority of the MFC, though, impacts within the existing regulations of the Commission of Public Health are potentially less likely to impact marine and estuarine resources without also impacting public health.

The authority of the EMC is defined in N.C.G.S. 143 Article 21. Among the duties outlined in this Article, the EMC has authority over administering the federally mandated National Pollutant Discharge Elimination System (NPDES) permit and certifications pursuant to section 401 of the Clean Water Act, 33 U.S.C. § 1341(a)(1), and impacts from non-discharge related effects, animal feeding operations, and impacts to air quality. While these impacts are, as a result, not under the authority of the MFC, the CHPP implementation by the EMC can still address them. This delineation of authority also encompasses the other listed DEQ Divisions, namely, DWR and the Division of Air Quality (DAQ).

Lastly, among this list is the Coastal Resources Commission (CRC), whose authority is defined in N.C.G.S. 113A Article 7, or the Coastal Area Management Act (CAMA). This Article gives the CRC and DCM authority over development impacts to coastal wetlands and waters. As a result, the MFC has no direct authority over impacts from coastal development, though, the CRC's rules rely on the MFC's definitions of certain marine and estuarine resources and protected areas (e.g., SAV, nursery areas, anadromous fish spawning areas). DMF also reviews potential impacts from CAMA permit applications utilizing the applicable CRC and MFC rules to determine and address impacts on marine and estuarine resources. Additionally, the CHPP implementation by the CRC can also address coastal development impacts.

Supporting statutory authority

The statutory authority outlined above is further supported by additional general statutes that provide clarification of the delineation of authority and provide management tools for the MFC to fulfill its powers and duties.

N.C.G.S. § 113-134.1 clarifies the geographic extent of the MFC's authority by directing the MFC to exercise its regulatory authority over marine and estuarine resources in the Atlantic Ocean to the extent of state jurisdiction of ocean waters (three nautical miles). This statute also grants enforcement authority of these regulations to marine fisheries inspectors in these waters.

A vital tool of the MFC to be able to responsibly manage marine and estuarine resources is proclamation authority, authorized by N.C.G.S. § 113-221.1. This statute enables the MFC to delegate authority to the Fisheries Director to issue proclamations that suspend or implement rules (in whole or in part) of the MFC that may be affected by variable conditions. Of the three commissions charged with reviewing and revising CHPPs, only the MFC has proclamation authority. The MFC's delegation of proclamation authority to the Fisheries Director through adoption of a rule (e.g., 15A NCAC 03K .0201), is described in more detail in the MFC Rules and Historical Management Actions and Basis for Additional Action sections below.

CHPP and FMP statutory authority

The MFC has two statutorily authorized tools that are required to address marine and estuarine resource and habitat management issues: FMPs and CHPPs.

N.C.G.S. § 113-182.1 sets the requirements for management of commercially or recreationally significant species or fisheries that comprise state marine or estuarine resources through FMPs. Each FMP shall contain, among other items, "fishery habitat and water quality considerations consistent with Coastal Habitat Protection Plans" that have been adopted. Additionally, this statute states in subsection (f) that the MFC "shall adopt rules to implement Fishery Management Plans."

The requirements for management of critical fisheries habitats through CHPPs is set forth in N.C.G.S. § 143B 279.8, which states that the CHPPs shall "describe and classify biological systems in the habitats" among other requirements. The 2005 CHPP (Street et al., 2005) further classified the state's coastal waters into six basic fish habitat types: water column, shell bottom, SAV, soft bottom, hard bottom, and wetlands. This statute also sets forth in subsection (c) that the MFC "shall adopt rules to implement Coastal Habitat Protection Plans." The MFC has adopted numerous rules to implement North Carolina's 13 FMPs since the FRA was enacted in 1997 but has not yet exercised its authority to adopt rules to implement the CHPP.

MFC rules for habitats

The MFC has several rules in place to protect habitat, but they have been promulgated from the primary perspective of protection of FMP-covered species, such as shrimp, bay scallops, or juvenile finfish, for example. In other words, the currency used to date has not been "habitat," but the MFC has the authority to do so as explained in the first part of this examination.

The first instance of habitat-related MFC rules, is 15A NCAC Subchapter 03I, Rule .0101, which defines important fish habitat areas, including primary and secondary nursery areas, strategic habitat areas, and SAV habitat. Not only do these definitions play a role in the MFC's rules and management through FMPs, they also are referenced in the EMC and CRC rules. These definitions, therefore, are pivotal to the protection of these habitat types from fisheries, water quality, and coastal development impacts.

Subchapter 03K contains three instances of gear restrictions designed to protect SAV. These rules prohibit the use of certain rakes for clamming in established SAV beds or in areas of *Spartina alterniflora* (15A NCAC 03K .0102(2)); the use of mechanical methods for oystering or clamming in established SAV beds or in areas of *Spartina alterniflora* (03K

.0108(b)(1)); and the taking of clams by hand tongs in established SAV beds or in areas of *Spartina alterniflora* (03K .0304(a)).

Subchapter 03N establishes and provides protections for nursery areas and anadromous fish spawning areas. Rule 03N .0103 clarifies the specific bounds of a particular nursery area in relation to specific coordinates, inland-coastal boundary lines, or headwaters of the named waterbody. Rule 03N .0104 then provides protection for primary nursery areas through prohibition of the use of trawl nets, long haul seines, swipe nets, dredges, or mechanical methods used to take clams or oysters. Rule 03N .0105 provides protections for permanent and special secondary nursery areas through prohibition of trawls nets, and it allows for the fisheries director to open special secondary nursery areas to shrimp and crab trawling with certain restrictions by proclamation. Primary nursery areas as defined and designated in MFC rules, along with definitions of SAV and shellfish producing habitat, are also cited in CRC[1] and EMC[2] rules for further protections within the respective Commissions' jurisdictions. The protections found in these Commissions' rules include protections for these MFC defined resources from specific activities and through elevating surface water classifications to further protected levels, respectively.

Subchapter 03R designates the geographic locations of primary nursery areas (.0103), permanent secondary nursery areas (.0104), special secondary nursery areas (.0105), and anadromous fish spawning areas (.0115), among other areas of gear-based management. The designation, through MFC rule, of these areas began with primary nursery areas in 1977, continued with permanent and special secondary nursery areas in 1986, and finally with anadromous fish spawning areas in 2007, with a handful of amendments in the last 20 years.

Although not in and of itself a protection of habitat, the MFC's delegation of proclamation authority creates a useful tool for habitat protection and management. 15A NCAC 03H .0103 sets forth the scope of the Fisheries Director's to implement management through proclamations. It outlines the variable conditions through which the Fisheries Director can issue a proclamation if a specific variable condition is not set forth in a rule of the MFC delegating proclamation authority. This rule also makes it unlawful to violate a proclamation, which creates an important tool for enforcement.

[1] References to MFC definitions and designations of primary nursery areas and the MFC definition of SAV within CRC Rules can be noted in 15A NCAC 07H .0208, .0209, and .1505.

[2] References to MFC definitions SAV and shellfish producing habitat within EMC Rules can be noted in the surface water classification of outstanding resource waters (ORW) in 15A NCAC 02B .0225 that provide set protections from activities within the EMC's jurisdiction based on the classification.

Historical management actions and basis for additional action

The MFC's management of impacts to the CHPP-defined habitats has occurred through species- or gear-based management actions taken through species-specific FMPs or the defined fish habitat areas, outlined above, in subchapters 03N and 03R. However, the MFC has authority to proceed with adopting rules for habitat-based management actions consistent with the CHPP.

Management actions, which can include habitat protection and habitat management, are implemented through permanent rulemaking, which can include the use of proclamations. Permanent rulemaking follows the formal process set forth in the Administrative Procedure Act, N.C.G.S. Chapter 150B. It may take up to two to three years if legislative review is required to complete this process for a rule to go into effect. In contrast, the use of proclamations allows for more responsive management, given that the variable conditions and specific restrictions have previously been set in rule through the formal rulemaking process and must be met prior to issuance. However, this requirement means that as part of the delegation of MFC rulemaking authority to the Fisheries Director, the MFC must first undergo permanent rulemaking for a specific static rule to prescribe the applicable restrictions for which the proclamation authority can be used.

Recent developments have highlighted the difficulty in achieving comprehensive protections for habitats in the MFC's implementation of protections and restrictions for habitat management. One such development is an increasing interest in SAV restoration projects across the east coast. While there is not currently a method by which public trust waters can be leased for the growout and harvest of SAV, SAV seeds can be harvested with proper permitting and replanted in restoration project areas. The success rate of such replanting is not yet well understood in North Carolina; however, the potential development of viable replanting methods could lead to much greater management needs to regulate SAV seed harvest. The existing permit does not limit the amount, season, or methodology used to harvest SAV. Unchecked, an increase in SAV harvest combined with seasonal variation among SAV beds and unknown long-term impacts from harvest activities (e.g., water quality and physical destruction), could further exacerbate SAV loss in key historical SAV areas. Additionally, outside of the currency the MFC has historically used for management—gear- and species-driven rule restrictions and protections—outlined above, the MFC has no existing rules to broadly address protections for SAV or other habitats at large that are under its authority. An additional habitat currency would enable SAV management that could benefit all estuarine fisheries in NC outside of the individual species FMP process.

Another example comes from the designation of Deep-Water Oyster Recovery Areas (DORAs) in the Eastern Oyster FMP Amendment 5, adopted by the MFC in 2025 (NCDMF, 2025). As a management strategy, designation of DORAs recognized the habitat value of deep-water oyster reefs. Mechanical oyster dredging in DORAs is prohibited, as these natural reefs are particularly susceptible to mortality from water quality impacts. The Director has proclamation authority as set forth in 15A NCAC 03K .0201(b); however, the management options apply only to the taking of oysters. This does not prevent impacts from other bottom disturbing gears (fishing and non-fishing) that can contribute to the degradation of these reefs. This concern is especially prevalent for reefs that may be identified to have little to no living oyster presence but still have a shell matrix capable of recovery. Further protections of these vacant shell bottom reefs could encourage recovery with no expense to the oyster fishery. Additionally, a habitat-based management approach could allow for coordinated FMP and non-FMP management to benefit the oyster stock from multiple avenues.

Need for habitat-based rulemaking

This analysis of MFC authority, as it pertains to direct SAV protections outside of species-specific FMPs or defined fish habitat areas, has highlighted the applicability and need to develop a rule framework to enable habitat-based management of all habitat types under the MFC's jurisdiction. Rulemaking specific to these habitats would be consistent with the statutorily defined authority of and existing rules adopted by the MFC.

Additionally, developing rules specific to these habitats would enable the MFC to address direct impacts to each type and provide management solutions for needs outside of or broader than an individual FMP. As expressed above in the SAV considerations in the Shrimp and Bay Scallop FMPs and the shell bottom considerations in the Eastern Oyster FMP, management specific to each habitat type could address impacts beyond the restrictions currently provided in each species-based rule (15A NCAC 03L .0101, 03K .0501, and 03K .0201, respectively).

Conclusion

The authority of the MFC within the context of the CHPP, as outlined above, is sufficiently broad to encompass regulating individual impacts to marine and estuarine resources, aside from the jurisdictional boundaries with other agencies and commissions. The definition of marine and estuarine resources also confirms that the MFC's authority encompasses both biotic and abiotic factors that the habitat types fall under. This authority given over the “conservation and regulation of marine and estuarine resources,” per N.C.G.S. § 113-132(a), along with the requirement of each CHPP to “recommend actions to protect and restore the habitats,” per N.C.G.S. § 143B-279.8(a)(4), implies the statutory responsibility of the MFC to act to protect and conserve the CHPP-defined habitats.

As a result of this analysis, this CHPP amendment recommends the initiation of the formal MFC rulemaking process to develop a CHPP habitat-based rule framework following the adoption of the CHPP amendment. This rulemaking process, consistent with the Administrative Procedure Act, would include significant coordination between and input from the MFC, DMF, regulated stakeholders, and the general public.

Recommended Action

DMF will initiate formal rulemaking to develop a CHPP habitat-based rule framework through development of a rulemaking issue paper beginning in 2027. This issue paper will address the need for rules specific to each habitat type, including consideration of regulatory needs for SAV harvest and transplanting for restoration projects, considerations regarding gear and activity impacts in DORAs, and parameters for establishing criteria for habitat-based management. The public, stakeholder, and advisory committee comments related to the rulemaking issue paper will be brought to the Habitat and Water Quality Advisory Committee to evaluate and develop proposed management options for the rule frameworks regarding SAV and the other habitats within the MFC’s jurisdiction.

References

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